WATER LEVEL STATION SPECIFICATIONS

AND DELIVERABLES FOR

COASTAL SHORELINE MAPPING PROJECTS

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

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1. Tides and Water Levels Requirements

1.1. General Project Requirements and Scope

1.1.1. Scope

The requirements and specifications contained in this section cover the water level and tidal datum requirements for the operational support of the remote sensing surveys conducted as part of the NOAA National Geodetic Survey (NGS) Coastal Mapping Program (CMP). The scope of this support is comprised of the following functional areas:

1. Tide and water level requirements planning
2. Tidal zoning development
3. NWLON control water level station operation, monitoring, and maintenance
4. Subordinate water level station installation, operation, monitoring, maintenance, and removal
5. Data quality control, processing, and tabulation
6. Tidal datum computation and tidal datum recovery
7. Quality control check and data validation of contractor submitted data to CO-OPS

For NGS in-house CMP surveys, personnel from the NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) are responsible for functional areas 1, 2, 3, 5, and 6. CO-OPS, NGS, or CO-OPS or NGS selected contractors may install, maintain, and remove the gauges, but CO-OPS will be responsible for monitoring and operation of the water level gauges.

For NGS contract CMP surveys, NOS CO-OPS personnel are responsible for functional areas 1, 2, 3 and 7. NGS contract personnel shall be responsible for functional areas 4 through 6 above. NOS CO-OPS will be responsible for operating, maintaining, and processing data from the National Water Level Observation Network (NWLON) control stations.

1.1.2. Objectives

The work performed according to the requirements and specifications of this document is required for NOS major program areas of coastal shoreline mapping and aerial photogrammetry products and services. The first objective is to provide the tidal predictions and tidal zoning so that flight windows can be determined. The second objective is to ensure remotely sensed data can be collected at the proper stages of the tide (Mean High Water (MHW) plus or minus tolerances, and Mean Lower Low Water (MLLW) plus or minus tolerances) (http://tidesandcurrents.noaa.gov/publications/glossary2.pdf) as per the NGS specifications based upon the tidal zoning. A third objective is to establish and/or recover tidal datums, connect to geodetic datums where possible, and connect to ellipsoid via GPS observations on a tidal or geodetic bench mark. A fourth objective is to provide new information or updated information that can be used to update tide prediction tables, produce or update coastal shoreline mapping products, support coastal resource management, and support marine engineering applications.

The products derived support the NOAA strategic goals of Commerce and Transportation, Weather and Water, and Ecosystem and Climate.

1.1.3. Planning and Tidal Zoning

CO-OPS is responsible for all planning of tide and water level requirements for NOS Coastal Mapping surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify operational NOS control water level stations, specify subordinate water level station locations to be installed, and provide the tidal zoning to be used during coastal shoreline mapping surveys. CO-OPS will provide six-minute interval tide predictions relative to MLLW for appropriate NOS control stations prior to each survey and will also provide historical published bench mark information available for all historical tide stations specified for reoccupation.

1.1.4. NOS Control Stations and Data Quality Monitoring

1.1.4.1. National Water Level Observation Network (NWLON)

CO-OPS manages the NWLON of approximately 210 continuously operating water level observation stations in the U.S. coastal zone, including the Great Lakes. As most of these stations are equipped with satellite radios, near real-time (within about 18 minutes of collection) preliminary data are made available to all users through the CO-OPS Web page at http://tidesandcurrents.noaa.gov. Verified products, such as edited six-minute data, hourly heights, high and low waters, and monthly means are made available over the Web within one to four weeks after data collection for NWLON stations. Accepted tidal datums relative to the National Tidal Datum Epoch (NTDE) are also available on the web. NWLON data and accepted tidal datums are used either to provide tide reducers, control for tidal zoning, or for control for datum determination at subordinate (short-term) stations. Preliminary and verified data are made available over the Web relative to MLLW, or MHW datum, station datum, or special water level datum (such as Columbia River datum) as an user option in the interface.

1.1.4.2. National Water Level Observation Network (NWLON)

CO-OPS has an in-place Continuous Operational Real-Time Monitoring System (CORMS) that provides quality control and system monitoring functions on a 24 hour/day, 7 days/week, all year around basis for CO-OPS monitored gauges. CORMS will monitor the status and performance of all in-house water level gauges equipped with satellite radios using the NOS satellite message format and that are installed by either CO-OPS, or CO-OPS contractors for NOAA in-house coastal shoreline mapping projects only, and once these gauges are listed on the Hydro Hot List (HHL) by CO-OPS. CORMS monitors all NOS water level systems, including all NWLON stations. HHL is a web-based list where real time preliminary water level data for selected stations is made available to users. HHL lists water level gauges that are configured in CO-OPS Database Management System (DMS).

For NOAA coastal shoreline mapping contract surveys, the contractor is responsible for all data monitoring, repairs, and ensuring the proper gauge operation of the subordinate stations.

1.1.5. General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is MLLW (*Tide and Current Glossary*, at 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 datum is MHW. 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 areas 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.

1.1.6. Error Budget Considerations

The accuracy of measuring shoreline can vary significantly depending upon the slope the coastline. The error for estimating the shoreline (horizontal location of MHW or MLLW intersects the shore) is reduced for steep slope of coastline, whereas for areas of flat coastline the error for estimating the shoreline is enhanced.

The following table provides potential horizontal displacements of boundary positions resulting from errors in vertical datum determinations

Error in datum (in meters and feet)	**Horizontal Displacement of Boundary for Beach Slope of Angle with Horizontal as listed below (in meters & feet)**		
	30 degrees	**10 degrees**	**1 degree**
0.61 m (2.0 ft)	1.05 m (3.46 ft)	3.46 m (11.34 ft)	34.92 m (114.58 ft)
0.91 m (1.5 ft)	0.79 m (2.60 ft)	2.59 m (8.51 ft)	16.19 m (85.94 ft)
0.30 m (1.0 ft)	0.52 m(1.73 ft)	1.73 m (5.67 ft)	17.46 m (57.29 ft)
0.15 m (0.5 ft)	0.26 m (0.87 ft)	0.86 m (2.84 ft)	8.72 m (28.64 ft)
0.03 m (0.1 ft)	0.05 m (0.17 ft)	0.17 m (0.57 ft)	1.74 m (5.73 ft)

What the table shows is that the horizontal displacement is the largest for a flat beach slope. The errors demonstrated in this table in turn drive the operational error budgets described in the next paragraph.

According to NGS specifications (Attachment J – Tide Coordination Requirements), the imagery shall be obtained within a tolerance as specified of MHW and MLLW to determine the shoreline. When the mean range of the tide station is five feet (1.5 m) or less the tolerance is +/- 0.3 feet (o.1 m), and when the mean range of the tide station is greater than five feet (1.5 m), the tolerance is +/- 10% of the mean range. Therefore, the MHW +/- tolerance creates time windows during which the imagery needs to be obtained for high water shoreline, and MLLW +/- tolerance creates time windows during which the imagery needs to be obtained for the low water shoreline.

In order to meet these error and tolerance targets, the allowable contribution of the error for tides and water levels is estimated between 0.20 m and 0.45 m (at the 95% confidence level) depending on the complexity of the tides. These numbers were developed from NOS internal study.

The total error of the tides and water levels can be considered to have component errors of:

1. The measurement error of the gauge/sensor and processing error to refer the measurements to station datum. Gauges/sensors need to be calibrated, and sensor design and data sampling need to include strategies to reduce measurement errors due to waves, currents, temperature, and density effects. The measurements need to be properly referenced to the bench marks and tide staffs, as appropriate and monitored for vertical stability. The measurement error, including the dynamic effects, should not exceed 0.10 m at the 95% confidence level. The processing error also includes interpolation error of the water level at the exact time of the imagery. An estimate for a typical processing error is 0.10 m at the 95% confidence level.

2. The error in computation of tidal datums for the adjustment to an equivalent 19-year National Tidal Datum Epoch (NTDE) periods for short-term stations. The shorter the time series, the less accurate the datum, i.e. bigger the error. An inappropriate control station also decreases accuracy. The NTDE does not apply in the Great Lakes, however the accuracy of datum based on shorter time series is analogous. The estimated error of an adjusted tidal datum based on one month of data is 0.08 m for the east and west coasts and 0.11 m for the Gulf coast (at the 95% confidence level).

3. The error in application of tidal zoning. Tidal zoning is the extrapolation and/or interpolation of tidal characteristics from a known shore point(s) to a desired survey area using time differences and range ratios. The greater the extrapolation/interpolation, the greater the uncertainty and error. Estimates for typical errors associated with tidal zoning are 0.20 m at the 95% confidence level. However, errors for this component can easily exceed 0.20 m if tidal characteristics are very complex, or not well-defined, and if there are pronounced differential effects of meteorology on the water levels across the survey area.

Project planning by NOS attempts to minimize and balance these potential sources of errors through the use and specification of accurate and reliable water level gauges, optimization of the mix of zoning required, the number and locations of water level gauges required, and the length of observations required within practical limits of the survey area and survey duration. The practical limits depend upon the tidal characteristics of the area and suitability of the coastline for the installation and operation of appropriate water level stations.

1.2. Data Collection and Field Work

Continuous and valid water level data series are required. Accurate datums cannot be computed for a month of data with a break in the water level measurement series in excess of three days. Even breaks of significantly less than three days duration will not allow for interpolation during times when strong meteorological conditions are present and in areas with little periodic tidal influence. Any break in the water level measurement series affects the accuracy of datum computations. Breaks in data also result in increased error in the tide reducers when interpolation is required to provide data at the time of soundings. At each measurement site where the water level measurement data cannot be transmitted or monitored during the survey operations, an independent backup sensor or a complete redundant water level collection system shall be installed and operated during the project.

1.2.1. Water Level Station Requirements

Data from NWLON stations will be provided to support the both in-house and contract coastal shoreline mapping survey operations as appropriate. Tidal Predictions are also made available for NWLON stations on CO-OPS web page. Tidal predictions for historic subordinate stations can also be made available if CO-OPS has the historical tide station information.

The acquisition of water level data from subordinate locations may be required for coastal shoreline mapping surveys and if so shall be specified by NOS in each individual set of Project Instructions. These stations shall be used to provide 6-minute time series data, tidal datum references and tidal zoning which all factor into the production of final tide reducers for specific survey areas. Station locations and requirements may be modified after station reconnaissance or as survey operations progress. Any changes shall be made only after consultation between the CO-OPS and Chief, Remote Sensing Division (RSD) (and COTR if contract survey) as relocating the required stations to new locations may require assignment of new seven-digit station identifier numbers, and new/historical station and bench mark information.

The duration of continuous water level data acquisition shall be a 30-day minimum. Water level Data acquisition shall be from at least four hours before the beginning of the coastal shoreline mapping survey operations to four hours after the ending of coastal shoreline mapping survey operations, and/or shoreline verification in the applicable areas.

1.2.2. Water Level Measurement Systems and Data Transmissions

1.2.2.1. Water Level Sensors and Data Collection Platform

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), microwave radar, or other suitable type that is approved by CO-OPS. The sensor measurement range shall be greater than the expected range of water level. Gauge/sensor systems shall be calibrated prior to deployment. 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 coastal shoreline mapping surveys are planned. For tidal range less than or equal to 5 m, the required water level sensor resolution shall be 1 mm or less; for tidal range between 5 m and 10 m, the required water level sensor resolution shall be 3 mm or less; and for tidal range greater than 10 m, the required water level sensor resolution shall be 5 mm or less.

The Data Collection Platform (DCP) shall acquire and store water level measurements at every 6- minutes. The water level measurements shall consist of an average of at least 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 which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data is required for compatibility with the NWLON stations, and the standard deviation provides valuable data quality information regarding each measurement. The clock accuracy of a satellite radio system shall be within 1 second per month so that channel "stepping" does not occur. Non-satellite radio systems shall have a clock accuracy of within one minute per month. 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.

The NOS is currently using the Aquatrak® self-calibrating air acoustic sensors at the majority of the NWLON stations. (For further information refer to *Next Generation Water level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual*, NOAA/NOS, January 1991, which is available at CO-OPS web page at the following url: (http://tidesandcurrents.noaa.gov/publications/NextGenerationWaterLevelMeasurementSystemMANUAL.pdf) and *User's Guide for 8200 Acoustic Gauges*, NOAA/NOS, Updated August 1998 which is available at http://tidesandcurrents.noaa.gov/publications/hy8200aco_manual.pdf).

At stations where the acoustic sensor cannot 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 well/float with absolute shaft angle encoder (Great Lakes Stations) are used by NOS for water level measurements. (For further information refer to *User's Guide for 8200 Bubbler Gauges*, NOAA/NOS, Updated February 1998 which is available at CO-OPS web page at the following url: http://tidesandcurrents.noaa.gov/publications/hy8200bub_manual.pdf). Also refer to User's Guide for 8210 Bubbler Water Level Gauge for Hydrographic Surveying Applications (Installation and Operation) February 2001 which is available at CO-OPS web page at the following URL: http://tidesandcurrents.noaa.gov/publications/8210_guide.pdf

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle (minimum 3 hours) shall be required, see Section 1.2.4.2 Staff Observations for further details. Along with the averaging procedure described above which works as a digital filter, NOS uses a combination protective well/parallel plate assembly on the acoustic sensor and a parallel plate assembly (with 2" orifice chamber) on the bubbler orifice sensor to minimize systematic measurement errors due to wave effects and current effects, as shown in Figure 1.1.

When pressure sensors are used to collect the water level data, orifice should be mounted on vertical surface such as piling of a wharf so that the precise elevation of the orifice below a staff stop can be measured with a steel tape, and the elevation of the staff stop can be measured via differential leveling to the nearest benchmark and with the primary bench mark. If the orifice is mounted vertically and its elevation can be determined precisely with reference to the primary bench mark, then staff to gauge readings are not necessary, and the requirement for staff-to- gauge readings is waived. If the orifice cannot be mounted to a vertical surface i.e. if the elevation of the orifice cannot be determined precisely with the primary bench mark, then staff- to-gauge readings are required to relate the water level datums to the bench marks.

1.2.2.2. Bottom Mounted Pressure Gauges and Data Collection Platform

Requirement

This configuration is required for survey locations where traditional shore based tide stations with tide gauges mounted on near shore infrastructure are not possible during the summer months (non-ice deployments). This includes areas with bathymetry where the low tide line is far off shore and measuring the full range of tide with typical MWWL, acoustic, or bubbler gauges is not feasible. This has most often occurred in Alaska.

Configuration

Bottom-mounted pressure gauge (BMPG) station consist of bottom-mount moorings and recovery lines, water density sensors (conductivity sensor or hydrometer), barometric pressure sensor, tide staff (fixed scale, or leveling-to-water's edge rod equipped with wave stilling tube(staff shots)), five tidal bench marks, and GPS survey equipment. The BMPG requires the configuration of two systems for redundancy.

Specifications:

Water Level:

The water level pressure sensor shall be a Paroscientific Digiquartz or equivalent (with respect to accuracy and performance). The sensor shall have a documented calibration and certification by the manufacturer or an independent lab such as NIST.

The contractor/instrument lab shall perform a documented acceptance check regarding sensor operation prior to deployment. The sensor shall be calibrated immediately if a drift of 0.5 cm or more in one month data is noticed, otherwise sensor shall be calibrated every 10 years.

The system shall have internal recording capability with a sampling scheme of producing an average pressure reading every six-minutes, similar to CO-OPS' Digiquartz DQAP in which 36 five-second water level samples centered on each tenth of an hour are averaged. A three standard deviation outlier rejection test is applied and the recalculation of the mean and standard deviation along with the number of outliers is recorded internally.

The system shall keep accurate internal time with no noticeable drift over a 3-month deployment period, e.g. less than five seconds drift over a three-month period.

The system shall be deployable for a minimum of 30-days without having to retrieve for maintenance or data collection.

Water level is generally derived from BMPGs by applying corrections for barometric pressure and for water density to the pressure measurements using standard manufacturer software and the hydrostatic equation relationships. Barometric pressure shall be measured at a location within five miles from the BMPG deployment site and at a minimum sample rate of hourly observations.

