

Wave Induced Sediment Transport in the Vicinity of Tidal Inlets along Karnataka Coast

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ABSTRACT: The sediment transport along the inlets of Karnataka coast were computed from CERC formula. The net Long Shore Sediment transport (LST) pre-monsoon is in the order of 0.0045 Mm³/yr to 0.15 Mm³/yr, 0.002 Mm³/yr to 0.3 Mm³/yr during monsoon and 0.0005 Mm³/yr to 0.06 Mm³/yr during post-monsoon. The net LST estimated during southwest monsoon is observed to be 2 times higher than that of pre-monsoon and 4 to 5 times higher than that of post-monsoon. The sediment transport is southerly for about 60% of time during monsoon whereas it is 70% southerly during post-monsoon.

KEYWORDS: Longshore Sediment transport, Karnataka coast, tidal inlets, CERC formula.

I. INTRODUCTION

Tidal inlets are short, narrow waterways that connect an estuary to a large body of water, generally an ocean. They typically feature an ebb-tidal delta seawards and a flood-tidal delta landwards of a deep inlet throat that is bordered by shallow sandy shoals and marginal flood channels (De Gennaro & Wright, 2007, Herrling & Winter, 2014). Sediment transport in the vicinity of tidal inlets is complex, making it one of the most difficult systems in the coastal environment to quantify. At tidal inlets, sand moves under the combined action of waves and currents, superimposed on highly variable bathymetry with constantly changing water levels (FitzGerald *et al.*, 2000). Sediment transportation data is being used in various engineering applications such as erosion-accretion studies, stability analysis of shoreline and design of coastal construction works. In this study inlets having width more than 5m are considered.

II. STUDY AREA

The present study is carried out along the Karnataka coast located between 11°30' N and 18°30' N latitudes and 74° E and 78°30' E longitude. It lies in between the states of Goa on north and Kerala on south. Coastal Karnataka has three districts viz., Uttara Kannada, Udupi and Dakshina Kannada. Karnataka has a coastline of 320 km with 27 tidal inlets, of which 16 are in Uttara Kannada district, 8 are in Udupi district and 3 are in Dakshina Kannada district. The Hadin inlet, protected by headland on the west, is oriented East-West unlike the other inlets which are oriented North-South.

III. METHODOLOGY

LST ESTIMATION - CERC FORMULA

LST rates calculation in the present study is carried out using the United States Army Corps of Engineer's Coastal Engineering Research Centre (CERC) formula. The savage (1962) formula for estimating LST adopted by U.S Army Corps in 1966 in costal design manual is known as "CERC formula". This is developed by relating the immersed weight of the longshore sediment transport (I) and the longshore wave energy flux (E). This is a commonly used formula to predict longshore sediment transport and is given in Equation 1.

$$Q = \frac{KA\rho g H_b^2 T \sin(2\theta)}{64\pi} \quad (1)$$

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Where Q is sediment transportation rate in m^3/yr , K is dimensionless empirical proportionality constant taken as 0.39 as per CERC, $A = \frac{1}{(\rho_s - \rho)g(1 - F)}$, ρ_s is density of the sediment (kg/m^3), ρ is density of sea water (kg/m^3), g is acceleration due to gravity (m/s^2), H_p is breaking wave height (m), T wave period (s), θ wave angle with respect to shore (deg). Two equidistant points on either sides of the inlet with in the depth of closure are considered for required data extraction such as wave height, wave period and wave angles to estimate the gross and net sediment transport rates along with the direction. The wave angles with respect to shore were derived as per previous studies (Chandramohan & Nayak, 1991). Spectral Wave numerical model setup for each of the tidal inlets.

MODELLING

The major input parameters for numerical simulations using MIKE by DHI software suit are domain and boundary conditions. The domain in the present model is given as mesh file generated by defining the boundary with suitable code values as either land or open boundary and triangulating it with available bathymetry. The land boundaries and bathymetry were obtained from the hydrographic charts available and Google maps. The offshore boundary is taken till 10 meters water depth for most of the inlets. The input wave boundary conditions include significant wave height, wave period, mean wave direction and directional standard deviation. The wave parameters at the required boundaries were extracted from the wave data predicted at CSIR-NIO from both swells and seas for the year 2014.

STUDY PERIOD

The present study is carried out for one month period for each of the three seasons to compare the variability of the sediment transport in pre, post and monsoon seasons. The months of April, August and November respectively were considered to represent pre-monsoon, monsoon and post-monsoon periods.

