Sea Level Rise along the Coast of Bangladesh

By Md. Abdul Matin Mondal, Bangladesh Inland Water Transport Authority, Ministry of Shipping

Introduction

Bangladesh has about 24,000 km of rivers, streams and canals that together cover about 7% of the country's surface. Most part of the country is linked by a complex network of waterways which reaches its extensive size in the monsoon period. Out of 24,000 km of rivers, streams and canals only about 5,970 km is navigable by mechanized vessels during monsoon period which shrinks to about 3,870 km during dry period. The IWT sector carries over 50% of all arterial freight traffic and one quarter of all passenger traffic.

The river system of Bangladesh is highly complex and dominated by three major rivers namely the Gauges, Brahmaputra & Meghna which formed the world's largest delta. River instability coped with rapid deterioration of the river system through massive siltation not only cause serious problems to navigation but also the management, operation and development of IWT system.

Reduction of water depth due to siltation and migration of thalweg etc. are common phenomenon of the rivers of the country. These are caused by natural processes and by human interference. Abstraction/diversion of water, deforestation in the river basin, dumping of chemical and toxic waste in the river etc. are occurring in international rivers beyond the national boundaries and within the country and thereby deteriorating river regime and water qualities. Within the country water is also being abstracted from ground water by tube-wells and from rivers by low lift pumps resulting in reduced stream flow and more siltation.

As a maritime country, Bangladesh has about 9,000 sq nautical mile of territorial waters and 20,000 sq. nautical mile of economic resources zone in the sea. The bottom topography of the coastal waters in Bangladesh is very shallow having several detached shoals with shifting sand banks. As such navigation by the ocean-going ships in these waters is hazardous and demands regular hydrographic surveys and studies of the area. Regular publications of up-to-date nautical charts and tide tables for the waterways and port are, therefore, required for the safety of navigation. In general, the topography of the country is extremely flat except marginal hills along the North-East and South-East region. The average land elevation is about 7.62 meters (25 ft.) above mean sea level whereas for coastal and offshore island is about 1.5 meters (approx.) above mean sea level and as such major portion of the waterways are under tidal influence.

Tides in Bangladesh Coast

Tides in Bangladesh coast originate in the Indian Ocean. It enters the Bay of Bengal through the two submarine canyons, the ‘Swatch of No Ground’ and the ‘Burma Trench’ and thus arrives very near to the 10 fathom contour line at Hiron point and Cox’s Bazar respectively at about the same time. Of the principal constituents, most dominant are M_2 and S_2 whose natural periods of oscillations are 12 hours 25 minutes and 12 hours respectively. Extensive shallowness of the North-Eastern Bay gives rise to partial reflections thereby increasing the tidal range and the

friction distortions concurrently. Large seasonal effects of meteorological origin coupled with the complexity of the non-linear shallow water interaction give rise to considerable number of higher harmonics. All such higher harmonic terms are needed in predicting tide to make it as nearly representative as possible. Besides numerous inlets, there are six entrances of major importance through which tidal waves penetrate into the waterways system in Bangladesh and these are:

1. The Pussur Entrance 2. Harin Ghata Entrance, 3. The Tentullia Entrance, 4. The Shahbazpur Entrance, 5. The Hatia river Entrance and 6. The Shandwip Channel Entrance. Storong tide, north of Sandwip, is caused by the shallowness and funnel effect in the Hatiya river. The spring range here is more than 7 meter during vernal equinoxes and at upstream of Sandwip the tidal wave entering the channel sometimes deforms into a bore.

History of Establishment of MSL

The Mean Sea Level was established at 9 places along coast of Indian sub-continent during the period 1858 to 1909. The MSL value at Kiddirpore Docks in Kolkata (the then Calcutta) established at that time has since been regarded as MSL of the coast of Bangladesh. The new MSL was then found to be 1.899 meter above the old MSL (Figure1) at Sadarghat of Karnafully River, Chittagong.

Chart Datum

The Second International Hydrographic Bureau (IHB) in 1926 provided a definition for the chart datum as:

"The tidal datum should be the same as the datum for sounding reduction on nautical charts and it should be a plane so low that the tide will but seldom fall below it."

