1. Introduction

1.1 U.S. Ports for the Gulf of Mexico

Six of the top ten ports by tonnage in the United States are located on the Gulf of Mexico; two of the top ten busiest global ports are located on the Gulf. As of 2009, Gulf ports accounted for 48% of the total tonnage handled by U.S. ports. The principal ports in the Gulf of Mexico, with U.S. rank by total tonnage as of 2009, are:

- Port of South Louisiana, LA*—rank 1, rank 2 in terms of foreign tonnage, largest port in the western hemisphere, accounts for 15% of total U.S. export tonnage
- Port of Houston, TX*—rank 2, busiest U.S. port in terms of foreign tonnage, and fifteenth busiest in the world
- Corpus Christi, TX—rank 5
- Port of New Orleans, LA*—rank 6
- Beaumont, TX*—rank 7, second busiest military port in the world
- Texas City, TX*—rank 10
- Lake Charles, LA*—rank 11
- Port of Mobile, AL*—rank 12 and only deepwater port in Alabama
- Baton Rouge, LA*—rank 13
- Plaquemines Port, LA—rank 14, home to two largest coal terminals in U.S.
- Pascagoula, MS*—rank 16 and largest in Mississippi
- Port of Tampa, Florida*—rank 17 and largest port in Florida
- Port Arthur, TX*—rank 19
- Freeport, TX—rank 27
- Galveston, TX*—rank 47, homeport to three cruise liners
- Matagorda Port Ll Pt Com (Lavaca Port Comfort), TX—rank 58
- Brownsville, TX—rank 72
- Vicksburg, MS—rank 84
- Biloxi, MS—rank 84
- Port Manatee, FL*—rank 88
- Panama City, FL—rank 90
- Port of Morgan City, LA—rank 98
- Greenville, MS—rank 99
- Victoria, TX—rank 105
- Gulfport, MS*—rank 108, prior to Hurricane Katrina this was the third busiest container port in the Gulf
- Guntersville, AL—rank 110
- Rosedale, MS—rank 137
- Pensacola, FL—rank 140, leading deepwater port in northwest Florida with Free Trade Zone and Enterprise Zone
• Sabine Pass, TX*—rank 142
• Lake Providence, LA—rank 146
• Orange, TX—rank 150

In addition, several ports are key to offshore petroleum production in the Gulf of Mexico:

• Ports of Intracoastal City, LA—at the junction of the Vermilion River and the Intracoastal Waterway
• Louisiana Offshore Oil Port, LA—handles large tankers supplying 13% of nation's foreign oil
• Port Fourchon, LA—services 90% of domestic deepwater oil and gas exploration, drilling, and production in the Gulf

* Ports served by an existing PORTS system

1.2 Physical Oceanographic Real-Time Systems and the Requirements Therefore

The Federal Advisory Committee Special Report 2007 prepared by the Hydrographic Services Review Panel (HSRP 2007) recommended to NOAA five necessary, priority actions to maintain and improve a competitive U.S. Marine Transportation System. This was updated with the document “Most wanted Hydrographic Services Improvement” dated September 2010 and referred to here as HSRP 2010 (see http://www.nauticalcharts.noaa.gov/ocs/hsrp/docs/2010_Most_Wanted_Hydrographic_Services_Improvements.pdf).

One of the HSRP recommendations is to “Modernize heights and implement real-time water level and current observing systems in all major commercial ports.”

Findings of HSRP 2010 related to this recommendation are: “NOAA’s Navigation Services are a critical component of the federal effort to build an Integrated Ocean Observing System (IOOS), delivering real-time data to a multitude of navigation and non-navigation users. The Integrated Coastal and Ocean Observation System Act of 2009 highlights the importance of observing systems and data, first and foremost for national defense, marine commerce, and navigation safety, among a host of other uses. The need for accurate and reliable ocean observing data is reiterated in the July 2010 Interagency Ocean Task Force Final Recommendations and the National Ocean Policy. Central to IOOS is the concept that, in many cases, measurements and predictions taken and made for a particular need can serve other national and regional needs.

