THE LOCATIONAL SIGNIFICANCE OF MANMADE PROTECTIVE STRUCTURES ON THE LAKE MICHIGAN SHORELINE OF MILWAUKEE COUNTY, WISCONSIN

by

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This study is a preliminary qualitative analysis of the locational significance of manmade shoreline protective structures and landfill jetties along the Milwaukee County shore of Lake Michigan. Position of structures relative to shoreline orientation and to other structures is analyzed in terms of erosional/depositional patterns and for implications regarding shoreline morphology alteration and land use. Thus far no research seems to have been conducted in the area of macroscalic spatial distribution analysis of effects of manmade structures.

Physical Environment of Milwaukee County Shoreline

Milwaukee County bluffs consist of unconsolidated glacial till, standing generally between 30 and 120 feet high. Bluffs north of the Milwaukee River mouth have a clay and sand composiiton, while those to the south are predominantly sand and gravel. The latter type is thus able to supply greater volumes of the coarser sediment necessary for beach creations.

Higher lake levels between February and July directly enact shore erosion. Lake level fluctuation is presumably climatological in origin, and related to regional ground water levels and seepage into the lakes.

A second process instrumental in effecting erosion is storm wave activity. Although the county's west lake shore location portends lower water levels during the usual westerly wind flow, occasional northeasterly storm action allows transmission of kinetic wave energy over a vast fetch of water, thus inducing extensive erosion.

Running north to south is a littoral current, which carries coarse sediment southward until blocked by some obstacle. Sediment may also be held in abeyance just off-shore for hours or days after storm activity,

and then may be either redeposited by post-storm wave activity, or transported as part of the littoral drift.

Projection Analysis

A natural projection (see Figure 1) is that segment of shoreline protruding conspicuously into the lake, relative to adjacent shoreline. In Milwaukee County it consists of a northeast-facing (north) and a southeast-facing (south) side. In relation to storm direction, these may also be termed the front and back sides, respectively. A natural half projection consists only of a curvilinear front side and linear section, with no back side indentation. It follows that north and south projection sides correspond, respectively, to the south and north sides of bays. The smooth form of natural projection coastlines allows easy passage of shore current because it is associated with the original processes of lake shore creation.

Artificial structures placed on projection coastlines may either directly buffer shoreland, as do seawalls and revetments, or be used to create and maintain beaches, as do groins, jetties, and piers. Breakwaters might be classed in either category. Landfill jetties, to which primary attention is given in this study, are more readily identifiable in the second group but, as will be seen by virtue of their physical shape and large dimensions, might easily be considered as constituting a third class.

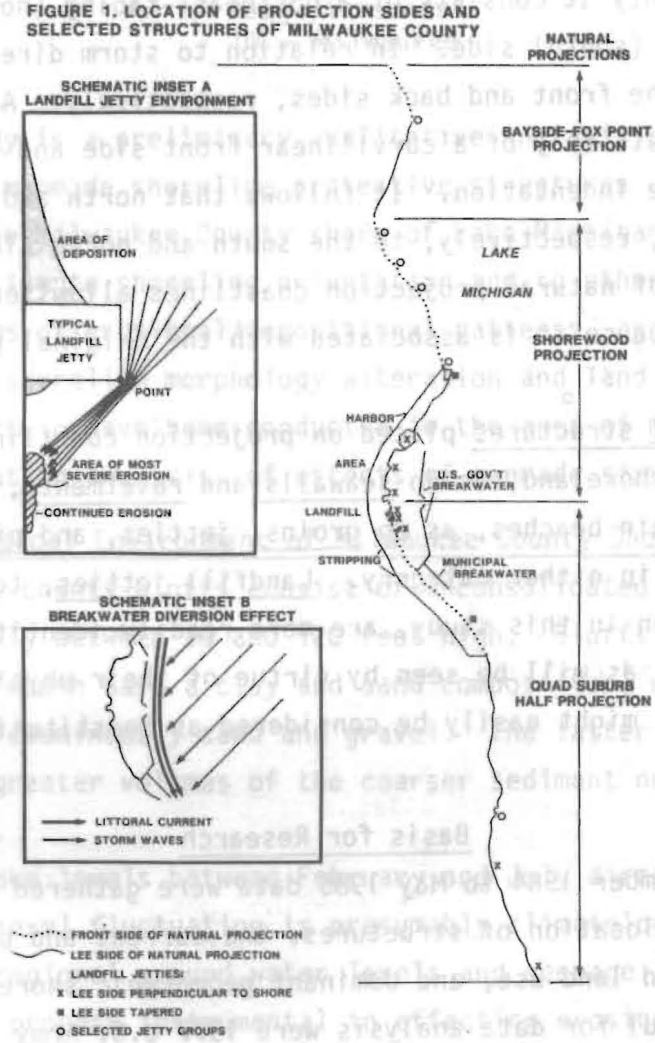
Basis for Research

From September 1984 to May 1985 data were gathered pertaining to construction and location of structures, the current and past history of landfilling and land use, and dominant geomorphic shore processes. Particularly useful for data analysis were 1977 U.S. Army Corps of Engineers photographs, at a scale of 1 inch to 200 feet, which cover the entire Milwaukee County shoreline. Extensive map analysis, personal interviews, and study of various charts and reports, along with field visitation were necessary to substantiate the essential relationships.