Professor G. H. Darwin devised a harmonic chart datum (CD) formula for use in Indian Ocean areas where tide is predominantly Semi-diurnal and this CD is referred to as Indian Spring Low Water (ISLW). The formula is :

$$ISLWL = Z_0 - (M_2 + S_2 + K_1 + O_1)$$

where Z_0 is the Mean Sea Level above CD,
M_2 is the principal lunar semidiurnal constituent,
S_2 is the principal solar semidiurnal constituent,
K_1 is luni solar diurnal constituent,
O_1 is the lunar diurnal constituent.

Indian Spring Low Water has been found to be suitable for chart datum in certain parts of the world, notably in the South West part of Persian Gulf and certain parts of Indian Sub-continent, Malaysia and Borneo.

ISLW formula does not give uniform result, because at some places both the diurnal and semi-diurnal tides are equally important. The relative times of diurnal & semidiurnal low waters may coincide near springs, and other constituents may cause the tide to fall below datum, whereas at other places the coincidence occurs near neaps and the datum may be considerably

below the lowest level of tide. The formula also fails where shallow water constituents are large, specially in the coastal area of Bangladesh.

NEDECO Formulae

In 1966-67 the Netherlands Engineering Consultant (NEDECO), a consultant of erstwhile East Pakistan Inland Water Transport Authority (EPIWTA) carried out intensive survey of the navigable waterways in the country and formulated Standard Low Water (SLW) as the Chart Datum for Bangladesh Waters based on 1961-1965 water level data from 116 gauge stations with the provision of updating the datum at 5 yearly intervals to take into account the gradual changes in the hydrological regime and morphology of the waterways system.

The formula for CD is:

$$SLW = FML\ 95\% + MS_f - (M_2 + S_2)$$

where FML 95% is the 5% Exceedance of Fortnightly Mean Level.

Determination of MSL by JICA

Japan International Cooperation Agency (JICA) collected gauge data from the Karnafully mouth and determined MSL value as 3.486 m. JICA determined the above MSL value using observation period from 1600 hours 28th January, 1993 to 2300 hrs. 30th November, 1994. Contents of Data as mentioned in their report (Tidal observation reference data 1, no determination of the Mean Sea Level, March 1995) is shown below in tabular form:

Table -1

Year	Total Heights	Numbers of Value	Mean
1993	20813.33	5832	3.569
1994	26944.64	7866	3.425
Total	47757.97	13698	3.486 (AV)

JICA’s computed MSL value in the mouth of Karnafull river differs about 1 (one) meter from the BIWTA's computed MSL value at Sadarghat, Chittagong.

In their report JICA mentioned that the MSL value should be updated after 18.6 years (the cycle of the moon’s node) of data collection from the observatory station.

Modification of Darwin's Chart Datum by BIWTA

The Chart Datum “Indian Spring Low Water (ISLW)” developed by Professor G. H. Darwin for use in Indian Waters was found practically unsuitable for Bangladesh Waters as Low Waters in Bangladesh fall much below the said Darwin datum (ISLW).

BIWTA, established Chart Datum (CD) values by using the extended harmonic analysis by Admiralty method along the different river systems and off-shore islands which is internationally accepted. The modified chart datum formula is:

$$CD = Z_0 - (M_2 + S_2 + K_1 + O_1) - S_A * SSF$$

Network of Tide Gauges

BIWTA has been forecasting tides in Bangladesh in the form of Tide Tables for 17 tide gauge stations (Figure 2 and Table 2) using BIWTA's computer since 1987. BIWTA has been maintaining an extensive network of automatic tide gauges (float type) along the inland waterways extending over the entire coastal belt and offshore islands. BIWTA has nearly 45 tide gauges at different strategic locations of the waterways system and coastal belt and is solely responsible for the preparation of annual Tide Tables for Bangladesh Waters. Meteorology Department's requirement for storm surge data is also being looked after by BIWTA. Besides, Bangladesh Water Development Board (BWDB) and Port Authorities of Chittagong and Mongla also have additional tide gauge within their jurisdictions for specific development projects. Close collaboration and coordination exit between the Port Authorities and BIWTA. In Bangladesh locations of tide gauge represents a formidable problem specially along the coastal belt and offshore island. The places are mostly remote and inaccessible, desolate and severely affected by unstable beds and banks, and above all they are shelterless and cyclone prone too. Obviously no Observer would like to stay in the job for a long period at the cost of their health and security. Such problems can only be taken care of by installing long recording tide gauges which can be left unattended.

