The Texas Coastal Ocean Observation Network

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Abstract - Tidal Datums are utilized in the determination of littoral boundaries differentiating state owned lowlands and privately owned uplands along the Texas Coastal shoreline. The collection of water level data for the purposes of establishing these datums became critical during a dispute between the State of Texas and a private land owner. The Texas General Land Office (TGLO in partnership with the CBI at TAMUCC began the installation of a network of water level data collection stations in 1989. The Texas Coastal Ocean Observation Network (TCOON) came into existence in 1991with the acceptance of a bill that identified the TCOON as a network that would collect data and information utilized for the management and protection of state resources along the Texas Coast. Since 1989, CBI has implemented numerous changes, upgrades, updates, and the installation of many new systems that now make up the TCOON. As of 2014, the TCOON consists of 30 data collection systems operating continuously to standards developed by the Center for Operational Oceanographic Products and Services (CO-OPS), a division of the National Oceanic and Atmospheric Administrations (NOAA) National Ocean Service (NOS).

With the initial installation, CBI began the development of a database that is capable of collecting and archiving the data collected by the stations that make up the TCOON. Since the early 1990's, the database and related software has grown into CBI's PHAROS. The network and database operate in concert, both performing specific functions required with the primary purpose of the production of Water Level Datum's and providing coastal information to a broad range of users. All TCOON stations are installed, operated, and maintained following the CO-OPS standards. Related data processing software are designed as well to follow related standards and processes. The Systems are installed remotely and the data is transferred back to the CBI and the PHAROS via automated processes relying on various communication channels, including satellite transmission and IP modems. The database is then tasked with various functions to include archival, processing, and dissemination of the data. Using PHAROS automated capabilities; the CBI processes water level data and produces Tidal Datums. The capabilities of PHAROS are extensive, performing internal functions such as collection and archival of all data collected in its raw format, QA/QC of the datasets to identify and remove erroneous data, archival of all relevant information about the data collection system, its components, systems, and operation.

The end result of these activities is user friendly access to high quality time series of Environmental and Oceanographic data sets with data lengths now over 20 years for several locations. Along with the sponsors of the network, the general public, educators, researchers, industry, and the recreational user all have access to the data. Specific products can and are produced for a fee should a user require data in a specific format or via specific medium other that those provided. The CBI has produced Web and Mobile Apps to support specific industry requests, and provide data to researchers in addition to internal use of the data for research in modeling and other environmental applications. The TCOON, PHAROS, and the primary components of each system are discussed within this publication.

Keywords—TCOON, NOAA, NOS, CO-OPS, TGLO, Datums, Water Level, Data, Monitoring

I. Introduction

The collection of federally approved water level data along the Texas Coast is critical for establishing Datums that can be used to determine littoral boundaries. In 1989, the CBI was contacted by the Texas General Land Office (TGLO) concerning the need for Tidal Datums in an area of the Texas Coast known as the Lower Laguna Madre. More specifically, the ownership of an area locally known as the El Toro Mud Flats *(Fig. 1)* was in question. The adjacent land owner was claiming ownership which had previously resided with the State of Texas. Upon filing of a lawsuit questioning the littoral boundary between state owned submerged land and privately owned uplands, the TGLO requested assistance from NOS, asking for the production of datums along the Texas Coast and the Lower Laguna Madre in order to resolve the issue. Due to lack of resources, the NOS was not able to meet the needs of the State directly but did offer training and support to a local agency should the state choose to undertake the necessary data collection and processing.

CBI began in 1989 with the installation of the first two (2) data collection with assistance from NOS: 001 CCNAS and 002 T-Head, both in Corpus Christi Bay. In 1990, CBI installed an additional 5 stations from Corpus Christi Bay south into the Laguna Madre. By 1992, the TCOON had grown to 42 DCPs installed along the Texas Coast. Technology transfer between NOS CO-OPS and CBI has been continuous since that time.

The authors wish to acknowledge the sponsors of the TCOON, the Texas General Land Office, Texas Water Development Board, US Army Corps of Engineers-Galveston District and the collaboration of NOAA in the operation of the TCOON.

Fig.1. El Toro Mudflats, South Texas Coast

In 1991, the Texas State Legislature approved a bill adding the Texas Coastal Ocean Observation Network (TCOON) (F*ig. 2*) to the state's Natural Resources Code establishing the TCOON as a source of data and information supporting scientific study, planning, and resource management for the State of Texas. Currently, the TCOON consists of 30 water level and meteorological data collection platforms (DCP) installed along the Texas Coast from South Padre Island Texas to the Texas/Louisiana boarder and the Sabine River. All DCPs are installed and operated following Standard Operating Procedures established by NOS and the Center for Operational Oceanographic Products and Services (CO-OPS). Over the years, and utilizing additional resources, CBI has updated and hardened all TCOON stations thus reducing the possibility of damage caused by hurricanes and tropical storms. Several of the TCOON stations are located on "Sentinel of the Coast" single-pile instrumentation platforms (SPIPs) rated to withstand the effects of a category 4 hurricane. Since the inception of the TCOON in 1990 and the formalization of the network in 1991, additional agencies have joined the network sponsor list providing funding towards the installation, maintenance, operation, and management of the network. The Texas Water Development Board (TWDB) joined the sponsor group identifying the need for water level and meteorological data in support of bay circulation studies and other water related studies and activities along the Texas Gulf Coast. In 1994, the U. S. Army Corps of Engineers (USACE) acknowledged the importance and relevance of federally approved data and its use in support of dredge operations and maintenance of navigable channels along the Texas Gulf Coast. The information collected by the TCOON stations and the datums produced are a great resource in support of maintenance and operations of the USACE Navigation Branch.

