EROSION CRITERION APPLIED TO A SHORELINE ADJACENT TO A COASTAL INLET

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INTRODUCTION

The potential for erosion (or accretion) by cross-shore transport processes was parameterized by the ratio of the wave height to the product of the wave period and the grain settling speed (i.e. the Dean Number, No). Values of No were compared to a two-year series of volume changes for a downdrift shoreline adjacent to a barrier inlet (Shinnecock Inlet, New York). Initially, No was calculated using wave data five days prior to the date of beach surveys. Established criteria for prediction of accreted (No < 3.2) or erosive beaches (No ≥ 3.2)(Kraus et al, 1991) were then applied to the data, resulting in 60% agreement to the criterion. Recalculation of the data with particular attention to specific storm or swell events resulted in 97% agreement between the measured changes and the criterion. The successful application of this criterion demonstrates the importance of cross-shore transport for inlet-adjacent shoreline dynamics.

The object of this study was to evaluate criteria established by Kraus, Larson and Kreibel (1991) for the prediction of beach erosion or accretion by cross-shore transport processes for a shoreline adjacent to a coastal inlet. Dean (1973) first established a relationship between wave characteristics and beach shapes using a heuristic argument and small-scale laboratory data. This work resulted in the relationship $N_o = H_o / wT$; where H_o is the deepwater wave height; w is the particle fall velocity and T is the wave period. Kraus et al (1991) applied N_o (using $H_{1/3}$) to a field data set of 99 events of erosion and accretion, exploring whether a beach is likely to erode or accrete from cross-shore transport. From this investigation, Kraus et al (1991) established the following criteria for N_o: Values of N_o greater than or equal to 3.2 indicate probable erosion, values less than 3.2 predict probable accretion. In addition, values above 4.0 indicate that erosion is highly probable; whereas values below 2.4 indicate that accretion is highly probable.

STUDY SITE

Shinnecock Inlet is the easternmost of six stabilized tidal inlets located on the south shore of Long Island, New York (Figure 1). The inlet was stabilized between 1952-1954 with stone jetties, fixing the width at 800 ft (244 m) (Taney, 1961). The construction of the jetties and dredging of the navigation channel increased sand trapping at the inlet, evident by growth of the flood tidal delta which doubled in size between 1950 and 1955 (McCormick, 1973). A shoreline analysis conducted by Leatherman and Allen (1985) found the shoreline from Moriches Inlet to Shinnecock Inlet stable to accretionary from 1889 through 1933, however, from 1933 to 1979 most sections of Westhampton Beach had lost significant amounts of shoreline. Typical shoreline recession rates were estimated at greater than 1 m/yr, Westhampton beaches suffered recession rates greater than 2.4 m/yr subsequent to the stabilization of the inlet (Leatherman and Allen, 1985). A recent study (Batten, 1999) examined shoreline recession from 1976-1996 for a 475-meter reach adjacent to the west jetty at Shinnecock Inlet; a rate of 13 m/yr was determined from this analysis.

Figure 1. Shinnecock Inlet shoreline on 4/10/97. Shoreline appears in nourished state (fill placed on 1/97).

The shoreline directly west (1.2 km) of Shinnecock Inlet is a jetty shadow (Figure 1)(Dean, 1988). The extent of erosion along the west beach has repeatedly threatened infrastructure on the barrier, including a regionally important commercial fishing marina, recreational marinas, and an access road leading to these facilities. In response to persistent erosion along the west beach, 2,099,756 m^3 of nourishment fill have been placed along this stretch of shoreline between 1948 and 1998, and 40% of this was placed within the last six years (Morang,1999).

The south shore of Long Island experiences semi-diurnal tides with a mean range of 0.88 m and a spring range of 1.1 m on the ocean side of Shinnecock Inlet (Morang, 1999). The wave climate is dominated by SE to S waves; mean spectral wave height during the study period was 0.9 m, mean spectral wave period was 8.2 s. Wave direction was predominately SSE at 152 degrees. The average sediment grain size in the swash zone was 0.394 mm. Littoral transport is from the east to west.

METHOD

The beach profile was surveyed at nine transects established along the western beach at Shinnecock Inlet during the interval from November 1997 to December 1999. The surveys were made at intervals between 2 and 6 weeks. Measurements were made with an automatic level and level rod following standard techniques. Survey data were reduced and plotted, and profile volume and contour position were evaluated to NGVD in the Beach Morphology Analysis Package (BMAP)(USACE, 1995). Measurements were taken at four transects beginning in November 1997 and increased to nine transects in February 1998. The number of transects was again reduced to four from April 1999 to December 1999. Profile data entering the following calculations represent 34 beach surveys or volume-change data for 33 dates (Batten, 1999).

