Tidal level predictions in reference to their datum, based on particular, selective sources

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ABSTRACT: The article presents differences between tidal datum of predictions taken from six official data sources (British, American and Caribbean comprising both paper and electronic form) for three pairs of ports located on the Atlantic coast of North, Central and South America. Two day of predictions represent spring and neap tide. It can be treated as a continuation, a deeper stage of works focused on tidal comparisons. The most essential trial of tidal datum unification for particular ports gives the more adequate base for comparison of Height Deviations from reference values (for particular ports: local or mean) and shows wide variety of the results.

1 INTRODUCTION

One of the most essential elements of safe navigation within limited waters and harbour approach phase is the under keel clearance, which is closely bound with (among others) the level of tide as a correcting factor to depths read from navigational chart directly. In some harbours the phenomenon of tides seems to be the only friend enabling safe call of a ship.

In that type situations it is unusually essential, to get exact prediction of changes of water level in strategic places. The safety of ship and crew depends on accuracy of tidal predictions in even degree with the possible quantity of cargo to transport, and also the time and speed of a vessel on stage of entry to/ exit from harbour and its adjacent waters.

2 LIST OF TIDAL DATA SOURCES

2.1 *British (worldwide):*

– Traditional (paper) – Admiralty Tide Tables [ATT, vol.2] issued annually [1];
– Electronic (PC software) – SHM (Simplified Harmonic Method of Tidal Prediction for Windows) DP560-Edition 2 (2004) [4] and ADMIRALTY TOTALTIDE DP550, Version 5 (2004); all the above mentioned released by the U.K. Hydrographic Office [5].

2.2 *American (worldwide):*

– Traditional (paper) – Tide Tables 2004 issued annually by International Marine, formerly by the NOS (National Ocean Service) – a division of the NOAA (National Oceanic and Atmospheric Administration) and accepted by the U.S.Coast Guard [2];
– Electronic – archive data to be found on official NOAA web site: www.noaa.org [6];

2.3 *Trinidadian (local):*

– Traditional (paper) –Tide Tables 2004 issued annually by Trinidad and Tobago Hydrographic Unit [3];

3 PORT SELECTION

Due to tidal sources available on board a vessel, where the origin of the researches took place, Six ports were chosen forming 3 geographical pairs, located as follows:

– SE Caribbean Sea: PORT OF SPAIN and Scarborough (Trinidad and Tobago);
– East Coast of South America: PUNTA LOYOLA and Bahia San Sebastian (Argentina);
– East Coast of the United States: CHARLESTON and Eastport (United States);

Every pair consists of PRIMARY and Secondary station within their geographical region.

Last two ports represent NOAA water-level observation stations, that offer additionally rich and

detailed database (available on Internet [6]) including for example 6 minute step tidal predictions. Such additional information allowed to:
- use them as a reliable and accurate background for other tidal data (predictions);
- compare Datum of predictions (heights) – next paragraph;

4 ASTRONOMICAL AND OTHER ONDITIONS

The term ‘astronomical’ covers all elements and factors creating the origin of tides. Actual Moon & Sun condition-as two the most important determinants of tides were specified for days used in predictions:

*20th December 2004: – Moon’s First quarter [on 18th]; – Moon on Equator (slightly N); – Moon between Apogee and Perigee; – Sun’s Winter Solstice [on 21st];

*27/28th December 2004: – Full Moon [on 26th]; – Moon farthest N of Equator [on 26th]; – Moon in perigee [on 27th]; – Sun’s Winter Solstice [on 21st];

However, one must be aware of particular weather conditions, such as: heavy rainfall, unusually low/high barometric pressure, strong on/offshore winds, etc. Their exact influence on tide (both time and height) is difficult to evaluate, but may be significant (!)

5 DATUM OF HEIGHTS PREDICTIONS

All predicted HEIGHTS originally represented as they usually refer to Chart Datum of the largest scale chart for the locality.

In case of the United States ports it is a level of MLLW (Mean Lower Low Water). For other ports mentioned here, it represents levels (Datum) oscillating between MLWS (Mean Low Water Springs) or MLLW (Mean Lower Low Water) and LAT (Lowest Astronomical Tide). Such a condition creates the primary problem of the water heights comparisons.

In a few cases-ports declared by tidal publications as Primary Stations- tidal datum (being Chart Datum at the same time) is clearly defined as MLLW, MLWS (American ports) or LAT (Port of Spain).

The Chart Datum for Secondary/Subordinative Stations remains unnamed (undesignated) among tide tables used here.

