Ocean Systems Test and Evaluation Program

Microwave Air Gap-Bridge Clearance Sensor Test, Evaluation, and Implementation Report

Silver Spring, Maryland
May, 2005

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services
Center for Operational Oceanographic Products and Services  
(CO-OPS)  
National Ocean Service (NOS)  
National Oceanic and Atmospheric Administration (NOAA)  
U.S. Department of Commerce

The CO-OPS mission is to deliver the operational environmental products and services necessary to support NOAA’s Environmental Stewardship and Environmental Assessment and Prediction Missions. CO-OPS provides the focus for operationally sound observation and monitoring capability coupled with environmental predictions to provide the quality data and information needed to support the cross-cutting NOS Primary Goals of Navigation, Coastal Communities, Habitat, and Coastal Hazards.

Ocean Systems Test & Evaluation Program

The CO-OPS Ocean Systems Test and Evaluation Program facilitates the transition of new technology to an operational status, selecting newly developed sensors or systems from the research and development community and bringing them to a monitoring setting. OSTEP provides a quantifiable and defensible justifications for the use of existing sensors, and methods for selecting new systems. The program establishes and maintains field reference facilities where, in cooperation with other agencies facing similar challenges, devices are examined in a non-operational field setting. Through OSTEP, sensors are evaluated, quality control procedures developed, and maintenance routines generated. The quality of the reference systems used in the field are assured by both rigorous traceable calibrations and redundant sensors.

The Program receives guidance from the Ocean Systems Test & Evaluation Advisory Board.

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Microwave Air Gap - Bridge Clearance Sensor
Test, Evaluation, and Implementation Report

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May 2005
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CO-OPS STATEMENT OF ACCEPTANCE

CO-OPS management personnel have reviewed this document and concur that the evaluated sensor/system, when deployed and implemented as described herein, will meet the defined requirements and is suitable for operational use. While additional testing may lead to superior performance or more economical operation, the existing sensor/system configuration is sufficient as described.

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EXECUTIVE SUMMARY

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) manages several programs to monitor the Nation's coastal waters, including PORTS® (Physical Oceanographic Real-Time System). PORTS® provides ship masters and pilots with accurate, real-time information to help avoid groundings and collisions. CO-OPS requires an expanding suite of instruments to provide critical data from bays and harbors to support the maritime community.

Many harbors are depth-constrained, and many bridge heights also limit safe vessel passage. With increasing vessel size and vessel traffic, there is a continually increasing risk of overhead allision with bridges. Some vessels may also avoid entering or departing a harbor because of bridge clearance (i.e. air gap) limitations. The economic gains potentially realized by both increased commerce and the avoidance of allisions are considerable, and a clear requirement for air gap information has been voiced by the maritime industry.

Concerns over bridge allisions and resulting litigation prompted the Port Authority of New York and New Jersey (PANYNJ), the United States Coast Guard (USCG), the Maryland Port Administration (MPA) and the Port of Long Beach (PLB) to request and/or fund the development and installation of air gap sensors. Houston/Galveston and San Francisco have also expressed interest in air gap sensors. In response to these requests, CO-OPS has entered into agreements with several entities to procure a commercially available microwave air gap sensor and conduct tests and evaluations to ensure satisfactory performance of the sensor.

CO-OPS evaluated three types of air gap sensor technologies that measure the air gap, (or distance from the lowest structure of a bridge to the water surface) within the navigational zone. Based on these evaluations, the microwave air gap bridge clearance sensor technology best meets the requirements for this need. After evaluations and dialogue with vendors, CO-OPS selected the MIROS SM-094 microwave air gap sensor to further test for air gap measurement applications.
PURPOSE

The purpose of this report is to describe, in detail, the steps taken to confirm that the proposed air gap sensor is suitable for the required application. It includes a brief review of the requirements, a rationale for the selection of the sensor, a description of the incrementally-challenging tests used in evaluating the performance of the sensor, a discussion of the margin of error (error budget) of those tests and the sensor itself, a description of the test data and metadata management, and finally, a description of the potential tools available for real-time quality control (QC) of air gap data.

This report is one of several documents that will be promulgated. The other reports within this suite of documents include:

- Air Gap Implementation Process Checklist
- Air Gap Introductory Flyer

RESULTS/CONCLUSIONS

Six MIROS SM-094 microwave air gap sensors were subjected to a rigorous and extensive series of bench and field tests conducted from May 2001 through March 2004. The testing has demonstrated that the SM-094 meets or exceeds the CO-OPS requirements for range, resolution, power consumption, signal processing, data output, and all-weather operation. It provides satisfactory performance, as long as the operational use adheres to the manufacturer’s guidelines.

There were several issues that surfaced during the test and evaluation period, including instrument calibration, failure of sensors under extreme conditions, and long-term deployments. The accuracy of the manufacturer’s calibration was questioned; therefore CO-OPS must conduct operational sensor calibrations on each air gap sensor prior to operational use. At present, the best calibrations are obtained in-situ, through precise trigonometric leveling using a Total Station and a Next Generation Water Level Measurement System (NGWLMS) gauge.

Two air gap sensor housings have malfunctioned due to water intrusion - one understandably leaked when the pier, (where the sensor was installed) was pounded by twenty-seven-foot waves during Hurricane Isabel. To correct this problem, CO-OPS is now using after-market sealants, and the manufacturer is investigating alternate housings in an effort to remedy the water intrusion issue.
The long-term deployment issue cannot be addressed until further testing is conducted.

The selected sensor has been tested over a three-year period, at several locations and under a wide variety of conditions. The manufacturer has implemented corrective actions where deficiencies were identified. The device has proven to be immune to rain, snow, temperature extremes, waves, vibration, radio frequency (RF) noise, and other potential interferences. It has exceeded precision requirements to the extent that CO-OPS is now beginning to investigate the use of this technology for standard observations of water level. All test results are documented and are freely available electronically.

Most significantly, the introduction of air gap to the CO-OPS “tool bag” has shown that, through the private/Federal PORTS® partnership and the matrix-managed OSTEP, a new data product can be developed. CO-OPS is presently embracing many other new technologies that will require personnel and process adaptation. The success of the air gap development shows that it can be done, and done well.
1.0 INTRODUCTION

As many harbors are depth-constrained, many bridge heights also limit safe vessel passage. With increasing vessel size, there is a continually increasing risk of overhead allision with bridges. Vessels may also avoid entering or departing a harbor because of bridge clearance (i.e. air gap) limitations. The potential economic gains to be realized by both increased commerce and the avoidance of allisions are considerable, and as a result, a clear requirement for air gap information has been voiced by the maritime industry.

Tides are a major source of variation in bridge clearance. Additional sources include river stage (water depth), wind and wave setup, bridge altitude variations caused by varying traffic loads, and temperature-related structural expansion and contraction. Sources of noise for detection of air gap include bridge vibration, waves, and water level setup or set down caused by water current interaction with bridge supports. Sampling techniques must consider these noise sources to avoid bias and to extract the maximum accuracy possible from the sensor. No two bridges will offer the same conditions or results with various technologies. For example, in 1999, CO-OPS participated with the National Geodetic Survey (NGS) in the static air gap determination of the U.S. Route 17 Cooper River bridges in Charleston, South Carolina. Traditional trigonometric surveys, continuous Global Positioning System (GPS) observations, and water level data were successfully used to establish the air gap with an accuracy of better than one centimeter. In this case, the GPS observations showed there was virtually no movement of the bridge.

The bridges for which air gap sensors have been requested have clearances of approximately 150 feet, but others have requested observations at bridges with larger clearances. For example, a barge delivering a new crane to the Port of Richmond in San Francisco Bay came within inches of the Richmond bridge, prompting the request for a quick response air gap installation. “Despite its vertical clearance of 185 feet, the bridge has been struck by passing ships several times. However, it has never sustained sufficient damage for it to be closed, not even when bumped by a Navy radar vessel and a veteran World War II warship on the same day.” (Reference: http://www.lib.berkeley.edu/Exhibits/Bridge/rsr.html)

Just as all other data disseminated via PORTS®, the air gap observations must be quality-controlled and verifiable to accepted standards. Several users have also requested a local “billboard” displaying the clearance near the bridge. While such a request is understandable, the real-time quality control of the display itself must be considered (e.g. how to ensure against failure of a digital display segment). Neither this requirement nor a fast response capability has been addressed at this time.
2.0 USER REQUIREMENTS AND SENSOR

2.1 User Requirements

The potential users of air gap sensor data have requested continuous, real-time observations of the clearance beneath a bridge with an accuracy of ±15 centimeters (cm) (six inches). Since the precise meaning of this specification has not been defined by the users, this value is used only to roughly determine the requirement (the topic is discussed further in the Section 9.3). CO-OOPS further reduces this accuracy requirement to ±75 millimeters (mm) (three inches) in order to maintain an initial level of quality assurance, and considers the value to represent two standard deviations of the difference between the final system output and a reference observation.

The system must provide useful observations of air gap every six minutes in real time, corrected for any sensor mounting offset on the bridge from low steel. It must operate in all weather conditions and survive in the hostile bridge environment, where vibration can be a significant issue. The test procedures listed in Appendix A show the potential sensor perturbations that the air gap sensor/system must tolerate.

2.2 Sensor Selection

A variety of air gap sensor technologies are available, including GPS/acoustic water level observations, laser ranging devices, and microwave radar sensors. A GPS/acoustic water level system simply observes the bridge height and water levels in the vicinity of the bridge, deriving the air gap from the difference between the two observations. This system makes use of well-established technology and is immune to fog or rain. However, the drawbacks include high cost (requiring the installation of both a water level gauge and differential GPS receivers), the requirement of two operational sensors to derive the desired measurement, and the potential compounding of observational errors from the two systems.

In response to a request for air gap information from the Charleston Branch Pilots Association, CO-OOPS and NGS personnel conducted GPS leveling, traditional leveling, and trigonometric leveling studies to evaluate and verify each method. GPS receivers were installed on the Grace Memorial and the Silas Pearman bridge superstructures to monitor bridge motion, and at the Pilot’s station to serve as a GPS control point to provide differential corrections to the GPS data. Traditional leveling rod surveys were run from the bridge to a network of surrounding benchmarks, and trigonometric height determinations were made using a Leica Total Station. The results (see Appendix K) show that GPS and trigonometric leveling techniques agreed well and could be useful tools for the observation of air gap.
Laser ranging sensor technology is also well established, although the use of this technology for ranging to a water surface is not widespread. Advantages of a laser sensor include low cost, small size, and long range. However, laser operation is inadequate in limited visibility situations, such as fog and rain.

A microwave sensor has the advantage of a relatively large footprint on the water surface, providing a spatial integration in contrast to a laser’s single point. It is also immune to fog and rain. As a result, a microwave-based detector has been selected.

There were few commercial microwave altimeter sensors with a sufficient range available at the time of sensor selection. MIROS representatives discussed their plans for advances to their existing sensor, indicating a willingness to incorporate the latest technology to match CO-OPS’ requests. MIROS also had the largest existing user base, and was the most responsive to OSTEP inquiries. For these reasons, the MIROS SM-094 was identified as the sensor that was most likely to meet the users’ requirements.
3.0 DEVELOPMENT OF TEST PLANS

CO-OPS personnel, through a contract to the Mitretek Corporation, developed a MIROS Microwave Air Gap Sensor Detailed Test Plan (Test Plan); an overview of the specific series of tests identified and described in the plan provided to OSTEP follows:

- Sensor air gap reading against fixed target
- Sensor programmable functions
- Sensor recovery after power supply interruption
- Sensor operation under varied power supply output
- Custom developed software test
- Accuracy of sensor at varied distances from target
- Accuracy at varied alignment of sensor to water surface
- Accuracy of reporting under different configuration of sensor programmable functions
- Temperature impact on accuracy
- Rain impact on accuracy
- Humidity impact on accuracy
- Icing on sensor surface impact on accuracy
- Vibration impact on accuracy
- Ice on water surface impact on accuracy
- Varied sea condition impact on accuracy
- Natural conditions (combination of environmental factors)
- Operational deployment on Norfolk & Portsmouth Belt Line railroad bridge
- Reliability test and data collection about failures

Appendix A contains a summary of these test procedures.

Data files and associated metadata describing the data collected during the functional test, the bench test, and the controlled field test (to a hard target) have been placed in the publicly available OSTEP FTP (File Transfer Protocol) site located at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap/ MIROS Validation.
4.0  DISCUSSION OF FIELD STANDARDS

Several tools were obtained to test and evaluate the selected microwave sensors. They are discussed in the following paragraphs.

4.1  Total Station

Trigonometric surveys (similar to those conducted for the air gap study of the Charleston bridges) can provide accurate and traceable observations of clearance at a point in time. Such observations have the longest history of use and are not constrained by the “clear sky, top of the bridge” requirements of GPS. However, the surveys are labor-intensive and only provide an instantaneous observation.

To assist with surveys, CO-OPS has acquired a Leica Total Station (model TC2003, serial number 439213) for the routine annual surveys of air gap sensor installations, with the cost distributed among several PORTS® installations.

4.2  Invar Tape

CO-OPS procured from Cooper Tools a 200-foot (') steel tape serial number 12662, which is directly traceable to the National Institute of Standards and Technology (NIST). A certificate from Cooper Tools contains a full description of the process relating tape #12662 to the NIST standard. The certificate, dated 28 May 2003, is attached as Appendix B.

4.3  Field Baseline

On 8 January 2004 a precision air gap baseline was established in the CO-OPS Chesapeake Facility parking lot using the Leica Total Station. This baseline was established to ensure precise examination of ranges obtained from microwave air gap sensors and laser range finders. Two parallel lines, defined by marked railroad spikes driven into the asphalt, were placed and marked at 50.0001 meters (m) as measured by the Total Station, with center points on the parallel lines marked to ensure that the air gap sensor and the target can be aligned.

Input parameters to the Total Station (temperature, barometric pressure) were also observed. Temperature was obtained using both an Omega TPD31 temperature sensor and the shielded air tunnel thermistor on the tripod. Barometric pressure was monitored using a Paroscientific 760-16B field standard (serial number 71336).

After the baseline was established, the two Laser Technology Impulse LR laser range finders were tested on the same two tripods used to build the baseline, with a mirror target. Serial number i07728 (the “new” sensor dated 20 August 2002) consistently read about five centimeters (cm) too long. Serial number i06021 (the “older” sensor dated 9 November 2000) consistently read 50.00 m (no offset). However, past field use of these two devices over water has shown that the newer
unit typically gives a more consistent reading, with higher scatter seen in the older unit.

The Cooper Tools 200' steel tape (#12662) was used to verify the length of the air gap 50-meter (m) baseline. It was laid on the ground and pulled to a tension of 20 pounds (lbs). Air temperature was 50 degrees Fahrenheit (° F) in the sun and 36° F in the shade. With no corrections applied for either temperature or the fact that the tape followed the non-level pavement surface, a baseline measurement between the baseline center spikes of 50.0088 m (164 feet 0.85 inches) was obtained.

The temperature correction for the steel tape yielded improved results. The correction factor is 0.00000645 feet per degree F different from 68° F. We assumed the tape was at 50° F because it was laying in the sun. Shrinkage (due to contraction of the cold steel tape) made the tape read 5.8 mm longer. The temperature-corrected tape reading for the 50 m baseline is then 50.0030, resulting in a difference of less than three mm between the tape and the Total Station.

The tape value should not be used to replace the measure of 50.0001 obtained using the Total Station. It is noted that the tape value compares favorably, is longer (presumably because of the non-level surface the tape laid upon), and provides the best traceable standard (in terms of ease and in-hand documentation). Test result details are archived in files located at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap.
4.4 Laser Range Finder

CO-OPS procured a Laser Technology Impulse 200LR laser range finder (which meets the requirements and costs only $2,500) for the evaluation and operation of air gap sensors. A laser is not suitable for continuous-range observations because of weather effects on the sensor. However, recent advances in the technology have reduced cost and increased the precision, making the sensor a good choice for fast, accurate distance measurements—just as required for validation and monitoring of a microwave air gap sensor.

A Laser Technology Impulse 200LR is fitted with an optional inclinometer, a necessary feature to ensure accurate vertical ranging. The following specifications apply:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tr>
<td>Maximum range</td>
<td>575 m</td>
</tr>
<tr>
<td>Accuracy</td>
<td>3 cm at 50 m range</td>
</tr>
<tr>
<td>Resolution</td>
<td>1 cm</td>
</tr>
<tr>
<td>Inclinometer accuracy</td>
<td>+/- 0.1 degree</td>
</tr>
<tr>
<td>Laser wavelength</td>
<td>904 nanometers (nm)</td>
</tr>
</tbody>
</table>

This rangefinder uses a 904-nm infrared laser, while many others use a visible red laser. Light at 904 nm is quickly absorbed by water and has very little chance of penetrating the air/water interface, reflecting from a submerged object, again penetrating the water/air interface and completing the trip back to the rangefinder. The light is either successfully reflected at the interface or simply absorbed, ensuring an accurate range. Range finders operating at visible wavelengths will experience difficulties with returns from submerged objects in clear water. While the manufacturer of the Laser Technology Impulse 200LR has twice indicated the device will not provide returns from a water surface, CO-OPS personnel have found that it does so reliably. It is, however, a noisier measurement compared to the microwave sensor.

4.5 Next Generation Water Level Measurement System (NGWLMS)

Present water level stations use advanced sensor technology (NRC, 1986), improved instruments, digital recording, satellite communication, and additional geophysical instruments. Many stations also measure wind speed and direction, barometric pressure, air and water temperature. These are used to interpret the sea level records, perform scientific analyses of the natural phenomena in the coastal zone, and, when disseminated to mariners through PORTS®, provide real-time environmental conditions suitable for navigational decision making (NRC, 1986; 1996).

The system that accomplishes these tasks is known as the Next Generation Water Level Measurement System (NGWLMS). The NGWLMS (Figure 1) was developed by NOS to modernize the water level (WL) station (e.g., Scherer, 1986;
Mero and Stoney, 1988). A NGWLMS is a stand-alone system that acquires, stores, and transmits water level, weather, and other data from the field unit (Edwing, 1991). The main requirement for the unit is to accurately measure water level information with low power consumption, high reliability, and defined accuracy. The goal is to monitor water levels with an accuracy of better than one cm, as the present global estimate of sea level rise is 0.15 cm per year. Considering all of the variability in water level measurements (resulting from the various factors noted earlier), this level of accuracy presents a challenge for instrumentation and research. The NGWLMS water level sensors have an accuracy of approximately 1.0 cm for each sample (Schultz, et al., 1998).

Instruments. The NGWLMS field unit is an automated system for data acquisition and transmission. It was developed and procured from off-the-shelf components in the mid-1980s, and underwent extensive evaluation prior to delivering data from which operational products are developed. In addition, the internal firmware (and some of the internal modules of the field unit) has received periodic upgrades to maintain or enhance capabilities.

The Data Collection Platform (DCP) (Figure 2) consists of a Sutron 9000 Remote Terminal Unit (RTU). This is a modular unit that contains a power supply, communications controller, Geostationary Operational Environmental Satellite (GOES) transmitter, central processor unit, memory expansion module, telephone modem, general purpose Input/Output (I/O) module, and an Aquatrak water level sensor controller. The unit receives data from the sensors which measure the

![Figure 1. The NGWLMS station](image-url)
water level and geophysical parameters (Edwing, 1991). This measurement sub-
system accommodates up to eleven additional instrument channels. The field unit
is fully-automated for remote installations. The unit’s design and satellite data
transmission streamlines the digital data relay and processing.

The instruments typically installed at a WL station are:

1. Primary water level sensor (an “Aquatrak” acoustic sensor);
2. Strain-gauge pressure transducer (for back-up water level measurements);
3. Anemometer (manufactured by R.M. Young for measuring wind speed,
direction and maximum hourly gusts);
4. Thermistor (manufactured by Yellow Springs Instruments Corporation
(YSI) for measuring air or water temperature; a Greenspan or Falmouth
Scientific Instruments (FSI) water conductivity instrument);
5. Barometer (by Setra or Vaisala) for measuring atmospheric pressure
(Edwing, 1991).

Since technology is constantly evolving, the mix of computers and sensors is
subject to change in the future. For example, shaft-angle encoders and float/wire
sensors are used instead of acoustic sensors because of the environment at the
Great Lakes station. NOS is investigating the replacement of the acoustic sensor,
which still requires a protective well, with a newer sensor, such as a microwave
sensor.

Figure 2. The Sutron 9000 Data Collection Platform
**Measurement of Water Levels.** The primary requirement of a WL station is to accurately and reliably measure the varying water levels, often in hostile conditions. The primary water level sensor is a non-contact sensor, (i.e., the sensor never contacts the water). It consists of an acoustic transducer head connected to a one-half-inch diameter, vertical, polyvinyl chloride (PVC) tube open at the lower end, which is in the water. The water level in the tube moves up and down with the tide. The tube, and the sturdy environmental protective well housing which surrounds the tube, provide a limited damping effect. The protective well is a 15.24 cm (six-inch) diameter PVC well with a 5.08 cm (two-inch) inverted cone orifice in water. Typically, 45.7 cm (18-inch) diameter parallel plates at the orifice are also installed. This design reduces the unwanted mechanical filtering effects of a true protective well, while permitting the field unit to be sited in dynamic environments with wave action and high velocity currents. The design also reduces the errors (to wave motion and stream flow) associated with currents on the internal water level. This arrangement, as far as possible, gives a linear response to exterior changes in sea level (Scherer et al, 1981).

The acoustic head emits a sound pulse, which travels from the top of the tube to the water surface in the tube, and is then reflected up the tube. The reflected pulse is received by a transducer and the Aquatrak controller, or water level sensor module. The Sutron 9000 unit then calculates the distance to the water level using the travel time of the sound pulse (Sutron, 1988) with corrections for air temperature and density effects (Edwing, 1991).

In addition to the reflected pulse from the water level, there is also a reflection from a hole in the side of the sounding tube at an accurately-known distance from the transducer head, normally a distance of 1.22 m (four feet). The Aquatrak controller uses this measured reflection to continually self-calibrate the measuring system.

Temperature gradients in the protective well can introduce a source of systematic error. Two temperature thermistors are installed at two locations on the sounding tube to monitor temperature uniformity in the protective well (Edwing, 1991). A correction factor can be applied if a temperature gradient is observed in the protective well. At the present time only about four of 175 stations in the NGWLMS have such a correction routinely applied. A system of tidal benchmarks ensures the stability and continuity of the measurements and recovers the tidal datums (Edwing, Mero and Stoney, 1988).

The standard air gap deployment also makes use of two thermistors (but in a slightly different manner than in the water level measurement) to monitor the temperature outside and within the electronics housing. These temperatures can be used to examine bridge expansion/contraction/elevation responses to thermal variations. The internal temperatures are used to ensure that temperature extremes don’t exceed the specifications of the electronics.
5.0 LABORATORY TEST RESULTS

This section describes the test facilities, procedures, and documentation of the laboratory test results. The Test Plan (CO-OPS, February 2002) calls for laboratory performance tests to be carried out in an environmentally-controlled space. This was not feasible given the need for 10 m of unobstructed horizontal space. Therefore, a testing area was established in the parking lot of the CO-OPS Chesapeake Facility.

5.1 Test Conditions

The following six items (or conditions) were required in order to perform the static air gap tests (range 9 m and 10 m): 1) a moveable target which is microwave reflective; 2) a secure mounting device to hold the air gap sensor in a completely vertical position; 3) a testing area with at least 10 m of horizontal clearance; 4) a NIST-traceable metal Invar measuring tape; 5) a laser range finder aligned with the air gap sensor zero; and 6) a personal computer (PC) with data collection software to log both microwave and laser sensor readings.

5.2 Target

The 50 m range MIROS sensor has a five-degree beam width. For testing at up to 10 m, a 1.75 m x 1.75 m target is needed, based on a five-degree beam width. CO-OPS personnel constructed an 8' x 8' wooden target braced vertically to a standard shipping pallet (Figure 3). The target is easily repositioned by one person using a pallet jack. Sheet metal fastened to the target provides a completely reflective surface.

Figure 3. Air gap sensor test target
5.3 Air Gap Sensor Mount

CO-OPS personnel purchased a steel mounting bracket (designed for bridge installations) from the MIROS vendor. For testing purposes, the bracket was mounted to a wooden cable spool (Figure 4), carefully ensuring that the sensor was level and vertical. The entire system (spool plus sensors) is moveable using a forklift.

![Figure 4. Air gap sensor mounting bracket](image)

5.4 Metal Invar Measuring Tape

A NIST-traceable certified Invar tape was used to establish the distance between the air gap sensor zero, which is the green face of the instrument, and the test target (Figure 5). The limitations of precisely measuring this distance should be noted. Personnel carefully aligned the tape markings at each standard distance using a level and a straight edge. However, it was impossible to do this with absolute precision, therefore a potential source of measurement error was introduced. Additionally, because the target was mounted on a pallet, it was impossible to absolutely reoccupy the same position after each test movement. These positioning errors are evident in the test data.
5.5 Laser Range Finder

A Laser Technology Incorporated Impulse LR laser range finder was attached to the MIROS mounting bracket so that the zero of that instrument (specified by the manufacturer to be at the center of mounting bolt) aligns with the air gap sensor zero (Figure 6). The laser range finder was removed each evening because it is not weather-proof.

Figure 5. View of alignment of the calibrated tape with the MIROS

Figure 6. Laser range finder affixed to air gap sensor mounting bracket
5.6 Data Collection System

A standard desktop PC was configured with specialized testing software; the software logs five-second readings from both the microwave and laser, which are connected by direct cables to the serial ports of the PC.

The MIROS SM-094 altimeter employs a single tasking processor with limited capabilities, leading to timing inconsistencies when operated in a free-cycling mode. Consequently, the nominal two-Hz data rate yields infrequent occasions where as many as three or four observations are output during a one second period, or as few as none. Similarly, in the polled mode (command GV, Get Value) the SM-094 occasionally failed to respond. These deficiencies have been corrected through firmware modifications. Further, the vendor is introducing a new Digital Signal Processing (DSP) chip with greatly expanded capabilities. This hardware addition permits multi-tasking and output rates up to 100 Hz, which may be an important consideration for future use of the sensor as a water level sensor where corrections for wave forms may be required.

The SM-094 two-Hz RS232 ASCII (American Standard Code for Information Interchange) output provides two range values. Each range value may be filtered by a smoothing algorithm, which is controlled by a user-selected time constant. The default factory settings provide an unfiltered observation in the first value and a smoothed second value. The default time constant for the smoothed second value is 60 seconds, and several of the early tests used these unsmoothed or smoothed values for data examination. The altimeter also may be operated in a polled mode rather than free-cycling, by transmitting first a serial output off-command (SER=0), and then polling to obtain the two values by issuing the command GV. After the development of the new DCP hardware and software, only the unfiltered values were used, and they were obtained by polling the device at a one-Hz rate.
5.7 Test Procedures and Objectives

The tests described in Section 5.9 are laboratory functional performance tests. As stated above, all tests were carried out in the parking lot at the CO-OPS Chesapeake Facility. The test procedures were prescribed in the Test Plan (CO-OPS, February 2002).

Testing was conducted by incremental adjustment to a hard target with the following objectives:

1. Verify the system accuracy against a target at a fixed distance
2. Verify the capability to change user-selected measurement parameters and settings
3. Document the system performance after power outage
4. Document the system performance under decreased voltage of power supply
5. Document the system performance under different alignments to the target
6. Test whether the custom-developed software can receive and process data from the MIROS microwave air gap sensor
7. Test the end-to-end system with a direct connection between the MIROS microwave air gap sensor and the computer system that will receive and process data

5.8 Test Documentation and Test Data Archival

This test report constitutes the documentation of all formal tests, including scanned copies of the completed test logs (Appendix C) and a summary of test results. Two copies of original test data are stored on disc, one copy resides at the CO-OPS Chesapeake Facility, and the other resides at CO-OPS Headquarters in Silver Spring, Maryland. The original test logs, which are also kept at the CO-OPS Chesapeake Facility, are archived in binders specific to each sensor.