Grain size analysis was performed on samples taken on 27 May 1998, 17 August 1998, 1 October 1998 and 8 April 1999. Beach sediment was sampled from the swash zone at low tide and measured on a half-phi interval (-2 to 4 phi) on a Tyler RoTap following standard procedures (Lewis and McChonchie, 1994). Median sediment grain size (D_{50} = 0.383) was determined from these four dates and used to calculate particle fall velocity as described in CETN II-4 (USACE, 1981). Temperature data for this calculation were taken from NDBC buoy 44025 and averaged monthly (NOAA, 1999). Fall velocity ranged from 5.01 cm/s in summer to 4.19 cm/s in winter.

Wave data for the study period were retrieved from Corps of Engineers gauge NY001, moored off Westhampton, Long Island (40.79° N., 72.72° W) at a depth of 10 m (USACE, 1999). Wave height is reported as time-domain derived significant wave height in deep water, and wave period is reported as peak spectral period. Wave period was converted to wavelength through the deep-water relationship $L = (g / 2\pi)\, T^2$, where L is wavelength, and g is the gravitational acceleration.

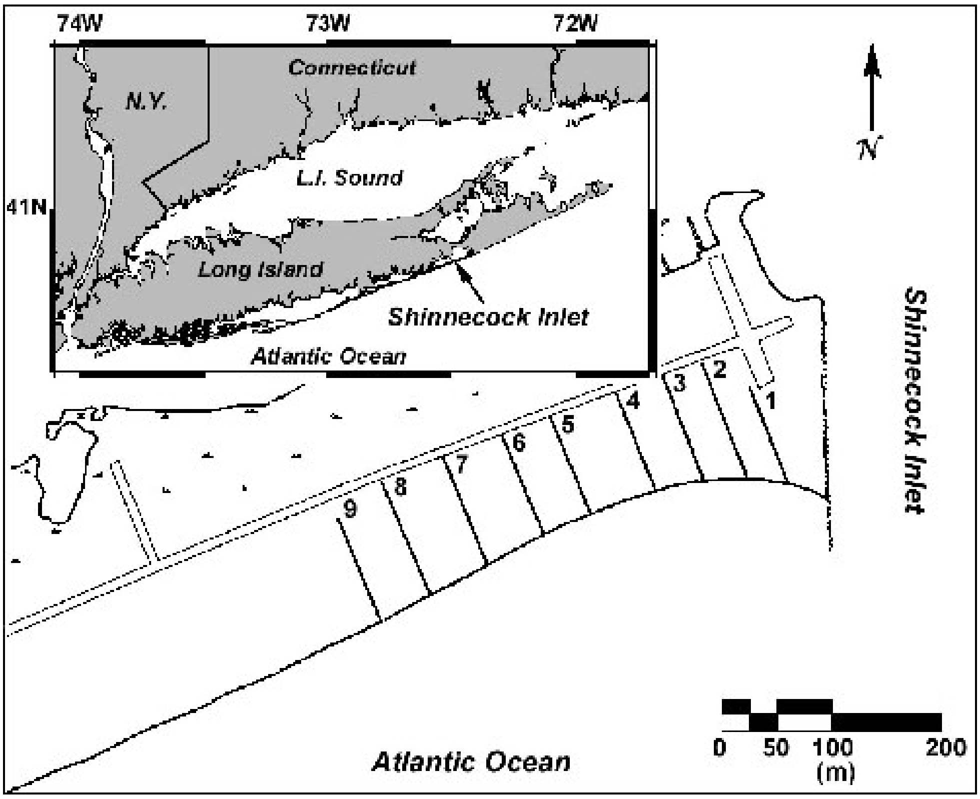

Figure 2. Study area map. Survey transects 1-9 were located along a 475-meter reach adjacent to the west jetty at Shinnecock Inlet.

RESULTS

Values of N_o were calculated for each survey date by entering wave data recorded 5, 3 and 2 days prior to that date. The distribution of calculated volume changes with respect to the criterion was not substantially different. Therefore, only the results for the 5-day calculation will be presented here. Figure 3 shows the results for the 5-day evaluation of N_o plotted against volume change. For this plot, thirteen points (40%) disagree with the criterion for eroded/accreted beaches. In principle, if the relation between $N_o < 3.2$ (or greater than or equal to 3.2) were completely random, 50% of the data should be expected to meet the criterion since there are four possible outcomes ($N_o < 3.2$ and accretion, $N_o < 3.2$ and erosion, $N_o \geq 3.2$ and accretion or $N_o \geq 3.2$ and erosion). Therefore, this result falls above expectations considering the arbitrary sampling of wave data and the fact that the wave data were not randomly distributed over each of the four possibilities (Figure 3); there were no data showing accretion and $N_o > 3.2$ simultaneously. All of the data points failing to agree with the criteria were, as expected, erosive events. Given the episodic nature of erosion, in general, it seems reasonable to assume that the averaging period, instead of being five days, should depend on the magnitude of the last erosive event. After a large storm, accretionary wave conditions may follow; considering the longer duration of such the storm event would effectively become lost through the 5-day sampling. With this in mind, the data set was re-examined for storm events.