IV. RESULTS

WAVE HEIGHT

The average wave heights at all the inlets are shown in Figure 1. The wave heights in the Uttara kannada is in the range of 0.2m to 0.76m during the pre-monsoon period. The least wave height 0.2m is observed at Chendia inlet and the maximum of 0.76m at Tadadi port. The wave heights during monsoon were comparatively high in the order of 0.13m to 1.13m. The minimum and the maximum wave heights during monsoon is observed at Todur and Alvekodi 1 inlets respectively. It is in the range of 0.16m to 0.48m during post monsoon at Belekeri and Jali respectively. The wave heights at Chendia and Todur were observed to be lower in monsoon than the other two seasons.

The wave heights in Ullal during pre-monsoon season is in the order of 0.2m to 0.57m. It is in the range of 0.22m to 1.28m during monsoon. Koderi records the highest wave height along the Karnataka coast. It is in the range of 0.15m to 0.47m during post monsoon season. Gangoli shows the lowest and kaup shows the maximum wave heights.

The wave heights at inlets of Daksina Kannada are in the range of 0.21m to 0.44m during pre-monsoon, 0.27m to 0.44m during monsoon, 0.147m to 0.38m during post monsoon seasons. Gurupur and Kanwatheertha shows the minimum and maximum wave heights in all the three seasons respectively.

WAVE PERIOD

The averaged mean wave periods at all the inlets of Karnataka are shown in Figur 2. Wave periods in Uttara kannada coast is in the range of 9.18s to 10.37s during pre-monsoon season. Wave periods at all the inlets in Uttara kannada were close to each other except Belekeri showing the minimum wave period of 7.6s. The wave period during monsoon varied much along Uttara kannada coast in the range of 7.39s to 8.8s. Belekeri inlet again showed least wave period of 6.4s during post-monsoon, the rest were in the range of 7.9s to 8.6s.

The wave period at kundapura drops to 6.8s where the rest are in the range of 8.3s to 10s along the ullal coast during pre-monsoon period. They are in the range of 6.8s to 9s during the monsoon period. The same trend of wave periods as seen in the pre monsoon is observed even in the post-nsoon period, in the range of 7.2s to 8.6s.

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Wave periods at the inlets of Dakshina Kannada follow a similar trend in both pre-monsoon and post-monsoon in the range of 8.9s to 9.3s, 7.5s to 8.1s respectively. Gurupur drops to 7.7s and Kanwatheertha peaks at 7.9s during monsoon period.

SEDIMENT TRANSPORT

Earlier studies by Sanil kumar V near Karwar shows an average measured gross LST of 0.2 Mm³/yr and 0.4 Mm³/yr from CERC formula which likely higher than that estimated in the present study. The gross LST at the inlets of Uttara Kannada varies from 0.01Mm³/yr to 0.2 Mm³/yr during pre-monsoon period. The maximum gross LST is observed at Tadadi port. The gross LST in monsoon is high in the range of 0.006 Mm³/yr to 0.47 Mm³/yr. Gross LST at Tadadi port rose to 0.47 Mm³/yr during monsoon period. Post-monsoon records very lowest gross LST in Uttara kannada varying from 0.006 Mm³/yr to 0.08 Mm³/yr. The gross LST at Tadadi port shows a very less gross LST than the other two periods at 0.04 Mm³/yr. Gross LST at the inlets along Ullal coast is in the range of 0.001 Mm³/yr to 0.16 Mm³/yr during pre-monsoon and post-monsoon poses very low transport rates of 0.005 Mm³/yr. Kaup inlet stands out with highest gross LST in both seasons. The sediment rates during monsoon is high in the range of 0.02 Mm³/yr to 0.75 Mm³/yr. The highest gross LST rates is found at Koderi inlet. The gross LST along Dakshina Kannada is very less in all the three seasons. It is in the range of 0.02 Mm³/yr to 0.07 Mm³/yr during pre-monsoon and 0.008 Mm³/yr to 0.05 Mm³/yr during post-monsoon. Kanwatheertha has the highest gross sediment transport in both the seasons. The gross LST rates in monsoon period are in the range of 0.01 Mm³/yr to 0.085 Mm³/yr. Gurupur shows a very low gross sediment transport rates in all the three seasons. The variation of gross LST rates in all the three seasons is shown in Figure 1 and Table 1.