Real time data telemetry is desirable so that system performance and data quality monitoring.

Moorings:

The hydrographic survey contractors shall design and support their own mooring systems.

Typical installations require self-contained sensors each mounted to a 300-1000 pound anchor with a 45' -120' buoy line (depending on water depth) and an 80'-150' drag line attached to a 150-pound anchor. The objective is to have a mooring that will not drag or move horizontally and vertically during deployment, yet be capable of being deployed using relatively small boats and the sensors are deployed offshore far enough (200 -1500m) to ensure measurement of the lowest expected water level.

Water Density:

Water density shall be obtained, at least hourly and preferably, every six-minutes by using a bottom mounted conductivity and temperature (CT) sensor, or daily hydrometer measurements during the deployment period. Surface measurements using hydrometer may be inaccurate in areas of high freshwater runoff. Conductivity and temperature sensors shall undergo documented manufacturer recommended calibrations and field team acceptance tests prior to each deployment.

Barometric Pressure:

Barometric pressure shall be obtained using a nearby reliable existing source (NWS or airport). If these sources are not available, then a separate barometric pressure sensor shall be installed at the tide station location or on land as close to the BPMG location as practicable for the duration of the survey. Barometric pressure sensors shall also have documented manufacturer recommended calibrations and acceptance tests performed by the field teams prior to each deployments. This correction is an added correction to those needed for a normal in-house shore-based pressure gauge(s) vented to the atmosphere. With a standard industry barometric pressure sensor, this correction should be of suitable accuracy.

Tide staff readings:

Routine tide staff readings at the shore shall be taken in order to complete a simultaneous staff-to gauge comparison. This comparison provides offsets that are applied to the water level data to reference them to a Station Datum, the tidal bench marks, and to tidal, geodetic, and ellipsoidal datums. A fixed scale tide staff shall be installed at shore-mounted pressure (bubbler) tide gauges by mounting on existing infrastructure or by driving a piling or post just offshore; close enough to be leveled to the local bench marks and be easily read.

At most locations requiring BMPG deployments a "virtual tide staff" procedure may be required. This procedure requires repeat geodetic leveling from a bench mark or temporary bench mark (backsight) to a level rod held at the water's edge (foresight staff shots). The water level shall be read off the level rod scale, taking into account wave action (a small stilling tube attached to the rod helps with this reading). Foresight water level readings shall be made every 6-minute for a three-hour period after initial deployment of the pressure sensors and just prior to retrieval of the sensors. Back sight closures to the bench mark shall be made at the beginning and end of the three hour periods with the leveling instrument set-up remaining undisturbed.

Interim tide staff readings during the deployment period shall be taken periodically and spread over the month as specified. Interim tide staff readings shall be taken a minimum of (a) eight times a month spread out over each month (e.g. two times a week) and at each time 1 hour of observations at 6 minute interval, or (b) minimum of four observations spread out over each month (e.g. one time per week) and at each time at least two hours of observations at six minute interval. The interim, installation, and removal staff readings should remain constant throughout the set of observations and show no increasing or decreasing trends. A higher number of independent staff readings decrease the uncertainty in transferring the measurements to station datum and bench marks.

Final Water levels:

Pressure gauge readings are converted to water level via application of documented barometric pressure and water density corrections prior to performing the staff to-gauge comparisons. Staff-to-gauge constants are determined for each separate deployment. Often, the systems are recovered, checked out, batteries refreshed, etc., and then re-deployed during a survey period. Staff-to-gauge differences are analyzed for outliers and consistency prior to determination of the final constant(s) to be applied to the data. The water level data, level abstracts, and metadata shall be submitted in CO-OPS specified formats.

1.2.2.3. Data Transmissions

The Data Transmissions requirements are applicable where CO-OPS is monitoring the gauges as described in Section 1.1.4.2 Data Quality Monitoring above. The ability to monitor water level measurement system performance for near real-time quality assurance is essential to properly support coastal shoreline mapping survey operations. Therefore, it is required that, where access to the satellite is available, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS every three hours, hourly, or every 6 minutes. The data transmissions must use a message format identical to the format as currently implemented in NOS' Next Generation Water Level Measurement Systems (NGWLMS). This is required to assure direct compatibility with the NOS Data Management System (DMS). This data format is detailed in the reference document "NGWLMS GOES MESSAGE FORMATTING" (refer to Section 1.6 for Guidelines and References) and is available at CO-OPS web page at the following URL: http://tidesandcurrents.noaa.gov/publications/newgoes_format.pdf. Once the station and gauge information is configured in DMS and station listed on the Hydro Hot List (HHL), (which is available at CO-OPS web page at the following url: http://tidesandcurrents.noaa.gov/hydro.shtml) the NOS Continuous Operational Real-Time System (CORMS) will monitor all water level measurement system GOES transmissions to assure they are operating properly, provided that the GOES data transmitted is compatible with NOS format and CO-OPS is responsible for the operation of the gauge. Data that is not transmitted by GOES, or data transmitted but not in NOS compatible GOES format, or is submitted to CO-OPS on electronic formats currently used such as, CD-ROM, DVD-ROM or such other digital media, must also conform to the format specified in the above document so that data can be loaded properly into DMS software. Refer to Section 1.5.2 for further details about the water level data format specifications.

Close coordination is required between NGS personnel, installer, and the Operational Engineering Team (OET) of the Engineering Division (ED) of CO-OPS for all NOAA in-house coastal shoreline mapping survey projects that have satellite transmission capability for water level installations. NOS will assist in acquiring assigned platform ID's, time slots, etc. for NGS in-house coastal shoreline mapping projects. At least three business days prior to the installation of the tide gauge in the field, information about the station number, station name, latitude, longitude, platform-ID, transmit time, channel, and serial numbers of sensors, and DCP shall be faxed (telephone 301-713-4465), phoned (telephone 301-713-2897), or e-mailed (nos.coops.oetteam@noaa.gov) or sent to ED. Test transmissions conducted on site are outside this requirement. This station and DCP information must be configured in DMS before data transmissions begin so that the all data will be accepted in DMS. The documentation required prior to transmission in field is defined in the NGWLMS Site Report, or Tide Station Report, or Xpert Site Report, as appropriate. (Refer to Section 1.5 Data Submission Requirements).

1.2.3. Station Installation, Operation and Removal

Installer shall obtain all required permits and permissions for installation of the water level sensor(s), Data Collection Platforms (DCP), bench marks, and utilities, as required. The installer shall be responsible for security and/or protective measures, as required. The installer shall install all components in the manner prescribed by manufacturer, or installation manuals. The installer shall provide CO-OPS of the geographic position of all tide gauges installed before the coastal shoreline mapping survey begins, including those that were not specified in the Project Instructions, as appropriate. The horizontal geographic positions of bench marks, sensors, and DCP installed or recovered shall be obtained and reported as latitudes and longitudes (degrees, minutes, seconds and tenth of seconds).

The water level station and its various components (tide house, DCP, all sensors, 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, contractors, and public, as appropriate.

The following paragraphs provide general information regarding requirements for station installation, operations and maintenance, and station removal.

1.2.3.1. Station Installation

A complete water level measurement gauge installation shall consist of the following:

A. The installation of the water level measurement system (water level sensor(s), DCP, and satellite transmitter, as appropriate) and its supporting structure and a tide staff, if required.

B. The recovery and/or installation of a minimum number of bench marks and a level connection between the bench marks and the water level sensor(s), and tide staff as appropriate.

C. The preparation of all documentation and forms.

1.2.3.2. Operation and Maintenance

When GOES telemetry and NOS satellite message format is used for NOS in-house coastal shoreline mapping surveys, the installer 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. This monitoring can be performed by accessing the COOPS web page (http://TidesandCurrents.noaa.gov). The data over this system are typically available for review within one to four hours after collection.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate maintenance forms (see Section 1.5.1 on water level station documentation below) 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 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; etc.

For water level stations that are collecting data for more than six months duration, a check level is required at every six month duration from the installation of the gauge till the water level gauge is removed. See Section 1.2.5.4 Leveling Frequency for further details.

1.2.3.3. Removal

A complete removal of the water level measurement gauge shall consist of the following:

A. Closing levels - a level connection between the minimum number of required bench marks and the water level sensor(s) and tide staff as appropriate.

B. Removal of the water level measurement system and restoration of the premises, reasonable wear and tear accepted.

C. Disposal of expendable or unusable components in an environmentally friendly manner

D. Termination of any utilities

E. Close out or terminate license agreement

F. The preparation of all documentation, forms, data, and reports.

1.2.4. Tide Staffs, Staff Observations, and Bubbler/Pressure Sensor Orifice

1.2.4.1. Staff

The installer shall install a tide staff at a station if the reference measurement point of a sensor (zero of a gauge) cannot be directly leveled to the local bench marks (e.g. orifice/pressure sensor has to be installed offshore on the sea floor). The tide staff is generally not required for acoustic gauges because the sensor elevation (the sensor zero reference point) can be measured during leveling. Even if a pressure gauge sensor elevation (the sensor zero reference point) can be leveled directly, staff readings shall be still required for assessment of variations in gauge performance due to density variations in the water column over time. The tide staff shall be mounted independent of the water level sensor so that stability of the staff or sensor is maintained. Staff shall not be mounted to the same pile on which the water level sensor is located. The staff shall be plumb. When two or more staff scales are joined to form a long staff, the installer shall take extra care to ensure the accuracy of the staff throughout its length. The

distance between staff zero and the rod stop shall be measured before the staff is installed and after it is removed and the rod stop above staff zero height shall be reported on the documentation forms including leveling abstracts.

In areas of large tidal range and long sloping beaches (i.e. Cook Inlet and the Gulf of Maine), the installation and maintenance of tide staffs can be extremely difficult and costly. In these cases, the physical installation of a tide staff(s) may be substituted by systematic leveling to the water's edge from the closest bench mark. The bench mark becomes the "staff stop" and the elevation difference to the water's edge becomes the "staff reading".

1.2.4.2. Staff Observations

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle (minimum 3 hours) shall be required (1) at the start of water level data collection, (2) at frequent intervals during deployment, and (3) at the end of a deployment before gauge has been removed. Frequent gauge/staff comparisons during deployment shall be required

to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations at the start and end of deployment shall be at least each three hours long and the periodic observations during the deployment shall be at least 1 hour long. The staff to gauge observations shall be performed three times per week, during each week of the project, with at least one hour long observations of 6 minute intervals for each time. Where staff to gauge observations cannot be performed three times a week as required then an explanation is required for the deficiency of number of observations and staff to gauge observations shall be performed at least (a) minimum eight times spread out over each month (e.g. two times per week) and at each time at least 1 hour of observations at 6 minute interval, or (b) minimum of four times spread out over each month (e.g. one time per week) and at each time at least 2 hours of observations at 6 minute interval, whichever is convenient.

The staff-to-gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. After the water level data has been collected, the averaged staff-to-gauge shall be applied to water level measurements to relate the data to staff zero. A higher number of independent staff readings decrease the uncertainty in transferring the measurements to station datum and the bench marks. Refer to Figure 1.2 for an example pressure tide gauge record.

If a tide staff is found destroyed by elements during the deployment, then a new staff shall be installed for the remainder period of the deployment and a new staff to gauge constant needs to be derived by new sets of staff to gauge observations. Also when a staff or an orifice is replaced or re-established, check levels shall be run to minimum of three bench marks including the Primary Bench Mark (PBM). Refer to Section 1.2.5 for leveling frequency and other leveling requirements.

For water level historic stations that are reoccupied, CO-OPS will provide the station datum (SD) information for the station. This information is generally given for the PBM above the historic SD. In that case, for pressure sensors that require staff-to-gauge observations, all the water level data shall be placed on the station datum using the following equation:

Water level data on the SD = (Preliminary pressure water level data on an arbitrary datum as collected by the gauge) + (PBM above SD) - (Staff zero below PBM) - (weighted staff-to-gauge constant)

Staff zero below PBM = (Staff stop below PBM) + (Staff zero below Staff stop)

The staff-to-gauge constant shall be derived as a weighted average of all the staff-to-gauge readings done for the project. The staff zero below PBM is obtained generally by (a) leveling from PBM to staff stop and (b) then measuring the staff stop to staff zero elevation with a steel tape and (c) then combining the two (a and b) elevation values. The staff zero below PBM is obtained by averaging the elevations differences during the opening (installation) and closing (removal) leveling runs for short term occupations.

The orifice elevation above station datum is also defined as an accepted orifice offset in CO-OPS Data Management System (DMS).

1.2.4.3. Bubbler Orifice and Parallel Plate Assembly

This bottom assembly is made of red brass; its chemical properties prevent the growth of marine life by the slowly releasing copper oxide on its metal surface. A Swagelok® hose fitting is screwed into the top end cap and is used to discharge the Nitrogen gas. The Nitrogen gas flows through the bottom of the orifice at a rate sufficient to overcome the rate of tidal change and wave height. This opening establishes the reference point for tidal measurements. The parallel plates produce a laminar flow across the orifice to prevent the venturi effect. A two inch by eight-inch pipe (as shown in Figure 1) provides the correct volume gas for widest range of surf conditions encountered by most coastal surveys. Bubbler orifice with parallel plates is generally preferred and used by CO-OPS and shall be used.

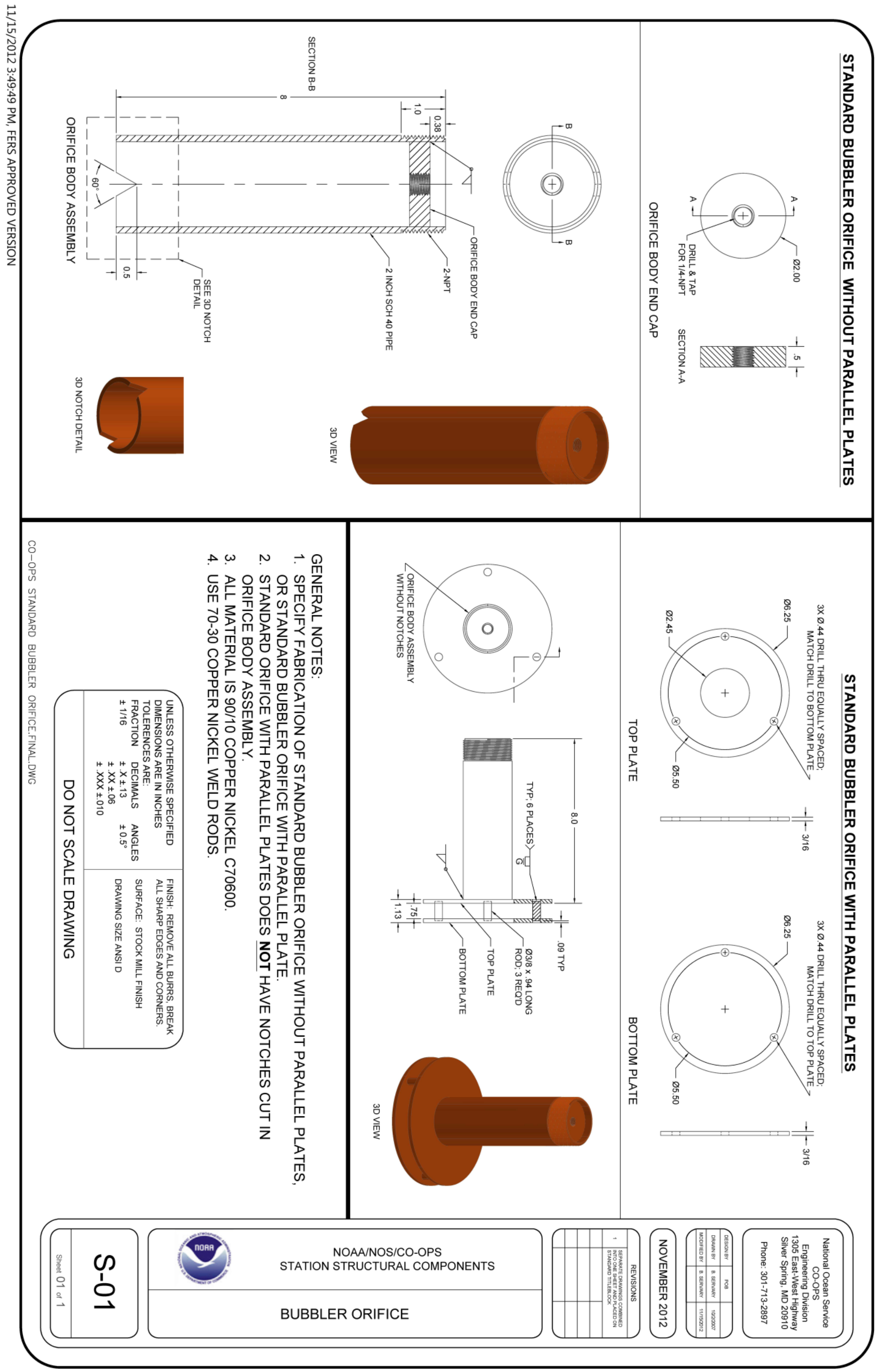

Figure 1 Bubbler Orifice and Parallel Plate Assembly

PRESSURE TIDE GAUGE RECORD

Station Name:______________________ **Station No. (7 digit #) ______________________**

Date	Time		Staff Reading		Gauge/Staff Difference	Gas Pressure		Wind (Dir/Spd)	Air Temp.	Remarks
(M,D,Y)	Gauge	Correct	High	Low		Cyln	Feed			

Figure 2 Pressure Tide Gauge Record

1.2.5. Bench Marks and Leveling

1.2.5.1. Bench Marks

A bench mark is a fixed physical object or marker (monument) set for stability and used as a reference to the vertical and/or horizontal datums. Bench marks in the vicinity of a water level measurement station are used as the reference for the local tidal datums derived from the water level data. The relationship between the bench marks and the water level sensor or tide staff shall be established by differential leveling.