A Procomm log was opened to record all output (Table 1). Procomm Plus is a commercial terminal emulation program which permits flexible communications and file transfers between a PC and a digital device. Script files running under Procomm are used to control sensor and PC operations. Procomm is widely used by CO-OPS personnel to configure and operate sensors, and log the resulting data. The MIROS sensor requires approximately 16 seconds to lock on target. Because of the nature of these data, they are easily eliminated by a software filter for out-of-range data.
Table 1. A log records all output using Procomm software

<table>
<thead>
<tr>
<th>Time</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>-94575670000000000.000</td>
</tr>
<tr>
<td>0.000</td>
<td>-94575670000000000.000</td>
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<td>96.000</td>
</tr>
<tr>
<td>10.009</td>
<td>10.009</td>
</tr>
</tbody>
</table>

Begin acquisition of valid data.
5.9 Detailed Test Results and Analysis

The operational installation of an air gap sensor requires precise and careful range calibration. CO-OPS personnel have found that the manufacturer’s calibration is insufficient; therefore corrections to the manufacturer’s calibration are necessary. The first estimate of the correction is determined using the 50 m reference range facility previously described. Another estimate may be obtained by comparing air gap observations from an uncorrected sensor to those obtained from a corrected operational sensor (the Reedy Point site has been used as an occasional reference). A final estimate is obtained in-situ after the installation at the operational site, using the Total Station and WL observations to calculate a reference air gap. These estimates are compared, with the most weight given to the in-situ estimate. A final offset value is selected and applied at the Data Acquisition System (DAS). The original manufacturer’s calibration stored on the SM-094 is not altered. In addition to the calibration offset correction, the correction for the offset to low steel is also applied at the DAS.

5.9.1 Results of Test 1-Sensor Air Gap Reading Against a Fixed Target

Test 1 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 1. The factory defaults were used for the selectable parameters (Table 2). Appendix D contains more detail about these settings. Thirty minutes of test data were collected with the target positioned at 10 m, 9 m, then back to 10 m (Figures 7a, 7b, and 7c).

During all three portions of Test 1, the MIROS sensor performed well within the ±75 mm (three-inch) uncertainty requirement, with a difference between the nominal (tape measured) distance and the mean of the MIROS data of −17 mm, +21 mm, and −15 mm respectively (MIROS minus steel tape values).

The laser range finder shows greater variability than the MIROS sensor, as evidenced in the two orders of magnitude difference between the standard deviations of the two measurement series. There is an offset in the means from the two different sensors which is not constant in value or direction mean - raw MIROS. For the first 10 m test, the laser measured longer by 15 mm; for the 9 m test, the laser measured shorter by 8 mm; and for the second 10 m test, the laser measured longer by only 5 mm. These differences (although interesting) are not significant, because they are within the uncertainty of the measurement.

<table>
<thead>
<tr>
<th>Table 2. Factory Default Settings for Selectable Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>min 100 freq 2</td>
</tr>
<tr>
<td>det 100 htc 0.5</td>
</tr>
<tr>
<td>wtc 4.5 atc 59.5</td>
</tr>
<tr>
<td>Win 6 ntc 0</td>
</tr>
<tr>
<td>tout 10 top 1</td>
</tr>
<tr>
<td>ser 1 ch 3.0 20.0</td>
</tr>
</tbody>
</table>
Figure 7a. Thirty minutes of test data against a fixed target positioned nominally at 10 m

Figure 7b. Thirty minutes of test data against a fixed target positioned nominally at 9 m
5.9.2 Results of Test 2 - Sensor Programmable Functions

Test 2 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 2. The factory default settings were changed one by one, and test measurements were collected. The values changed during testing are shown in red in Table 3. The first value listed is the default value, and the second value is the tested setting. Appendix D contains more detailed information about these settings.

<table>
<thead>
<tr>
<th>Changes</th>
<th>min</th>
<th>75</th>
<th>freq</th>
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<td>50</td>
<td>htc</td>
<td>0.5</td>
</tr>
<tr>
<td>wtc</td>
<td>4.5</td>
<td>atc</td>
<td>59.5</td>
<td></td>
</tr>
<tr>
<td>Win</td>
<td>6</td>
<td>ntc</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>tout</td>
<td>10</td>
<td>top</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ser</td>
<td>1</td>
<td>ch</td>
<td>3.0 20.0</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7c.** Thirty minutes of test data against a fixed target. The target is moved back to 10 m. Notice the residual effect of 9 m in the averaged value (red line).
Five minutes of test data were collected with the target positioned at 10 m and 9 m for each parameter change (Figures 8a-g). During all 16 portions of Test 2, the MIROS sensor performed well within the 75 mm uncertainty requirement. It is important to keep in mind that the target was hand-positioned each time with a pallet jack. Although there was a chalk line on the pavement, exact repositioning was impossible.

**Figure 8a.** Test of readings with all settings as delivered from the factory
Figure 8b. Test of changing MIN, DET, and WTC with target positioned nominally at 10 m

Figure 8c. Tests of changing MIN and DET with target nominally positioned at 9 m
Figure 8d. Tests of changing WIN and HTC with target at ~ 10 m

Figure 8e. Tests of changing HTC and ATC with target at ~ 9 m
Figure 8f. Tests of changing ATC and NTC with target at ~ 10 m

Figure 8g. Tests of changing NTC and CH with target at ~ 9 m
5.9.3 Results of Test 3 - Sensor Recovery After Power Interruption

Test 3 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 3. The factory default settings were used for the selectable parameters (Table 2).

Five minutes of test data were collected with the target positioned at 10 m, 9 m, and then back to 10 m (Figure 9a). The power supply was then unplugged for one minute. The long time that it takes for the averaged MIROS measurements to reach the new target distance after target repositioning reflects the effect of the long averaging constant (ATC = 59.5 sec). Figure 9b shows the readings after power was restored.

During both portions of Test 3, the MIROS sensor performed well within the 75 mm uncertainty requirement. The difference between the nominal (tape measured) distance and the mean of the MIROS data was 8 mm after power was restored. It is important to note that, since the specialized logging software samples every five seconds and ignores spurious data; it does not totally reflect the output of the MIROS after a power outage.
Figure 9a. Five minutes of test data with the target positioned at 10 m, 9 m, and 10 m

Figure 9b. Test results after power was restored
6.0 FIELD TEST RESULTS

CO-OPS personnel conducted a series of field tests using five different MIROS air gap sensors. Four of these units are the SM-094/50 fifty-meter range devices, and the fifth is an SM-094/85 eighty-five-meter range device.

Each field test incrementally provided additional information, as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chesapeake Bay Bridge Tunnel</td>
<td>First marine environment tested by OSTEP</td>
</tr>
<tr>
<td>St. Georges Bridge</td>
<td>First bridge, long-range marine environment for both SM-094 and laser range finder</td>
</tr>
<tr>
<td>USACE/Duck</td>
<td>First long-term comparison to NGWLMS</td>
</tr>
<tr>
<td>San Francisco</td>
<td>First use of Total Station, first use of 85-meter range SM-094</td>
</tr>
<tr>
<td>Crescent City New Orleans</td>
<td>First long-term bridge deployment using MIROS software</td>
</tr>
<tr>
<td>Reedy Point</td>
<td>First long-term bridge deployment using Xpert/9210 software</td>
</tr>
</tbody>
</table>

Each field test is further described Sections 6.1-6.6, along with the results from each test.
6.1 Chesapeake Bay Bridge Tunnel

The WL station at the Chesapeake Bay Bridge Tunnel (CBBT) is the primary site of the distributed OSTEP test facility. The first test of the SM-094/50 over open water was conducted at this readily accessible site. CO-OPS personnel examined the sensor response in the presence of tidal variations, waves, and currents. No leveling was conducted; the NGWLMS and SM-094 data were simply demeaned for comparison. The SM-094 was free cycling and logging to a laptop PC using a Procomm script file that time-stamped the incoming data and wrote it to a daily file. Figure 10 shows the Bayonne Bridge system (SM-094/50 serial number P010034) temporary mount over the access hatch used to gain access to the conductivity/temperature sensor (CT) and NGWLMS wells. The figure shows that the CT well is clearly within the five-degree beam of the air gap sensor. It was impossible to easily install the sensor with a clear beam path, yet the SM-094 returned a very satisfactory record that qualitatively matched the NGWLMS (Figure 11).

The results of this test showed that the sensor agreed with the NGWLMS WL gauge within approximately one cm. Since the SM-094 and the WL gauge were sampled at different times, direct differences were not computed. Visual comparison of the WL and the SM-094 time-series curves revealed that a single six-minute WL point at JD 194.76 (which appeared to be an outlier) was actually a point on a smooth anomalous waveform, thought to be caused by the wake of a submarine transiting the CBBT (Figure 12). Data and additional test documentation are available at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap/CBBT.

Figure 10. SM-094 temporarily mounted over the access hatch
Figure 11. Comparison of CBBT water level sensor and air gap sensor

Figure 12. Detail of Figure 9 showing anomalous wave passages, possibly caused by a submarine
6.2 St. Georges Bridge

The first test of the SM-094/50 at an extended range to a water surface target was conducted on the St. Georges Bridge over the Chesapeake and Delaware (C&D) Canal, testing the sensor at a range of 135'. The United States Army Corps of Engineers (USACE) permitted a temporary installation of less-than-24-hours. The test satisfied some of the requirements set forth in the Test Plan, specifically Test 6.1—Field Operational Test and Evaluation, Natural Conditions. It was also the first data acquisition and comparison to the laser range finder at long range. Again, the SM-094 was free cycling and logging to a laptop PC using a Procomm script file that time-stamped the incoming data and wrote it to a daily file.

Data from the WL gauge at Reedy Point were used for comparison. The tidal amplitude diminishes considerably as one proceeds westward through the C&D canal, reducing the range by approximately 50 percent across the full length of the canal. A time offset of 18 minutes exists between the two sites (St. Georges Bridge leads Reedy Point, Figure 13).

Test results showed that the SM-094 continued to track within an accuracy of a few cm, even at the extended ranges. Figure 14 shows the demeaned difference time series with a standard deviation of just 2.2 cm. It was also found that the LR200 laser range finder yielded reliable returns from a water surface at the extended range.

![Figure 13. Comparison of WL and microwave air gap data after applying offset and zoning correction](image)

-36-
Figure 14. Demeaned Reedy Point .82 + MIROS mean
6.3 USACE Field Research Facility (FRF)/Duck

CO-OPS conducted a one-week deployment (1-8 August 2001) of the MIROS microwave altimeter for use as an air gap and water level measurement sensor at the USACE FRF in Duck, North Carolina. This site was chosen to provide maximum exposure to waves and to be co-located with a CO-OPS WL station.

**Test Configuration.** A MIROS microwave altimeter model SM-094/50 (with a maximum range of 50 m) was secured to the underside of the USACE FRF pier. The pier extends approximately 565 m from the shore where the water depth at the WL sensor is 8.83 m mean lower low water (MLLW). The MIROS sensor was approximately two m from the WL station, which housed a laptop PC used for data collection during the test. Care was taken to ensure that the MIROS beam was unobstructed by the pier pilings, however, wave interaction with the pilings may have caused noise in the signal. The SM-094 has a number of user-selectable parameters (Table 4). The averaging time constant (ATC) has considerable impact on the data output of the air gap sensor as it comes from the manufacturer. For the first few days of the experiment, ATC was set to 30 seconds. ATC was changed to 60 seconds on 3 August 2001. The manufacturer’s explanation of each of these parameters is found in Appendix D.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>100</td>
<td>FREQ</td>
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</tr>
<tr>
<td>DET</td>
<td>100</td>
<td>HTC</td>
<td>0.5</td>
</tr>
<tr>
<td>WTC</td>
<td>4.5</td>
<td>ATC</td>
<td>30/60</td>
</tr>
<tr>
<td>WIN</td>
<td>6</td>
<td>NTC</td>
<td>0</td>
</tr>
<tr>
<td>TOUT</td>
<td>10</td>
<td>TOP</td>
<td>1</td>
</tr>
</tbody>
</table>

**Data Sources and Processing.** Quality-controlled water level data were obtained from the CO-OPS database. The data were demeaned over the same time period as the MIROS data and inverted to correspond to the downward-looking MIROS data. Sounding tube temperatures (T1, T2) were obtained from the Product and Services Division (PSD).

The SM-094/50 samples nominally at two Hz. Because the MIROS was in “free run” mode, some of the output data had gaps and times when three values per second were recorded. The decimal Julian day was calculated from the Procomm-stored time stamp. The MIROS data were then processed in two different ways for comparison with the WL.
First, both the raw and smoothed data were decimated to a six-minute time series by taking the first of the two-Hz values at each six-minute interval. The MIROS data were also decimated to one Hz (again by taking the first value), then run through a program to find the average and standard deviation of the 181 values around the six-minute value. In order to analyze the effect of employing the CO-OPS Data Quality Assurance Processing (DQAP) scheme used on WL data, the standard deviation calculated from the 181 points around the six-minute value was used to determine a three-sigma cut-off value. Values lying outside of the three-sigma range were rejected, and the mean and standard deviation were then recomputed. This process did not result in the rejection of many points.

Results. A cursory look at the MIROS data without applying any post processing (other than to decimate the two-Hz data to six-minute samples) reveals several features. First, the open coastal nature of the test site is clearly visible in the MIROS raw data, since it is observing waves on the ocean surface. The WL data show very little effect of waves because of the presence of the protective well and because of the CO-OPS standard DQAP that has been applied to derive the WL values. Wave array data collected at FRF show significant wave heights of nearly two meters on 1 August 2001, relaxing to only 0.5 meters at the end of the week. The energetic waves observed during deployment are evidenced by the high variability at the beginning of the time series. The standard deviation of these three time series is very similar, since it is dominated by tidal variability.

Using the WL data as the standard, the differences between the WL and the MIROS raw and smoothed data were calculated. As expected from the water level time series, the raw MIROS data did not agree well with the WL data. The mean of the absolute value of the difference is nearly 14 cm (standard deviation 14 cm). The data that have undergone smoothing within the MIROS sensor compare much better to the NGWLMS data, with a mean of just over one cm (standard deviation one cm).

It is important to note that the MIROS smoothing scheme and the CO-OPS DQAP (which acts as a smoother) produce different results. This difference can be seen by comparing the MIROS smoothed data (decimated to six-minute intervals) with the MIROS raw data (decimated first to one Hz) that has been processed using CO-OPS standard DQAP. During the time period with high wave action, the difference between these two schemes is greater than six cm. In order to provide consistent comparisons, the remaining analyses will show only NGWLMS and MIROS raw data that have been processed using the DQAP procedure.

The agreement between the MIROS and NGWLMS data is greatly improved by processing the MIROS data in the same manner as the NGWLMS (Figure 15). There is no appreciable difference between the MIROS raw and smoothed data after application of the DQAP algorithm, therefore only the MIROS raw data which have been processed using DQAP are shown.
Again, using the NGWLMS data as the standard, the differences between the NGWLMS water level and the DQAP processed MIROS data were calculated. The mean of the absolute value of the difference between the NGWLMS and MIROS data is less than one cm (the standard deviation is also less than one cm). An interesting daily periodicity is evident in the difference of the two sets, perhaps pointing to a need to apply the temperature correction factor to the NGWLMS-measured water level based on the differences in sounding tube temperatures caused by diurnal temperature changes (Figure 16).

One concern about the MIROS was that the data would be excessively noisy due to the absence of any stilling hardware. The standard deviation obtained from averaging the 181 one-second values around the desired time or using the DQAP algorithm is larger than that for NGWLMS, but it is not an order of magnitude larger, nor even doubled (Figure 17). This important result translates into the ability to use CO-OPS standard water level QC rules for Continuous Operational Real-Time Monitoring System (CORMS) air gap monitoring (see Section 8.1).

Figure 15. One week of comparison demeaned water level data from the Duck NWLON station (red) and the MIROS microwave air gap sensor (blue)
Figure 16. Comparison of the temporal pattern of the difference in WL between NGWLMS and MIROS with the difference in temperature along the Aquatrak sounding tube.

Figure 17. Standard deviation (m) of NGWLMS (red) and MIROS (blue) water level data.
**FRF/Duck Conclusions and Future Testing.** The average difference between NOS-verified water level data and MIROS air gap data processed in a similar manner is less than one cm. The maximum difference is only six cm, and all differences are within the CO-OPS specified requirement for air gap accuracy of ±75 mm (3 inches). The users reported accuracy requirement for air gap is ±15 cm (six inches). The daily periodicity observed in the difference data correlate with peaks in sounding tube temperature gradients, suggesting that application of the temperature correction to the NGWLMS data would further reduce the differences. The standard deviation (sigma) of the MIROS data is of the same order of magnitude as that of NGWLMS, which greatly simplifies operational transition, since standard CORMS QC algorithms for water level can be used.

It is important to note that after this test was conducted, Hurricane Isabel (September 2004) brought 27-foot waves (the largest ever observed at the FRF) to the end of the pier. Both the SM-094/50 and the NGWLMS failed within the same sample interval. Breaking waves bent the SM-094 mount and caused water intrusion past the gasket. As a result, CO-OPS personnel requested and the manufacturer installed a new gasket. The NGWLMS installation failed when the entire protective well shifted, bending the massive stainless steel supports, and snapping the sounding tube.

Test result details are archived in files located at ftp://ftp.fod.noaa.gov, OSTEP/AirGap.
6.4 San Francisco-Oakland Bay Bridge

During the period 11-14 June 2002, NOS and NGS personnel conducted an air gap study at the San Francisco-Oakland Bay Bridge to collect data because massive cranes bound for the Port of Oakland (Figure 18) would be passing under the bridge. This test provided the first bridge installation with precision trigonometric survey by NGS and CO-OPS personnel using the new CO-OPS Total Station (Figure 19). It was also the first use of the extended 85 m range MIROS SM-094 procured for the USCG demonstration project in New Orleans. Finally, it provided the first direct observation of influence of a vessel transit under the sensor.

Data collected included:
- Approximately 70 hours of continuous MIROS microwave air gap sensor data, observations at two Hz, with the sensor mounted on the bridge (Figure 20);
- Approximately 270 bridge height observations relative to a tide staff, using a Total Station;
- Approximately 100 manual tide staff readings.

Figure 18. Port of Oakland: Cranes passing beneath the San Francisco-Oakland Bay Bridge
Figure 19. Total Station leveling operations on the San Francisco-Oakland Bay Bridge

Figure 20. Temporary air gap installation on the bridge
These observations provide two independent height determinations from the MIROS sensor to the water level: 1) the direct MIROS readings, and 2) the calculated Total Station plus tide staff height.

The observations show considerable high-frequency variability at amplitudes of interest. Both the MIROS sensor and the Total Station observations show bridge motion and/or air gap changes of approximately one cm/sec, making interpolation to the six-minute tide staff observations pointless. CO-OPS personnel obtained 46 “coincident” observations at six-minute intervals from these data sets (Table 5). Here, coincident is defined as observations occurring within NGWLMS ±30 seconds of a tide staff reading. In Table 5, Adjusted Tide Staff readings are heights from the 18-foot reference point on the tide staff to the water surface. Data are shown graphically in Figure 21.

Preliminary comparisons between the two measurements show that the MIROS measured 9.8 cm (3.86 inches) larger than the Total Station, with a standard deviation of 3.6 cm (1.4 inches). The mean difference may well be an overlooked or incorrect calculation, or perhaps a calibration adjustment. A significant positive test result is the low standard deviation, well below the air gap sensor accuracy requirement.

Test result details are archived in files located at ftp://ftp.fod.noaa.gov/, OSTEP/Airgap/SF.
Table 5. Raw Tide Staff versus Adjusted

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<tr>
<th>Month</th>
<th>Day</th>
<th>Year</th>
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<th>Min</th>
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<th>Tide Staff</th>
<th>Tot Sta</th>
<th>Tot Sta+</th>
<th>MIROS</th>
<th>Diff</th>
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</thead>
<tbody>
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<td>65.5780</td>
<td>69.7235</td>
<td>69.8310</td>
<td>0.1102</td>
</tr>
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</table>

Table 5. Raw Tide Staff versus Adjusted
6.5 Crescent City, New Orleans

In September 2001, CO-OPS entered into an agreement with the USCG to procure a commercially available microwave air gap sensor. The agreement set forth the expectations from CO-OPS and the USCG, with CO-OPS assuming responsibility for procurement of the agreed-upon microwave air gap sensor, performance of tests and evaluations for satisfactory performance, installation on a mutually acceptable bridge, and operation for demonstration to signatories of the agreement.

This test provided the first long-term (one year) installation at long range. It was a demonstration of the commercial off-the-shelf system, and MIROS supplied the hardware and software, with no CO-OPS software or DCP involved. The bridge operator declined to provide a power source, so the installation was solar-powered. Data were transmitted to the New Orleans Vessel Traffic System (VTS) office at the standard output rate of two Hz using 0.1 watt Maxstream spread spectrum radios. Air gap plots were displayed using the Oracle-based MIROS software. CO-OPS personnel revisited Crescent City and documented several installation issues.

**Radio link.** During a service call on 10 February 2003, CO-OPS personnel found that the Maxstream spread spectrum radio link had degraded, with perhaps only one-third of the data being transmitted. Personnel enabled retries on the radios and installed a much higher gain (13 decibel [dB]) antenna, but there was no improvement in data reception. The addition of 100 feet of strategically-placed cable, (30 feet away, 10 feet lower, and rotated 15 degrees north of the transmit antenna) resulted in the reception of 99 percent of the expected data - over a three-hour and 20-minute test period.

**Software.** Once the received data rate increased, the software began to plot. The screen was configured to show ten-minute mean values over a variety of time scales instead of plots showing ten-minute minimums (min) & maximums (max), because the min/max plots only showed the spikes in the data (Figure 22).
**Figure 22.** Ten-minute mean values over a variety of times

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>WL1a-2</th>
<th>WL1a-4</th>
</tr>
</thead>
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<tr>
<td>10 minutes</td>
<td>175.4</td>
<td>175.4</td>
</tr>
<tr>
<td>12 minutes</td>
<td>175.4</td>
<td>175.4</td>
</tr>
<tr>
<td>24 hours</td>
<td>175.4</td>
<td>175.4</td>
</tr>
</tbody>
</table>

No parameter selected.

NA
Comparison of Laser Rangefinder to MIROS Microwave Air Gap Sensor at the Crescent City Bridge. A Laser Technology Impulse 200 laser range finder (with internal tilt sensor for vertical height calculation) was mounted adjacent to, and at the same elevation as, the MIROS air gap sensor (Figure 23). Data were acquired about every three seconds, time-stamped, and logged to a laptop PC over a thirty-minute period.

![Figure 23. Laser range finder installed adjacent to microwave air gap sensor](image)

The plots of the raw laser data, the raw MIROS data, and the smoothed MIROS data are shown in Figure 24. The mean offset between the two raw data series is 7.9 cm (3.1 inches), with the laser reading the shorter distance. Subsequent testing of additional MIROS SM-094 units has lead to the conclusion that the factory calibration results in readings that are approximately three inches too great at 50 m. Section 9.1 further addresses the calibration issue.
When comparing the two absolute air gap time series, both sensors perform well. It appears that either device can provide air gap to the required ± six-inch specification. The advantage of the MIROS is that it is an all-weather sensor. Also, the laser is measuring a single point, while the MIROS footprint is approximately five m (15’) in diameter.

Figure 25 shows a plot of the smoothed MIROS air gap data for the same time period at a better scale and a much better behaved curve. Note that the entire vertical scale of the plot is 7.6 cm (three inches). The two peaks are likely real, since there are similarities in the laser data. Such local small scale perturbations would not correlate with the Carrolton gauge eight miles upstream, and would look like noise in the absence of the collaborating laser data.

These data sets and full resolution plots/figures are available on our FTP site at ftp://ftp.fod.noaa.gov, OSTEP/AirGap/USCGNewOrleans/LaserRF.
Figure 25. Smoothed MIROS air gap data
6.6 Reedy Point and Chesapeake City

The MPA funded the installation of two air gap sensors for the Reedy Point and Chesapeake City bridges over the C&D Canal, as part of the Chesapeake Bay PORTS®. The Reedy Point sensor was installed in June 2003, and the Chesapeake City installations occurred in October 2003. These two installations were used to develop an operational configuration, and then became the first operational air gap sensors on 01 March 2004.

Air gap data collected at each bridge during this pre-operational period were used to develop QC criteria. At both locations a Sutron Xpert Lite was used as the DCP. Software (described in more detail in Section 7.0) on the DCP produced a mean air gap, standard deviation, and number of outliers for each six-minute sample. This information is recorded in a standard “PORTS tag” file (see Section 7.3). Software was written to generate QC flags associated with air gap data output from the “PORTS tag” file using the same format and code scheme described in the PUFFF documentation (Evans et al., 1998). These flags are sent to and interpreted by CORMS (see Section 8.1) software and presented to the CORMS operators for their information and possible action. A Standard Operating Procedure (SOP), written for the CORMS operators by Michael Connolly, provides instruction for action based on the QC flag values.

Occasional large negative spikes are observed in the data series from both bridges. Although the negative spikes are very likely ship passages, dissemination of these points may give the impression that the sensor is inaccurate, so the decision was made to flag these points as an error (denoted with an $F = \text{Failure}$). These values are not disseminated, but these errors do NOT mean the instrument has failed and does not cause CORMS to turn off dissemination of the air gap data.

The following series of graphs and statistics show how these data were used to develop the QC criteria. At Reedy Point, 91 days of data were used. Figure 26 shows the raw air gap data and associated statistics that were used to establish the lowest and highest acceptable air gap values. Figure 27 shows a time series of standard deviation values obtained for each six-minute observation, and the associated statistics shown on that figure were used to assign an upper-bound for an acceptable standard deviation. Figure 28 shows the number of outliers discarded for each six-minute sample, used to establish the upper limit of outliers permitted while still providing a six-minute result. There are two temperature sensors, one at the instrument (external) and one in the electronics box (internal); however T1 and T2 have not been assigned quality flags because lab tests have demonstrated that temperature does not affect the accuracy of this microwave sensor. Figure 29 shows a time series of first differences (delta) used to determine an acceptable sample-to-sample rate of change.

Similarly, a month of data from Chesapeake City was used (Figures 30-33) to develop the QC criteria for that location. The criteria are contained in Tables 6-7.
Table 6. QC Criteria for Reedy Point

<table>
<thead>
<tr>
<th>Lowest</th>
<th>Highest</th>
<th>Delta</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>41.5</td>
<td>45.3</td>
<td>0.5</td>
<td>Observed air gap (m)</td>
</tr>
<tr>
<td>0</td>
<td>15</td>
<td>0.0</td>
<td>Outliers (count)</td>
</tr>
<tr>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
<td>Standard deviation (m)</td>
</tr>
</tbody>
</table>

Table 7. QC Criteria for Chesapeake City

<table>
<thead>
<tr>
<th>Lowest</th>
<th>Highest</th>
<th>Delta</th>
<th></th>
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<tbody>
<tr>
<td>41.5</td>
<td>45.3</td>
<td>0.5</td>
<td>Observed air gap (m)</td>
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<tr>
<td>0</td>
<td>0.5</td>
<td>0.0</td>
<td>Outliers (count)</td>
</tr>
<tr>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
<td>Standard deviation (m)</td>
</tr>
</tbody>
</table>

Figure 34 shows the final operational air gap web page for these two Chesapeake Bay PORTS® sensors.