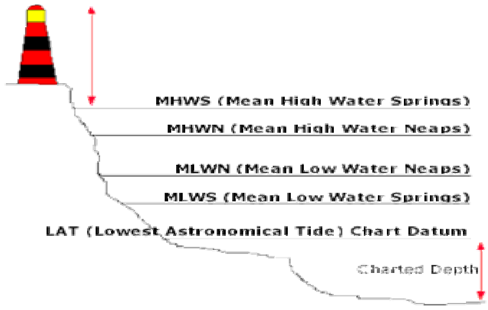

Fig. 1. The most popular Tidal Levels [6]

6 UNIFYING THE TIDAL DATUM

In order to compare tidal datum and water heights in consequence, the best solution would be to find their (particular tidal datum) relation to fix Ordnance Datum, an universal land levelling system for instance. Unfortunately, such an universal system does not exist, while majority of countries use their own levelling systems incomparable to each other.

For that reason it is essential to find another reference level, even such far from perfection as MSL (Mean Sea Level).

Table 1 presents the results of Chart Datum researches for the six ports mentioned here.

Table1. Datum of tide level predictions (heights)

Explanations: **P**-Primary Station, **S**-Secondary Station,

SOURCE / PLACE	BRITISH ADMIRALTY (m below MSL)	UNITED STATES -NOAA (m below MSL)	TRINIDADIAN HYDROGR UNIT (m below MSL)
Port of Spain	**LAT** (0,73m) P [MLLW-0,3]	(0,725m) S	**LAT** (0,73) P
Scarborough	(0,69m) S	(0,425m) S	(0,70) P
Punta Loyola	(6,2 m) P [LAT+0,6 =MLWS-1,6]	(6,20m) P	-
Bahia San Sebastian	(5,4 m) S	(5,40m) S	-
Charleston	**MLWS** (0,9m) P [LAT+0,4]	**MLLW** (0,85m) P	-
Eastport	(3,85m - 0,9m*) S	**MLLW** (2,93m) P	-

(*) Heights originally adjusted by 0.9m ([1] -‘Notes’- page 291) corrected here to conform with British Datum

Mean Sea Level is to be treated as the average level of the sea surface over a long period, preferably 18,6 years (USA: 19-year Metonic cycle [the National Tidal Datum Epoch]). One must be aware that MSL is not an equal level, a flat surface. It is just the opposite actually! The MSL surface varies, fluctuates geographically from place to place in some extend. For that reason it is simply impossible to unify and compare tidal/chart datum between different places. The attempt may be successful (in relation to MSL) for water heights within particular port only!

Furthermore, Chart Datum level along the coast forms very diversified and quite complicated area (surface), difficult to reconstruct, characterize and define mathematically.

Table 2 presents values needed to bring water heights up to the same chart datum within each port separately. The algorithm used here was based on assumption that local data sources are the most accurate and reliable among available information.

Table 2. Chart Datum Corrections to apply in order to unify local tide level (heights)

SOURCE / PLACE	BRITISH ADMIRALTY (+…m/--...m)	UNITED STATES NOAA (+…m/--…m)	TRINIDADIAN HYDROGR UNIT (+…m/--…m)
Port of Spain	LAT [0,73]*	**(-0,01m)**	LAT [0,73]*
Scarborough	**(-0,01m)**	**(-0,28m)**	[0,70]*
Punta Loyola	[6,20]*	[6,20]*	-
Bahia San Sebastian	[5,4]*	[5,40]*	-
Charleston	(MLWS **+0,05m**)	MLLW [0,85]*	-
Eastport	**(+0,02m)**	MLLW [2,93]*	-

(*) Values in brackets [ ] represent existing Chart Datum depression [in metres] relating to local MSL.

7 MODIFIED TIDAL DATA

High and Low Water predictions used for comparison [7] have been corrected according to table 2. The results of the comparison are presented in following paragraph:

8 FINAL RESULTS, CONCLUSIONS

The general method of comparison was based on assumption that local data sources are the most accurate and reliable among available information. For that reason different reference sources (Trinidadian for the Trinidad and Tobago ports, NOAA for United States ports) were used. Lack of such local data created a necessity to calculate mean height values as a reference to other predictions. Tidal height predictions [7] were compared (High and Low Waters separately) to appropriate reference data, then mean HW/LW values calculated for particular ports and days. Figures 2-5 and Tables 3&4 illustrate their composition.

