SUMMARY OF LAKE-BOTTOM CHANGES ALONG THE CHICAGO LAKESHORE NORTH OF LINCOLN PARK between 1872 and 1990

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INTRODUCTION

Changes in the Lake Michigan shore and nearshore--whether caused by natural forces, by lakefill or by manmade structures--commonly alter wave and current regimes as well as the availability of sediment resources. Material eroded from the shore feeds the longshore drift and provides silt, sand, and gravel for beaches and bars as well as the submerged littoral slopes that front the Lake Michigan shore.

North of Chicago, the net longshore drift moves toward the south (Illinois Division of Waterways, 1958, p. 33). Consequently, sediments for the Chicago shore are largely dependent on longshore transport from the north in order to maintain sedimentary shore features. In addition, sediments must be added continuously to replace materials transported offshore by waves and currents. These replacement volumes are almost entirely derived from eroding northerly shore areas or from artificial nourishment projects.

For some time, coastal specialists have known that increasing development of the Illinois shore has reduced the availability of sediments and changed wave and current effects. Unfortunately, usable data are rare due to a paucity of both historic and modern records. Consequently, the present project was developed to seek out a part of the shore where acceptable, historic records exist and where modern maps could be added so that long term sediment loss or gain trends could be analyzed. There is a great need to quantify long term rates of change and to foretell shore and lake-bottom futures.

Bathymetric maps, suitable for this study, were found for the Edgewater/Rogers Park area covering the years 1872 and 1955. Maps for 1975 and 1990 were produced by the Illinois State Geological Survey. All maps were made compatible scale-wise, they then were contoured and digitized for computer analysis (Figures 1-4). Sediment volume losses or gains for the periods between map dates--83 years, 20 years, and 15 years, respectively--were calculated and mapped (Figures 10-13). The source maps differ greatly in nature and quality, but significant gain/loss trends, nevertheless, are recognizable and informative.

STUDY AREA

The study area includes Chicago's Edgewater District and the southern half of the Rogers Park District (Figure 1). This reach of shoreline, approximately 8000 feet

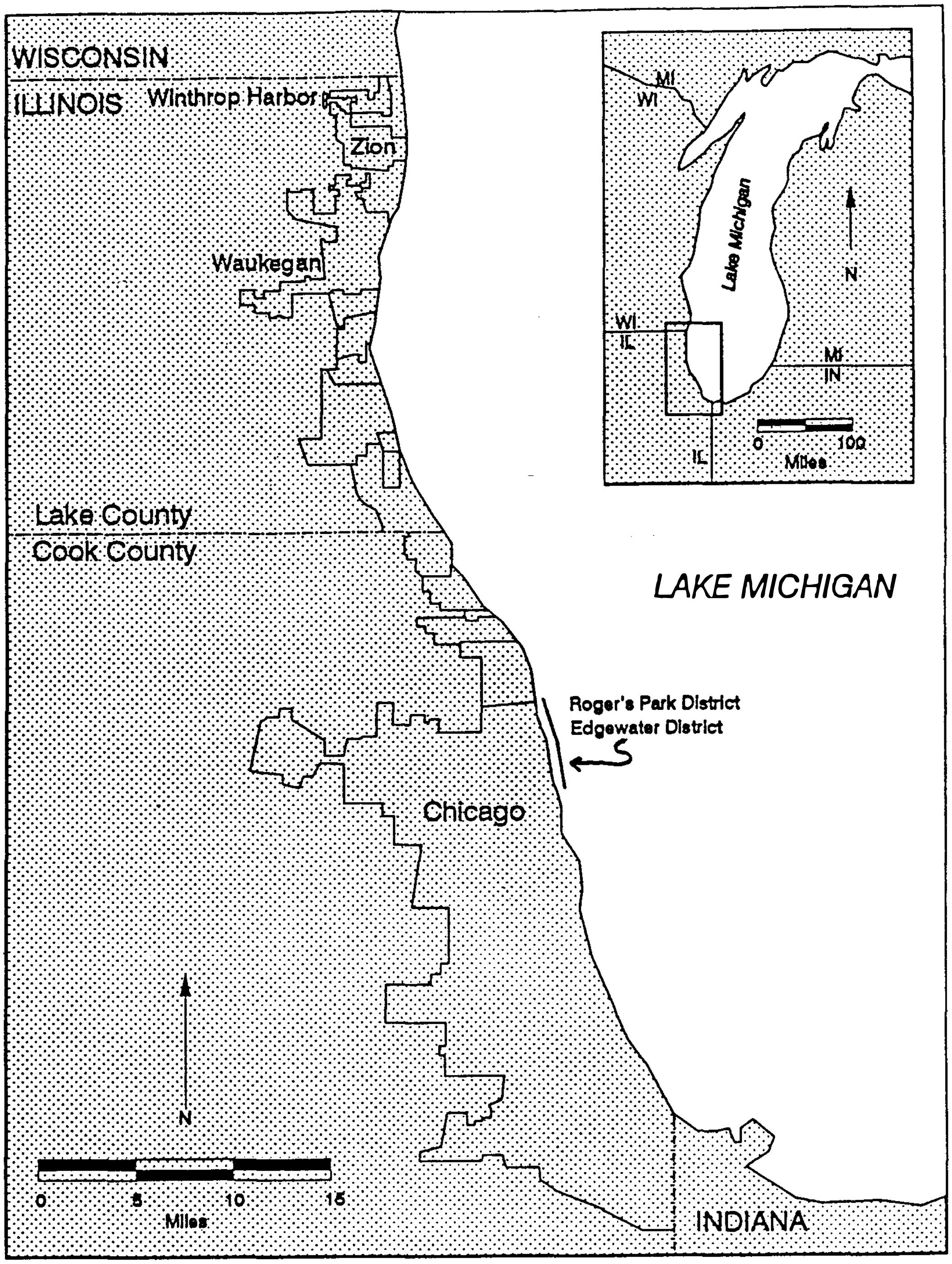

Figure 1. Location of study area.

from north to south, lies between two structures that have functioned as sediment collectors and by-passers–the Hollywood Groin at the northern limit of the Lincoln Park Lakefill and the Farwell Groin at the southern boundary of Loyola Park. The littoral subcell lying between these two barriers is an urban residential area with only minor lakefill associated with construction and protection of high-rise apartment buildings and condominiums. The lakeward limit of the study area is the position of the 20-foot depth contour on the 1955 bathymetric map (Figure 7). This contour was chosen as an estimate of the approximate lakeward limit of longshore drift in this area. In depths greater than 20 feet, lake-bottom material is predominantly till (Fucciolo, 1993) rather than the mobile sand and silt found at shallower depths. The position of the 20-foot contour on the 1955 map was selected because it is farther east than on other maps involved in the study.

METHOD

Lead-line "sounding" points obtained by the U. S. Lake Survey in 1872 and acoustic sounding points obtained by the U. S. Lake Survey in 1955 were traced onto computer-generated plots of the modern Chicago lakeshore. Manual rubber-sheeting techniques were used to align the known reference points on the historical maps with their modern counterparts. The point data were then contoured with a one-foot contour interval and digitized using the ARC/INFO Geographic Information System (Figures 2, 3, 6, and 7). Each contour was then attributed with a z-value in feet below the Lake Michigan-Huron Low-Water Datum (LWD) of 576.8 feet above International

Great Lakes Datum (IGLD, 1955). Also digitized were bathymetric contour maps surveyed by the Illinois State Geological Survey in 1975 (Drake, et al., 1977) and 1990. Bathymetric data for 1985 and 1990 were obtained using a recording fathometer along shore-normal profile lines (Figures 4, 5, 8, and 9). Contours on these maps were likewise attributed with z-values referenced to LWD.