CO-OPS asked the NGS to conduct trigonometric leveling of these sensors as an independent check of the elevations determined by CO-OPS trigonometric leveling efforts. NGS determined the elevation of the Reedy Point MIROS device on 17 March 2004 and determined the elevation of the Chesapeake City MIROS device on 18 March 2004. A full report of this successful elevation check can be found in Appendix E.
Figure 26. Air gap at the navigation channel light on Reedy Point Bridge

Figure 27. Standard deviation of air gap data when processed through DQAP
Figure 28. Number of one-second values rejected from the six-minute average done by DQAP at Reedy Point

Figure 29. Change (delta) in air gap between successive six-minute samples
Figure 30. Air gap at the navigation channel light on Chesapeake City Bridge

Figure 31. Change (delta) in air gap between successive six-minute samples
Figure 32. Standard deviation in air gap when processed through DQAP

Figure 33. Number of one-second values rejected form the six-minute average done by DQAP
Figure 34. Chesapeake Bay PORTS®: Operational Air Gap Web Page
7.0 DEVELOPMENT OF DATA COLLECTION SYSTEM

A data collection system is required in order to gather, store, and support data retrieval. CO-OPS is presently converting to a new DCP—the Sutron Xpert/9210. The Xpert and the 9210 hardware use a Windows CE operating system, a popular operating system that increases the quantity of programs available to support the device. Software to support data acquisition from the SM-094 to the Xpert/9210 was generated through a contract to Sutron. This software, known as a Sutron Dynamic Linked Library (DLL or SLL) works in concert with other existing SLLs to acquire, process, and provide air gap data at the CO-OPS standard six-minute sample interval.

The SM-094 offers two methods of data output: free-cycling and polled. When free-cycling, the SM-094 provides a continuous two-Hz output, for a total of 720 data points, during a six-minute interval. An optional advanced data filter with a user-selectable time constant can be applied to either or both of two data records. CO-OPS has chosen to operate the SM-094 in polled mode. Rather than using all available data and the advanced filter, the DCP polls the SM-094 at a one-Hz rate for three minutes during the six-minute sample interval. The air gap data are processed exactly as the NGWLMS data are processed in order to provide a measure of continuity, and to ensure a more equitable intercomparison with water levels derived from an NGWLMS station.

The NGWLMS algorithm used, known as the Data Quality Assurance Processing (DQAP), is as follows: during a six-minute sample interval centered on each tenth of an hour, 181 one-second samples are acquired (polled) and averaged. A three standard deviation outlier rejection test is applied and the mean and standard deviation are recalculated. The output record consists of the recalculated mean, the recalculated standard deviation, and the number of discarded outliers. This DQAP process has been incorporated into the air gap SLL acquisition module.

7.1 SLL Installation, Test, and Operation

Sutron provided SLL installation, test, and operation procedures. These processes are described in the Air Gap DLL Users Manual (Appendix G). The manual also describes troubleshooting techniques to assist operators in the installation, test, and operation procedures.

7.2 DCP-Generated Errors/Status Codes

The air gap SLL can produce two status messages (no data returned and loss of synchronization) and one error message (COM port communications failure). The Air Gap DLL Users Manual (Appendix G) contains more detail on these messages and their meanings.
7.3 Air Gap Data Flow

Air gap sensor data are collected using two distinct methods: (1) using a PORTS® Data Acquisition System (DAS), (2) using six-minute GOES.

A centralized or local DAS collects data from the air gap sensor by polling the DCP. The DAS has no direct connection or interaction with the air gap sensor, but uses the DCP as a go-between to acquire the DQAP data.

The DAS acquires the data from the DCP by using one of several communication methods. Once a connection is made to the DCP, the DAS enters a special login which triggers the DCP to output the last data sample collected from the air gap sensor. The DCP outputs the data in a pre-determined format called a PORTS TAG. The PORTS TAG has the following format:

```
NOS 85519111 09/08/2004 13:06:00
Q1 ( 43.332 0.015 4.000 24.197 23.292
L1 < 12.174
DAT 0.000
SNS 0.000
REPORT COMPLETE
```

After the DAS has acquired the air gap data, it begins a series of steps to process and QC the data. As a result of the processing, the DAS produces a PUFFF (PORTS Uniform Flat File Format) file, a PORTS® standard data format. A detailed description of the PUFFF documentation is available at http://co-ops.nos.noaa.gov/publications/pufff4.pdf.

The DAS then sends data to Silver Spring for ingestion into the CO-OPS databases. The data are transferred from the DAS to TESTPORT, a server in Silver Spring, which adds no value to the data but acts as a “traffic cop” by transferring data to the appropriate servers (all of which are protected behind the CO-OPS firewall) throughout CO-OPS.

The air gap data are distributed, along with all the other data types collected in the form of PUFFF files, to a number of CO-OPS servers that are involved in the ingestion process (Figure 35). The data ingestion server (DIS) acquires, processes, generates QC flags, and loads the data into the DMS (CO-OPS databases). The CORMS server (Section 8.1) provides an interface for the CORMS operators to see the flags that are generated at the DAS. It allows the operators to stop and start dissemination of sensor data. The users then access the data using various interfaces that CO-OPS has developed.
Air gap data can also be acquired using NOAA’s GOES satellite. Data from the DCP are transmitted via the satellite every six minutes. Data are received by the National Environmental Satellite, Data, and Information Service (NESDIS) and stored on data servers for retrieval by the DIS. NESDIS also rebroadcasts the data over DOMSAT (Domestic Satellite), which is the primary method used by CO-OPS to retrieve the data. Once the DIS acquires the satellite data, the data follows a similar path as data collected by the DAS. It is important to note that air gap data follows the same path as other CO-OPS data types.

Figure 35. Air gap data flow
8.0 DATA QUALITY CONTROL/QUALITY ASSURANCE

Dissemination of high quality data is a priority for CO-OPS. Bridge clearance data, by nature of how they will be used, require particular attention to quality assurance (QA). Fortunately, QA/QC of air gap data from fixed bridges bears many similarities to QA/QC of water level data—a field in which CO-OPS has much expertise.

8.1 CORMS

The objective of CORMS is 24-hour monitoring and quality control to ensure the availability and accuracy of water level, meteorological, current observations, and other parameters that are used for navigation and safety-of-life and property decisions. CORMS is a quality-control and decision-support system that combines real-time communications, data analysis, system monitoring, graphical user interface (GUI), and system “watch dog” and notification capability.

CORMS functions include:
- Ingest real-time and near real-time data and information;
- Determine data completeness;
- Monitor data quality;
- Generate statistics used to evaluate system performance;
- Provide decision-making information for possible field team response;
- Communicate to real-time and near real-time users the identification of invalid or suspect data.

8.2 Sensor Quality Control Flags for CORMS

Air gap data are fed to the CORMS system just like any other sensor that CORMS monitors. The CORMS Operators have SOPs for all instrument data types, including air gap. The CORMS SOP for air gap instrumentation (Appendix H), reveals that CORMS has multiple paths for monitoring air gap sensors. For example, there are web-based tools that visually display an air gap time series, as well as the point measurements (Figure 36). The Main CORMS application continuously maintains the status of the air gap sensor and allows the operator to see the CORMS flags in more detail. There are also text-based files (Figure 37) that allow the CORMS operators to see the raw data collected.
Figure 36. Air gap time-series and point measurements for Reedy Point

Figure 37. CORMS site monitoring
CO-OPS processes perform air gap data QC at multiple locations during the ingestion process—when data are collected at the DAS and when data arrives at the DIS. CORMS Operators conduct QA by visual inspection of the data through the use of the CORMS interface and various plotting tools.

The DAS provides point-to-point QC of the air gap data as data are collected via the following checks:

- **Time Check**
  The time associated with each data sample is compared to the DAS system clock. The DAS uses a time range of 15 minutes into the past to two minutes into the future. If the time of the data are outside this range, then the DAS flags these data as bad. The time check was implemented to handle clock drift at the DCP.

- **Absolute Range**
  The computed air gap value must be between a pre-determined lower and upper limit. The upper and lower limits were determined by analysis of the data for each specific air gap location. If air gap value is greater than or equal to the upper limit and less than or equal to the lower limit, the DAS flags the data as bad.

- **Outliers**
  The number of outliers from the air gap measurement must be less than or equal to a pre-determined value. The value was determined by analysis of the data. If the number of outliers for a particular sample exceeds the pre-determined value, the DAS flags the data as bad.

- **Standard Deviation**
  The standard deviation of the air gap value must be less than or equal to a pre-determined value. The value was determined by analysis of the data. If the value of the standard deviation for a particular sample exceeds the pre-determined value, the DAS flags the data as bad.

Table 8 provides the values used for the air gap checks and stored on the DAS. The file that contains these values, called a criteria file, is transferred along with the data every six minutes.
Table 8. Values Used for the Air Gap Checks

<table>
<thead>
<tr>
<th>Station</th>
<th>Absolute Range (m)</th>
<th>Standard Deviation (m)</th>
<th>Outliers</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
</tr>
<tr>
<td>Chesapeake City</td>
<td>41.6</td>
<td>45.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Reedy Point</td>
<td>40.2</td>
<td>44.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Once the data have been acquired and QC’d at the DAS, they are transferred to Silver Spring for distribution to various systems as detailed in Figure 35.

The DIS acquires air gap data from the DAS or from GOES if the station is configured to do so; the DIS performs the same checks as the DAS using the same limits and ranges outlined in the DAS QC.
9.0 UNCERTAINTY ESTIMATES

As stated previously, air gap users have requested an air gap observation with an accuracy of ±75 mm (six inches). It has not been specified precisely what this value indicates—it could be interpreted to be the value of one, two, three or more standard deviations of a sample population.

The stated accuracies of the MIROS microwave sensor and the Laser Technologies laser range finder—and the known accuracies of the water level measurements at Money Point, traditional trigonometric leveling procedures, and GPS observations—all greatly exceed the required air gap accuracy. The final air gap observations easily exceed the required accuracy.

9.1 Calibration

The operational installation of an air gap sensor requires a precise and careful range calibration effort. CO-OPS personnel have found that the manufacturer’s calibration is insufficient, and that corrections to the manufacturer’s calibration are necessary. The first estimate of the correction is determined using the 50 m reference range facility previously described. Another estimate may be obtained by comparing air gap observations from an uncorrected sensor to those obtained from a corrected operational sensor (the Reedy Point site has been used as an occasional reference - see Section 6.6). A final estimate is obtained in-situ after the installation at the operational site, using the Total Station and WL observations to calculate a reference air gap. These estimates are compared, with the most weight given to the in-situ estimate. A final offset value is selected and applied at the DAS. The original manufacturer’s calibration stored on the SM-094 is not altered. In addition to the calibration offset correction, the correction for the offset to low steel is also applied at the DAS.

9.2 Traceability

Our principal traceable reference is the Cooper Tools 200' long steel tape, previously described in Section 4.2 and also in Appendix B. This tape is used to confirm all other linear length measurements (laser, Total Station, microwave altimeter). Temperature corrections to observations obtained from the steel tape are applied as described in the calibration certificate.
9.3 Error Identification

There are errors in the sensor observation combined with errors external to the measurement in all of the validation methods used during these tests. For example, the Laser Technologies laser range finder has a stated accuracy of 2-3 cm at 50 m. Errors arising from measurements of mounting hardware were added to this known error. Each component of the mounting hardware was measured, with an error of approximately 1-2 mm. All of these errors are simply added together to provide the maximum possible error, which presumes that the maximum possible error has indeed occurred in each measurement, and that in each case, the error has the same sense (no offsetting errors have occurred). The more accepted method is to combine the errors in a root mean square (RMS)-sense, presuming that errors occur in a more random manner. Each measurement taken during the course of the tests had an error bar associated with that measurement. These error bars were summed in both RMS and total sense.

9.4 Error Budget

The altimeter test’s total error budget included four components:

1. Errors associated with the sensor itself, such as uncompensated electronic circuit temperature dependencies, receiver noise, output resolution;
2. Errors related to signal path propagation rate variations, dependent upon unmeasured parameters such as temperature, barometric pressure, and humidity;
3. Errors generated as target noise, which includes significant consideration about the definition of “water level” (over what space and time scales?);
4. Errors that may arise during the data processing and product generation.

These four components are addressed in the following paragraphs.

Regarding sensor errors, a measure of the sensor noise floor was obtained by the range variation observed during tests in which all other perturbations were constrained. In practical applications this cannot be achieved, but it can be approximated. These tests include the bench and field tests described in Section 5.9.1. Total errors attributable to the sensor itself are typically less than one mm (one standard deviation).

Regarding signal path propagation rate dependencies, the inherent assumption is that the transmitted signal travels at the nominal speed of light, defined as 299,792,458 m/sec in a vacuum, but rounded to $3 \times 10^8$ in the sensor firmware. The earth’s atmosphere will reduce this velocity. Density variations caused by changes in temperature, barometric pressure, and humidity will cause speed variations, but the effect is negligible over this relatively short path length. This source of error is minimal, which is essentially why this technology was selected.
Target noise includes those target characteristics that require definition. The surface to which the range is desired undulates over a wide variety of periods and amplitudes, and the measurement of this range is defined by spatial and temporal considerations, including mechanical and mathematical filters. The existing measurement of water level within NOS includes precise definitions of mechanical and electronic filtering, as well as computational signal processing.

Filtering variations can generate very different answers, which is why CO-OPS has elected to sample and process observations from differing acoustic and microwave ranges using the same algorithm. While this retains the same mathematical smoothing, there is a fundamental difference in the physical smoothing of the acoustic (NGWLMS) and microwave techniques. The reference acoustic WL is physically smoothed by a narrow orifice, protective well, and sounding tube. The microwave altimeter is physically smoothed by the beam-width of the transmitted signal, which translates into a variable footprint size, dependent upon range. The signal returned to the sensor includes target range variations caused by waves with this footprint. These variations are addressed by the internal sensor continuous wave frequency modulation (CWF) signal processing capability, which turns a rough sea surface observation into a broader signal peak, but does not shift the location of that peak in the frequency domain.

Errors that arose during the data processing and product generation were the easiest to manage, as they were fully controlled. Such errors include resolution of constants used in calculations, which are easily modified to reduce or eliminate the error. The total error has been found to be well below what is required. An accuracy of a few centimeters (± one inch) has been demonstrated, where an accuracy of ±75mm (six inches) was requested (Table 9). CO-OPS has begun evaluating microwave devices for use as a primary NGWLMS sensor, which requires an accuracy measured in millimeters. For that application, a more thorough understanding of each of the error sources will be necessary.

<table>
<thead>
<tr>
<th>Error Source</th>
<th>Error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1</td>
</tr>
<tr>
<td>Path</td>
<td>1</td>
</tr>
<tr>
<td>Target</td>
<td>20</td>
</tr>
<tr>
<td>Data Processing</td>
<td>15</td>
</tr>
<tr>
<td>TOTAL</td>
<td>37</td>
</tr>
<tr>
<td>RMS TOTAL</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 9. Error Sources
9.4 Further Testing

OSTEP will continue testing the MIROS air gap sensor in order to continually refine the understanding of the performance of the sensor and to optimize the application. An operational test on USACE Cape Cod Canal under ice flow conditions is scheduled for the winter of 2004-2005. Other studies planned include long-term drift, corrosion, and vibration studies.
10.0 OPERATIONAL IMPLEMENTATION

10.1 Installation

The installation of an air gap sensor on a bridge requires careful consideration of unique field difficulties. These factors include vibration, corrosion, data transmission, and others. Service intervals should be scheduled to inspect the installation and prevent failure before it occurs.

Bridge vibration caused by heavy traffic must be mitigated by using vibration-resistant fasteners. Field technicians must use nylon insert nuts (aircraft fasteners), Loctite, and/or lock washers at all times. Mounting frames should be overbuilt to withstand continuous vibration. Electronic components should be fastened inside the enclosure, preferably with rubber shock mounts.

Corrosion can be reduced by using non-metallic components whenever possible. When using metallic components, dissimilar metals must be electrically isolated to prevent galvanic corrosion.

Data transmission is accomplished using either line-of-sight radio or GOES. In each case a clear antenna path close to the electronics housing is required. Sensor location selection should include this consideration.

Recommended maintenance intervals are:
- Visual inspection every two months
- Annual verification by in-situ calibration using trigonometric leveling
- Battery replacement every two years

Insufficient experience with the sensor exists at present to address longer term reliability issues. A three- or five-year sensor refurbishment may or may not be required.

10.2 Sensor Offsets

There are two sensor offsets that must be considered. The location of the air gap sensor creates the first offset scenario, because the sensor is not located precisely at low steel of the bridge. The correction is made by subtracting out the low steel offset.

The second offset is a result of the manufacturer’s calibration insufficiency, as addressed in Section 9.1. The most precise measurement is derived from the tide gauge plus the Total Station.
PORTS® partners voiced a requirement for a bridge air gap sensor to support safe and economic maritime commerce. CO-OPS agreed to develop the capability to provide the required data, and this development process has been successful. Following a rigorous evaluation of existing technologies, a sensor was selected, fully evaluated, and found to meet all requirements. Data delivery pathways were established, QA/QC parameters determined and implemented, and air gap products were developed. Bench and field references for use as standards during operational acceptance testing and field verification have been identified, described, and documented; ultimately, all requirements have been met or exceeded. The creation of this new capability has been embraced by the maritime community, as witnessed by the quick interest and follow-on requests for air gap sensors at many additional locations.

The selected sensor has been tested over several years, at several locations and under a wide variety of conditions. The manufacturer has implemented corrective actions where deficiencies were identified. The device has proven to be immune to rain, snow, temperature extremes, waves, vibration, RF noise, and other potential interferences. It has exceeded precision requirements to the extent that CO-OPS is now beginning to investigate the use of this technology for standard observations of water level. All test results are documented and are freely available electronically.

Most significantly, the introduction of air gap to the CO-OPS “tool bag” has shown that, through the private/Federal PORTS® partnership and the matrix-managed OSTEP, a new data product can be developed. CO-OPS is presently embracing many other new technologies which will require personnel and process adaptation. The success of the air gap development shows that it can be done, and done well.
12.0 ACKNOWLEDGEMENTS

OSTEP is a matrix-managed program and consequently draws upon many CO-OPS resources. The success of the entire program and this air gap sensor evaluation is a tribute to the dedication of all CO-OPS personnel who have enthusiastically accepted additional tasks to improve our products and services.

Bridges are invariably cold, noisy, dirty, and dangerous. The elevated level of risk requires extra attention, caution, and dedication. Special thanks go to Warren Krug and John Stepnowski (CO-OPS), as well as John Abbitt and Jennifer Dussault (REMSA contractors), for providing valuable support.

We also would like to thank:

The Sutron Corporation, under contract to CO-OPS, for providing an air gap DLL;

Jeff Oyler (CO-OPS) and Audie Murray (NGS) for providing Leica Total Station leveling and height datum guidance, and to Jeff for his expertise in leveling surveys at Reedy Point and Chesapeake City;

Karen Grissom (REMSA) for providing C&D Bridge access request documentation;

Dave Hatcher (CO-OPS) for helping to establish the 50 meter Reference Range at CO-OPS Chesapeake Facility;

Warren Krug, Philip Libraro, and Chris McGrath (CO-OPS) for their long hours developing air gap data communications and DCP operations;

Mike Evans, Geoff French, and Robert Gillium (CO-OPS Information Systems Division) for development of the web services and QA/QC procedures;

Mike Connolly (CO-OPS Products and Services Division) for the implementation of those QA/QC procedures in CORMS;

Marti Ikehara for planning and arranging the San Francisco test during the passage of the Oakland cranes;

USCG personnel for their assistance in the air gap demonstration on the Crescent City Bridge;

Sandra Borden for funding the Crescent City deployment;

George Petras for his support at the New Orleans VTS;
LCDR Dennis Evans of the USCG for his installation help on a rainy day (special thanks!)

NGS personnel for their efforts conducting the GPS air gap survey in Charleston:
  Dave Crump
  Ed Carlson
  Curt Smith
  Audie Murray
  Frank Marion

US Army Corps of Engineers personnel for their cooperation in deploying the air gap sensors at Reedy Point and Chesapeake City:
  Jim Tomlin
  Larry Brown
  Doug Patterson
  Bobby Parlier
  Heather Sachs

USACE personnel at the FRF in Duck, North Carolina, for their excellent cooperation with the deployment on their pier. The entire FRF staff has supported OSTEP in many ways over the years.

Finally, thanks to the Port Authority of New York and New Jersey for funding the first acquisition of a microwave air gap sensor. PANYNJ personnel who deserve special thanks: Patrick McKeon and Ron Borup.
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### 14.0 ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>ATC</td>
<td>Averaging Time Constant</td>
</tr>
<tr>
<td>CBBT</td>
<td>Chesapeake Bay Bridge Tunnel</td>
</tr>
<tr>
<td>C &amp; D</td>
<td>Chesapeake and Delaware</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>CO-OPS</td>
<td>Center for Operational Oceanographic Products and Services</td>
</tr>
<tr>
<td>CORMS</td>
<td>Continuous Operational Real-Time Monitoring System</td>
</tr>
<tr>
<td>CT</td>
<td>Conductivity/Temperature sensor</td>
</tr>
<tr>
<td>CWFM</td>
<td>Continuous Wave Frequency Modulation</td>
</tr>
<tr>
<td>DAS</td>
<td>Data Acquisition System</td>
</tr>
<tr>
<td>dB</td>
<td>Decibels</td>
</tr>
<tr>
<td>DCP</td>
<td>Data Collection Platform</td>
</tr>
<tr>
<td>DIS</td>
<td>Data Ingestion Server</td>
</tr>
<tr>
<td>DLL</td>
<td>Dynamic Linked Library</td>
</tr>
<tr>
<td>DMS</td>
<td>Database Management System</td>
</tr>
<tr>
<td>DOMSAT</td>
<td>Domestic Satellite</td>
</tr>
<tr>
<td>DQAP</td>
<td>Data Quality Assurance Processing</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital Signal Processing</td>
</tr>
<tr>
<td>FRF</td>
<td>Field Research Facility</td>
</tr>
<tr>
<td>FSI</td>
<td>Falmouth Scientific Instruments</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GOES</td>
<td>Geostationary Operational Environmental Satellite</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>GV</td>
<td>Get Value</td>
</tr>
<tr>
<td>Hz</td>
<td>Hertz</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>MMAGSDTP</td>
<td>Mitretek MIROS Air Gap Sensor Detailed Test Plan</td>
</tr>
<tr>
<td>MLLW</td>
<td>Mean Lower Low Water</td>
</tr>
<tr>
<td>MPA</td>
<td>Maryland Port Administration</td>
</tr>
<tr>
<td>NESDIS</td>
<td>National Environmental Satellite, Data, and Information Service</td>
</tr>
<tr>
<td>NGS</td>
<td>National Geodetic Survey</td>
</tr>
<tr>
<td>NGWLMN</td>
<td>Next Generation Water Level Measurement System</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>nm</td>
<td>Nanometer</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NOS</td>
<td>National Ocean Service</td>
</tr>
<tr>
<td>NRC</td>
<td>National Research Council</td>
</tr>
<tr>
<td>NWLON</td>
<td>National Water Level Observation Network</td>
</tr>
<tr>
<td>NWLP</td>
<td>National Water Level Program</td>
</tr>
<tr>
<td>OSTEP</td>
<td>Ocean Systems Test and Evaluation Program</td>
</tr>
<tr>
<td>OSTEF</td>
<td>Ocean Systems Test and Evaluation Facility</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>PANYNJ</td>
<td>Port Authority of New York and New Jersey</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PLB</td>
<td>Port of Long Beach</td>
</tr>
<tr>
<td>PORTS®</td>
<td>Physical Oceanographic Real-Time System</td>
</tr>
<tr>
<td>PSD</td>
<td>Products and Services Division</td>
</tr>
<tr>
<td>PUFFF</td>
<td>PORTS® Uniform Flat File Format</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RTU</td>
<td>Remote Terminal Unit</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>SLL</td>
<td>Sutron Dynamic Linked Library</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
</tr>
<tr>
<td>USACE/FRF</td>
<td>United States Army Corps of Engineers / Field Research Facility</td>
</tr>
<tr>
<td>USCG</td>
<td>United States Coast Guard</td>
</tr>
<tr>
<td>WL</td>
<td>Water Level</td>
</tr>
<tr>
<td>YSI</td>
<td>Yellow Springs Instrument Corporation</td>
</tr>
</tbody>
</table>

° Fahrenheit  Degrees Fahrenheit
APPENDICES

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## APPENDIX A

### MIROS MICROWAVE AIR GAP SENSOR TEST SUMMARY

*(TEST PROCEDURES)*

<table>
<thead>
<tr>
<th>TEST</th>
<th>SHORT DESCRIPTION</th>
<th>CONTROLLED MEASUREMENT</th>
<th>EXPECTED RESULTS OR MEASUREMENT OF UNCERTAINTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sensor air gap reading against fixed target</td>
<td>Taking reading against fixed target, vertically against water surface, horizontally against Invar surface</td>
<td>Invar tape</td>
<td>+/- 75 millimeters</td>
</tr>
<tr>
<td>2. Sensor programmable functions</td>
<td>To test correct response to changed parameters, change all programmable parameters, one by one, and take reading while changing distance between sensor and fixed surface</td>
<td>Invar tape</td>
<td>Programmable functions take their effect</td>
</tr>
<tr>
<td>3. Sensor recovery after power supply interruption</td>
<td>While taking reading against fixed surface, unplug the power supply, restore the power supply, and continue the test</td>
<td>Invar tape</td>
<td>Sensor recovers and continues to send correct reading</td>
</tr>
<tr>
<td>4. Sensor operation under varied power supply output</td>
<td>Perform accuracy test of sensor reading under varied power supply output</td>
<td>Invar tape</td>
<td>Sensor provides accurate reading using battery power supply</td>
</tr>
<tr>
<td>5. Custom developed software test</td>
<td>Perform test of data processing by DCP component (statistical calculations and storing results into output file using correct data structure and formats)</td>
<td></td>
<td>Converted units represent correct results based on unit conversion table</td>
</tr>
<tr>
<td>6. Accuracy of sensor at varied distances from target</td>
<td>Perform sensor accuracy test while changing distance between sensor and fixed surface using a range from 10 to 150 feet</td>
<td>Invar tape</td>
<td>+/- 75 millimeters</td>
</tr>
<tr>
<td>7. Accuracy at varied alignment of sensor to water surface</td>
<td>Perform sensor accuracy test between sensor surface and fixed target surface by raining and lowering the sensor.</td>
<td>Invar tape</td>
<td>+/- 75 millimeters</td>
</tr>
<tr>
<td>8. Accuracy of reporting under different configuration of sensor programmable functions</td>
<td>Perform sensor accuracy test while changing programmable parameters to determine the best set up for operational environment</td>
<td>Invar tape</td>
<td>Selected parameter set up will deliver uncertainty of +/- 75 millimeters</td>
</tr>
<tr>
<td>9. Temperature</td>
<td>Perform sensor accuracy test</td>
<td>Invar tape</td>
<td>Consistent reading with</td>
</tr>
<tr>
<td>Impact on Accuracy</td>
<td>Details</td>
<td>Consistency and Uncertainty</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>---------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>10. Rain impact on accuracy</strong></td>
<td>Perform sensor accuracy test while changing sensor exposure to rain</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>11. Humidity impact on accuracy</strong></td>
<td>Perform sensor accuracy test while changing sensor exposure to humidity</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>12. Icing on sensor surface impact on accuracy</strong></td>
<td>Perform sensor accuracy test while surface is covered by icing</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>13. Vibration impact on accuracy</strong></td>
<td>Perform sensor accuracy test while changing sensor exposure to vibration</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>14. Ice on water surface impact on accuracy</strong></td>
<td>Perform sensor accuracy test against water surface with floating ice blocks</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>15. Varied sea condition impact on accuracy</strong></td>
<td>Perform sensor accuracy test while changing sensor exposure to simulated sea conditions (waves)</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>16. Natural conditions (combination of environmental factors)</strong></td>
<td>Perform sensor accuracy test while changing sensor exposure to combination of environmental factors</td>
<td>Invar tape</td>
<td>Consistent reading with uncertainty +/- 75 millimeters during the test</td>
</tr>
<tr>
<td><strong>17. Operational deployment on N&amp;PBL railroad bridge</strong></td>
<td>Perform sensor accuracy in field deployment environment over long period of time</td>
<td>GPS, Invar tape, water level gauge, laser range finder Environmental data</td>
<td>Sensor provides reliable reading over period of deployment With uncertainty of +/- 75 millimeters</td>
</tr>
<tr>
<td><strong>18. Reliability test and data collection about failures</strong></td>
<td>Collect and log all sensor failures during the field deployment test</td>
<td></td>
<td>MTBF is at least 5,000 hrs.</td>
</tr>
</tbody>
</table>
APPENDIX B  
COOPER TOOLS CERTIFICATE OF TRACEABILITY TO NIST

CERTIFICATE OF CALIBRATION

COTAGOL NUMBER: C12760
SERIAL NUMBER: 12662

CALIBRATION TESTS (at 68 degrees Fahrenheit)

1. Supported throughout with ___ lbs. / ___ kg of tension.
   Interval 0-100'
   Interval 0-200'
   Interval

2. Supported for accuracy with ___ lbs. / ___ kg of tension.
   Interval 0-100'
   Interval 0-200'
   Interval

3. Supported at 0 and ___ ft. / ___ meters with ___ lbs. / ___ kg of tension.
   Interval 0-100'
   Interval 0-200'
   Interval

4. Supported at 0 and ___ ft. / ___ meters with ___ lbs. / ___ kg of tension.
   Interval 0-200'
   Interval

This tape was checked against our Level II standard 14757. Level II standards are re-calibrated every six months. The level II standards are verified by our level I standards NIST 14757 for English and NIST 14466 for metric, as appropriate. Level I standards are re-calibrated every three years and are directly traceable to the National Institute of Standards and Technology. Coefficient of expansion of steel tapes is 0.000000645 per degree F., 0.0000011$^\circ$ per degree C. This amounts to 0.000645 or 0.00111$^\circ$ per degree F. on a 100-foot tape, and one-half as much on a 50-foot tape.