Mean Variation of Coastal Water Level

The mean variations of yearly water level of coastal gauges for the periods 1977-1997 of Hiron Point, Khepupara, Char Changa, Sandwip, Sadarghat, Cox’s Bazar and Shahpuri Island/Taknaf gauges including 10 Nos. inland gauges with their Bench Mark information located at important waterways are shown in Table 2.

Impacts of Flood 1998 in Sea Level Rise

The flood 1998 is described as a great catastrophe for the country and its destruction was beyond any apprehension. The people never experienced such a devastation of the flood in the 100 year history of this region. The deluge of 1998 was unprecedented in terms of its devastation, duration, vastness and magnitude.

The rainfall analysis for July and August 1998 showed that there was very excessive rainfall over the South-East part of Bangladesh. Heavy rainfall also occurred over the Central and Northern parts of Bangladesh but rainfall over the Northern part was significantly higher than the Central part. It may be mentioned here that normally during June and July the Brahmaputra basin receives comparatively higher rainfall during August and September. Unfortunately in the year under review most of the basins within and outside the country were showered heavily simultaneously during July leading to confluence of higher water levels which caused the flood 1998 with prolonged duration of about 78 days. Moreover, between 1st of July to 30th of September 1998 6(six) Nos. spring tides occurred. During the new Moon & full Moon time declination of the Moon with the 21- 23 º N Latitude was minimum as a result Higher High Water (HHW) due to diurnal inequality was more higher than the normal and water level could not fall during low water (Spring and Neap) period owing to excessive rainfall as received from upland. As a result coastal area gained higher water level for more than 2.5 lunar months than the normal level and this higher level causes the Sea Level Rise (SLR) along the coast of

Bangladesh. This abnormal rise of water level has been recorded along the few coastal gauges of BIWTA and two Port Authorities.

Mean Sea Level (MSL) of 1998 from one year observed data at Hiron Point of Pussur river system has been computed and trend of Sea Level Rises has been found much significant in comparison with other years (Table 3).

Conclusions

Sea level variation is of major concern in Bangladesh because vast low-lying area of the Country experiences large tidal range, heavy river run-off and frequent severe storm surges. For the study of Sea Level Rise (SLR) millimeter accuracy of tidal data is an essential prerequisite. But at present BIWTA is collecting tidal data in centimeter accuracy along the Coast of Bangladesh which is about 720 km. in length. To collect distortion free tidal data in open Sea at least 3 Nos. Acoustic Tide Gauge (ATG) needs to be installed along the Coast. To meet the above requirement three possible location may be at (i) St. Martins Island (South East), (ii) Kuakata (Central South) and (iii) Hiron Point (West). In this connection it may be mentioned that BIWTA proposed 2 Nos. ATG in the IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts held in Zanziber, Tanzania (17-21 January, 1994) and in that Workshop IOC approved 1 No. ATG only. With reference to above proposal presently IOCINDIO has allotted 1 No. ATG for Bangladesh out of the total 40 Nos. to be set up along the Indian Ocean, Bay of Bengal and Arabian Sea Coast. Again in the IOC-INDIO Workshop on Tropical Ocean and Climate held in Bangalore, India from-3-6 November, 1998 two more ATG was requested for Bangladesh Coast.

Since BIWTA is solely responsible and analysis of tidal data and prediction of Bangladesh Tide Tables it is urgently necessary to replace the old and obsolete Micro-Vax 3300 computer presently used by BIWTA with a modern one. For measurements of other associated parameters such as Temperature, Salinity, Depths, Currents, Turbidity, etc. necessary equipment/machines need to be provided. To study the Sea Level Rise (SLR) and Storm Surge, bathymetric survey of the Bay Bengal (which has not been surveyed for over 100 years) needs to be undertaken. Training on the use of oceanographic equipment/machines and transfer of technology in the field Sea Level Rise, Storm Surge and oceanographic technique may be provided.

References

1. Admiralty Manual of Tides

2. Bangladesh Tide Tables 2001 published by BIWTA

3. International Seminar on Mean Sea Level Monitoring 26-28 November 1991 Tokyo, Japan (A.M. Mondal).

4. East Pakistan Inland Water Transport Authority Surveys of Inland Waterways and ports volume III and volume IV by NEDECO-1967.