Maps of lake-bottom changes between one time frame and another were obtained by subtracting one digital surface from the other and contouring the difference between them using ARC/INFO's TIN surface modeling techniques (Environmental Systems Research Institute, 1991). Volumes of accretion and erosion were computed by two different methods: 1) using the CUTFILL (ARC/INFO) command on lattices representing each of the two surfaces, and 2) using VOLUME (ARC/INFO) command on Triangulated Irregular Network (TIN) created from an edited version of the contoured coverage representing the difference between the two surfaces. The CUTFILL method has the advantage of being fast, but it can sometimes produce inflated values of accretion and erosion due to the presence of spurious z-values at the surface boundaries (i.e., edge effects). In the VOLUME method, such undesirable edge effects can be, and were, edited out. The results of the volume calculations, using these two methods, are shown in Table 1 under the headings "CUTFILL" and "TIN/VOLUME (Datum = 0 ft)."

Table 1 presents a summary of the net sediment volume changes for the time intervals 1872-1955, 1955-1975, and 1975-1990. There are, however, problems in interpreting such erosion/accretion volumes. Errors in the original maps such as inaccurate determinations of boat position during data collection, inadequate water-

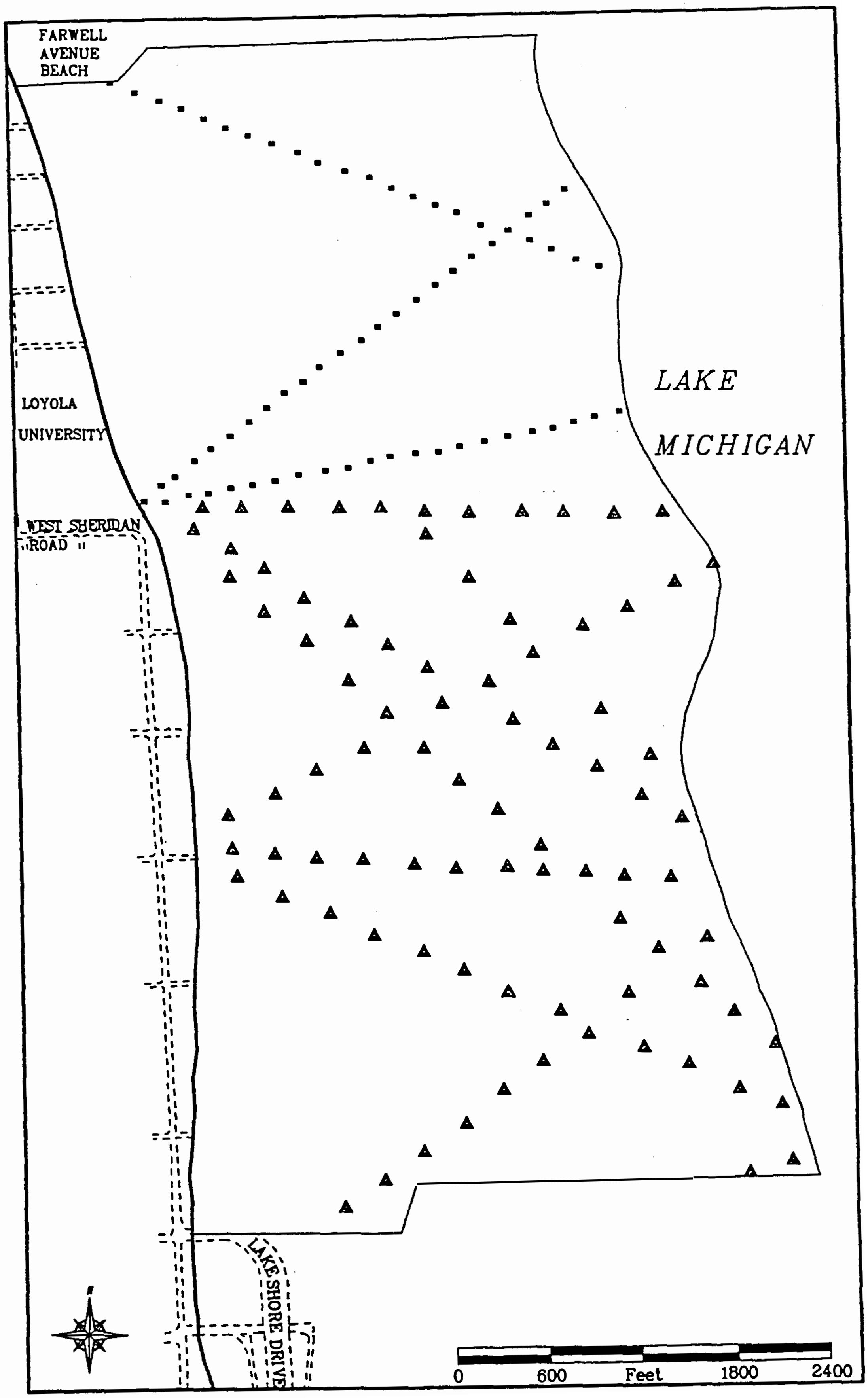

Figure 2. Location of points surveyed in 1872. Points marked with a square are from U.S. Lake Survey, 1873, those with a triangle were taken from U.S. Lake Survey, 1872.

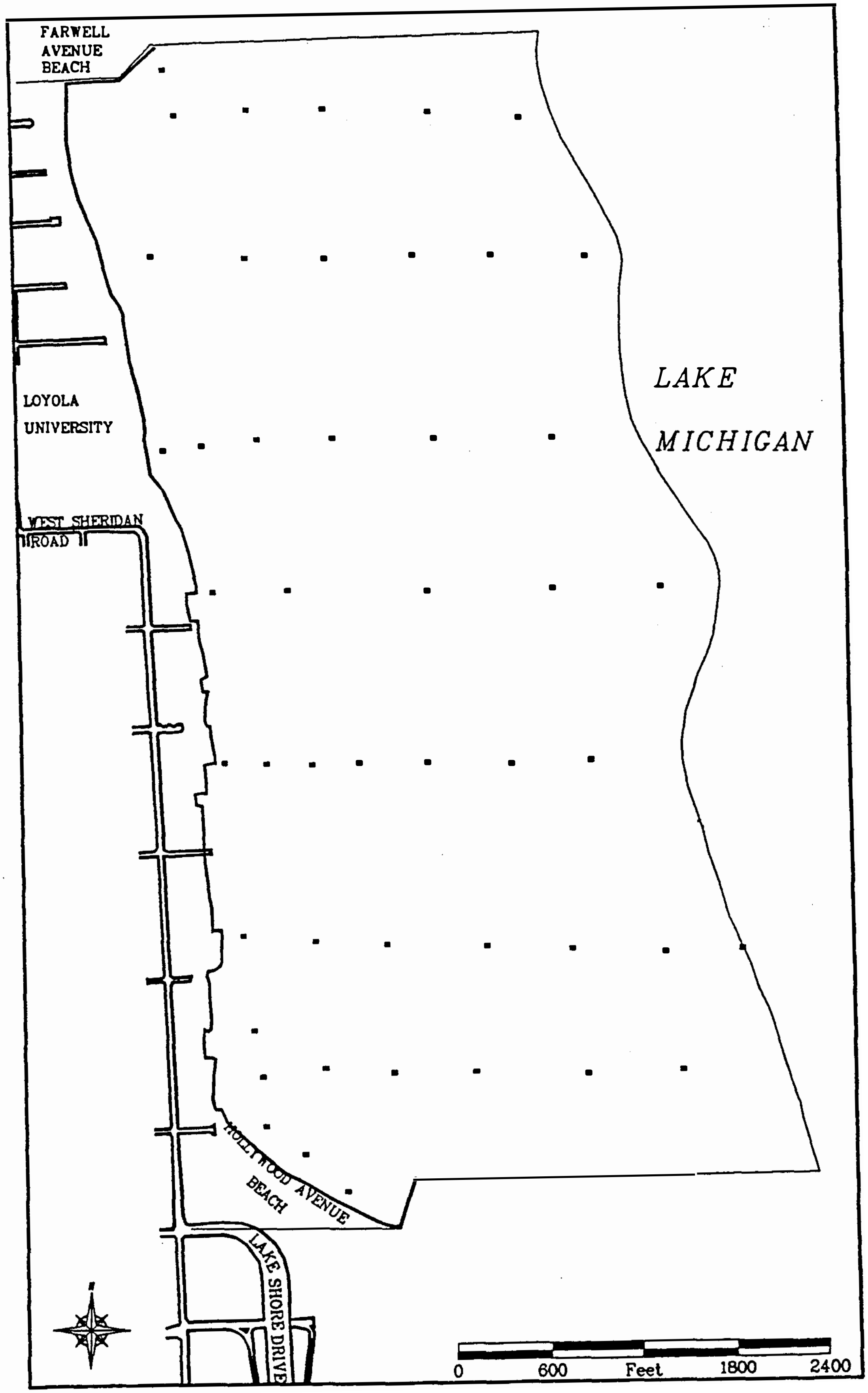

Figure 3. Location of points surveyed in 1955.