NOAA is the lead agency for IOOS, and the physical observations collected by the Navigation Services programs are a critical component of the IOOS backbone. The environmental parameters (meteorological, currents, water levels, hydrography, bathymetry, shoreline, and geo-positioning) that NOAA Navigation Services gathers, integrates, and quality controls on behalf of the mariner are also baseline datasets for other stakeholders: coastal zone managers, coastal engineers, researchers, and first responders. Some of these parameters also provide information critical to mitigating natural hazards, such as storm surge, tsunamis, and other extreme events. Thus, the HSRP believes support for comprehensive expansion of the maritime components and building on existing capabilities to link users to useful and timely data should be the top priority for IOOS, and for NOAA.”
The National Ocean Service (NOS) of NOAA is responsible for providing real-time oceanographic data and other navigation products to promote safe and efficient navigation within U.S. waters. This is a major challenge. By volume, more than 95 percent of U.S. international trade moves through the nation’s ports and harbors, with about 50 percent of these goods being hazardous materials. The Physical Oceanographic Real-time System (PORTS) is one component of NOS’s integrated program to promote safe and efficient navigation. It is combined with up-to-date nautical charts and precise positioning information.

From the NOS web site: “PORTS is a decision support tool that improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts and other geospatial information. PORTS measures and disseminates observations and predictions of water levels, currents, salinity, waves and meteorological parameters (e.g., winds, atmospheric pressure, fog, relative humidity, air and water temperatures) that mariners need to navigate safely.” The PORTS provides information of critical importance to harbor masters and to masters and pilots of merchant vessels. Such information also is available and used by commercial and recreational fishers and recreational boaters.

From HHSRP 2010: “A critical component of IOOS, PORTS® is a localized sensor suite that disseminates observations and predictions of water levels, currents, salinity, winds, atmospheric pressure, and air and water temperatures for an area every six minutes. A recent addition is the air gap, or bridge clearance sensor, which addresses the emerging issue of ever taller vessels striking bridges. Each system installation is uniquely tailored to the needs of local users. All PORTS observations are quality controlled 24 hours per day, seven days per week.”

Within the Gulf of Mexico PORTS are operational at the following eight locations out of a total of 20 within the U.S.: Houston/Galveston, TX; Tampa Bay, FL; Lake Charles, LA; Sabine Neches, LA/TX; Mobile Bay, AL; Gulfport, MS; Pascagoula, MS; and Lower Mississippi River, LA (see http://tidesandcurrents.noaa.gov/ports.html). Tampa Bay and Houston-Galveston PORTS have Operational Forecast Systems that utilize numerical models to make predictions of tides, currents, and salinities (see http://tidesandcurrents.noaa.gov/models.html).

From HSRP 2010: “The HSRP recommends the expansion of the PORTS program to additional major U.S. seaports be made a high priority for future IOOS funding appropriated to NOAA, including the ability to implement operational forecast models coupled with each PORTS system.”

2. Design Considerations

2.1 Parameters measured or modeled

PORTS measures and disseminates observations and predictions of water levels, currents, salinity, waves and meteorological parameters (e.g., winds, atmospheric pressure, fog, relative humidity, air and water temperatures). PORTS also have a sensor to measure the air gap beneath a bridge, providing mariners the information they need to safely navigate under bridges.

All data from PORTS are quality controlled through the Continuous Operational Real-Time Monitoring System (CORMS). CORMS is the primary system for real-time Quality Assurance (QA)/Quality Control (QC) efforts in NOS’ Center for Operational Oceanographic Products and Services (CO-OPS). The primary mission of CORMS is to perform thorough and robust QA/QC on all
real-time data, systems, and products in the CO-OPS domain, ensuring that a reliable source of real-time data is readily available, while not disseminating data of questionable quality.