Quality Assurance Manager  

Gauge Calibration Technician

Ferm CALCERT doc. Revised 4/27/01

CAMPBELL  •  CRESCENT  •  DIAMOND  •  ERIE  •  LUFKIN  •  Nicholson  •  PLUMB  •  R.K. PORTER  •  WELLER  •  WIRE-WRAP  •  HSS  •  XCELITE
APPENDIX C  SCANNED COPIES OF THE COMPLETE TEST LOGS
Test #   N/A   Test Name   BATTERY DRAW #1
Tester’s Name   Marc Bushnell

Brief Description of Test Procedure: Configure system as planned for USC6 installation in New Orleans (CH-094/85 Unit #1-4) and retest. Add 24 AH Batteries. Briefer short during weekend reduced capacity.

Start Date and Time (GMT or local)   8/21 13:00 Local
End Date and Time (GMT or local)   8/26/02 09:00 Local
Location   FOD LOSTER Office

Lab/Environmental Data (or source for time series or data file name):

<table>
<thead>
<tr>
<th>Air Temp</th>
<th>78°F</th>
<th>Wind Speed</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baro</td>
<td></td>
<td>Wind Direction</td>
<td>N/A</td>
</tr>
<tr>
<td>Humidity</td>
<td>40%</td>
<td>Water Temp</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Miros Model/Serial Number   M006 SN094/85 *010168
Comparison Standard (S/N)   KOMELLOV 0633

Test Data or Data File Names (if files provide original media, FTP location, and backup)

\[\text{Log file}\]  \[FW02_CAP]\  \[OSTER PUBLIC SITE]\
**Test #**

**Test Name** Battery Draw #2

**Tester's Name** Mary Bushwell

**Brief Description of Test Procedure**
SAME AS Battery Draw #1 BUT w/ 2 40 AH Batteries

---

**Start Date and Time (GMT or local)** 8/26/02 11:00 Local

**End Date and Time (GMT or local)** 9/5/02 09:00 Local

**Location** Food/Logist Office

**Lab/Environmental Data (or source for time series or data file name):**

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Temp</td>
<td>78°F</td>
<td></td>
</tr>
<tr>
<td>Baro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Wind Speed</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Wind Direction</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Water Temp</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

**Miros Model/Serial Number** SM094/85 #01016B

**Comparison Standard (S/N)** KOMELON 4633

**Test Data or Data File Names (if files provide original media, FTP location, and backup)**

Y:\ARO  TW\#3.CAT  OSTEP_PUBLIC SITE

**FTP:**

---

**Tester's Signature** Mary Bushwell
Test # 1/51-54
Test Name Sensor Air gap reading against Fixed Target
Tester's Name Bosley, Kate
Brief Description of Test Procedure Test then page 61 - modified
target in metal filing cabinet in 4m away

Start Date and Time (GMT or local) 10/18/02 06:18 PM
End Date and Time (GMT or local) 10/18/02 06:18 PM
Location F00/R00 lab

Lab/Environmental Data (or source for time series or data file name):
Air Temp ___________ Wind Speed ___________
Baro ___________ Wind Direction ___________
Humidity ___________ Water Temp ___________

Miros Model/Serial Number 5M-094 Golden Gate 85m 5NP010164
Comparison Standard (S/N) no laser range finder

Test Data or Data File Names (if files provide original media, FTP location, and backup)
calibrated tape under 3.942 m using vertical from green face to floor
to filing cabinet
data stored on fujitsu
C: data\Air 60p\Ag 1018\dat 10/18.dat

Then moved miros to 3.461 and ran from 11:19:16

Tester's Signature

Stopped at 10:47
10/21/02 To install new cable
Test # part 87  Test Name ___________________________
Tester's Name  Bushnell
Brief Description of Test Procedure test of adjusting offset for New Orleans deploy

Start Date and Time (GMT or local) 10/23/02 10:12
End Date and Time (GMT or local) ___________________________
Location  Bushnell office
Lab/Environmental Data (or source for time series or data file name):
Air Temp __________ Wind Speed __________
Baro __________ Wind Direction __________
Humidity __________ Water Temp __________

Miros Model/Serial Number 5194/85
Comparison Standard (S/N) PO1016 not comparing

Test Data or Data File Names (if files provide original media, FTP location, and backup)
using procomm script to Bushnell laptop
attempted to change offset to -5000 mm return +1553.6 mm
offset to -999 changed it to -999 mm
-3276 mm is greatest negative offset it will accept
+3276 mm is greatest positive offset
note: offset was returned -385 as delivered from manufacturer

Tester's Signature  [Signature]
This test also proves reliability of laptop's procomm
connection to the New Orleans Miros
Test #

Test Name

Tester's Name  Kate Busley

Brief Description of Test Procedure
dried out trying to see if still works

Start Date and Time (GMT or local)  Oct 3, 2003
End Date and Time (GMT or local)  Oct 6, 2003

Location  parking lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp
Wind Speed

Baro
Wind Direction

Humidity
Water Temp

Miros Model/Serial Number  9020143
Comparison Standard (S/N)  

Test Data or Data File Names (if files provide original media, FTP location, and backup)

10.11m measured w/ certified tape

Tester's Signature  [Signature]
Test # test
Test Name long term stability
Tester's Name Rodney
Brief Description of Test Procedure install at Duck

Start Date and Time (GMT or local) 4/14/03 PM
End Date and Time (GMT or local) 
Location NE corner of pier handrail
Lab/Environmental Data (or source for time series or data file name):

<table>
<thead>
<tr>
<th>Air Temp</th>
<th>Wind Speed</th>
<th>Baro</th>
<th>Wind Direction</th>
<th>Humidity</th>
<th>Water Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.5 °C</td>
<td>4.7 m/s</td>
<td>1015.8</td>
<td>223°</td>
<td></td>
<td>8.6 °C</td>
</tr>
<tr>
<td></td>
<td>1.1 m/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Miros Model/Serial Number SM-09410W S/N 020143
Comparison Standard (S/N) will use NULON

Test Data or Data File Names (if files provide original media, FTP location, and backup) stored on Argonaut in tide house will be retrieved periodically.
originally had trouble because factory offset had been changed.

Tester's Signature

- 11 -
<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/16/03</td>
<td>duck pie</td>
<td>min 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>det 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wtc 0.5 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>win 6 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tout 10 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sea 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>freq 0</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>htc 0.0</td>
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<tr>
<td></td>
<td></td>
<td>top 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ch 5 12</td>
</tr>
<tr>
<td>5/29/03</td>
<td>installing expect + temp probe + modem</td>
<td>min 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>det 100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wtc 0.5 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>win 6 m</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>sea 0</td>
</tr>
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<td></td>
<td></td>
<td>freq 2.42</td>
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<tr>
<td></td>
<td></td>
<td>htc 0.1 sec</td>
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<tr>
<td></td>
<td></td>
<td>atc 30.0 sec</td>
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<td></td>
<td></td>
<td>ntc 0.0</td>
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<tr>
<td></td>
<td></td>
<td>top 1</td>
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<td></td>
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<td>ch 5 12</td>
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<table>
<thead>
<tr>
<th>Measure</th>
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<th>-627 mm</th>
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<tr>
<td>ft+</td>
<td>64</td>
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<tr>
<td>ft - time</td>
<td>46.32</td>
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<tr>
<td>tot</td>
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<tr>
<td>sweep</td>
<td>5.6</td>
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<tr>
<td>range</td>
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<td>as type</td>
<td>2</td>
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<tr>
<td>as gain</td>
<td>10.5</td>
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<tbody>
<tr>
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<td>20 m</td>
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</tr>
<tr>
<td>ant</td>
<td>10 deg</td>
<td></td>
</tr>
<tr>
<td>as type</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>as gain</td>
<td>10.5%</td>
<td></td>
</tr>
</tbody>
</table>
Test # 1
Test Name: Fixed Target

Tester's Name: Kathryn T. Bosley

Brief Description of Test Procedure: 30 minutes @ 10 m, 9 m, 10 m

Start Date and Time (GMT or local): 9/2/2003 09:09:12, local
End Date and Time (GMT or local): 9/2/2003 11:08

Location: For packing lot 4 warehouse

Lab/Environmental Data (or source for time series or data file name):

- Air Temp
- Wind Speed
- Baro
- Wind Direction
- Humidity
- Water Temp

Miros Model/Serial Number: 020149
Comparison Standard (S/N): laser range finder 107728

Test Data or Data File Names (if files provide original media, FTP location, and backup):

- Fig. run 100
  - DAT 100%
  - UTC 4:55 sec
  - W/T 6.0 m
  - N/T 10 sec
  - Freq 2 Hz
  - ASC 0.5 sec
  - TCH 0.0 sec
  - Top ch 2.0

- Mean 295 mm/s - 913.0 mm
  - Fit 256
    - For time 226.47 m sec
    - Sweeptime 12.21 m sec
  - Range 50 m
    - Art 5 deg
    - As type 1
    - As gain 0.09
  - 09020909.dat 9m

- 09021037.dat 10m

Tester's Signature: Kathryn T. Bosley
Test # 02  Test Name programmable function

Tester's Name Kathryn Baslay

Brief Description of Test Procedure test accuracy of/changed settings

Start Date and Time (GMT or local) 09/02/2003 12:26:50 local

End Date and Time (GMT or local) 09/02

Location FedEx parking lot + warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp Wind Speed

Baro Wind Direction

Humidity Water Temp

Miros Model/Serial Number 54104/50 020149 Sw ver 6.4a

Comparison Standard (S/N) laser range finder i.07728

Test Data or Data File Names (if files provide original media, FTP location, and backup)

min 50 9m 09021226.dat

9m 09021233.dat

dat 50 9m 09021240.dat

10m 09021249.dat

re 10sec 10m 09021257.dat

9m 09021305.dat

win 2m 7m 09021401.dat

10m 09021502.dat

out 5sec 10m 09021509.dat

9m 09021516.dat

Tester's Signature

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Test # 3  
Test Name Sensor Recovery after Power Interruption

Tester's Name Kathryn Basley

Brief Description of Test Procedure 10 minute power off 5 min Power on

Start Date and Time (GMT or local) 09/02/2003 11:08 local
End Date and Time (GMT or local) 09/02/2003 11:39 local
Location 5th parking lot of warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp ____________  Wind Speed ____________
Baro _______________  Wind Direction ____________
Humidity ____________  Water Temp ____________

Miros Model/Serial Number 020149 survei 6.4a
Comparison Standard (S/N) laser range finder 167728

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Miros config same as test #1 begin ending config

(42 sec)
09/02/09.dat
09/02/29.dat

power cat 118 47 sec
up 1124 45 sec

Tester's Signature ____________________________
Test # 1  
Test Name Fixed Target

Tester’s Name Kathryn T Bosley

Brief Description of Test Procedure
30 min @ 10m + 30 min @ 9m + 30 min @ 10m

Start Date and Time (GMT or local) 2/21/03 12
End Date and Time (GMT or local) 2/21/03 14:09

Location PNB Warehouse & lot

Lab/Environmental Data (or source for time series or data file name): Army Pt FOBIS

Air Temp 44°F Wind Speed calm
Baro 1018mb Wind Direction
Humidity 86% Water Temp 47°F seawater

Miros Model/Serial Number 020152 SN 94/50m
Comparison Standard (S/N) Laser 107728 metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)
02211222.dat 10m
02211302.dat 9m
02211338.dat 10m

Tester’s Signature Kathryn T Bosley
Test # 17

Test Name: Search for Offset / Gain Correction

Tester's Name: Kathryn T. Bosley

Brief Description of Test Procedure:

O大海建立了非常精确的深水基线。这一基线将被再次测试。

Start Date and Time (GMT or local): 1/20/04 11:36

End Date and Time (GMT or local): 1/23/04 09:20

Location: FDR parking lot

Lab/Environmental Data (or source for time series or data file name):

from Honey Pt.

Air Temp ____________ Wind Speed ____________

Baro ____________ Wind Direction ____________

Humidity ____________ Water Temp ____________

Miros Model/Serial Number: SN 071/50m PO20152

Comparison Standard (S/N): test pressure - metal type see attached.

Test Data or Data File Names (if files provide original media, FTP location, and backup):

01201133.DAT: has perched trace of sea motion targets etc.

01201433 - 012113.DAT: hourly files at 50m

01 211449 = 01220849.DAT & ke "at 90m

1/21/04 012406.DAT moved sensor to 90m

01220823 - 01230824.DAT also 90m

1/21/04 0241.DAT: moved sensor to 90m

01220824 - 01230824.DAT also 90m

Min 100

Det 100

WTC 4.5 sec

Win 8m

Pat 10 sec

Htc 0.5 sec

Art 29.5 sec

Trip 0.0 sec

Ch 2 50m

Mean 30.5 mm/h -83.3 mm

Tester's Signature: Kathryn T. Bosley

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Test # 2

Tester's Name: Kathryn J. Bosley

Brief Description of Test Procedure:
Verify functionality of all settings. Vary only one setting at a time.

Start Date and Time (GMT or local): 2/24/03 07:50:17

End Date and Time (GMT or local): 2/24/03 09:40

Location: Food Warehouse 10T

Lab/Environmental Data (or source for time series or data file name):

- Air Temp
- Wind Speed
- Baro
- Wind Direction
- Humidity
- Water Temp

Miros Model/Serial Number: 020152 5M 94/50m

Comparison Standard (S/N): Laser 107928

Test Data or Data File Names (if files provide original media, FTP location, and backup):

- 02240750.dat
- 02240812.dat
- 02240818.dat
- 02240823.dat
- 02240828.dat
- 02240833.dat
- 02240838.dat
- 02240843.dat
- 02240848.dat
- 02240853.dat
- 02240858.dat
- 02240863.dat
- 02240868.dat
- 02240873.dat
- 02240878.dat
- 02240883.dat
- 02240888.dat
- 02240893.dat
- 02240898.dat
- 02240903.dat
- 02240908.dat
- 02240913.dat
- 02240918.dat
- 02240923.dat
- 02240928.dat
- 02240933.dat
- 02240938.dat
- 02240943.dat
- 02240948.dat

Test Data:

- 10 - 9 - 10m w/ factory settings
- 10.1-9.3-10m w/ factory settings
- 10.0-9.3-10m w/ factory settings

- min = 75°
- det = 50%
- det = 2
- det = 5 sec

- 100% det
- win = 6
- tout = 10
- frq = 2 Hz
- atc = 2
- top = 1
- ch = 3.0

- 9m
- 9m
- 9m
- 10m
- 10m
- 10m
- 10m
- 10m

- 4.6 sec
- 8.5
- 4.6 sec
- 20.0

Tester's Signature: Kathryn J. Bosley

Note: The data appears to be related to a test setup and verification process.
Test # 6
Test Name Long Range
Tester's Name Kathryn T Bosley
Brief Description of Test Procedure against target longrange of parking lot

Start Date and Time (GMT or local) 06/02/2003 10:23:05
End Date and Time (GMT or local) 06/02/2003 10:11:40
Location Foot lot & warehouse

Lab/Environmental Data (or source for time series or data file name):
Air Temp
Baro
Humidity
Wind Speed
Wind Direction
Water Temp

Miros Model/Serial Number SM/091 50m S/N 020152
Comparison Standard (S/N) Laser 106021 (old one)

Test Data or Data File Names (if files provide original media, FTP location, and backup)
data 06021001.dat - 10:01
06021023.dat
06021023.dat
06022223.dat
06030423.dat

Tester's Signature

meas 375.0 mm/ch - 853.0 mm
Test # 3  Test Name Power Interruption

Tester's Name Kathryn Bosley

Brief Description of Test Procedure cut off power log after return of power

Start Date and Time (GMT or local) 2/21/03 14:11
End Date and Time (GMT or local) 2/21/03 14:43

Location FOOD warehouse + lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp Wind Speed
Baro Wind Direction
Humidity Water Temp

Miros Model/Serial Number SH94/50m 020152
Comparison Standard (S/N) laser 117728 metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)
0221 1411.dat reading before power interrupt
02211438.dat " after "

varpowe.log procomm.log

Tester's Signature Kathryn J. Bosley
Test # 4

Test Name Variable Power

Tester's Name K. Bosley

Brief Description of Test Procedure

Vary power and record giro's response

Start Date and Time (GMT or local) 2/24/03 10:40

End Date and Time (GMT or local) 2/24/03 14:12

Location Feed lot & warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp __________ Wind Speed __________

Baro __________ Wind Direction __________

Humidity __________ Water Temp __________

Miros Model/Serial Number 020152 SM94/50m

Comparison Standard (S/N) Laser 167728 metal type

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02.24 1042.dat running @ 24V

02.24 1319.dat 24V

13.22:08 down to 23V

13.25:13 down to 22V

13.28:13 down to 21V

13.31:13 down to 20V

13.34:18 down to 18V

13.37:23 down to 16V

13.41:23 down to 14V

13.43:28 down to 12V

13.46:28 down to 10V

13.49:23 down to 8V

13.52:28 down to 7V

13.55:08 down to 6V

phil's program stop

Tester's Signature K. Bosley
Test # 1

Test Name: Sensor Air Gap Reading Against Fixed Target

Tester's Name: Katheryn T. Bosley

Brief Description of Test Procedure:
Tape used to position metal sheeked target at 10m
then at 9m
then back to 10m

Start Date and Time (GMT or local): 01-16-2003 13:00

End Date and Time (GMT or local): 14:48

Location: Ford warehouse parking lot

Lab/Environmental Data (or source for time series or data file name):
Air Temp (hand held) Wind Speed 1.5 m/s
Baro: 1023.4 mb Wind Direction
Humidity Water Temp

Miros Model/Serial Number: P010162 SN 09/15/00
Comparison Standard (S/N): P3 Laser range finder SN 106021 Nov. 9, 2000

Test Data or Data File Names (if files provide original media, FTP location, and backup):
cad files togethee in OSTEP/Air Gap/P010162/1.dat
individual files at O1 012580.DAT 014819.DAT on floppy
O1 014306.DAT 014637.DAT
O1 01316.DAT 014637.DAT
O1 014637.DAT

issues 2000 laser range finder had 15cm offset to other known distance:
buts only range finder we can track to. SN N1 07728 8/6/2002
reads 10.01 consistently
when manually
fine from that position

Tester's Signature: Katheryn T. Bosley
Test # 3
Test Name Power Failure

Tester's Name Kate Bosley

Brief Description of Test Procedure
Shut off power - make sure Miro's
recorded after 1 minute. Look difference on test par

Start Date and Time (GMT or local) 02/06/03 11:09
End Date and Time (GMT or local) 02/06/03 12:15

Location FOO Warehouse 1st

Lab/Environmental Data (or source for time series or data file name):

Air Temp

Baro

Humidity

Wind Speed

Wind Direction

Water Temp

Miro's Model/Serial Number SM094/50m P010162

Comparison Standard (S/N) laser S/N 107728 metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Reading before power = 02061109.dat
Running program after power intro
For 30 secs of noise
Then running Miro's program
02061121.dat after power intro
To view all info also have a
proxbar log powoff.dat

Tester's Signature Kate Bosley
Test # 4  Test Name varying power supply

Tester's Name Kate Bosley

Brief Description of Test Procedure  attach voltage regulator
                                          & see how Mirros performs w/ varying power

Start Date and Time (GMT or local) 02/06/03 1253
End Date and Time (GMT or local) 02/06/03 1415
Location Foo Warehouse Tart

Lab/Environmental Data (or source for time series or data file name):

Air Temp
Baro
Humidity

Wind Speed
Wind Direction
Water Temp

Miros Model/Serial Number SM094/50m P010162
Comparison Standard (S/N) Laser 4107728 metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)
02061253.dat  15 minute "reading at 24V" not error in total paper page 71
02061309.dat set up w/ voltage regulator
  1311 V 23 V
  1311 V 13 V
  1311 V 17 V
  1311 V 19 V
  1311 V 18 V
  1311 V 12 V
  1311 V 15 V
  1311 V 14 V
  1311 V 09 V
  1311 V 07 V
  1311 V 08 V
  1311 V 09 V
  1311 V 07 V

Tester's Signature Kate Bosley

Note 02061416 contains me on overnight @ 12V
Test # __________________________  Test Name  Looking at long range effect
Tester's Name  Kathleen T. Basley
Brief Description of Test Procedure  parking lot on trug established baseline

Start Date and Time (GMT or local) 1/3/04 09:31:29
End Date and Time (GMT or local) __________________________________________
Location __________________________________________ This unit was pulled from Duck on 1/2/04.
Lab/Environmental Data (or source for time series or data file name):
Air Temp __________________________ Wind Speed __________________________
Baro __________________________ Wind Direction __________________________
Humidity __________________________ Water Temp __________________________

Miros Model/Serial Number 54094 / P010162 (OSJEP) 5° beam width
Comparison Standard (S/N) __________________________________________

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Target 0123200.DAT
40m target 01231131.DAT
40m target 01231134.DAT
40m target 01231900.DAT
40m target 01231700.DAT
40m target 01231900.DAT
40m target 01232000.DAT
40m target 01232000.DAT

Tester's Signature __________________________________________

- 25 -
Test # 2  Step 5  Test Name Sensor Programable Function

Tester's Name Kathryn Bosley

Brief Description of Test Procedure Change settings & test at 10 m & 9 m

Start Date and Time (GMT or local) 01/28/2003 9:22:33

End Date and Time (GMT or local) TBC on new day

Location FOO Warehouse +10

Lab/Environmental Data (or source for time series or data file name):

Air Temp Cold  Wind Speed

Baro  Wind Direction

Humidity  Water Temp

Miros Model/Serial Number SN-094/50m P010162

Comparison Standard (S/N) SN 10602 Nov 9, 2000 + irnax tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

012804.dat Setting one 10m MIN 100
0128009.dat MIN 15 75 9m
0128117.dat MIN 15 75 9m
01281029.dat DET 75 10m
01281045.dat DET 75 10m
01281132.dat WTC 0.3 9m
01281145.dat WTC 0.3 9m
01281155.dat WIN 2m 10m

Tester's Signature /KPB/
Test # 2  Test Name Sensor Programmable

Tester's Name Kate Forsy

Brief Description of Test Procedure Change settings on test at 10m and 9m
Continuation of 1/28 testing with returned laser range
finder

Start Date and Time (GMT or local) 2/6/03 0941
End Date and Time (GMT or local) 2/6/03 1050

Location Foo warehouse - lot

Lab/Environmental Data (or source for time series or data file name):

<table>
<thead>
<tr>
<th>Air Temp</th>
<th>Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>colder</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Baro</th>
<th>Wind Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Humidity</th>
<th>Water Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Miros Model/Serial Number SM094/50m PO10162
Comparison Standard (S/N) new laser range finder SN 107728

Test Data or Data File Names (if files provide original media, FTP location, and backup)

<table>
<thead>
<tr>
<th>02060941.dat</th>
<th>win = 2 m - 9m</th>
</tr>
</thead>
<tbody>
<tr>
<td>02060948.dat</td>
<td>HIC = 5 sec - 9m</td>
</tr>
<tr>
<td>02061003.dat</td>
<td>10 - 10 m</td>
</tr>
<tr>
<td>02061011.dat</td>
<td>ARC = 90 sec - 10 m</td>
</tr>
<tr>
<td>02061020.dat</td>
<td>9 - 9 m</td>
</tr>
<tr>
<td>02061028.dat</td>
<td>NTC = 10 sec - 9 m</td>
</tr>
<tr>
<td>02061041.dat</td>
<td>10 - 10 m</td>
</tr>
</tbody>
</table>

Tester's Signature [Signature]

- 27 -
### SOFTWARE PARAMETER SETTINGS

SM-048/2 and all SM-094 versions are basically running the same software. Configuration changes required to adapt SW to the different versions cannot be done by the user because hardware modifications are also required to achieve specified measurement performance.

Some signal processing parameters may be changed from the default values by the user by connecting an ASCII terminal to the RS232 port of the MIROS Microwave Range Finder.

By typing the command

```
ALL < > CR/LF
```

(no argument) the current parameter settings are printed (typical example - for actual settings please see test report for the specific range finder);

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>100</td>
</tr>
<tr>
<td>det</td>
<td>50 (%)</td>
</tr>
<tr>
<td>wtc</td>
<td>1.0 (sec)</td>
</tr>
<tr>
<td>win</td>
<td>6.0 (m)</td>
</tr>
<tr>
<td>tout</td>
<td>10.0 sec</td>
</tr>
<tr>
<td>ser</td>
<td>1</td>
</tr>
<tr>
<td>freq</td>
<td>2 (Hz)</td>
</tr>
<tr>
<td>htc</td>
<td>1 (sec)</td>
</tr>
<tr>
<td>atc</td>
<td>60 (sec)</td>
</tr>
<tr>
<td>ntc</td>
<td>30 (sec)</td>
</tr>
<tr>
<td>top</td>
<td>1</td>
</tr>
<tr>
<td>ch</td>
<td>20 -40 (m)</td>
</tr>
</tbody>
</table>

SM-094/50 Miros Range finder SW ver. 6.4
Maximum range 50 m
Ant. beam width 5 deg

The following signal processing parameters may be selected by the user:

**Minimum signal level**

The minimum signal level may be set by the command

```
MIN <level> CR/LF
```

where `<level>` is a real number in the dimension of internal units.
Detection level

The detection level is set in % of the peak value by the command

\[ \text{det} <\% \text{ of peak}> \text{ CR/LF} \]

where <% of peak> is a real number in the dimension of %.

Tracking window time constant

The time constant of the tracking window may be set by the command

\[ \text{wtc} <\text{timeconst in sec}> \text{ CR/LF} \]

where <timeconst in sec> is a real number in the dimension of seconds. A value of 0 turns the filter off.

Tracking window size

The size of the tracking window is set by the command

\[ \text{win} <\text{absolute size in metres}> \text{ CR/LF} \]

where <absolute size in metres> is a real number in the dimensions of metres.

Lost signal time-out

Time-out value for lost signal is set by the command:

\[ \text{tout} <\text{time-out in seconds}> \text{ CR/LF} \]

where <time-out in seconds> is a real number in the dimensions of seconds.