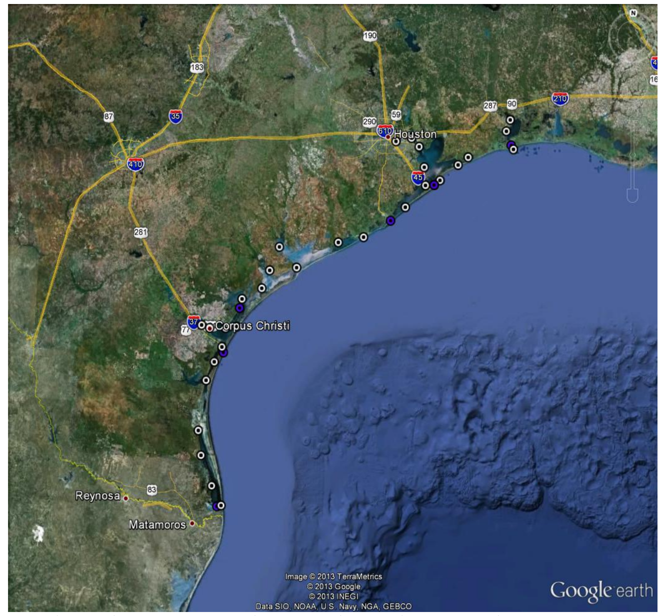

Fig.2. The Texas Coastal Ocean Observation Network

II. The Network

A. The Texas Coastal Ocean Observation Network stations

The 30 active TCOON stations stretch from the southernmost tip of Texas, near the border with Mexico, to the Texas Louisiana border at Sabine Pass. During the fall of 2014, CBI will be installing four additional SPIP data collection stations along the Texas Coast. Figure 3 presents a list of all presently active TCOON stations.

B. Site selection

The location for each data collection station is sponsor driven. CBI personnel meet annually with network sponsors and discuss each agency's upcoming project requirements or "Hot Spots" that will require additional information. The sponsor group currently includes several state and federal agencies to include the TGLO providing funding and overall management of the TCOON, TWDB, and the USACE-Galveston Division. In addition, NOAA's CO-OPS is considered a partner of the network through a Memorandum of Agreement with the TGLO. Each agency has roles and responsibilities in support of the TCOON's maintenance and operation and the products produced as a result of the data collection.

THE NETWORK:

ACCESS FULL-SCREEN MAP

Map | List

DNR ID	Abbr.	Name	Field ID	Location
003	RINCON	Rincon del San Jose	87778121	26.8015,-97.4706 gps
005	PACKER	Packery Channel	87757921	27.63457,-97.23696 gps
006	INGLES	Ingleside	87752831	27.8217,-97.2040 est
008	USSLEX	USS Lexington	87752961	27.8143,-97.3984 gps
009	PTARAN	Port Aransas	87752371	27.83975,-97.07274
013	BIRDIS	S. Bird Island	87761391	27.4847,-97.3181 gps
017	PTMANS	Port Mansfield	87784901	26.5595,-97.4247 gps
031	SEADRI	Seadrift	87730371	28.4073,-96.7122 gps
033	PTLAVA	Port Lavaca	87732591	28.6404,-96.6097 gps
036	COPANO	Copano Bay	87745131	28.114436,-97.024389 gps
051	SPICGS	S. Padre Island Coast Guard Sta.	87797481	26.0726,-97.1671 gps
057	PTOCON	Port O'Connor	87737011	28.44603,-96.39607 est
068	BAFFIN	Baffin Bay	87766041	27.29702,-97.40491
126	TEXASP	Texas Point	87708221	29.67833,-93.83722
181	REALPN	Realitos Peninsula	87792801	26.26223,-97.28537
185	NUEBAY	Nueces Bay	87752441	27.83275,-97.4859583
198	HILAND	High Island ICWW	87708081	29.594792,-94.390325
200	SRGENT	Sargent	87729851	28.771633,-95.616839
201	MATCIT	Matagorda City	87731461	28.710072,-95.914075
202	ARANWR	Aransas Wildlife Refuge	87742301	28.227733,-96.796583
248	GALVRR	Galveston Railroad Bridge	87714861	29.302336,-94.896493
255	SANLUT	San Luis Pass Temporary	87719723	29.07570,-95.12257 est
503	MORGAN	Morgans Point	87706131	29.681969,-94.984664 est
504	RAINBO	Rainbow Bridge	87705201	29.981119,-93.884622 gps
507	EAGLEP	Eagle Point	87710131	29.48131,-94.91721
513	MANCHE	Manchester Houston	87707771	29.726239,-95.265808 gps
517	LYNCHB	Lynchburg	87707331	29.7650,-95.0783 est
518	ROLLOV	Rollover Pass	87709711	29.5150,-94.5133 est
524	PTARTH	Port Arthur	87704751	29.8672,-93.9310 gps
526	SANLUI	San Luis Pass	87719721	29.07570,-95.12257 gps
529	NJETTY	Galveston Entrance Channel, North Jetty	87713411	29.358201,-94.725978 gps
014	BOBHAL	Bob Hall Pier	87758701	27.58102,-97.21646 gps
015	ROCKPO	Rockport	87747701	28.0243,-97.0478 gps
016	SABINE	Sabine Pass	87705701	29.7298,-93.8709 gps
018	PTISAB	Port Isabel	87797701	26.0612,-97.2154 gps
022	PIER21	Galveston Pier 21	87714501	29.3133,-94.7867 est
152	USCGFP	USCG Freeport	87724471	28.94331,-95.3025