5. Determination of SLW and SHW in Bangladesh Vol-II : Technical Report by Interconsult As consulting Services, Norway (December 1991)

6. Tidal observation reference data-1 on determination of the Mean Sea Level, March 1995. The study on the Geodetic Survey in the People's Republic of Bangladesh by Japan International Cooperation Agency (JICA), Survey of Bangladesh (SOB).

Figure Captions

1. Changes of datum for the Karnaphuli River in Bangladesh.

2. Tide table station index for Bangladesh.

Table-2: VARIATION OF TIDAL LEVELS

STATION	LAT	MLWS	MLWN	MTL	MHWN	MHW	HAT
Hiron Point	-0.256	0.225	0.905	1.700	2.495	3.175	3.656
Sundarikota	-0.553	0.036	0.636	1.829	3.022	3.694	4.211
Mongla	-0.261	0.325	1.194	2.310	3.427	4.296	4.882
Khal No 10	-0.444	0.261	1.231	2.664	4.097	5.067	5.772
Sadarghat	-0.423	0.239	1.100	2.481	3.861	4.722	5.385
Cox's Bazar	-0.339	0.205	1.023	1.995	2.967	3.785	4.329
Shahpuri Island	-0.348	0.191	1.045	1.874	2.703	3.557	4.096
Sandwip	-0.583	0.238	1.634	3.243	4.851	6.248	7.070
Char Changa	-0.375	0.256	1.060	2.037	3.014	3.818	4.449
Khepupara	-0.323	0.195	1.025	2.060	3.096	3.925	4.445
Char Ramdaspur	-0.261	0.189	0.763	2.036	3.309	3.883	4.333
Barisal	+0.134	0.434	0.692	1.539	2.386	2.644	2.944
Chandpur	+0.019	0.256	0.493	2.172	3.852	4.088	4.326
Nalmuri	+0.078	0.370	0.722	2.195	3.669	4.021	4.313
Narayanganj	+0.458	0.585	0.697	2.770	4.844	4.956	5.083
Galachipa	-0.159	0.283	0.9.7	1.764	2.592	3.245	3.689
Patuakhali	-0.143	0.242	0.740	1.575	2.409	2.907	3.293

Table-2 (continued): STATION INFORMATION

STATION	RIVER	LAT. (N)	LONG. (E)	BENCH MARK HTS. (m) CD	PWD
Hiron Point	Pussur	21:48	89:28	3.784	
Sundari Kota	Pussur	22:07	89:36	3.369	
Mongla	Pussur	22:27	89:36	4.657	
Khal No. 10	Karnaphuli	22:16	91:49	6.481	
Sadarghat	Karnaphuli	22:20	91:50	5.822	
Cox's Bazar	Bag Khali	21:26	91:59	4.836	3.931
Shahpuri Island	Naaf	20:47	92:20	4.380	
Sandwip	Satalkhal	22:29	91:26	7.540	
Char Changa	Shahbazpur	22:08	91:06	4.996	
Khepupara	Nilganj	21:54	90:13	3.757	1.797
Char Ramdaspur	Meghna	22:48	90:39	5.137	
Barisal	Barisal	22:41	90:22	3.365	2.946
Chandpur	Dakatia	23:13	90:40	5.812	6.062
Nalmuri	Meghna	23:06	90:26	5.312	5.088
Narayanganj	Lakhya	23:31	90:29	5.981	6.179
Galachipa	Lohalia	22:10	90:24	5.119	4.404
Patuakhali	Patuakhali	22:22	90:19	3.785	2.889