Analogue or digital signal output

By typing the command

\[ \text{ser} <\text{x}> \text{ CR/LF} \]

analogue or digital signal output is selected.
x=0 gives analogue output
x=1 gives digital output

**Digital data output rate**

The digital data output rate may be selected by typing

```
freq <rate> CR/LF
```

where "rate" may be

- **SM-O48/2**: 2, 4 or 8 (measurements per second)
- **SM-O94/10**: 2, 4 or 8 (measurements per second)
- **SM-O94/20**: 2 or 4 (measurements per second)
- **SM-O94/50**: 2 (measurements per second)
- **SM-O94/85**: 2 (measurements per second)

**Data output averaging time constants**

The output channels may be averaged by different time constants. Time constant may be changed by typing

```
htc <time-constant> CR/LF
```

and

```
atc <time-constant> CR/LF
```

for the two output channels respectively. "time constant" is an integer in the unit of seconds

**Suppression of unwanted fixed echoes**

Unwanted, fixed echoes may be suppressed by subtracting an averaged signal vector from each new measurement. The averaging time constant is user selectable:

```
ntc <time-constant> CR/LF
```

where "time-constant" is an integer in the unit of seconds. Setting "time-constant"=0 turns off the updating of the average signal vector.

Two different modes exist for estimating the averaged signal vector. The mode may be selected using the command:
where "x" may be 0 or 1:

- \( x = 1 \) means that the strongest echo does not contribute to the average background echo estimate. This is the default mode and is suitable for stationary targets.

- \( x = 0 \) means that all echoes contribute to the average background echo estimate. This mode is suitable only for very dynamic targets.

The command

```
resn <>CR/LF
```

sets the average signal vector to zero. In order to turn off the suppression of unwanted fixed echoes completely set "nte"=0 and type "resn".

By typing the command

```
info 8<> CR/LF
```

the estimated average signal vector ("noise vector") will be printed to the screen. If all elements equals zero suppression will not take place.

**Actual measurement range**

The actual measurement range may set within the limits given by the maximum range for each version. By typing

```
ch < min max> CR/LF
```

where "min" and "max" are real numbers in the unit of metres. "max" must be less than the given maximum range. If for example a SM-O94/50 is used for bridge airgap monitoring and the actual distance from the bridge down to the water surface may vary from 35 to 45 m the values of "min" and "max" may be set accordingly. This will completely eliminate all echoes from outside of this range.

The analogue output signal will be scaled according to the measurement range. 0 V will correspond to "min" and 10 V to "max".

**Reading data on command (get value)**

If the range finder is used for measurements of average distances and the user is not interested in
APPENDIX E  NGS ELEVATION DETERMINATION SURVEY

National Geodetic Survey
Geodetic Services Division
Instrumentation & Methodologies Branch

Field Report
Reedy Point/Chesapeake City Bridges - Miros Elevation Determination Survey
March 17 & 18, 2004

Report by: Kendall L. Fancher

Purpose

CO-OPS has installed a MIROS microwave altimeter instrument (air gap measuring device) on two bridges (Reedy Point & Chesapeake City) along the C & D Canal in Maryland and Delaware. The MIROS is a microwave altimeter capable of determining the distance from the electronic phase center of the device to a water surface. This information is very useful to ships whose maximum height approaches that of the available bridge clearance. Due to the location of these devices, CO-OPS used trig leveling as a means of transferring the Mean Lower Low Water (MLLW) heights to the electronic phase centers of these devices from nearby tidal bench marks. Standard Second-order, class 1 leveling procedures (maximum length, 60 meters, between leveling instrument and survey rod) to the MIROS device, mounted over the side center of the bridge would prove to be extremely difficult, if not impossible. NGS was asked to conduct trig leveling to the electronic phase centers of these devices as an independent check of the elevations determined by CO-OPS trig leveling efforts. Roy Anderson and I determined the elevation of the Reedy Point MIROS device, by trig levels, on the 17<sup>th</sup> of March. We determined the elevation of the Chesapeake City MIROS device, by trig levels, on the 18<sup>th</sup> of March. Jeff Oyler and Brad Wynn, tended the trig target at both MIROS devices. These devices are located in areas on the bridges that require special safety gear to access.

Survey Procedures

The same survey procedures were used for both the Reedy Point Bridge and Chesapeake City bridge MIROS surveys. The same instrument (Wild TC2002 s/n 359817) was used for both surveys. Parts Per Million (PPM) corrections, based upon atmospheric conditions, (air temperature and barometric pressure) were determined and applied during the surveys as needed.

1) The Wild TC2002 vertical index error was determined using the manufacturers standard check and adjust procedures and the correction applied and stored in the instrument.

2) The trig target pole bubbles were checked for plumb.

3) The trig target heights were calibrated and determined to be of equal value.
4) A tidal bench mark was selected to serve as primary vertical control for the trig leveling. The selection of this bench mark was dictated by proximity to the MIROS device and the bench mark having a published MLLW elevation.

5) The stability of the selected vertical control station was verified by conducting trig leveling to a second tidal bench mark (two mark tie). The Wild TC2002 was set up between the two bench marks in a location to minimize stadia imbalance (equal distance between back sight and fore sight targets). Two sets of direct and reverse observations were recorded to both the back sight (primary vertical control station) and fore sight (check bench mark). The mean average of the back sight and fore sight observations were used to determine an observed elevation difference between the bench marks. This observed elevation difference was compared to the observed elevation difference between the two bench marks taken from second-order, class 1 leveling field abstracts provided by CO-OPS. Second-order, class 1 tie allowances were determined based upon the observed distance between the bench marks. The field abstracts provided to NGS are included with this report.

6) The Wild TC2002 instrument was set up in a location that provided a good angle of observation to the MIROS device and minimized the stadia imbalance between the back sight and fore sight as much as was possible. From this location, a single shot section was used to trig level from the primary vertical control station to the MIROS electronic phase center. Five sets of direct and reverse readings were recorded to both the back sight and fore sight. The mean average of the fore sights and back sights were used to determine the observed elevation difference between the primary vertical control station and the MIROS electronic phase center.

7) The Wild TC2002 instrument height was reset. From this location, a single shot section was used to trig level from the MIROS electronic phase center to the primary vertical control station. Five sets of direct and reverse readings were recorded to both the back sight and fore sight. The mean average of the fore sights and back sights were used to determine the observed elevation difference between the MIROS electronic phase center and the primary vertical control station.

8) A Second-order, class 1 allowable closure was determined based upon the observed distances between the back sight and fore sight. The observed elevation differences between the forward and reverse sections were evaluated to insure that they agreed within the allowable closure tolerance.

### Trig Target Calibration

<table>
<thead>
<tr>
<th></th>
<th>Rod 1</th>
<th>Rod 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>-0.1143</td>
<td>-0.1147</td>
</tr>
<tr>
<td>R</td>
<td>-0.1150</td>
<td>-0.1147</td>
</tr>
<tr>
<td>mean</td>
<td>-0.1147</td>
<td>-0.1147</td>
</tr>
</tbody>
</table>
Reedy Point Bridge

Two Mark Tie (855 1910 C TIDAL to 855 1910 B TIDAL)
Check between observed forward and reverse sections = 0.0007m
Allowable check 0.0033m

Check between observed elevation difference and abstract elevation difference = 0.0031m
Allowable check 0.0033m

Determination of Elevation to MIROS Electronic Phase Center
Check between observed forward and reverse sections = 0.0011m
Allowable check 0.004m

Published elevation of 855 1910 C TIDAL = 3.148m (MLLW)
Mean of observed elevation differences (forward and reverse sections) = 41.2095m
Elevation of MIROS electronic phase center is (3.148m + 41.2095m) = 44.3575m (MLLW)
Mean of observed elevation difference from 855 1910 C TIDAL to additional foresight to “low steel below obstruction light” = 40.1118m
Elevation of “low steel below obstruction light” is (3.148m + 40.1118m) = 43.2598m (MLLW)

Chesapeake City Bridge

Two Mark Tie (NO 3 1972 to U 2 1931 6.834)
Check between observed elevation difference and abstract elevation difference = 0.0001m
Allowable check 0.001m

Check between observed forward and reverse sections = 0.0012m
Allowable check 0.0045m

Determination of Elevation to MIROS bracket
Note—Previous surveys conducted by CO-OPS had been to the bracket rather than the electronic phase center.
Check between observed forward and reverse sections = 0.0012m
Allowable check 0.0045m

Published elevation of NO 3 1972 = 2.455m (MLLW)
Mean of observed elevation differences (forward and reverse sections) = 42.2472m
Elevation of MIROS bracket is (2.455m + 42.2472m) = 44.7022m (MLLW)

Published elevation of NO 3 1972 = 2.455m (MLLW)
Mean of observed elevation difference from Instrument to NO 3 1972 (second set) = 0.6055m
Mean of observed elevation difference to additional foresight “MIROS electrical phase center” = 42.8838m
Mean of observed elevation difference to additional foresight “bottom of navigation light” = 41.6314m
Mean of observed elevation difference to additional foresight “low steel” = 41.9831m (MLLW)
Elevation of MIROS electronic phase center is (2.455m+(42.8838m-0.6055m)) = 44.7333m (MLLW)
Elevation of “bottom of navigation light” is (2.455m+(41.6314-0.6055m)) = 43.4809m (MLLW)
Elevation of “low steel” is (2.455m = (41.9831-0.6055m)) = 43.8326m (MLLW)
Recommendations for future air gap height determination surveys:

1) When installing the MIROS instrument determine a bench mark point (reference point) on the electronic phase center. Be consistent with a common reference point selection for all MIROS devices. Ensure that during the installation of the MIROS device that the selected reference point remains accessible for direct occupation by a trig target pole.

2) If possible conduct near simultaneous trig observations (requires two instruments, preferably one setup close to the MIROS and the other instrument close to the bench mark) reading the same targets to reduce the refractive effects of unbalanced shots and inconsistent air layers. Near simultaneous trig observations would cancel out this source of error.

3) If near simultaneous trig observations are not feasible, conduct a separate and independent determination of the MIROS electronic phase center height. RTK GPS could provide such a separate and independent height determination. This would serve as a means of detecting any large errors that might be induced while trig leveling.

4) Trig target poles should be calibrated before each survey and bubbles checked to ensure they have not strayed. Reduce sources of error by maintaining a back sight and fore sight with equal prism heights whenever possible. Avoid having to add corrections for different prism heights.

5) The amount of expansion and contraction of bridge frameworks, due to seasonal atmospheric conditions should be examined for each location. Conducting trig leveling to the MIROS during the winter and again during the summer, might provide insight into the magnitude, of the elevation change, if any, occurring at each bridge.
***** RECOVERY DESCRIPTION *****

SSN: 0220
Designation: 855 1910 R 72 W
PID:
Approx. Latitude: 393242N
State: DE
Approx. Longitude: 0753450W
County: NEW CASTLE
Approx. Elevation:
Disk From: US ARMY
CORPS OF ENG
Stamping: R 72 W

Surface Mark
Type: Survey disk
Magnetic code: N
Setting: SET INTO THE TOP OF A CONCRETE MONUMENT
Rod depth:

Mark condition reported in descriptive text by - NOS on 06112003, chief of party

THIS MARK IS DESTROYED

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE
CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE WEST SIDE
OF U.S. HIGHWAY 9
NEAR THE SOUTH END OF THE BRIDGE LEADING OVER THE CANAL, 121.3 M (398.0
FT) NE
CF THE JUNCTION OF ROUTE 9 AND SOUTH REEDY POINT ROAD, 59.62 M (195.60 FT)
SOUTH OF THE SOUTH END OF THE BRIDGE, 7.19 M (23.59 FT) SW OF THE
CENTERLINE OF
ROUTE 9, AND 0.21 M (0.69 FT) WEST OF THE CURB.
The NGS Data Sheet
See file dsdata.txt for more information about the datasheet.

DATABASE = Sybase PROGRAM = datasheet, VERSION = 6.98
- National Geodetic Survey, Retrieval Date = MARCH 16, 2004

JU2188 TIDAL BM - This is a Tidal Bench Mark.
JU2188 DESIGNATION - 855 1910 C TIDAL
JU2188 PID - JU2188
JU2188 STATE/COUNTY- DE/NEW CASTLE
JU2188 USGS QUAD - DELAWARE CITY (1993)
JU2188
JU2188 *CURRENT SURVEY CONTROL

JU2188

JU2188* NAD 83(1986)- 39 33 25. (N) 075 34 34. (W) SCALED
JU2188* NAVD 88 - 2.244 (meters) 7.36 (feet) ADJUSTED
JU2188
JU2188 GEOID HEIGHT- -33.39 (meters) GEOID03
JU2188 DYNAMIC HT - 2.243 (meters) 7.36 (feet) COMP
JU2188 MODELED GRAY- 980,127.3 (mgal) NAVD 88
JU2188
JU2188 VERT ORDER - FIRST CLASS II

JU2188 The horizontal coordinates were scaled from a topographic map and have
JU2188 an estimated accuracy of +/- 6 seconds.
JU2188
JU2188 The orthometric height was determined by differential leveling
JU2188 and adjusted by the National Geodetic Survey in June 1991.
JU2188
JU2188 This Tidal Bench Mark is designated as VM 381
JU2188 by the Center for Operational Oceanographic Products and Services.
JU2188
JU2188 The geoid height was determined by GEOID03.
JU2188
JU2188 The dynamic height is computed by dividing the NAVD 88
JU2188 geopotential number by the normal gravity value computed on the
JU2188 Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
JU2188 degrees latitude (g = 980.6199 gals.).
JU2188
JU2188 The modeled gravity was interpolated from observed gravity values.
JU2188
JU2188
JU2188 HISTORY - Date Condition Report By
JU2188 HISTORY - 1979 MONUMENTED NOS
JU2188 HISTORY - 1979 GOOD NGS

http://www.ngs.noaa.gov/cgi-bin/ds pid.prl/1

Page 1 of 2

3/16/2004
JU2188 HISTORY - 19950328 POOR NJGS
JU2188 HISTORY - 20010919 GOOD NGS
JU2188 HISTORY - 20030309 GOOD USPSQD

JU2188 STATION DESCRIPTION
JU2188
JU2188 'DESCRIBED BY NATIONAL GEODETIC SURVEY 1979
JU2188 '2.1 MI SE FROM DELAWARE CITY.
JU2188 '2.1 MILES SOUTHEAST ALONG STATE ROUTE 9 FROM THE INTERSECTION OF
JU2188 'CLINTON STREET IN DELAWARE CITY, THENCE 0.8 MILE NORTH ALONG OLD
JU2188 'ROUTE 9, THENCE 0.3 MILE EAST ALONG DUTCH NECK ROAD TO THE MARK ON
JU2188 ' THE RIGHT, B.M. 1910 C 1979 IS A STANDARD NOS DISK STAMPED 1910 C
JU2188 ' 1979 CRIMPED ON TOP OF 30 FOOT DEEP DRIVEN STAINLESS STEEL ROD
JU2188 'SURROUNDED BY 4 INCHES P.V.C. PIPE AND CONCRETE KICK PAD. THE MARK
JU2188 ' IS 0.2 MILES WEST OF PIER, 22.0 FEET SOUTH OF CENTER OF DIRT ROAD
JU2188 ' ALONG SOUTH SIDE OF CANAL, 45.0 FEET SOUTH AND IN LINE WITH POWER
JU2188 ' POLE 85 WITH LIGHT, ABOUT 10 FEET SOUTH OF EDGE OF ROAD AND 6 INCHES
JU2188 ' ABOVE GROUND.
JU2188 ' THE MARK IS 1 FT N FROM A WITNESS POST.
JU2188 ' THE MARK IS ABOVE LEVEL WITH ROAD.
JU2188
JU2188 STATION RECOVERY (1995)
JU2188
JU2188 'RECOVERY NOTE BY NEW JERSEY GEODETIC SURVEY 1995 (ECB)
JU2188 'RECOVERED AS DESCRIBED WITH THE FOLLOWING CHANGES. THE DITCH THAT THE
JU2188 'STATION IS SET NEAR HAS BEEN WIDENED SINCE THE LAST RECOVERY. THE
JU2188 'DISK AND THE ROD WERE FOUND FIRMLY WEDGED AGAINST THE INSIDE OF THE
JU2188 'PLASTIC PIPE.
JU2188
JU2188 STATION RECOVERY (2001)
JU2188
JU2188 'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2001 (JMW)
JU2188 '0.8 KM SOUTHWESTERLY ALONG CLINTON STREET FROM THE POST OFFICE IN
JU2188 ' DELAWARE CITY,
JU2188 ' THENCE 3.5 KM SOUTHERLY ALONG STATE HIGHWAY 9, THENCE 1.3 KM NORTHERLY
JU2188 ' ALONG REEDY
JU2188 ' POINT ROAD, THENCE 0.5 KM EASTERLY ALONG A GRAVELED ROA

http://www.ngs.noaa.gov/cgi-bin/ds_pid.prl/13/16/2004
<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Database</td>
<td>Sybase</td>
</tr>
<tr>
<td>Program</td>
<td>datasheet</td>
</tr>
<tr>
<td>Version</td>
<td>6.98</td>
</tr>
<tr>
<td>Retrieval Date</td>
<td>MARCH 16, 2004</td>
</tr>
<tr>
<td>JU2189 TIDAL BM</td>
<td>This is a Tidal Bench Mark.</td>
</tr>
<tr>
<td>JU2189 DESIGNATION</td>
<td>- 855 1910 B TIDAL</td>
</tr>
<tr>
<td>JU2189 PID</td>
<td>JU2189</td>
</tr>
<tr>
<td>JU2189 STATE/COUNTY</td>
<td>DE/NEW CASTLE</td>
</tr>
<tr>
<td>JU2189 USGS QUAD</td>
<td>DELAWARE CITY (1993)</td>
</tr>
<tr>
<td>JU2189 CURRENT SURVEY</td>
<td>CONTROL</td>
</tr>
<tr>
<td>JU2189 NAD 83(1991)</td>
<td>39 33 29.67449(N) 075 34 25.05431(W)</td>
</tr>
<tr>
<td>JU2189 NAVD 88</td>
<td>-2.366 (meters) 7.76 (feet)</td>
</tr>
<tr>
<td>JU2189 X</td>
<td>-1,226,760.738 (meters)</td>
</tr>
<tr>
<td>JU2189 Y</td>
<td>-4,768,803.475 (meters)</td>
</tr>
<tr>
<td>JU2189 Z</td>
<td>-4,040,271.335 (meters)</td>
</tr>
<tr>
<td>JU2189 LAPLACE CORR</td>
<td>-2.93 (seconds)</td>
</tr>
<tr>
<td>JU2189 ELLIP HEIGHT</td>
<td>-31.04 (meters) (02/12/02) GPS OBS</td>
</tr>
<tr>
<td>JU2189 GEOID HEIGHT</td>
<td>-33.39 (meters) GEOID03</td>
</tr>
<tr>
<td>JU2189 DYNAMIC HT</td>
<td>2.365 (meters) 7.76 (feet) COMP</td>
</tr>
<tr>
<td>JU2189 MODELED GRAV</td>
<td>980,127.1 (mgal) NAVD 88</td>
</tr>
<tr>
<td>JU2189 HORZ ORDER</td>
<td>A</td>
</tr>
<tr>
<td>JU2189 VERT ORDER</td>
<td>FIRST CLASS II</td>
</tr>
<tr>
<td>JU2189 ELLP ORDER</td>
<td>FOURTH CLASS I</td>
</tr>
<tr>
<td>JU2189 This is a reference station for the REEDY POINT 1</td>
<td></td>
</tr>
<tr>
<td>JU2189 National Continuously Operating Reference Station (RED1).</td>
<td></td>
</tr>
<tr>
<td>JU2189 The horizontal coordinates were established by GPS observations</td>
<td></td>
</tr>
<tr>
<td>JU2189 and adjusted by the National Geodetic Survey in February 2002.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The orthometric height was determined by differential leveling</td>
<td></td>
</tr>
<tr>
<td>JU2189 and adjusted by the National Geodetic Survey in June 1991.</td>
<td></td>
</tr>
<tr>
<td>JU2189 This Tidal Bench Mark is designated as VM 376</td>
<td></td>
</tr>
<tr>
<td>JU2189 by the Center for Operational Oceanographic Products and Services.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The X, Y, and Z were computed from the position and the ellipsoidal ht.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The Laplace correction was computed from DEFLEC99 derived deflections.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The ellipsoidal height was determined by GPS observations</td>
<td></td>
</tr>
<tr>
<td>JU2189 and is referenced to NAD 83.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The geoid height was determined by GEOID03.</td>
<td></td>
</tr>
<tr>
<td>JU2189 The dynamic height is computed by dividing the NAVD 88</td>
<td></td>
</tr>
<tr>
<td>JU2189 geopotential number by the normal gravity value computed on the</td>
<td></td>
</tr>
<tr>
<td>JU2189 Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45</td>
<td></td>
</tr>
<tr>
<td>JU2189 degrees latitude (g = 980.6199 gals.).</td>
<td></td>
</tr>
<tr>
<td>JU2189 The modeled gravity was interpolated from observed gravity values.</td>
<td></td>
</tr>
<tr>
<td>JU2189 North East Units Scale Factor Converg.</td>
<td></td>
</tr>
<tr>
<td>JU2189 SPC DE</td>
<td>-172,993.451 186,510.713 MT 0.99999724 -0.05 59.9</td>
</tr>
<tr>
<td>JU2189 UTM 18</td>
<td>-4,378,885.481 450,721.217 MT 0.99962990 -0.21 55.2</td>
</tr>
<tr>
<td>JU2189 Elev Factor x Scale Factor = Combined Factor</td>
<td></td>
</tr>
<tr>
<td>JU2189 3.35 MI SE FROM DELAWARE CITY. JU2189 2.1</td>
<td></td>
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</tbody>
</table>

http://www.ngs.noaa.gov/cgi-bin/ds_pid.plf/1

3/16/2004
JU2189 SPCE DE - 1.00000487 x 0.99999724 = 1.00000211
JU2189 UTM 18 - 1.00000487 x 0.99962990 = 0.99963477

JU2189
JU2189 SUPERSEDED SURVEY CONTROL
JU2189
JU2189 NAVD 88 (02/12/02) 2.37 (m) 7.8 (f) LEVELING 3
JU2189
JU2189 Superseded values are not recommended for survey control.
JU2189 NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
JU2189 See file data.txt to determine how the superseded data were derived.
JU2189
JU2189 U.S. NATIONAL GRID SPATIAL ADDRESS: 18SVJ5072178885(NAD 83)
JU2189 MARKER: DJ = TIDAL STATION DISK
JU2189 SETTING: 49 = STAINLESS STEEL ROD W/O SLEEVE (10 FT.+)
JU2189 STAMPING: 1910 B 1979
JU2189 MARK LOGO: NOS
JU2189 PROJECTION: PROJECTING 0 CENTIMETERS
JU2189 MAGNETIC: N = NO MAGNETIC MATERIAL
JU2189 STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
JU2189 SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
JU2189 SATELLITE: SATELLITE OBSERVATIONS - March 09, 2003
JU2189 ROD/PIPE-DEPTH: 9.75 meters

<table>
<thead>
<tr>
<th>Date</th>
<th>Condition</th>
<th>Report</th>
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</thead>
<tbody>
<tr>
<td>1979</td>
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<tr>
<td>1979</td>
<td>GOOD</td>
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<tr>
<td>- 19950328</td>
<td>POOR</td>
<td>NJGS</td>
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<tr>
<td>20000228</td>
<td>GOOD</td>
<td>NGS</td>
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<tr>
<td>20010919</td>
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<td>NGS</td>
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<tr>
<td>20030309</td>
<td>GOOD</td>
<td>USPSQD</td>
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</tbody>
</table>

JU2189

JU2189 STATION DESCRIPTION

JU2189

JU2189* DESCRIBED BY NATIONAL GEODETIC SURVEY 1979
To reach the tidal bench marks from the intersection of Clinton Street and State Highway 9 in Delaware City, proceed 3.5 km (2.2 mi) south on Highway 9 over the Reedy Point bridge to South Reedy Point Road, turn right and continue 1.3 km (0.8 mi) to a gravel road that parallels the Chesapeake and Delaware Canal, then turn right and proceed 0.8 km (0.5 mi) to the Corps of Engineers T-pier. The bench marks are along South Reedy Point Road, the gravel road, and State Highway 9. The tide gauge and staff are on the pier, east of the bridge and on the south side of the canal.

TIDAL BENCHMARKS

PRIMARY BENCHMARK STAMPING: R 41 1979
DESIGNATION: R 41
MONUMENTATION: Bench Mark disk VM#: 383
AGENCY: National Geodetic Survey (NGS) PID#: JU2187
SETTING CLASSIFICATION: Bridge pier foundation

The primary bench mark is a disk set in the concrete foundation of the most easterly of the two concrete piers of the first row of bridge piers south of the south bank of the Chesapeake and Delaware canal, 16.70 m (54.8 ft) east of a gravel service road that parallels the bridge, 0.3 m (1 ft) south of the north face of the pier, and 0.02 m (0.8 ft) west of the west edge of the pier.

BENCHMARK STAMPING: 1910 B 1979
DESIGNATION: 855 1910 B TIDAL
MONUMENTATION: Tidal Station disk VM#: 376 AGENCY: National Ocean Survey (NOS) PID#: JU2189 SETTING CLASSIFICATION: Stainless steel rod

The bench mark is a disk located west of the pier on the south side of the dirt road along the canal bank, 129.2 m (424 ft) WSW of the SW corner of the pier, 12.07 m (39.6 ft) south of utility pole number 75 with light, and 6.40 m (21.0 ft) south of the center of the dirt road. The bench mark is 15 cm (0.5 ft) above ground, crimped to a stainless steel rod driven 9.8 m (32 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

Station ID: 8551910  
CANAL: REEDY POINT, C&D CANAL  
DELAWARE  
NOAA Chart: 12277  
USGS Quad: DELAWARE CITY  
Latitude: 39° 33.5' N  
Longitude: 75° 34.4' W

**TIDAL BENCHMARKS**

**BENCHMARK STAMPING:** 1910 C 1979  
**DESIGNATION:** 855 1910 C TIDAL  
**MONUMENTATION:** Tidal Station disk  
**VM#:** 381  
**AGENCY:** National Ocean Survey (NOS)  
**PID#:** JU2188  
**SETTING CLASSIFICATION:** Stainless steel rod

The bench mark is a disk located on the south side of the dirt road along the canal bank, 0.3 km (0.2 mi) west of the pier, 13.72 m (45.0 ft) south of utility pole number 85 with light, 6.71 m (22.0 ft) south of the centerline of the dirt road, and 0.61 m (2.0 ft) north of a NOS witness post. The bench mark is 15 cm (0.5 ft) above ground, crimped to a stainless steel rod driven 9.1 m (30 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

**BENCHMARK STAMPING:** 1910 G 1982  
**DESIGNATION:** 855 1910 G  
**MONUMENTATION:** Tidal Station disk  
**VM#:** 382  
**AGENCY:** National Ocean Survey (NOS)  
**PID:**  
**SETTING CLASSIFICATION:** Stainless steel rod

The bench mark is a disk set on the south side of the dirt road along the canal bank, on the extended centerline of the wood pier located on the bank, 26.06 m (85.5 ft) SW of a utility pole with light on the east side of the pier, 15.24 m (50.0 ft) south of the SW end of the pier, and 7.01 m (23.0 ft) south of the centerline of the dirt road. The bench mark is 0.3 m (1 ft) below ground, crimped to a stainless steel rod driven 8.8 m (29 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

- 43 -
TIDAL BENCHMARKS

BENCHMARK STAMPING: RP 3 1975
DESIGNATION: 855 1910 TIDAL RP 3

MONUMENTATION: Tidal Station disk VM#: 385 AGENCY: National Ocean Survey (NOS) PID#: JU2186
SETTING CLASSIFICATION: Concrete culvert head wall

The bench mark is a disk set in a concrete culvert headwall along the east side of South Reedy Point Road, 147.2 m (483 ft) south of the canal, 50.11 m (164.4 ft) west of bridge pier R38W, and 5.49 m (18.0 ft) east of the centerline of the road.

