NECESSITY OF IMPROVING WATER LEVEL TIME SERIES DATA ACCURACY FROM NON-VENTED INSTRUMENTATION THROUGH POST-PROCESSING OF BAROMETERIC PRESSURE EFFECTS

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BACKGROUND

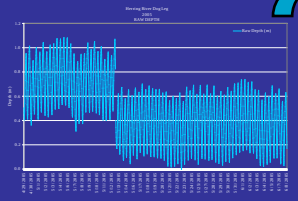
The Cape Cod National Seashore (CCNS) collects data on water quality and quantity in near real time to assess environmental impact and change at representative locations throughout the park. Water level has been a key parameter measured since 2005 for tracking system responses to the projected restoration of tidal exchange. Water level data collected from our sites to date had not included any compensation for changes in barometric pressure during deployments. Cape Cod National Seashore is undertaking the largest restoration project in the Gulf of Maine (~11oo acres) located in the Herring River in Wellfleet, MA. There is significant local concern of the potential affects of flooding associated with the restoration on nearby properties especially coupled with the effects of an increase in sea level rise. It was essential to gain the most accurate water level data set that we could to make the best management decisions possible. In May 2009 a workshop was held to introduce a new and more accurate way of calibrating a non-vented YSI instrument as a first step in achieving this higher level of accuracy. Several federal and state agencies, as well as private scientific institutions attended and we found that no one that used non-vented instruments had been compensating for barometric pressure. As a result, a simple procedure was developed to post process the depth data and remove the barometric pressure affects from past, present and future data sets. Our work with restricted systems at Cape Cod National Seashore has allowed us to realize the importance that barometric pressure has on our systems. It is important for others monitoring tidal signals to understand how these pressure differences will affect the signals that they are analyzing at their specific site locations around the planet.

Herring River Restoration Site

METHODS

Water level has been a key parameter measured at Cape Cod National Seashore since 2005 for tracking system response to the projected restoration of tidal exchange. High temporal resolution salinity, temperature, dissolved oxygen and turbidity data have been monitored by a 6-Series non-vented YSI sonde to document tide-restricted conditions for ongoing modeling, planning, and sediment transport work. There are two steps that one should take in achieving the most accurate water level data:

STEP 1: CONVERT RAW DEPTH TO OFFSET DEPTH (see handout)



NOTE: All readings are +/-0.018 m (0.06 ft) -- non-vented, shallow depth tolerance

Pressure mm Hg	Offset meter	Offset feet	Pressure mm Hg	Offset meter	Offset feet	Pressure mm Hg	Offset meter	Offset feet
708	-0.707	-2.320	758	-0.027	-0.089	808	0.653	2.142
709	-0.693	-2.274	759	-0.014	-0.046	809	0.666	2.185
710	-0.680	-2.231	760	0.000	0.000	810	0.680	2.231
711	-0.666	-2.185	761	0.014	0.046	811	0.693	2.274
712	-0.653	-2.142	762	0.027	0.089	812	0.707	2.320
713	-0.639	-2.097	763	0.041	0.135	813	0.721	2.366

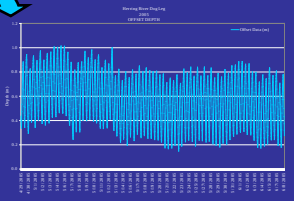


Figure 1. A barometric pressure Offset Table (middle) was used in order to establish a zero reference point of 760 mm Hg. It was generated under the assumption that 1 decibar of atmospheric change was equivalent to 1 centimeter of water level change. The graphs above illustrate how this table allows for data collected throughout a season to be appended seamlessly from one deployment to another.