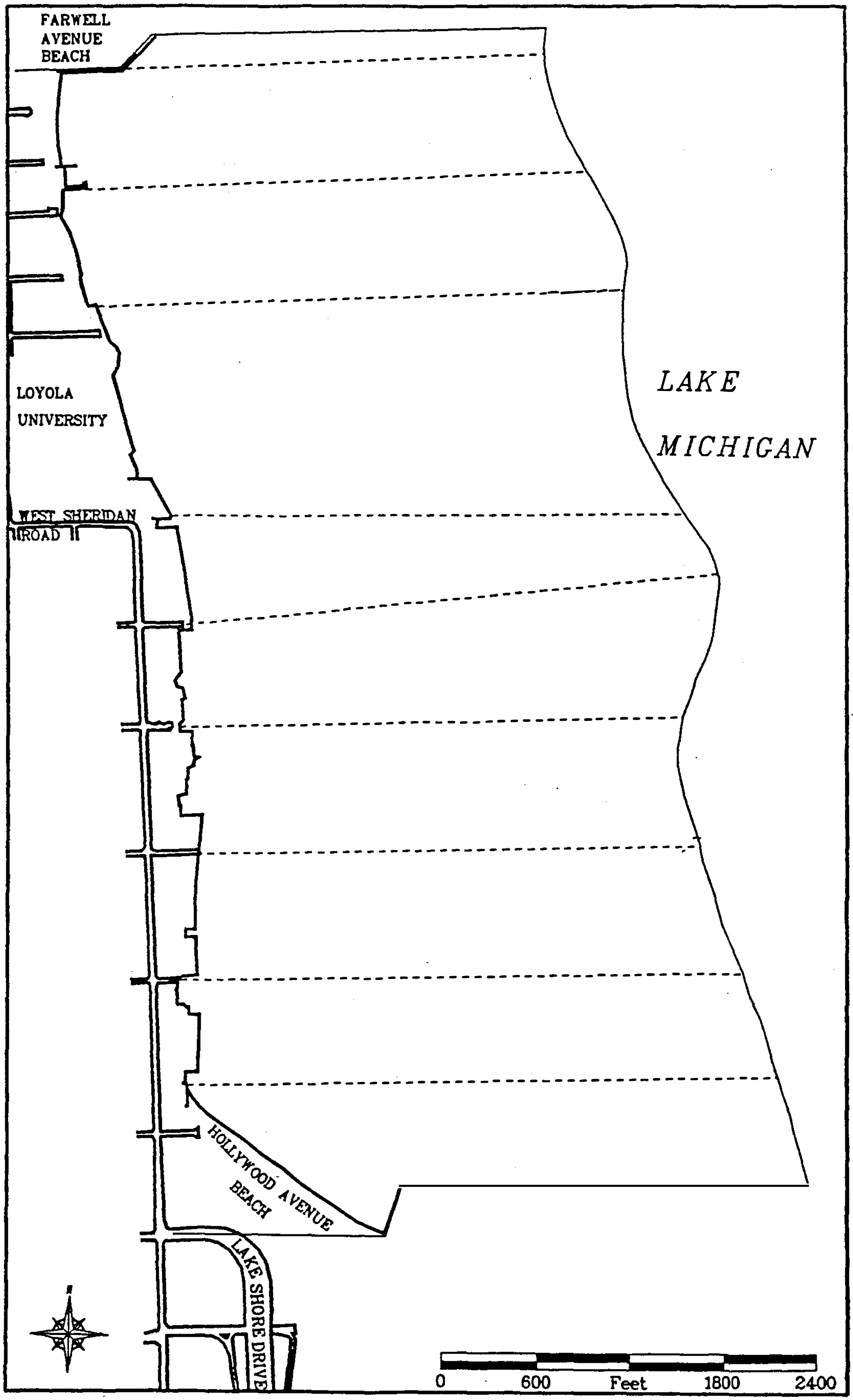

Figure 4. Location of profile lines surveyed in 1975.

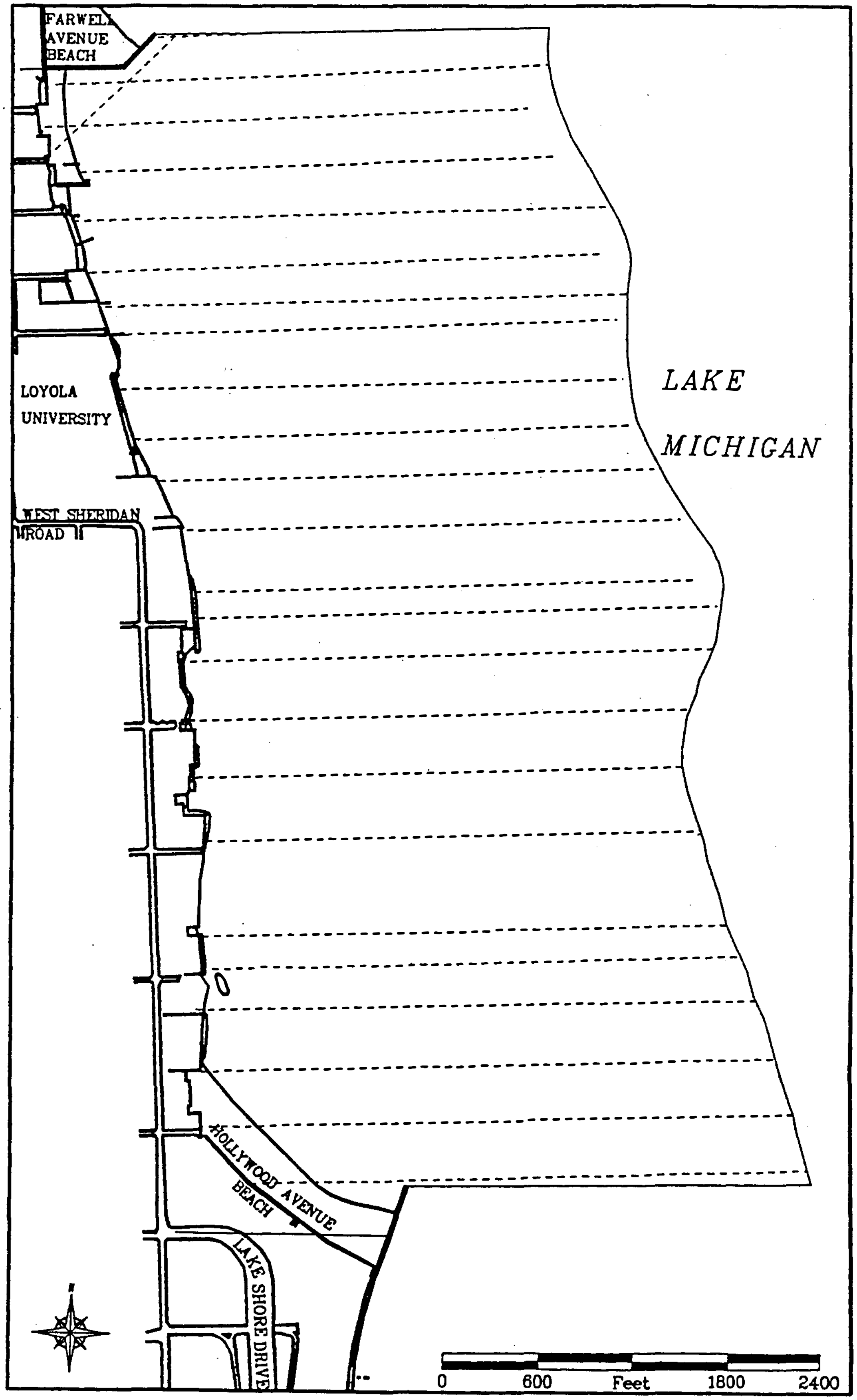

Figure 5. Location of profile lines surveyed in 1990.