1.2.5.2. Number and Type of Bench Marks

The number and type of bench marks required depends on the duration of the water level measurements. The *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, dated October 1987,* which is available at the following URL: http://tidesandcurrents.noaa.gov/publications/users_guide_for_installation_of_Bench_Mark.pdf specifies the installation and documentation requirements for the bench marks. Each station will have one bench mark designated as the PBM, which shall be leveled to on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The contractor shall select a PBM at sites where the PBM has not already been designated. For historic NOS station reoccupations, CO-OPS will furnish the designation/stamping of the PBM and PBM elevation above station datum, as appropriate and if available.

The most desirable bench mark for GPS observations will have 360 degrees of horizontal clearance around the mark at 10 degrees and greater above the horizon and stability code of A or B. Refer to *User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, Updated November 2008* which is available at the following URL: http://tidesandcurrents.noaa.gov/pub.html for further information.

If the PBM is determined to be unstable, another mark shall be designated as PBM. The date of change and the elevation difference between the old and new PBM shall be documented. NOAA will furnish the individual NOS standard bench mark disks to be installed. Bench mark descriptions shall be written according to *User's Guide for Writing Bench Mark Descriptions, updated January 2003* (http://tidesandcurrents.noaa.gov/publications/bmguide5.pdf).

1.2.5.3. Leveling

At least, geodetic third-order levels (but 2nd order class I levels are preferred) shall be run at short-term subordinate stations operated for less than one-year. Requirements for higher order levels will be specified in individual project instructions, or statement of work, as appropriate. Standards and specifications for leveling are found in *Standards and Specifications for Geodetic Control Networks and Geodetic Leveling (NOAA Manual NOS NGS 3*). Additional field requirements and procedures used by NOS for leveling at tide stations can be found in the *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations*. Electronic digital/barcode level systems are preferable. Specifications and standards for digital levels can be found in *Standards and Specifications for Geodetic Control Networks* (http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-

geodetic-control-networks.htm#3.5) and additional field requirements and procedures used by NOS for electronic leveling at water level stations can be found in the *User's Guide for Electronic Levels with Translev and Windesc, updated March 2003*, which is available at the following url:
http://tidesandcurrents.noaa.gov/publications/Users_Guide_for_Electronic_Levels_with_Translev_and_WinDesc_March_2013.pdf

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. The leveling connection to a MWWL sensor shall be done at the MWWL Leveling Point (LP). The MWWL LP is located on the top of the flange as shown in the picture below (Figure 1).

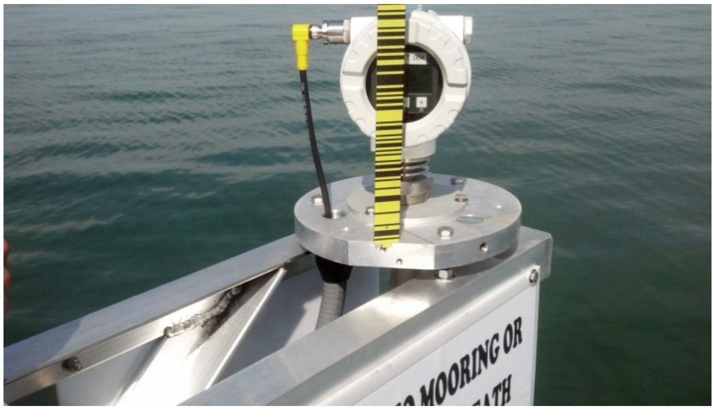

Figure 3: MWWL Leveling Point

In order to facilitate rod holding, a prefabricated leveling fixture may be slipped over the acoustic 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. ED must approve use of other leveling fixtures and leveling techniques in advance.

1.2.5.4. Leveling Frequency

Levels shall be run between the water level sensor(s) or tide staff (depending on the type of gauge) and the required number of bench marks when the water level measurement station is installed, modified (e.g., water level sensor serviced, staff, or orifice replaced), for time series bracketing purposes, or prior to removal. In any case, levels are required at a maximum interval of six (6) months during the station's operation, and are required after severe storms, hurricanes, earthquakes to document stability (see stability discussed below).

Bracketing levels to appropriate number of marks (five for subordinate stations) are required (a) if smooth tides (water level data reducers) are required 30 days or more prior to the planned removal of a applicable gauge(s) (for shoreline mapping survey projects, or (b) after six months for stations collecting data for long term projects.

1.2.5.5. Stability

If there is an unresolved movement of the water level sensor or tide staff zero relative to the PBM, from one leveling to the next, of greater than 0.006 m, the leveling party shall verify the apparent movement by re-running the levels between the sensor zero or tide staff to the PBM. The confirmation levels provide verification that sensor/bench mark indeed moved, or did not move. Since short term water level gauges generally do not have long term leveling history as do the NWLON permanent water level gauges, hence, the confirmation levels provide information that can be used to verify sensor/bench mark stability during the data processing. This threshold of 0.006 m should not be confused with the closure tolerances used for the order and class of leveling.

1.2.6. Water Level Station Documentation

The field team shall maintain a documentation package for each water level measurement station installed for coastal shoreline mapping projects. The documentation package shall be forwarded after a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to time frames for submission of documentation in Section 1.5.3.

Generally, all documentation (see Section 1.5 for Data Submission Requirements) shall be forwarded when a station is installed. For other situations, only information that has changed shall be submitted (e.g., levels and abstract for bracketing or removal levels, eSite report NGWLMS Site Report, or Tide Station Report, or Xpert Site Report, as appropriate, for maintenance and repair or station removal, etc.)

1.2.7. Additional Field Requirements

A. Generally upon completion of the data acquisition for each gauge installed, the data must be sent as a batch for a 30-day minimum station unless the data are transmitted via satellite.

B. All water level data from a gauge shall be downloaded and backed up on electronic formats currently used such as CD-ROM or DVD-ROM, whether the gauge data are sent via satellite or not.

C. For new water level stations that do not have station numbers assigned, once the location of the gauge has been finalized, then contact CO-OPS or COTR and provide latitude and longitude of the gauge site at least three business days prior to actual installation of the gauge in field. CO-OPS will assign a new station number within three business days and inform the installer.

D. At each water level station, GPS observations at one bench mark shall be performed according to the most recent copy of CO-OPS' "User's Guide for GPS Observations At Tide and Water level Station Bench Marks".

1.3. Data Processing and Reduction

1.3.1. Data Quality Control

The required output product used in generation of tide control for the stage of tide and for tidal datum determination is a continuous time series of 6-minute interval water level data for the desired time period of survey and for a specified minimum time period from which to derive tidal datums. The 6-minute interval water level data from the water level gauges shall be quality controlled to NOS standards by the contractor for invalid and suspect data as a final review prior to product generation and submission to CO-OPS for data validation. This includes checking for data gaps, data discontinuities, datum shifts, anomalous data points, data points outside of expected tolerances such as expected maximum and minimum values and for anomalous trends in the elevations due to sensor drift or vertical movement of the tide station components and bench marks.

Quality control shall include comparisons with simultaneous data from backup gauges, predicted tides or data from nearby stations, as appropriate. Data editing and gap filling shall use documented mathematically sound algorithms and procedures, and an audit trail shall be used to track all changes and edits to observed data. All inferred data shall be appropriately flagged. Water level measurements from each station shall be related to a single, common datum, referred to as Station Datum. Station Datum is an arbitrary datum and should not be confused with a tidal datum such as MLLW or a geodetic datum such as NAVD 88. All discontinuities, jumps, or other changes in the gauge record (refer to the specific gauge user's guide) that may be due to vertical movement of any the gauge, staff, or bench marks shall be fully documented. All data shall be recorded on Greenwich Mean Time (GMT) or Universal Time Coordinated (UTC) and the metric units of measurement shall be properly denoted on all hard-copy output and digital files. Refer to Section 1.5 Data Submission Requirements for details.

Refer to Tidal Datums and Their Applications at http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf and Computational Techniques for Tidal Datums Handbook at http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.p df for additional information.

1.3.2. Data Processing and Tabulation of the Tide

The continuous 6-minute interval water level data are used to generate the standard tabulation output products. These products include the times and heights of the high and low waters, hourly heights, maximum and minimum monthly water levels, and monthly mean values for the desired parameters. Examples of these tabulation products are found in Figure 1.3 and 1.4 for tide stations and 1.5 for Great Lakes stations. The times and heights of the high and low waters shall be derived from appropriate curve-fitting of the 6-minute interval data. For purposes of tabulation of the high and low tides and not non-tidal high frequency noise, successive high and low tides shall not be tabulated unless they are greater than 2.0 hours apart in time and 0.030 meters different in elevation. Hourly heights shall be derived from every 6-minute value observed on the hour. Monthly mean sea level and monthly mean water level shall be computed from the average of the hourly heights over each calendar month of data. Data shall be tabulated relative to a documented consistent station datum such as tide staff zero, arbitrary station datum, MLLW, etc., over the duration of the data observations. Descriptions of general procedures used in tabulation are also found in the *Tide and Current Glossary, Manual of Tide Observations,* *Tidal Datum Planes, and Computational Techniques for Tidal Datums Handbook.*

Refer to Tidal Datums and Their Applications at http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf and Computational Techniques for Tidal Datums Handbook at http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.p df for additional information.

1.3.3. Computation of Monthly Means

Monthly means are derived on a calendar month basis in accordance with the definitions for the monthly mean parameters as found in the Tide and Current Glossary. Examples of the desired monthly means are found in Figure 1.7. For purposes of monthly mean computation, monthly means shall not be computed if gaps in data are greater than three consecutive days. For partial month (any data less than full month) water level data, perform tide by tide comparison with the control station data.

1.3.4. Data Editing and Gap Filling Specifications

When backup sensor data are not available, data gaps in 6-minute data shall not be filled if the gaps are greater than three consecutive days in length. Data gap filling shall use documented mathematically and scientifically sound algorithms and procedures and an audit trail shall be used to track all gap-fills in observed data. Data gaps of less than 3-hours can be inferred using interpolation, curve-fitting techniques, and predictions. Data gaps of longer than three hours but less than 3 days may use external data sources such as data from a nearby station, provided the data matches and there are no meteorological events during that gap. All data derived through gap-filling procedures shall be marked as inferred. Individual hourly heights, high and low waters, and daily means derived from inferred data shall also be designated as inferred.

```
 Jan 31 2007 14:09          HIGH/LOW WATER LEVEL DATA        July, 1998
                          National Ocean Service (NOAA)
Station:  9414290                                          T.M.:     0 W
Name:     SAN FRANCISCO, SAN FRANCISCO BAY, CA             Units:    Meters
Type:     Mixed                                            Datum:    STND
Note:     > Higher-High/Lower-Low   [] Inferred Tide       Quality:  Verified

         High             Low                      High             Low
Day   Time  Height     Time  Height      Day   Time  Height     Time  Height
---   ----  ------     ----  ------      ---   ----  ------     ----  ------
 1  >  1.4   3.337      6.8   2.521      16  >  0.6   3.550      6.2   2.343
      12.6   2.996   > 18.5   2.253            12.6   3.187   > 18.1   2.195
 2  >  2.0   3.393      7.8   2.434      17  >  1.4   3.654      7.4   2.205
      13.9   2.950   > 19.4   2.406            14.1   3.096     19.0   2.335
 3  >  2.6   3.458   >  9.1   2.367      18  >  2.2   3.725   >  8.6   2.054
      15.2   2.941     20.1   2.498            15.6   3.132     20.2   2.504
 4  >  3.2   3.524   >  9.7   2.210      19  >  3.1   3.819   >  9.7   1.891
      16.5   2.988     21.1   2.612            16.9   3.188     21.5   2.586
 5  >  4.0   3.584   > 10.3   2.018      20  >  4.1   3.899   > 10.7   1.763
      17.6   3.054     22.0   2.644            18.0   3.267     22.5   2.597
 6  >  4.6   3.656   > 11.1   1.913      21  >  4.9   3.903   > 11.6   1.654
      18.3   3.124     22.7   2.682            18.8   3.309     23.4   2.583
 7  >  5.1   3.711   > 11.8   1.812      22  >  6.0   3.884
      19.1   3.194     23.4   2.697            19.6   3.347   > 12.4   1.587
 8  >  5.8   3.754                       23  >  6.4   3.880      0.2   2.587
      19.7   3.223   > 12.4   1.730            20.3   3.390   > 13.1   1.611
 9  >  6.3   3.789      0.1   2.703      24  >  7.4   3.833      1.1   2.586
      20.4   3.285   > 13.1   1.669            20.9   3.409   > 13.9   1.659
10  >  7.3   3.795      0.9   2.709      25  >  8.1   3.780      1.7   2.562
      21.1   3.306   > 13.7   1.627            21.6   3.445   > 14.5   1.719
11  >  8.0   3.712      1.6   2.614      26  >  8.7   3.668      2.6   2.564
      21.7   3.302   > 14.4   1.579            22.2   3.437   > 14.9   1.826
12  >  8.8   3.639      2.5   2.584      27  >  9.3   3.510      3.2   2.549
      22.3   3.356   > 15.1   1.609          > 22.8   3.416   > 15.6   1.932
13  >  9.3   3.547      3.1   2.530      28    10.1   3.356      4.1   2.538
      23.1   3.419   > 15.6   1.692          > 23.5   3.430   > 16.1   2.042
14    10.1   3.443      4.1   2.522      29    10.9   3.202      5.0   2.495
    > 23.9   3.484   > 16.5   1.800                           > 16.6   2.199
15    11.3   3.282      5.1   2.422      30  >  0.1   3.432      5.9   2.492
                     > 17.0   1.967            12.0   3.099   > 17.3   2.402
                                         31  >  0.8   3.472   >  6.9   2.431
                                               13.1   3.018     18.5   2.513

Highest Tide:            3.903    4.9 Hrs  Jul 21 1998
Lowest  Tide:            1.579   14.4 Hrs  Jul 11 1998

Monthly Means:     MHHW    3.641
                   MHW     3.433     DHQ    0.208
                   MTL     2.832                  GT    1.720     HWI   7.57  Hrs
                   DTL     2.781                  MN    1.203     LWI   0.76  Hrs
                   MSL     2.816
                   MLW     2.230     DLQ    0.309
                   MLLW    1.921
```

