## CHAPTER 80

## SAND-BYPASS AND SHORE EROSION, BRIDGMAN, MICHIGAN BY C. N. JOHNSON AND L. W. HIIPAKKA<sup>1</sup>

The objectives of this paper are two-fold:

- Demonstrate by means of a well-documented full-scale case history in the Great Lakes that beach nourishment can mitigate shore damage due to a littoral barrier;
- b. Detail a methodology for analysis of the effectiveness of mitigation measures which lead to conclusions on the needed frequency of nearshore soundings as a tool for monitoring.

In 1970 a temporary harbor was installed by private interests along the southeastern Lake Michigan shoreline near Bridgman, Michigan, (Figure 1). The harbor was necessary to protect floating plant involved in building a large privately-owned electric generating facility. The harbor was constructed of steel sheet pile and extended lakeward about 125 meters from the water's-edge to a depth about 3 meters below low water datum (LWD)<sup>2</sup>. Net littoral transport is about 75,000 cubic meters per year southward. The updrift and downdrift lakebed and bluff materials consist of sand.

To ensure that this littoral barrier would not have an adverse effect on adjacent properties it was necessary for the Corps of Engineers to impose stringent requirements for issuance of a Federal permit for the installation. Bypass of at least 75,000 cubic meters per year of sand was required to mitigate potential erosion of downdrift beaches due to interruption of littoral transport. The permit also required intensive monitoring of the shoreline to ensure that any adverse effects of the harbor would be promptly detected and remedied. The monitoring consisted of:

- a. Monthly 1:3000 scale aerial photographs of the shoreline sixteen kilometers north (updrift) to sixteen kilometers south (downdrift) of the harbor.
- b. Monumenting and thrice-yearly measurement of backshore-nearshore profiles spaced 150 meters apart, for a distance of 2450 meters north and 2450 meters south of the harbor, extending about 900 meters lakeward to about -8 meters LWD (Figure 2). The nearshore soundings were made by acoustic sounder every 30 meters along each profile. The survey boat was located along the profile by triangulation. Backshore profiles were provided by photogrammetric mapping.

<sup>&</sup>lt;sup>1</sup>The authors are Hydraulic Engineers in the Coastal Engineering and Hydraulic Design Branch, U. S. Army Engineer Division, North Central, Chicago, Illinois, USA.

<sup>&</sup>lt;sup>2</sup>Low water datum for Lake Michigan is 175.B1 meters (576.B feet) above mean sea level at Father Point, Quebec.

Figure 1. Location Map





- c. Sand samples were taken during May 1973 at the water's edge, on the first and second sandbars for each profile and from the borrow sites. Additional water's-edge samples were taken during October 1973 near the property lines updrift and downdrift from the harbor.
- d. Wind speed and direction were recorded hourly near the water'sedge at an anemometer height of about 10 meters above LWD.

The permit went into effect and the temporary harbor was constructed in late 1970. The harbor was removed in late 1973. The monitoring program continued until December 1974. Tanner (1974) reported on an analysis of some of the resulting data. There is little overlap between his work and that of the authors.

The power company emplaced the following approximate quantities of sand in the feeder beach south of the harbor: 129,000 cubic meters in 1971, 143,000 cubic meters in 1972, and somewhat more than 230,000 cubic meters in 1973. About 40,000 cubic meters of those quantities were obtained by hydraulically bypassing sand from the accretion fillet. The remainder came from mining of the backshore dunes. The dune sand was used to comply with the permit requirements for a total of at least 75,000 cubic meters bypassed per year. The mined sand was much finer and better sorted than that of the beach north of the harbor. About 90% of the mined sand would be lost from the beach, based on overfill-ratio calculations (Shore Protection Manual, 1973) from the May 1973 sampling.

A thorough interim analysis of the data obtained as of October 1972 was done in early 1973 to determine if the sand-bypassing operation was mitigating the effects of the structure.