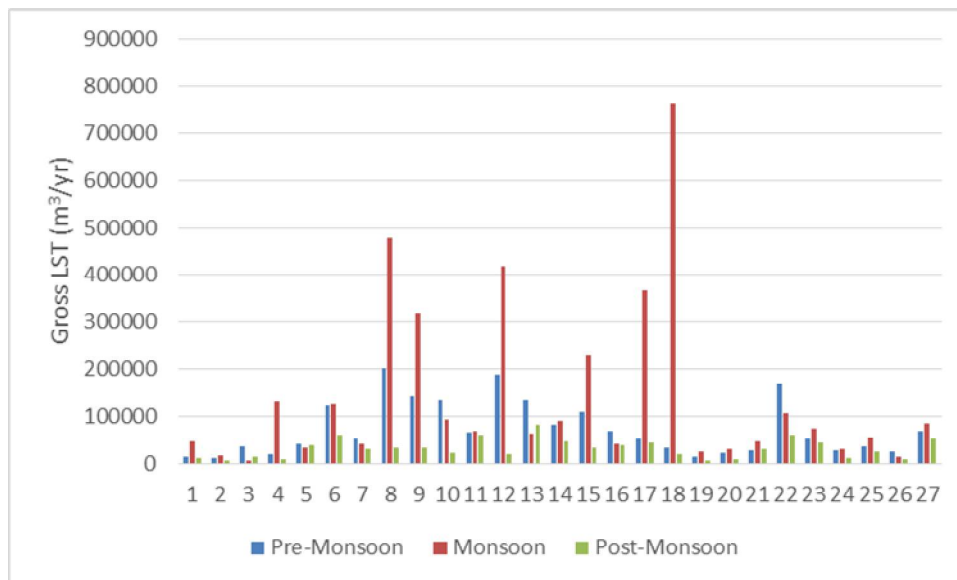


Figure 1: Gross LST at all the inlets along the Karnataka coast

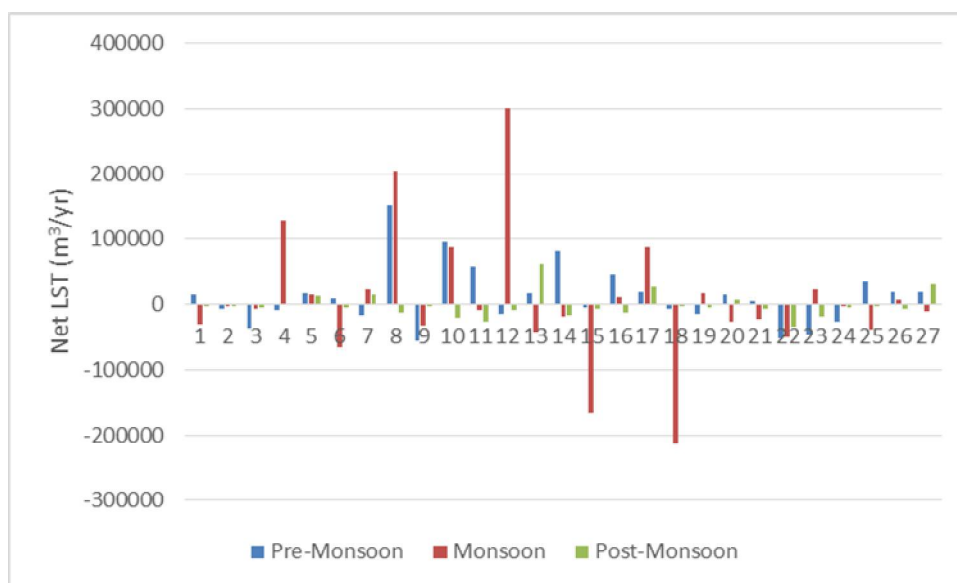
The net LST at the inlets of Uttara kannada is in the range of 0.005 Mm³/yr to 0.15 Mm³/yr mostly towards north in pre-monsoon and 0.0005 Mm³/yr to 0.06 Mm³/yr mostly towards south during post-monsoon. It is in the range of 0.001 Mm³/yr to 0.3 Mm³/yr with most of the time towards south during monsoon period. It is observed to be very less during post monsoon having a peak of 0.06 Mm³/yr towards north and 0.04 Mm³/yr towards south. Except Chendia, Todur, Ankola, Alvekodi 2, Hadin inltes all the other change direction with respect to seasons. It is observed that the net sediment transport towards north is very less at the inlets of Ullal coast. The net LST is in the order of 0.005 Mm³/yr to 0.05 Mm³/yr during pre-monsoon, 0.003 Mm³/yr to 0.03 Mm³/yr during post-monsoon and 0.003 Mm³/yr to 0.2 Mm³/yr during monsoon with most of the sediment transport towards south. The net LST at inlets Paduvari, Gangoli, Kundapura and Nadsal inlets change direction with respect to season. The net LST in Dakshina kannada is less

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compared to the other two districts. It is mostly towards north during pre-monsoon in the range of 0.02 Mm³/yr to 0.03 Mm³/yr. Most of the net LST is towards south during monsoon period in the order of 0.006 Mm³/yr to 0.04 Mm³/yr. The net LST rate during post monsoon is in the order of 0.003 Mm³/yr to 0.03 Mm³/yr with most of it towards south. The variation of net LST rates in all the three seasons is shown in Figure 2 and Table 2.