Typical data transmission updates are every 6 min. except for waves, which are 30 to 60 min. Data delayed by more than one hour are typically not useful, as conditions vary quickly in most ports and harbors. PORTS data that are more than 18 minutes old (or 3 data collection cycles) are considered late and are not displayed. When this occurs flags are sent to CORMS to review station data.

NOS/CO-OPS also has models at 11 locations, five of which coincide with PORTS locations. These numerical models produce automated, numerical model-generated now-cast guidance (analyses) of present physical conditions and forecast guidance of future conditions. Now-cast and forecast output from these models include water levels, water currents, surface winds, salinity and water temperature and are updated four times a day. Forecasts are provided 48 hours into the future.

At present, there are operational models for only two of the Gulf PORTS: Houston-Galveston and Tampa Bay. CO-OPS plans to establish a regional near shore model for the central northern Gulf during 2011 and to set up models for PORTS in that region beginning in 2012. The next region planned for new PORTS models would be the Texas coast.

2.2 Assumptions

The spatial scales of phenomena to be observed by the PORTS differ for different physical settings; so the placement of observing stations is dependant on the conditions found in the port or harbor under consideration. In each case, the design is based on gaining access to information that will yield the maximum degree of safety for vessels using the information given that resources are limited.

2.3 Existing Capabilities

There are currently PORTS at 20 locations around the U.S. serving approximately 50 ports. As mentioned above, eight of these PORTS serve the Gulf region. Each PORTS is configured differently depending on the needs of the local maritime community. Below is a list of the existing PORTS in the Gulf and how each are configured.

Tampa Bay, FL
- 7 meteorological stations
- 4 water level stations (3 with meteorological sensors)
- 2 current meters

Mobile Bay, AL
- 1 meteorological stations
- 8 water level stations (2 with meteorological sensors, one has a salinity sensor)
- 3 current meters
- 2 visibility (fog) stations

Pascagoula, MS
- 3 meteorological stations
- 2 water level stations
- 3 current meters
Lower Mississippi River, LA
- 3 water level stations (2 with meteorological sensors)
- 2 current meters
- 2 air gap stations

Lake Charles, LA
- 3 water level stations (1 with meteorological sensors)
- 3 current meters
- 1 air gap station

Sabine Neches, LA/TX
- 2 water level stations (1 with meteorological sensors)
- 7 current meters

Houston/Galveston, TX
- 4 water level stations (3 with meteorological sensors, 2 have salinity sensors)
- 1 current meters

Appendix 1 gives a figure showing the locations of sensors in the Houston-Galveston PORTS.

Information on waves and visibility are important to mariners trying to navigate up narrow crowded waterways. Until recently this information was not available through PORTS. In 2010 sensors that measure waves and visibility were added to the suite of PORTS sensors. PORTS does a good job at provided information for mariners to navigate safely and efficiently, however improvements could be made in providing better environmental information such as water quality. PORTS stations are designed to be able to handle multiple sensors

How are the PORTS funded and operated?

PORTS is a partnership program between NOAA and the local maritime community. NOAA is funded for program management, 24x7 quality control of data (CORMS), data collection infrastructure and data dissemination via the Internet and phone systems. NOAA is not funded for local PORTS equipment purchase, installation or annual operations and maintenance (O&M) costs. This responsibility falls on the local maritime community. The preferred PORTS business model is for a local partner to be identified, an agreement established with NOAA and money exchanged for the purchase, installation and operation and maintenance of a PORTS. NOAA contracts out this work but oversees all aspects of the project. There are other models where PORTS are installed and maintained by the local partner. An agreement to install and maintain the system to NOAA standards still needs to be established.