Count: 37

TCOON IS PART OF THE TEXAS INTEGRATED OCEAN OBSERVING SYSTEM (TIOOS PLAN)

Fig.3. Active TCOON stations

C. Specific Station Location

Once an area has been identified by the sponsor group and the requirements of the area are known, CBI personnel in consultation with CO-OPS perform a site reconnaissance to determine the best location for the DCP. Based on this reconnaissance, CBI determines if there are any suitable docks, bulkheads, piers, wharfs, or any other "structure of opportunity" that can be utilized in support of the data collection equipment and sensors. Each station is different as there are several key factors to consider when identifying a location for the successful collection of water level and meteorological data. These include but are not limited to the following:

1. Water body – The DCP should be installed such that the data collected are representative of the intended water body. If the targeted water body is a bay or estuary, the DCP should not be installed in an enclosed marina or at the end of a channel leading away from the water body.
2. Water Depth - The DCP should be installed in a location such that the equipment will never be in a dry state. Locations that will never experience a "no water" situation, either during the normal Semi Diurnal or Diurnal tide cycle, seasonal variation, or extreme events such as strong frontal passage, Tropical Storm or Hurricane Passage.
3. Structure – The ability to collect continuous data throughout all events is critical. The successful collection of continuous data is largely dependent on the structure supporting the associated data collection equipment. Structural integrity as well as elevation above the water surface are critical components for the continuous collection of high quality data during high-energy events. The majority of the TCOON stations are installed on 4 pile platforms which vary in size from 6'x6' to 10'x10' square structures. The TCOON also utilizes NOAA CO-OPS designed SPIPs with instrumentation platforms 32' above mean sea level. CBI is in the process of installing four (4) additional SPIPs along the Texas Coast.
4. Proximity to land – Proximity to a relatively large land mass elevated as much as possible is important for the installation and recovery of survey benchmarks. Water level sensor elevation is checked and verified annually through a National Geodetic Survey (NGS) Second Order, Class 1 level tie to benchmarks installed in the vicinity of each DCP.
5. Control – Every DCP has an associated number of survey benchmarks installed supporting verification and maintenance of the water level sensor elevation. Water level datums are established relative to Station Datum which is a local elevation established during installation. The number of benchmarks associated with each DCP installation is based on criteria established by NOS CO-OPS for water level stations. TCOON stations were initially installed as secondary data collection stations requiring 5 benchmarks, however, with the length of time series recovered by many of the existing stations, CBI is working on increasing the number of benchmarks at each location to 10. The increased number of benchmarks increases the resiliency of the benchmark network and the ability to recover datums in the future.

D. Configuration

Since its inception, CBI personnel have been trained following the Standard Operating Procedures established by NOAA CO-OPS [1]. By design, and because the data and datums established are used to establish littoral boundaries, all TCOON stations are installed, operated, and repaired following the Standard Operating procedures and processes found at the link provided above.

1. The Equipment – (Fig. 4)

a) Primary DCP – Sutron NOS G3

b) Redundant DCP – Sutron XPert Dark

c) 48"x60"x15" NEMA 4X enclosure

d) I P Antennas

e) Satellite Antenna – Vitel V2TH

f) Solar Panel

g) Air Temp Sensor Housing

2. The Sensors

a) Water Level – All TCOON stations are configured with 1 primary and 1 redundant water level sensor.

   I. Primary Sensor- Aquatrak 3000-XRC-4 model 3000 Acoustic Transducer with 4100-MC-2 controller.

   II. Redundant Sensor-Druck PDCR 5030 Pressure Transducer with Design Analysis H-3551 Smart Gas System.

b) Wind – RM Young 05103

c) Air Temperature – YSI 44032 Thermistor

d) Atmospheric Pressure - Sutron Accubar® 5600-0120-3 Barometric Pressure Sensor

E. Sensors Data Processing [2]

1. Primary Water Level Data

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)

2. Redundant Water Level Data

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.