Distribution of Man-Made Structures on Milwaukee County Shoreline

Structures are located according to position on natural projections (Fig. 1), and by use of Milwaukee's north to south street numbering system, in which 800 equals one mile.

FIGURE 1. LOCATION OF PROJECTION SIDES AND SELECTED STRUCTURES OF MILWAUKEE COUNTY



The shoreline segment from the Ozaukee County Line (9600N) to 6400N is termed the Bayside-Fox Point Projection, that from 6400N to the Milwaukee River mouth (700S) the Shorewood Projection, and that from 700S to the Racine County Line (11100S) the Quad Suburb Half Projection. Only the representative structures, including a few major landfill jetties, are highlighted here.

The Bayside-Fox Point front projection side, oriented at S30°E, shows evidence of extreme beach erosion. Only a few private jetties and seawalls are located here, and appear to be mostly ineffective or damaged. Doctors Park has five public jetties that accrete only small amounts of beach material because of direct exposure to northeast storm action.

Severity of beach erosion is almost as intense on the lee side, apparently because the angle of indentation, S20°W, is too low to prevent direct storm wave penetration, most commonly observed at N45°E. The only stable shore areas are several low, natural terraces.

The Shorewood Projection front side is oriented at an average of S45°E over 60%, and at S20°E over 40%, of its shoreline. It contains five park areas - Klode, Silver Spring, Big Bay, Buckley and Atwater Beach parks. Jetties and seawalls present here are minimally effective, and are located in places with a history of failed structures. A Big Bay seawall is exposed, with no intervening beach, and may be eventually undermined, isolated, and destroyed, as was its predecessor. Jetties and seawalls on this shoreline are consistently associated with extraordinary erosion to their leeside locations (Fig. 1, Inset A). Only at Atwater Beach is there considerable frontside deposition due to three unusually large jetties, all of which are, however, greatly damaged in parts and in need of repair.

Several Whitefish Bay and Shorewood residents have constructed sizable landfills affixed to their property. While backyards may be temporarily secured, new fill material, being loose and unconsolidated, and establishing steeper slopes, usually promotes greater slope instability and susceptibility to erosion than previously. The most notable example is an illegal, 93 foot long pile of soil, rock, and debris on the property just north of Big Bay Park, where, interestingly, the harshest evidence of leeside erosion was found.

The lee side of the Shorewood projection (but containing only city of Milwaukee shoreline) is inclined at an average S50 W, and affords the

first significant beach accumulations. The Linnwood Ave. Water Filtration Plant (3100N to 2900N), the first large landfill perpendicular to the path of the shore current, blocks considerable sediment. Other beaches include Bradford Beach, partially maintained by the North Point landfill, and McKinley Beach, created and maintained almost entirely by the northern terminus of the United States government breakwater (1700N to 2400S).

Attached to the southern end of the federal breakwater is a municipally owned breakwater of a rock and rubble material. Much of its length is destroyed. The shore behind the breakwater shows erosion and gullying beyond that expected for a presumably protected area. Just south of the breakwaters and the Lakeside Power Plant landfill is an especially eroding section called the St. Francis Bluffs. It is thus hypothesized that the two breakwaters tend to divert and channel kinetic storm wave energy and the shore current, with its clear-water erosive potential, around the breakwaters to impact and carry away shore material. This process may be termed a "breakwater diversion effect" (Fig. 1, Inset B).

All remaining shoreline south of the Milwaukee Harbor is part of the Quad Suburb Half Projection. It contains a number of large beaches created by various landfill jetties on their front sides, such as the Lakeside Power Plant (4100S), the rock pier at the mouth of Oak Creek (7500S), the Milwaukee Metropolitan Sewerage District (MMSD) Plant (8300S to 9100S), and the Wisconsin Electric Power Company (WEPCO) Plant (10300S to 11100S). The beaches are much larger than their counterparts on the north county shore because of the greater supply of coarser particles which compose the south county bluffs. Nevertheless, beach erosion is clearly more severe to the south of the large landfills listed above. Thus the pattern of erosion and deposition remains essentially the same as in the north, but at a higher equilibrium with respect to amount of beach material in the system. A noteworthy example of severe erosion is found within a mile south of the MMSD landfill, where long- and short-term bluff recession rates have been measured. Between 1836 and 1980 a bluff recession rate of 2.6 feet per year was established. However, from 1965 to 1980, which also corresponds roughly to the existence of the landfill projection, a rate of 5 feet/year, was established. Thus about 75 of the 370 feet eroded was during the 15-year period.