PORTS have been funded in many different ways in the 20 years they have been in existence. Many existing PORTS have been funded with federal dollars. Most recently several Gulf PORTS were funded through various hurricane recovery funds. Several other PORTS were funded by local partners, including port authorities, marine exchanges, the Navy, oil companies, city and state governments and the Army Corp of Engineers. Remaining as a challenge to many local partners is the ongoing operations and maintenance costs.
NOAA is funded for the data collection infrastructure for PORTS. NOAA collects and stores all data from PORTS and backs it up on a daily basis. In addition to providing PORTS information on the web and through phone systems, NOAA also proves this information through web services which can be used to download data into other databases. The web services URL for PORTS data is: http://.opendap.co-ops.nos.noaa.gov/content/.

2.4 Needed new assets

Many of the Gulf PORTS are new and rudimentary. They need additional sensors and models.

The Port of South Louisiana stretches 54 miles along the Mississippi River between New Orleans and Baton Rouge, Louisiana, and is the largest tonnage port in the Western Hemisphere. It should have a PORTS system.

Other ports such as Corpus Christi did have their own system but measurements typically did not follow NOS standards for PORTS and is now defunct due to lack of funding.

The Port of Corpus Christi is seeing a rapid increase in barge movements due to the production from the nearby Eagle Ford shale play. This increased traffic is increasing the risks of a collision during periods of high winds and sudden weather change events. A PORTS system would assist in reducing these risks by allowing barge operators access to real time weather and current data, which is presently unavailable.

The Port of Morgan City is located at the confluence of the Atchafalaya River and the Intracoastal Waterway. Together with Bayou Bouef, Bayou Black, and Bayou Chene these waterways are connections for traffic to the continental U.S. and abroad. It is recommended that a PORTS be located there.

The Matagorda Port area has been identified as a clear danger area for shipping. The Port of Victoria is located on the Victoria Barge Canal that opens into San Antonio Bay with access to the open Gulf via Matagorda Bay. Consideration should be given to establishing a PORTS for this area.

The broad region of the Mississippi-Atchafayala Delta, including the Pontchartrain and Lake Borgne Area, St. Bernard and Plaquemines Area, Barataria Area, Fourchon and South Lafourche Area, Terrebonne Area, Atchafalaya, and St. Mary, Iberia, Vermilion Area, is a major transportation region. Consideration should be given to establishing a regional PORTS there.

2.5 General Integrating Considerations

In addition to PORTS and certain PORTS-like systems in the Gulf, there are many other data systems that improve the safety and efficiency of marine transportation. It is desirable that these other data systems be integrated with the PORTS, but they are not included in this plan.
3. Preliminary Design

PORTS contingency plan

As part of an the annual O&M cost NOAA builds in a 10% capital reserve to set aside money to replace equipment. It is also a recommended policy to have one spare sensor for every three sensors in the field. If the PORTS program were fully funded it would be desirable to maintain a pool of sensors to serve the entire network. The existing business model of individually funded PORTS does not lend itself to a central pool of spare sensors, therefore each PORTS needs to have spare sensor available to assure reliability of the system.

4. Cost estimates

4.1 Assumptions for costing

PORTS are not one size fits all; they are developed based on local user requirements for information in critical areas. Therefore PORTS sensors are selected a la carte