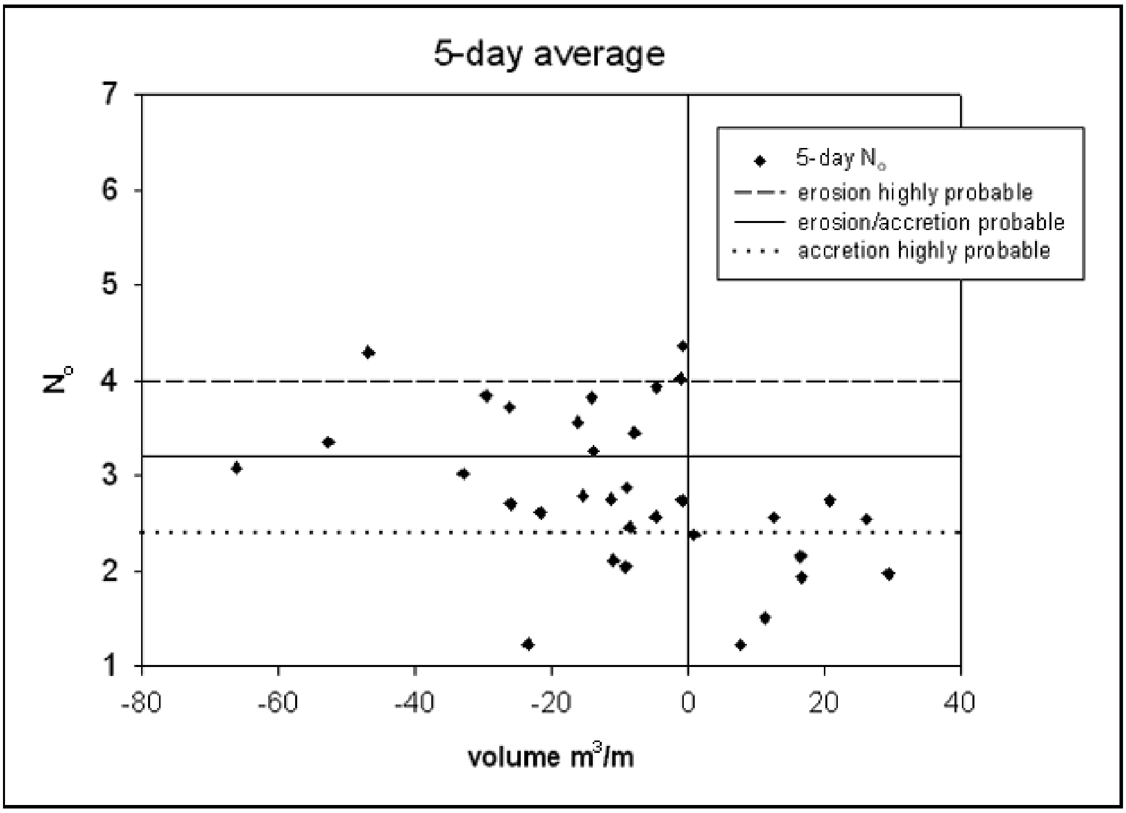

Figure 3. Kraus et al (1991) criteria applied to Dean number values calculated for wave parameters 5 days prior to profile measurements.

Storm events were identified within the wave record for the following conditions: wave height >1m and wave period < 10s with a duration of 24 hr or greater. This was repeated for each erroneous value from the 5-day average. When storm events were detected within a survey interval, N_o was calculated based on the event. If two or more events were identified for a specific survey interval N_o values calculated for each event were averaged. If no event was apparent, the 5-day average was used. The results of this resampling are shown in Figure 4. For this calculation, 3 points (9%) of disagreement were present within the data. 57% of the data points were erosive events, with 43% of this amount falling within the "probable" zone and 62% within the "highly probable" zone. The higher magnitude erosive events (loss of 30 m^3/m or greater) all fell within the "highly probable" zone. 27% of points represented accretion; 22% of which fell within the "probable" zone, and 78% fell within the "highly probable" category.