In addition to creating beaches on their front sides and inducing accentuated erosion on their lee sides, many manmade perpendicular projections, especially the large landfill jetties, were associated with particularly severe storm damage at leeward distances approximately equal to those of perpendicular projection into the lake (Fig. 1, Inset A). The most recent and spectacular example involves a March 5, 1985 storm which penetrated the U.S. breakwater and sent 15-foot waves over the revetment at the Milwaukee Summerfest grounds at a distance of approximately 500 feet leeward of the Municipal Pier landfill, which itself projects 500 feet into the lake. Since the arctangent (500/500) = arctangent (1) = 45 degrees, the waves responsible for damage must have entered from a direction of approximately N45°E, which also runs through the north breakwater gap. There is a proposal to build a boat basin in the same location victimized by the March 1985 storm and a special 1400 foot long breakwater to protect it. It is hoped that there is an awareness of the potential danger here.

Philosophic Framework and Conclusions

This study shows that erosion ordinarily occurs on the front side of natural projections and the lee side of manmade projections with deposition occurring in the reverse locations: on the lee side of natural projections and frontward of manmade projections. Thus manmade structures, as they have been constructed in the past, produce an effect opposite to that of natural shoreline projections. These conditions may result from the following processes:

Jetties perpendicular to the shore on their front side effectively block the littoral drift and lead to deposition, but allow the shore current greater erosive power in the region leeward of the projection, especially if the back side is at right angles to the shore. It is this phenomenon of exacerbated leeward erosion that has been disregarded in the past. The perpendicular front edge is usually planned in order to create beaches frontward, but the back edge seems to have retained its perpendicularity either to preserve symmetry or for other aesthetical reasons. Only two large landfill jetties on the county shoreline were observed to have a somewhat tapered back side. If manmade landfill projections continue to be constructed, care should be taken to curve the back side so as to (1) facilitate movement of littoral current and

(2) partially offset the extreme concentration of storm wave energy in a small area leeward of the projection. If jetty construction remains as it is, storm waves will continue to weaken and dislodge disproportionate volumes of material in regions leeward of the jetties, and the emerging, clearer littoral current, robbed of its sediment while coming around the obstacle, will continue to transport eroded shore material southward until once again blocked by some obstacle.

It is well known that exposed coastline facing incoming storm waves experiences far greater erosion than do lee projection sides indented away from the shore. If a leeward coast is not sufficiently indented, however, it may be vulnerable to erosion almost as severe as that on the front projection side. The lee side of the Bayside-Fox Point Projection fits into this category. In contrast, the lee side of the Shorewood Projection is sufficiently indented, in the direction of approximately S50°W, to escape this fate. Still, it is very important for long-range planning to recognize that further landfilling - even in the breakwater-enclosed area - may seriously jeopardize the immunity heretofore enjoyed.

The net action of any kind of jetty depends largely upon where it is placed on a natural projection coastline. Jetties (and seawalls) placed on front sides of projection in Milwaukee County experience extreme impact by storm waves and thus often have to be replaced. Since these structures are expensive to install, repair, or replace, they should not be used unless absolutely necessary, in the opinion of the author, to maintain a vital and permanent public shoreland use.

An example of the interaction of above-mentioned factors to produce desired beach accumulation is found at the Bradford Beach site: the original beach was created decades ago under different shoreline conditions. Currently the beach is partially maintained by (1) position on a sufficiently-indented lee projection side, which promotes deposition, and (2) position just frontward of a small, but right-angled artificial landfill called North Point, also promoting deposition.

Placement of manmade protective structures should be evaluated, not just in terms of the immediate locality they are designed to protect, but also in terms of the desired morphological configuration and composition of the shoreline. It appears that use of manmade shoreline devices

in Milwaukee County has, in the name of protecting small specific localities, induced changes from a relatively uniformly-eroded shoreline to one experiencing highly differential erosion. If shoreland owners understand how and to what extent protective structures alter the pattern of erosion and deposition, they will be able to predict how future installations will affect shoreline features, and can then plan shoreline use so as to accommodate the change.

Placement of manmade shoreline structures seems to have become "addictive" and has established a spiraling self-reinforcement: the greater the number of devices, the greater the number of sites experiencing extreme cases of erosion, and the greater the demand for more protective structures.

Coastal land use and morphologic change derived from the existence of shoreline structures are often related. Consider a specific case in point: Recently, the entire city of St. Francis shoreline (including the WEPCO Lakeside Power Plant) was purchased by a development group from Carpentersville, Illinois. Even though they will have to contend with storm erosion generally south of the municipal breakeater, they nonetheless plan to build condominiums on the landfill site now occupied by the Lakeside Plant. A good reason is that a beach, having been created and maintained by the physical obstruction of littoral drift by the landfill site, already exists there, and can be used as a pre-existing real estate amenity. This is surely one example of many in which land use depends in part on shoreline morphological features and processes.

Any future landfilling along the lakeshore should be planned to preserve shoreline shape and not to produce unpredictable complications. Even uniform landfilling, however, must be executed with caution because as bays fill up, or as projections are enlarged, differential rates of erosion and deposition are also likely to change. If landfilling is employed in a bay, and erosion continues unabated on a front projection side, a greater degree of linearity ensues. The safeguard in this is that as the projection and bay become more aligned, the erosional/depositional differential becomes less. Careful macroscale planning of future manmade shoreline structures in Milwaukee County may eventually lead to greater shoreline stabilizaiton.