4.2 PORTS Sensor equipment, installation and operations and maintenance costs

In the following Table are a list of sensors that are currently being used by the PORTS systems along with associated cost for equipment installation and annual operations and maintenance (O&M) costs. See Appendix 2 for a list of sensor specifications.
<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Equipment/Installation</th>
<th>Annual O&amp;M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Level Station</td>
<td>$66,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>Water Level Station Remote</td>
<td>$72,000</td>
<td>$25,000</td>
</tr>
<tr>
<td>Water Level Station w Structure (hurricane hardened)</td>
<td>$530,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>Current meter bottom mounted</td>
<td>$95,000</td>
<td>$33,000</td>
</tr>
<tr>
<td>Current meter buoy mounted</td>
<td>$62,000</td>
<td>$28,000</td>
</tr>
<tr>
<td>Current meter horizontal mount</td>
<td>$70,000</td>
<td>$25,000</td>
</tr>
<tr>
<td>Meteorological – Add on to existing station</td>
<td>$19,000</td>
<td>$5,000</td>
</tr>
<tr>
<td>Meteorological Station</td>
<td>$32,000</td>
<td>$11,000</td>
</tr>
<tr>
<td>Conductivity/Salinity – Add on to existing station</td>
<td>$9,000</td>
<td>$11,400</td>
</tr>
<tr>
<td>Visibility Station</td>
<td>$64,000</td>
<td>$13,000</td>
</tr>
<tr>
<td>Air Gap Station</td>
<td>$61,000</td>
<td>$15,000</td>
</tr>
</tbody>
</table>

4.3 Costs of maintaining existing PORTS assets

Below are costs for the total replacement of the existing eight Gulf PORTS along with annual operations and maintenance costs.
Initial installation or replacement costs: $4M
Annual O&M costs (include refurbishment): $1.4M per year

4.4 Costs of upgrading existing PORTS

It will be necessary to do a local assessment in each case to determine the sensors needed to meet user requirements. However, the impacts of fog on shipping are large, and it seems likely that adding visibility stations will be of high priority.

4.5 Costs of new assets needed

Corpus Christi is the only existing observing system in the area that was identified as needing to be upgraded to a PORTS system. An upgrade in this region should include the following ports:

- Corpus Christi, TX
- Matagorda Ship Channel, TX
- Victoria, TX
- Brownsville, TX
- Freeport, TX
- Aransas Pass, TX
- Port Isabel, TX

Below are cost figures to properly outfit this region.
Initial installation or upgrade costs: $1.2M
Annual O&M costs (include refurbishment): $390K per year
It will be necessary to carry out local assessments of user needs for other new PORTS to determine what sensors are needed where.

4.6 Costs not included in the estimate

Not included are costs for the following needed improvements or new assets:
- Enhancements to existing PORTS,
- Implementation and maintenance of PORTS models, and
- Establishment and operation of new PORTS in addition to the Port of Corpus Christi.

5. Implementation Priority and Recommendations

5.1 Suggested Priority for Implementation

Priority order for implementation. 1 is the sub-element of highest priority.
1. Establish a PORTS for the Port of South Louisiana
2. Establish a PORTS for the Port of Corpus Christi
3. Establish a PORTS for the Port of Morgan City
4. Establish a PORTS for the Matagorda Bay area

Planning Team Members

The team that developed the plan for this element is identified in Table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark Luther</td>
<td>University of South Florida</td>
<td>Physical oceanographer; PORTS Operator</td>
</tr>
<tr>
<td>Worth Nowlin</td>
<td>Texas A&amp;M University</td>
<td>Physical Oceanographer; GCOOS-RA Board member</td>
</tr>
<tr>
<td>Darren Wright</td>
<td>NOAA</td>
<td>PORTS Director in CO-OPS</td>
</tr>
<tr>
<td>Gary Jeffress</td>
<td>Texas A&amp;M University Corpus Christi, Conrad Blucher Institute</td>
<td>Geodesist; PORTS operator</td>
</tr>
<tr>
<td>Philippe Tissot</td>
<td>Texas A&amp;M University Corpus Christi, Conrad Blucher Institute</td>
<td>Coastal Scientist</td>
</tr>
</tbody>
</table>
Appendix 1: Sensors in Houston-Galveston PORTS (Credit NOAA’s CO-OPS)

![Map of Houston-Galveston PORTS sensors](image)