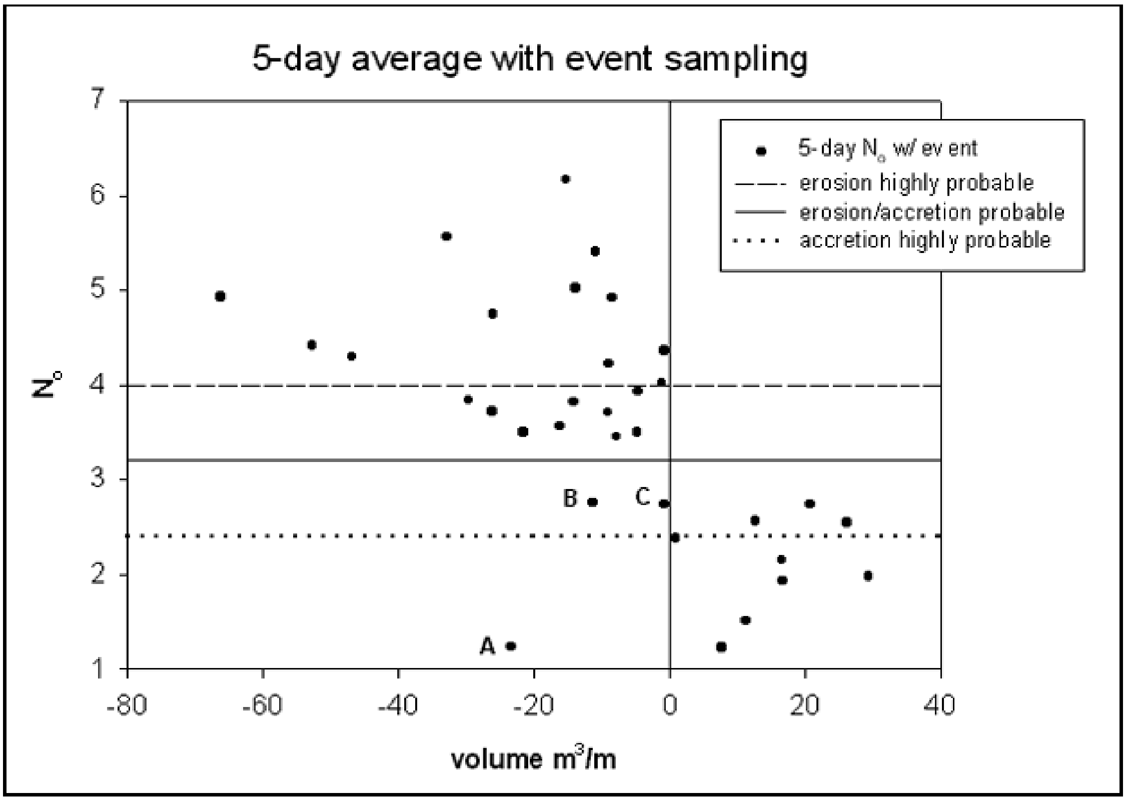

Figure 4. Kraus et al (1991) criteria applied to Dean numbers calculated from 5-day average and event re-sampling. (A) and (B) represent data points within 1 month of beach nourishment. (C) represents the single unexplained point of disagreement with the criteria.

Two of the three data that do not conform to the criteria can be explained. These measurements were made shortly after a nourishment fill project at the site. Data points A (11/3/98) and B (11/18/98)(Figure 4) represent profile data taken within one month of the October 1998 nourishment (310,000 m^3) of Shinnecock (Morang, 1999). Beach nourishment projects are expected to be initially unstable due to readjustment of the profile (Komar, 1998; Silvester and Hsu, 1993), so that some beach erosion is expected regardless of wave conditions. The magnitude of discrepancy decreased in time (from A to B), that is as the fill deposit aged and the profile adjusted itself closer to an equilibrium position. Thus, it is reasonable to exclude these two data points, resulting in 97% agreement with the criterion. The third point of error occurred for the 27 April 1998 survey (C on Figure 4). No identifiable event was present within the wave record for this interval. The calculated N_o (2.74) represents the 5-day average. Volume loss was small within this survey interval (0.8 m^3/m in 30 days); this value may represent "noise" (volume change less than 0.1 m^3/m/day) as defined by Seymour and Castel (1989).