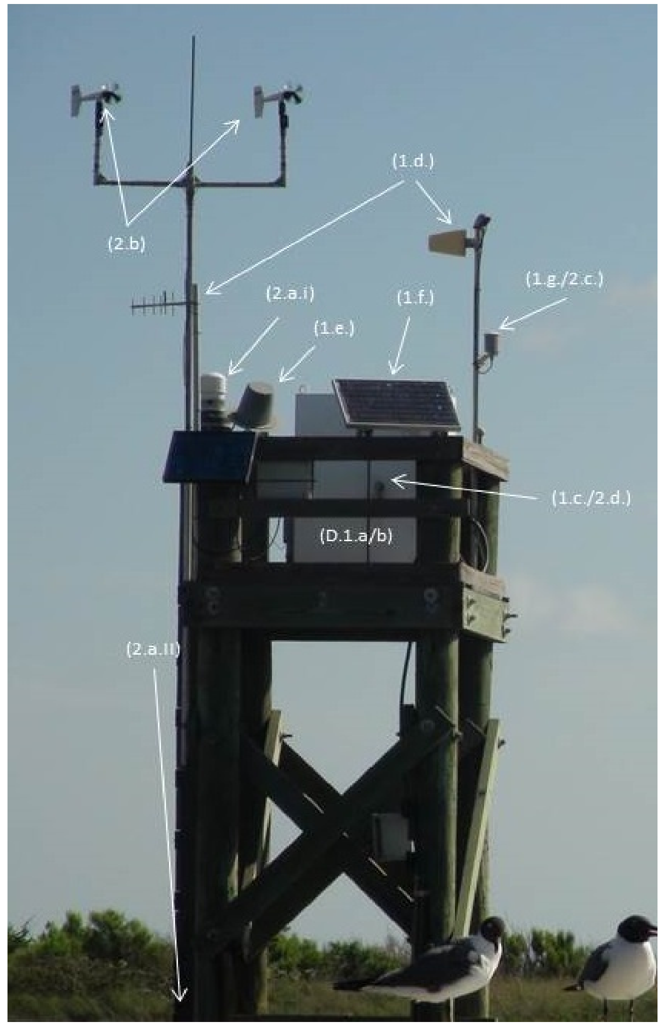

Fig.4. Typical hardened station

3. Wind Data –

a) Wind Speed-2 minute scalar average of 1 second wind speed measurements collected prior to each tenth hour.

b) Wind Direction-2 minute unit vector average of wind direction collected prior to each tenth hour.

c) Wind Gust-The maximum 5 second moving scalar average of wind speed that occurred during the previous 6 minutes for PORTS® stations.

4. *Air Temperature* – 21 six-second samples collected over a 2 minute period and are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites.

5. *Atmospheric Pressure* (not shown in Fig.4.)– 21 six-second samples collected over a 2 minute period and are averaged for each measurement. The samples are collected starting one minute prior to each tenth hour at PORTS® sites.

In 2008, Hurricane Ike made landfall along the Texas Coast near Galveston. Storm surge, waves, and wind damaged or destroyed 5 TCOON data collection stations. As a result of the loss and damage, and with funding provided by the sponsors, CBI installed two SPIPs (Fig 5). In 2011, CBI installed SPIPs at the Galveston Entrance Channel North Jetty and Texas Point, on the Texas-Louisiana border. In 2012, CBI received a Coastal Impact Assistance Grant Award that provides for the installation of 4 additional Sentinel of the Coast structures along the Texas Coast. These new SPIPs will be installed near the Jetties at Surfside (Freeport), Matagorda Ship Channel, Port Aransas, and South Padre Island, Texas. Figure 6 depicts other data collection installations along the Texas Coast.

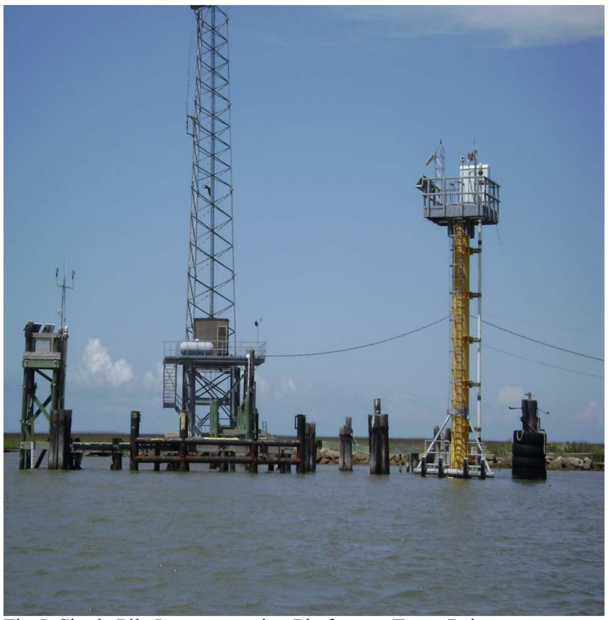

Fig.5. Single Pile Instrumentation Platform at Texas Point.

Fig.6. Installations along the Texas Gulf Coast

The software system known as PHAROS is used for data collection, archival, processing, and dissemination of all products produced from the TCOON. PHAROS began with basic data collection and archival processes. Over the past 20+ years PHAROS has evolved into a multidimensional system used for all aspects of data collection, processing, and dissemination as well as archival of all pertinent station information. All data collection stations included in the TCOON have separate web pages that contain all pertinent information, key attributes for identification and data decoding, site visit and elevation history, water level datums, and data retrieval systems. All station pages are set up with the same capabilities which are discussed in more detail below.

A. *Data Collection* - Data are collected by automated processes within the PHAROS software system. A computer at CBI downloads the latest satellite transmissions from each TCOON station directly from NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) every 6 minutes. As a redundant means of data collection, the systems at CBI also contact each station directly every 6 minutes via a network of Internet Protocol Modems (IP Modem) installed at each station, thus increasing the data availability from all stations.