<table>
<thead>
<tr>
<th>Sensor Location</th>
<th>Sensor Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morgans Point</td>
<td>wi, wind, at, wt, bare, ct</td>
</tr>
<tr>
<td>Morgans Point</td>
<td>cu</td>
</tr>
<tr>
<td>Eagle Point</td>
<td>wi, wind, at, wt, bare, ct</td>
</tr>
<tr>
<td>Bolivar Roads</td>
<td>cu</td>
</tr>
<tr>
<td>Galveston Causeway</td>
<td>cu</td>
</tr>
<tr>
<td>Galveston Bay Entr Channel LB 11</td>
<td>cu</td>
</tr>
<tr>
<td>Pleasure Pier</td>
<td>wi, wind, at, wt, bare</td>
</tr>
<tr>
<td>Pier 21</td>
<td>wi, at, wt, bare</td>
</tr>
</tbody>
</table>

**Legend:**
- **wi**: water level
- **wt**: water temperature
- **at**: air temperature
- **cu**: current
- **ct**: conductivity/salinity
- **wind**: speed and direction
- **baro**: barometric pressure
- **ag**: air gap
- **vi**: visibility

Voice data response system:
1-866-HG-PORTS (1-866-447-6787)

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# Appendix 2

**NOAA’s Ocean Service**  
Center for Operational Oceanographic Products and Services (CO-OPS)  
Environmental Measurement Systems  
Sensor Specifications and Measurement Algorithm