Both Tables 3&4 together with Fig. 2-5 illustrate detailed results of the research based on water heights corrected according to Tables 1&2 (Paragraph 6). Height Deviations of values 0,2m and more are printed in *italic*, **bold** (0,5m-0,59m) and underlined **bold** (over 0,59m).

Terms *Springs* and *Neaps* used here play a key role to distinguish the biggest and smallest tides within the lunar cycle. The days does not represent strict spring and neap tides as their delay from astronomical moments (Full/New Moon and It's First/Last Quarter) varies from port to port up to 4 days.

Table 3. High Water heights in relation to local or mean predictions **[HW Height Deviations]**

PORTS (Date of Predictions)	**REFERENCE TIDE**		Admiralty Tide Tables	Trinidadian Tide Tables	American Tide Tables	SHM software	TOTALTIDE (software)	NOAA (web site)
PORT OF SPAIN	Trinidadian Prediction	HW	0,09m	Reference Tide	0,01m	0,01m	0,01m	
28.12.2004 Springs		HEIGHTS	0,09m		0,14m	0,01m	0,01m	
PORT OF SPAIN		HW	0,16m		0,18m	0,16m	0,16m	
20.12.2004 Neaps		HEIGHTS	0,13m		0,10m	0,13m	0,13m	
Scarborough		HW	0,10m		0,04m	0	0,10m	
28.12.2004 Springs		HEIGHTS	0,10m		*0,29m*	0,02m	*0,39m*	
Scarborough		HW	0,03m		**0,50m**	0,13m	0,03m	
20.12.2004 Neaps		HEIGHTS	0,01m		**0,59m**	0,09m	0,09m	
PUNTA LOYOLA	Mean Values	HW	0,10m		0	0,10m	**0,60m**	
27.12.2004 Springs		HEIGHTS	0,13m		0,03m	0,17m	**0,67m**	
PUNTA LOYOLA		HW	*0,20m*		0,10m	*0,30m*	**0,60m**	
20.12.2004 Neaps		HEIGHTS	*0,27m*		0,17m	*0,43m*	*0,43m*	
Bahia S.Sebastian		HW	*0,42m*		*0,34m*	0,08m	**0,68m**	
27.12.2004 Springs		HEIGHTS	**0,82m**		0,14m	0,02m	**0,68m**	
Bahia S.Sebastian		HW	*0,39m*		**0,69m**	*0,29m*	**0,59m**	
20.12.2004 Neaps		HEIGHT	0,19m		**0,62m**	0,19m	*0,39m*	
CHARLESTON	**NOAA Predictions (official web site)**	HW	0,08m		0,01m	0,03m	0,02m	Reference Tide
27.12.2004 Springs		HEIGHTS	0,03m		0,02m	0,03m	0,03m	
CHARLESTON		HW	0,05m		0,02m	0,05m	0,05m	
20.12.2004 Neaps		HEIGHTS	0,05m		0,01m	0,05m	0,05m	
Eastport		HW	0,12m		0,01m	0,12m	0,12m	
27.12.2004 Springs		HEIGHTS	0,05m		0	0,05m	0,15m	
Eastport		HW	0,08m		0,01m	0,18m	0,02m	
20.12.2004 Neaps		HEIGHTS	0,03m		0,01m	*0,27m*	0,05m	

Table 4. Low Water heights in relation to local or mean predictions [**LW Height Deviations**]