B. *Archival*- As the data are collected, they are aggregated into daily files per station, per data collection method. Thus, the raw data collected via IP Modem or via NESDIS for a given station for a given day can be found in a single file. Each file is given a name based on the name of the station, the year and day of the year for which the data was collected, and the format of the data within the file. All source records from instruments are kept and archived in their original format, and these serve as the basis for all "derived" products. All changes (adjustments and deletions) are performed as annotations to the data sets without modifying the source data.

C. *Processing*- Once archived, the individual data files are parsed based on their particular data format and a new data set in a common format so that the data may be entered into a database within the PHAROS software system. Figures 7 and 8 show samples of the raw data input and Figure 9 is a sample of the common format used by PHAROS.

```
NOS 87737011 07/04/2014 00:00:00
A1 1       4.966    0.004        4      31.2      30.7
C1 3         6.6      149      7.9
D1 4        28.8
E1 5        28.2
F1 6      1017.5
L1 <        13.3
B1 2       0.408    0.002        0
C2 3         6.6      151      8.1
L2 <        12.9
DAT     8.425
SNS    -0.102

REPORT COMPLETE
```

Fig.7. Sample data direct from station

```
3371660814185000201G39-0NN209EUB00087"P87737011BCi
~Z@@v0hXW1AMg@DADyDt>AMj3ACBIAP<BG2@FY@B@"@FX3AEBK
AR<BC hTW{SCYCYCZCZC[CY
```