<table>
<thead>
<tr>
<th>Measurement Parameter</th>
<th>Sensor Manufacturer</th>
<th>Estimated Accuracy</th>
<th>Resolution</th>
<th>Sample Interval</th>
<th>Trans-mittal Interval</th>
<th>Measurement Algorithm</th>
</tr>
</thead>
</table>
| Water Level (Primary)  | Aquatrak®            | Relative to Datum  | 0.001 m    | 6 minutes      | 6 minutes             | 181 one-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation are recalculated and reported along with the number of outliers. (3 minute water level average)  
Note - Tsunami Ready stations also send 6 - 1 minute average water level measurements per Tx. |
<p>|                        | (Air Acoustic sensor in protective well) | ± 0.02 m (Individual measurement) ± 0.005 m (monthly means) |            |                |                      |                       |
| Water Level (Primary)  | Dual Orifice Bubbler Paroscientific Quartz sensor Model # 1030G-01 (Pressure) | Relative to Datum | 0.001 m    | 6 minutes      | 6 minutes             | 36 five-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation are recalculated and reported along with the number of outliers. Note - Tsunami Ready stations also send 6 - 1 minute average water level measurements per Tx. |
|                        |                     | ± 0.02 m (Individual measurement) ± 0.005 m (monthly means) |            |                |                      |                       |
| Water Level Stations Great Lakes (Primary) | BEI Absolute Shaft Angle Encoder Model # MT-40D (Float) | Relative to Datum | 0.001 m    | 6 minutes      | 6 minutes             | 181 one-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation are recalculated and reported along with the number of outliers. |
|                        |                     | ± 0.006 m (Individual measurement) ± 0.003 m (monthly means) |            |                |                      |                       |
| Water Level (Backup)   | Single Orifice Bubbler Strain Gauge Sensor (Pressure) | Relative to Datum | 0.001 m    | 6 minutes      | 6 minutes             | 181 one-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation are recalculated and reported along with the number of outliers. (3 minute water level average) |
|                        |                     | ± 0.05 m (Individual measurement) ± 0.02 m (monthly means) |            |                |                      |                       |</p>
<table>
<thead>
<tr>
<th>Measurement Parameter</th>
<th>Sensor Manufacturer</th>
<th>Estimated Accuracy</th>
<th>Resolution</th>
<th>Sample Interval</th>
<th>Trans-mittal Interval</th>
<th>Measurement Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Level (Short Term)</td>
<td>Aquatrak® (Air Acoustic sensor in protective well)</td>
<td>Relative to Datum ± 0.02 m (Individual measurement) ± 0.005 m (monthly means)</td>
<td>0.001 m</td>
<td>6 minutes</td>
<td>1 hourly (Satellite-GOES)</td>
<td>181 one-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation are recalcualted and reported along with the number of outliers. (3 minute water level average )</td>
</tr>
<tr>
<td>Air Temp</td>
<td>Yellow Springs Instruments</td>
<td>± 0.2°C</td>
<td>0.1°C</td>
<td>6 minutes</td>
<td>6 minutes (Satellite-GOES or IP Modem)</td>
<td>20 equally spaced samples collected over a 2 minute period are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites or centered on the hour otherwise.</td>
</tr>
<tr>
<td>Water Temp</td>
<td>Yellow Springs Instruments</td>
<td>± 0.2°C</td>
<td>0.1°C</td>
<td>6 minutes</td>
<td>Internet (every 6 minutes), GOES (1 hour, or 3 hour)</td>
<td>20 equally spaced samples collected over a 2 minute period are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites or centered on the hour otherwise.</td>
</tr>
<tr>
<td>Wind S/D/G (Typically installed approximate 10 m above sea level)</td>
<td>R.M. Young</td>
<td>Speed ± 0.3 m/sec. Direction ± 3° (Speed Threshold 1 m/sec)</td>
<td>Speed 0.1 m/sec. Direction 0.1°</td>
<td>6 minutes</td>
<td>6 minutes (Satellite-GOES or IP Modem)</td>
<td>Speed - 2 minute scalar average of 1 second wind speed measurements collected prior to each tenth hour. Wind Direction - 2 minute unit vector average of wind direction collected prior to each tenth hour. Wind Gust - The maximum 5 second moving scalar average of wind speed that occurred during the previous 6 minutes for PORTS® stations, during the previous hour otherwise.</td>
</tr>
<tr>
<td>Baro Press.</td>
<td>Setra or Vaisala</td>
<td>± 0.5 mbar</td>
<td>0.1 mbar</td>
<td>6 minutes</td>
<td>6 minutes (Satellite-GOES or IP Modem)</td>
<td>20 equally spaced samples collected over a 2 minute period are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites or centered on the hour otherwise.</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Falmouth Sci. or Greenspan</td>
<td>Conductivity ± 0.1 mS/cm Temperature ± 0.05°C</td>
<td></td>
<td>6 minutes</td>