BENCHMARK STAMPING: RP 5 1975
DESIGNATION: 855 1910 TIDAL RP 5

MONUMENTATION: Tidal Station disk VM#: 386 AGENCY: National Ocean Survey (NOS) PID#: JU 2186 SETTING CLASSIFICATION: Concrete culvert head wall

The bench mark is a disk set in a concrete culvert headwall along the west side of South Reedy Point Road, 23.01 m (75.5 ft) NW of bridge pier R53W, 20.42 m (67.0 ft) SW of bridge pier R52W, 6.80 m (22.3 ft) SE of utility pole number DP&L 27, and 6.71 m (22.0 ft) west of the road centerline.
Station ID: 8551910  PUBLICATION DATE: 04/21/2003  Name: REEY POINT, C&D CANAL  DELAWARE
NOAA Chart: 12277  Latitude: 39° 33.5' N
USGS Quad: DELAWARE CITY  Longitude: 75° 34.4' W

TIDAL BENCHMARKS

BENCHMARK STAMPING: R 72 W
DESIGNATION: 855 1910 R 72 W
MONUMENTATION: Survey disk  VM#: 12414
AGENCY: US Army Corps of Engineers (USE)
PID: SETTING CLASSIFICATION: Concrete monument

The bench mark is a disk set in a concrete monument located on the west side of U.S. Highway 9 near the south end of the bridge leading over the canal, 121.3 m (398 ft) NE of the junction of Route 9 and South Reedy Point Road, 59.62 m (195.6 ft) south of the south end of the bridge, 7.19 m (23.6 ft) SW of the centerline of Route 9, and 0.21 m (0.7 ft) west of the curb.

BENCHMARK STAMPING: 1910 H 1997
DESIGNATION: 855 1910 H
MONUMENTATION: Flange-encased Rod  VM#: 13758
AGENCY: National Ocean Service (NOS)
PID: SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a flange encased rod located on the east side of South Reedy Point Road, 65.2 m (214 ft) south of the stop sign on the east side of the road, 4.50 m (14.8 ft) east of the road centerline, and 0.35 m (1.15 ft) west of a NOS fiberglass witness post. The datum point is the top of a stainless steel rod driven 17.4 m (57 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

Stations ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL

DELAWARE

NOAA Chart: 12277 Latitude: 39° 33.5' N
USGS Quad: DELAWARE CITY Longitude: 75° 34.4' W

TIDAL BENCHMARKS

BENCHMARK STAMPING: 1910 J 1997
DESIGNATION: 855 1910 J

MONUMENTATION: Flange-encased Rod
VM#: 13759
AGENCY: National Ocean Service (NOS)
PID: SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a flange-encased rod located on the west side of South Reedy Point Road, 49.25 m (161.6 ft) north of power pole number 29, 33.60 m (110.2 ft) south of the south side of the driveway for the residence at 270 South Reedy Point Drive, 8.20 m (26.9 ft) west of the centerline of South Reedy Point Road, and 6.25 m (20.5 ft) SSE of power pole number 30. The datum point is the top of a stainless steel rod driven 18.0 m (59 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

BENCHMARK STAMPING: 1910 K 1997
DESIGNATION: 855 1910 K

MONUMENTATION: Flange-encased Rod
VM#: 13760
AGENCY: National Ocean Service (NOS)
PID: SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a flange-encased rod located on the east side of South Reedy Point Road, 19.30 m (63.3 ft) NE of power pole 6, 9.86 m (32.4 ft) west of the curb on the west side of Highway 9, 7.20 m (23.6 ft) east of the centerline of South Reedy Point Road, and 0.25 m (0.8 ft) west of an orange fiberglass NOS witness post. The datum point is the top of a stainless steel rod driven 11.9 m (39 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE
NOAA Chart: 12277 Latitude: 39° 33.5' N
USGS Quad: DELAWARE CITY Longitude: 75° 34.4' W

TIDAL DATUMS

Tidal datums at REEDY POINT, C&D CANAL 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 (10/25/1980) = 2.707
MEAN HIGHER HIGH WATER (MHHW) = 1.780
MEAN HIGH WATER (MHW) = 1.683
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.905
MEAN SEA LEVEL (MSL) = 0.890
MEAN TIDE LEVEL (MTL) = 0.869
MEAN LOW WATER (MLW) = 0.055
MEAN LOWER LOW WATER (MLLW) = 0.000
LOWEST OBSERVED WATERLEVEL (04/07/1982) = -1.222

Bench Mark Elevation Information

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<thead>
<tr>
<th>Stamping or Designation</th>
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<th>MHW</th>
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<td>1.620</td>
<td>-0.063</td>
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<tr>
<td>1910 B 1979</td>
<td>3.267</td>
<td>1.584</td>
</tr>
<tr>
<td>1910 C 1979</td>
<td>3.148</td>
<td>1.465</td>
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<td>1910 G 1982</td>
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<tr>
<td>RP 3 1975</td>
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<td>1910 K 1997</td>
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<td>0.852</td>
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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 National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, 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 National Geodetic Survey.

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.

http://www.co-ops.nos.noaa.gov/benchmarks/8551910.html

3/16/2004
<table>
<thead>
<tr>
<th>B.S. PT</th>
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<th>F.S. PT</th>
<th>F.S.</th>
<th>F.S. + B.S.</th>
<th>ELEV.</th>
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<td>1910 1</td>
<td>0.0126</td>
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<tr>
<td>R</td>
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<td>0.0126</td>
<td>R</td>
<td>0.0126</td>
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**PROJECT:** Rocky Point Bridge

**LINE TIE (2 MARK)**

**DISC:**

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<tbody>
<tr>
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**1910 C**

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<tr>
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<td>0.1233</td>
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**1910 B**

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<tr>
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**TARGET HEIGHT CORRECTION**

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<tbody>
<tr>
<td>Mn</td>
<td>0.0252</td>
<td>Mn</td>
<td>0.1233</td>
</tr>
</tbody>
</table>

**REMARKS**

- L-B = 0.12010
- 2-6-30, 2010
- L/B = 0.125
- TRIG OBS 0.0125
- 0.0021

- 0.0021
- 0.0021
- 0.0021

- 0.0021
**WATER LEVEL STATION SITE REPORT**

CO-OPS Form FODSR12-00f

<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>SITE ID NUMBER</th>
<th>DATES VISITED</th>
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<tbody>
<tr>
<td>Reedy Point, DE</td>
<td>85519101</td>
<td>6/11-12/03</td>
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<tr>
<th>Established</th>
<th>Inspected</th>
<th>x</th>
<th>Repaired</th>
<th>Removed</th>
<th>Team Leader</th>
<th>Other Team Members</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rick James</td>
<td>Oliver Jones</td>
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<table>
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<tr>
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<th>Longitude</th>
<th>Time Meridian</th>
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<tr>
<td>39 33 30 N</td>
<td>075 34 24 W</td>
<td>75 W</td>
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</table>

<table>
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<tr>
<th>Station Owner and Local Contact Information</th>
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<tbody>
<tr>
<td>FOD Approval (signature) Date</td>
</tr>
<tr>
<td>Facility</td>
</tr>
<tr>
<td>US Corps Of Engineers Pier</td>
</tr>
<tr>
<td>Owner Work Phone</td>
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<tr>
<td>410-885-5621</td>
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<td>Local Contact</td>
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<tr>
<td>Date Last Trained</td>
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<tr>
<td>N/A</td>
</tr>
</tbody>
</table>

Remarks: The station is located on the east end of the C&D canal just across the canal from Delaware city, DE. Well is on the Corps dock and the shelter is across the dirt road set on a concrete pad with chain link fence around it. THIS STATION IS PART OF THE DELAWARE PORTS

<table>
<thead>
<tr>
<th>Equipment Shelter</th>
<th>Shelter Type</th>
<th>Install Date</th>
<th>Lock Type</th>
<th>Power Supply</th>
<th>Shelter Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4'x6'x7' fiberglass building</td>
<td>06/01/94</td>
<td>combo</td>
<td>ac/solar</td>
<td>302-832-2869</td>
</tr>
</tbody>
</table>

Remarks: The shelter is a 4'x6'x7' white fiberglass building which is located across the road from the pier secured to pressure treated wood frame, elevated three feet above and anchor bolted to a 10'x10'16" concrete pad. The shelter is surrounded by a 6' chain link fence. The gate lock combo and the shelter lock combo are 1910. Phone line in house and NOS sign on door. Station also has AC power. Phone surpressor was installed this inspection

<table>
<thead>
<tr>
<th>Wells/ Sump Description</th>
<th>Well</th>
<th>Dia.</th>
<th>Length</th>
<th>Material</th>
<th>Intake Type</th>
<th>Install Date</th>
<th># Brackets</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>6&quot;</td>
<td>6.100 m</td>
<td>sch. 80 pvc</td>
<td>2&quot; brass</td>
<td>06/15/94</td>
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</tbody>
</table>

Top Hat Type: yes, Parallel Plate (y/n): yes, Winterized (y/n): no
Copper Insert (y/n): yes, Well Pumped (y/n): no, Heater Setting (F): n/a
Bracket/Valve Description

Remarks: The 6' aquatrak well is secured to a pier piling on the west side of the pier about 10' south of the T section. The well is secured with a s/s face clamp about five feet down from the top flange and two s/s long arm pile clamps about five feet apart below the face clamp. New T1 was run under pier and into house, 200 ft in length.

Permanent Station Inspection Notes (Pre-Visit Notification, Items stored in enclosure, etc.):

This is a Ports site and CORMS must be notified before work is performed. AC power only works at night

Work Requests for Next Annual O&M

Crew fixed well temp problem but the cause of the problem is the A/C power which runs through the same conduit as our cables. The wires for the A/C power are shorting out and melting our cables to the aquatrak well and need to be fixed ASAP or more problems will occur.
<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Power Sup</th>
<th>Satellio</th>
<th>CCM</th>
<th>GPU</th>
<th>RAM Exp</th>
<th>CPU</th>
<th>Modem</th>
<th>Aquatrak</th>
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</thead>
<tbody>
<tr>
<td>12v 40 ahf</td>
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<td>88040</td>
<td>910165</td>
<td>88063</td>
<td>910397</td>
<td>30069</td>
<td>30121</td>
</tr>
</tbody>
</table>

**Descendant (y/n):** yes  
**DSCP:** Term board was replaced, 9000 was hit by lightning through phone line.

**Serial (y/n):** yes  
**Attachment:**

**AC (y/n):** yes  
**Description:**

**Remarks:** 9000 unit is mounted to a 3/4" backing board which is secured to the back wall of the gagehouse. All board serial numbers were checked. New descendant was installed this inspection.

<table>
<thead>
<tr>
<th>Aquatrak Sensor</th>
<th>Install Date</th>
<th>Aq. Hl. s/n</th>
<th>CatTube s/n</th>
<th>Sens Offset</th>
<th>SmgTube L</th>
<th>Brass Tube</th>
<th>TT1/2 Sep</th>
<th># Balls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6/11/2003</td>
<td>1271-3510</td>
<td>1372</td>
<td>1.1068</td>
<td>6.0625</td>
<td>0.314</td>
<td>1.524</td>
<td>4</td>
</tr>
</tbody>
</table>

**Aquatark:** The Aquatrak 9200 is mounted to the backing board next to the 9000 unit. New guts were installed in the 9200 this inspection. Descendant was also changed.

**Remarks:** A California leveling plate was installed on wall. New head and cast tube installed (old style). Casting tube was cleaned and ping tested good. COE 1 was changed to 1.110 @ 0950 EDT on 6/11/03.

<table>
<thead>
<tr>
<th>Paros/ Digiquartz</th>
<th>Install Date</th>
<th>Model</th>
<th>Range</th>
<th>Vent</th>
<th>Flow</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:**

<table>
<thead>
<tr>
<th>Backup Sensor</th>
<th>Manufacture</th>
<th>Sensor s/n</th>
<th>Install Date</th>
<th>Ship Config</th>
<th>Manifold Type</th>
<th>Tank PSI</th>
<th>Feed PSI</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IMO</td>
<td>L401391</td>
<td>06/20/84</td>
<td>Dry Pierce</td>
<td></td>
<td>2125</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

**Remarks:** IMO pressure sensor is fed into the bubbler tubing inside the gage shelter. Sensor was checked for leaks, none found. Tank was not charged.

<table>
<thead>
<tr>
<th>GOES &amp; Antenna</th>
<th>GOES IDP</th>
<th>Channel</th>
<th>Xmit Time</th>
<th>Xmit Interval</th>
<th>Xmit Power</th>
<th>Antenna s/n</th>
<th>Azimuth</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23489745</td>
<td>117E</td>
<td>03:37-03</td>
<td>1 hour</td>
<td>1 hour</td>
<td>50021</td>
<td>215</td>
<td>41 degrees</td>
</tr>
</tbody>
</table>

**Remarks:** The GOES antenna is mounted on the gagehouse roof with standard alum. bracket and指责 hardware.
<table>
<thead>
<tr>
<th>Panels</th>
<th>Purpose</th>
<th>Panel s/n</th>
<th>Install Date</th>
<th>Angle</th>
<th>Watts</th>
<th>Cable L</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>9800 W</td>
<td>FV#4028/7/12</td>
<td>06/22/04</td>
<td>45</td>
<td>30</td>
<td>30'</td>
<td>Both panels are mounted on the tidehouse roof with standard aluminum brackets and set carriage head bolts.</td>
</tr>
<tr>
<td></td>
<td>8200 W</td>
<td>JP#32/50/000/00</td>
<td>06/22/04</td>
<td>45</td>
<td>15</td>
<td>20'</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS RADIO</td>
<td>5132</td>
<td>09/12/02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Ancillary Sensors

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Air Temp</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Water Temp</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>ysl</td>
<td>07/13/08</td>
<td>&quot;2.0400&quot;</td>
<td>Water temp, probe is attached to the sounding tube at the bottom with plastic wire ties.</td>
</tr>
</tbody>
</table>

### Wind

<table>
<thead>
<tr>
<th>MANUFACT.</th>
<th>Model</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Cable L</th>
<th>Height</th>
<th>Mast Type</th>
<th>Install Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21 ft</td>
<td>shakespeare</td>
<td>07/15/08</td>
</tr>
</tbody>
</table>

### Barometer

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Conductivity

<table>
<thead>
<tr>
<th>Initial Temp</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Coeff 3</th>
<th>Sensor Cleaned</th>
<th>Initial RDG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Loop</td>
<td>1 Loop 2</td>
<td>1 Loop 3</td>
<td>F Loop 1</td>
<td>F Loop 2</td>
<td>F Loop 3</td>
<td>Final RDG</td>
</tr>
</tbody>
</table>

### Visibility

<table>
<thead>
<tr>
<th>Visibility</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Cal. Data</th>
<th>Height</th>
<th>Remarks</th>
</tr>
</thead>
</table>

### Rain Gauge

<table>
<thead>
<tr>
<th>Rain Gauge</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
</tr>
</thead>
</table>

### Dissolved O2

<table>
<thead>
<tr>
<th>Dissolved O2</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
</tr>
</thead>
</table>

### Other

<table>
<thead>
<tr>
<th>Other</th>
<th>Serial #</th>
<th>Manuf.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
</tr>
</thead>
</table>

### Remarks

- A fiberglass pole 21' high was installed with aluminum base plate, anchor bolts into the concrete pad surrounding the pole. Pole has four 30 watt panels mounted with aluminum brackets and set carriage head bolts. Two radio antennas are mounted on the top of pole which has aluminum goalpost.

### Tests

<table>
<thead>
<tr>
<th>Tests</th>
<th>Temp Sensor Test</th>
<th>Backup Pressure Sensor Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td></td>
<td>TA</td>
<td>TB</td>
</tr>
<tr>
<td></td>
<td>TW</td>
<td>T1</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Sensor</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Sensor</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Sensor</td>
</tr>
<tr>
<td></td>
<td>Sensor</td>
<td>Time</td>
</tr>
</tbody>
</table>

### GOES Knell Test

<table>
<thead>
<tr>
<th>GOES Knell Test</th>
<th>DCP</th>
<th>WATM</th>
<th>REF</th>
<th>Loop 1</th>
<th>Loop 2</th>
</tr>
</thead>
</table>

**Note:** Significant differences are defined as more than 3 watts per 10 minutes of wind.
<table>
<thead>
<tr>
<th>Dive</th>
<th>Station Inspected (yn)</th>
<th>Not Diverse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report</td>
<td>Intake Cleared (yn) no</td>
<td>Marine Fouling Potential (H/ML) L</td>
</tr>
<tr>
<td>Remarks</td>
<td>No dive was made well was found to be clean.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shaft Angle Encoder</th>
<th>SAE s/n</th>
<th>Install Date</th>
<th>Fcltd Dia</th>
<th>Tape Length</th>
<th>Current Displ</th>
<th>Current ETG</th>
<th>ETG Display</th>
<th>Reset C2 (y/n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display = ETG = S14 Coef 2</td>
<td>0.000</td>
<td>Remarks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Transfer</th>
<th>Hydraulic</th>
<th>Corrector</th>
<th>Retained ZETG</th>
<th>Valve Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remarks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference Gauge Readings</th>
<th>ETG</th>
<th>Spike</th>
<th>Other</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HydCor Zero Readings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WLR Surface</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

| ETO Description | |
| Spike Description | |

<table>
<thead>
<tr>
<th>Levels/ Surveying</th>
<th>Date</th>
<th>Datum station</th>
<th>PBM Stamping</th>
<th>PBM Elev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Number</td>
<td>Rod 1 s/n</td>
<td>25338</td>
<td>C-Shot Coeff</td>
<td>2,310</td>
</tr>
<tr>
<td>Rod 2 s/n</td>
<td>25004</td>
<td>-3.9</td>
<td>Downshot Reg'd (y/n): no</td>
<td></td>
</tr>
<tr>
<td># of Marks Established: 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument Operator</td>
<td>Rodman 1</td>
<td>Oliver Jones</td>
<td>Rodman 2</td>
<td>Dave Hatcher</td>
</tr>
<tr>
<td># of Marks Recovered: 8</td>
<td># of Marks Connected: 8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| Aquatrak Coefficient Calculations | |</p>
<table>
<thead>
<tr>
<th>Ag Coeff 2A PBM above Silo Datum (HQ #11)</th>
<th>Ag Coeff 2B Leveling Pl above PBM from Levels</th>
<th>Aquatrak Coeff 2 (2A+2B+2)</th>
<th>Accepted Coeff 2</th>
<th>Difference (change if clipping of 0.000m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeff 2 Changed (y/n): no</td>
<td>New Value:</td>
<td>Date:</td>
<td>Time:</td>
<td></td>
</tr>
<tr>
<td>Ref Gauge or BM</td>
<td>Latest Inspection</td>
<td>Present Inspection</td>
<td>Change</td>
<td>Recovered (y/n)</td>
</tr>
<tr>
<td>ETG</td>
<td>5.14370</td>
<td>5.14705</td>
<td>-0.00335</td>
<td>Y</td>
</tr>
<tr>
<td>SPIKE</td>
<td>2.03100</td>
<td>2.03100</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>AQUATRAK</td>
<td>2.36350</td>
<td>2.36350</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>1910 C</td>
<td>3.55010</td>
<td>3.55997</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>1910 B</td>
<td>3.67859</td>
<td>3.67907</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>1910 G</td>
<td>2.83120</td>
<td>2.83120</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>RP5</td>
<td>2.73546</td>
<td>2.73546</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>1910 J</td>
<td>2.87817</td>
<td>2.87817</td>
<td>0.00000</td>
<td>Y</td>
</tr>
<tr>
<td>1910 K</td>
<td>2.94313</td>
<td>2.94313</td>
<td>0.00000</td>
<td>N</td>
</tr>
<tr>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GPS</th>
<th>Benchmark</th>
<th>GPS Elev</th>
<th>Level Elev</th>
<th>Difference</th>
<th>Benchmark</th>
<th>GPS Elev</th>
<th>Level Elev</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R 41 PBM</td>
<td>2.03100</td>
<td>2.03100</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RP 3</td>
<td>2.28642</td>
<td>2.28642</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1910 C</td>
<td>3.55997</td>
<td>3.55997</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1910 B</td>
<td>3.67907</td>
<td>3.67907</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1910 G</td>
<td>2.83120</td>
<td>2.83120</td>
<td>0.00000</td>
<td>Y</td>
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<tr>
<td>RP5</td>
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<td>2.73546</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1910 J</td>
<td>2.87817</td>
<td>2.87817</td>
<td>0.00000</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1910 K</td>
<td>2.94313</td>
<td>2.94313</td>
<td>0.00000</td>
<td>N</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Remarks | All benchmarks recovered were recovered in good condition, 1910 H and RP 72 W are destroyed. |

Miscellaneous Comments: (Station History, Motel Contacts, etc.)
Two of the solar panels on the fiberglass pole serial numbers 101059281642379 and 1010591568934 are for the current meter batteries and the other two panels, serial numbers 10106291842379 and 1010594768934 are for the LCS radio antenna batteries.
## Field Abstract

**Leveling to Tide Stations in Delaware**

<table>
<thead>
<tr>
<th>FROM</th>
<th>START</th>
<th>F/B</th>
<th>DIST (km)</th>
<th>ELEV DIFF (m)</th>
<th>-(F+B) (m)</th>
<th>MEAN DIFF (m)</th>
<th>FLD ELEV (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0211 R 41</td>
<td>6111445 F</td>
<td>0.24</td>
<td>0.25503</td>
<td>0.77</td>
<td>0.25542</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0215 855 1910 TIDAL R 6111627 B</td>
<td>0.24</td>
<td>-0.25580</td>
<td>0.77</td>
<td>2.28642</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0215 855 1910 TIDAL R 6111456 F</td>
<td>0.42</td>
<td>0.59728</td>
<td>-2.06</td>
<td>0.59175</td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>0217 855 1910 J 6111609 B</td>
<td>0.42</td>
<td>-0.59072</td>
<td>1.29</td>
<td>2.87817</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>0217 855 1910 J 6111515 F</td>
<td>0.16</td>
<td>-0.14265</td>
<td>-0.12</td>
<td>-0.14271</td>
<td>1</td>
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<tr>
<td>0218 855 1910 R 6111602 B</td>
<td>0.16</td>
<td>0.14277</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0218 855 1910 TIDAL R 6111522 F</td>
<td>0.62</td>
<td>0.20806</td>
<td>-0.78</td>
<td>0.20767</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0219 855 1910 K 6111544 B</td>
<td>0.62</td>
<td>-0.20728</td>
<td>2.19</td>
<td>2.94313</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0211 R 41</td>
<td>6111442 B</td>
<td>0.48</td>
<td>-1.52681</td>
<td>-2.32</td>
<td>1.52797</td>
<td>1</td>
<td></td>
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<tr>
<td>0214 855 1910 C TIDAL 6111637 F</td>
<td>0.51</td>
<td>1.52913</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>0214 855 1910 C TIDAL 6111407 B</td>
<td>0.31</td>
<td>-0.11958</td>
<td>-1.03</td>
<td>0.12010</td>
<td>1</td>
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</tr>
<tr>
<td>0213 855 1910 B TIDAL 6111657 F</td>
<td>0.31</td>
<td>0.12061</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0213 855 1910 B TIDAL 6111358 B</td>
<td>0.14</td>
<td>0.87792</td>
<td>-0.12</td>
<td>0.87786</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>0212 855 1910 G 6111711 F</td>
<td>0.13</td>
<td>-0.87780</td>
<td>3.47</td>
<td>2.80221</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0212 855 1910 G 6111346 B</td>
<td>0.04</td>
<td>-2.34560</td>
<td>-0.48</td>
<td>2.34584</td>
<td>1</td>
<td></td>
<td></td>
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### Elevation Rejection and Error Codes

- C - section elevation difference was rejected for cause
  - R - section elevation difference was rejected by Halperin rejection algorithm
  - @ - section elevation difference does not include refraction correction
  - * - section elevation difference does not include rod correction

### Instrument Code

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### Level Line Section Running Tree

0211 (0215) 0217 0218
SSN: 0211
Designation: R 41
PID: JU2187
Approx. Latitude: 393326N
State: DE
Approx. Longitude: 0753455W
County: NEW CASTLE
Approx. Elevation: 0.714M
Disk From: NATIONAL GEODETIC SU
Stamping: R 41 1979

Surface Mark
Type: Bench Mark disk
Magnetic code: N
Setting: BRIDGE PIER FOUNDATION
Rod depth:
Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

4.7 KM (2.90 MI)SE FROM DELAWARE CITY, ALONG THE SOUTH BANK OF THE
CHESAPEAKE AND DELAWARE CANAL AT THE STATE ROUTE 9 BRIDGE, THE
PRIMARY BENCH MARK IS SET IN THE CONCRETE FOUNDATION OF THE MOST
EASTERLY OF THE TWO CONCRETE PIERS OF THE FIRST ROW OF BRIDGE PIERS
SOUTH OF THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, 16.70
M (54.79 FT) EAST OF A GRAVEL SERVICE ROAD THAT PARALLELS THE
BRIDGE, 0.3 M (1.0 FT) SOUTH OF THE NORTH FACE OF THE PIER,
AND 0.02 M (0.07 FT) WEST OF THE WEST EDGE OF THE PIER.
***** RECOVERY DESCRIPTION*****

SSN: 0212
Designation: 855 1910 G

Approx. Latitude: 393328N
State: DE

Approx. Longitude: 0753416W
County: NEW CASTLE

Approx. Elevation: Disk From: NATIONAL OCEAN SURVEY
Stamping: 1910 G 1982

Surface Mark
Type: Tidal Station disk
Magnetic code: N
Setting: STAINLESS STEEL ROD
Rod depth: 8.8

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS SET ON THE SOUTH SIDE OF THE DIRT ROAD ALONG THE CANAL BANK, ON THE EXTENDED CENTERLINE OF THE WOOD PIER LOCATED ON THE BANK, 26.06 M (85.50 FT) SW OF A UTILITY POLE WITH LIGHT ON THE EAST SIDE OF THE PIER, 15.24 M (50.00 FT) SOUTH OF THE SW END OF THE PIER, AND 7.01 M (23.00 FT) SOUTH OF THE CENTERLINE OF THE DIRT ROAD. THE BENCH MARK IS 0.3 M (1.0 FT) BELOW GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 8.8 M (28.9 FT) TO REFUSAL, AND ENCASED IN A 6 INCH PVC PIPE WITH CONCRETE KICKBLOCK.
******* RECOVERY DESCRIPTION*******

SSN: 0213
Designation: 855 1910 B TIDAL
PID: JU2189
Approx. Latitude: 393327N
State: DE
Approx. Longitude: 0753423W
County: NEW CASTLE
Approx. Elevation: 2.366M
Disk From: NATIONAL OCEAN SURVEY
Stamping: 1910 B 1979

Surface Mark

Type:TidalStation
disk Magnetic code:N
Setting: STAINLESS STEEL ROD

Rod depth: 9.
Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED WEST OF THE PIER ON THE SOUTH SIDE OF THE DIRT ROAD ALONG THE CANAL BANK, 129 M (423.2 FT) WSW OF THE SW CORNER (OF THE PIER, 12.07 M (39.60 FT) SOUTH OF UTILITY POLE NUMBER 75 WITH LIGHT, 6.40 M (21.00 FT) SOUTH OF THE CENTER OF THE DIRT ROAD. THE BENCH MARK IS 0.15 M (0.49 FT) ABOVE GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 9.8 M (32.2 FT) TO REFUSAL, AND ENCASED IN A 5 INCH PVC PIPE WITH ALUMINUM ACCESS COVER AND CONCRETE KICKBLOCK.
****** RECOVERY ********  ******** DESCRIPTION *******

SSN: 0214
Designation: 855 1910 C TIDAL
PID: JU2188
Approx. Latitude: 393325N State: DE
Approx. Longitude: 0753434W County: NEW CASTLE Approx.
Elevation: 2.244M Disk From: NATIONAL OCEAN SURVEY
Stamping: 1910 C 1979

Surface Mark
Type: Tidal Station disk
Magnetic code: N
Setting: STAINLESS STEEL ROD
Rod depth: 9.1

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE
CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE SOUTH SIDE
OF THE DIRT ROAD ALONG THE CANAL BANK, 0.3 KM (0.20 MI) WEST OF THE PIER,
13.72 M (45.01 FT) SOUTH OF UTILITY POLE NUMBER 85 WITH LIGHT, 6.71 M
(22.01 FT) SOUTH OF THE CENTERLINE OF THE DIRT ROAD, AND 0.61 M (2.00 FT)
NORTH OF A NOS WITNESS POST. THE BENCH MARK IS 0.15 M (0.49 FT) ABOVE
GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 9.1 M (29.9 FT) TO
REFUSAL, AND ENCASED IN A 5 INCH PVC PIPE WITH ALUMINUM ACCESS COVER AND
CONCRETE KICKBLOCK.
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Surface Mark
Type: Tidal Station disk
Setting: CULVERT HEADWALL
Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS SET IN A CONCRETE CULVERT HEADWALL ALONG THE EAST SIDE OF SOUTH REEDY POINT ROAD, 147 M (482.3 FT) SOUTH OF THE CANAL, 11 M (164.40 FT) WEST OF BRIDGE PIER R38W, AND 5.49 M (18.01 FT) EAST OF THE CENTERLINE OF THE ROAD.
SSN: 0216
Designation: 855 1910 H
State: DU
Approx. Latitude: 393323N
County: NEW CASTLE
Approx. Longitude: 0753458W
Disk From: NATIONAL OCEAN SURVEY
Approx. Elevation: 1
Stamping: 1910 H 1997

Surface Mark
Type: Flange-encased Rod
Magnetic code: N
Setting: STAINLESS STEEL ROD IN SLEEVE
Rod depth: 17.4 Sleeve Depth: 1

Mark condition reported in descriptive text by - NOS on 06112003, chief of party

THIS MARK WAS NOT RECOVERED AND IS BELIEVED DESTROYED

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE EAST SIDE OF SOUTH REEDY POINT ROAD, 65.2 M (213.9 FT) SOUTH OF THE STOP SIGN ON THE EAST SIDE OF THE ROAD, 4.50 M (14.76 FT) EAST OF THE ROAD CENTERLINE, AND 0.35 M (1.15 FT) WEST A NOS FIBERGLASS WITNESS POST. THE DATUM POINT IS THE TOP OF A STAINLESS STEEL ROD DRIVEN 17.4 M (57.1 FT) TO REFUSAL, IN A GREASE FILLED SLEEVE EXTENDING TO A DEPTH OF 1 M (3.3 FT) , AND ENCASED IN A 5-INCH LOGO CAP.
SSN: 217  
Designation: 855 1910 J  
PID:  
State: DE  
County: NEW CASTLE  
Disk From: NATIONAL OCEAN SERVICE  

39330N  
Approx. Latitude: 0753424W  
Approx. Longitude: 1910 J 1997  
Approx. Elevation:  
Stamping:  

Surface Mark Flange-encased Rod  
Type:  
Magnetic code: N  

Setting: STAINLESS STEEL ROD IN SLEEVE  
Rod depth: 18.0  
Sleeve Depth: 1  

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.  