Fig.8.Sample satellite data

```
057 2014185+0000 wgt 79 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wdr 149 NA NA NA NA NA NA NA NA NA
057 2014185+0000 pwl 3561 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wsd2 66 NA NA NA NA NA NA NA NA NA
057 2014185+0000 out 4 NA NA NA NA NA NA NA NA NA
057 2014185+0000 bat 133 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wgt2 81 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wtp 282 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wdr2 151 NA NA NA NA NA NA NA NA NA
057 2014185+0000 bat2 129 NA NA NA NA NA NA NA NA NA
057 2014185+0000 wsd 66 NA NA NA NA NA NA NA NA NA
057 2014185+0000 sig 4 NA NA NA NA NA NA NA NA NA
057 2014185+0000 atp 288 NA NA NA NA NA NA NA NA NA
057 2014185+0000 clb 307 NA NA NA NA NA NA NA NA NA
057 2014185+0000 cla 312 NA NA NA NA NA NA NA NA NA
057 2014185+0000 bpr 10175 NA NA NA NA NA NA NA NA NA
057 2014185+0000 bwl 408 NA NA NA NA NA NA NA NA NA
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Fig.9.Formatted data decoded

D. *QA/QC*- The PHAROS environmental software system runs automated processes that examine data collected from every station. Errors discovered by these automated QA/QC systems are logged so that CBI personnel can take corrective action. To provide further quality control, each business morning CBI personnel perform a visual inspection of the recently retrieved data via a web interface that shows graphs of the most recent data. These graphs usually include: primary water level; backup water level; standard deviation; wind speed; wind gust; wind direction; stilling well calibration temperatures, air, and water temperatures; atmospheric pressure; and battery power. Each graph is inspected for missing data, anomalies, or equipment malfunctions. Any gaps or other problems are noted via "quality-control messages" posted on each individual station QC page. A summary of these quality-control messages are then sent to the entire CBI staff via electronic mail upon completion of the QA/QC process. CBI Field Operations establishes daily and weekly work plans accordingly.

III. STATION INFORMATION

Via a web interface, users have access to multiple electronic documents pertaining to different aspects of the station including the following:

A. *Observations* – Fig. 10 provides the official station name and other pertinent information such as coordinates, NOAA Chart section, and USGS Quad Sheet name. Observations from the previous 24 hour period are provided along with a link to a diagram depicting the most recent water level observation relative to the datums. Users can view various images relating to the station and view the station location on an interactive map for reference.

B. *Datums* – When a station has collected sufficient water level data, datums are computed. The Datums section contains the status of the datums, the date the datums were computed, the length of observational data used in the computation, the NOAA CO-OPS station used as control, and link to a graphic indicating the relationship between the datums. Fig. 11 is an example of PHAROS selecting the high and low waters used to generate the Tidal Datums. This process is initiated after the month is complete in order to produce the monthly means required for datums processing. PHAROS selects the Highest and Lowest water level points for each day following algorithms produced by CBI based on consultation with NOAA CO-OPS personnel. The monthly means are used during the production of tidal datums.

LATEST OBSERVATIONS

Series	Metric	English	Marine	Observed at
Primary Water Level (rel. to STND) (click here for diagram)	0.939 m	3.08 ft	3.08 ft	Jul 10 16:06 CDT 00h08m ago
Primary Water Level (rel. to MSL) (click here for diagram)	-0.026 m	-0.09 ft	-0.09 ft	Jul 10 16:06 CDT 00h08m ago
Backup Water Level	0.002 m	0.01 ft	0.01 ft	Jul 10 16:06 CDT 00h08m ago
Air Temperature	23.3 °C	73.9 °F	73.9 °F	Jul 10 16:06 CDT 00h08m ago
Water Temperature	28.6 °C	83.5 °F	83.5 °F	Jul 10 16:06 CDT 00h08m ago
Wind Speed	8.500 m/s	19.0 mph	16.5 knots	Jul 10 16:06 CDT 00h08m ago
Wind Gusts	12.200 m/s	27.3 mph	23.7 knots	Jul 10 16:06 CDT 00h08m ago
Wind Direction	162 °	162 °	162 °	Jul 10 16:06 CDT 00h08m ago
Wind Speed B	8.400 m/s	18.8 mph	16.3 knots	Jul 10 16:06 CDT 00h08m ago
Wind Gusts B	12.200 m/s	27.3 mph	23.7 knots	Jul 10 16:06 CDT 00h08m ago

Fig.10. Observations

C. *Benchmarks* - Following NOAA CO-OPS SOP's, data collection stations are required to be serviced annually. Once per year, every TCOON station is visited for a comprehensive Annual Inspection (AI). One of the tasks required during the AI is the completion of elevation verification of the primary water level sensor. This is accomplished by the completion of a Second Order, Class 1 digital level loop following NGS Bluebook Standards through the benchmarks associated and described *(Fig. 12)* on the Benchmarks page for each water level station. Each level run is archived in PHAROS and posted on the benchmark page such that the variations in benchmark and primary water level sensor can be monitored. A complete level history of all benchmarks and Primary Water Level Sensor elevation is maintained and archived.

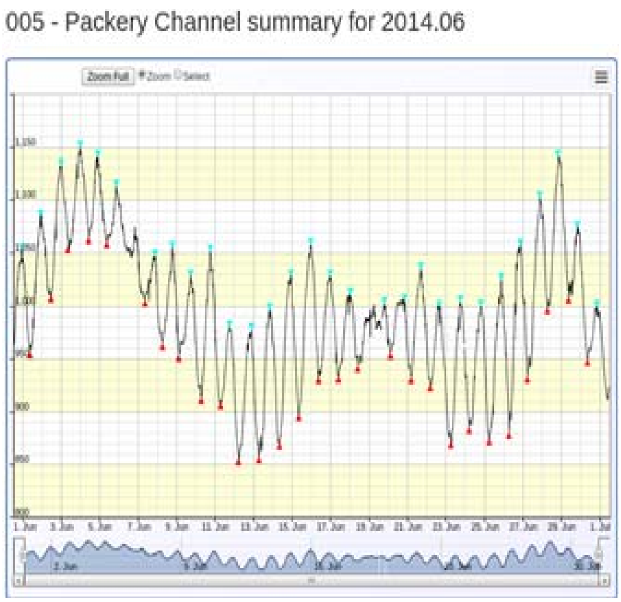


Fig.11. Automated high and low water picks

BENCH MARK DESCRIPTIONS

BENCH MARK STAMPING: 5792 F 2006