* For inlets orienting NS positive is directed north and negative is directed south, for those orienting WE positive is directed east and negative towards west

Figure 2: Net LST at all the inlets along Karnataka coast

V. TABLES

Table 1: Gross LST rates at all the inlets along Karnataka coast

No.	Inlet Name	Gross LST (m ³ /yr)		
		Pre-Monsoon	Monsoon	Post-Monsoon
1	Karwar	14243	45504	10703
2	Chendia	9562	17439	5976
3	Todur	35661	6799	14887
4	Belekeri	20133	130635	7290
5	Ankola	41910	33455	36966
6	Belambar	123545	125740	59278
7	Manjaguni	50822	39975	29265
8	Tadadi Port	200576	477292	33428
9	Alvekodi 2	142035	318358	32486
10	Karki	131926	92925	21310
11	Nakhuda	64732	66658	58714
12	Alvekodi 1	188005	418786	19597
13	Jali	133598	61453	81662

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14	Mavakurve	82241	89736	46441
15	Hadin inlet	107625	227956	31862
16	Alivey Gadde	68370	40341	38520
17	Paduvari	50439	367580	44219
18	Koderi	33553	764822	19678
19	Gangoli	13786	23688	5634
20	Kundapura	22089	29677	7873
21	Malpe	26568	46810	28846
22	Kaup	168993	106020	58812
23	Nadsal	50814	73201	43201
24	Hejamadi	26912	30035	10431
25	NMPT	34480	53910	23446
26	Gurupur	24803	12771	8101
27	Kanwatheertha	68087	85105	52543

Table 2: Net LST rates at all the tidal inlets along Karnataka with direction

No.	Inlet Name	Net LST (m ³ /yr)					
		Pre-Monsoon	Dir	Monsoon	Dir	Post-Monsoon	Dir
1	Karwar	14243	N	30330	S	3494	S
2	Chendia	5776	S	2075	S	1798	S
3	Todur	35661	S	6799	S	4454	S
4	Belekeri	8820	S	129057	N	521	N
5	Ankola	16848	N	14625	N	13582	N
6	Belambar	8157	N	66224	S	4298	S
7	Manjaguni	15935	S	22667	N	14300	N
8	Tadadi Port	152313	N	205726	N	12814	S
9	Alvekodi 2	55030	S	31880	S	2658	S
10	Karki	95247	N	87329	N	21310	S
11	Nakhuda	58909	N	7795	S	25532	S
12	Alvekodi 1	14475	S	302134	N	8336	S
13	Jali	16037	N	41005	S	62734	N
14	Mavakurve	82241	N	17574	S	16668	S
15	Hadin inlet	5441	W	165038	W	6542	W
16	Alivey Gadde	45434	N	11149	N	11992	S
17	Paduvari	18260	N	87338	N	27560	N
18	Koderi	6845	S	212754	S	3316	S
19	Gangoli	13786	S	17510	N	4094	S
20	Kundapura	14870	N	25369	S	7086	N
21	Malpe	4572	N	22074	S	7446	S

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22	Kaup	51144	S	50765	S	33151	S
23	Nadsal	46340	S	22106	N	18217	S
24	Hejamadi	26384	S	3269	S	4496	S
25	NMPT	34480	N	38163	S	3346	S
26	Gurupur	19498	N	6257	N	6039	S
27	Kanwatheertha	18877	N	9763	S	30704	N

VI. CONCLUSION

All the inlets along Karnataka coast shows very less net sediment transport rates of around $0.1\text{Mm}^3/\text{yr}$ or less than that during non-monsoon periods. 1 to 13 times higher net sediment transport rates are observed during monsoon than the other two seasons. Sediment transport is mostly towards south in both monsoon and post-monsoon seasons and likely to be neutral during pre-monsoon. Koderi inlets shows the maximum net LST of all the inlets along Karnataka coast at $0.2\text{Mm}^3/\text{yr}$.

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