Figure 3 High and Low Water Level Data

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA Time Meridian 0 W Tide Type: Mixed

HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16
00	3.247	3.183	3.119	3.052	2.936	2.837	2.770	2.724	2.717	2.763	2.814	2.960	3.152	3.354	3.481	3.529
01	3.329	3.333	3.319	3.274	3.157	3.066	2.972	2.851	2.762	2.694	2.637	2.723	2.901	3.162	3.365	3.517
02	3.311	3.391	3.449	3.437	3.378	3.293	3.173	3.060	2.913	2.799	2.627	2.602	2.653	2.868	3.123	3.395
03	3.164	3.312	3.463	3.526	3.526	3.504	3.423	3.298	3.171	2.988	2.750	2.618	2.529	2.621	2.792	3.103
04	2.948	3.158	3.338	3.469	3.595	3.629	3.617	3.555	3.420	3.261	2.985	2.755	2.606	2.523	2.523	2.741
05	2.725	2.914	3.091	3.304	3.474	3.628	3.714	3.707	3.652	3.519	3.247	3.012	2.757	2.576	2.423	2.459
06	2.558	2.651	2.811	3.012	3.209	3.430	3.640	3.740	3.782	3.711	3.508	3.252	2.986	2.745	2.472	2.302
07	2.528	2.451	2.531	2.651	2.833	3.112	3.342	3.580	3.746	3.785	3.668	3.485	3.217	2.954	2.619	2.399
08	2.581	2.453	2.387	2.366	2.448	2.653	2.915	3.225	3.496	3.677	3.715	3.628	3.433	3.155	2.804	2.480
09	2.648	2.510	2.375	2.228	2.133	2.243	2.435	2.701	3.060	3.348	3.540	3.626	3.535	3.354	2.997	2.651
10	2.778	2.568	2.400	2.229	2.017	1.994	2.057	2.236	2.477	2.819	3.159	3.410	3.510	3.444	3.185	2.870
11	2.890	2.696	2.494	2.280	2.057	1.909	1.859	1.919	2.081	2.327	2.576	2.970	3.257	3.389	3.283	3.040
12	2.976	2.813	2.643	2.431	2.159	1.972	1.826	1.719	1.774	1.922	2.101	2.422	2.818	3.165	3.248	3.162
13	2.995	2.917	2.750	2.581	2.327	2.124	1.913	1.756	1.674	1.667	1.781	2.000	2.350	2.735	3.051	3.175
14	2.904	2.945	2.897	2.760	2.559	2.338	2.117	1.908	1.744	1.633	1.588	1.706	1.946	2.305	2.737	3.069
15	2.742	2.903	2.922	2.898	2.778	2.611	2.387	2.154	1.944	1.759	1.625	1.612	1.732	1.965	2.365	2.831
16	2.505	2.783	2.909	2.986	2.937	2.862	2.683	2.455	2.260	2.014	1.791	1.690	1.697	1.794	2.053	2.492
17	2.359	2.594	2.814	2.976	3.040	3.034	2.954	2.786	2.585	2.366	2.084	1.911	1.852	1.854	1.971	2.258
18	2.250	2.473	2.649	2.915	3.028	3.137	3.124	3.015	2.936	2.739	2.449	2.242	2.074	1.986	2.020	2.177
19	2.272	2.401	2.550	2.773	2.960	3.099	3.190	3.187	3.141	3.021	2.814	2.618	2.419	2.256	2.193	2.269
20	2.336	2.413	2.484	2.647	2.812	2.990	3.149	3.215	3.271	3.239	3.094	2.975	2.797	2.595	2.462	2.415
21	2.508	2.514	2.527	2.637	2.690	2.843	2.999	3.128	3.251	3.310	3.275	3.220	3.131	2.954	2.781	2.677
22	2.736	2.685	2.631	2.636	2.634	2.709	2.835	2.982	3.130	3.233	3.280	3.369	3.339	3.242	3.104	2.961
23	2.965	2.912	2.814	2.752	2.703	2.700	2.688	2.779	2.916	3.063	3.177	3.322	3.422	3.417	3.336	3.284
Mean	2.761	2.791	2.807	2.826	2.808	2.822	2.824	2.820	2.829	2.819	2.762	2.755	2.755	2.767	2.766	2.802

HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31	
00	3.514	3.373	3.180	2.993	2.778	2.625	2.586	2.678	2.821	3.048	3.228	3.317	3.411	3.444	3.438	
01	3.654	3.617	3.485	3.264	3.035	2.810	2.649	2.586	2.613	2.749	2.951	3.122	3.270	3.357	3.466	
02	3.620	3.720	3.720	3.573	3.322	3.071	2.848	2.682	2.573	2.590	2.680	2.834	3.030	3.195	3.394	Monthly
03	3.427	3.686	3.818	3.785	3.641	3.379	3.133	2.884	2.694	2.576	2.550	2.625	2.735	2.937	3.148	Max HWL
04	3.111	3.433	3.737	3.907	3.840	3.659	3.444	3.201	2.926	2.761	2.591	2.538	2.547	2.704	2.888	04:54/21
05	2.704	3.048	3.487	3.775	3.898	3.849	3.697	3.460	3.206	2.978	2.759	2.586	2.487	2.523	2.660	3.903
06	2.398	2.607	3.017	3.452	3.745	3.887	3.866	3.717	3.505	3.247	2.976	2.757	2.553	2.486	2.467	
07	2.215	2.254	2.539	2.948	3.376	3.678	3.851	3.828	3.704	3.501	3.210	2.928	2.697	2.545	2.448	
08	2.255	2.073	2.167	2.436	2.810	3.269	3.593	3.770	3.778	3.652	3.390	3.150	2.860	2.659	2.477	Monthly
09	2.319	2.064	1.953	2.018	2.299	2.662	3.083	3.430	3.637	3.659	3.504	3.302	3.031	2.809	2.571	Min LWL
10	2.483	2.155	1.884	1.806	1.896	2.146	2.526	2.942	3.284	3.486	3.479	3.358	3.144	2.948	2.725	14:24/11
11	2.691	2.304	1.993	1.757	1.696	1.794	2.071	2.397	2.758	3.107	3.252	3.294	3.203	3.055	2.856	1.579
12	2.876	2.544	2.195	1.877	1.664	1.603	1.743	1.981	2.282	2.618	2.907	3.090	3.119	3.107	2.975	
13	3.037	2.784	2.453	2.094	1.808	1.637	1.621	1.723	1.924	2.215	2.471	2.741	2.953	3.037	3.031	
14	3.088	2.995	2.738	2.387	2.076	1.816	1.662	1.644	1.740	1.919	2.149	2.402	2.658	2.905	2.975	Monthly
15	3.038	3.104	2.978	2.738	2.434	2.122	1.918	1.797	1.762	1.827	1.956	2.144	2.396	2.676	2.908	Mean
16	2.880	3.119	3.134	3.028	2.790	2.510	2.249	2.056	1.942	1.882	1.950	2.016	2.231	2.493	2.725	MSL
17	2.621	3.011	3.191	3.220	3.078	2.887	2.646	2.422	2.219	2.117	2.061	2.118	2.218	2.398	2.595	2.816
18	2.400	2.812	3.107	3.284	3.266	3.162	3.018	2.791	2.604	2.412	2.302	2.244	2.299	2.432	2.508	
19	2.323	2.600	2.938	3.179	3.300	3.316	3.273	3.162	2.978	2.775	2.615	2.496	2.465	2.490	2.527	
20	2.402	2.513	2.731	3.013	3.210	3.336	3.394	3.345	3.271	3.109	2.939	2.795	2.688	2.663	2.620	
21	2.554	2.550	2.605	2.755	3.012	3.214	3.345	3.401	3.415	3.335	3.215	3.075	2.963	2.884	2.766	
22	2.789	2.698	2.619	2.612	2.735	2.975	3.189	3.316	3.427	3.428	3.369	3.310	3.184	3.109	2.984	
23	3.073	2.920	2.760	2.631	2.613	2.707	2.912	3.118	3.300	3.400	3.407	3.429	3.373	3.308	3.178	
Mean	2.811	2.833	2.851	2.855	2.847	2.838	2.847	2.847	2.848	2.850	2.830	2.820	2.813	2.840	2.847	

[ ] denotes inferred water level values Data Status: Verified

Figure 4 Hourly Height Water Level Data for a Tide Station

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters IGLD (1985)

Station: 9052030 Oswego, Lake Ontario , NY Time Meridian: 75 W Data Type: Great Lakes

HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16
01	75.21	75.21	75.19	75.18	75.19	75.17	75.15	75.17	75.17	75.20	75.21	75.21	75.20	75.17	75.17	75.17
02	75.25	75.21	75.19	75.19	75.22	75.14	75.17	75.16	75.19	75.19	75.20	75.22	75.18	75.17	75.18	75.16
03	75.26	75.21	75.19	75.17	75.19	75.18	75.18	75.16	75.16	75.19	75.21	75.19	75.18	75.18	75.15	75.17
04	75.25	75.20	75.19	75.20	75.21	75.18	75.17	75.16	75.17	75.20	75.21	75.18	75.17	75.18	75.16	75.16
05	75.25	75.21	75.20	75.19	75.21	75.18	75.17	75.20	75.20	75.18	75.21	75.20	75.19	75.17	75.19	75.16
06	75.25	75.21	75.19	75.20	75.20	75.19	75.17	75.16	75.19	75.20	75.20	75.20	75.17	75.17	75.14	75.15
07	75.25	75.20	75.19	75.19	75.19	75.17	75.18	75.20	75.20	75.19	75.21	75.20	75.18	75.17	75.14	75.17
08	75.24	75.21	75.19	75.21	75.20	75.17	75.17	75.14	75.19	75.20	75.22	75.20	75.19	75.15	75.18	75.15
09	75.24	75.21	75.19	75.20	75.19	75.19	75.16	75.17	75.18	75.18	75.22	75.20	75.19	75.18	75.16	75.14
10	75.24	75.20	75.19	75.18	75.19	75.18	75.16	75.20	75.17	75.20	75.22	75.22	75.18	75.18	75.17	75.16
11	75.23	75.19	75.17	75.18	75.20	75.18	75.15	75.15	75.19	75.20	75.22	75.20	75.19	75.18	75.16	75.15
12	75.22	75.21	75.18	75.18	75.17	75.17	75.17	75.16	75.17	75.19	75.22	75.20	75.18	75.18	75.17	75.16
13	75.22	75.20	75.18	75.19	75.18	75.16	75.16	75.15	75.17	75.18	75.21	75.19	75.19	75.17	75.16	75.16
14	75.23	75.20	75.19	75.21	75.18	75.19	75.14	75.15	75.16	75.18	75.20	75.22	75.17	75.17	75.18	75.17
15	75.22	75.21	75.17	75.19	75.17	75.15	75.14	75.18	75.17	75.19	75.20	75.18	75.18	75.17	75.17	75.17
16	75.21	75.20	75.19	75.18	75.19	75.16	75.18	75.18	75.17	75.19	75.19	75.19	75.17	75.16	75.16	75.16
17	75.21	75.20	75.20	75.21	75.20	75.17	75.17	75.18	75.17	75.19	75.20	75.18	75.17	75.17	75.17	75.15
18	75.22	75.20	75.20	75.21	75.21	75.20	75.18	75.18	75.15	75.17	75.20	75.18	75.16	75.15	75.16	75.16
19	75.21	75.20	75.19	75.21	75.19	75.19	75.18	75.20	75.18	75.22	75.19	75.19	75.17	75.16	75.16	75.17
20	75.20	75.22	75.19	75.25	75.19	75.17	75.18	75.18	75.20	75.22	75.20	75.20	75.16	75.16	75.16	75.13
21	75.20	75.18	75.18	75.15	75.19	75.19	75.15	75.19	75.22	75.18	75.21	75.19	75.18	75.16	75.15	75.17
22	75.21	75.20	75.17	75.17	75.19	75.18	75.19	75.17	75.23	75.20	75.21	75.19	75.18	75.18	75.15	75.13
23	75.20	75.19	75.17	75.24	75.19	75.16	75.18	75.19	75.22	75.22	75.21	75.17	75.18	75.16	75.17	75.13
24	75.21	75.20	75.17	75.20	75.18	75.17	75.17	75.19	75.18	75.21	75.21	75.18	75.18	75.15	75.16	75.15
Mean	75.23	75.20	75.19	75.19	75.19	75.18	75.17	75.17	75.18	75.20	75.21	75.19	75.18	75.17	75.16	75.16

HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31	
01	75.17	75.17	75.14	75.12	75.13	75.14	75.11	75.16	75.14	75.11	75.09	75.07	75.07	75.10	75.09	
02	75.17	75.18	75.14	75.16	75.12	75.16	75.12	75.16	75.14	75.10	75.08	75.09	75.06	75.11	75.08	
03	75.16	75.19	75.15	75.15	75.11	75.16	75.12	75.15	75.13	75.10	75.08	75.06	75.06	75.10	75.08	Monthly
04	75.17	75.18	75.14	75.14	75.13	75.15	75.10	75.14	75.14	75.10	75.07	75.09	75.02	75.09	75.08	Max HWL
05	75.16	75.18	75.16	75.13	75.14	75.13	75.14	75.16	75.13	75.10	75.06	75.11	75.07	75.08	75.08	03:00/01
06	75.17	75.16	75.15	75.16	75.10	75.17	75.12	75.16	75.12	75.10	75.06	75.07	75.16	75.07	75.08	75.259
07	75.16	75.16	75.17	75.14	75.12	75.13	75.14	75.14	75.13	75.10	75.07	75.06	75.14	75.07	75.07	
08	75.16	75.16	75.14	75.15	75.15	75.12	75.14	75.16	75.13	75.10	75.06	75.08	75.11	75.05	75.07	
09	75.15	75.15	75.11	75.14	75.12	75.20	75.15	75.17	75.13	75.11	75.06	75.06	75.10	75.08	75.07	Monthly
10	75.16	75.15	75.11	75.14	75.11	75.18	75.10	75.15	75.13	75.12	75.08	75.07	75.11	75.07	75.06	Min LWL
11	75.16	75.16	75.13	75.14	75.11	75.16	75.11	75.16	75.12	75.11	75.08	75.06	75.11	75.06	75.07	04:00/29
12	75.16	75.17	75.16	75.14	75.12	75.12	75.13	75.14	75.11	75.11	75.09	75.07	75.12	75.10	75.07	75.021
13	75.16	75.15	75.14	75.14	75.12	75.14	75.13	75.14	75.11	75.10	75.07	75.05	75.08	75.08	75.07	
14	75.16	75.17	75.13	75.15	75.10	75.11	75.14	75.14	75.10	75.11	75.06	75.08	75.08	75.08	75.06	
15	75.17	75.16	75.13	75.13	75.12	75.12	75.12	75.13	75.11	75.09	75.07	75.06	75.07	75.08	75.05	Monthly
16	75.16	75.16	75.13	75.13	75.13	75.14	75.14	75.13	75.12	75.09	75.08	75.05	75.09	75.05	75.06	Mean
17	75.18	75.16	75.13	75.13	75.08	75.11	75.16	75.13	75.10	75.07	75.08	75.07	75.08	75.09	75.06	MSL
18	75.17	75.15	75.14	75.16	75.12	75.13	75.13	75.13	75.10	75.07	75.08	75.06	75.08	75.09	75.06	75.152
19	75.16	75.16	75.13	75.14	75.11	75.11	75.10	75.14	75.10	75.08	75.06	75.05	75.07	75.09	75.06	
20	75.17	75.16	75.16	75.15	75.12	75.13	75.16	75.14	75.11	75.09	75.06	75.07	75.09	75.07	75.06	
21	75.18	75.14	75.11	75.13	75.16	75.12	75.17	75.14	75.11	75.08	75.07	75.05	75.09	75.07	75.04	
22	75.18	75.15	75.14	75.13	75.10	75.15	75.17	75.14	75.11	75.08	75.07	75.06	75.09	75.08	75.06	
23	75.18	75.14	75.14	75.12	75.09	75.14	75.18	75.14	75.11	75.08	75.09	75.05	75.10	75.08	75.05	
24	75.19	75.14	75.11	75.11	75.09	75.12	75.17	75.15	75.11	75.09	75.10	75.08	75.09	75.09	75.06	
Mean	75.17	75.16	75.14	75.14	75.12	75.14	75.14	75.15	75.12	75.10	75.07	75.07	75.09	75.08	75.07	

[ ] denotes inferred water level values Data Status: Verified

Figure 5 Hourly Height Water Level Data for a Great Lakes Station

1.4. Computation of Tidal Datums and Water Level Datums

1.4.1. National Tidal Datum Epoch

Tidal datums shall be computed relative to a specific 19 year tidal cycle adopted by the National Ocean Service (NOS) called the National Tidal Datum Epoch (NTDE). The present NTDE is the period 1983 through 2001. A primary datum determination is based directly on the average of tide observations over the 19 year Epoch period at NOS permanent long term primary control stations in the National Water Level Observation Network (NWLON). The data from NOS primary stations are used to compute datums at short term subordinate stations by reducing the data from those subordinate stations to equivalent 19 year mean values through the method of comparison of simultaneous observation.