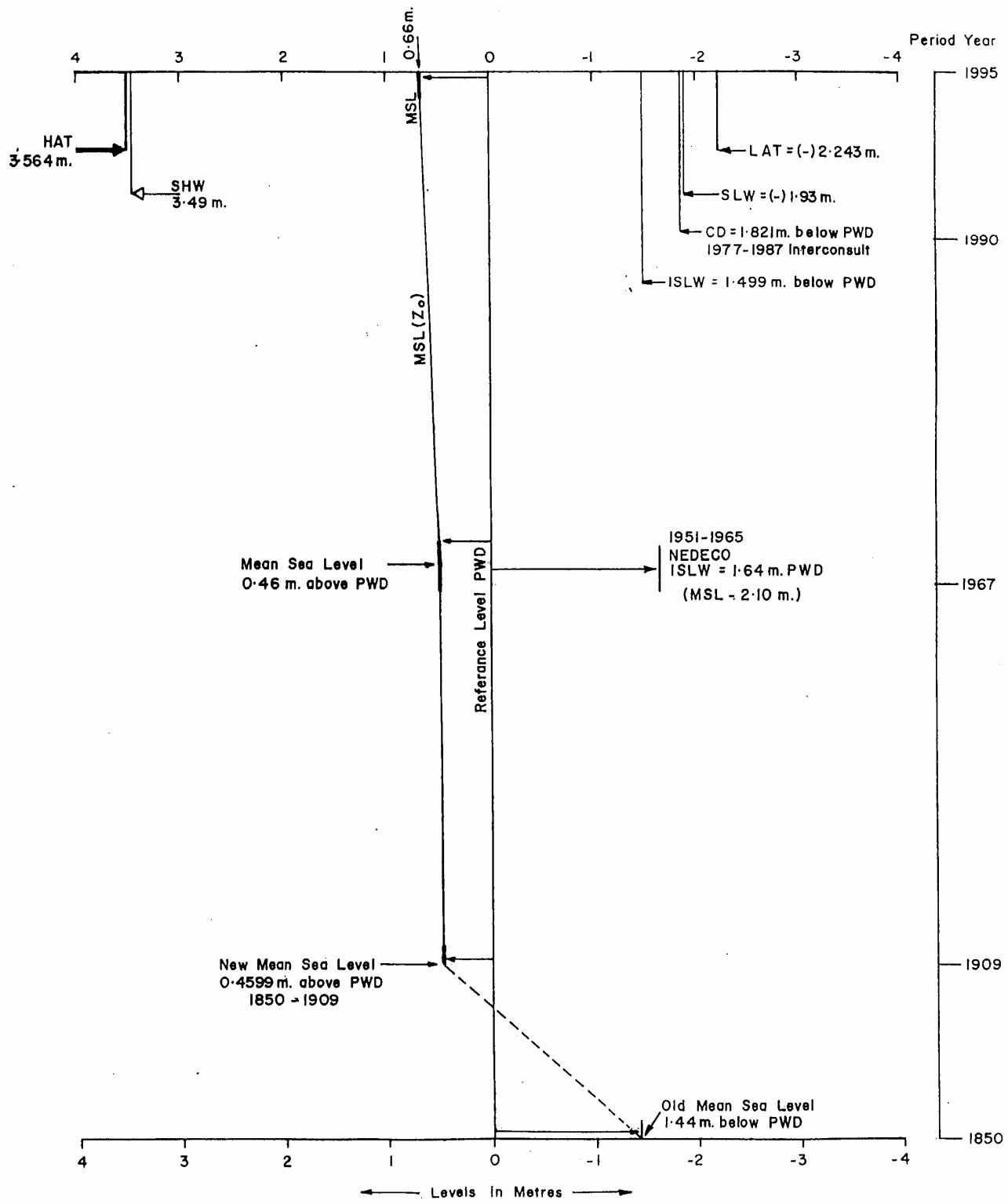
Table-3: Sea Level Rise due to Impacts of Flood 1998 along the Coast of Bangladesh.