MONUMENTATION: 49=Stainless Steel Rod
AGENCY:
Description will be added at a later date.

BENCH MARK STAMPING: 5792 E 1988
MONUMENTATION: Tidal Station Disk
AGENCY:
To reach bench mark 5792 E 1988 go 22.9 km (14.20 mi) southeasterly along State Highway 358 and Park Road 22 from the junction of State Highway 286 in Corpus Christi, thence 0.6 km (0.35 mi) westerly along the Intracoastal Waterway turn around, in top of and 1.3 m (4.3 ft) north of the south end of the concrete pile cap of the 15th pier west of the east abutment of the JFK causeway bridge spanning the Intracoastal Waterway, 32.2 m (105.6 ft) north of the center of the south turn around, 5.8 m (19.0 ft) south of the road center, 1.0 m (3.3 ft) above the level of the road, and 0.9 m (3.0 ft) west of a witness post. The bench mark is a survey disk. The GPS coordinates at the mark are 27 deg 38�01.6� N, 097 deg 14� 12.4� W.

Fig.12. Benchmark Description

D. *Site Visits*-Each time a station is visited for regularly scheduled or emergency maintenance, a "site visit report" is generated detailing the particulars of the visit. These records indicate what work was accomplished at the station whether it was a cursory inspection or a complete AI. Having these site visit reports provides verification as to why data may be missing and more importantly, what was done to resolve any issues in order to resume data collection. This is particularly important given the time scales over which data must be collected in order to establish tidal datums, which could range from months to years.

E. *Data* - Within the data section, the individual parameters collected at each station may be queried by specifying the various parameters available for each station. Some of the more commonly used parameters are:

1. Station
2. Data series
3. Dates or range of dates
4. Data Format
5. Units
6. Relative elevation

F. *Maps* - This section (Fig. 13) allows the user to view the station selected on an interactive Google map. The station selected is identified along with the location of other data collection systems maintained by CBI.

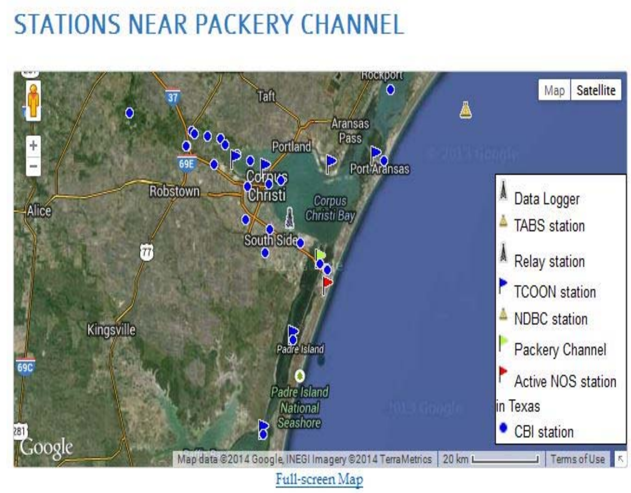


Fig.13. Station Map

G. *Forecasts* - This section is relatively new and provides water level predictions for the respective station (Fig. 14). The predictions consist of the Harmonic Predicted Water Level (blue), a persistence model (green), and a neural network (orange) following the most recent measured water level recorded. CBI utilizes an Automated Neural Network and imports data from other sources along with the Harmonic predicted and actual water level and produces predicted water levels out to 48 hours. Past model performance for 12, 24 and 48 hour predictions is provided by a link above the forecast graph.

H. Data Availability – This section provides a list of the data series available for the selected station and the time period for which the data are available.

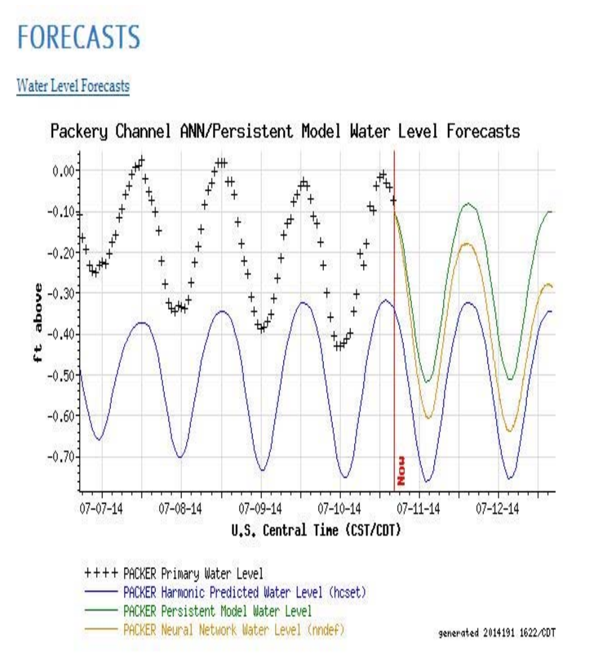


Fig.14. Past water level measurements and predictions to 48 hours.

ELEVATIONS

NAVD 88 elevation updated 5/2013, stated accuracy is 0.017m

Status	=	Published
Date Computed	=	06.26.2012
Length of Observations	=	60
Time Period	=	1.2006-12.2010
Control Station	=	015 (1983-2001)
Accuracy	=	unstated

Elevations of datums above station datum:
(click here for diagram)

	Meters	Feet
Mean Higher High Water (MHHW)	1.019	3.34
Mean High Water (MHW)	1.018	3.34
Mean Tide Level (MTL)	0.963	3.16
Mean Sea Level (MSL)	0.965	3.17
Mean Low Water (MLW)	0.909	2.98
Mean Lower Low Water (MLLW)	0.908	2.98
North American Vertical Datum 1988 (NAVD88)	0.748	2.45
Station Datum (STND)	0.000	0.00
Mean Tide Range (Mn)	0.109	0.36
Great Diurnal Range (Gt)	0.110	0.36
DHQ (DHQ)	0.001	0.00
DLQ (DLQ)	0.001	0.00

Fig.15. Example the information presented in a datum page.

IV. Products

The TCOON provides information to a broad range of users, each with different needs and access modes, personal computers, tablets, or smart phones.

A primary use of the TCOON data, since its inception, has been the establishment of accurate tidal or water level datums. All related computations and processing follow the guidelines established by NOAA CO-OPS for use in the production of datums. More detailed information regarding the computation of datums at CBI can be found in another paper in the same proceedings [3]. The resulting information is presented for all TCOON stations in datums page (Fig. 15). Every component of the TCOON data collection, documentation and processing system, including datums computations are designed in part to facilitate review and examination by the legal profession as property or boundary disputes often are resolved by a Court of Law.

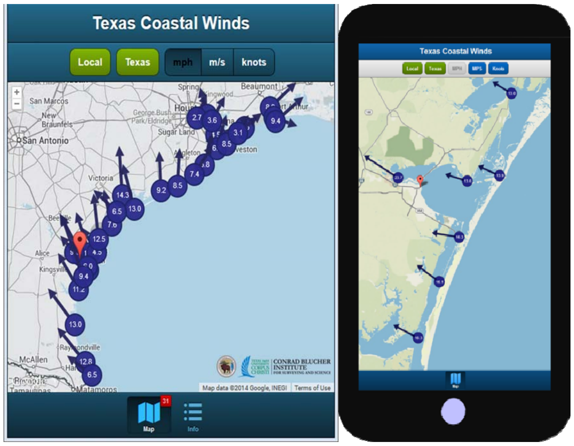
Other users such as scientists and coastal engineers often require multiple time series data from a single station or a single time series from multiple stations. For these users, providing metadata is important for documentation of the information source. For general access to the data, CBI has developed over the past 20 years a query system allowing selecting any combination of stations and time series with several options for the presentation and the format of the output.