1.4.2. Computational Procedures

The equivalent 19 year tidal datums for subordinate stations are computed for certain phases of the tide using tide-by-tide comparisons or monthly mean comparisons with an appropriate NOS long term control station. Accepted 19 year mean values of mean tide level (MTL), mean range (MN), diurnal high water inequality (DHQ), diurnal low water inequality (DLQ), diurnal tide level (DTL), and great diurnal range (GT) are required in the reduction process in which a "short series" of tide observations at any location are compared with simultaneous observations from an NOS control station. Datums are computed by the "standard" method of range ratio comparison generally on the West coast and Pacific Islands where there exists a large diurnal inequality in the low and high waters. The "modified" method of range ratio comparison is generally used on the East coast and Caribbean where small differences exist in the low and high water diurnal inequalities. For stations requiring a datum determination, at least 30 continuous days of tide observations are required for stations where adequate primary datum control exists. For error budget purposes, one month of data results in a datum accuracy of 0.11 m (95% confidence level) for Stations in the Gulf of Mexico and 0.08 m (95% confidence level) for east and West Coast stations. Examples of a tide by tide and a monthly mean simultaneous comparison for datum determination are found in Figures 1.6 and 1.7.

Descriptions of the tidal datum computational procedures are found in the *Tide and Current Glossary (http://tidesandcurrents.noaa.gov/publications/glossary2.pdf), Tidal Datum Planes, Manual of Tide Observations, NOAA Special Publication NOS CO-OPS 1 Tidal Datums and Their Applications (http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf) and Computational Techniques for Tidal Datums Handbook (http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf).*

1.4.3. Tidal Datum Recovery

Whenever tide stations are installed at historical sites, measures shall be taken to "recover" the established tidal datums through leveling which shall be accomplished by referencing the gauge or tide staff zero ("0") to more than one existing bench mark (three bench marks are preferred) with a published tidal elevation. Through this process, the published MLLW elevation is transferred by level differences to the "new" gauge or tide staff and compared to the MLLW elevation computed from the new data on the same zero ("0"). Factors affecting the datum recovery (i.e. differences between old and newly computed datums) include the length of each data series used to compute the datums, the geographical location, the tidal characteristics in the region, the length of time between reoccupations, the sea level trends in the region, land level trends, and the control station used. Based on all of these factors, the datum recovery can be expected to vary from +/- 0.03 m to +/- 0.08 m. Thus successful datum recovery is defined as the difference of 8 cm or less between the old and newly computed datums. After a successful datum recovery is performed and benchmark stability is established, the historical value of Mean Lower Low Water (MLLW) and Mean High Water (MHW) shall be used as the operational datum reference for data from the gauge during coastal shoreline mapping survey operations. Hence, this process also serves as a very useful quality control procedure. An example of a published tidal datum sheet for a station for which a datum recovery could be made is found in Figure 1.8.

1.4.4. Datum Quality Control

It is essential for tidal datum quality control to have data processing and leveling procedures carried out as specified. Caution must also be used in computing tidal datums in rivers, tributaries, or in regions of unknown tidal regimes. Tide-by-tide comparisons between subordinate and control station data will often detect anomalous differences which should be investigated for possible gauge malfunction or sensor movement. Differences in elevations between bench marks based on new leveling must agree with previously established differences from the published bench mark sheets unless marks are destroyed or marks are disturbed by earthquakes, hurricanes, etc. Any changes in the elevation differences must be reconciled before using in any datum recovery procedure. Datum accuracy at a subordinate station depends on various factors, but availability and choice of an adequate control station of similar tidal characteristics, similar daily mean sea level and seasonal mean sea level variations, and similar sea level trends are the most important. The length of series will also determine accuracy. The longer the series, the more accurate the datum and the greater quality control and confidence gained from analyzing numerous monthly mean differences between the subordinate and control station. At reoccupied historical stations for which datum recoveries are made, updated datums shall be computed from the new time series and compared with the historical datums as the survey progresses.

Begin: Jun 15 2005 00:00
End: Jul 14 2005 23:54
Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
Expected Diff: 0.55 Hrs
* Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER Verified T.M.: 0W Tide Type: Mixed
(B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Verified T.M.: 0W Tide Type: Mixed

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference	
	HW		LW		HW		LW	HW	LW	HW	LW	HW	LW	HW	LW
2005	Hour	Date	Hour	Date	Hour	Date	Hour	Hours	Hours	Meters	Meters	Meters	Meters	Meters	Meters
Jun 15	2.3 HH	Jun 15	8.4 L	Jun 15	2.0 HH	Jun 15	7.5 L	0.3	0.9	5.091	4.266	3.304	2.546	1.787	1.720
Jun 15	13.6 H	Jun 15	19.7 LL	Jun 15	13.2 H	Jun 15	19.0 LL	0.4	0.7	4.745	3.890	2.970	2.222	1.775	1.668*
Jun 16	3.0 HH	Jun 16	9.3 L	Jun 16	2.5 HH	Jun 16	8.4 L	0.5	0.9	5.193	4.065	3.412	2.362	1.781	1.703
Jun 16	15.0 H	Jun 16	20.5 L	Jun 16	14.6 H	Jun 16	19.7 L	0.4	0.8	4.731	4.070	2.953	2.350	1.778	1.720
Jun 17	3.4 HH	Jun 17	10.0 LL	Jun 17	3.0 HH	Jun 17	9.1 LL	0.4	0.9	5.347	3.861	3.566	2.144	1.781	1.717
Jun 17	16.1 H	Jun 17	21.4 L	Jun 17	15.7 H	Jun 17	20.6 L	0.4	0.8	4.736	4.140	2.960	2.418	1.776	1.722
Jun 18	4.0 HH	Jun 18	10.8 LL	Jun 18	3.5 HH	Jun 18	10.1 LL	0.5	0.7	5.400	3.657	3.612	1.919	1.788	1.738
Jun 18	17.4 H	Jun 18	22.2 L	Jun 18	17.0 H	Jun 18	21.6 L	0.4	0.6	4.793	4.265	3.015	2.539	1.778	1.726
Jun 19	4.5 HH	Jun 19	11.8 LL	Jun 19	4.1 HH	Jun 19	11.1 LL	0.4	0.7	5.528	3.440	3.728	1.714	1.800	1.726
Jun 19	18.6 H	Jun 19	23.0 L	Jun 19	18.1 H	Jun 19	22.4 L	0.5	0.6	4.833	4.365	3.057	2.626	1.776	1.739
Jun 20	5.2 HH	Jun 20	12.6 LL	Jun 20	5.0 HH	Jun 20	11.9 LL	0.2*	0.7	5.603	3.249	3.806	1.503	1.797	1.746
Jun 20	19.5 H	Jun 20	23.8 L	Jun 20	19.1 H	Jun 20	23.2 L	0.4	0.6	4.893	4.452	3.107	2.722	1.786	1.730
Jun 21	5.8 HH	Jun 21	13.4 LL	Jun 21	5.5 HH	Jun 21	12.9 LL	0.3	0.5	5.681	3.127	3.887	1.368	1.794	1.759
Jun 21	20.4 H	Jun 22	0.6 L	Jun 21	20.1 H	Jun 22	0.1 L	0.3	0.5	4.961	4.482	3.167	2.753	1.794	1.729
Jun 22	6.5 HH	Jun 22	14.2 LL	Jun 22	6.2 HH	Jun 22	13.6 LL	0.3	0.6	5.727	3.026	3.933	1.248	1.794	1.778
Jun 22	21.3 H	Jun 23	1.6 L	Jun 22	20.9 H	Jun 23	1.0 L	0.4	0.6	4.984	4.498	3.192	2.766	1.792	1.732
Jun 23	7.6 HH	Jun 23	15.0 LL	Jun 23	7.2 HH	Jun 23	14.4 LL	0.4	0.6	5.736	2.999	3.936	1.230	1.800	1.769
Jun 23	22.1 H	Jun 24	2.5 L	Jun 23	21.7 H	Jun 24	1.9 L	0.4	0.6	5.024	4.476	3.230	2.755	1.794	1.721
Jun 24	8.2 HH	Jun 24	15.9 LL	Jun 24	7.8 HH	Jun 24	15.1 LL	0.4	0.8	5.711	3.054	3.935	1.307	1.776	1.747
Jun 24	22.9 H	Jun 25	3.5 L	Jun 24	22.3 H	Jun 25	2.9 L	0.6	0.6	5.084	4.436	3.309	2.714	1.775	1.722
Jun 25	9.2 HH	Jun 25	16.6 LL	Jun 25	8.8 HH	Jun 25	15.7 LL	0.4	0.9	5.615	3.164	3.839	1.415	1.776	1.749
Jun 25	23.7 H	Jun 26	4.5 L	Jun 25	23.1 H	Jun 26	4.0 L	0.6	0.5	5.165	4.387	3.394	2.678	1.771	1.709
Jun 26	10.3 HH	Jun 26	17.5 LL	Jun 26	9.9 HH	Jun 26	16.6 LL	0.4	0.9	5.453	3.316	3.674	1.577	1.779	1.739
Jun 27	0.4 H	Jun 27	5.7 L	Jun 26	23.7 HH	Jun 27	5.1 L	0.7*	0.6	5.243	4.299	3.477	2.579	1.766*	1.720
Jun 27	11.4 HH	Jun 27	18.1 LL	Jun 27	10.8 H	Jun 27	17.3 LL	0.6	0.8	5.257	3.478	3.467	1.744	1.790	1.734
Jun 28	1.2 HH	Jun 28	6.9 L	Jun 28	0.6 HH	Jun 28	6.4 L	0.6	0.5	5.313	4.167	3.538	2.451	1.775	1.716
Jun 28	12.6 H	Jun 28	18.7 LL	Jun 28	12.1 H	Jun 28	18.1 LL	0.5	0.6	5.007	3.639	3.217	1.921	1.790	1.718
Jun 29	1.9 HH	Jun 29	8.2 L	Jun 29	1.4 HH	Jun 29	7.5 L	0.5	0.7	5.381	3.997	3.591	2.274	1.790	1.723
Jun 29	14.0 H	Jun 29	19.5 LL	Jun 29	13.6 H	Jun 29	18.9 LL	0.4	0.6	4.883	3.908	3.094	2.210	1.789	1.698
Jun 30	2.6 HH	Jun 30	9.3 LL	Jun 30	2.1 HH	Jun 30	8.7 LL	0.5	0.6	5.486	3.850	3.711	2.119	1.775	1.731
Jun 30	15.6 H	Jun 30	20.6 L	Jun 30	15.2 H	Jun 30	20.1 L	0.4	0.5	4.824	4.151	3.047	2.445	1.777	1.706
Jul 1	3.3 HH	Jul 1	10.3 LL	Jul 1	2.9 HH	Jul 1	9.8 LL	0.4	0.5	5.521	3.694	3.741	1.957	1.780	1.737
Jul 1	17.1 H	Jul 1	21.8 L	Jul 1	16.7 H	Jul 1	21.2 L	0.4	0.6	4.867	4.347	3.083	2.625	1.784	1.722
Jul 2	4.2 HH	Jul 2	11.3 LL	Jul 2	3.7 HH	Jul 2	10.7 LL	0.5	0.6	5.554	3.565	3.768	1.816	1.786	1.749
Jul 2	18.4 H	Jul 2	22.7 L	Jul 2	17.9 H	Jul 2	22.2 L	0.5	0.5	4.943	4.500	3.152	2.770	1.791	1.730
Jul 3	4.7 HH	Jul 3	12.2 LL	Jul 3	4.3 HH	Jul 3	11.5 LL	0.4	0.7	5.590	3.464	3.809	1.712	1.781	1.752
Jul 3	19.4 H	Jul 3	23.5 L	Jul 3	18.9 H	Jul 3	23.1 L	0.5	0.4	4.963	4.519	3.180	2.797	1.783	1.722
Jul 4	5.6 HH	Jul 4	12.9 LL	Jul 4	5.1 HH	Jul 4	12.2 LL	0.5	0.7	5.571	3.379	3.782	1.637	1.789	1.742
Jul 4	20.1 H	Jul 5	0.4 L	Jul 4	19.6 H	Jul 4	23.9 L	0.5	0.5	5.016	4.579	3.230	2.853	1.786	1.726
Jul 5	6.0 HH	Jul 5	13.5 LL	Jul 5	5.5 HH	Jul 5	12.7 LL	0.5	0.8	5.540	3.354	3.751	1.598	1.789	1.756
Jul 5	20.9 H	Jul 6	1.2 L	Jul 5	20.3 H	Jul 6	0.6 L	0.6	0.6	5.029	4.598	3.244	2.861	1.785	1.737
Jul 6	6.9 HH	Jul 6	14.1 LL	Jul 6	6.3 HH	Jul 6	13.5 LL	0.6	0.6	5.521	3.354	3.734	1.601	1.787	1.753
Jul 6	21.5 H	Jul 7	1.9 L	Jul 6	20.9 H	Jul 7	1.3 L	0.6	0.6	5.056	4.584	3.272	2.860	1.784	1.724

Figure 6 Tide-By-Tide Comparison

Begin: Jun 15 2005 00:00
End: Jul 14 2005 00:00
Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
Expected Diff: 0.55 Hrs
* Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER — Verified — T.M.: 0W — Tide Type: Mixed
(B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY — Verified — T.M.: 0W — Tide Type: Mixed

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference	
2005	HW Hour	Date	LW Hour	Date	HW Hour	Date	LW Hour	HW Hours	LW Hours	HW Meters	LW Meters	HW Meters	LW Meters	HW Meters	LW Meters
Jul 7	7.4 HH	Jul 7	14.8 LL	Jul 7	7.2 HH	Jul 7	13.9 LL	0.2*	0.9	5.510	3.380	3.715	1.622	1.795	1.758
Jul 7	22.0 H	Jul 8	2.4 L	Jul 7	21.4 H	Jul 8	1.9 L	0.6	0.5	5.037	4.533	3.248	2.822	1.789	1.711
Jul 8	8.0 HH	Jul 8	15.3 LL	Jul 8	7.6 HH	Jul 8	14.5 LL	0.4	0.8	5.444	3.397	3.660	1.654	1.784	1.743
Jul 8	22.5 H	Jul 9	3.0 L	Jul 8	21.9 H	Jul 9	2.4 L	0.6	0.6	5.016	4.478	3.225	2.775	1.791	1.703
Jul 9	8.7 HH	Jul 9	15.8 LL	Jul 9	8.2 HH	Jul 9	15.1 LL	0.5	0.7	5.375	3.453	3.587	1.719	1.788	1.734
Jul 9	23.1 H	Jul 10	3.7 L	Jul 9	22.5 H	Jul 10	3.2 L	0.6	0.5	5.036	4.462	3.245	2.760	1.791	1.702
Jul 10	9.5 HH	Jul 10	16.2 LL	Jul 10	8.9 HH	Jul 10	15.5 LL	0.6	0.7	5.267	3.541	3.476	1.802	1.791	1.739
Jul 10	23.6 H	Jul 11	4.5 L	Jul 10	23.1 H	Jul 11	4.0 L	0.5	0.5	5.059	4.432	3.260	2.728	1.799	1.704
Jul 11	9.9 HH	Jul 11	16.8 LL	Jul 11	9.5 HH	Jul 11	16.0 LL	0.4	0.8	5.153	3.622	3.365	1.900	1.788	1.722
Jul 12	0.1 H	Jul 12	5.5 L	Jul 11	23.7 H	Jul 12	4.9 L	0.4	0.6	5.110	4.359	3.325	2.651	1.785	1.708
Jul 12	10.8 H	Jul 12	17.2 LL	Jul 12	10.4 H	Jul 12	16.5 LL	0.4	0.7	4.992	3.705	3.211	1.998	1.781	1.707
Jul 13	0.6 HH	Jul 13	6.3 L	Jul 13	0.1 HH	Jul 13	5.8 L	0.5	0.5	5.155	4.294	3.362	2.565	1.793	1.729
Jul 13	11.7 H	Jul 13	17.8 LL	Jul 13	11.3 H	Jul 13	17.1 LL	0.4	0.7	4.875	3.899	3.090	2.204	1.785	1.695

