

Coastal processes along the shorefront of Chilka lake, east coast of India

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Chilka lake inlet mouth is exposed to high annual littoral drift of about $1 \times 10^6 \text{ m}^3$. The inlet mouth was observed to migrate about 500 m northward during the period of one year study. Measurement on daily longshore currents indicated that the predominant longshore sediment transport across the mouth is towards north throughout the year.

Most of tidal inlets of engineering importance are of littoral drift origin, where the littoral sediment transport conditions determine the state of stability and dynamic equilibrium of the inlet¹. Stability of the inlet depends on the resultant state of the forcing parameters between the tidal prism and the littoral drift across the mouth. High rate of littoral transport, reduced inlet cross section, low tidal prism and migration of the mouth have deeply damaged the ecosystem of the entire water body of the lake. In the present study, the sediment transport processes along the shorefront of Chilka lake have been assessed based on the field observations.

Materials and Methods

Chilka lake; the largest tidal inlet in Asia, is about 64 km long in NE-SW direction with an average width of 13.5 km and a bay surface area of 756 km² (Fig.1). The average depth of the lake is 1.3 m. The tides in this region are semidiurnal. The spring tidal range varied between 1.72 m and 2.39 m and the neap tidal range between 0.18 m and 0.85 m.

A waverider buoy was deployed at 10 m water depth (Fig.1) and the wave height and period were recorded for 20 min duration every 3 h from July 1990 to April 1991. Monthly beach levels were measured from June 1990 to May 1991, at 6 stations at 5 m intervals, along a transect from the backshore dune to about 1 m water depth at low tide. Daily measurements on longshore current velocity and direction were made at sts 1,2 and 6 by releasing the fluorescent dye in the surfzone and noting the distance travelled by the dye patch in 2 min. Sieve analysis was carried out to determine grain size distribution of the

beach sediment. The numerical wave refraction studies for the stretch of coastline between Jodikuda and Puri were carried out based on the procedure presented by Skovgaard *et al.*², for the deepwater wave directions 90°, 135°, 155° and 180°, and wave periods 6,8 and 10 sec. Nearshore bathymetric maps for the refraction study were extracted from the Indian Naval Hydrographic Chart no.353. The longshore sediment transport rates at the Chilka lake shorefront were estimated using the Walton's equation^{3,4}. The surfzone width, and the longshore current velocity and direction measured every day at sts 1,2 and 6 were used in the Walton's equation^{3,4} for estimating the sediment transport rate. The breaking wave heights were estimated from the significant wave heights computed using wave rider buoy data measured at 10 m water depth, by applying necessary corrections for shoaling and refraction⁵.

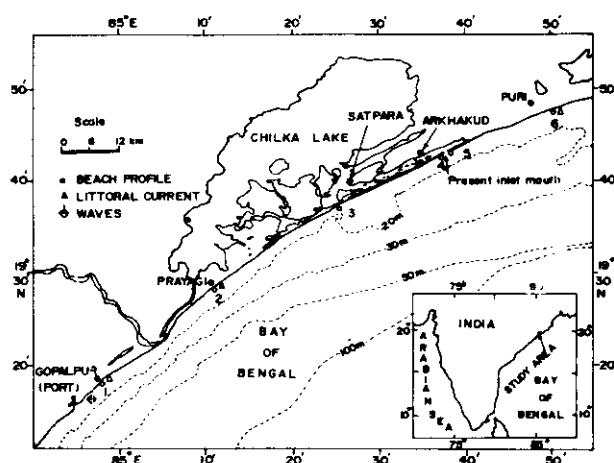


Fig. 1—Location map

Results and Discussion

Waves—The wave climate in the Bay of Bengal can be characterised under different seasons, viz. southwest monsoon (June-September), northeast monsoon (October-January) and fair weather period (February-May). The 3 hourly variation of the significant wave height, maximum wave height and the zero crossing wave period are presented in Fig.2.