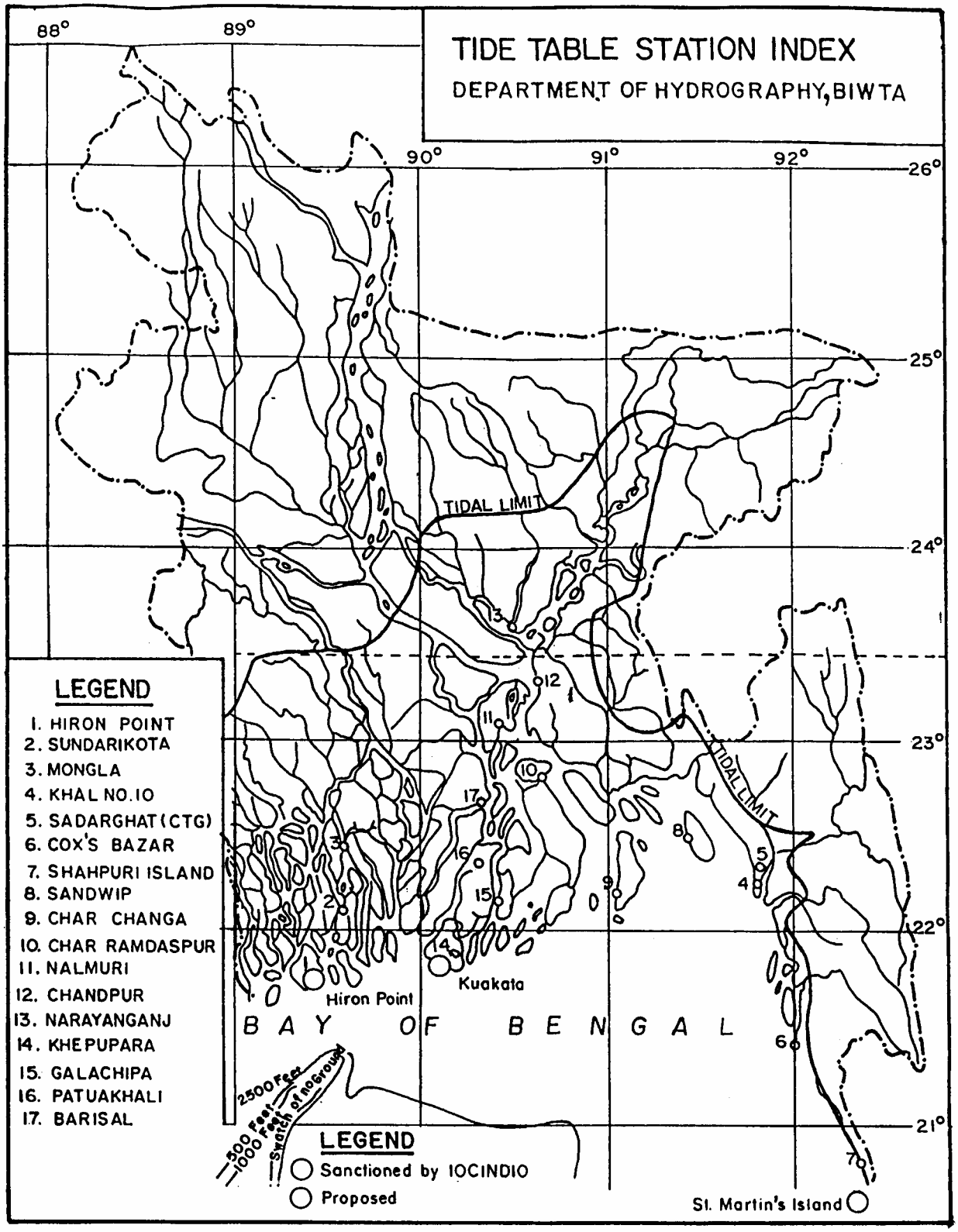
SL NO.	Gauge Station	MSL (Metres)	
		1998 (As per BD Tide Tables)	1998 (SLR due to flood)
1.	Hiron Point	1.700	1.842
2.	Khepupara	2.060	2.332
3.	Char Changa	2.037	2.248
4.	Sandwip	3.243	3.377
5.	Sadarghat (Ctg.)	2.481	2.486
6.	Cox’s Bazar	1.997	2.028
7.	Shahpuri Island/Teknaf	1.874	2.079

CHANGES OF DATUM

Karnaphuli River

Sadarghat, Chittagong.




TIDE TABLE STATION INDEX
DEPARTMENT OF HYDROGRAPHY, BIWTA
88°
89°
90°
91°
92°
26°
25°
24°
23°
22°
21°
TIDAL LIMIT
TIDAL LIMIT
LEGEND
1. HIRON POINT
2. SUNDARIKOTA
3. MONGLA
4. KHAL NO.10
5. SADARGHAT (CTG)
6. COX'S BAZAR
7. SHAHPURI ISLAND
8. SANDWIP
9. CHAR CHANGA
10. CHAR RAMDASPUR
11. NALMURI
12. CHANDPUR
13. NARAYANGANJ
14. KHEPUPARA
15. GALACHIPA
16. PATUAKHALI
17. BARISAL
Hiron Point
Kuakata
B A Y O F B E N G A L
2500 Feet
1000 Feet
Swatch of no Ground
LEGEND
Sanctioned by IOCINDIO
Proposed
St. Martin's Island