DISCUSSION AND CONCLUSION

The method of sampling the wave data proved to be an important factor for the calculation of N_o. In sampling of wave parameters 5 days prior to surveys, 60% of the data points met the criteria. While this method effectively captured all accretion events, discrepancies in applying the criteria occurred if the wave conditions remained in the stable range of the criteria (N_o~3.2) for several days before the survey, but were preceded by events occurring over 24 to 48 hr. Eleven of the 12 points re-sampled for events were within the winter storm season or during hurricane season when events are more apt to induce large, rapid volume changes than the prevailing wave conditions. The averaging of data through these time intervals misrepresents the factors most responsible for coastal change. With this in consideration, it is essential to account for these processes when performing analyses relating wave conditions to erosion or accretion.

Kraus et al (1991) identified jetties as well as other structures inhibiting littoral drift as a possible source of error within N_o calculations, and suggests that the criterion is most applicable to "straight stretches of beach distant from inlets, jetties…" It seems that the criterion is reasonable when applied with understanding of the physical processes for the beach adjacent to Shinnecock Inlet.

The criteria for the prediction of an eroded or accreted beach established by Kraus et al (1991) for field conditions were successful in describing volume change for the shoreline directly adjacent to Shinnecock Inlet. Sampling of wave parameters for 5-days prior to beach surveys accurately described all accretion events within the study period. However, this method proved unreliable for the winter storm and hurricane seasons. For these periods, which represent the most active changes in shoreline position, sampling of events within the wave record was proven the most reliable method for predicting erosion or accretion.

References:

Batten, B. 1999. An Investigation of Barrier Beach Shoreline Dynamics at Shinnecock Inlet, New York. Masters Thesis, State University of New York, Stony Brook. 143 pp.

Dean, R.G. 1973. Heuristic models of sand transport in the surf zone. *Proc. Conf. On Engineering Dynamics in the Surf Zone,* Institution of Engineers, 208-214.

Dean, R.G. 1988. Sediment Interaction at Modified Coastal Inlets: Processes and Policies. Lecture Notes on Coastal and Estuarine Studies. v.29, p. 412-439.

Komar, P. 1998. *Beach Processes and Sedimentation.* Prentice Hall, New Jersey. 2nd ed., 544 pp.

Kraus, N.C., Larson, M., and Kreibel, D.L. 1991. Evaluation of beach erosion and accretion predictors. *Proc. Coastal Sediments '91,* ASCE, 572-587.

Kreibel, D.L., Dally, W.R., and Dean, R.G. 1986. Undistorted Froude scale model for surf zone sediment transport. *Proc. 20th Intl. Coastal Engineering Conf.,* ASCE, 1296-1310.

Leatherman, S.P. and Allen, J.R. 1985. Geomorphic Analysis: Fire Island Inlet to Montauk Point, Long Island, New York, Reformulation Study. Report to U.S. Army Corps of Engineers, New York District, New York, N.Y., pp. 350 + appendices.

Lewis, D.W. and McChonchie, D. 1984. *Analytical Sedimentology.* Chapman and Hall, New York. 197 pp.

McCormick, C. L. 1973. Probable Causes of Shoreline Recession and Advance on the South Shore of Eastern Long Island. *Proceedings of Ann. Geomorphology Series*: p. 61-71.

Morang, A. 1999. Shinnecock Inlet, New York, Site Investigation, Report 1, Morphology and Historical Behavior. TR-CHL-98-32. Coastal Inlets Research Program, USACE Waterways Experiment Station, Coastal and Hydraulics Laboratory.

NOAA. 1999. National Data Buoy Center, buoy 44025. URL: http://seaboard.ndbc.noaa.gov/station _page?$station=44025

Seymour, R.J. and Castel, D. 1989. "Modeling cross-shore transport." *Nearshore Sediment Transport*, Plenum Press, New York, N.Y., 387-401.

Silvester, R. and Hsu, J. 1993. *Coastal Stabilization, Innovative Concepts.* Prentice Hall, New Jersey. 576 pp.

Taney, N.E. 1961. Geomorphology of the south shore of Long Island, New York. Beach Erosion Board, T.M. No. 128.

USACE. 1981. Fall Velocity of Beach Sands, CETN II-4. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, Mississippi.

USACE. 1984. *Shore Protection Manual*, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, U. S. Government Printing Office, Washington, D.C., 4th ed., 2 vols.

USACE. 1995. Beach Morphology Analysis Package (BMAP) version 1. CETN II-34. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, Mississippi

USACE. 1999. U.S. Army Corps of Engineers, Waterways Experiment Station, Prototype Measurement and Analysis Branch. URL: http://sandbar.wes.army.mil/public_html/pmab2web/htdocs/ny001.html

Wright, L.D., and Short, A.D. 1984. Morphodynamic variability of surf zones and beaches: A synthesis. *Marine Geology*, v. 56, 93-118.