The significant wave height varied from 0.83 to 2.09 m in July, 0.39 to 2.22 m in August, 0.5 to 1.58 m in September, 0.2 to 1.5 m in October, 0.29 to 2 m in November, 0.23 to 2.36 m in December, 0.25 to 0.8 m in January, 0.2 to 1 m in February, 0.31 to 1.22 m in March and 0.4 to 2.15 m in April. The highest significant wave height of 2.36 m was measured in December. The maximum wave height varied from 1.15 to 3.38 m in July, 0.55 to 3.5 m in August, 0.69 to 2.5 m in September, 0.24 to 2.22 m in October, 0.3 to

2.92 m in November, 0.3 to 3.8 m in December, 0.35 to 1.25 m in January, 0.25 to 1.45 m in February, 0.52 to 1.95 m in March and 0.5 to 3.2 m in April. High waves were recorded in July and August 1990. The highest maximum wave height of 3.8 m was measured in December.

The zero-crossing period varied between 5.5 and 11.5 sec in July, 6.5 and 18 sec in August, 4 and 18 sec in September, 5 and 18 sec in October and November, 3 and 16 sec in December, 3 and 12 s in January, 4 and 14 sec in February, 4 and 12 sec in March and 5 and 15 sec in April.

The ship reported visual wave data compiled for the year 1968 to 1986, for the grid lat. 15°-20° N, and long. 85°-90° E shows that the predominant wave direction with respect to north, varies between 40° and 90° from November to February, 210° and 230° from March to July, and 170° and 200° from August to October⁶.