The results were as follows:

- a. There was no detectable net nearshore erosion or accretion. The nearshore profiles exhibited large volumetric fluctuations with time but little net change. Figures 3, 4, and 5 are examples. The straight lines on the plots are the regression lines of volume with time. Nearly all of the net changes were shown by t-test (Li, 1964) to be statistically insignificant at about the 80 percent level (Figure 6). There was no perceptible seasonal pattern.
- b. Volumetric bluff erosion varied considerable from profile to profile, but the average rate was essentially the same on both sides of the harbor (Figure 7). The symmetry of the average bluff erosion rates about the harbor indicate that the sand-bypassing and dune-mining operation compensated for sand entrapment by the littoral barrier.
- c. The analysis represented in Figure 8 shows that the nearshore profiles which eroded or accreted the most from July 1970 to



Figure 3. Time History of Cumulative Cut and Fill - Sec 4-S



Figure 4. Time History of Cumulative Cut and Fill Sec 4-N



Figure 5. Time History of Cumulative Cut and Fill - Sec 3-N

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nearshore least-squares profile-area changes

October 1972 did not coincide with the bluff profiles which exhibited the greatest changes. The profiles chosen for this figure are those whose correlation coefficients fell outside of 95 percent lines and the 80 percent lines, respectively, in Figure 6.

d. The lack of any perceptible trends in Figures 6 and 8 indicate that no net deposition of eroded bluff material could be detected in the nearshore zone.

A second analysis was done in late summer 1973, using additional data from April and July 1973. Two unusually severe storms occurred during the 1972-73 storm season. These two storms evidently eroded about 1.5 times as much bluff material as had occurred in the preceding 2.5 years. However, average erosion was the same on both sides of the harbor (Figure 7). This symmetry indicates the continuing success of the sand-bypassing operation since natural updrift bluff erosion equalled bluff erosion downdrift of the harbor.

The third and final analysis, using data from October 1973 through July 1974, was done in late 1974. The harbor was removed early in this period. Storm-season water-levels were about 1.0 meters above LWD, the same as during the 1972-73 storm season. This level was about 0.3 meters higher than during the 1970-71 and 1971-72 storm seasons. There were no storms during the 1973-74 storm season as severe as in the preceding storm season. Bluff erosion took place at roughly the same rate as during the first two years, even though the water level was much higher (Figure 9). Average erosion rates were lower south of the harbor (1.7 m3/m) than north of it (5.3 m3/m). Much of this difference may be due to the large volume of sand emplaced when the harbor was removed.

The sand samples were not taken over a sufficient number of years to justify making firm conclusions from them. However, a few working hypotheses for future research seem to be noteworthy.

- a. Figures 10 and 11 show typical particle-size gradations from the May 1973 samplings. These samples were taken at the end of the severe storm-season discussed above. For all profiles, the median particle sizes were larger at the water's-edge than on the bars. Figure 12 compares the May 1973 water's-edge computed composite and borrow samples with the October 1973 samples (Krumbein, 1957, describes how computed composites are derived). The May water's-edge samples are coarser than the October ones. The May borrow-material gradation was similar to the October water's-edge gradation. If the observed changes in water's-edge material from May to October are typical of seasonal effects, considerable caution should be used in specifying artificial beach-fill gradations based on summertime beach samples.
- b. Trend estimates of nearshore erosion in Lake Michigan and, probably, the other four Great Lakes can be very misleading if















based on soundings taken one or more years apart. As a consequence, soundings every three months apart for at least two years may be necessary to estimate the effects of random fluctuations on nearshore profiles.

- c. There was only weak correlation between Lake Michigan water levels and bluff erosion rates. Bluff erosion rates were highly variable from profile to profile. Severe storms seem to be the dominant factor in Lake Michigan shore erosion. Limited beach accretion, not erosion, took place when water levels were seasonally highest (summer). Erosion was severest during the late autumn and early spring when water levels were about 0.2 to 0.3 meters lower than their summer highs.
- d. Large quantities of finer-than-native sand, in excess of the longshore transport rate, were placed on the shore south (downdrift) of the harbor. Downdrift bluff erosion rates were the same as updrift in spite of the excessive quantities. These results imply that beach nourishment with finer-than-native sand may be an inefficient way to control erosion. In spite of the massive quantities of material, erosion still proceeded at the natural rate.

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