	HW Hours	LW Hours	HHW	HLW	HHW	HLW	HHW	HLW
SUMS			152.709	122.201	102.699	74.045	50.010	48.156
ITEMS			28	28	28	28	28	28
MEANS			5.454	4.364	3.668	2.644	1.786	1.720
STD DEV							0.007	0.011

	HW Hours	LW Hours	LHW	LLW	LHW	LLW	LHW	LLW
SUMS	25.60	36.50	138.919	97.465	88.944	48.861	49.975	48.604
ITEMS	56	56	28	28	28	28	28	28
MEANS	0.46	0.65	4.961	3.481	3.177	1.745	1.785	1.736
STD DEV	0.11	0.13					0.008	0.024

Figure 6 Tide-By-Tide Comparison (continued)

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Begin:  Jun 15 2005 00:00                 COMPARISON OF SIMULTANEOUS OBSERVATIONS                    Tidal Epoch:   1983-2001
End:    Jul 14 2005 00:00                                                                            Expected Diff:  0.55 Hrs
Run:    Jan 31 2007 16:30                                                                            * Exceeds 2 Standard Dev

(A) Subordinate Station:  9414863  RICHMOND, CHEVRON OIL PIER                     Verified     T.M.:   0W   Tide Type:         Mixed
(B) Standard    Station:  9414290  SAN FRANCISCO, SAN FRANCISCO BAY               Verified     T.M.:   0W   Tide Type:         Mixed


Mean Difference in HWI:    0.46                                             Mean Difference in LWI:    0.65
Mean HHW Height at (A):    5.454                                            Mean HLW Height at (A):    4.364
Mean LHW Height at (A):    4.961                                            Mean LLW Height at (A):    3.481
DHQ             at (A):    0.246                                            DLQ             at (A):    0.442
Mean HW Height  at (A):    5.208                                            Mean LW Height  at (A):    3.923
MN              at (A):    1.285                                            MTL             at (A):    4.565
GT              at (A):    1.973                                            DTL             at (A):    4.467

Mean HHW Difference:       1.786                                            Mean HLW Difference:       1.720
Mean LHW Difference:       1.785                                            Mean LLW Difference:       1.736
DHQ      Difference:       0.001                                            DLQ      Difference:      -0.008
Mean HW  Difference:       1.785                                            Mean LW  Difference:       1.728
MN       Difference:       0.058                                            MTL      Difference:       1.757
GT       Difference:       0.050                                            DTL      Difference:       1.761
MN       Ratio:            1.047                                            DHQ      Ratio:            1.003
GT       Ratio:            1.026                                            DLQ      Ratio:            0.982
MSL (100.00%)   at (A):    4.548
MSL (100.00%)   at (B):    2.782
MSL      Difference:       1.766

                            HWI    LWI     MTL      MN     MSL     DHQ     DLQ
                          Hours  Hours  Meters  Meters  Meters  Meters  Meters
Accepted  for B:           7.53   0.85   2.792   1.248   2.773   0.186   0.346
Differences and Ratios:    0.46   0.65   1.757   1.047   1.766   1.003   0.982
Corrected for A:           7.99   1.50   4.549   1.307   4.539   0.186   0.340

                                          FINAL/PRELIMINARY DATUMS   Standard Method

                                          MHHW  ---|---   5.388
                                                   |                DHQ   0.186
                                          MHW     -|-     5.202
                                                   |
                                          DTL     -|-     4.472
                                                   |                              GT    1.833
                                          MTL     -|-     4.549
                                                   |                              MN    1.307
                                          MSL     -|-     4.539
                                                   |                                                          Date         ID
                                          MLW     -|-     3.895
                                                   |                DLQ   0.340
                                          MLLW  ---|---   3.555                   HWI:  7.99         Comparison   ___________  ____

                                          On Staff Of:                            LWI:  1.50         Verified     ___________  ____
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Figure 6 Tide-By-Tide Comparison (concluded)

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005) Feb 01, 2007
1983-2001 TIDAL EPOCH

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER Product TM (0W) TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Product TM (0W) TIDE TYPE (M)

Mon Year		M T L			M S L			H W I			L W I			M N	
	A	B	A - B	A	B	A - B	A	B	A - B	A	B	A - B	A	B	A / B
	METER	METER	METER	METER	METER	METER	HRS	HRS	HRS	HRS	HRS	HRS	METER	METER	RATIO
Jan 2005	4.665	2.900	1.765	4.650	2.876	1.774	7.890	7.450	0.440	1.380	0.750	0.630	1.293	1.212	1.067
Feb 2005	4.639	2.875	1.764	4.626	2.853	1.773	7.970	7.520	0.450	1.430	0.800	0.630	1.315	1.239	1.061
Mar 2005	4.593	2.813	1.780	4.575	2.791	1.784	7.890	7.450	0.440	1.320	0.690	0.630	1.288	1.207	1.067
Apr 2005	4.503	2.740	1.763	4.485	2.713	1.772	7.890	7.500	0.390	1.380	0.720	0.660	1.276	1.199	1.064
May 2005	4.563	2.805	1.758	4.542	2.773	1.769	7.890	7.480	0.410	1.430	0.720	0.710	1.281	1.209	1.060
Jun 2005	4.535	2.780	1.755	4.517	2.750	1.767	7.870	7.450	0.420	1.430	0.710	0.720	1.274	1.210	1.053
Jul 2005	4.607	2.856	1.751	4.590	2.826	1.764	7.950	7.490	0.460	1.460	0.840	0.620	1.284	1.231	1.043
Aug 2005	4.604	2.864	1.740	4.593	2.838	1.755	7.970	7.520	0.450	1.490	0.880	0.610	1.279	1.230	1.040
Sep 2005	4.571	2.838	1.733	4.565	2.819	1.746	7.880	7.460	0.420	1.420	0.830	0.590	1.273	1.225	1.039
Oct 2005		2.809			2.787			7.420			0.810			1.235	
Nov 2005		2.781			2.751			7.440			0.830			1.229	
Dec 2005		2.840			2.805			7.460			0.800			1.245	

Mon Year		D H Q			D L Q			M H W			M L W	
	A	B	A / B	A	B	A / B	A	B	A - B	A	B	A - B
	METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan 2005	0.227	0.224	1.013	0.401	0.406	0.988	5.312	3.506	1.806	4.019	2.294	1.725
Feb 2005	0.207	0.204	1.015	0.350	0.354	0.989	5.296	3.494	1.802	3.981	2.255	1.726
Mar 2005	0.154	0.152	1.013	0.329	0.324	1.015	5.237	3.417	1.820	3.949	2.210	1.739
Apr 2005	0.156	0.156	1.000	0.388	0.380	1.021	5.141	3.339	1.802	3.865	2.140	1.725
May 2005	0.179	0.179	1.000	0.431	0.427	1.009	5.204	3.409	1.795	3.923	2.200	1.723
Jun 2005	0.246	0.245	1.004	0.439	0.439	1.000	5.172	3.385	1.787	3.898	2.175	1.723
Jul 2005	0.258	0.257	1.004	0.429	0.441	0.973	5.249	3.471	1.778	3.965	2.240	1.725
Aug 2005	0.218	0.216	1.009	0.376	0.393	0.957	5.244	3.479	1.765	3.965	2.249	1.716
Sep 2005	0.161	0.156	1.032	0.305	0.324	0.941	5.207	3.451	1.756	3.934	2.226	1.708
Oct 2005		0.140			0.324			3.427			2.192	
Nov 2005		0.204			0.417			3.395			2.166	
Dec 2005		0.256			0.487			3.462			2.217	

Mon Year		D R L(TL)			G T			M H H W			M L L W	
	A	B	A - B	A	B	A / B	A	B	A - B	A	B	A - B
	METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan 2005	4.579	2.809	1.770	1.921	1.842	1.043	5.539	3.730	1.809	3.618	1.888	1.730
Feb 2005	4.567	2.800	1.767	1.872	1.797	1.042	5.503	3.698	1.805	3.631	1.901	1.730
Mar 2005	4.505	2.728	1.777	1.771	1.683	1.052	5.391	3.569	1.822	3.620	1.886	1.734
Apr 2005	4.387	2.628	1.759	1.820	1.735	1.049	5.297	3.495	1.802	3.477	1.760	1.717
May 2005	4.438	2.680	1.758	1.891	1.815	1.042	5.383	3.588	1.795	3.492	1.773	1.719
Jun 2005	4.439	2.683	1.756	1.959	1.894	1.034	5.418	3.630	1.788	3.459	1.736	1.723
Jul 2005	4.521	2.764	1.757	1.971	1.929	1.022	5.507	3.728	1.779	3.536	1.799	1.737
Aug 2005	4.526	2.776	1.750	1.873	1.839	1.018	5.462	3.695	1.767	3.589	1.856	1.733
Sep 2005	4.498	2.755	1.743	1.739	1.705	1.020	5.368	3.607	1.761	3.629	1.902	1.727
Oct 2005		2.718			1.699			3.567			1.868	
Nov 2005		2.674			1.850			3.599			1.749	
Dec 2005		2.724			1.988			3.718			1.730	

Figure 7 Monthly Mean Simultaneous Comparison Example

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005) Feb 01, 2007
1983-2001 TIDAL EPOCH

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER Product TM (0W) TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Product TM (0W) TIDE TYPE (M)

	M T L	M S L	H W I	L W I	M N
	A - B	A - B	A - B	A - B	A / B
	METER	METER	HRS	HRS	RATIO
TOTAL MONTHS	9.000	9.000	9.000	9.000	9.000
SUMS	15.809	15.904	3.880	5.800	9.494
MEANS	1.757	1.767	0.431	0.644	1.055
ACCEPTED FOR B	2.792	2.773	7.535	0.848	1.248
CORRECTED FOR A	4.549	4.540	7.966	1.492	1.317

	D H Q	D L Q	M H W	M L W
	A / B	A / B	A - B	A - B
	RATIO	RATIO	METER	METER
TOTAL MONTHS	9.000	9.000	9.000	9.000
SUMS	9.090	8.893	16.111	15.510
MEANS	1.010	0.988	1.790	1.723
ACCEPTED FOR B	0.186	0.346	3.416	2.168
CORRECTED FOR A	0.188	0.342	5.206	3.891

	D R L(TL)	G T	M H H W	M L L W
	A - B	A / B	A - B	A - B
	METER	RATIO	METER	METER
TOTAL MONTHS	9.000	9.000	9.000	9.000
SUMS	15.837	9.322	16.128	15.550
MEANS	1.760	1.036	1.792	1.728
ACCEPTED FOR B	2.712	1.780	3.602	1.822
CORRECTED FOR A	4.472	1.844	5.394	3.550

METHOD	DATUM	VALUE
MODIFIED RANGE RATIO	MHHW =	5.394
MODIFIED RANGE RATIO	MLLW =	3.550
MODIFIED RANGE RATIO	DHQ =	0.187
MODIFIED RANGE RATIO	DLQ =	0.340
STANDARD	MHW =	5.207
STANDARD	MLW =	3.890
STANDARD	MHHW =	5.395
STANDARD	MLLW =	3.548
DIRECT	MN =	1.315
DIRECT	GT =	1.844
DIRECT	DHQ =	0.188
DIRECT	DLQ =	0.342