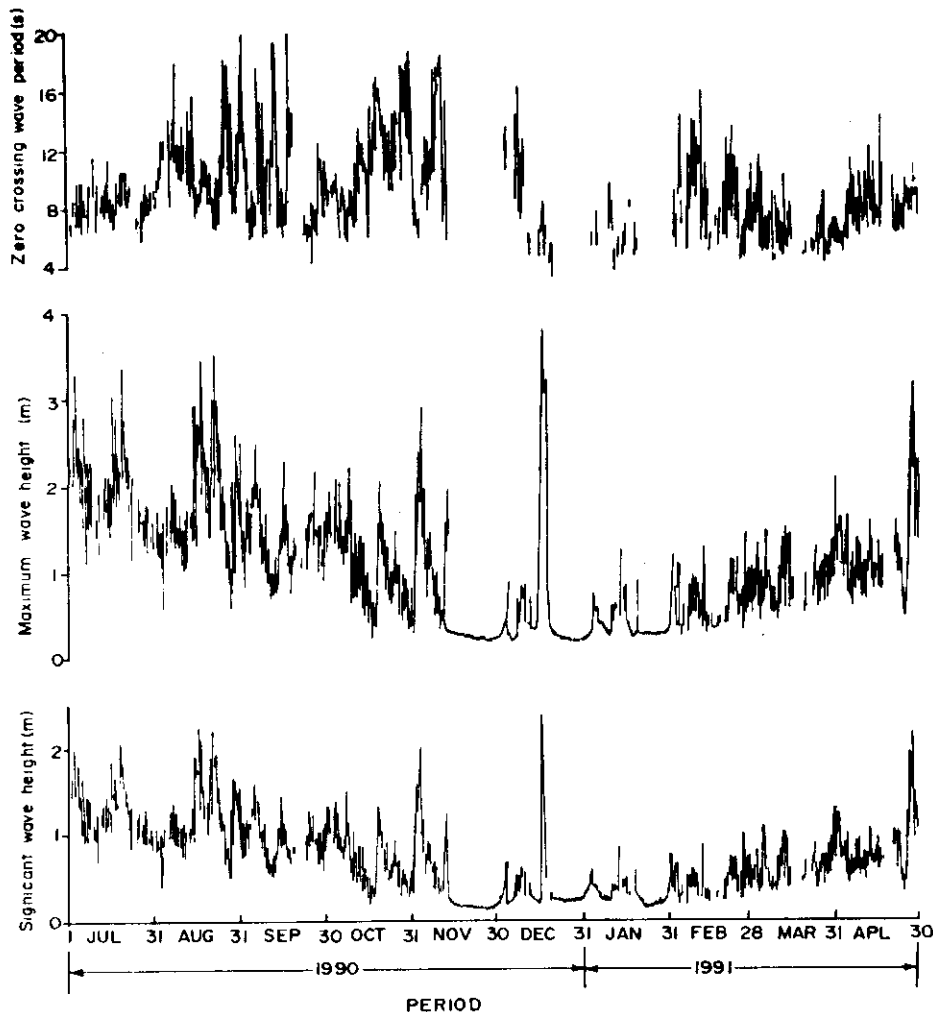


Fig. 2—Three-hourly variation of significant wave height, maximum wave height and zero-crossing wave period

Beach processes—The relative changes in the volume of sediment at each station are presented in Fig.3. The beach volume at st. 5 is presented till February 1991, as the beach here was washed off in March 1991 due to the northward migration of the inlet mouth. Variation in beach levels indicates the seasonal pattern viz., fair weather, southwest monsoon and northeast monsoon. The beaches had lowest profile in August at sts 1-4 and 6. When the study was started in June 1990, st. 5 was about 500 m northward of the inlet location. During the subsequent southwest monsoon, considerable changes occurred with the northward migration of the tidal inlet. The inlet mouth reached st. 5 in March 1991, thereby washing away the portion of the beach at st.5.

Longshore current—The daily variation of longshore current speed and direction is shown in Fig.4. At st. 1, the longshore current was northward throughout the year except in December and January during which it was equally distributed in either direction. At st.2 the longshore current was northward throughout the year. At st.6 the longshore current was northward in all the months except in November, December and January during which it was equally distributed in either direction. The longshore current speed varied between 0.2-0.5 m.sec⁻¹ at sts 1 and 6. At st.2 it generally varied 0.3-0.4 m.sec⁻¹ except in May and June, during which it exceeded 0.8 m.sec⁻¹. The longshore currents in the surfzone flowed in northerly direction both during the southwest and northeast monsoon seasons contrary to the views generally held that the longshore sediment transport along this region would be southward during the northeast monsoon period of November to February⁷.

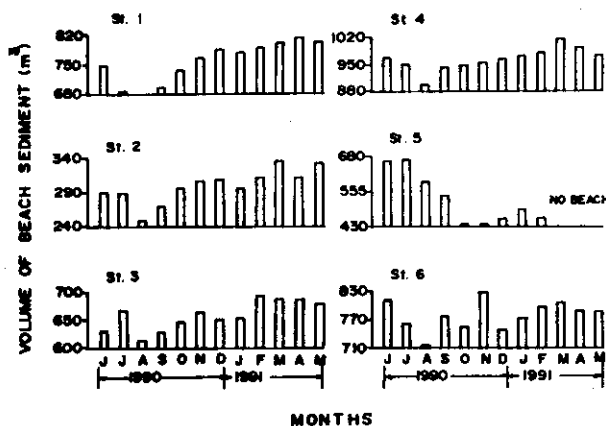


Fig. 3—Monthly variation of beach sediment volume per metre length of the beach

Wave refraction—The typical wave refraction diagram for the waves approaching from the east is shown in Fig.5. The refraction pattern of orthogonals for the waves approaching from the east indicates no significant refraction for 6 sec waves. The 8 sec waves showed divergence of orthogonals between Bajarkot and Brahampur, and at the inlet mouth, indicating accretion conditions at this stretch of the coast. Slight convergence of orthogonals was observed over a small stretch of the shorefront between Satpara and Arkhakud, and the northern side of the entrance channel. This indicates the erosional trend along these stretches. For 10 sec waves, the convergence of wave orthogonals is found to be more pronounced. The refraction diagram for the waves approaching from 135° and 155° with respect to the north showed uniform distribution of wave energy along the entire stretch for 6,8 and 10 sec wave periods. The refraction pattern for the 6 sec waves arriving from the south showed uniform distribution of wave energy along the entire stretch. For 8 sec and 10 sec waves, divergence of wave orthogonals was observed between Satpara and Puri, indicating the possibility of deposition of sediment at these places.