RAD 6/11/03  

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE WEST SIDE OF SOUTH REEDY POINT ROAD, 49.25 M (161.58 FT) NORTH OF POWER POLE NUMBER 29, 33.60 M (110.24 FT) SOUTH OF THE SOUTH SIDE OF THE DRIVEWAY FOR THE RESIDENCE AT 270 THE REEDY POINT DRIVE, 8.20 M (26.90 FT) WEST OF THE CENTERLINE OF SOUTH REEDY POINT ROAD, AND 6.25 M (20.51 FT) SSE OF POWER POLE NUMBER 30. THE DATUM POINT IS THE TOP OF A STAINLESS STEEL ROD DRIVEN 18.0 M (59.1 FT) TO REFUSAL, IN A GREASE FILLED SLEEVE EXTENDING TO A DEPTH OF 1 M (3.3 FT), AND ENCASED IN A 5-INCH LOGO CAP.
SSN: 0218
Designation: 855 1910 TIDAL RP 5
PID: JU2185

Approx. Latitude: 393304N
Approx. Longitude: 0753449W
Approx. Elevation: 

State: DE
County: NEW CASTLE

Disk From: NATIONAL OCEAN SURVEY

Stamping: RP 5 1975

Surface Mark
Type: Tidal Station disk Magnetic code: N
Setting: CONCRETE CULVERT HEADWALL
Rod depth: Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE ANDDELWARE CANAL, THE BENCH MARK IS SET IN A CONCRETE CULVERT HEADWALL ALONG THE WEST SIDE OF SOUTH REEDY POINT ROAD, 23.01 M (75.49 FT) NW OF BRIDGE PIER R53W, 20.42 M (66.99 FT) SW OF BRIDGE PIER R52W, 6.80 M (22.31 FT) SE OF UTILITY POLE NUMBER DP+L 27, AND 6.71 M (22.01 FT) WEST OF THE ROAD CENTERLINE.
## TRIG. LEVELING-ONE OR TWO RODS

**Proj. I.D.** CHESAPEAK CITY BRIDGE - MIROS

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**Remarks**

2 marks toe

39°C

POM-105

Start - 1021 mb @0950

*vs. elev. at. from leveling*
## TRIG. LEVELING—ONE OR TWO RODS

**Proj. I.D.** Chesapeake City Bridge  Miroș 3-18-04

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**STOP: 12:25**

**DISTANCE A → TIDAL 3 = 185.6055**

**A → Miroș = 385.2348**

**REMARKS**

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*65*
## Trig. Leveling - One or Two Rods

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<tr>
<td>Mn</td>
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</tr>
</tbody>
</table>

**Remarks:**
- MROS Diff in Bracket / Label
- 317
- MROS BRACKET MECH 42.828 - 44.732
- NAV L 13.4808
- 0.0310 (44.7022 + 0.0310) - 44.7332

---

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WATER LEVEL STATION SITE REPORT

CO-OPS Form FODSR12-00f

<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>SITE ID NUMBER</th>
<th>DATES VISITED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chesapeake City, MD</td>
<td>857-3927</td>
<td>08/20-23/03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Established</th>
<th>X</th>
<th>Inspected</th>
<th>Repaired</th>
<th>Removed</th>
<th>Team Leader</th>
<th>Other Team Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>N 39 31 39</td>
<td>Longitude</td>
<td>W 075 48 35</td>
<td>Time Meridian</td>
<td>75 W</td>
<td>Metzger</td>
</tr>
</tbody>
</table>

Station Owner and Local Contact Information

<table>
<thead>
<tr>
<th>Facility</th>
<th>FOD Approval (signature)</th>
<th>Date</th>
<th>CO-OPS Review Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.O.E. Chesapeake City</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Owner Work Phone: (410) 885-5621
Owner Home Phone:Owner E-Mail:
City: Chesapeake City
State: MD
Zip: 21915

Local Contact:
Mr. Doug Patterson
Local Contact Home Phone:
Local Contact Work Phone:
E-Mail:
Date Last Trained:

Remarks: The tide station is located at the west end of the Coors of Engineers Base Chesapeake City. Field crew should call base before going to site to perform any work.

<table>
<thead>
<tr>
<th>Equipment Shelter</th>
<th>Shelter Type</th>
<th>Install Date</th>
<th>Lock Type</th>
<th>Power Supply</th>
<th>Shelter Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6'x6'x7' Fiberglass Enclosure</td>
<td>08/20/03</td>
<td>Combo 1807</td>
<td>AC**/Solar</td>
<td>(410) 885-5174</td>
</tr>
</tbody>
</table>

Remarks: ** AC Power is on only at night, AC is tied in the light system for the base and is operated by a photo-cel.

The 6'x6' fiberglass enclosure is secured to a 6'x6'x2' aluminum frame that is secured to a 10'x7'x9' concrete foundation with 4 5'x3/4' S/S wedge anchors. The enclosure is located at the west end of the COE base, at the end of the main road on the base.

<table>
<thead>
<tr>
<th>Wells/ Sump Description</th>
<th>Well</th>
<th>Dia.</th>
<th>Length</th>
<th>Material</th>
<th>Intake Type</th>
<th>Install Date</th>
<th># Brackets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aquatrak</td>
<td>4&quot;</td>
<td>5.33 M</td>
<td>Sch 80 PVC (W)</td>
<td>Double Cone</td>
<td>08/21/03</td>
<td>5</td>
</tr>
</tbody>
</table>

Top Hat Type: Standard
Parallel Plate (yn): Yes
Winterized (yn): Winterized

Copper Insert (yn): Yes
Well Pumped (yn): Heater Setting (F):

Brckt/Valve Description: Two 4" S/S face Clamps / Three 4" Long Arm Pile Clamps (LAPC).

Remarks: The Protective well is secured to a 12" wooden pile with 5 S/S clamps (2 face clamps & LAPC), the protective well is located at the west end of the COE base and near the NW corner of the Sheet-pile bulkhead. All hardware is 1/2" S/S steel.

Permanent Station Inspection Notes

(Pre-Visit Notification, Items stored in Enclosure, etc.)

The AC power is supplied to the enclosure only at night, AC power operates on a photo-cel. The phoneline D-mark point is located in the basement of the Administration building (Main office) at the east end of the base. The phoneline runs from the D-mark under ground to a panel in a small red shed near the COE pier on the north side of the harbor. Phoneline then runs under ground to a one story cinderblock building (the carpenter shop) to another panel in the center bay of the carpenter shop. From the panel in the carpenter shop the phoneline runs through the rafters to a 11/2" conduit under the road to the gauge enclosure.

Work Requests for Next Annual O&M

Seven Bench marks were recovered during the installation, five surface marks and two deep rod marks. One more deep rod (3-D) should be established.

8573927_08_23_03.xls
Page 1 of 4
- 67 -
<table>
<thead>
<tr>
<th>Sutron 9000 -Vitel DCP</th>
<th>Type of DCP</th>
<th>DCP s/n</th>
<th>Install Date</th>
<th>OpSysVers</th>
<th>SDL Vers.</th>
<th>Battery Date</th>
<th>DCP Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutron 9000</td>
<td>91026</td>
<td>08/21/02</td>
<td>2.5 F</td>
<td>KS 1.00x</td>
<td>08/21/03</td>
<td>(410) 885-5174</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Power Sup</th>
<th>Satellite</th>
<th>CCM</th>
<th>GPIO</th>
<th>Mem Exp</th>
<th>CPU</th>
<th>Modem</th>
<th>Aquatrak</th>
</tr>
</thead>
<tbody>
<tr>
<td>12v 38 Amp</td>
<td>951264</td>
<td>99059</td>
<td>999786</td>
<td>89007</td>
<td>88019</td>
<td>91081</td>
<td>90637</td>
<td>90105</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Backplane Type</th>
<th>Transition</th>
<th>Termination</th>
<th>AC/Step</th>
<th>VITEL DCP s/n</th>
<th>CPU</th>
<th>Mod Voice</th>
<th>Data Card</th>
</tr>
</thead>
<tbody>
<tr>
<td>88018</td>
<td>979526</td>
<td>88061</td>
<td>90045</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks**
- The Sutron 9000 is mounted to the west wall of the enclosure on a 3/4" plywood backing board using 3/8" S/S hardware.

---

**Sutron 8200/8210**

<table>
<thead>
<tr>
<th>Sutron 8200/8210</th>
<th>DCP s/n</th>
<th>Install Date</th>
<th>Prog Vers.</th>
<th>Pwr Source</th>
<th>Tiny Basic Version</th>
<th>Battery Type</th>
<th>Battery Date</th>
<th>Amp Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>8200/8210</td>
<td>89020</td>
<td>08/21/03</td>
<td>2.1</td>
<td>Solar / DC</td>
<td></td>
<td>12v 24 Amp</td>
<td>08/21/03</td>
<td>46.57</td>
</tr>
</tbody>
</table>

**Remarks**
- The Sutron 8200 is secured to the west wall of the enclosure on the a 3/4" plywood backing board using 3/8" S/S steel hardware.

---

**Aquatrak Sensor**

<table>
<thead>
<tr>
<th>Install Date</th>
<th>Aqu. Hd. s/n</th>
<th>CalTube s/n</th>
<th>Sens Offset</th>
<th>Sndg Tube L</th>
<th>Brass Tube</th>
<th>T1/T2 Sep</th>
<th># Baits</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/22/2003</td>
<td>979-3256</td>
<td>448</td>
<td>1.1183</td>
<td>5.365</td>
<td>0.91 m</td>
<td>1.52 M</td>
<td>4</td>
</tr>
</tbody>
</table>

**Aquatrak changed**
- Display: + Coeff 1 = Sum - S Tube L = Difference* - Allowable Tolerance is +/- 0.06 M or 0.2 ft
- 4.227 1.118 5.345 5.365 -0.020 1.118

**Remarks**
- The Aquatrak and sounding tube are configured to meet the standards set by NOS for the Sutron 9000.
- COE#1 was entered 1.118 @ 1500 EDST on 08/22/2003.

---

**Paros/ Digiquartz**

<table>
<thead>
<tr>
<th>N1 s/n</th>
<th>Install Date</th>
<th>Model</th>
<th>Range</th>
<th>Vent</th>
<th>Flow</th>
<th>Feed</th>
</tr>
</thead>
</table>

**Orifice Delta**

<table>
<thead>
<tr>
<th>T1 s/n</th>
<th>Install Date</th>
<th>Model</th>
<th>Range</th>
<th>Vent</th>
<th>Flow</th>
<th>Feed</th>
</tr>
</thead>
</table>

**Remarks**
- NOTE: T1 is the primary lower orifice.
- T1 is secondary upper orifice.

---

**Backup Sensor**

<table>
<thead>
<tr>
<th>Manufacture</th>
<th>Sensor s/n</th>
<th>Install Date</th>
<th>Snsr Config</th>
<th>Manifold Typ</th>
<th>Tank PSI</th>
<th>Feed PSI</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPSI</td>
<td>O200943</td>
<td>08/21/03</td>
<td>Bubbler</td>
<td>Dry Purge</td>
<td>2350</td>
<td>14</td>
<td>32 CCM</td>
</tr>
</tbody>
</table>

**Remarks**
- The KPSI Redundant Water level sensor is secured to the plywood backing board between the Sutron 9000 and the Dry Purge system. The Barsdale High Pressure sensor is mounted to the N2 tank regulator in the SE corner of the enclosure.

---

**GOES & Antenna**

<table>
<thead>
<tr>
<th>GOES ID#</th>
<th>Channel</th>
<th>Xmit Time</th>
<th>Xmit Interval</th>
<th>Xmit Power</th>
<th>Antenna s/n</th>
<th>Azimuth</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>334D4708</td>
<td>113</td>
<td>0.28:33</td>
<td>1 Hr</td>
<td>169326</td>
<td>169326</td>
<td>45 Deg.</td>
<td>45 Deg.</td>
</tr>
</tbody>
</table>

**Remarks**
- The GOES antenna is mounted to the top of a 20' Fiberglass tower, the antenna is secured with a S/S bracket and 5" U-bolt.
<table>
<thead>
<tr>
<th>Solar Panels</th>
<th>Purpose</th>
<th>Panel s/n</th>
<th>Install Date</th>
<th>Angle</th>
<th>Watts</th>
<th>Cable L</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutron 9000</td>
<td>Fi9909751512745</td>
<td>08/21/03</td>
<td>45</td>
<td>30</td>
<td>15 M</td>
<td>Both Sutron 9000 &amp; 8200 solar panels are mounted to the Fiberglass tower with brackets supplied by manufacturer.</td>
<td></td>
</tr>
<tr>
<td>Sutron 8200</td>
<td>FE95G12621539</td>
<td>08/21/03</td>
<td>45</td>
<td>30</td>
<td>15 M</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Ancillary Sensors</th>
<th>Air Temp</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Water Temp</th>
<th>YSI</th>
<th>Install Date</th>
<th>Coeff 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind</th>
<th>Manu/Model</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Cable Leng.</th>
<th>Height</th>
<th>Mast Type</th>
<th>Fiberglass</th>
<th>Install Date</th>
<th>08/20/03</th>
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</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
<th>Barometer</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>PBM/ISD</th>
<th>Baro/PBM</th>
<th>MSL/ISD</th>
<th>Baro/MSL</th>
<th>Elev Corr.</th>
<th>Cal Corr.</th>
<th>Total Corr.</th>
<th>Coeff #</th>
<th>Calibration</th>
<th>Time</th>
<th>Baro</th>
<th>Portable</th>
<th>Difference</th>
<th>0.000</th>
<th>0.000</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Fiberglass tower is mounted to an aluminum hinged plate, the plate is secured to the concrete foundation with four 3&quot;x1/2&quot; S/S wedge anchor bolts.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conductivity</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Coeff 3</th>
<th>Sensor Cleaned (y/n)</th>
<th>Initial Rdg.</th>
<th>Initial Temp</th>
</tr>
</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
<th>Visibility</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Cal. Date</th>
<th>Height</th>
<th>Remarks</th>
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</table>

<table>
<thead>
<tr>
<th>Rain Guage</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
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</table>

<table>
<thead>
<tr>
<th>Dissolved O₂</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Other</th>
<th>Serial #</th>
<th>Manufact.</th>
<th>Install Date</th>
<th>Coeff 1</th>
<th>Coeff 2</th>
<th>Remarks</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Tests</th>
<th>Temp Sensor Test</th>
<th>Backup Pressure Sensor Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>T 1</td>
<td>T 2</td>
</tr>
<tr>
<td>GOES Xmit Test</td>
<td>DCP</td>
<td>Wattmeter</td>
</tr>
</tbody>
</table>

Note: If power at antenna is less than 7 watts, or there is significant line loss, contact HQ. Significant line loss is defined as more than 3 watts per 10 meters of line.
### Shaft Angle Encoder

<table>
<thead>
<tr>
<th>SAE s/n</th>
<th>Install Date</th>
<th>Float Die</th>
<th>Tape Length</th>
<th>Current Disp</th>
<th>Current ETG</th>
<th>ETG-Display Reset</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

#### Initial Encoder Setup

<table>
<thead>
<tr>
<th>Display</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

#### Water Transfer

<table>
<thead>
<tr>
<th>Hydraulic Corrector</th>
<th>Retained ZETG</th>
<th>Valve Elev</th>
<th>Reference Gauge Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

#### ETG Description

<table>
<thead>
<tr>
<th>Level surveying</th>
<th>Datum</th>
<th>PBM Stamping</th>
<th>PBM Elev</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

#### Aquatrack Coefficient Calculations

<table>
<thead>
<tr>
<th>Coeff 2 Changed (y/n)</th>
<th>New Value</th>
<th>Date:</th>
<th>Time:</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>1430 GMT</td>
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</tbody>
</table>

#### Coeff 2 Changed (y/n) NO New Value: 4.312

<table>
<thead>
<tr>
<th>Ref Gauge or BM</th>
<th>Latest Inspection</th>
<th>Present Inspection</th>
<th>Change</th>
<th>Recovered (y/n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETC</td>
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<td>SPIKE</td>
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<tr>
<td>AQUATRACK</td>
<td>4.3186</td>
<td>-4.3186</td>
<td>Established</td>
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</tr>
<tr>
<td>Tidal No. 1</td>
<td>3.2448</td>
<td>-3.2448</td>
<td>Recovered</td>
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<tr>
<td>Tidal No. 3</td>
<td>3.3653</td>
<td>-3.3653</td>
<td>Recovered</td>
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<tr>
<td>Tidal No. 2</td>
<td>4.3480</td>
<td>-4.3480</td>
<td>Recovered</td>
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<td>Tidal No. 4</td>
<td>5.2499</td>
<td>-5.2499</td>
<td>Recovered</td>
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<tr>
<td>3327 B</td>
<td>2.1538</td>
<td>-2.1538</td>
<td>Recovered</td>
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</table>

#### GPS

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>GPS Elev</th>
<th>Level Elev</th>
<th>Difference</th>
<th>Benchmark</th>
<th>GPS Elev</th>
<th>Level Elev</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>0.0000</td>
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#### Remarks

- Miscellaneous Comments: (Station History, Motel Contacts, etc.)
ABSTRACT Version 5.21 -- October 1991 Tue Sep 02 09:58:51 2003

--- FIELD ABSTRACT ---

030823-030823
HGZ L26422 7 6.0 MM ORDER 2 CLASS 1
2003 LEVELING TO TIDE STATIONS IN MARYLAND
857 3927 CHESAPEAKE CITY

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ELEVATION REJECTION AND ERROR CODES

C - section elevation difference was rejected for cause
ie. *43* record rejection code set to "F"
R - section elevation difference was rejected by Halperin rejection algorithm
@ - section elevation difference does not include refraction correction
* - section elevation difference does not include rod correction

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LEVEL LINE SECTION RUNNING TREE

0711 (0716)
0713 (0714)
0712
0708

Page 1
***** RECOVERY DESCRIPTION *****

SSN: 0711
Designation: U 2
PID: JU1833

Approx. Latitude: 39°31'38"N
Approx. Longitude: 75°49'25"W
Approx. Elevation:

Stamping: U 2 1931 6.834

State: MD
County: CECIL
Disk From: NGS

Surface Mark:
Type: Bench Mark disk
Magnetic Code: n
Setting: SET INTO THE TOP OF A CONCRETE MONUMENT
Rod depth: 
Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 06202003, chief of party JRS.

FROM CHESAPEAKE CITY, ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.19 MI) NORTH EAST ALONG A PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK IS SET FLUSH IN A 0.24 METER (0.79 FT) SQUARE CONCRETE MONUMENT SOUTH OF THE COR ANDISTRATION BUILDING, 14.57 METERS (47.80 FT) SOUTH OF THE WEST WALL FOR THE STEPS LEADING TO THE BASEMENT OF THE ADMINISTRATION BUILDING, 10.27 METERS (33.52 FT) NORTH OF THE CENTRELINE OF MAIN ROAD, 8.56 METERS (28.08 FT) WEST OF THE WEST EDGE OF THE SIDEWALK LEADING TO THE ADMINISTRATION BUILDING, AND 0.15 ABOVE THE GROUND.
******* RECOVERY DESCRIPTION *******

SSN: 0712
Designation: TIDAL 1 STA 62
PID: JU1835
Approx. Latitude: 393139N
Approx. Longitude: 0754834W
Approx. Elevation: Stamping: NO 1 1938

Surface Mark- State: MD
Type: Tidal Station disk
Magnetic Code: N
Setting: SIDEWALK
Rod Depth: Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.S.CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK IS SET FLUSH IN CONCRETE WALKWAY AT THE NW CORNER OF A SINGLE STORY WHITE BRICK BUILDING (BRIDGE REPAIR SHOP) NEAR THE WEST END OF THE COE PROPERTY 20.48 METERS (67.19 FT) SOUTH OF THE CENTERLINE OF MAIN ROAD, 0.52 METERS (1.71 FT) NORTH OF THE NORTH WALL OF THE BRICK BUILDING, AND 0.46 METERS (1.51 FT) EAST OF THE WEST WALL OF THE BRICK BUILDING.
*****RECOVERY DESCRIPTION*****

SSN: 0713
Designation: 857 3927 TIDAL 3
PID: 
Approx. Latitude: 393138N
Approx. Longitude: 0754828W
Approx. Elevation: NO. 3 1972
Stamping: State: MD
County: CECIL
Disk From: NOS

Surface Mark-
Type: Tidal Station disk
Magnetic code: N
Setting: CONCRETE FOUNDATION
Rod depth: 
Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

FROM CHESAPEAKE CITY, ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK IS SET FLUSH IN NW CONCRETE PUMP WELL LOCATED SW OF THE COE ADMINISTRATION BUILDING, 5.94 METERS (19.49 FT) NORTH OF THE NW CORNER OF A VENTILATOR SHAFT, 4.63 METERS (15.19 FT) SOUTH OF THE CENTERLINE OF THE MAIN ROAD, AND 4.45 SW OF THE SOUTHERNMOST OF TWO STEEL GATE POSTS FOR A ROAD GATE.
*****RECOVERY DESCRIPTION*****

SSN: 6714
Designation: 857 392? TIDAL 2

State: MD
County: CECIL

Disk From: USCGS

Stamping: NO. 2 1938

Surface Mark:
Type: Tidal Station Disk

Magnetic code: N

Setting: STONE RETAINING WALL

Rod depth:

Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222603, chief of party JRS.

FROM CHESAPEAKE CITY, ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 236 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.S.CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK IS SET PLUSH IN THE TOP OF A STONE RETAINING WHICH IS AROUND THE BETHEL BRIDGE LIGHTHOUSE, 73.71 METERS (241.83 FT) WEST OF THE WEST FACE OF THE US CO ADMINISTRATION BUILDING, 16.32 METERS (53.54 FT) NORTH OF THE CENTERLINE OF THE ROAD ON BASS, 9.0 METERS (29.5 FT) SOUTH OF THE RIP-RAP BULKHEAD OF THE CHESAPEAKE / DELAWARE CANAL, 3.19 METERS (10.17 FT) EAST OF THE WEST END OF THE STONE RETAINING WALL AROUND THE BETHEL BRIDGE.
****** RECOVERY DESCRIPTION ******

SSN: 0715
Designation: 357 3927 TIDAL 4
PID:
Approx. Latitude: 39°31'35"N
State: MD
Approx. Longitude: 75°48'26"W
County: CECIL
Approx. Elevation:
Disk From: NOS

Stamping: NO. 1 1972

Surface Mark-
Type: Tidal Station disk
Magnetic code: N
Setting: ANTENNA TOWER FOUNDATION
Rod depth:
Sleeve Depth:

****Mark is not suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY
THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEKE
DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTH
A PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDING
BENCH
SET FLUSH IN THE CONCRETE FOUNDATION OF THE WESTERNMOST LEG OF
LEGS OF A 49.0 METER (160.8 FT) HIGH STEEL RADIO ANTENNA 40.57
10 FT) NORTH OF THE CENTERLINE OF THE MAIN ROAD, 16.73 METERS (54
1E OF THE OUTSIDE NW CORNER OF THE REINFORCED BULKHEAD ON THE SOUT
IE NW CORNER OF THE OBSERVATION ADDITION TO THE TWO STORY COE
ISTRATION BUILDING.
RECOVERY DESCRIPTION

SSN: 0716
Designation: 857 3927 B

Approx. Latitude: 393135N
Approx. Longitude: 6754825W
Approx. Elevation: 3927 B 1982

State: MD
County: CECIL
Disk From: NOS

Surface Mark:
Type: Tidal Station disk

Magnetic code: N
Setting: GALVANIZED STEEL ROD
Rod depth: 7.0

Sleeve Depth:

***Mark is suitable for GPS

Recovered in Good condition by - NOS on 082226003, chief of party JRS.

FROM CHESAPEAKE CITY, ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 266 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.S.CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK IS LOCATED SE OF THE COE ADMINISTRATION, 34.59 METERS (113.48 FT) SW OF THE CENTERLINE OF THE MAIN ROAD, 10.58 METERS (34.71 FT) NNE OF THE CENTER OF THE SOUTHERNMOST SECTION OF A DOCK ON THE NORTH SHORE OF THE HARBOR, 4.48 METERS (14.70 FT) SE OF THE CONCRETE WALKWAY LEADING TO THE DOCK, AND 0.61 METERS (2.00 FT) EAST OF THE EASTERNMOST POLE SUPPORTING THE ELECTRICAL BOXES.
***** RECOVERY DESCRIPTION *****

SSN: 0717                  State: MD
Designation: 857 3927 C    County: CECIL
PID: 393135N               Disk From: NOS disk
Approx. Latitude: 0754824W
Approx. Longitude: 3927 C 1982
Approx. Elevation: Tidal Station
Stamping:

Surface MarkType:          Magnetic code:
Setting: N                 Rod depth: GALVANIZED 5.0 STEEL ROD

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

CHESAPEAKE CITY ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK NEAR THE END OF COE FACILITY JUST EAST OF THE MAIN GATE, 18.78 METERS (61.61 FT) SW OF THE CENTERLINE OF THE MAIN ROAD LEADING TO THE COE FACILITY, 14.48 METERS (47.51 FT) SE OF THE EASTERNMOST PICNIC TABLE, 8.99 METERS (29.49 FT) NW OF THE CENTERLINE OF STATE HIGHWAY 286, AND 0.61 METERS (2.00 FT) NW OF A UTILITY POLE NUMBER 17318. ENCASED IN IN A 4 INCH PVC PIPE WITH CAP.
The NGS Data Sheet

Data file .data.txt for more information about the dataset.