PORTS (Date of Predicions)	REFERENCE TIDE		Admiralty Tide Tables	Trinidadian Tide Tables	American Tide Tables	SHM software	TOTALTIDE (software)	NOAA (web site)
PORT OF SPAIN	Trinidadian Prediction	LW	0,12m	Reference Tide	0,11m	0,02m	0,12m	
28.12.2004 Springs		HEIGHTS	0,06m		0,04m	0,16m	0,16m	
PORT OF SPAIN		LW	0,06m		0,06m	0,06m	0,06m	
20.12.2004 Neaps		HEIGHTS	0,03m		0,03m	0,03m	0,03m	
Scarborough		LW	0,02m		**0,37m**	0,02m	0,02m	
28.12.2004 Springs		HEIGHTS	0,04m		0,09m	0,04m	0,06m	
Scarborough		LW	0,11m		*0,42m*	0,11m	0,11m	
20.12.2004 Neaps		HEIGHTS	*0,21m*		0,17m	0,11m	0,21m	
PUNTA LOYOLA	Mean Values	LW	0,03m		0,13m	0,17m	**0,63m**	
27.12.2004 Springs		HEIGHTS	0,03m		0,07m	0,03m	**0,77m**	
PUNTA LOYOLA		LW	0,10m		0,10m	*0,2m*	**0,70m**	
20.12.2004 Neaps		HEIGHTS	*0,30m*		*0,20m*	**0,50m**	**0,90m**	
Bahia S.Sebastian		LW	*0,40m*		**0,60m**	*0,20m*	**0,90m**	
27.12.2004 Springs		HEIGHTS	0,08m		*0,36m*	*0,28m*	**0,88m**	
Bahia S.Sebastian		LW	*0,26m*		0,11m	0,14m	**0,54m**	
20.12.2004 Neaps		HEIGHT	*0,45m*		0,19m	**0,65m**	**0,85m**	
CHARLESTON	**NOAA Predictions (official web site)**	LW	0,08m		0,03m	0,02m	0,08m	Reference Tide
27.12.2004 Springs		HEIGHTS	0,05m		0,02m	0,05m	0,05m	
CHARLESTON		LW	0,02m		0,01m	0,08m	0,02m	
20.12.2004 Neaps		HEIGHTS	0,06m		0,02m	0,14m	0,06m	
Eastport		LW	0,04m		0,01m	0,04m	0,04m	
27.12.2004 Springs		HEIGHTS	0,13m		0,01m	0,02m	0,08m	
Eastport		LW	0,06m		0,01m	0,19m	0,01m	
20.12.2004 Neaps		HEIGHTS	0,06m		0,03m	0,14m	0,06m	

Owing to very few statistic data used here drawing any conclusions is simply unacceptable.

Some **observations**, however, seem to be important and worth mentioning, such as:

- Notwithstanding tidal datum unification attempt the differences between water heights are considerable, quite often exceeding 0,1m, sometimes even 0,5-0,6m(!)
- The highest values of Height Deviations show South American ports: PUNTA LOYOLA and Bahia San Sebastian (Argentina), relating to Mean water heights(!). Supposedly it is caused by two factors:
  - * relatively much bigger tidal range than in other compared ports;
  - * lack of local tidal predictions sources;
- Neap tide heights presents uneven and more diversified deviations from reference values than Spring ones, which are slightly lower.
- In case of traditional British and American tidal publications, accuracy of predictions seems to be strictly connected with general classification of ports distinguishing a group of Primary stations (called STANDARD PORTS [UK] or REFERENCE STATIONS [USA]) and Secondary [UK] (Subordinate [USA]) stations comprising all other places. Secondary stations here show in most cases higher Deviations than Primary ones.
- Electronic tidal information programs treat every place equally due to harmonic method of prediction usually used by them (SHM, TOTALTIDE), being absolutely independent from above mentioned division and comparison results simply confirm that –similar Deviations within every geographical pair [look into Paragraph 3-PORT SELECTION].
- The TOTALTIDE predictions look very inaccurate in South American ports (Argentina). The reason must be insufficient harmonic data entered manually from ATT vol.2 (**CUSTOM Port** option) used here for all Totaltide predictions, however, U.S. ports predictions were based on set of 37 harmonic constituents available on web site [6] and the result is much better (no more than 0,15m!).

That is probably why despite using the same source data (except for U.S. ports), predictions within British sources differ.