Sediment size distribution—Variation of median size (d_{50}) of the beach sediment at each station

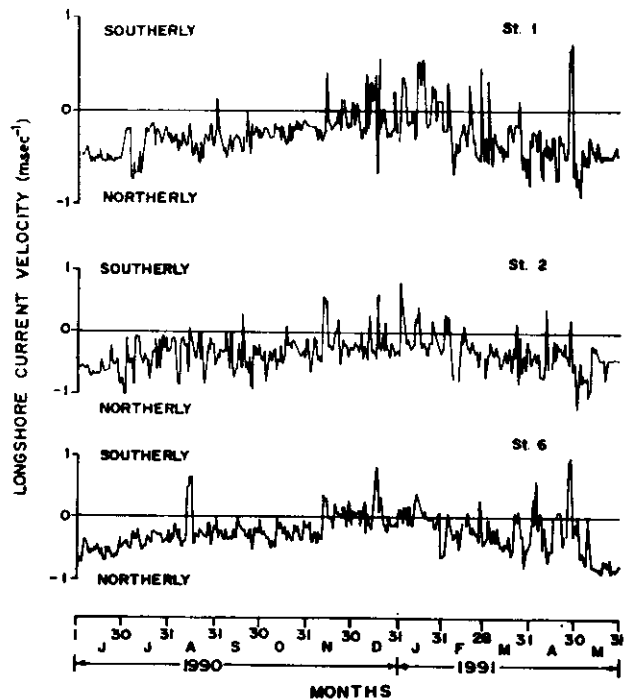


Fig. 4—Daily variation of longshore current velocity and direction

Table 1—Monthly beach particle median size (mm)

St. no.	1990							1991				
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	.1915	.2253	.3247	.3112	.1603	.2097	.1997	.1844	.0832	.1477	.2021	.1915
2	.2153	.2521	.3583	.2328	.2552	.1285	.1301	.1223	.0964	.2092	.3208	.2153
3	.1674	.2361	.3629	.2331	.2331	.1992	.1435	.1270	.1210	.1896	.2378	.1674
4	.1451	.2115	.3115	.2743	.2768	.2768	.2159	.1171	.1114	.1452	.1940	.1451
5	.1451	.3499	.2206	.2475	.2174	.2174	.1501	.1697	.1174	— No data —		
6	.1826	.2266	.3349	.2045	.1712	.1189	.1155	.2075	.1248	.1386	.1601	.1826