- 80 -
JU1833

STATION DESCRIPTION

JU1833

JU1833'DESCRIBED BY NATIONAL GEODETIC SURVEY 1971

JU1833'0.9 MI E FROM CHESAPEAKE CITY.


*** retrieval complete.

Elapsed Time = 00:00:01
To reach the tidal bench marks from the south end of the State Highway 213 bridge over the Chesapeake and Delaware (C & D) Canal at Chesapeake City, proceed south on State Highway 213 for 0.89 km (0.55 mi) and take the South Chesapeake City exit, continue 0.3 km (0.2 mi) NNE (towards canal) from the base of the exit to a signpost directing the way to the C & D Canal Museum, turn right and follow the curving road for 0.2 km (0.1 mi) to a T-intersection, turn right and follow the curving road for 0.6 km (0.4 mi) to a T-intersection, turn left and proceed 0.08 km (0.05 mi) to the main gate of the U.S. Army Corps of Engineers (COE) facility and the C & D Canal Museum. The bench marks are located on the COE grounds. The tide gage and staff were located at the SW corner of the bulkhead at the west end of the COE grounds.

**TIDAL BENCHMARKS**

**PRIMARY BENCHMARK STAMPING:** U 2 1931 6.834

**DESIGNATION:** U 2

**MONUMENTATION:** Bench Mark disk

**AGENCY:** US Coast and Geodetic Survey (USC&GS)

**SETTING CLASSIFICATION:** Concrete monument

The primary bench mark is a disk set flush in a 0.24 m (0.8 ft) square concrete monument south of the COE administration building, 14.57 m (47.8 ft) south of the west concrete wall for the steps leading to the basement of the administration building, 10.27 m (33.7 ft) north of the centerline of the main road, 8.56 m (28.1 ft) west of the west edge of a sidewalk leading to the administration building, and 0.15 m (0.5 ft) above the ground.

http://www.co-ops.nos.noaa.gov/benchmarks/8573927.html
TIDAL BENCHMARKS

BENCHMARK STAMPING: NO 1 1938
DESIGNATION: TIDAL 1 STA 62

MONUMENTATION: Tidal Station disk
AGENCY: US Coast and Geodetic Survey (USC&GS)
SETTING CLASSIFICATION: Concrete walkway

The bench mark is a disk set in a concrete walkway at the NW corner of a single story white brick building (Bridge Repair Shop), located near the west end of the COE grounds, 20.48 m (67.2 ft) south of the centerline of the main road, 0.52 m (1.7 ft) north of the north wall of the building, and 0.46 m (1.5 ft) east of the west wall of the building.

BENCHMARK STAMPING: NO 3
1972 DESIGNATION: 857
3927 TIDAL 3

MONUMENTATION: Tidal Station disk
AGENCY: National Ocean Survey (NOS)
SETTING CLASSIFICATION: Concrete foundation

The bench mark is a disk set flush in the NW corner of a concrete pump well located SW of the COE administration building, 5.94 m (19.5 ft) north of the NW corner of a ventilator shaft, 4.63 m (15.2 ft) south of the centerline of the main road, and 4.45 m (14.6 ft) SW of the southernmost of two steel gate posts for a road gate.

http://www.co-ops.nos.noaa.gov/benchmarks/8573927.html
The bench mark is a disk set flush in the concrete foundation of the westernmost of the three legs of a 49 m (160 ft) high steel radio antenna, 40.57 m (133.1 ft) north of the centerline of the main road, 16.73 m (54.9 ft) SE of the outside NW corner of the reinforced steel bulkhead on the south shore of the C & D Canal, and 8.87 m (29.1 ft) SW of the NW corner of the C & D Canal observation addition to the two story administration building.

The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 12 m (40 ft) to refusal, and encased in a 4-inch PVC pipe with cap and concrete kickblock. (Note: a large wrench is needed to remove the cap.)
TIDAL BENCHMARKS

BENCHMARK STAMPING: 3927 B
1982 DESIGNATION: 857 3927 B

MONUMENTATION: Tidal Station disk
AGENCY: National Ocean Survey (NOS)
SETTING CLASSIFICATION: Galvanized steel rod

The bench mark is a disk located SE of the COE administration building, 34.59 m (113.5 ft) SW of the centerline of the main road, 10.58 m (34.7 ft) NNE of the center of the most southeastern section of a dock on the north shore of the harbor, 4.48 m (14.7 ft) SE of the edge of the concrete runway to the dock, and 0.61 m (2.0 ft) east of the easternmost pole supporting electrical boxes. The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 7 m (24 ft) to refusal, and encased in a 4-inch PVC pipe with cap and concrete kickblock. (Note: A large wrench is needed to remove the cap.)

BENCHMARK STAMPING: 3927 C 1982
DESIGNATION: 857 3927 C

MONUMENTATION: Tidal Station disk
AGENCY: National Ocean Survey (NOS)
SETTING CLASSIFICATION: Galvanized steel rod

The bench mark is a disk located at the SE end of the COE facility, east of the main gate, 18.78 m (61.6 ft) SW of the centerline of the main road, 14.48 m (47.5 ft) SSE of the easternmost picnic table, 8.99 m (29.5 ft) NNW of the centerline of State Highway 286, and 0.61 m (2.0 ft) NNW of utility pole 17318. The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 5 m (16 ft) to refusal, and encased in a 4-inch PVC pipe with cap and a concrete kickblock. (Note: A large wrench is needed to remove the cap.)

http://www.co-ops.nos.noaa.gov/benchmarks/8573927.html

3/16/2004
Station ID: 8573927
Name: CHESAPEAKE CITY
NOAA Chart: 12277
USGS Quad: ELKTON

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

LENGTH OF SERIES: 48 MONTHS
TIME PERIOD: April 1979 - March 1983
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 8574680 BALTIMORE, FORT MCHENRY, PATAPSCO RIVER

HIGHEST OBSERVED WATER LEVEL (09/06/1979) = 2.036
MEAN HIGHER HIGH WATER (MHHW) = 1.005
MEAN HIGH WATER (MHW) = 0.941
MEAN TIDE LEVEL (MTL) = 0.505
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.500
MEAN SEA LEVEL (MSL) = 0.487
MEAN LOW WATER (MLW) = 0.069
MEAN LOWER LOW WATER (MLLW) = 0.000
LOWEST OBSERVED WATER LEVEL (04/05/1975) = -1.107

Bench Mark Elevation Information

Stamping or Designation  MLLW  MHW

U 2 1931 6.834  2.228  1.287
NO 1 1938  2.328  1.387
NO 3 1972  2.455  1.514
NO 4 1972  4.317  3.376
3927 A 1982  1.977  1.036
3927 B 1982  1.224  0.283
3927 C 1982  1.467  0.526

http://www.co-ops.nos.noaa.gov/benchmarks/8573927.html

3/16/2004
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 US. 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 National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, 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 National Geodetic Survey.

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.

http://www.co-ops.nos.noaa.gov/benchmarks/8573927.html
APPENDIX G  AIR GAP DLL USERS MANUAL

SUTRON

SUTRON XPert/XLite sll

MIROS AIR GAP WATER LEVEL SENSOR
Serial Interface Driver

For:
National Ocean Survey
Chesapeake, Virginia

October 21, 2002
Sutron Corporation
21300 Ridgetop Circle
Sterling, Virginia, USA 20166
PURPOSE
The purpose of this SLL is to allow users to connect a MIROS Air Gap water level sensor to one of the COM ports on a Sutron XPert or XLite (Model 9210) data logger. The purpose of the sensor is to provide the distance from the sensor’s location (normally the deck of a bridge) to a water surface. This SLL adds an Input (sensor) block to the XPert/XLite. The block handles serial communications with an Air Gap sensor connected to one of the serial ports. The sensor can be sampled by a standard Measure block at tested rates up to once per second. Note that the Air Gap block has two (2) outputs labeled WL1 and WL2. These correspond to the two water levels returned by the sensor when data are requested. Refer to the Miros documentation for an explanation of the difference between the two outputs.

SCOPE
This document contains:
Instructions for installing the SLL on an XPert
Instructions for connecting an Air Gap sensor to an XPert
Operating Instructions
Error Messages and Troubleshooting

SOFTWARE INSTALLATION
INSTALLING AN SLL
It is important to ensure that the SLL is compatible with the version of XPert software you are running. Log on to the XPert with SETUP privileges. Go to the STATUS tab and press the ABOUT button. Verify that the software is version 1.2.05 or higher.

SLLs are installed by copying the .SLL file to the \Flash Disk folder on the XPert. The easiest way to accomplish this is to use Sutron’s XTerm utility. Connect a PC or laptop computer to COM 1 on the XPert. The steps to load the SLL are as follows:

Run XTerm
If the XPert application is running, go to the STATUS tab and press the Exit App button to shut it down. (The new SLL will not take effect until the application is stopped and restarted.)
Press the File Transfer button. The File Transfer window is illustrated in Figure 1.
**Figure 1.** XTerm File Transfer Window

![XTerm File Transfer Window](image-url)

<table>
<thead>
<tr>
<th>File Name</th>
<th>Size</th>
<th>Date/Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>DelLib.dll</td>
<td>340992</td>
<td>02/04/02 15:39:10</td>
</tr>
<tr>
<td>Engine.dll</td>
<td>147466</td>
<td>02/04/02 15:39:06</td>
</tr>
<tr>
<td>LCRASerialDisplay.dll</td>
<td>15394</td>
<td>06/10/02 06:40:20</td>
</tr>
<tr>
<td>Logger.dll</td>
<td>12288</td>
<td>02/04/02 15:39:08</td>
</tr>
<tr>
<td>LogMgr.dll</td>
<td>20480</td>
<td>02/04/02 15:39:08</td>
</tr>
<tr>
<td>LZO.dll</td>
<td>9216</td>
<td>02/04/02 15:39:06</td>
</tr>
<tr>
<td>MOVING AVERAGE.ss</td>
<td>2225</td>
<td>04/02/02 08:09:24</td>
</tr>
<tr>
<td>NOS.ss</td>
<td>15560</td>
<td>03/07/02 08:09:24</td>
</tr>
<tr>
<td>NOSII.ss</td>
<td>14436</td>
<td>03/05/02 12:51:32</td>
</tr>
<tr>
<td>NOSIII.ss</td>
<td>15273</td>
<td>03/05/02 05:59:44</td>
</tr>
<tr>
<td>Remote.exe</td>
<td>100052</td>
<td>02/04/02 15:45:10</td>
</tr>
<tr>
<td>Satlink.dll</td>
<td>115200</td>
<td>02/04/02 15:39:10</td>
</tr>
<tr>
<td>SDI.dll</td>
<td>12800</td>
<td>02/04/02 15:38:28</td>
</tr>
<tr>
<td>station.dat</td>
<td>18</td>
<td>06/07/02 09:40:54</td>
</tr>
<tr>
<td>SYSTEM_log</td>
<td>65536</td>
<td>06/11/02 03:10:18</td>
</tr>
<tr>
<td>SYSTEM.txt</td>
<td>131766</td>
<td>02/28/02 12:42:08</td>
</tr>
<tr>
<td>TEST_log</td>
<td>65536</td>
<td>06/11/02 03:10:16</td>
</tr>
<tr>
<td>TEST.ss</td>
<td>14345</td>
<td>03/01/02 07:25:54</td>
</tr>
<tr>
<td>UTILs.dll</td>
<td>31232</td>
<td>02/04/02 15:38:28</td>
</tr>
</tbody>
</table>

- **Set All**
- **Delete**
- **Run**
- **Sel All**
- **Delete**
Set the left hand panel (PC Files) to display the folder on the PC containing the SLL to be loaded
Make sure the right hand panel (XPert Files) is pointed to Flash Disk
Highlight the SLL file and press the right-pointing arrow at the bottom of the screen to copy the SLL to the flash disk
You will be asked to confirm the operation. Press OK.
After the SLL load is completed you may restart the XPert application. You may do this by scrolling to the bottom of the Flash Disk panel (XPert Files), selecting XPert.exe, and pressing the RUN button at the bottom of the window. Powering off and on will also work if an Autoexec.bat file is defined on the XPert.

Verify that the SLL has loaded correctly. Log on to the XPert application (either through the front panel or using XTerm) with SETUP access privileges. Go to the SETUP tab and press the ADD button. The Select Category window (Figure 2) will appear.

![Select Category Window](image)

**FIGURE 2. – CATEGORY WINDOW FOR SELECTING BLOCK TYPE**

Select Input as the block type.
You will see the Air Gap sensor block with the following icon as an available input (Figure 3).

If the block is not available, or you received an error message when the XPert application started, then try powering down the XPert and restarting it. If you still can’t find the block or you still receive an error message, it is likely that the SLL is not compatible with the version of XPert software that you are running. Contact Sutron to obtain the latest updates.

If the block is available, the installation is successful. Press Cancel twice (once in the Input Module window and once in the Select Category window) to return to the Setup window. Using the Air Gap block in a setup is covered later in this manual.
HARDWARE REQUIREMENTS AND WIRING

COM PORT CONNECTIONS

Output Connection
No XPert output connection is required.

Input Connection
The Air Gap sensor block requires a connection to one of the available COM ports on the XPert. The default port is COM 2, but COM 2 through COM 4 (COM 8 with optional I/O expansion on XPert) may be selected as part of the setup.

The connection from the XPert to the Air Gap sensor is a standard, straight-wired (not null modem) male-female DB-9 cable.

analog connections
None required.

digital connections
None required.

operating instructions

setup
The Air Gap sensor block is a passive input. That is, it must be measured in order to obtain values. This is normally done by wiring the Air Gap block to a Measure block. The Air Gap block has been tested at sample rates up to once per second. Note that the Air Gap block has two (2) outputs labeled WL1 and WL2. These correspond to the two water levels returned by the sensor when the GV command is issued. Refer to the Miros documentation for an explanation of the difference between the two outputs.

Note that no RS-232 serial settings are required. The Air Gap block sets the selected input port to 9600 bps, no parity, 8 data bits, and one stop bit.

Test Setup
Figure 4. illustrates a simple test setup that may be used to determine if the Air Gap block is operating properly.
The test setup uses one Air Gap block, one Measure block, and one Log block.

The test setup is named AirGapTest.ssf. It can be copied to the \Flash Disk on the XPert and loaded through the SETUP tab File Open menu option.

Test an Air Gap sensor by connecting it to an available COM port. After the wiring is complete, go to the SETUP tab and click on the Air Gap icon. Select the Edit Properties option. The following dialog window will open:

Select the COM port to which the display is connected (default is COM 2). Set the Slope and Offset parameters (Output equals input times slope plus offset) if you want to scale the outputs. Click on OK.

Set the properties of the Measure block so that the Air Gap sensor is sampled frequently – for example every 5 seconds. Click on OK.

Go to the MAIN tab and turn recording on. (If recording was on when you entered SETUP then you will have the opportunity to turn it back on when you exit SETUP mode.) Examine the Status tab to ensure that there are no communications errors. View the log to see the sensor readings.

Normal Setup
There is no fundamental difference between a normal setup and the test setup except for processing. Typically the Air Gap block will be wired to a Measure block. The Measure block can be wired directly to the Log or to a DQAP block that filters and/or averages the output values. DQAP provides several outputs including average, standard deviation, and outlier count. Refer to the standard XPert documentation for information on DQAP.
Operations
When recording is turned on the Air Gap block sets the selected COM port properties to N-8-1 at 9600 bps. It then issues the Air Gap SER0 command to put the sensor into sampled mode. (The default Air Gap sensor mode is “streaming” with output of water levels at rates greater than once per second.) The software then looks for the returned message from the sensor indicating that the mode has been reset.

When the Air Gap sensor block is measured it issues the Air Gap GV command. The GV command requests data values. The sensor returns two water levels filtered in different ways. Both are available as outputs from the Air Gap block.

If the user has changed the Slope and Offset parameters in the Air Gap block properties then the values are first multiplied by the slope and then the offset is added. The Slope and Offset apply to both water levels. That is, there is no separate slope and offset for each one.

error messages and troubleshooting

error messages
The Air Gap block can produce two status messages and one error message. The messages and their meanings are presented in the following table.

<table>
<thead>
<tr>
<th>Message</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAirGapWL::Execute No data returned</td>
<td>When the Air Gap block issued the GV command to the sensor there was no data returned. That is, the input buffer was blank.</td>
</tr>
<tr>
<td>CAirGapWL::Execute Com out of synch</td>
<td>Line noise will occasionally cause corrupted characters in the data values. When this happens the software may not be able to correctly parse the data. The software will loose synchronization with the sensor for one or more sample intervals until all of the air gap error messages are cleared from the input buffer.</td>
</tr>
<tr>
<td>CAirGapWL::Execute OpenComm n failed</td>
<td>The Air Gap block was not able to establish communications with the selected COM port (number n).</td>
</tr>
</tbody>
</table>

Error messages will appear on the XPert Status tab as illustrated in Figure 6
FIGURE 6. - XPERT STATUS TAB WITH ERROR MESSAGES
The following table presents common problems and their solution.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unable to open the selected COM port</td>
<td>Likely wiring problem. Make sure that the DB-9 to air gap sensor connection is wired properly. Make sure that pins 2 and 3 (TXD/RXD) are not reversed in your cable. Test that the air gap sensor is generating output by connecting a PC or laptop to it and establishing a Hyperterm session with the sensor. Try issuing the SER0 and SER1 commands and the GV command to test the sensor.</td>
</tr>
<tr>
<td>XPert displays an hourglass cursor when recording is turned on.</td>
<td>The air gap sensor is connected to the wrong COM port. Go to the SETUP tab and edit the properties of the display block to match the port or move the DB-9 cable to the correct port. NOTE: If the hourglass is displayed it will eventually (about 4 minutes) time out and recording will start.</td>
</tr>
<tr>
<td>Error messages appear in the STATUS panel.</td>
<td>Error messages indicate severe errors. The most likely cause is a wiring error in the DB-9 cable or a hardware failure on the XPert.</td>
</tr>
</tbody>
</table>

It is possible to determine if the Air Gap block is operating by connecting a laptop computer to the COM port selected for the sensor. Establish a Hyperterm or other terminal emulator session with the port at 9600-N-8-1. When recording is turned on you should be able to see the XPert issue the SER0 command as well as the GV commands. Note that the commands only contain a carriage return and DO NOT contain a line feed character. This affects the appearance of the output in a terminal session. (It may be necessary to use a null modem cable for the connection.)
Introduction and Purpose

Air Gap is the measured distance between the height, in this case a bridge, over water and the surface of the water. Historically, ship traffic was not considered on some of the smaller navigable bodies of water. Dredging to change channel depths and shorter routes combined with the economic benefits of larger ships with larger cargo produced a requirement for more accurate measurement. CO-OPS has conducted extensive research on an air gap instrument and is prepared to install these sensors as part of our suite of real time monitoring sensors. The first two deployed, located in the C&D Canal, have generated enthusiasm in the shipping community. Refining our monitoring skills of these sensors will be important for the future.

PROCEDURE

1. The CORMS Operator should monitor each of these sensors in the combined PICS graphics and also in the three day Air Gap, water Level and wind. These data are consider part of the PORTS complement of sensors and as such should be monitored as on the same schedule as Chesapeake Bay PORTS.

2. To view the air gap bring up the Chesapeake PICS graphics. Locate the Chesapeake City and Reedy Point station rows. Locate the Air Gap columns and click on the associated red circles. The PICS time series graphics will appear.

3. The Air Gap sensor has several built in error checking routines. As well as a standard flag for failure no data, there are tests for excessive standard deviation and number of outliers. At the moment, the QC flags are not integrated into the Main CORMS screens. Go to either of the two links below and review the data. Embedded in the data string at the end of the top line is the area for flags. Either the bit is set or not

Chesapeake City
ftp://tidepool.nos.noaa.gov/pub/outgoing/PUFFF/cbports/8573928.ag

Reedy Point
ftp://tidepool.nos.noaa.gov/pub/outgoing/PUFFF/cbports/8551911.ag

4. While doing your PICS check should you observe that the data is not
available, refer to this link for explanation of the error being received. If the failure is not caused by FNOD, Failure No Observed Data, use the following link to go to the offline links and review the data there.

http://developers.co-ops.nos.noaa.gov:8083/cbports/AirGap.html

This link will plot data that has failed QC along with good data and allow you to visually inspect the data. If the error continues for longer than 4 samples, and it is not a Failure No Observed Data error and the data appears to be tracking correctly, page the on call ISD personnel.

5. Should the data fail Quality Control with a Standard Deviation or Outlier error, notify the PORTS Operations Manager immediately during business hours. After business hours until 9PM notify the PORTS Operations Manager. For Failure No Data errors, notify the appropriate individuals for Chesapeake Bay PORTS by E-Mail.
APPENDIX I. MIROS SM-094 MANUFACTURER SPECIFICATION SHEET

SM-094 RANGE FINDER

The MIROS Range Finder is designed for measurement of:
- Airgap and draught
- Ocean wave profiles and tidal variations
- Water level in dams, rivers, canals, lakes etc.

The sensor emits a microwave FM chirp signal and receives the echo from the water surface. The signal propagation delay given by the distance from the antenna to the water surface causes a beat signal in the receiver. By means of advanced signal processing the beat frequency is converted to an accurate distance estimate.

The planar patch antenna provides small physical dimensions and low weight.

The FM chirp is generated by a digitally synthesized frequency sweep oscillator with absolute frequency linearity and high stability. The sensor therefore provides accurate range measurements with high long term stability.

Due to the low frequency of operation (compared to laser sensors) fog, rain and water spray will not cause measurement problems.

The sensor signal processing is performed by a micro-controller programmed in ANSI C. The sensor provides the measured range with 1 mm resolution as well as an averaged range. Averaging time constant may be selected by user. The signal output may either be continuous at selected rate, or single measurements in response to user request.

SM-094 is available in three different range versions:
- 2 - 20 m
- 2 - 50 m
- 2 - 85 m

Specifications

Measurement Performance

<table>
<thead>
<tr>
<th>Range</th>
<th>SM-094/20: 2 - 20 m</th>
<th>SM-094/50: 2 - 50 m</th>
<th>SM-094/85: 2 - 85 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error (above 3 m)</td>
<td>&lt; 1 cm (individual measurements)</td>
<td>&lt; 1 mm (averaged measurements)</td>
<td></td>
</tr>
<tr>
<td>Modulation</td>
<td>Triangular FM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>9.4 - 9.8 GHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output power</td>
<td>&lt; 1 mW (0 dBm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Antenna

<table>
<thead>
<tr>
<th>Type</th>
<th>Planar patch (16 x 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam width</td>
<td>5 deg (-3 dB)</td>
</tr>
<tr>
<td>Gain</td>
<td>&gt; 24 dB</td>
</tr>
</tbody>
</table>

Power Requirements

<table>
<thead>
<tr>
<th>Voltage</th>
<th>22 - 32 VDC (nominal 24 VDC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>&lt; 200 mA</td>
</tr>
</tbody>
</table>

Environmental

<table>
<thead>
<tr>
<th>Temperature</th>
<th>-30 - +50 degC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>10 - 100 %RH</td>
</tr>
</tbody>
</table>

Housing

<table>
<thead>
<tr>
<th>Material</th>
<th>Aluminium AL57S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finish</td>
<td>Enamelled</td>
</tr>
<tr>
<td>Colour</td>
<td>Gray, RAL 7035</td>
</tr>
<tr>
<td>Protection</td>
<td>Designed to meet IEC IP66</td>
</tr>
</tbody>
</table>

Physical

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>70 x 510 x 420 mm (HxWxD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>7 kg</td>
</tr>
</tbody>
</table>

Analogue Signal Output

<table>
<thead>
<tr>
<th>Range</th>
<th>0 - 12 V (0 m - full range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>&gt; 1200 ohms</td>
</tr>
<tr>
<td>Current</td>
<td>&lt; 10 mA</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>2 Hz</td>
</tr>
</tbody>
</table>

Digital Signal Output

<table>
<thead>
<tr>
<th>Interface</th>
<th>RS-232 (V.24) or RS-422</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>ASCII</td>
</tr>
<tr>
<td>Baud rate</td>
<td>9600</td>
</tr>
<tr>
<td>Data bits</td>
<td>8</td>
</tr>
<tr>
<td>Stop bits</td>
<td>1</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Data rate</td>
<td>SM-094/20: 2&quot;, 4 or 8 Hz</td>
</tr>
<tr>
<td></td>
<td>SM-094/50: 2&quot; or 4 Hz</td>
</tr>
<tr>
<td></td>
<td>SM-094/85: 2 Hz</td>
</tr>
<tr>
<td>or polling mode</td>
<td></td>
</tr>
<tr>
<td>Data format</td>
<td>aa.aaa&lt;HT&gt;r.rr&lt;CR&gt;&lt;LF&gt;aa.aaa is measured range [m]</td>
</tr>
<tr>
<td>Note</td>
<td>Specifications are subject to change without prior notice.</td>
</tr>
</tbody>
</table>

DB/095 rev. 01

Miro A/S, Solbraveien 32, PO. Box 364, 1372 Asker, Norway
Tel: +47 66 98 75 00, Fax: +47 66 90 41 70
www.miros.no
APPENDIX J
PUFFF AIR GAP DATA

PUFFF air gap data details are available at:
APPENDIX K

CHARLESTON BRIDGE PROJECT
PURPOSE

Determine the precise “AIR GAP” of the bridges
(distance at Mean High Water and the bottom of the bridge)

METHODS TO BE USED

• GPS
• Trig-Leveling
• Classical Leveling

MOUNTING THE ANTENNAS
CLASSICAL LEVELING

Charleston Bridge Network

- C 69
- TBM SILE ARP
- HOLLINS
- TIDAL 13
- 10 012
- CBPA
- CHAI CORS

NAVD88 Bench Mark
Temporary (Project) CORS

NOAA, NOS, NGS
Free Vertical Adjustment minus NAVD88 Published

C 69
0.6cm
TBM SILE ARP
HOLLINS
0.9cm
0.1cm
10 012
-8.2cm
TIDAL 13 FIXED

NAVD88 Bench Mark FIXED
Temporary (Project) CORS

BOTTOM OF GPS ANTENNA
GPS ANTENNA
H (Determined by trig-leveling)

BOTTOM OF BRIDGE

△ h (Determined by GPS)

NAVD88 BM

MEAN HIGH WATER

NOAA, NOS, NGS
KNOWNS

HI = Height of the bottom of the bridge to the top of the antenna mounting bracket
    = 18.608 m

NAVD88 BM = 2.219 m

Geoid Heights = -33.140 at the NAVD88BM
    (GEOID99) = -33.145 at the GPS Antenna on top of bridge

Mean High Water = 2.04 ft above NAVD88

Δh = Height from NAVD88BM to the top of the antenna mounting bracket (mean of two one hour GPS observations)
    = 62.987 m

Height of the bottom of the bridge above Mean High Water

HEIGHT OF THE BOTTOM OF THE BRIDGE ABOVE MEAN HIGH WATER

\[
H_{GPSANT} = H_{NAVD88BM} + \Delta H_{GPS} \\
= H_{NAVD88BM} + [\Delta h - \Delta N] \\
= 2.219 + [62.987 - ((-33.145) - (-33.140))] \\
= 65.211
\]

HI = -18.608

\[
H_{GPSBotBr} = 46.603 \text{ m or 152.897 Ft.}
\]

NAVD88 - MHW = -204 Ft.

\[
H_{GPSBotBr} = 150.856 \text{ Ft.}
\]
COMPARISON OF ORHTOMETRIC HEGHTS NAVD88

<table>
<thead>
<tr>
<th>Method</th>
<th>HGPSANT</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>65.211 m</td>
<td></td>
</tr>
<tr>
<td>Trig-Leveling</td>
<td>65.203 m</td>
<td>0.8 cm</td>
</tr>
</tbody>
</table>

CONCLUSION

GPS METHODS WORK

NOAA, NOS, NGS