STEP 2: DEPTH COMPENSATION (see CD handout)

WHAT YOU NEED:

- Water Temperature (°C)
- Salinity (ppt)
- Raw Depth (ft)
- Uncorrected Barometric Pressure (mmHg)
- Barometric Pressure (mmHg) at calibration

BAROMETER AT DEPTH CALIBRATION, MM HG =					760
RAW INSTRUMENT DATA					
Date M/D/Y	Time hh:mm:ss	TEMP C	SAL PPT	DEPTH FT	BARO MMHG
4/29/2005	10:31:00	11.77	0.31	1.4305	761
4/29/2005	11:01:00	12.37	0.33	1.2927	761
4/29/2005	11:31:00	13.06	0.36	1.1877	761
4/29/2005	12:01:00	13.73	0.39	1.109	761

WHY YOU NEED IT:

↑ Temperature ↓ Water Density

DENSITY CALCULATIONS				
RHO	A	B	C	RHOS
999.552	0.785702	-0.004749	0.000483	999.795
999.483	0.784162	-0.004712	0.000483	999.741
999.398	0.782436	-0.004671	0.000483	999.679
999.310	0.780804	-0.004632	0.000483	999.614

↑ Salinity ↑ Water Density

RHO is water density in kg/m^3 as a function of temperature where T is temperature in °C
RHO = 1000(1 - (T+288.9414)/(508929.2*(T+68.12963))*(T-3.9863)^2)

RHOS is water density in kg/m^3 as a function of temperature and salinity where S is salinity in g/kg or ppt
RHOS = RHO + AS + BS^(3/2) + CS^2

A=8.24493E-1 - 4.0899E-3*T + 7.6438E-5*T^2 -8.2467E-7*T^3 + 5.3675E-9*T^4
B= -5.724E-3 + 1.0227E-4*T - 1.6546E-6*T^2
C=4.83E-04

Once the water density is calculated, a unique correction factor is calculated for each point. This correction factor can then be multiplied by the difference in barometric pressure at this point from the original calibration pressure.

CORRECTION	
CORR FACTOR	BARO CORR FT
0.04461416	-0.05523233
0.04461656	-0.05523530
0.04461932	-0.05523872
0.04462224	-0.05524233

FINAL DEPTH	DIFFERENCE
CORR DEPTH FT	DEPTH DIFF FT
1.375283674	0.055232326
1.237478704	0.055235296
1.132483277	0.055238723
1.05373567	0.05524233

The correction value for water level is then added or subtracted from the logged depth readings to result in a data set that has been compensated for temperature, salinity and barometric changes during the entire deployment. The final column ("DEPTH DIFF") was added to show the absolute value of the difference between the new calculated depth and the original raw depth.

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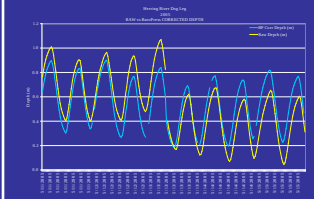
RESULTS

We looked at two stations representing 1) the diked river (Restricted) and 2) the river mouth (Unrestricted).

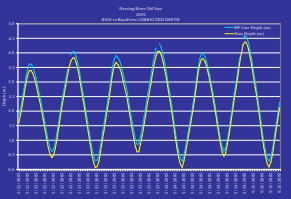
RESTRICTED SITE



Annual Averages

Temperature (°C)	17.6 (range: 8 to 30)
Salinity (ppt)	0.14 to 27
Tidal Range (m)	1.06
Accuracy Improvement	35%

UNRESTRICTED SITE



Annual Averages

Temperature (°C)	20.9 (range: 9 to 29)
Salinity (ppt)	21 to 34
Tidal Range (m)	4.42
Accuracy Improvement	20%

CONCLUSIONS

- Extensive work with large restoration projects within the Seashore has drawn us to conclude that calculating the most accurate depth measurements is essential.
- Simply using the offset tables will give you a high level of accuracy on the depth data that will set all of the raw data to the same reference point (760 mmHg). However, one can achieve an even higher level of accuracy by using the spreadsheet that was developed to post-process the raw data further.
- We found that the degree of improvement for the accuracy of depth data increases as the tidal range decreases.
- At times, centimeters of change can make a substantial difference in determining the best management practices when it concerns potential private property management, including flooding and salt water intrusion. It is also essential for gaining an understanding of what ecological impacts may occur.
- With the tools that we developed, we are able to infer more from these instruments about any impacts that sea level rise will have on our estuarine systems.

REFERENCES

McCutcheon, S.C., Martin, J.L, Barnwell, T.O. Jr. 1993. Water Quality in Maidment, D.R. (Editor). Handbook of Hydrology, McGraw-Hill, New York, NY (p. 11.3)
(citation taken from http://www.homepage.montana.edu/%7Euessc/esci432/ETlakecalculation.xls)