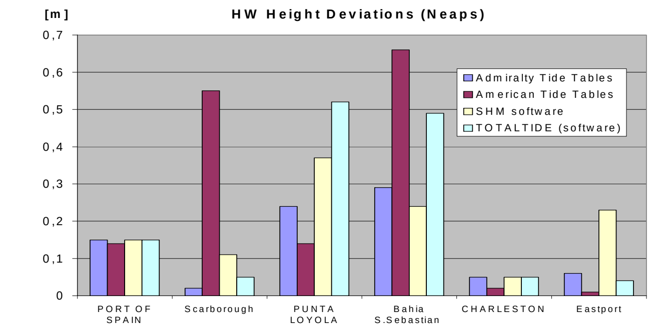

Fig. 2. High Water Height Deviations-Spring Tide

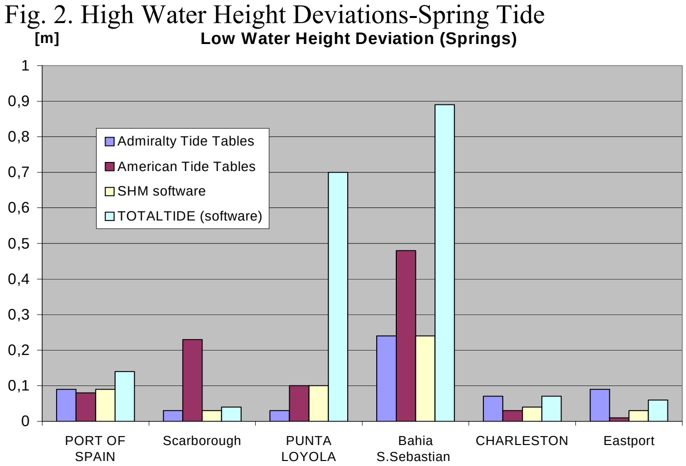

Fig. 3. High Water Height Deviations-Neap Tide

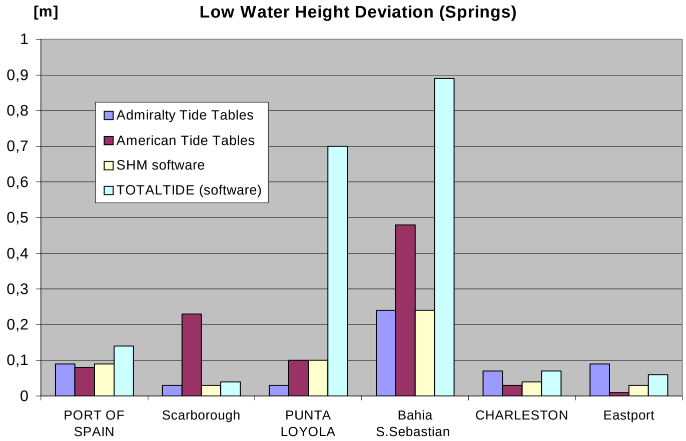

Fig. 4. Low Water Height Deviations-Spring Tide

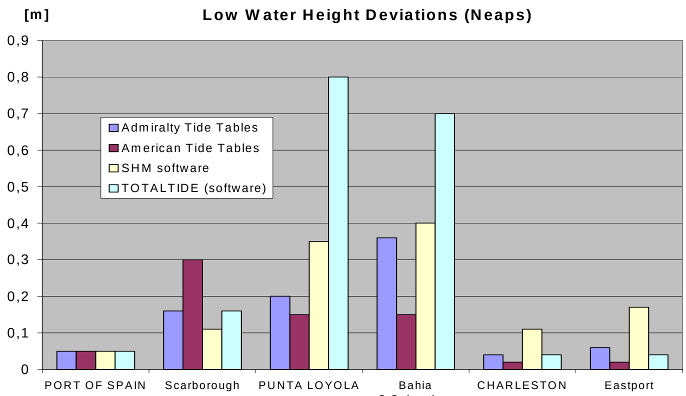

Fig. 5. Low Water Height Deviations-Neap Tide

9 SUMMARY

Generally accuracy and reliability of tidal predictions depends on many factors beginning with data sources, geographical region till meteorological ones. To rely upon them, navigator must bear in mind their limitations and remember: the higher tide range the bigger caution should be taken while using tidal prediction.

It is the user's (navigator's) responsibility to take into account as many factors, as possible including present situation and local conditions to foresee possible consequences of doubtful information and assure safety to the ship itself, people and cargo on board as well.

Presented here considerations are the second stage of tidal comparison research touching Chart Datum problem as a joint background for all tidal heights and a key factor in either cartography or practical navigation as well. Focusing on that question seems to be an area worth investigating. There are still no international norms or regulations concerning Chart Datum and there is much to deal with and explore for the future.

REFERENCES

[1] U.K. Hydrographic Office. 2004, NP202-04 Admiralty Tide Tables vol. 2.

[2] International Marine (accepted by the U.S.Coast Guard). 2004 Tide Tables

[3] Trinidad and Tobago Hydrographic Unit. 2004, Tide Tables.

[4] U.K. Hydrographic Office. 2004, SHM (Simplified Harmonic Method of Tidal Prediction for Windows) DP560-Edition 2.

[5] U.K. Hydrographic Office. 2004, ADMIRALTY TOTALTIDE DP550, Version 5

[6] NOAA web sites: http://tidesandcurrents.noaa.gov/, http://www.noaa.org/,

[7] Kabziński P. 2006, 'Comparative analysis of available information concerning tides, based on particular, selective sources', *XV-th International Scientific and Technical Conference "The Role of Navigation in Support of Human Activity on the Sea",Gdynia, Poland, November15-17, 2006*, Naval Academy of Gdynia.