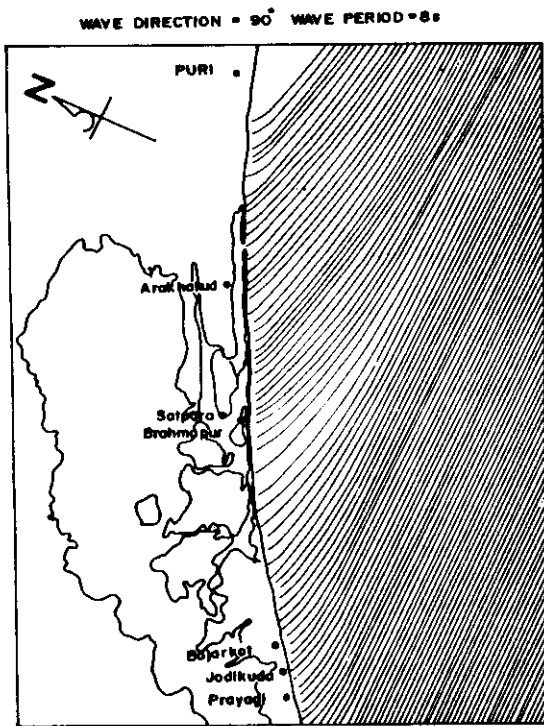


Fig. 5—Refraction of wave orthogonals for the waves approaching from east

(Table 1) shows that in general the beaches under study consist of mainly fine sand. The chemical analysis shows <1.5% of calcareous content in the beach sediment. The sediment size was relatively finer during the fair weather and northeast monsoon period at all stations, and relatively coarser during southwest monsoon period. Coarser sediment with size exceeding 0.36 mm was observed in August at st.3 and exceeding 0.41 mm in April at st.5. The coarse sand in July at st.5, indicated that this part of the beach was on erosional trend due to higher waves and strong tidal currents.

Longshore sediment transport—The monthly longshore sediment transport rates estimated for the sts 1,2 and 6 are presented in Table 2. It

Table 2—Longshore sediment transport rate (m^3)

Month	Gopalpur (St.1)	Prayagi (St.2)	Puri (St.6)
June '90	-199705	-203651	-187669
July '90	-145474	-136663	-145365
Aug. '90	-102539	-93701	-57050
Sept. '90	-66552	-76943	-59765
Oct. '90	-38993	-60954	-43689
Nov. '90	-13744	-20709	-5791
Dec. '90	-5210	-6384	-21766
Jan. '91	-6035	-1339	-1687
Feb. '91	-35609	-9320	-10991
March '91	-42621	-24507	-28432
April '91	-38839	-56997	-4967
May '91	-146795	-196359	-215171
Annual net transport	-830046	-887528	-735436
Annual gross transport	949520	997594	926637

(-) indicates transport towards north

shows that the monthly net longshore sediment transport rate is northward throughout the year at all the places except at st.1 in January, and at st.6 in January and December.

At st.1, the sediment transport rate was relatively high exceeding $14 \times 10^4 m^3$ month⁻¹ in May, June and July. The monthly net transport was low with magnitude less than $0.6 \times 10^4 m^3$ month⁻¹ in December and January. At st.2, the sediment transport rate was relatively high exceeding $19 \times 10^4 m^3$ month⁻¹ in May and June and low showing less than $0.6 \times 10^4 m^3$ month⁻¹ in December, January and February. At st. 6, the sediment transport rate was relatively high exceeding $18 \times 10^4 m^3$ month⁻¹ in May and June, and low showing less than $0.5 \times 10^4 m^3$ month⁻¹ in November, January and April.

As the sediment transport was predominantly northward throughout the year, there was no significant difference in the magnitude between the annual net transport and the annual gross trans-

port rates. The annual net transport rates were 0.83, 0.88 and $0.73 \times 10^6 \text{ m}^3 \cdot \text{y}^{-1}$ at sts 1, 2 and 6 respectively. The annual gross transport rates at sts 1, 2 and 6 were 0.95, 1 and $0.93 \times 10^6 \text{ m}^3 \cdot \text{y}^{-1}$ respectively.

The sediment transport rate at Prayagi (st.2) was relatively higher than at Gopalpur and Puri (sts.1 and 6). The study showed that the transport rate was relatively less during the northeast monsoon period (November to February). The longshore sediment transport was predominantly northward throughout the year along the shorefront of Chilka lake. Earlier studies based on theoretical approach without any field measurement reported that the longshore sediment transport at this shore segment is northerly during March to October and southerly during November to February, as in the rest of the southern part of the east coast^{7,8}. The major rivers viz. Krishna, Godavari, and Mahanadi supply large quantity of sediment in this region. The fresh water discharge during the southwest monsoon, flushes out the part of the sediment deposited across the inlet mouth. During fair weather period, considerable siltation

is observed along the inlet mouth. It would be important to investigate additional parameters like the tidal prism, siltation in the tidal inlet, inlet geometry etc. to understand the stability of the Chilka lake inlet.

Acknowledgement

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