Professional users including emergency and environmental managers, surveyors, and ship and barge captains often need access to the data while in the field, from a tablet or a smartphone. They require fast and easy access to the information, particularly in emergency and dynamic operation situations. Recreational users including beach goers, sailors, surfers, windsurfers are typically interested in only one type of data over a limited area or multiple measurements for one location. Additionally recreational users prefer a graphically pleasing and intuitive format and can find scientifically accepted presentation methods, such as graphs with axes, cumbersome and unnecessary.

CBI is developing user-focused apps compatible with today's smaller, mobile devices that can quickly provide data with one or two touches or clicks. Given that modern mobile devices generally have geolocation services, the apps use this information to provide location-based conditions or predictions.

An example is the recently released app "Texas Coastal Winds". The app presents wind readings along the Texas coast. Arrows, with length proportional to the latest measured wind speeds, indicate wind directions. The wind speed is further presented within a circle indicating the location of the measurement. The Texas Coastal Winds app (Fig.17.) can be accessed from a computer or smartphone or users can freely download the app from the Google Play store. Geolocation services allow users to view nearby wind speed and direction.

These data are updated every six minutes and are available in miles per hour, knots, and meters per second.



(a) (b)

Fig.17. Access to wind speeds and directions using the Texas Coastal Winds app as a web app (a) or trhough a native mobile app (b).

Another app under development at CBI provides significant wave height, typical wave period, water currents, water level, temperatures and winds on the Gulf of Mexico, at Bob Hall Pier, near Corpus Christi, Texas. This latest app is designed for recreational users such as surfers, beach goers, and fishermen who are interested in easy access to all the latest available information for one location on one intuitive screen.

While accurate near real-time measurements and historic time series provide essential information, predictive information can be invaluable to plan activities, in particular during extreme weather events. Over the past 14 years CBI has developed and implemented predictive models based on artificial intelligence techniques [4]. This modeling method was selected and implemented because of its ability to directly capture nonlinear relationships and its computational efficiency. Once the models are trained, the prediction is a simple matrix operation and is performed on-demand. This technique allows utilization of the latest information provided by the observing network. While the method provides only "point predictions" for the station location, users who are familiar with past measurements at that location, the predictions provide an invaluable extension of the measurements. The method was initially implemented for the prediction of water levels at several locations along the Texas coast [5,6]. Fig. 14 in section III provides example predictions.

Other implemented products include a water temperature prediction model [7,8]. In South Texas, the Gulf Intracoastal Waterway traverses shallow lagoons such as the Laguna Madre. Every few years, unusually strong frontal passages can lead to rapid water temperature declines resulting in damage to the ecosystem including fish and turtle populations. A cooperation between the Gulf Intracoastal Canal Association (GICA), the Coastal Conservation Association, Texas, local and state agencies, and the CBI led to an agreement for GICA members to voluntarily interrupt navigation during such events. An artificial intelligence approach was used to design and implement a predictive model in support of this cooperation [7]. The output of the prediction model ahead of a cold water event in February 2011 is presented in Fig. 18. Based on these predictions, navigation in the Intracoastal Waterway was interrupted from February 3, 6:00AM to February 5, 6:00PM. The performance of the model for 48 hour predictions for the same period is presented in Fig. 19. During these three days close to 1,000 green sea turtles were rescued. Fewer turtles were rescued during subsequent cold water events, February 10-13, 2011. In total, about 1,400 turtles were rescued in early February 2011 with the majority during the interruption of navigation.

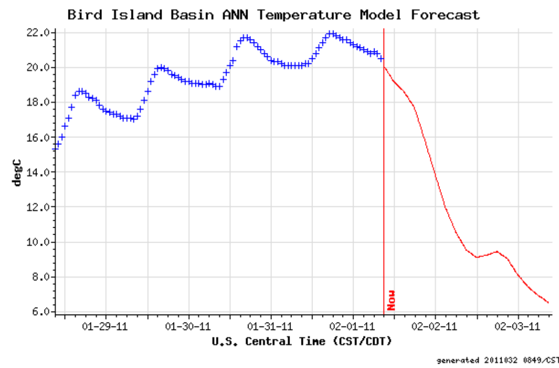


Fig. 18. Water temperature predictions for the TCOON station of Bird Island ahead of the passage of a strong cold front in February 2011. Blue crosses represent measurements; the red line represents predictions.

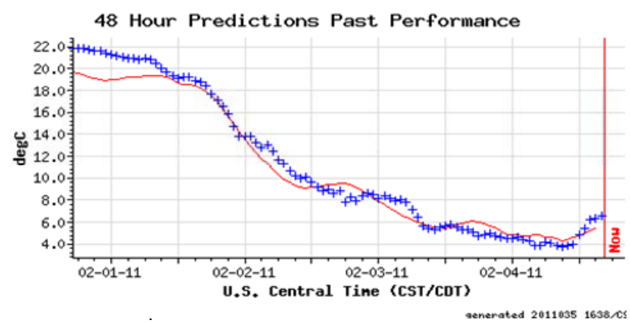


Fig 19. Performance of the model for the same cold water event as presented in Fig. 16 for 48 hour predictions.

V. Conclusion

The cooperative spirit among coastal stakeholders has enabled the installation of systems that have had a tremendous impact on the residents of the State of Texas. What began as a network installed for a single purpose, has grown to support a vast number of activities and projects along the Texas coast. The resulting data and products have made the network invaluable to the management of Texas coastal resources and the protection of the environment.

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