TABULATED ____________________________

VERIFIED ____________________________

FINAL/PRELIMINARY DATUMS

```
MHHW  ---|---  5.395
         |            DHQ   1.88
MHW     -|-    5.207
         |
MTL     -|-    4.549
         |                        GT  1.846
DTL     -|-    4.472
         |                        MN  1.317
MSL     -|-    4.540
         |
MLW     -|-    3.890
         |            DLQ 0.342
MLLW  ---|---  3.548

ON STAFF OF:
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Figure 7 Monthly Mean Simultaneous Comparison (continued)

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005) Feb 01, 2007
1983-2001 TIDAL EPOCH

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER Product TM (0W) TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Product TM (0W) TIDE TYPE (M)

O U T L I E R   R E P O R T

(MEAN DIFFERENCE EXCEEDS 2 STD. DEV. (MAX/MIN))

	M T L	M S L	H W I	L W I	M N	D H Q	D L Q	M H W	M L W	D T L	G T	M H H W	M L L W	
Std.Dev.	0.009	0.007	0.014	0.034	0.007	0.008	0.016	0.013	0.005	0.007	0.008	0.013	0.004	Std.Dev.
MAX	1.774	1.780	0.459	0.712	1.069	1.025	1.021	1.816	1.734	1.774	1.052	1.818	1.736	MAX
MIN	1.739	1.754	0.404	0.577	1.041	0.995	0.956	1.765	1.713	1.745	1.020	1.766	1.719	MIN
MON YEAR														
Jan 2005														Jan 2005
Feb 2005														Feb 2005
Mar 2005	1.780	1.784						1.820	1.739	1.777	1.052	1.822		Mar 2005
Apr 2005			0.390				1.021						1.717	Apr 2005
May 2005													1.719	May 2005
Jun 2005				0.720										Jun 2005
Jul 2005			0.460										1.737	Jul 2005
Aug 2005					1.040						1.018			Aug 2005
Sep 2005	1.733	1.746			1.039	1.032	0.941	1.756	1.708	1.743		1.761		Sep 2005
Oct 2005														Oct 2005
Nov 2005														Nov 2005
Dec 2005														Dec 2005

Figure 7 Monthly Mean Simultaneous Comparison (concluded)

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

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Station ID:	9414290	PUBLICATION DATE:	
	04/21/2003 Name:	SAN FRANCISCO	
	CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

To reach the tidal bench marks, proceed west along U.S. Highway 101 in the direction of the Golden Gate Bridge, then NW along Crissey Field Avenue (before the bridge) to the Golden Gate National Park (Presidio). The bench marks are located mostly along the coast in the vicinity. The tide gauge is located on the NE side of the National Parks Service wharf.

T I D A L   B E N C H   M A R K S

PRIMARY BENCH MARK STAMPING: 180 1936
DESIGNATION: 941 4290 TIDAL 180

MONUMENTATION:	Tidal Station disk	VM#:	967
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0702
SETTING CLASSIFICATION:	Concrete sea wall		

The primary bench mark is a disk set in the top of a 1 m (3 ft) high concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 15 m (50 ft) east of the NE corner of the Sanctuaries building, 6.10 m (20.0 ft) south of the south side of the garage building, and 1.07 m (3.5 ft) north of an angle in wall.

BENCH MARK STAMPING: BM 174 1925
DESIGNATION: 941 4290 TIDAL 174
ALIAS: TIDAL 174

MONUMENTATION:	Tidal Station disk	VM#:	971
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0697
SETTING CLASSIFICATION:	Concrete monument		

The bench mark is a disk set in a concrete post flush with the ground inside a circle of bricks in the pavement, 38.10 m (125.0 ft) west of the extended west edge of Engineer's Dock where it crosses Marine Drive, at the center of "Y" between Marine Drive and the road leading SE to Fort Winfield Scott, 12.95 m (42.5 ft) SW of the fire hydrant, and 8.69 m (28.5 ft) south of the south edge of an iron manhole cover.

Figure 8 Published Bench Mark Sheet

Station ID: 9414290 PUBLICATION DATE: 04/21/2003 Name: SAN FRANCISCO CALIFORNIA

NOAA Chart: 18649 Latitude: 37° 48.4' N

USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: BM 176 1925
DESIGNATION: 941 4290 TIDAL 176
ALIAS: TIDAL 176

MONUMENTATION: Tidal Station disk VM#: 972
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0705
SETTING CLASSIFICATION: Concrete step

The bench mark is a disk set in the west end of the lowest concrete step at the main entrance to the porch of the building at No. 651 Mason Street, 29.87 m (98.0 ft) SE of the intersection of Crissey Field Avenue and Mason Street, 15.24 m (50.0 ft) south of the centerline of Mason Street, and 0.21 m (0.7 ft) above sidewalk.

BENCH MARK STAMPING: 181 1945
DESIGNATION: 941 4290 TIDAL 181
ALIAS: TIDAL 181

MONUMENTATION: Tidal Station disk VM#: 973
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0701
SETTING CLASSIFICATION: Sea wall

The bench mark is a disk set in NW corner of a sea wall at the Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 62 m (204 ft) west of the inshore end of the pier, 45.87 m (150.5 ft) NW of a flag pole, 21.64 m (71.0 ft) NE of the north corner of Building S.F. 19.4 (paint shop and storage building), and 1.22 m (4.0 ft) above ground.

Figure 8 Published Bench Mark Sheet (continued)

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Station ID:	9414290	PUBLICATION DATE:	
	04/21/2003 Name:	SAN FRANCISCO	
	CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: NO 2 1948
DESIGNATION: CLARK RM 2
ALIAS: 941 4290 TIDAL 183

MONUMENTATION:	Triangulation Station disk	VM#:	975
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0700
SETTING CLASSIFICATION:	Sea wall		

The bench mark is a disk set flush in the top of a sea wall west of the public fishing pier, 11.43 m (37.5 ft) west of the west edge of the pier, 8.08 m (26.5 ft) NE of the NE corner of corrugated iron building No. 985, and about 0.91 m (3.0 ft) above ground.

BENCH MARK STAMPING: CLARK 1948
DESIGNATION: CLARK
ALIAS: 941 4290 TIDAL 185

MONUMENTATION:	Triangulation Station disk	VM#:	976
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0698
SETTING CLASSIFICATION:	Concrete sea wall		

The bench mark is a disk set in the top of a concrete sea wall west of the public fishing pier, about 549 m (1800 ft) NW of the Gulf of Farallons National Marine Sanctuary headquarters in Golden Gate National Park, 24.23 m (79.5 ft) west of the west edge of the pier, 6.86 m (22.5 ft) NE of the NW corner of corrugated iron building No. 985, 3.05 m (10.0 ft) west of the NW corner of a stucco paint locker building, and 1.07 m (3.5 ft) above ground.

Figure 8 Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 4290 K 1976
DESIGNATION: 941 4290 K TIDAL

MONUMENTATION: Tidal Station disk VM#: 978
AGENCY: National Ocean Service (NOS) PID: HT2255
SETTING CLASSIFICATION: Bedrock

The bench mark is a disk set vertically in bedrock on the south side of Marine Drive, 24 m (79 ft) SSW of the SE corner of the National Park Service building # T989, 14.69 m (48.2 ft) NW of bench mark BM 174 1925, and 2.44 m (8.0 ft) south of the road curb.

BENCH MARK STAMPING: 4290 L 1976
DESIGNATION: 941 4290 L TIDAL

MONUMENTATION: Tidal Station disk VM#: 979
AGENCY: National Ocean Survey (NOS) PID: HT2253
SETTING CLASSIFICATION: Bedrock

The bench mark is a disk set in bedrock on the south side of Marine Drive, 114 m (375 ft) west of the National Park Service building # T989, 15.70 m (51.5 ft) SE of the eastern-most concrete and steel safety chain stanchion on the seawall, 7.77 m (25.5 ft) from the centerline of Marine Drive, and 1.22 m (4 ft) above street level.

Figure 8 Published Bench Mark Sheet (continued)

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National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 9414290 PUBLICATION DATE:
04/21/2003 Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 4290 M 1982
DESIGNATION: 941 4290 M TIDAL

MONUMENTATION: Tidal Station disk VM#: 980
AGENCY: National Ocean Survey (NOS) PID: HT3538
SETTING CLASSIFICATION: Concrete foundation

The bench mark is a disk set flush in concrete foundation in front of Stilwell Hall (building # 650) on Mason Street, 27.34 m (89.7 ft) south of the centerline of Mason street, 10.30 m (33.8 ft) east of the NE corner of the west wing of the Stilwell Hall, 6.07 m (19.9 ft) west of the west edge of the sidewalk leading to the entrance of Stilwell Hall, 0.30 m (1.0 ft) SE of the NW corner of the foundation, and 0.12 m (0.4 ft) above ground level.

BENCH MARK STAMPING: BM 175 1925
DESIGNATION: 941 4290 TIDAL 175
ALIAS: TIDAL 175

MONUMENTATION: Tidal Station disk VM#: 1829
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0696
SETTING CLASSIFICATION: Sea wall

The bench mark is a disk set in top surface of the sea wall, near the National Park Service building at the intersection of the pavement and the seawall, 65.23 m (214.0 ft) NE of bench mark 4290 L 1976, 58.67 m (192.5 ft) west from the NW corner of the National Park Service building, 28.90 m (94.8 ft) WNW of the northern-most post of pedestrian gate, 6.86 m (22.5 ft) north of the centerline of Marine Drive, and 0.73 m (2.4 ft) south from the north edge of the sea wall.

Figure 8 Published Bench Mark Sheet (continued)

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Station ID:	9414290	PUBLICATION DATE:	
	04/21/2003 Name:	SAN FRANCISCO	
	CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 4290 N 1995
DESIGNATION: 941 4290 N

MONUMENTATION:	Tidal Station disk	VM#:	15436
AGENCY:	National Ocean Service (NOS)	PID:	AE5209
SETTING CLASSIFICATION:	Concrete sea wall		

The bench mark is a disk set in a concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, near an inshore end of a walkway leading to a pier, 13.70 m (44.9 ft) north of bottom of stairs leading to the Sanctuary building, 3.96 m (13.0 ft) east of a step in seawall, and 3.20 m (10.5 ft) west of the center of the walkway.

Figure 8 Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003 Name: SAN FRANCISCO CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L   D A T U M S

Tidal datums at SAN FRANCISCO based on:

LENGTH OF SERIES:	19 Years
TIME PERIOD:	January 1983 - December 2001
TIDAL EPOCH:	1983-2001
CONTROL TIDE STATION:	

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (01/27/1983)	= 2.640
MEAN HIGHER HIGH WATER (MHHW)	= 1.780
MEAN HIGH WATER (MHW)	= 1.595
MEAN TIDE LEVEL (MTL)	= 0.970
MEAN SEA LEVEL (MSL)	= 0.951
MEAN LOW WATER (MLW)	= 0.346
MEAN LOWER LOW WATER (MLLW)	= 0.000
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	= -0.018
LOWEST OBSERVED WATER LEVEL (12/17/1933)	= -0.877

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
180 1936	3.972	2.378
BM 174 1925	5.013	3.418
BM 176 1925	4.814	3.219
181 1945	3.987	2.392
NO 2 1948	4.221	2.626
CLARK 1948	4.233	2.639
4290 K 1976	5.828	4.234
4290 L 1976	6.620	5.025
4290 M 1982	3.705	2.111
BM 175 1925	4.160	2.566
4290 N 1995	3.646	2.051

Figure 8 Published Bench Mark Sheet (continued)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003 Name: SAN FRANCISCO CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, and minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

Figure 8 Published Bench Mark Sheet (concluded)

1.5. Data Submission Requirements

Data submission requirements for water level measurement stations are comprised of timely submissions of both documentation and data:
(a) Supporting documents for the installation, maintenance, and removal of stations,
(b) The formatted digital water level data collected by the water level measurement system required for NOS quality control and ingestion into the NOS database management system, and
(c) documentation for processing and tabulation of the data, and tidal datum computation are required.

Data submission requirements for GPS are listed as specified in CO-OPS "User's Guide for GPS Observations at Tide and Water Level Station Bench Marks".

1.5.1. Station Documentation

The documentation package shall be forwarded after a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to Section 1.5.3 for required documentation details and time lines for submission requirements.

1.5.2. Water Level Data

The final observed water level measurements shall be reported as heights in meters to three decimal places (i.e. 0.001 m). All heights shall be referenced to station datum and shall be referenced to UTC. The final tide reducer time series data shall be referenced to MLLW and shall be referenced to UTC. The contractor shall provide the water level data in the format specified below from the water level gauges installed.

The original raw water level data and the correctors used to convert the data to chart datum shall be retained until notified in writing or at least three years after the survey is completed. All algorithms and conversions used to provide correctors shall be fully supported by the calibrations, maintenance documentation, leveling records, and sound engineering/oceanographic practices. Factors used to convert the measured data (e.g. pressure to water level heights) shall be maintained for the entire water level collection period and reported.

All digital water level and ancillary data shall be transmitted to CO-OPS in a format dependent on the DCP configuration. If GOES satellite is used for NOAA in-house surveys, the data shall be transmitted and received using the NOS compressed pseudo binary format (see NGWLMS GOES Message Formatting, Libraro, January 2003 at the following url: http://tidesandcurrents.noaa.gov/publications/newgoes_format.pdf). These satellite messages are then decoded by NOS DMS upon receipt from NESDIS before further processing and review by CORMS can be completed. If satellite transmission configurations cannot be installed, the data shall be manually downloaded from the DCP and submitted to NGS, as shown in the format below, in a digital format, on CD-ROM, or by email as an ASCII data attachment.

6-minute water level data download files shall be named in the following format: xxxxxxxy.w1.dat, where xxxxxxx is the seven digit station number, y is the DCP number (usually 1), w1 is the product code for 6-minute data, and dat is the extension (Use t = 2,3...if more than one file is from the same station and DCP). This is the format needed when the data is loaded into DMS.

Multiple DCP may have been used to collect 6-minute water level data for a particular site, and backup or redundant DCP data may be used to fill the gap in the primary DCP data, but, water level data shall be submitted for a single DCP (numbered as 1). When data from more than one DCP is used to fill the gap, care should be taken to apply the proper correctors (such as gain and offsets, or appropriate staff constants for each DCP/sensor) so that all the 6-minute water level data and the processed products such as hourly heights, high and low data, monthly means data, and station shall be placed on the station datum.

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

The 6-minute interval data (acoustic sensor and pressure sensor examples follow) shall have the following format for CO-OPS database to accept.

1.5.2.1. Acoustic Sensor Data (XXX.ACO format)

```
Column  1- 7 Station ID (7 digits, assigned in the project instructions)
Column  8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column  9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20-20 Blank
Column 21-22 Hours in 24 hour format (i.e. 00, 01, ...., 23)
Column 23-23 : (colon)
Column 24-25 Minutes (00,06,12, ..., 54)
Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
Column 33-38 Sigma (standard deviation in millimeters in integer format)
Column 39-44 Outlier (integer format)
Column 45-50 Temperature 1 (tenth of degrees C in integer format)
Column 51-56 Temperature 2 (tenth of degrees C in integer format)
Column 57-58 Sensor type (A1 for acoustic type)
Column 59-60 blank
Column 61-61 Data Source (S for Satellite, D for Diskette)
```

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308 297A1 D
85169901AUG 17 2007 05:06 1126 26 0 308 298A1 D
85169901AUG 17 2007 05:12 1107 26 1 309 298A1 D
```

1.5.2.2. Pressure Sensor or Generic Data (XXX.BWL format)

```
Column  1- 7 Station ID (7 digits, assigned in the project instructions)
Column  8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column  9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20-20 Blank
Column 21-22 Hours in 24 hour format (i.e. 00, 01, ..., 23)
Column 23-23 : (colon)
Column 24-25 Minutes (00-54)
Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
Column 33-38 Sigma (standard deviation in millimeters in integer format)
Column 39-44 Outlier (integer format)
Column 45-50 Sensor temperature (tenth of degrees C in integer format)
Column 51-52 Sensor type (Z1 for generic or pressure)
Column 53-53 blank
```

Column 54-54 Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308Z1 D
85169901AUG 17 2007 05:06 1126 26 0 308Z1 D
85169901AUG 17 2007 05:12 1107 26 1 309Z1 D
```

Note: pressure data must be accompanied by documented staff observations as listed in Section 1.2.4.2, if applicable.

1.5.2.3 Microwave Water Level Sensor Data (XXX.QC format)

Column 1- 7 Station ID (7 character)
Column 8- 8 1 (DCP number, use 2, 3, etc., for additional DCPs)
Column 9- 10 Blank
Column 11- 27 Date and Time (MMM DD YYYY HH:MM format, e.g. Jun 01 2013 14:48)
Column 28- 28 Blank
Column 29- 30 Sensor Id (2 characters, e.g. Y1 for MWWL)
Column 31- 31 Blank
Column 32- 32 Source (1 character, e.g. Satellite [S], PORTS [Z], Tsunami [T], Storm surge [X], Diskette [D])
Column 33- 33 Blank
Column 34- 34 Type (1 character, e.g. Primary [P], Redundant [R])
Column 35- 35 Blank
Column 36- 41 Pressure value (integer divide by 1000 – field length 6)
Column 42- 42 Blank
Column 43- 48 Primary water level value   (integer divide by 1000) - (Acoustic [A1], Pressure [N1], Storm surge [S1], Tsunami [U1], Air gap [Q1, MWWL[Y1])
Column 49- 49 Blank
Column 50- 55 Primary water level sigma (integer divide by 1000 – field length 6)
Column 56- 56 Blank
Column 57– 62 Primary water level outliers (integer)
Column 63- 63 Blank
Column 64- 69 Backup water level value (integer divide by 1000 - field length 6) Backup [B1], Second Pressure [T1])
Column 70- 70 Blank
Column 71- 76 Backup water level sigma (integer divide by 1000 – field length 6)
Column 77- 77 Blank
Column 78– 83 Backup water level outliers (integer)
Column 84- 84 Blank
Column 85- 90 Backup water level water temp (integer divide by 10)
Column 91- 91 Blank
Column 92- 97 First air temperature (integer divide by 10)
Column 98- 98 Blank
Column 99- 104 Second air temperature (integer divide by 10)
Column 105- 105 Blank
Column 106- 111 Datum offset (integer divide by 1000)
Column 112- 112 Blank
Column 113- 118 Sensor offset (integer divide by 1000)
Column 119- 119 Blank
Column 120- 125 Backup water level gain (integer divide by 1000)
Column 126- 126 Blank
Column 127- 132 Backup water level offset (integer divide by 1000)

Sample data:

86310442 MAY 01 2013 15:24 Y1 D P 999999   3269   3   1 999999 999999 999999 999999 999999 999999 999999 999999 999999 999999

86310442 MAY 01 2013 15:30 Y1 D P 999999   3246   3   0 999999 999999 999999 999999 999999 999999 999999 999999 999999 999999

86310442 MAY 01 2013 15:36 Y1 D P 999999   3228   3   0 999999 999999 999999 999999 999999 999999 999999 999999 999999 999999

86310442 MAY 01 2013 15:42 Y1 D P 999999   3205   3   0 999999 999999 999999 999999 999999 999999 999999 999999 999999 999999

1.5.2.4. Tabulations and Tidal Datums

For contract surveys, the contractor shall provide digital tabulations of staff/gauge differences, hourly heights, high and low waters, monthly means, and water level datums for the entire time series of observations from each water level station. Along with the final contractor computed tidal datums, the contractor shall provide copies of the tide-by-tide and/or monthly mean simultaneous comparison sheets from which the final tidal datums were determined. Audit trails of data edits and gap-filling shall be summarized and provided also.

The digital tabulation files for hourly heights, high and low waters, monthly means, and station datum shall have the following formats:

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

1.5.2.5. Hourly Heights Data Format