<td>6 minutes (Satellite-GOES or IP Modem)</td>
<td>20 equally spaced samples collected over a 2 minute period are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites or centered on the hour otherwise.</td>
</tr>
<tr>
<td>Density</td>
<td>Derived from Conductivity and Water Temp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Parameter</td>
<td>Sensor Manufacturer</td>
<td>Estimated Accuracy</td>
<td>Resolution</td>
<td>Sample Interval</td>
<td>Trans-mittal Interval</td>
<td>Measurement Algorithm</td>
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<td>-----------------------</td>
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</tr>
<tr>
<td>Water Current Profiler (Vertical - Bottom Mount)</td>
<td>RD Instruments (4 beam configuration with 20° beam angle) Frequency 600 or 1200 KHz depending on water depth.</td>
<td>Speed ± 0.25 cm/sec. (1200 &amp; 600 kHz) ± 0.5 cm/s (300 kHz) Tilts ± 0.5° Compass ± 2° Max Tilts ± 15°</td>
<td>Velocity 0.1 cm/s Heading 0.01° Tilts 0.01°</td>
<td>6 minutes</td>
<td>6 minutes (IP Modem)</td>
<td>6 minute average comprised of approximately 345 profiles (pings) per measurement. Data includes east, north, and vertical velocities, echo amplitude, correlation magnitude, percent good pings for each beam and each bin. Included with each measurement are compass, pitch, and roll as well as water pressure and water temperature. Specs ref - <a href="http://www.rdinstruments.com/pdfs/datasheets/workhorse_sentinel_ds_lr.pdf">http://www.rdinstruments.com/pdfs/datasheets/workhorse_sentinel_ds_lr.pdf</a></td>
</tr>
<tr>
<td>Water Current Profiler (Vertical - Bottom Mount)</td>
<td>SonTek (3 beam configuration with 25° beam angle) Frequency 500 or 1500 KHz depending on water depth.</td>
<td>Speed ± 0.5 cm/sec (± 1% measured velocity) Heading ±2° Pitch, Roll ±1° Profiling range 15-25 meter (1500 kHz) pressure sensor 0.1%</td>
<td>Velocity 0.1 cm/s Heading 0.1° Tilts 0.1°</td>
<td>6 minutes</td>
<td>6 minutes (IP Modem)</td>
<td>6 minute average comprised of approximately 2000 profiles (pings) per measurement. Data includes east, north, and vertical velocity, standard deviation, and echo amplitude for each beam and each bin. Included with each measurement are compass, pitch, and roll as well as water pressure and water temperature. Specs ref - <a href="http://www.sontek.com/download/brochure/adp.pdf">http://www.sontek.com/download/brochure/adp.pdf</a></td>
</tr>
<tr>
<td>Water Current Profiler (Horizontal)</td>
<td>SonTek (2 beam configuration with 25° beam angle) Frequency 500 kHz and 250 kHz depending on range</td>
<td>Maximum profiling range is 70-120 meters (500 kHz) and 120-180 meters (250 kHz) Speed ± 0.5 cm/sec (± 1% measured velocity)</td>
<td>Velocity 0.1 cm/s Heading, 0.1° Tilts 0.1°</td>
<td>6 minutes</td>
<td>6 minutes (IP Modem)</td>
<td>6 minute average comprised of approximately 500 profiles (pings) per measurement (250kHz) and 700 profiles (pings) per ensemble (500kHz). Data includes east and north velocity, standard deviation, and echo amplitude for each beam and each bin. Included with each measurement are compass, pitch, and roll as well as water temperature and occasionally water pressure if ADP is equipped with one. Specs ref - <a href="http://www.sontek.com/download/brochure/adp.pdf">http://www.sontek.com/download/brochure/adp.pdf</a></td>
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<tr>
<td>Measurement Parameter</td>
<td>Sensor Manufacturer</td>
<td>Estimated Accuracy</td>
<td>Resolution</td>
<td>Sample Interval</td>
<td>Trans-mittal Interval</td>
<td>Measurement Algorithm</td>
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<tr>
<td>Water Current Profiler (Vertical - Buoy Mount)</td>
<td>Nortek Aquadopp Profiler (3 beam configuration with 25° beam angle). Frequency 1 MHz.</td>
<td>Profiling range 15-25 meters Speed ± 0.5 cm/sec (± 1% of measured velocity) Horizontal vel range ± 10 m/s Max tilts ± 30°</td>
<td>1 mm/s (Velocity) Heading, 0.1° Tilts 0.1° Pressure sensor 1mm Water Temp 0.01°C</td>
<td>6 minutes</td>
<td>6 minutes (IP Modem)</td>
<td>6 minute average comprised of approximately 1800 profiles (pings) per measurement. Data includes east, north, and vertical velocity, and echo amplitude for each beam and each bin. Included with each measurement are compass, pitch, and roll, water temperature, and water pressure. Specs ref - <a href="http://nortekusa.com/hardware/AquadoppProfiler.html">http://nortekusa.com/hardware/AquadoppProfiler.html</a></td>
</tr>
<tr>
<td>Air Gap (Bridge Clearance)</td>
<td>Miros SM094 (microwave)</td>
<td>± 0.03 m one standard deviation</td>
<td>0.01 m</td>
<td>6 minutes</td>
<td>6 minutes (Satellite-GOES or IP Modem)</td>
<td>181 one-second water level samples centered on each tenth of an hour are averaged, a three standard deviation outlier rejection test applied, the mean and standard deviation is recalculated and reported along with the number of outliers.</td>
</tr>
</tbody>
</table>