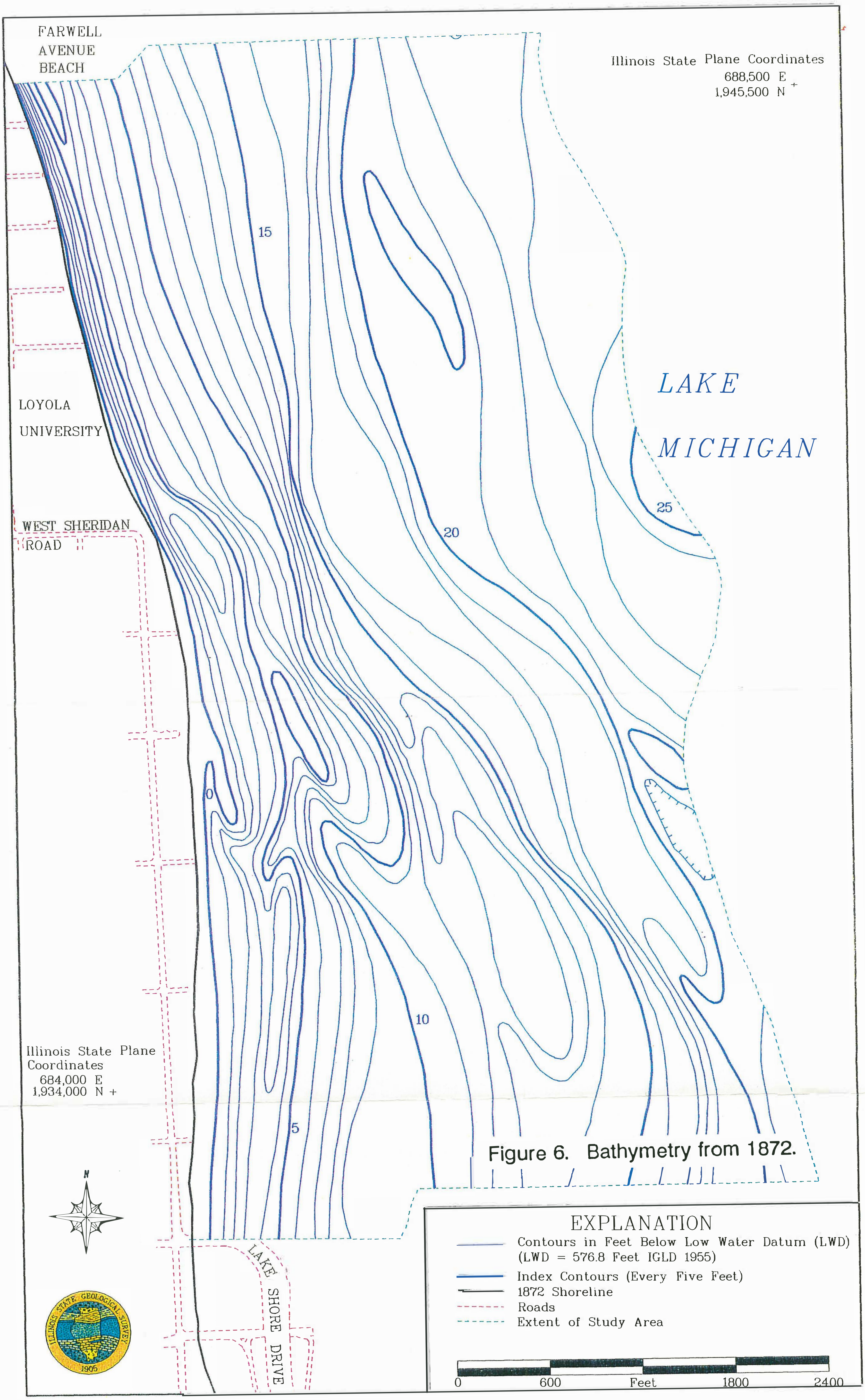

Figure 6. Bathymetry from 1872.

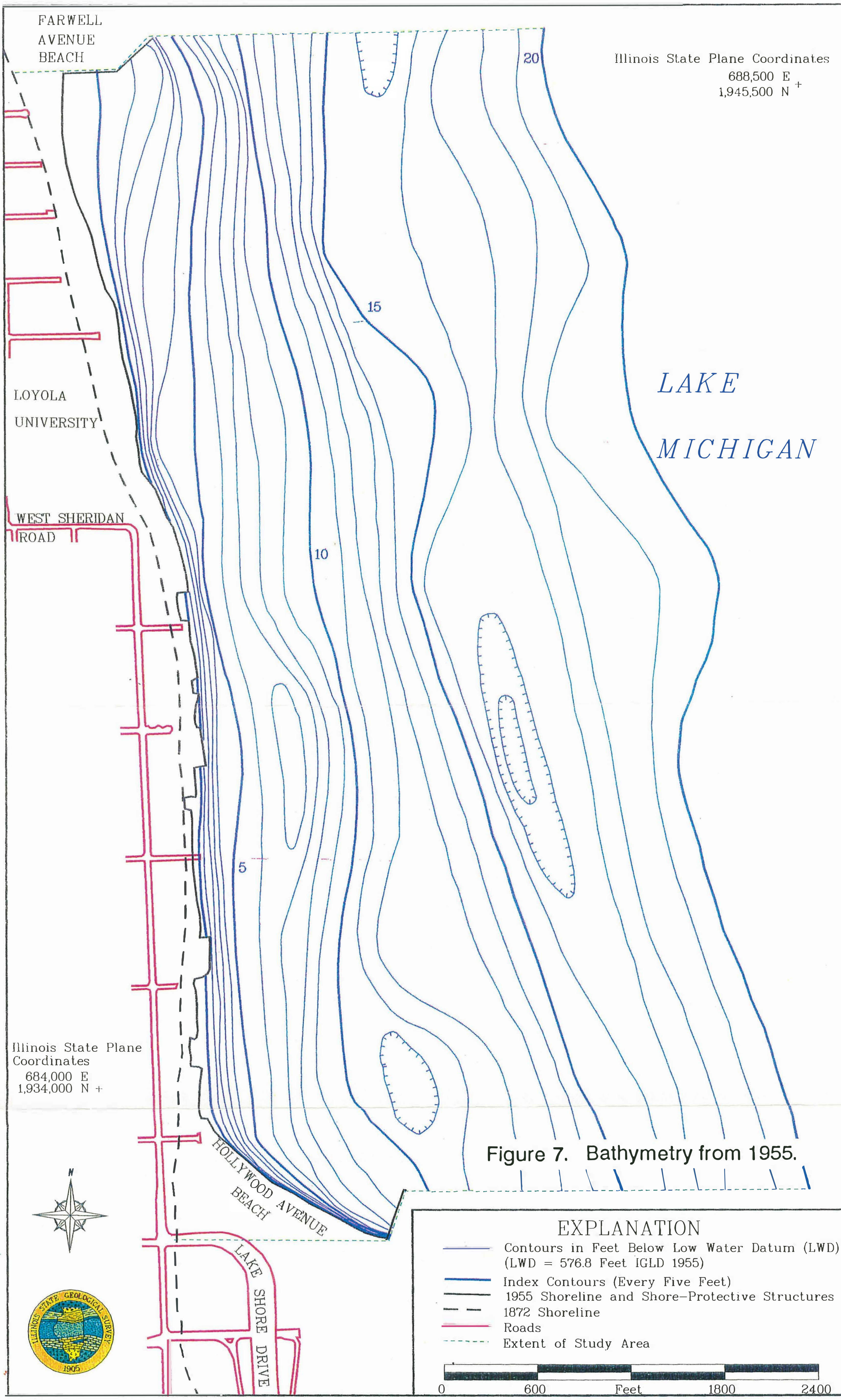

Figure 7. Bathymetry from 1955.

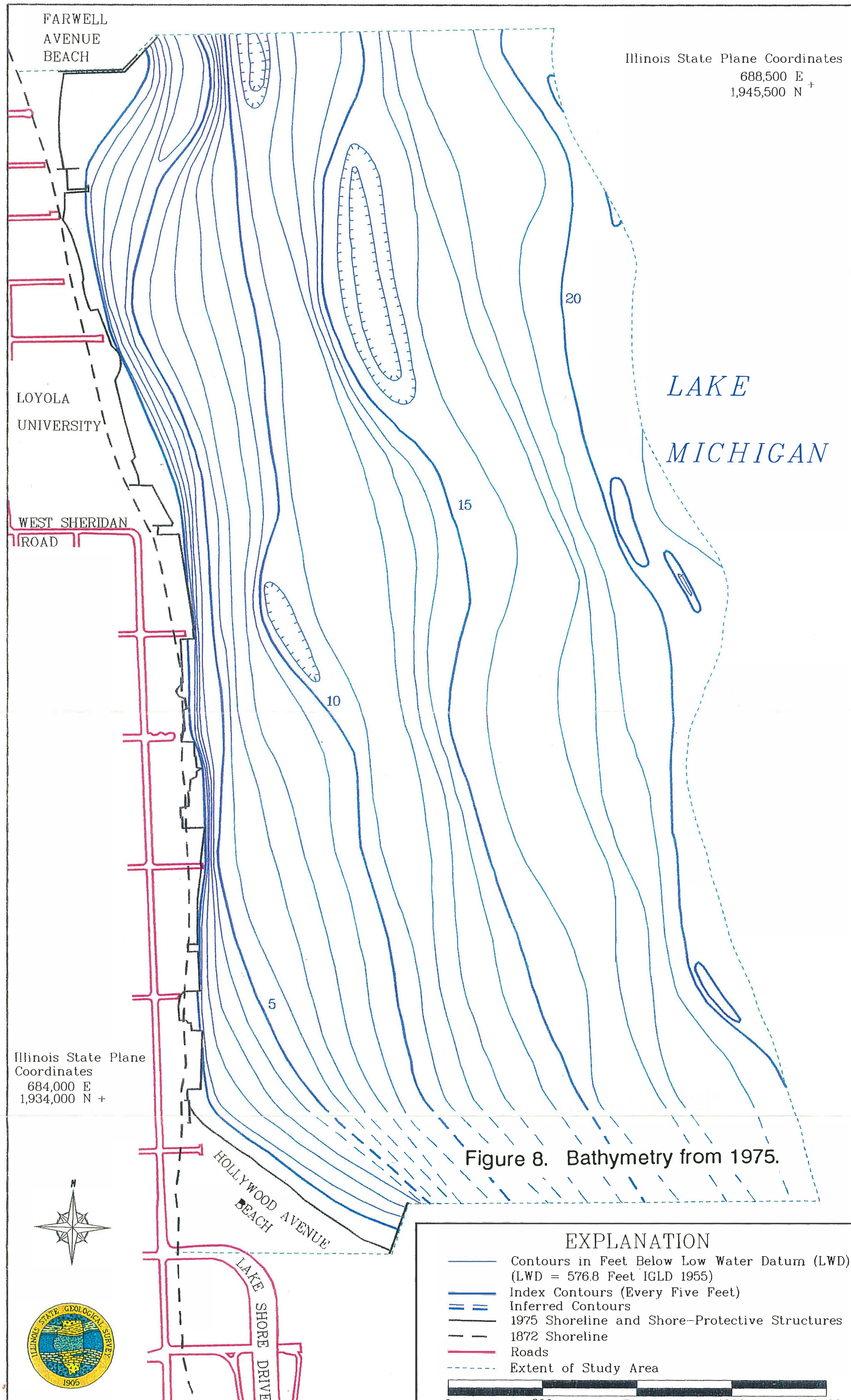

Figure 8. Bathymetry from 1975.

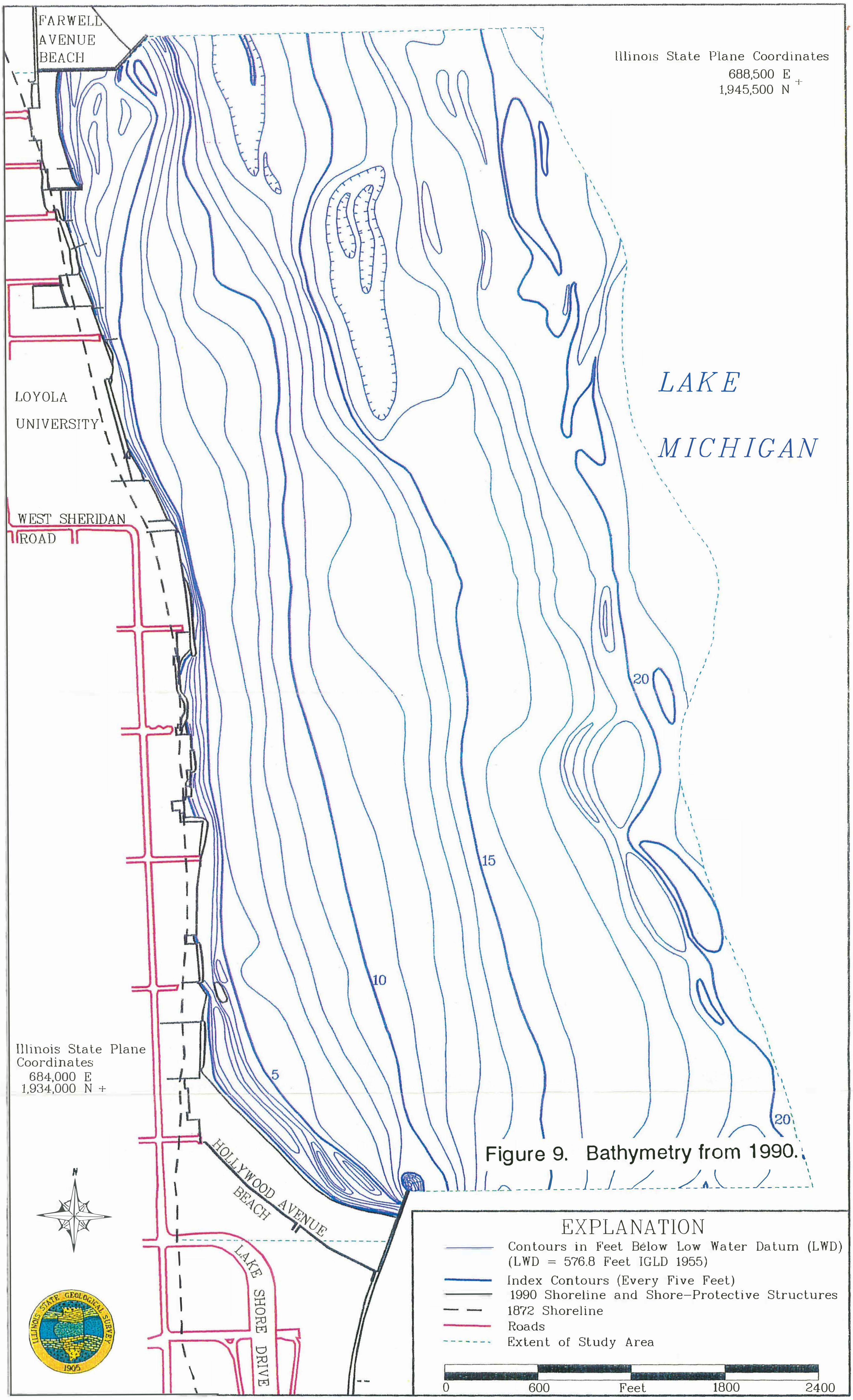

Figure 9. Bathymetry from 1990.

Table 1. Volumes of accretion and erosion in the study area. All numbers are reported in cubic yards.

	VOLUME CALCULATION METHOD		
	CUTFILL	TIN/VOLUME (Datum = 0 ft)	TIN/VOLUME (Datum = 1 ft)
1872 - 1955 "Landfill"			
Accretion		78,000	54,000
Erosion		0	0
Net Change		78,000	54,000
1872 - 1955 Entire Coverage			
Accretion	2,581,000	2,480,000	1,842,000
Erosion	382,000	377,000	156,000
Net Change	2,199,000	2,103,000	1,686,000
1872 - 1955 Entire Coverage minus "Landfill"			
Accretion		2,402,000	1,788,000
Erosion		377,000	156,000
Net Change		2,025,000	1,632,000
1955 - 1975			
Accretion	416,000	379,000	185,000
Erosion	641,000	624,000	174,000
Net Change	-225,000	-245,000	11,000
1975 - 1990			
Accretion	79,000	66,000	4000
Erosion	742,000	676,000	218,000
Net Change	-663,000	-610,000	-214,000
1872 - 1990 Entire Coverage			
Accretion	1,840,000	1,747,000	1,150,000
Erosion	541,000	526,000	283,000
Net Change	1,299,000	1,221,000	867,000
1872 - 1990 Entire Coverage minus "Landfill"			
Accretion		1,669,000	1,096,000
Erosion		526,000	283,000
Net Change		1,143,000	813,000

level corrections for compiled data, or errors in spacing of profile lines or sounding points cause apparent volumes of accretion and erosion to be larger than actual. For example, the depression off the end of the Hollywood Groin seen on the 1990 map may have been present in 1975, but the profile line spacing of the 1975 survey did not detect this feature. To lessen such possible overestimation of lake-bottom changes, volumes were also computed using a datum of one foot above and one foot below the zero-change datum plane. These results appear in Table 2 under the heading "TIN/VOLUME (Datum = 1 ft)." In the case of net change between 1955 and 1975, the use of the one-foot datum plane actually reverses the net change from erosion to accretion, since the erosion is low and spread out over a large area, and the accretion is concentrated in one large pile at the south end of the study area.

LAKE-BOTTOM CHANGES

Table 1 shows that during the 83 years following the completion of the 1872 survey, more than 2,000,000 cubic yards of sediment accumulated in the nearshore zone off the Chicago coast between Hollywood Avenue and Farwell Avenue. A minor part of this accretion can be attributed to the lakefill at the south end of the map (Hollywood Beach at the northern end of Lincoln Park). However, when the volume of the lakefill was computed separately and subtracted from the total net accretion, it was found to account for only 78,000 cubic yards, a minor portion of the net sediment accretion in the study area. When the lakefill volume is subtracted from the net accretion shown in Table 1 under the heading "TIN (Datum = 0 ft)", the resulting net accretion is still greater than 2 million cubic yards.

Two million cubic yards of capture is not surprising. During the two and a half decades that followed the 1872 survey, more than 50 miles of shore to the north were undeveloped. The undeveloped areas freely contributed newly eroded material to the longshore drift stream. Furthermore, much of the shore consisted of sand dunes and soft consolidated sediment. Longshore drift, consequently, was voluminous (Illinois Division of Waterways, 1958, p. 23). Such open conditions were not to continue, however.

Prior to 1908, harbor breakwaters were constructed at Waukegan, significantly closing off drift to the shore south of there. In 1923, the long outer harbor breakwaters at the Great Lakes Training Station in North Chicago were completed (Collinson, 1981, p. 8, 10, 11). They effectively reduced the meagre bypass-sediment received from the north to a mere trickle south of Great Lakes. Subsequently, resources for Chicago were limited to the shores of Lake Bluff and southward. Farther south, also affecting longshore drift, was Wilmette Harbor which was built in 1910 (Illinois Division of Waterways, 1958, p. 104). Although the harbor bypasses sediments fairly well, it also shunts much material offshore (Lineback and Collinson, 1975, p. 31-32).

Farwell Groin, which is a main element in the present study, was not built until 1937. Nevertheless, nearly all of the 2 million cubic yards of accretion (Figure 10) which accumulated between 1872 and 1955 can be attributed to its presence. Several years undoubtedly were required for longshore drift to fill the updrift side of the newly

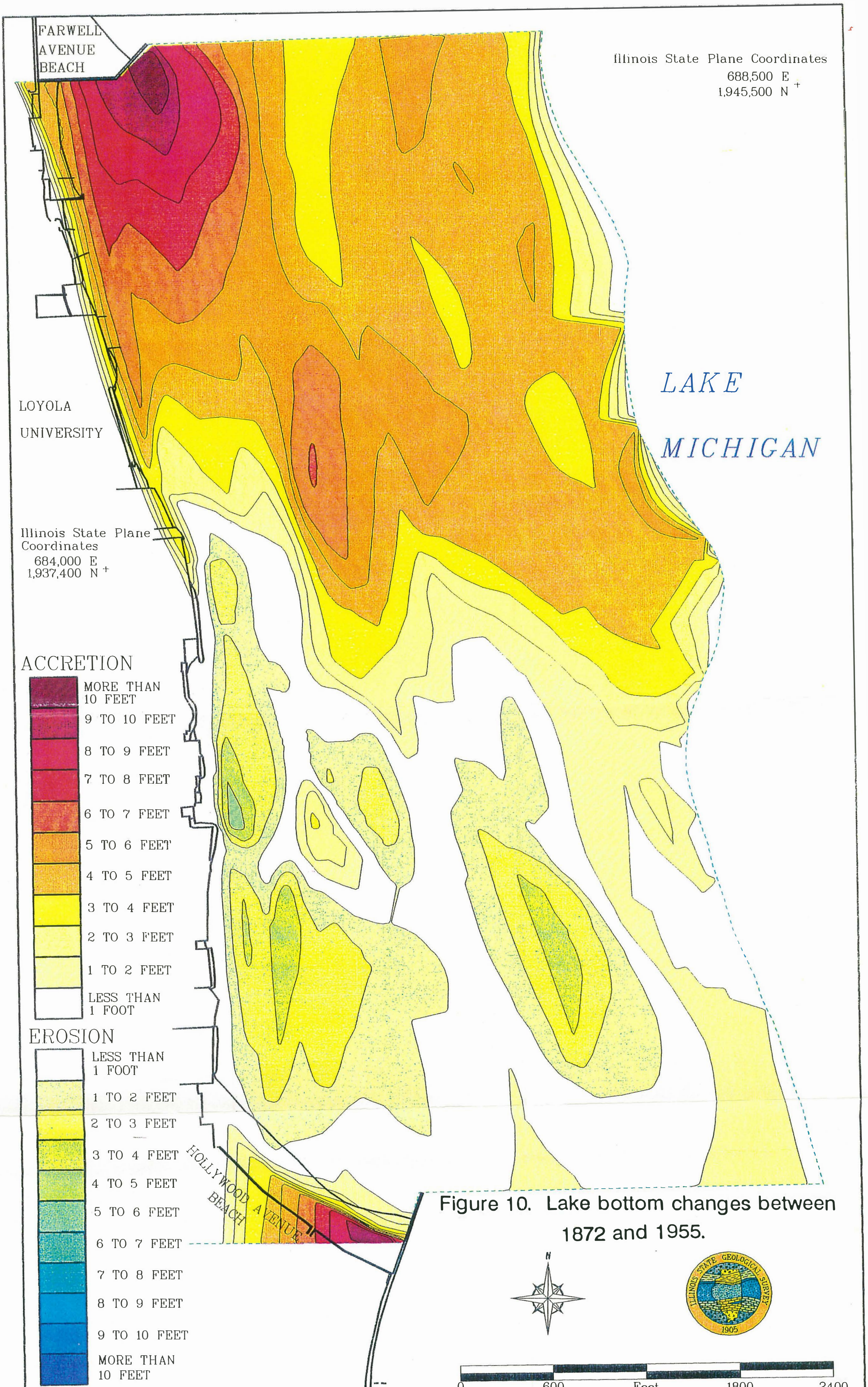

Figure 10. Lake bottom changes between 1872 and 1955.

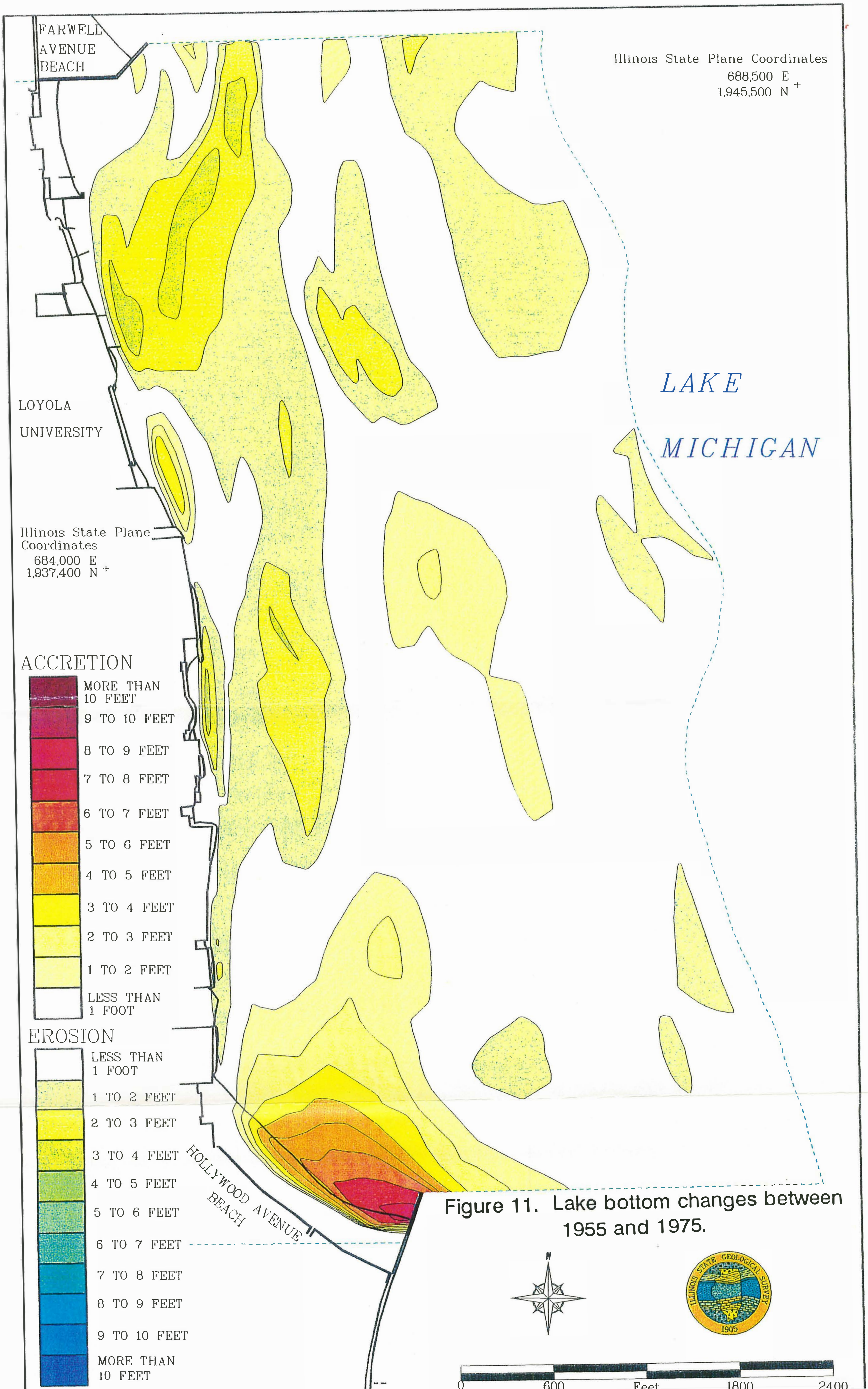

Figure 11. Lake bottom changes between 1955 and 1975.

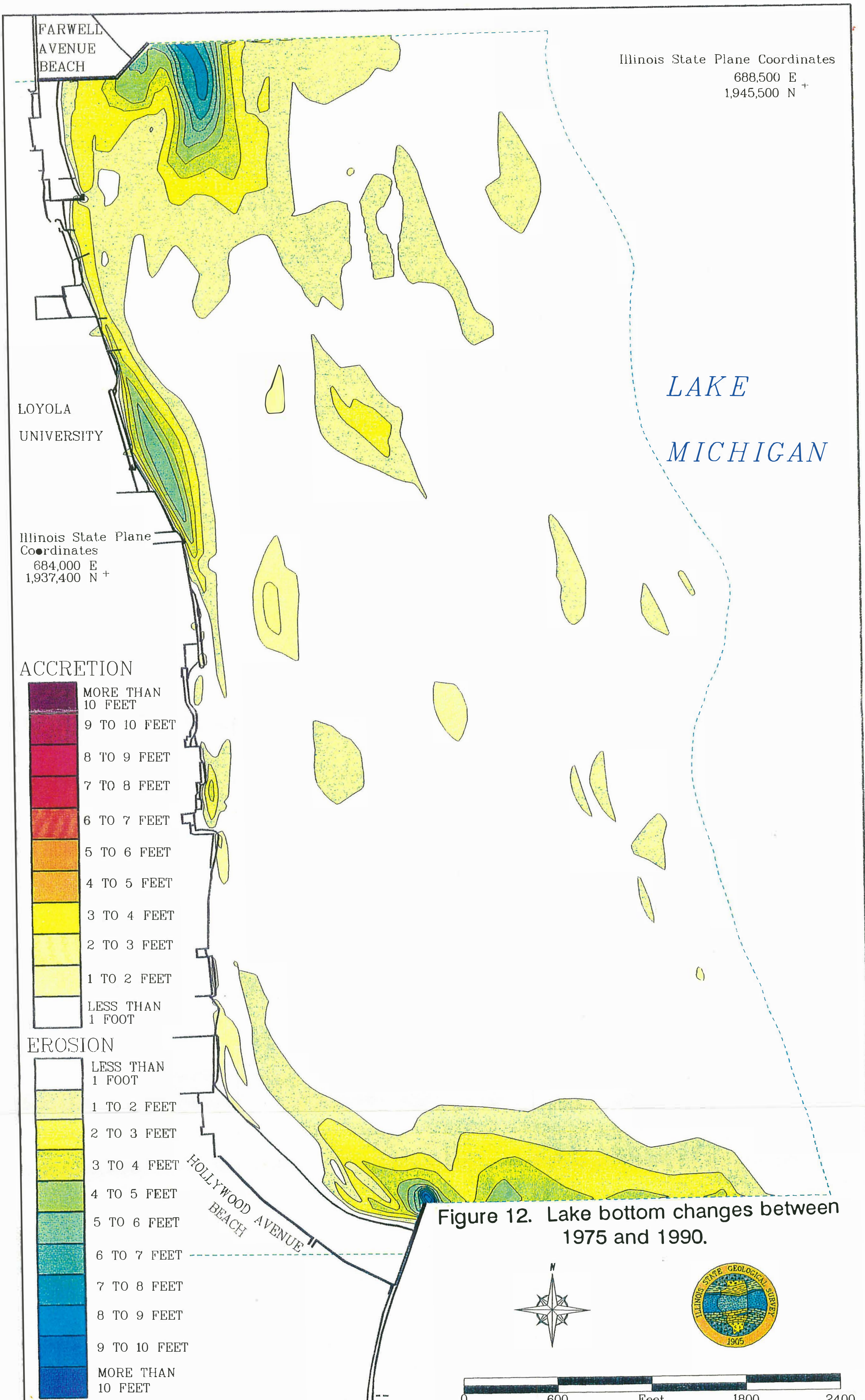

Figure 12. Lake bottom changes between 1975 and 1990.

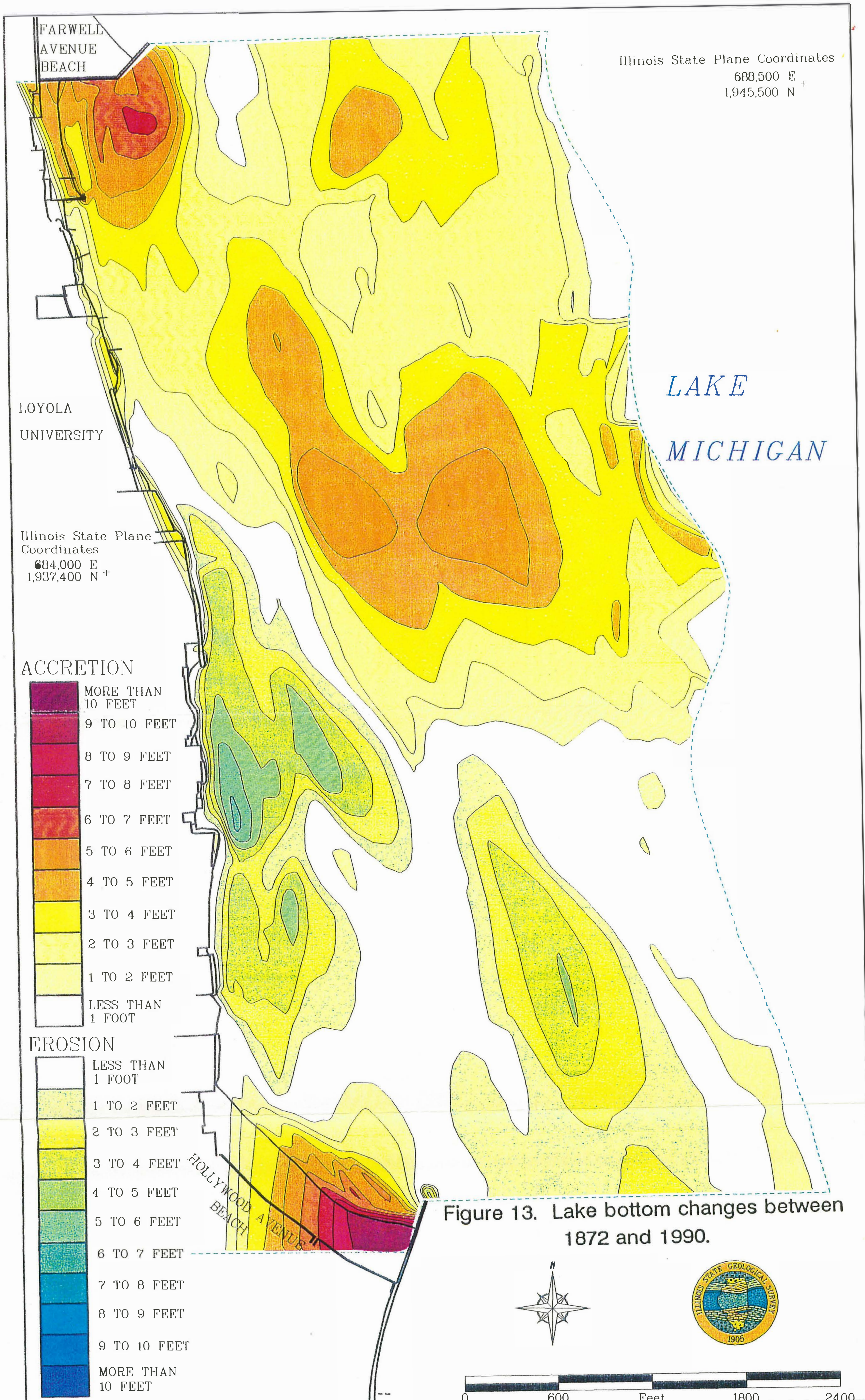

Figure 13. Lake bottom changes between 1872 and 1990.

built groin (see Waukegan and Great Lakes Harbors fillet growth in Collinson 1981, p. 11). Consequently, the main downdrift accumulation of 2 million cubic yards south of the groin, was mostly deposited by bypass material dropped in the downdrift shadow of the groin over a period probably less than 18 years. An exceedingly rich longshore drift certainly existed, probably in excess of 100,000 cubic yards per year for those years of accumulation. Southward, beyond the Farwell Groin impoundment, Figure 10 shows evidence of sediment loss. Most of the loss probably represents the result of sediment starvation in the area downdrift from the Farwell Groin impoundment area. The groins at Hollywood and Foster Avenues were not in place until the early 1950s. Consequently, sediment mobilized downdrift from Farwell was relatively free to pass the north end of the Lincoln Park lakefill traveling as far as the Wilson Avenue Groin.

Comparisons of Figures 10 and 11 show portents for the future. By 1955, more than 300 protective structures lined the shore north from the study area. By 1975, the number had grown to nearly 400, including such structures as the Northwestern University lakefill and the South Boulevard Groin, booth in Evanston. Figure 11, which illustrates the changes that took place over the twenty year period, shows a capture of more than 400,000 cubic yards at Hollywood Avenue Groin. It seems reasonable to assume that the capture was largely derived from southward movement of the major impoundment south of Farwell Groin (Figure 10).

Figure 11, which illustrates the effect of continued lean longshore drift from 1955 to 1975, shows remnants of the Farwell Groin impoundment caught on the Hollywood Groin. Significant erosion (Table 1) is evident for the remainder of the study area. Overall losses represent a serious trend for such a short period, losses of more than 600,000 cubic yards. Losses probably were approximately 30,000 cubic yards per year.

As shown by Figure 12, the 15 years between 1975 and 1990 also were years of sediment loss. Even the material trapped earlier by Farwell Groin had moved out of the study area. The Farwell Groin location not only lost its pre-1955 intercept but also much of what must have been preconstruction sediments. Norby and Collinson (1977, maps 37, 38) indicate that the longshore sediment apron in the study area commonly exceeded 5 feet in thickness in 1976 whereas Shabica et al (1991, p. 3) shows 1989 thicknesses to average around three feet. Table 1 shows a net loss of between 214,000 and 610,000 cubic yards for the 1975-1990 15 year period. In view of increasingly unfavorable resource conditions updrift, the maximum figure shown on Table 1 for the most recent period, 663,000 cubic yards, seems to be suggestive of future 15 year losses - about 40,000 cubic yards per year as long as the drift stream persists. Shore protective structures continue to be built. By 1989, following the high lake levels of the 1970s and 1980s, so many had been constructed that only 16 percent of the updrift shore had significant potential for providing new sediments to the Chicago shore. Today (1993), less than 3 percent of the updrift shore is contributing new sediments to the longshore drift. Fortunately, silt, sand and gravel still floor the lake out to just beyond 20 foot depth in Edgewater/Rogers Park (Fucciolo, 1993, pl. 10, 11). Baretill areas extend toward the shore downdrift from and offshore from the major structures verifying the thin nature of the drift. The drift probably is 1 to 3 feet thick judging from the report of Shabica et al (1991, p. 3). At an estimated loss of 1 to

2 feet every decade, littoral sediments may be largely depleted in a few decades leaving the shore increasingly vulnerable to storm damage.

SUMMARY

Littoral drift volumes along the undeveloped Illinois Lake Michigan shore prior to this century probably exceeded 100,000 cubic yards per year. Construction of harbors and shore protection structures during the present century have reduced the available new sediment resource areas to less than one mile of exposed shore. Consequently, littoral drift in the Edgewater/Rogers Park area has changed from a 100,000 cubic yard stable budget to an annual loss of approximately 40,000 cubic yards. Shore sediments in the study area average 1 to 3 feet in thickness, a supply expected to last 2 or 3 decades. Then a shore with deepened waters nearshore and an increased vulnerability to wave action can be anticipated.

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