```
Column  1- 7 Station ID (7 digits, assigned in the project instructions)
Column  8- 8 Blank
Column  9-16 Date (YYYYMMDD format, e.g. 20070120)
Column 17-17 Blank
Column 18-19 Hours   (2 digits 00-23, use leading zeros)
Column 20-20 : (colon)
Column 21-22 Minutes (2 digits 00-54, use leading zeros)
Column 23-23 Blank
Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)
```

Sample data:

```
9414290 20040101 00:00 123.456
```

Hourly height data file shall be named in the following format: xxxxxxx.w2.dat, where xxxxxxx is the seven digit station number, w2 is the product code for the hourly heights data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.6. High/Low Data Format

```
Column  1- 7 Station ID (7 digits, assigned in the project instructions)
Column  8- 8 Blank
Column  9-16 Date (YYYYMMDD format, e.g. 20070120)
```

```
Column 17-17 Blank
Column 18-19 Hours (2 digits 00-23, use leading zeros)
Column 20-20 : (colon)
Column 21-22 Minutes (2 digits 00-54, use leading zeros)
Column 23-23 Blank
Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)
Column 31-31 Blank
Column 32-33 Water level high/low type (H, L, HH, or LL)
```

Sample data:

```
9414290 20040101 00:00 123.456 HH
```

Definition of Acronym:

```
H:  Higher low  water level value
L:  Lower  high water level value
HH:  Higher high water level value
LL:  Lower  low  water level value
```

High and low data file shall be named in the following format: xxxxxxx.w3.dat, where xxxxxxx is the seven digit station number, w3 is the product code for the high/low data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.7. Monthly Mean Data Format

```
Column   1-  7 Station ID (7 digits, assigned in the project instructions)
Column   8-  8 Blank
Column   9- 12 Year (YYYY format, e.g. 2007)
Column  13- 13 Blank
Column  14- 15 Month (in 2 digits 01-12, use leading zeros)
Column  16- 16 Blank
Column  17- 23 MHHW in meters (F7.3 format, e.g. 123.456)
Column  24- 24 Blank
Column  25- 31 MHW  in meters (F7.3 format, e.g. 123.456)
Column  32- 32 Blank
Column  33- 39 DTL  in meters (F7.3 format, e.g. 123.456)
Column  40- 40 Blank
Column  41- 47 MTL  in meters (F7.3 format, e.g. 123.456)
Column  48- 48 Blank
Column  49- 55 MSL  in meters (F7.3 format, e.g. 123.456)
Column  56- 56 Blank
Column  57- 63 MLW  in meters (F7.3 format, e.g. 123.456)
Column  64- 64 Blank
Column  65- 71 MLLW in meters (F7.3 format, e.g. 123.456)
Column  72- 72 Blank
Column  73- 79 GT   in meters (F7.3 format, e.g. 123.456)
Column  80- 80 Blank
Column  81- 87 MN   in meters (F7.3 format, e.g. 123.456)
Column  88- 88 Blank
Column  89- 95 DHQ  in meters (F7.3 format, e.g. 123.456)
Column  96- 96 Blank
Column  97-103 DLQ  in meters (F7.3 format, e.g. 123.456)
Column 104-104 Blank
Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)
Column 112-112 Blank
Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)
Column 121-121 Blank
Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)
Column 124-124 : (colon)
```

```
Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)
Column 127-127 Blank
Column 128-128 Maximum Water Level occurrences (1 digit)
Column 129-129 Blank
Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)
Column 137-137 Blank
Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)
Column 146-146 Blank
Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)
Column 149-149 : (colon)
Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)
Column 152-152 Blank
Column 153-153 Minimum Water Level occurrences (1 digit)
```

Sample data (with column ruler):

```
        0        0        0        0        0        0        0        0
        1        2        3        4        5        6        7        8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
9414290 2004 01 123.456 123.456 123.456 123.456 123.456 123.456 123.456 123.456

        0        1        1        1        1        1        1
        9        0        1        2        3        4        5
1234567890123456789012345678901234567890123456789012345678901234567890123
123.456 123.456 123.456 123.456 20040101 00:00 1 123.456 20040101 00:00 1
```

Definition of Acronym:

```
MHHW        Mean Higher High Water
MHW         Mean High Water
DTL         Diurnal Tide Level
MTL         Mean Tide Level
MSL         Mean Sea Level
MLW         Mean Lower Water
MLLW        Mean Lower Low Water
GT          Great Diurnal Tide Range
MN          Mean Range of Tide
DHQ         Diurnal High Water Inequality
DLQ         Diurnal Low Water Inequality
MAX_WL      Maximum Water Level during the Month measurement period
MAX_DATE    Date of Maximum Water Level
MAX_HOUR    Hour of Maximum Water Level
MAX_MIN     Minute of Maximum Water Level
MAX_OCCUR   Number of occurrences during the month the Water Level meets the
MAX_WL
MIN_WL      Minimum Water Level during the Month measurement period
MIN_DATE    Date of Minimum Water Level
MIN_HOUR    Hour of Minimum Water Level
MIN_MIN     Minute of Minimum Water Level
MIN_OCCUR   Number of occurrences during the month the Water Level meets the
MIN_WL
```

Monthly Means data file shall be named in the following format: xxxxxxx.w5.dat, where xxxxxxx is the seven digit station number, w5 is the product code for the monthly means data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

1.5.2.8. Station Datum Format

```
Column   1-  7 Station ID (7 digits, assigned in the project instructions)
Column   8- 16 Blank
Column  17- 23 MHHW in meters (F7.3 format, e.g. 123.456)
Column  24- 24 Blank
Column  25- 31 MHW  in meters (F7.3 format, e.g. 123.456)
Column  32- 32 Blank
Column  33- 39 DTL  in meters (F7.3 format, e.g. 123.456)
Column  40- 40 Blank
Column  41- 47 MTL  in meters (F7.3 format, e.g. 123.456)
Column  48- 48 Blank
Column  49- 55 MSL  in meters (F7.3 format, e.g. 123.456)
Column  56- 56 Blank
Column  57- 63 MLW  in meters (F7.3 format, e.g. 123.456)
Column  64- 64 Blank
Column  65- 71 MLLW in meters (F7.3 format, e.g. 123.456)
Column  72- 72 Blank
Column  73- 79 GT   in meters (F7.3 format, e.g. 123.456)
Column  80- 80 Blank
Column  81- 87 MN   in meters (F7.3 format, e.g. 123.456)
Column  88- 88 Blank
Column  89- 95 DHQ  in meters (F7.3 format, e.g. 123.456)
Column  96- 96 Blank
Column  97-103 DLQ  in meters (F7.3 format, e.g. 123.456)
Column 104-104 Blank
Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)
Column 112-112 Blank
Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)
Column 121-121 Blank
Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)
Column 124-124 : (colon)
Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)
Column 127-127 Blank
Column 128-128 Maximum Water Level occurrences (1 digit)
Column 129-129 Blank
Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)
Column 137-137 Blank
Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)
Column 146-146 Blank
Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)
Column 149-149 : (colon)
Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)
Column 152-152 Blank
Column 153-153 Minimum Water Level occurrences (1 digit)
```

Sample data (with column ruler):

```
         0         0         0         0         0         0         0         0
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
9414290         123.456 123.456 123.456 123.456 123.456 123.456 123.456 123.456

         0         1         1         1         1         1         1
         9         0         1         2         3         4         5
12345678901234567890123456789012345678901234567890123456789012345678901234567890123
123.456 123.456 123.456 123.456 20040101 00:00 1 123.456 20040101 00:00 1
```

Definition of Acronyms for Station Datum data are same as that for the Monthly Mean data.

Station datum data file shall be named in the following format: xxxxxxx.w7.dat, where xxxxxxx is the seven digit station number, w7 is the product code for the station datum data, and dat is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

If the Greenwich high water interval (HWI) and Greenwich low water interval (LWI) are available, then contractor shall provide that information in F5.2 format and that file shall be named as station#.GWI.txt.

1.5.3. Submission and Deliverables – Documentation and Timelines

All documentation, water level data, processed data including hourly height, high/low data, monthly means data, and station datums data, GPS forms and data including OPUS results, other reports as required, shall be forwarded within 15 business days of the removal of the water level stations/gauges, or as specified in the contract.

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

All data and documentation shall be submitted in digital format. Please refer to Section 1.5.1. and 1.5.2, for details about various data and documentation.

The station documentation generally includes, but is not limited to the following:

1) Transmittal letter (PDF format)
2) eSite Report, or Water Level Station Xpert Site Report, or Tide Station Report (eSite report in web based electronic format, Water Level Station Xpert Site Report or Tide Station report in Microsoft Excel format)
3) Sensor test worksheet (PDF format)
4) Sensor elevation drawing (PDF format) showing sea floor, pier elevation, and sensor elevation if the sensor is mounted vertically.
5) Water level transfer form (for Great Lakes stations only - PDF format)
6) Barometer Installation Worksheet (for Great Lakes stations only - PDF format)
7) Bench mark Diagram (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 diagram shall include an arrow indicating north direction, a title block that includes: the station name and number, NOAA chart number, USGS Quad name, field unit, date created, drawn by, and latitude and longitude (obtained from hand-held GPS receiver) of the gauge, and label of the body of water. (Required for newly installed stations only – PDF format.)
8) Bench mark descriptions with handheld GPS coordinates (d/m/s.x format) (electronic file - Windesc) (See Reference 4).
9) "Station to Reach" statement in Microsoft Word format (See Reference 3).
10) Digital photographs of each bench mark disk (four views), station, DCP, equipment, underwater components, and vicinity (JPEG format).
11) Levels (electronic files) including leveling equipment information and field notes of precise leveling, if applicable.
12) Abstract of precise leveling (electronic format).

13) Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor “zero” measurement point is referenced to the bench marks.
14) Staff to gauge observations, if applicable (Microsoft Excel format)
15) Calibration certificates for Invar leveling rods, if applicable (PDF format)
16) Calibration records for sensors, if applicable (PDF format)
17) Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable (PDF format)
18) Other information as appropriate, or as specified in the contract (PDF format)
19) Water level data download in specified format
20) GPS Deliverables - the OPUS published datasheet and 4 photos of the GPSBM in electronic format for each observation session as described in the User’s Guide for GPS Observations at Tide and Water Level Bench Marks.
21) Annual Inspection (AI) checklist (Applicable for all CO-OPS’ NWLON AI or multiyear stations)
22) Diving Documents

For long term water level stations (more than 1 year), the bench mark diagram and "To Reach" statement need only be submitted if those items have been revised after the initial submission. When using the electronic/barcode system, the data of the abstract and bench mark description or recovery notes shall be submitted. For optical levels, submit the raw levels and the leveling abstract.

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 or FTP.

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

9414290 San Francisco 2010 Annual Inspection
/ Transmittal letter
/ eSite Report, Xpert Site Report or Tide Station Report
/ Sensor test worksheet
/ Sensor elevation drawing
/ Water level transfer form
/ Barometer Installation worksheet
/ Bench mark Diagram (new installations only)
/ Bench mark descriptions (Windesc)
/ “Station to Reach” Statement
/ Photographs of bench marks, station, DCP, equipment, and vicinity in digital format
/ Levels (raw) (electronic files) and field notes of precise leveling
/ Abstract of precise leveling
/ Datum offset computation worksheet or Staff/Gauge difference work sheet (elevation of sensor zero measurement point referenced to bench marks)
/ Staff to gauge observations, if applicable
/ Calibration certificates for Invar leveling rods, if applicable
/ Calibration records for sensors, 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
- Annual Inspection Checklist
- Diving Documents

Submit the completed station package to:

Mr. Greg Stinner
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

1.6 Guidelines and References

References for the water level measurement and leveling requirements issued by the NOS Center of Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) are listed below.

Most of these documents are available on CO-OPS web site at http://tidesandcurrents.noaa.gov or in the CO-OPS Field Library at http://tidesandcurrents.noaa.gov/fieldlibrary/Welcome.

1. NGWLMS Site Design, Preparation, and Installation Manual (NGWLMS Manual),
2. Xpert DCP User's Manual
3. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations
4. User's Guide For Electronic Levels with Translev and WinDesc
5. User's Guide for Writing Bench Mark Descriptions
6. User's Guide for GPS Observations at Tide and Water Level Station Bench Marks
7. CO-OPS Specifications and Deliverables for Installation, Operation, and Removal of Water Level Stations
8. SOP 5.4.1.4 (A) Sutron Accubar Barometer Field Calibration Procedures
9. Wind Sensor Alignment Procedure for the R. M. Young Wind Sensors
10. Procedure to Establish a Meteorological Sensor Reference Mark and to Measure Meteorological Sensor Heights
11. CO-OPS Water level and Meteorological Site Reconnaissance Procedures
12. User's Guide for 8200 Acoustic Gauge (Installation and Operation)
13. User's Guide for 8200 Bubbler Gauge (Installation and Operation)
14. NGWLMS GOES MESSAGE FORMATTING
15. Standards and Specifications for Geodetic Control Networks", Federal Geodetic Control Committee
16. Spatial Data Modifications and Enhancements, FY05 Functional Requirements Document
17. Revised NGS 3 – Dimensional (3 – D) Rod Mark, National Geodetic Survey
18. NWLON/DMS Quality Control Software (QC): Functional Requirements Document
19. NOS Hydrographic Surveys Specifications and Deliverables
20. Water Level Station Specifications and Deliverables for Shoreline Mapping Projects
21. Attachment R, Requirements for Digital Photographs of Survey Control, NGS

22. SOP 3.2.3.5 (E3) Upgrading or Installing a New Water Level Station
23. SOP 3.2.3.5 (E7) CO-OPS Evaluation Criteria for Water Level Station Documentation
24. Engineering Bulletin 07-006 Exporting Data from Xpert Family DCP
25. User's Guide for eSite Report Application
26. SOP 3.2.3.5 E(15) eSite Report User Access Guide to Build, Submit, Reject, Advance, and Approve Steps
27. Engineering Bulletin 07-007 Downloading (Exporting) Data from Xpert Log Files using Xterm
28. Engineering Bulletin 08-001 Standardization of Xpert Log File Sizes
29. Engineering Bulletin 09-003 Update to Xpert Log File Sizes
30. SOP 3.2.3.5 (E8) Procedures for Requesting GOES Platform ID Allocations
31. SOP 5.4.1.1 C Portable Tide Gauge Setup, Configuration, and Data Export Procedure
32. NGS Bluebook, Formats and Specifications of the National Geodetic Survey Data Base
33. SOP 5.3.1.1 Waterlog Field Installation Guide
34. SOP 6.3.2.1.0 Annual Inspection Checklist
35. SOP 5.4.1.5 (N) Inside/Outside Water Level Check for the Great Lakes Gauging Stations
36. ROS # 5.4.1.5(P) Procedure to Establish a Meteorological Sensor Reference Mark and to Measure Meteorological Sensor Heights
37. CO-OPS Numerical Rounding Policy
38. Tidal Datums and Their Applications, Special Publication No. CO-OPS 1, NOAA/NOS
39. Tidal Datum Planes, U.S. Department of Commerce, Special Publication No.135, Marmer 1951.
40. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS
41. Tide and Current Glossary, U.S. Department of Commerce
42. Standing Project Instructions: Great Lakes Water Levels.
43. NOAA Technical Report NOS 64 "Variability of Tidal Datums and Accuracy in Determining Datums from Short Series of Observations".
44. Data Quality Assurance Guidelines for Marine Environmental Programs,.
45. System Development Plan, CORMS: Continuous Operational Real-Time Monitoring System, NOAA Technical Report.
46. NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS- Derived Ellipsoid Heights (Standards 2 cm and 5 cm)
47. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey