COMMUNITY ASSISTANCE
PLANNING REPORT NO. 86

A LAKE MICHIGAN COASTAL EROSION MANAGEMENT STUDY FOR RACINE COUNTY, WISCONSIN

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NUMBER 86

A LAKE MICHIGAN COASTAL EROSION MANAGEMENT STUDY FOR RACINE COUNTY, WISCONSIN

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In Cooperation with the
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The preparation of this study and report was financed in part by the Wisconsin Coastal Management Program under the Coastal Zone Management Act of 1972, administered by the Federal Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

October 1982

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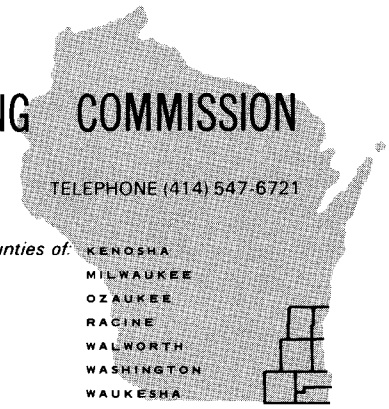

October 11, 1982

TO: The Honorable Chairman and Members of the Racine County Board of Supervisors

Ladies and Gentlemen:

Racine County, in February 1981, submitted an application to the Wisconsin Coastal Management Council for a grant in partial support of the conduct of a Lake Michigan coastal erosion management study and agreed to provide the necessary matching funds and in-kind services. Upon notification of grant approval, Racine County retained the Southeastern Wisconsin Regional Planning Commission as a consultant to the County for the project. The study was subsequently carried out by the staff of the Regional Planning Commission, working in cooperation with the staff of the Racine County Planning and Zoning Department and a 12-member technical advisory committee consisting of representatives of Racine County, the Racine County Coastwatch Program, the local units of government in the Lake Michigan shoreland area of Racine County, concerned citizen groups, private engineering consultants, the University of Wisconsin Sea Grant Program, and the Wisconsin Department of Natural Resources. Work on the study was initiated in January 1982, and completed on August 31, 1982. This report sets forth the findings and recommendations of the Lake Michigan coastal erosion management study for Racine County.

The erosion and attendant recession of the Lake Michigan coastal bluffs within Racine County constitute a serious threat to the valuable natural resources and to the real property and real property improvements lying near the bluff edge. The study indicates that bluff recession rates in Racine County range up to 14 feet per year, and average about two feet per year along the unprotected reaches of shoreline. This bluff recession results in the loss of about 6.6 million cubic feet of shore material each year. The primary purpose of the study was to develop and recommend a coordinated set of structural and nonstructural measures which can reduce shoreline erosion and bluff recession, and the resultant damages from such erosion and recession.

The study identifies the extent of shoreline erosion and bluff recession which may be expected to occur, over time, along the Lake Michigan shoreline of Racine County; quantifies the potential property losses which may be expected to result from continued shoreline erosion and bluff recession in the absence of a sound management program; identifies erosion risk distances and recommends associated setback distances for buildings along shoreline reaches not so protected; and recommends provisions which may be incorporated into existing shoreland regulations to restrict certain land uses and practices, as well as to guide the placement of new buidings, within those shoreland areas susceptible to erosion and bluff recession. Recommendations for both structural and nonstructural coastal erosion control measures previously made by the Racine County Technical Subcommittee on Shoreland Development Standards were adapted and incorporated into the findings and recommendations of this study.

Implementation of the recommendations presented in this report would, over time, provide shore protection with properly delineated setback distances from the bluff edge for new development for the entire county shoreline located south of Cliffside Park in the Town of Caledonia. For most of the county shoreline lying north of and including Cliffside Park, structural shore protection measures were not found to be warranted. For this shoreland reach setback distances are recommended which include the area expected to be affected by bluff recession during the next 50 years. These setback distance regulations are recommended to be incorporated as amendments to the county shoreland zoning ordinance, and may also be incorporated into local municipal ordinances.

The Regional Planning Commission is pleased to have been able to be of assistance to the County in the completion of this study. The Commission stands ready, upon request, to assist the County and constituent affected local units of government in the County in presenting the information and recommendations contained in this report to the public for its review and evaluation, and in adopting and implementing the recommendations contained in this report.

Sincerely,

Kurt W. Bauer
Executive Director

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Chapter I

INTRODUCTION

BACKGROUND

In response to increasing public concern over the many competing and frequently conflicting land uses within the unique and limited Lake Michigan shoreland area, Racine County recently completed a shoreland development management study.[1] The study, which was funded in part by a grant under the Wisconsin Coastal Management Program and in part by Racine County, was intended to help shape and guide development and redevelopment in the Lake Michigan shoreland area. The study included an analysis of shoreland development problems and resulted in recommendations relating to erosion hazard abatement, recreational access, natural resource preservation, and land use regulation.

The following recommendations relating to the abatement of erosion hazards were made:

1. Racine County should undertake a mapping program to identify those Lake Michigan coastal reaches which may be expected to be subject to severe erosion hazards.

2. Racine County should incorporate erosion area setbacks into the County shoreland zoning regulations.

3. Racine County, assisted by the Racine County Coastal Management Program Technical Advisory Committee, should modify its shoreland zoning regulations to indicate, in as much detail as practicable, the design criteria considered by the County in its review of conditional use permits for shore protection activities.

4. In preparing its new subdivision control ordinance, Racine County should require the identification of shore erosion hazard areas on land division plat maps and the preparation of erosion hazard abatement plans, where applicable.

5. Racine County should continue to collect and analyze information regarding Lake Michigan shoreline erosion hazards and erosion hazard abatement strategies.

6. The City of Racine and the Villages of North Bay and Wind Point should determine whether shoreline erosion-related zoning regulations are necessary after an analysis of the results of the previously recommended County effort to identify and map existing and future erosion hazard areas.

---

[1]The findings and recommendations of this study are documented in SEWRPC Community Assistance Planning Report No. 73, A Shoreland Development Management Study for Racine County, Wisconsin, January 1982.

7. The Racine County Planning and Zoning Department should serve as the "first contact" agency for all riparian landowners proposing structural shore protection or other erosion-related work.

In partial response to these recommendations concerning shoreland erosion control, Racine County, in 1981, requested and received a grant under the Wisconsin Coastal Management Program in partial support of a coastal erosion study. This study was subsequently carried out cooperatively by the staffs of the Regional Planning Commission and the Racine County Planning and Zoning Department and an advisory committee consisting of representatives from the University of Wisconsin Sea Grant Program, the City of Racine, the Town of Caledonia, the Racine County Coastwatch Program, the Racine Board of Realtors, Inc., the Wisconsin Department of Natural Resources, the Sierra Club, and private engineering consulting firms. A number of important studies regarding shoreline erosion and bluff recession rates, and erosion processes along the Racine County coastline have been completed, providing much of the basic information required to prepare an erosion management plan. In addition, Racine County has established the County Coastwatch Program as a means for continuously monitoring shoreland erosion.

DEFINITION OF COASTAL EROSION MANAGEMENT

Coastal erosion management may be defined as a coordinated set of measures designed to abate coastal erosion and reduce attendant property losses, aesthetic impacts, and risks to human safety which result from such erosion. Erosion management measures include both structural measures--such as the construction of revetments and bulkheads--and nonstructural measures--such as land use regulations which prohibit certain types of development in erosion-prone shoreland areas. The broad goal of coastal erosion management is the preservation of the overall quality of life of the residents of an area through the selective protection of high-value physical resources and those environmental values--recreational, aesthetic, ecological, and cultural--normally associated with and concentrated in coastal areas.

NEED FOR A COASTAL EROSION STUDY

The erosion, and subsequent recession, of coastal bluffs constitutes one of the most adverse impacts of coastal erosion processes. Bluff recession rates in Racine County range up to 14 feet per year.[2] This bluff recession results in the loss of approximately three acres of land each year containing 6.6 million cubic feet of shore material. This annual amount of eroded material would fill over 1,500 railroad boxcars, which, if placed end to end, would form a line 16 miles long. This extremely severe erosion is concentrated within a narrow strip of shoreline which contains valuable man-made and natural resources.

---

[2]J. P. Keillor, and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, University of Wisconsin Sea Grant College Program Advisory Services, April 1, 1978.

The Racine County shoreland zoning ordinance was enacted to regulate human activities in shoreland areas which could have adverse effects on those shoreland areas and the associated surface waters. The County's ordinance presently specifies a uniform 400-foot setback from the Lake Michigan shoreline for all structures except public utilities, public recreation facilities, and most single-family residences. In addition, tree and shrub cutting and clearing, road and trail development, earth moving activities, surface water use or discharge, and certain agricultural activities are regulated in the shoreland area. The specified setback distance and regulations may provide more than adequate protection in some shoreland areas; however, other areas may require more stringent regulations in order to provide a sufficient level of shore protection. The significant data base which has now been acquired relating to the coastal erosion problems in the County provides an opportunity to refine the County shoreland zoning ordinance and other pertinent County and local ordinances by establishing development setbacks and other use restrictions which are related specifically to existing and probable future beach and/or bluff recession rates, as well as to an expected stable slope configuration. Because the Racine County shoreland represents an extremely valuable resource, and because competition for coastal resources is increasing, the development of setback distances and other regulations based upon careful analysis of all available pertinent data warrants attention at this time.

REVIEW OF PREVIOUS STUDIES

A major work element of this study is the collation and analysis of previously collected data relating to shoreland erosion and recession in Racine County. Data on coastal erosion have been developed under the Racine County Coastwatch Program, the Wisconsin Coastal Management Program, the University of Wisconsin Sea Grant College Program, and by the firm Owen Ayres & Associates, Inc., working under contract to Racine County. The following section briefly describes each of the past coastal studies conducted in Racine County:

1. Racine County Coastwatch Program
   The Racine County Coastwatch Program was initiated in 1978 to monitor the causes, occurrence, and extent of bluff recession and related factors. Along the coast, 16 coastwatch stations were established and volunteer coastwatchers since 1978 have observed coastal erosion conditions. Data collection sheets were completed and photographs periodically taken of designated sections of the coastline. Data were collected on bluff erosion and recession, wave action, water level changes, precipitation, surface runoff, placement of man-made structures, and various shoreland uses. The findings of the program are set forth in the Racine County Coastwatch Program Final Report (1981). This report provides important insights into the processes affecting Lake Michigan shoreland erosion in Racine County and documents the relative bluff recession rates at several locations.

2. University of Wisconsin Sea Grant College Program
   The University of Wisconsin Sea Grant College Program undertook measurements of shoreline recession along the Lake Michigan coast over a period of eight years (1968-1976) during which water levels in Lake Michigan at Milwaukee rose gradually from their lowest recorded levels in the early 1960's to their highest levels since the 1870's. Long-term recession

rates were estimated. The study characterized the impacts of storm waves on recession rates. The study also characterized the general landforms along the Lake Michigan coast and discussed the causes of shoreline recession in the County. The findings of the study are documented in Recent Recession of Lake Michigan Shoreline in Racine County, Wisconsin, J. P. Keillor and R. DeGroot (1978).

The largest bluff recession rates were recorded along the northern reaches of the County coastline. In this area, bluff recession rates were found to average 5.8 feet per year over the period of observation, with one site averaging 14 feet per year. Recession rates measured south of the City of Racine averaged only 1.4 feet per year over the period of observation. Nearly five million cubic feet per year of bluff material, or about 75 percent of the total County loss of 6.6 million cubic feet per year, is estimated to be eroded from the northern segment of the County coastline. The most probable cause of the large land losses in the northern part of the County is a combination of high, unstable bluffs with a perched watertable, a lack of structural protection, and high exposure to storm wave action.

3. Wisconsin Coastal Management Program

An inventory of shoreline conditions was completed in 1976 under the Wisconsin Coastal Management Program. For each of four coastal reaches within the County, information assembled on short-term (10-year) and long-term (100-year) bluff recession rates; the physical characteristics of the bluffs, beach, and geologic formations present; observed shore damages; and known shore protection structures and boat ramps was presented. The findings of this study are presented in Shore Erosion Study Technical Report, Appendix Two, Racine County, A. F. Schneider, T. Edil, and B. Haas, Wisconsin Coastal Management Program (1977).

In the southern part of the County, numerous shore protection structures and artificial fill areas were noted. In unprotected areas, considerable property damage and shoreline recession were reported. Beach conditions and widths were extremely variable, depending upon the degree of structural protection provided, and bluff heights ranged from less than 10 feet to over 90 feet. Immediately north of the City of Racine, poorly protected areas were subject to severe wave erosion at the toe, or bottom, of the bluff, slumping at the top of the bluff, and material loss from the exposed face of the bluff, often due to groundwater discharge and surface water runoff. Bluff heights commonly ranged from 20 to 30 feet. The reach of coastline north of Wind Point is rated as the third most critical erosion area along the entire coastline of Wisconsin. The severe erosion and bluff recession along this northern section is attributed to the following factors:

- Narrow--10 to 40 foot wide--beaches.
- Relative lack of structural shore protection.
- Intense wave action against the toe of the bluff.
- A northwest-southeast orientation of the coast and its gentle concavity towards the northeast, which makes the shoreline particularly vulnerable to attack by winter storm waves from the northeast.
- Steep, high--over 80 feet--bluffs.
- A high content of easily eroded, fine-grained materials in the bluff.

- Permeable layers in the bluff which allow rapid groundwater flow-through.
- The massive groin structure at the Wisconsin Electric Power Company Oak Creek Power Plant that probably interrupts the prevailing longshore current and leads to increased net erosion along the predominant downcurrent side.

4. University of Wisconsin-Extension Report

The University of Wisconsin-Extension developed, for the Wisconsin Coastal Management Program, proposed regulations to reduce coastal erosion losses. The report suggests methods of determining erosion hazard areas, describes ways to reduce shoreline erosion, presents the rationale for developing zoning and subdivision regulations which adjust land use and development to the erosion hazard, and includes sample ordinance provisions for zoning ordinances and subdivision ordinances which take the shoreline erosion hazard into account. The report is set forth in Regulations to Reduce Coastal Erosion Losses, D. A. Yanggen (1981).

5. Racine County Erosion Control Study

In 1979, Racine County retained the firm of Owen Ayres & Associates, Inc., to prepare a combined lake access, ecological management, recreational activity and management, and coastal zone erosion study to help guide the future development of the County's Cliffside Park, the Town of Caledonia's Lake Michigan Park area, and adjacent areas in the Town of Caledonia. The study area consisted of the entire coastal region north of Six Mile Road in the Town of Caledonia, an area containing the most severe coastal erosion problems in Racine County. Bluffs range from 40 to more than 80 feet in height and beach widths are generally less than 30 feet. Soil boring logs indicated a zone of perched groundwater lying from three to eight feet below the ground surface. Strata of permeable sand and gravel were also located along the bluff face. These conditions allow groundwater to discharge at the bluff face, causing material flows and slumps. Toe erosion of the bluffs was also very common. The report cites references which state that the long-term (110-year) recession rate ranged from one to four feet per year. During the period of 1967 to 1975, recession rates ranged up to 12.5 feet per year. An estimated 300,000 cubic yards of material is eroded into the lake annually from the study area. The study evaluated alternative structural measures to reduce shoreline erosion. It was recommended that the bluff be regraded to a stable slope, that the bluff face be revegetated, that a granular bluff drain be constructed, that armor stone revetments be provided for bluff toe protection, and that overland flow and perched groundwater flow be collected and diverted to the stone revetments.

6. Racine County Shoreland Cadastre

In 1981, Racine County completed a multipurpose cadastre for that portion of Racine County perceived to have special Lake Michigan shoreland management needs. The cadastre file included real property boundaries, land use data, real estate tax information, parcel size, local zoning classification, and soil types. The area for which the cadastre was developed includes all real properties in Racine County abutting Lake Michigan, as well as properties between Lake Michigan and the first

major man-made or natural feature west of Lake Michigan. This area ranges in width from about 200 feet to 4,800 feet, and approximates the coastal erosion study area.

COASTAL EROSION STUDY AREA

For the purposes of this study, the shoreland area of Lake Michigan was defined as that area of Racine County lying within approximately 1,000 feet of the ordinary high water mark of Lake Michigan, as well as certain lands along the Root River east of the Marquette Street bridge (see Map 1).[3] The study area thus includes lands subject to County shoreland zoning regulations, one of the most important of all shoreland development management mechanisms. In general, the study area includes those lands which most directly affect, and are most affected by, Lake Michigan resources and processes. The Racine County cadastral map was prepared for the shoreland area covering an area ranging in width from 200 feet to 4,800 feet. The area covered by the cadastral mapping program approximates the coastal erosion study area.

SUMMARY

Several previous studies on shoreland development and shoreline erosion in Racine County have been prepared in response to increasing public concern over land use in the shoreland area and the erosion of that area. A recently completed shoreland development management study for Racine County analyzed shoreland development problems, including shore erosion, recreational access, natural resource preservation, and land use regulations.

Coastal erosion management may be defined as a coordinated set of measures--both structural and nonstructural--designed to abate shoreline erosion and reduce damages which result from such erosion. Currently, shoreland development in the unincorporated portions of Racine County is regulated by the county shoreland zoning ordinance. Because of the extremely valuable resources contained within the shoreland area and the increasing demand for these coastal resources, there is a need to establish development setbacks and other use restrictions which are related specifically to existing and probable future bluff recession rates and stable slope configurations.

Previous studies pertinent to coastal erosion in Racine County have been prepared by the Racine County Coastwatch Program, the University of Wisconsin Sea Grant College Program, the Wisconsin Coastal Management Program, the University of Wisconsin-Extension, and Racine County. These studies provide much of the basic data needed to prepare an erosion management plan.

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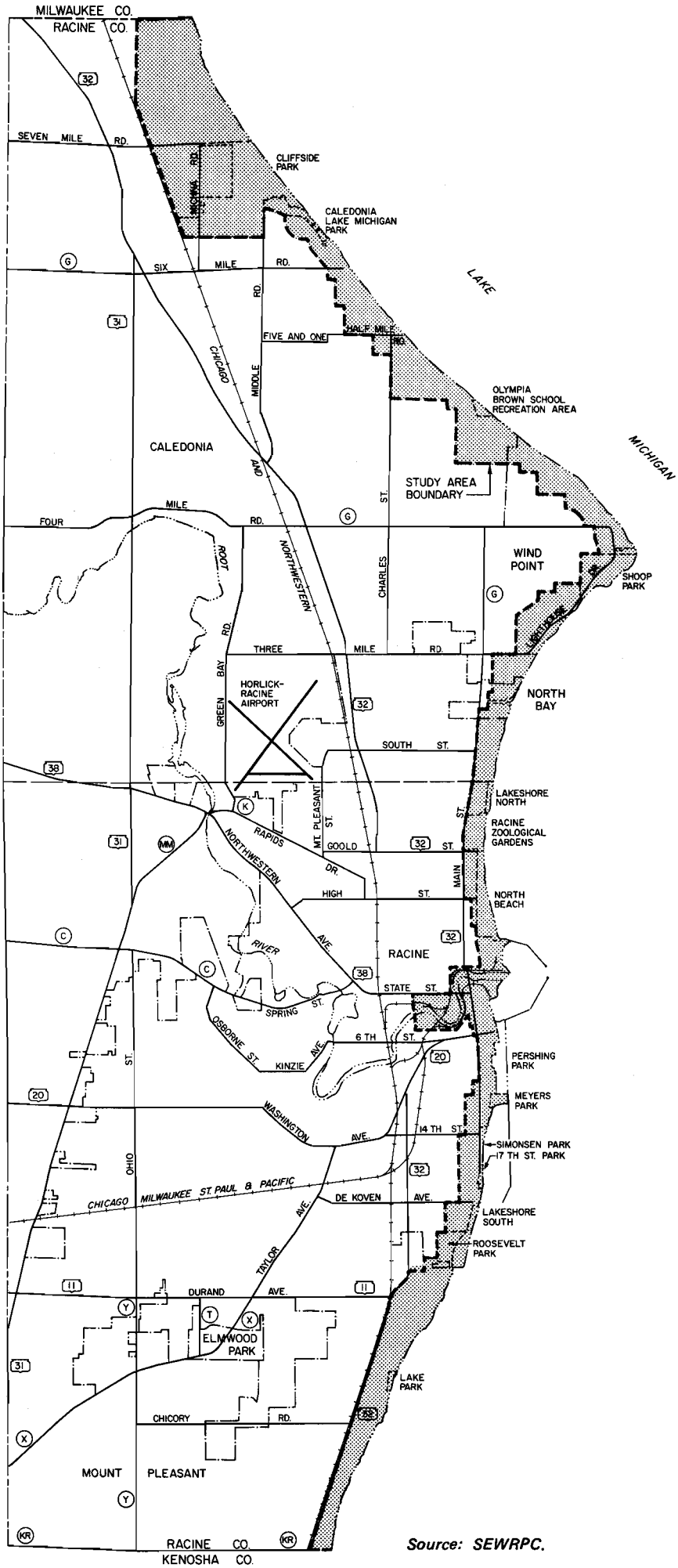
[3]The actual study area boundary is the man-made or natural physical feature lying closest to a line 1,000 feet from the ordinary high water mark of Lake Michigan. Along several reaches of the study area in the northern portion of the County, real property lines had to be used as the study area boundary, owing to absence of major physical features near the shoreline in this area.

Map 1

COASTAL EROSION MANAGEMENT STUDY AREA FOR RACINE COUNTY



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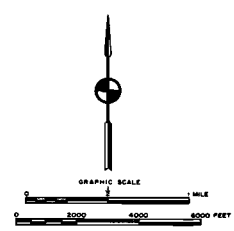

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Chapter II

PURPOSE AND SCOPE

INTRODUCTION

The purpose and scope of the Racine County coastal erosion study were developed on the basis of the knowledge and experience of persons who were well informed and intimately familiar with the coastal area of the County, as well as the knowledge of persons who possess the technical skills important to good coastal zone erosion management. To place such knowledge and experience at the disposal of the study, the Racine County Board established the Coastal Erosion Technical Advisory Committee, the composition of which is given on the inside front cover of this report. One of the important functions of this Committee was to articulate the purpose and define the scope and content of the study, so that the findings and recommendations would be relevant and useful to the public officials and private interests concerned with the development and redevelopment of the coastal area, providing a sound guide to decision making over time related to such development and redevelopment.

RELATION TO OTHER STUDIES

As noted in Chapter I, several previous studies have addressed coastal erosion in Racine County and the findings and recommendations of these studies constituted important considerations in defining the purpose and scope of this study. The recommendations for both structural and nonstructural coastal erosion control measures made by the Racine County Technical Subcommittee on Shoreland Development Standards were incorporated into this study and used to estimate potential future coastal conditions, to coordinate the nonstructural control measures developed in this study to potential structural control measures, and to reflect the coastal erosion control objectives of the local agencies of government concerned.[1] The Technical Subcommittee made recommendations for three subareas of the coastal zone: 1) the "undeveloped area," that is, the subareas of the coastal zone not yet developed for intensive urban uses; 2) the "undeveloped coastal strip" located adjacent to the developed areas of the coastal zone; and 3) the "developed area," that is, the subareas of the coastal zone developed for intensive urban uses. The recommendations made by the Technical Subcommittee are summarized in the following paragraphs.

The "undeveloped area" was defined as the coastal area from the northern County boundary to the southern boundary of Cliffside Park. This area consists of about 1.8 miles of coastline not yet developed for intensive urban use. Nonstructural measures were generally recommended for this area to reduce losses by shore erosion. These measures included: beach nourishment, sand bypassing at the Oak Creek Power Plant, acquisition of additional land for

[1]Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards for the Racine County Land Use Committee, 1982.

Cliffside Park, setback restrictions on new buildings and public roads, and the use of relocatable structures for any planned development in this subarea of the coastal zone. These measures recognized and sought to protect the natural resource-related values and use opportunities in the coastal areas, and recognize that structural shore protection measures and bluff stabilization efforts are generally very costly.

The "undeveloped coastal strip" located adjacent to developed areas was defined as the coastal area from the southern edge of Cliffside Park to Six Mile Road. This area is generally undeveloped except for a few residences. Recommended measures to reduce losses by shore erosion in this area included bluff stabilization and structural shore protection measures to reduce the erosion hazard; private relocation, or public acquisition and removal of existing structures; application of minimum setback distances to proposed new structures where predictable; and adequate shore protection measures for proposed new facilities which are not relocatable and do not meet minimum setback distances.

The "developed area" was defined as the coastal area from Six Mile Road to the southern County line. The coastline in this area is generally developed for intensive urban uses except for occasional vacant lots and municipal parkland. In this area structural measures were considered the only feasible means of reducing losses by shore erosion. The recommended measures for this area include structural protection, prohibition of new facilities vulnerable to erosion damage in the erosion hazard area, special public review procedures for proposed bluff stabilization and shore protection measures to ensure proper design and sound land management practices to reduce erosion potential, continued use of conditional use permit application procedures, encouragement of cooperative structural protection and bank stabilization measures, use of minimum setback requirements with a required justification by the owners concerned of the use of subminimal setback distances, and the provision of shore protection measures for all new major facilities which are not relocatable.

PURPOSE AND SCOPE

The primary purpose of the Racine County coastal erosion management study is to identify and map high erosion risk areas along the Lake Michigan shoreline of Racine County and to develop a coordinated set of land use regulations properly related to existing and probable future bluff recession rates within the identified high-risk areas. The study is thus intended to provide a sound technical basis for providing information to the public and for amending the County shoreland zoning ordinance and other local land use regulations in order to more effectively reduce erosion hazards, and to guide and shape future coastal development in the public interest. To accomplish this purpose, the following specific work elements were undertaken as part of the coastal erosion management study:

1. The collation of all existing pertinent data on Lake Michigan coastal erosion processes, problems, and rates in Racine County; pertinent land use regulations; and structural and nonstructural erosion control measures;

2. The collection of additional data, as necessary, to verify or update the results of previous studies;

3. The identification and mapping of high erosion risk areas and the establishment of coastal recession rates, stable slope angles, and areas of impact;

4. The formulation of recommendations to amend the County shoreland zoning ordinance and other applicable local land use regulations to better meet the agreed-upon coastal management objectives;

5. The conduct of special evaluations of critical high erosion risk areas to provide additional data needed to define alternative erosion control measures.

The results of this study represent an important step towards the development of a total coastal erosion management program for Racine County. Control of coastal erosion in Racine County requires an integrated approach involving both structural and nonstructural measures. The degree of erosion and the effectiveness of erosion abatement measures are highly site specific and may vary over time. Factors such as Lake Michigan water elevations, upcurrent erosion control measures, and changing wind and wave characteristics contribute to and complicate this variability. Therefore, structural erosion control measures, as well as a continuing program of data collection and refinement, will be needed in addition to nonstructural measures to fully attain an effective coastal erosion control program in Racine County.

SUMMARY

The purpose and scope of the Racine County coastal erosion study was developed under the guidance of the Coastal Erosion Advisory Committee established by the Racine County Board. As a basis for estimating future coastal conditions and to coordinate the nonstructural control measures developed in this study to potential structural control measures, recommendations for structural measures made by the Racine County Technical Subcommittee on Shoreland Development Standards were incorporated into this study. These structural control recommendations were prepared for developed and undeveloped reaches of the coast. Generally, structural control measures were not found to be cost-effective for undeveloped coastal areas, with the exception of a small area south of Cliffside Park adjacent to an urban development. For the remaining coastal area developed for intensive urban uses, the consideration of structural control measures was recommended.

The primary purpose and scope of this study is to identify and map high erosion risk areas along the Lake Michigan shoreline of Racine County and to develop a coordinated set of land use regulations properly related to existing and probable future bluff recession rates within the identified high-risk areas. Work elements undertaken as part of this study include the collection, verification, and updating of existing coastal erosion data, the mapping of high erosion risk areas based on coastal recession rates and stable slope angles, the formulation of recommendations to amend the County shoreland zoning ordinance and other applicable local land use regulations, and the conduct of special evaluations of critical high-risk areas.

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Chapter III

INVENTORY FINDINGS

INTRODUCTION

The formulation and application of land use regulations to reduce existing and probable future losses due to shoreline erosion requires the delineation of high-risk erosion areas; and careful consideration of the existing land use pattern, of the natural resource base of the shoreland area, and of coastal erosion processes, rates, and control measures. Accordingly, this chapter provides a description of the shoreland study area, pertinent information on the natural resource base elements relevant to coastal erosion management, a summary of existing land use and zoning patterns, and information specific to coastal erosion in Racine County.

Much of the data presented herein, including most of the specific coastal erosion data, were originally collected in the previous studies referenced in Chapter I. Other data were collected specifically for this study; these data were used to verify and extend the results of previous studies. Full use was also made of the findings of the recently completed Racine County shoreland development management study.[1]

The study area was defined in Chapter I and shown on Map 1. Some of the inventory data, such as land use, surface water drainage, and soils, are presented for the entire study area. Other inventory information, particularly that specifically related to coastal erosion processes, rates, problems, and control measures, is presented only for the immediate shoreland area. As appropriate, other data, such as climatic and groundwater data are presented for adjacent inland portions of Racine County as well as for the shoreland area.

This chapter consists of six sections. The first section presents data on the natural resource base pertinent to coastal erosion management. The second section concerns the existing land use pattern and zoning district regulations and boundaries within the study area. The third section addresses coastal erosion processes. The fourth section concerns shoreland development regulations. Structural shore protection measures are discussed in the fifth section, and the sixth section addresses coastal erosion problems.

NATURAL RESOURCE BASE

This section presents data on those aspects of the natural resource base which affect, or may be affected by, coastal erosion management. Data are presented on the geology, soils, beach and bluff characteristics, surface water resources, groundwater resources, and climate of the shoreland and related areas.

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[1]See SEWRPC Community Assistance Planning Report No. 73, A Shoreland Development Management Study for Racine County, Wisconsin, 1982, pp. 90.

Geology

The consolidated bedrock underlying Racine County generally dips eastward at a rate of 10 to 15 feet per mile. Precambrian age crystalline rock formations generally lie between 2,000 to 3,000 feet below the surface. Cambrian sandstone rock formations imbedded with shale and dolomite lie above the crystalline rock formations and generally range in thickness up to 2,000 feet. Above the Cambrian rock formations lie Ordovician sandstone, dolomite, and shale formations which vary in thickness from 500 to 850 feet. The bedrock closest to the surface is comprised of Silurian rock formations, primarily Niagara dolomite, which ranges up to 350 feet in thickness.

The Niagara dolomite formations are covered by unconsolidated glacial deposits which range up to 300 feet in thickness in the extreme northern end of the County. Glacial deposits in other portions of the County generally range from 20 to 100 feet in thickness in the northern part of the County, and from 100 to 200 feet in thickness in the southern part of the County.

Materials directly deposited by glacial ice are called till. Although unconsolidated, the till deposited over Racine County is relatively uniform in terms of physical and engineering properties. The till present in Racine County, called the Wadsworth till, is relatively fine-grained and interspersed with lake sediment deposits. The Wadsworth till is the most predominant material comprising the eroding bluff faces along the Lake Michigan shoreline in Racine County. Following the retreat of the glacier which deposited the Wadsworth till, a lake--called Glacial Lake Chicago--filled the southern part of the now Lake Michigan basin at an elevation of about 640 feet above National Geodetic Vertical Datum (NGVD), or about 60 feet above the present level of Lake Michigan. The remnants of this lake in Racine County consist of ridges of sand and other lake sediments which cover the Wadsworth till at an elevation of about 640 feet NGVD. The present level of Lake Michigan is at an elevation of about 580 feet NGVD.

Soils

Soil properties influence the rate and amount of storm water runoff, thereby affecting the severity of surface erosion at the top of the lake bluffs. Soil properties also are an important consideration in the evaluation of shallow groundwater seepage from the bluff face. The angle of stable slope and the type of vegetative cover which can be supported along the shoreline are greatly influenced by soil properties.

In order to assess the significance of the diverse soils found in southeastern Wisconsin, the Southeastern Wisconsin Regional Planning Commission, in 1963, negotiated a cooperative agreement with the U. S. Soil Conservation Service under which detailed operational soil surveys were completed for the entire planning Region. The results of the soil surveys have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil surveys have resulted in the mapping of the soils within the Region in great detail. At the same time, the surveys have provided data on the physical, chemical, and biological properties of the soils and, more importantly, have

provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes. Detailed soils maps are thus available for the entire shoreland area for use in coastal erosion management.

With respect to surface storm water runoff, which is a contributing factor to bluff erosion, the most significant soil interpretation is the categorization of soils into four hydrologic soil groups: A, B, C, and D. In terms of runoff characteristics, these four hydrologic soil groups are defined as follows:

Hydrologic Soil Group A: Very little runoff because of high infiltration capacity, high permeability, and good drainage. Covers 180 acres, or about 7 percent of the study area.

Hydrologic Soil Group B: Moderate amounts of runoff because of moderate infiltration capacity, moderate permeability, and good drainage. Covers 535 acres, or about 21 percent of the study area.

Hydrologic Soil Group C: Large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage. Covers 1,041 acres, or about 41 percent of the study area.

Hydrologic Soil Group D: Very large amounts of runoff because of very low infiltration capacity, low permeability, and poor drainage. Covers 362 acres, or about 14 percent of the study area.

The remaining 434 acres, or about 17 percent, are covered by disturbed soils and man-made features.

The spatial distribution of the four hydrologic soil groups within the study area is shown on Map 2. Hydrologic soil groups C and D soils may contribute substantial surface runoff from the top edge of the bluff and over the bluff face, causing severe surface erosion of bluffs. Soil groups A and B, due to increased infiltration capacity, may produce higher levels of groundwater seepage from the bluff face, which also may cause severe bluff slumping.

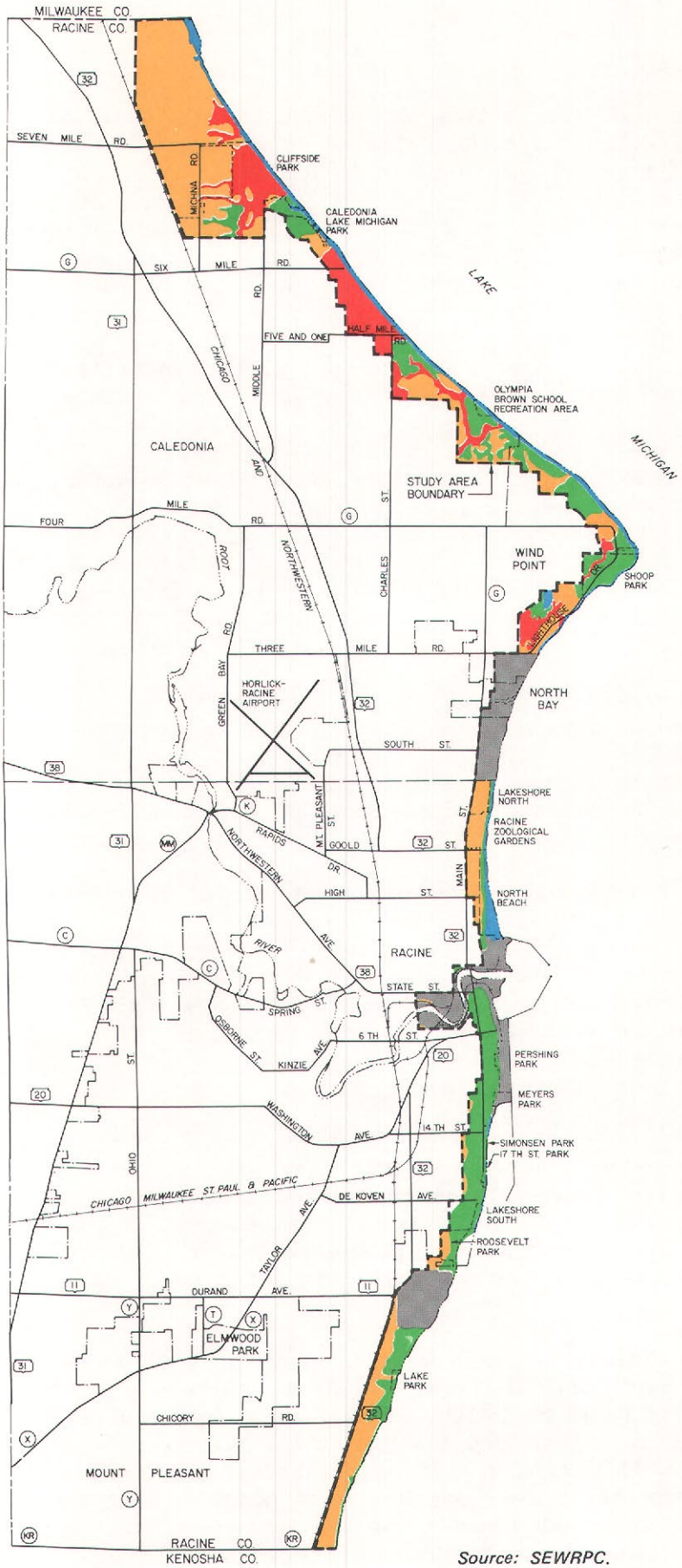
Bluff Characteristics

The bluffs along the Racine County shoreline of Lake Michigan exhibit a range of height, composition, vegetative cover, level of structural protection, and recession rates. This section describes the physical characteristics--the height and composition--of the bluffs. Bluff erosion processes, structural protection measures, and bluff recession rates are described in later sections of this chapter.

Table 1 summarizes the length of shoreline within various bluff height ranges. Bluff heights are also shown on Map 3 and in Figure 1. South of the City of Racine Harbor, the bluffs generally range in height from 30 to 40 feet. Between the northern breakwater of the Racine harbor and Six Mile Road in the Town of Caledonia, the height of the coastal bluffs varies considerably, but is generally less than 40 feet. North of Six Mile Road the bluff heights increase with bluffs of more than 80 feet in height found along the shoreline north of Cliffside Park. Typically, the coastal bluffs in Racine County extends to the

Map 2

HYDROLOGIC SOIL GROUPS IN THE LAKE MICHIGAN COASTAL EROSION STUDY AREA OF RACINE COUNTY



LEGEND

- GROUP A WELL DRAINED SOILS
- GROUP B MODERATELY DRAINED SOILS
- GROUP C POORLY DRAINED SOILS
- GROUP D VERY POORLY DRAINED SOILS
- MAN MADE FEATURES OR DISTURBED SOILS

GRAPHIC SCALE

0 2 MILE

0 2000 4000 6000 8000 FEET

Source: SEWRPC.

County extend to the water's edge or to the edge of a narrow beach area parallel to the water's edge. Notable exceptions occur at Pershing Park, North Beach, the Racine sewage treatment plant, and the Wisconsin Electric Power Company site, where extensive areas of natural or man-made land exist between the base of the bluff and the water's edge. Only about 21 percent of the shoreline has bluffs equal to or less than 20 feet in height. Nearly 56 percent of the shoreline has bluff heights ranging from 21 through 40 feet in height, and about 22 percent of the shoreline has bluff heights ranging from over 40 to 80 feet in height. Less than 2 percent of the shoreline has bluffs in excess of 80 feet in height.

The Racine County bluffs are composed of a large variety of materials. Table 2 indicates the predominance of various materials, and Figure 1 and Map 3 show the distribution of various types and combinations of materials along the shoreline. Till is the most predominant bluff material, comprising at least a portion of the bluffs along approximately 57 percent of the shoreline. Silt and clay are the second most predominant bluff materials, occurring in about 48 percent of the bluff shoreline length, with the next most common material being sand, present in about 30 percent of the bluff shoreline length. Nearly 65 percent of the bluffs contained portions, or strata, of an unknown composition. Some of these unknown strata may be composed of artificial fill containing gravel, stone, concrete, iron, glass, slag, asphalt, and solid waste.

Table 1

SUMMARY OF BLUFF HEIGHTS ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY 1978

Bluff Height (feet)	Length of Shoreline (feet)	Percent of Total County Shoreline Length
0-10	7,280	9.3
11-20	9,070	11.6
21-30	12,790	16.4
31-40	30,810	39.5
41-50	6,020	7.7
51-60	4,620	5.9
61-70	4,160	5.3
71-80	2,180	2.8
81-90	680	0.9
91-100	480	0.6
Total	78,090	100.0

Source: Keillor and DeGroot (1979) and SEWRPC.

Table 2

PREDOMINANCE OF BLUFF COMPOSITION MATERIALS ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY: 1977

Material	Shoreline Length Which Contains Material in Bluff (feet)	Percent of Total County Shoreline Length
Till.....	44,750	57.3
Silt and Clay....	37,250	47.7
Sand.....	23,270	29.8
Sand and Gravel..	1,800	2.3
Unknown	50,370	64.5

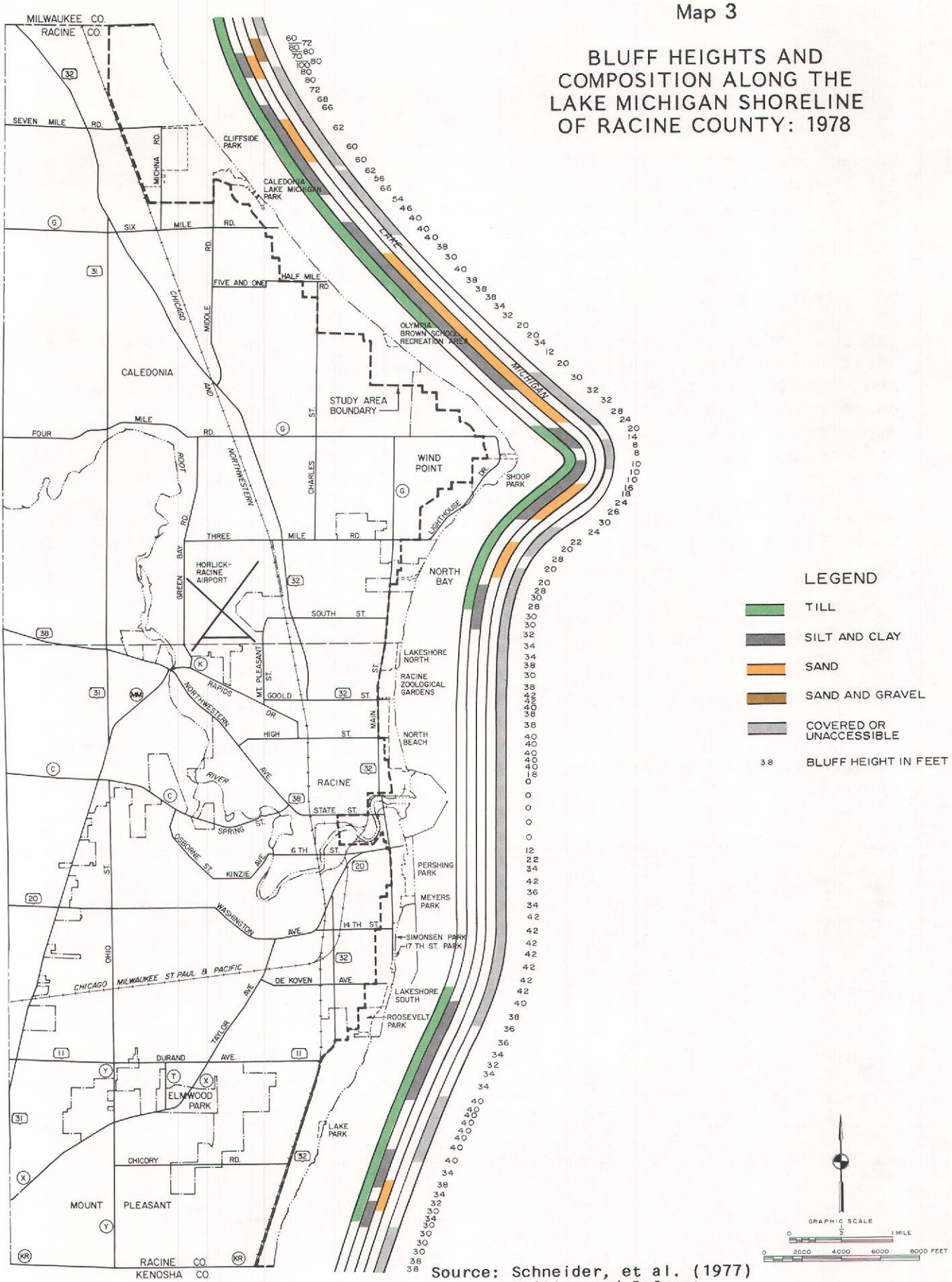
[a] The shoreline length shown is the length of the bluff which is at least partially composed of more than one material. Therefore, the totals exceed 100 percent of the county shoreline.

[b] Usually only certain portions, or strata, of a bluff are of unknown composition.

Source: Schneider, et al. (1977); and SEWRPC.

Map 3

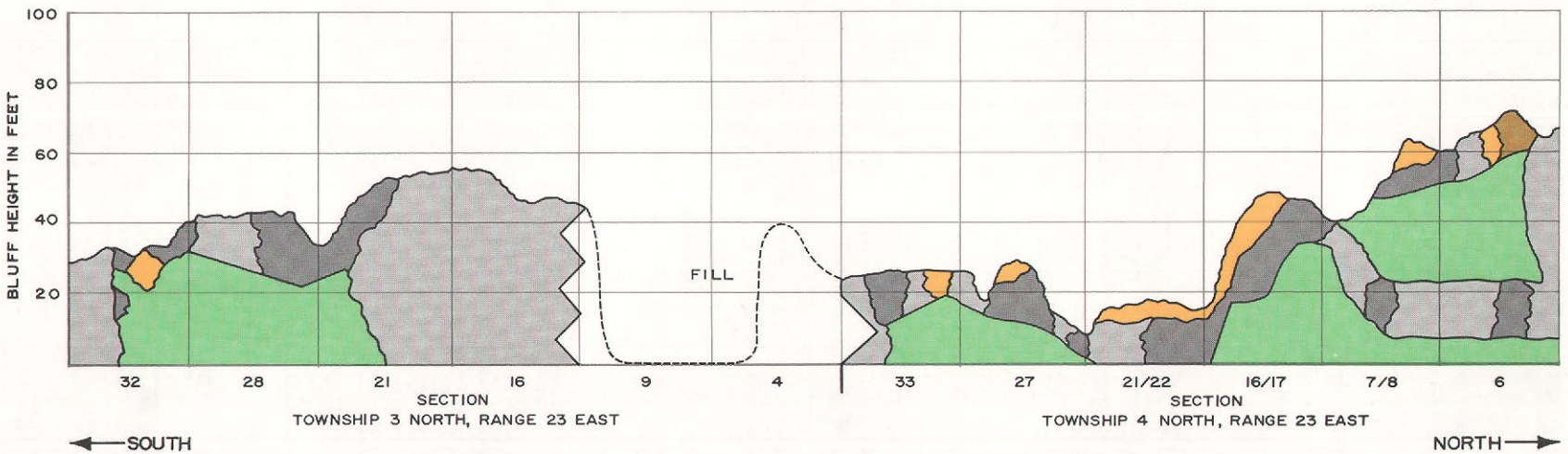
BLUFF HEIGHTS AND COMPOSITION ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY: 1978



Source: Schneider, et al. (1977) Keillor and DeGroot (1978) and SEWRPC.

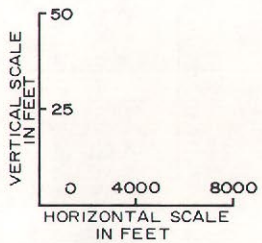
Figure 1

LONGITUDINAL SECTION THROUGH LAKE MICHIGAN SHORELINE
OF RACINE COUNTY SHOWING BLUFF HEIGHT AND COMPOSITION: 1977



LEGEND

- TILL
- SILT AND CLAY
- SAND
- SAND AND GRAVEL
- COVERED OR UNACCESSIBLE



Source: Schneider et al. (1977) and SEWRPC.

Beach Characteristics

A beach may be defined as an area of unconsolidated material which extends landward from the ordinary low-water line to the line marking a distinct change in physiographic form or the beginning of permanent terrestrial vegetation. The width of a beach and the size and character of the sediments found on beaches vary widely in response to the degree of wave action affecting the beach, the slope of the beach face and the nearshore lake bottom, the kinds of material available near the shore for the formation of beaches, and man-made structures. Table 3 sets forth beach characteristics for the Racine County shoreline of Lake Michigan.

The table indicates that the beaches in the County are composed primarily of sand, gravel, cobbles, and pebbles; smaller particles like silt and clay do not usually remain on the beach as do the large-size materials, since clay and silt are more readily kept in suspension and carried out into the lake. These finer materials tend to ultimately settle out in calmer, deeper, offshore waters. In 1977, about 32 percent of the county shoreline contained no beach--the lake reaches the bluff toe or, in some cases, a shore protective structure. Less than 3 percent of the beach length was composed of artificial fill.

Map 4 shows the distribution of various beach materials along the county coast. Sand and gravel are predominant along the far northern and southern coastal reaches in the County. The larger cobble- and pebble-size materials are primarily located near Wind Point--south of the Crestview subdivision and north of the Village of North Bay. The largest sand deposits are found adjacent to the northern section of the City of Racine. Much of the remainder of the coastal area through the City of Racine contains no beach, largely a result of the protective structures present. Beach materials are supplied by littoral drift transporting particles contributed to the lake by watershed drainage and up-current shoreline erosion and bluff recession.

Table 3 and Map 4 also indicate the beach widths along the coast. About 54 percent of the shoreline has a beach width equal to or less than 10 feet. About 25 percent of the shoreline has a beach width ranging from 11 feet through

Table 3

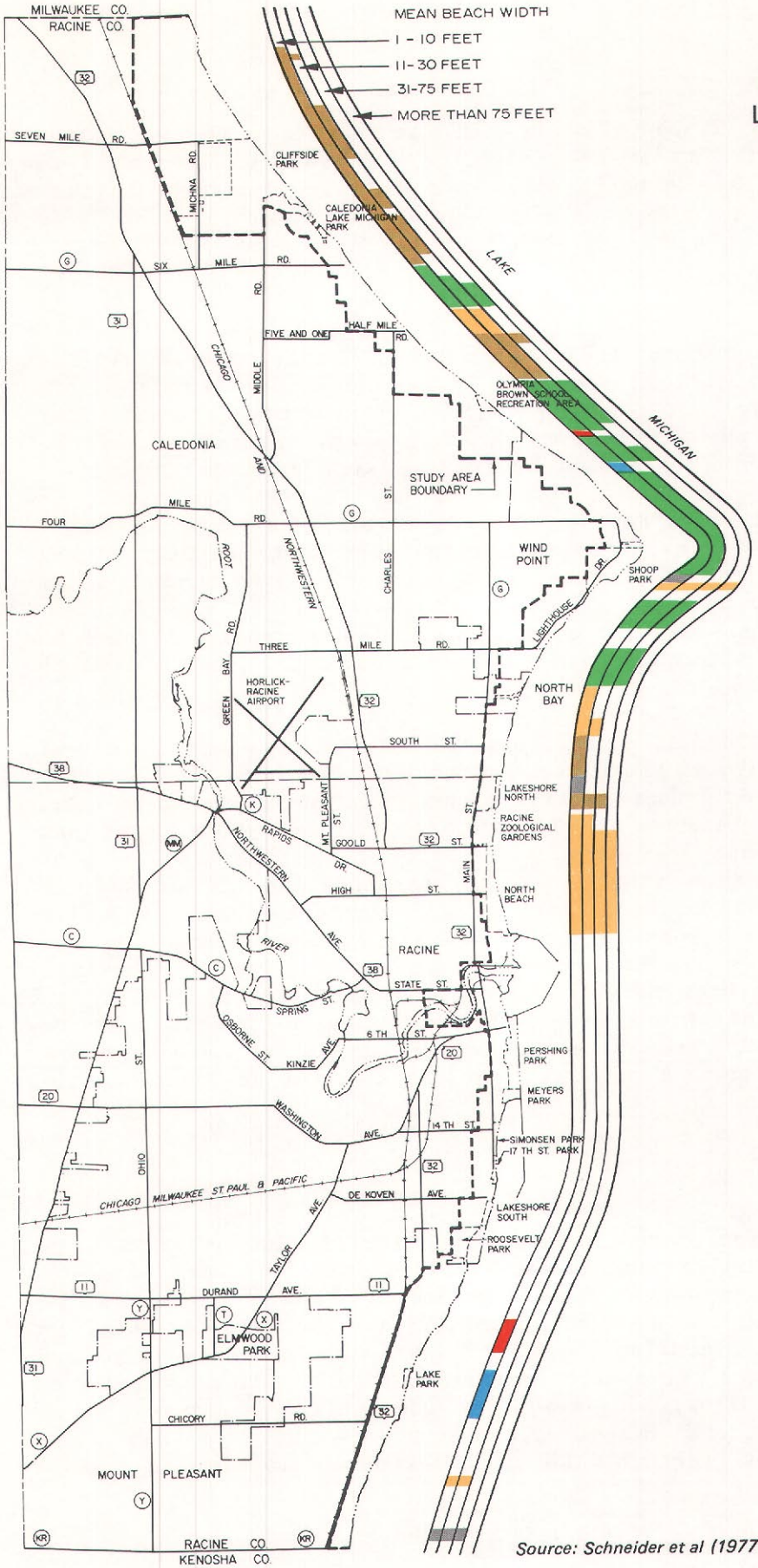
BEACH CHARACTERISTICS OF THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY: 1977

Beach Composition	Shoreline Length (feet)	Percent of Total County Shoreline Length	Beach Width (feet)							
			1-10	Percent of Total County Shoreline Length	11-30	Percent of Total County Shoreline Length	31-75	Percent of Total County Shoreline Length	>75	Percent of Total County Shoreline Length
Sand	9,145	11.7	1,460	1.9	3,185	4.1	--	--	4,500	5.7
Gravel	2,230	2.9	1,710	2.2	--	--	520	0.7	--	--
Gravel and Sand	20,515	26.3	8,610	11.0	9,855	12.6	2,050	2.7	--	--
Cobbles and Pebbles	3,260	4.2	3,260	4.2	--	--	--	--	--	--
Sand, Cobbles, Pebbles	16,160	20.7	355	0.5	--	8.5	9,130	11.7	--	--
Artificial Fill	1,940	2.5	1,940	2.5	--	--	--	--	--	--
No Beach Area	24,840	31.7	--	--	--	--	--	--	--	--
Total	78,090	100.0	17,335	22.3	19,715	25.2	11,700	15.1	4,500	5.7

Source: Schneider, et al. (1977).

Map 4

BEACH WIDTH AND COMPOSITION ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY: 1977



LEGEND

- SAND
- GRAVEL
- GRAVEL AND SAND
- COBBLES AND PEBBLES
- SAND, COBBLES AND PEBBLES
- ARTIFICIAL FILL

NOTE: UNMARKED COASTAL REACHES HAVE NO BEACH AREAS

GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

Source: Schneider et al (1977) and SEWRPC.

30 feet, and about 15 percent has a beach width ranging from 31 feet through 75 feet. Only about 6 percent of the shoreline, located just north of the Racine harbor breakwater, has a beach over 75 feet wide, and this beach is composed entirely of sand.

Surface Water Resources

Surface water resources in the coastal zone of Racine County consist primarily of Lake Michigan but also include the Root River and certain minor streams tributary to Lake Michigan, and form a particularly important element of the natural resource base of the study area. In some areas, surface runoff has an important effect on bluff recession by eroding material from the face of the bluff and by forming gullies and ravines at the edge of the bluff. The Lake Michigan shoreline through Racine County measures 14.8 miles in length. The shoreland area also contains a portion of the Root River estuary as well as all or portions of two unnamed perennial streams and seven unnamed intermittent streams (see Map 5), all of which discharge into Lake Michigan. Within the study area, there is a total of 1.6 miles of perennial streams and 5.1 miles of intermittent streams. There are also a few small ponds within the study area.

The quality of both the inland surface waters and Lake Michigan are susceptible to deterioration as a result of the activities of man. The quality of surface waters is influenced by pollutant contributions from sewage treatment plant outfalls, separate and combined sewer flow-relief devices, storm sewer outfalls, direct surface runoff from adjacent lands, and coastal beach and bluff erosion. Coastal bluff erosion contributes a substantial amount of sediment to the lake; about 6.6 million cubic feet of shore material is estimated to be eroded into the Lake each year in Racine County. By comparison, less than 0.8 million cubic feet of sediment is transported annually by the Root River at the City of Racine.[2] A more detailed discussion of the water quality and sources of pollution of Lake Michigan and of the streams and rivers tributary to the lake is found in the Lake Michigan Estuary and Direct Drainage Area Subwatersheds Planning Programs Prospectus, published by the Regional Planning Commission in 1978.

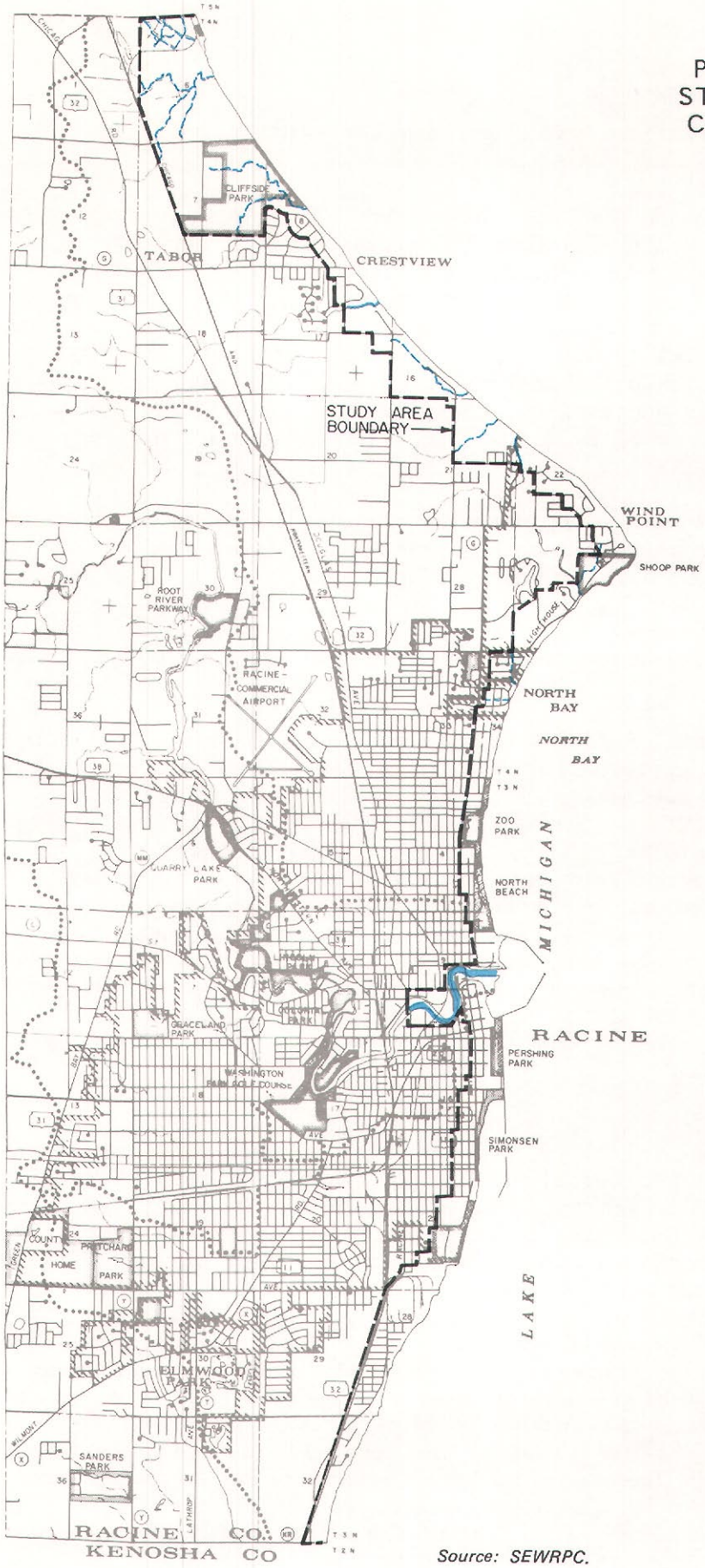
Groundwater Resources

The occurrence, distribution, direction, and quantity of flow of groundwater resources have important impacts on the stability of bluff slopes. Along the Racine County shoreline, groundwater generally flows towards the lake and discharges either at, or below, the base of the bluff into the lake, or seeps out of the bluff slope at some elevation above lake level. The presence of groundwater reduces the frictional resistance to stress, creates a seepage pressure in the direction of water flow, adds weight to the bluff, and causes undercutting of bluff materials. A U. S. Geological Survey report noted that within Racine and Kenosha Counties, surface water runoff contributes about 125 cubic

[2]See SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, 1978, pp. 791.

Map 5

PERENNIAL AND INTERMITTENT STREAMS IN THE LAKE MICHIGAN COASTAL EROSION STUDY AREA OF RACINE COUNTY: 1982



LEGEND

PERENNIAL STREAM

INTERMITTENT STREAM

GRAPHIC SCALE

0 1/2 1 MILE

0 2000 4000 6000 8000 FEET

Source: SEWRPC.

feet per second to Lake Michigan, while groundwater contributes only about five cubic feet per second to the lake.[3]

Three major aquifers underlying the study area yield water to wells, springs, lakes, and streams. These aquifers are commonly called the deep sandstone aquifer, the shallow Niagara dolomite aquifer, and the shallow sand and gravel aquifer. The sandstone aquifer underlying the entire County and comprised of the Cambrian and Ordovician strata is used primarily as an industrial water supply source in the study area. About 80 percent of the recharge of the sandstone aquifer occurs in a corridor which runs through western Washington, Waukesha, and Walworth Counties. Wherever the water table level of the sandstone aquifer lies beneath the level of Lake Michigan, some recharge from the lake is induced.

The Niagara dolomite, of Silurian age, is the principal shallow aquifer in the area. This aquifer, which underlies the entire study area, produces water yields which are somewhat erratic, depending upon the size and number of crevices and solution cavities in the portion of the aquifer contributing to the well. Recharge of the aquifer is by the downward seepage of precipitation which falls in the immediate area. Some recharge is also induced from Lake Michigan.

Water-saturated sand and gravel deposits above the bedrock form a third source of groundwater in Racine County. The sand and gravel aquifer is discontinuous. Where the sand and gravel deposits are deep and overlie the Niagara dolomite, the two aquifers are hydraulically connected, and the lateral movement of water within the two aquifers is similar. The recharge of the sand and gravel aquifer is by local downward percolation of precipitation. However, because of the hydraulic interconnection between the Niagara dolomite and the sand and gravel deposits, groundwater seepages from the sand and gravel deposits could occur even during periods of low precipitation. The groundwater discharges and seepages from the bluff slopes are primarily contained within the sand and gravel aquifer.

Climate

Air temperature and the type, intensity, and duration of precipitation events affect the degree and extent of erosion. Climate impacts on coastal erosion include freeze-thaw actions caused by water contained within the bluff material, high surface runoff from frozen soils in early spring, the reduction of wave action due to ice formation on the lake, high levels of surface runoff, and soil erosion following periods of heavy rainfall.

Air temperature impacts are primarily related to the formation of ice on the lake, the initiation of freeze-thaw actions on soils, and the high runoff rates from frozen soils. Table 4 presents average monthly air temperature variations at the Racine National Weather Service Station. As shown in the table, winter temperatures, as measured by the monthly means for December, January, and February, range from 17°F to 26°F. Summer temperatures, as mea-

[3]R. D. Hutchinson, Water Resources of Racine and Kenosha Counties, Southeastern Wisconsin, U. S. Geological Survey Water Supply Paper No. 1878, 1970.

sured by the monthly means for June, July, and August, average from 66°F to 77°F.

The depth and duration of ground frost, or frozen ground, influences hydrologic and soil erosion processes, particularly the proportion of rainfall or snowmelt that will run off of the land and freeze-thaw activity. The amount of snow cover is a major determinant of frost depth. Since the thermal conductivity of snow cover is less than one-fifth that of moist soil, heat loss from the soil to the colder atmosphere is greatly inhibited by the insulating snow cover. Snow cover is most likely during the months of December, January, and February, during which at least a 40 percent probability exists of having one inch or more of snow cover, as measured at the Milwaukee weather station. Frozen ground is likely to exist throughout the study area for approximately four months each winter season, extending from late November through March, with more than six inches of frost occurring in January, February, and the first half of March. As frozen ground on the slopes thaws, it frequently is susceptible to active slumping of the bluff, as observed by Racine County coastwatchers. Streams and lakes begin to freeze over in late November, and ice breakup normally occurs in late March or early April.

Precipitation within the study area takes the form of rain, sleet, hail, and snow, and ranges from gentle showers of trace quantities to brief but intense and potentially destructive thunderstorms or major rainfall-snowmelt events causing severe bluff and beach erosion. Average monthly and annual total precipitation and snowfall for the Racine National Weather Service Station are presented in Table 5. The average annual total precipitation in the Racine area is 34.19 inches during the period of 1970 through 1980. The average annual snowfall and sleet measured as snow and sleet also over the period of 1970 through 1980 is 43.43 inches. Assuming that 10 inches of measured snowfall

Table 4

AVERAGE MONTHLY AIR TEMPERATURE AT RACINE 1970 THROUGH 1980

Month	Average Daily Maximum	Average Daily Minimum	Mean
January.....	25	8	17
February....	31	15	23
March.....	41	26	34
April.....	54	36	45
May.....	66	46	56
June.....	76	56	66
July.....	82	72	77
August.....	80	61	71
September...	72	54	63
October.....	61	44	52
November....	46	31	39
December....	33	18	26
Yearly Average	55.5	38.9	46.2

Source: National Weather Service and SEWRPC.

Table 5

AVERAGE MONTHLY PRECIPITATION AND SNOW AND SLEET AT RACINE 1970 THROUGH 1980

Month	Average Total Precipitation (inches)	Average Snow and Sleet (inches)
January....	1.34	14.39
February...	1.07	8.50
March.....	2.98	7.60
April.....	4.22	1.63
May.....	2.79	--
June.....	3.73	--
July.....	3.81	--
August.....	3.71	--
September..	4.13	--
October....	2.19	0.38
November...	1.98	2.46
December...	2.24	8.47
Yearly Average	34.19	43.43

Source: National Weather Service and SEWRPC.

and sleet are equivalent to one inch of water, the average annual snowfall of 43.43 inches is equivalent to 4.34 inches of water. Therefore, only about 13 percent of the average annual total precipitation occurs as snowfall and sleet. Average total monthly precipitation for the Racine area ranges from 1.07 inches in February to 4.22 inches in April. The principal snowfall months are December, January, February, and March, during which 90 percent of the average annual snowfall may be expected to occur.

Extreme precipitation events may result in massive coastal losses due to high levels of erosion, seepage, and slumping. A one-hour storm with an expected average recurrence interval of once every two years would have a total rainfall of about 1.2 inches.[4] A one-hour, 10-year recurrence interval storm would have a total rainfall of about 1.8 inches and a 24-hour, 10-year recurrence interval storm would have a total rainfall of about 3.7 inches. Extended wet periods may also result in unusually high coastal losses. Over the period 1895 to 1980, the maximum annual amount of precipitation at Racine was 48.33 inches in 1954, or 41 percent above the 1970 to 1980 annual average.[5] The maximum monthly precipitation amount was 10.98 inches, which occurred in May 1933.

MAN-MADE FEATURES

An understanding of the existing civil divisions, land use patterns, and zoning is essential to the sound formulation of practical development guidelines based upon anticipated bluff recession rates. Accordingly, this section describes the existing civil divisions, land use, and zoning within the study area.

Civil Divisions

Local civil division boundaries within the study area are shown on Map 6. The study area, which lies entirely within Racine County, contains portions of the City of Racine, the Villages of North Bay and Wind Point, and the Towns of Caledonia and Mt. Pleasant. The area and proportion of the study area, as well as the length of Lake Michigan shoreline lying within the jurisdiction of each of these general-purpose local units of government, are shown in Table 6.

Existing Land Use

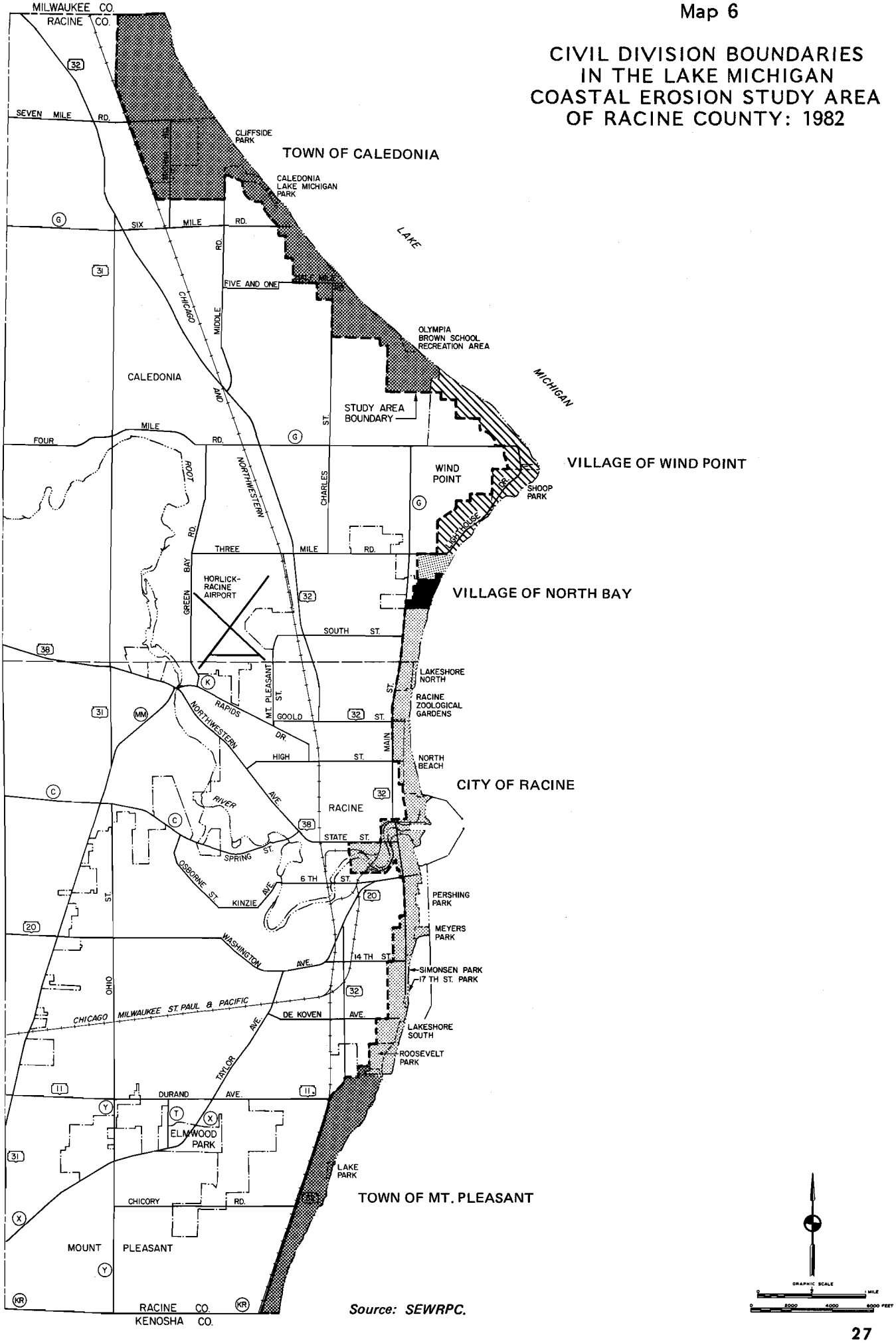
The type and spatial distribution of major categories of land use existing within the coastal erosion study area of Racine County in 1980 are summarized on Map 7. The areal extent of the land use categories within the shoreland study area, which encompasses a total of 2,552 acres, is presented in Table 7. As shown on Map 7, and indicated in Table 7, a significant portion of the study area, 1,429 acres, or 56 percent of the total area--was devoted to urban uses in 1980, including residential; commercial; industrial; transportation, communication, and utility; and governmental and institutional uses. Of these

[4]K. W. Bauer, "Determination of Runoff for Urban Storm Water Drainage System Design," SEWRPC Technical Record, Volume Two, Number Four, April-May 1965.

[5]National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

Map 6

CIVIL DIVISION BOUNDARIES IN THE LAKE MICHIGAN COASTAL EROSION STUDY AREA OF RACINE COUNTY: 1982



Source: SEWRPC.

Table 6

AREA AND SHORELINE LENGTH OF CIVIL DIVISIONS WITHIN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1982

Civil Division	Area (square miles)	Percent of Study Area	Lake Michigan Shoreline Length (feet)	Percent of County Total
Town of Caledonia.....	1.8	43.7	23,600	30.2
Town of Mt. Pleasant.....	0.5	11.9	13,360	17.1
Village of Wind Point....	0.6	15.8	12,690	16.3
Village of North Bay.....	0.1	3.3	3,300	4.2
City of Racine.....	1.0	25.3	25,140	32.2
Study Area Total	4.0	100.0	78,090	100.0

Source: SEWRPC.

Table 7

EXISTING LAND USE IN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1980

	Land Use			
Land Use Category	Acres	Percent of Urban Subtotal	Percent of Rural Subtotal	Percent of Total
Residential.....	695	48.6	--	27.3
Commercial.....	47	3.3	--	1.8
Industrial.....	130	9.1	--	5.1
Transportation, Communication, and Utilities[a].....	373	26.1	--	14.6
Governmental and Institutional.....	184	12.9	--	7.2
Urban Subtotal	1,429	100.0	--	56.0
Recreational[b].....	414	--	36.9	16.2
Wetlands.....	50	--	4.5	2.0
Woodlands.....	146	--	13.0	5.7
Agricultural and Other Open Lands...	476	--	42.4	18.7
Water.....	37	--	3.2	1.4
Rural Subtotal	1,123	--	100.0	44.0
Total	2,552	--	--	100.0

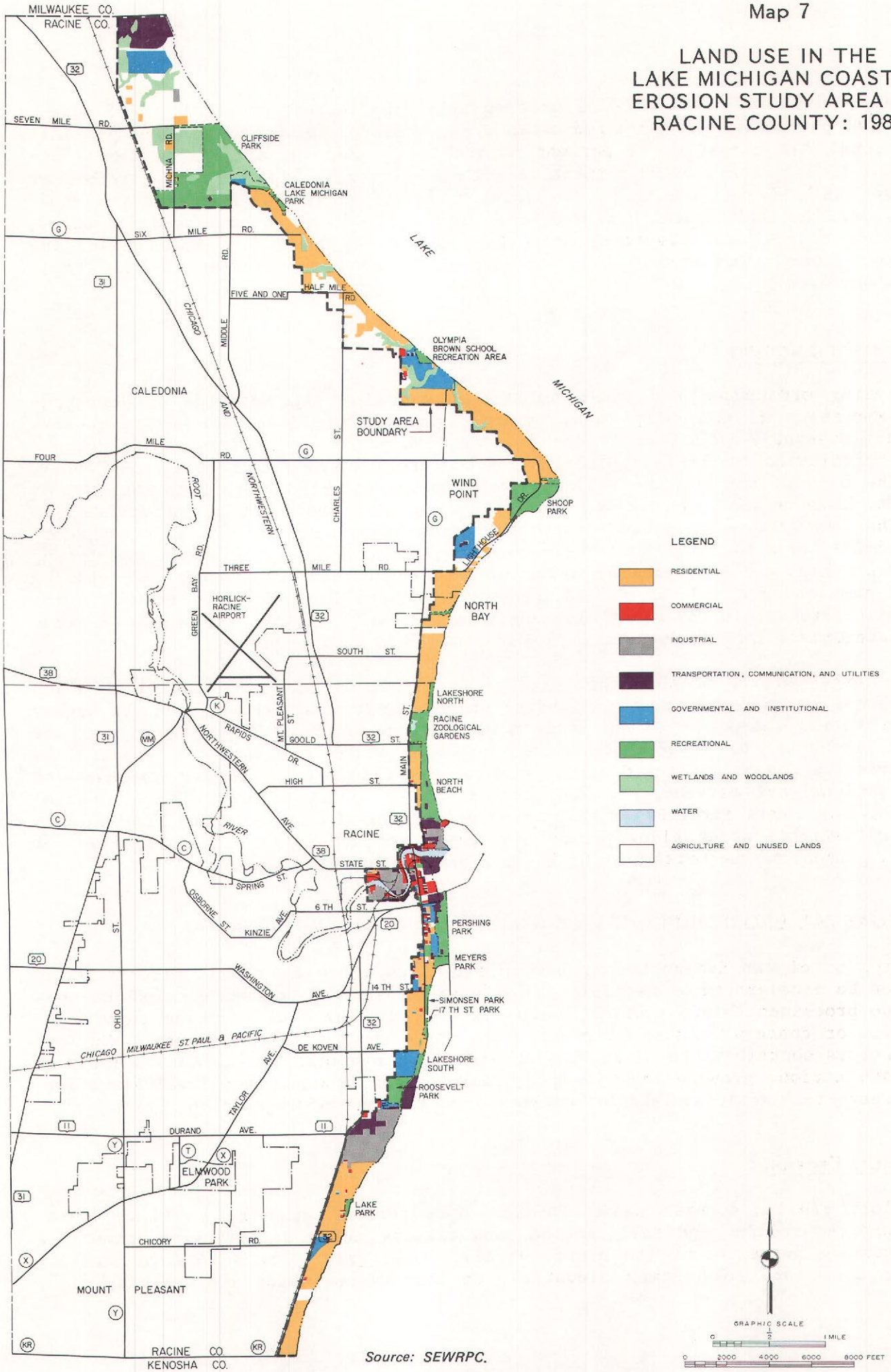
[a]Includes off-street parking, terminals, communication facilities, and utilities.

[b]Excludes wetlands, woodlands, and off-street parking within existing park and outdoor recreation sites.

Source: SEWRPC.

Map 7

LAND USE IN THE LAKE MICHIGAN COASTAL EROSION STUDY AREA OF RACINE COUNTY: 1980



LEGEND

- RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- TRANSPORTATION, COMMUNICATION, AND UTILITIES
- GOVERNMENTAL AND INSTITUTIONAL
- RECREATIONAL
- WETLANDS AND WOODLANDS
- WATER
- AGRICULTURE AND UNUSED LANDS

GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

Source: SEWRPC.

urban land uses, residential uses comprise the largest proportion--695 acres, or 49 percent of the developed urban area. Recreational uses comprised an additional 414 acres, or 16 percent of the total area. Of this recreational use total, 396 acres, or 96 percent, are in public ownership, while the remainder are in private ownership. Remaining undeveloped lands, including wetlands, woodlands, and agricultural and other open space lands, encompassed 672 acres, or 26 percent of the total area. Surface water, consisting primarily of the Root River, accounted for the balance--37 acres, or 1 percent of the total study area.

Existing Zoning

Zoning ordinances and attendant zoning district maps provide an important expression of community land use development objectives. Zoning ordinances are presently in effect in each of the five minor civil divisions which have jurisdiction in the Lake Michigan coastal erosion study area of Racine County. The City of Racine, the Villages of North Bay and Wind Point, and the Town of Mt. Pleasant have adopted and currently administer their own zoning ordinances. The Town of Caledonia has adopted the Racine County zoning ordinance, which is administered for the Town of Caledonia by the Racine County Planning and Zoning Department. The Village of Wind Point is currently in the process of preparing a new zoning ordinance and zoning district map. Generalized existing zoning districts within the study area are shown on Map 8. Table 8 presents the areas categorized into various zoning districts.

A large portion of the study area has been placed in zoning districts which permit urban development--a finding which is not surprising, given the highly urbanized character of the study area. As indicated in Table 8, a total of 2,331 acres, or 91 percent of the study area, have been placed in zoning districts which permit residential, commercial, industrial, and governmental and institutional development. The largest single zoning category is residential which accounts for 1,094 acres, or 43 percent of the study area. Lands placed in districts which allow urban development account for 13.6 linear miles, or 95 percent of the total Lake Michigan shoreline in Racine County.

COASTAL EROSION PROCESSES

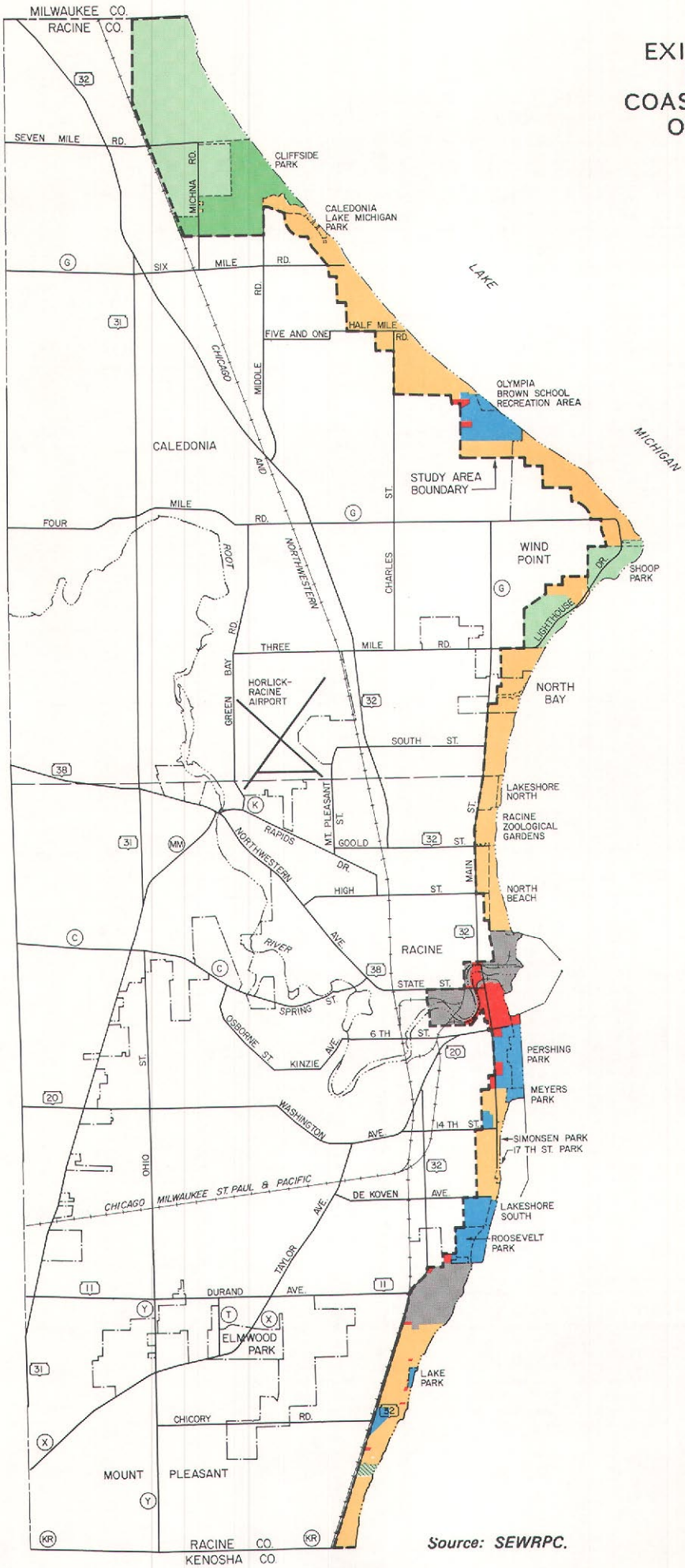
Erosion of the Racine County Lake Michigan coast is a natural process which can be accelerated or decelerated by human activities. Coastal erosion includes two processes, bluff erosion and beach erosion, but bluff erosion is of particular concern because it poses a threat to human life and property. Various factors contribute to bluff erosion and beach erosion. These factors include: wave action, groundwater seepage, precipitation runoff, lake level elevation, freeze-thaw actions, lake ice movement, and the type of vegetative cover.

Bluff Erosion

Bluff erosion occurs in the form of toe erosion, slumping, sliding, flow, surface erosion, and solifluction, and results in the intermittent, sometimes massive, recession of the bluff. On all slopes gravity acts to move material on the slope to a lower elevation. On most slopes which are undisturbed by

Map 8

EXISTING ZONING DISTRICTS IN THE LAKE MICHIGAN COASTAL EROSION STUDY AREA OF RACINE COUNTY: 1981



LEGEND

- RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- GOVERNMENTAL AND INSTITUTIONAL
- RECREATIONAL
- AGRICULTURAL (PERMITS RESIDENTIAL DEVELOPMENT)
- AGRICULTURAL – URBAN HOLDING

GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

Source: SEWRPC.

Table 8

EXISTING ZONING IN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1981

General Zoning District[a]	Town of Caledonia				Town of Mt. Pleasant			
	Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan	
	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent
Districts Which Permit Urban Development								
Residential	343	29.0	1.91	45.8	179	57.2	1.64	66.1
Commercial	6	0.5	--	--	7	2.2	--	--
Industrial	--	--	--	--	106	33.9	0.61	24.6
Governmental and Institutional	77	6.5	0.45	10.8	14	4.5	0.15	6.1
Agricultural	546	46.0	1.10	26.4	--	--	--	--
Subtotal	972	82.0	3.46	83.0	306	97.8	2.40	96.8
Districts Which Prohibit Urban Development								
Agricultural-Urban Holding District	--	--	--	--	7	2.2	0.08	3.2
Recreational	214	18.0	0.71	17.0	--	--	--	--
Subtotal	214	18.0	0.71	17.0	7	2.2	0.08	3.2
Total	1,186	100.0	4.17	100.0	313	100.0	2.48	100.0

General Zoning District[a]	City of Racine				Village of Wind Point			
	Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan	
	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent
Districts Which Permit Urban Development								
Residential	321	48.2	2.82	57.0	210	60.7	1.48	60.7
Commercial	64	9.6	0.28	5.7	--	--	--	--
Industrial	136	20.4	0.66	13.3	--	--	--	--
Governmental and Institutional	145	21.8	1.19	24.0	--	--	--	--
Agricultural	--	--	--	--	136	39.3	0.98	39.8
Subtotal	666	100.0	4.95	100.0	346	100.0	2.46	100.0
Districts Which Prohibit Urban Development								
Agricultural-Urban Holding District	--	--	--	--	--	--	--	--
Recreational	--	--	--	--	--	--	--	--
Subtotal	--	--	--	--	--	--	--	--
Total	666	100.0	4.95	100.0	346	100.0	2.46	100.0

Table 8 (continued)

General Zoning District[a]	Village of North Bay				Study Area Total			
	Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan	
	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent
Districts Which Permit Urban Development								
Residential	41	100.0	0.30	100.0	1,094	42.9	8.15	56.8
Commercial	--	--	--	--	77	3.0	0.28	1.9
Industrial	--	--	--	--	242	9.5	1.27	8.8
Governmental and Institutional	--	--	--	--	236	9.2	1.79	12.5
Agricultural	--	--	--	--	682	26.7	2.08	14.5
Subtotal	41	100.0	0.30	100.0	2,331	91.3	13.57	94.5
Districts Which Prohibit Urban Development								
Agricultural-Urban Holding District	--	--	--	--	7	0.3	0.08	0.6
Recreational	--	--	--	--	214	8.4	0.71	4.9
Subtotal	--	--	--	--	221	8.7	0.79	5.5
Total	41	100.0	0.30	100.0	2,552	100.0	14.36	100.0

[a] The zoning district categories are generalized categories. The residential category on Map 8 includes the R1, R2, R3, R4, and R5 Districts of the City of Racine zoning ordinance; the R2, R3, R4, R5, R7, and R8 Districts of the Racine County zoning ordinance; the R40E, R100, and RM2 Districts of the Town of Mt. Pleasant zoning ordinance; and the residential districts of the zoning ordinance of the Villages of North Bay and Wind Point. The commercial category on Map 8 includes the B1, B2, B3, B4, B5, and O Districts of the City of Racine zoning ordinance; the B1 District of the Racine County zoning ordinance; and the B1, B2, and B3 Districts of the Town of Mt. Pleasant zoning ordinance. The industrial category on Map 8 includes the I2 District of the City of Racine zoning ordinance; and the M1 and ME Districts of the Town of Mt. Pleasant zoning ordinance. The governmental and institutional category on Map 8 includes the O/I District of the City of Racine zoning ordinance; the P1 District of the Racine County zoning ordinance; and the PUL District of the Town of Mt. Pleasant zoning ordinance. The recreational category on Map 8 includes the P2 District of the Racine County zoning ordinance. The agricultural category on Map 8 includes the A2 District of the Racine County zoning ordinance and the agricultural district of the Village of Wind Point zoning ordinance. The agricultural-urban holding category on Map 8 includes the AUH District of the Town of Mt. Pleasant zoning ordinance.

Source: Racine County Planning and Zoning Department and SEWRPC.

man, and where waves are not eroding the base of the slope, an equilibrium is established over a relatively long period of time between the stresses acting to move material down the slope and the resistance of the materials in the slope to those stresses. The shear stress of the materials in the bluffs is primarily determined by the weight of the soil and water mass in the bluff, water pressures in the bluff, external loads such as buildings, vibrations, and the degree of lateral support from the bluff slope. Bluff materials have a shear strength which is normally greater than these stresses. Shear strength depends on the properties of the soil, the loading on the soil, and the moisture content, which is in part determined by the degree of soil drainage. Bluffs erode when either the shear stress is increased or the shear strength decreased, altering the balance of forces until the stresses exceed the resisting soil strength. Undercutting at the toe of the slope by waves steepens the bluff and increases the shear stress.

One major type of slope failure is sliding. In this type of failure the material generally moves along a single slide plane. The two forms of slides common along the Racine County coast are translational slides and slumps. On many slopes which have very little or no vegetation, translational slides occur. This type of failure involves a surface layer several inches to one or two feet thick sliding either rapidly or fairly slowly down the bluff. The term slump is used when sliding of a fairly large mass takes place along a curved surface. The slide mass is actually rotated and often the top of the slump block is tilted back and toward the hill slope. Slumps usually take place fairly rapidly and can cause extensive damage.

A second major type of slope failure is flow. With this kind of slope failure large amounts of water are present and the soil mass actually liquifies and moves like a fluid. Some flow commonly occurs at the toe of slump blocks during and relatively soon after failure. Since slump blocks undergo rotation and the top of the block is often tilted back toward the bluff, surface water can accumulate in these depressions and saturate the underlying soil. Flows also occur when intense rains saturate the surface layer of soil or in the spring as intergranular ice melts near the soil surface and very wet conditions occur. Flows can also occur where groundwater discharges along the bluff face through silts or fine sands. If these more permeable soil layers are located between less permeable clay layers, this removal of sediment by flow due to groundwater seepage is referred to as sapping, and can cause undercutting which creates an unstable slope in which slumps or slides will occur.

A third type of slope failure, related to flow, is solifluction. Solifluction, or soil flow resulting from freeze-thaw activity occurring both in fall and spring, can reduce the stability of bluff slopes. During the thawing period, there is a buildup of excess pore pressure within the soil mass. Because of underlying impermeable frozen ground, the pore pressures cannot be dissipated and thus, shear resistance decreases. Also, the growth of ice crystals within the soil during winter months weakens the structure of the soil. The amount of moisture in a soil prior to freezing will affect the shear strength after it is thawed; the higher the moisture content before freezing the greater the reduction in shear strength after thawing. The net result is a shear resistance or strength, which is less than the shear stress, and therefore, even gentle slopes may erode.

A fourth type of slope failure is sheet wash and rill and gully erosion. Both sheet wash and rill and gully erosion result from surface water runoff flowing over the top of the bluff, and over the slope face itself. Sheet wash is the unconfined flow of water over the soil surface during and following a rainfall. Depths of flow are generally only a few millimeters. Raindrop impact is the dominant factor in the detachment of soil particles and once the particles are detached, they are transported downslope at a rate determined by the water runoff rate, slope steepness, vegetative cover, roughness of the surface, and the transportability of the detached soil particles. Rills and gullies are formed by the concentrated, channelized, flow of water on the surface. Rill and gully formation tends to follow zones of weakness established by desiccation cracking and differences in soil expansion due to freeze-thaw and wetting and drying. On the lake bluffs, the rills are generally destroyed over the winter months by freeze-thaw activity and solifluction, whereas, gullies may exist for years.

A fifth type of slope failure is rock or soil fall. This type of failure takes place when undercutting is extreme and near vertical cliffs are produced. Even though some such segments of bluff are present along the Racine County coast, these are generally fairly small and rock or soil fall from vertical faces plays only a small role in the overall coastal erosion of the County.

Because slope stability is influenced by dynamic factors, slope failure is a process that occurs in an unpredictable, abrupt fashion as opposed to a uniform, relatively continuous, fashion. After each incremental slope failure, the soil masses tend to temporarily assume a stable configuration until the net effect of the many influencing factors once again decreases slope stability, thus precipitating another incremental failure.

Several factors affect the type of slope failure which occurs and the severity of that failure. The physical characteristics of the beach and bluff, as previously discussed in this chapter, have a major influence on the resistance of the slope to failure. Numerous other factors affect the external stresses which are placed upon the slope, resulting in various types of failure.

The degree of wave energy affecting toe erosion is related to the slope of the beach and offshore areas, the orientation of the beach in relation to storm wind and waves, the lake distance over which waves can develop, and the elevation of the water surface relative to the elevation of the base of the bluff. Most of the strong lake winds over Lake Michigan near Racine County approach from a direction of 10° to 20° east of north.[6] As these wind-generated waves approach the coast, wave refraction in shallow water bends the waves more perpendicular to the shore. Almost half of the major storm events approaching the Racine County coast from this direction during the period of 1968 through 1973 generated waves 10 feet or more in height. A wave refraction pattern analysis indicated that for the shoreline north of Wind Point, which exhibits the highest bluff recession rates in the County, storm waves were concentrated due to the alignment of the coast to the waves and to the nearshore bathymetry. South of Wind Point, the waves were dispersed, losing 40 to 75 percent of their

[6]J. P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, April 1, 1978.

deep water wave energy. This may partially account for the lower bluff recession rates exhibited south of Wind Point. Wave information collected under the Racine County Coastwatch Program also indicates that significant waves often approach the county shoreline from the southeast.

Lake water level fluctuations affect rates of wave-induced toe erosion. High water levels result in more rapid recession of the bluffs. When the water level is low, wave energy is expended as waves break along the beach. When water levels rise, waves can break directly on the toe of the bluff and erode the bluff material. The base of the bluff is then undercut, creating unstable conditions in the slope above. This is eventually followed by slope failure and the movement of material down to the base of the bluff. As water levels decrease, the beach again widens and much of the wave energy is dissipated. There is a time lag, however, between bluff recession rates and the decline in lake level because materials in the bluff take time to form a stable slope. Thus, even after water levels decline and wave erosion is decreased, bluff recession continues at a fairly high rate until the bluffs have reached a stable slope angle.

Since 1860, average annual surface elevations of Lake Michigan at Milwaukee have ranged from a low of 577.06 feet above National Geodetic Vertical Datum (NGVD) in 1964, to a high of 582.24 feet above NGVD in 1886 (see Figure 2). The level of Lake Michigan is a function of inflow from Lake Superior, storm water runoff from the tributary land surface, precipitation falling directly on the Lake, outflow from Lake Michigan through the Straits of Mackinac, evaporation from the lake surface, and changes in the storage--volume of water--in the Lake. Seasonal water level changes also occur, with generally the highest water level elevations occurring during June, July, and August, and the lowest levels occurring in January and February.[7]

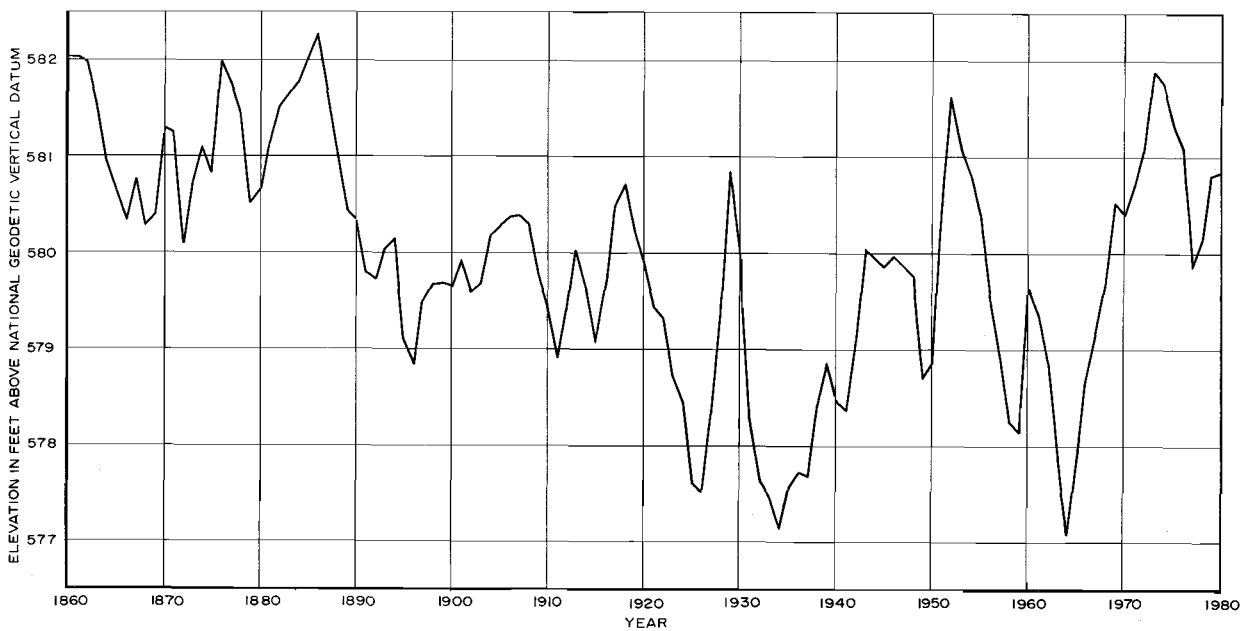
The anticipated occurrence of high Lake Michigan water levels was presented in a report prepared by the U. S. Army Corps of Engineers.[8] For various reaches of the Lake Michigan coast, the report includes estimates of the highest water levels along the open coast expected to be equalled or exceeded for various recurrence intervals. Estimates were made of the highest water levels to be expected on an average of once every 10 years, as well as once every 50 years, 100 years, and 500 years. These levels were based on water level frequency curves derived by the Corps from the maximum instantaneous water levels recorded each year by the National Oceanic and Atmospheric Administration over an approximately 70-year period, adjusted to current outlet conditions. Lake Michigan levels on the Racine County coast may be expected to equal or exceed maximum levels of 582.7 feet NGVD an average of once every 10 years, 583.6 feet NGVD every 50 years, 583.9 feet NGVD every 100 years, and 584.5 feet NGVD every 500 years. Even the 10-year recurrence interval maximum water level is higher than the maximum level shown in Figure 2, because the values shown in Figure 2

[7]C. H. Mortimer, Environmental Status of the Lake Michigan Region, Volume 2, Physical Limnology of Lake Michigan, Part 1, Physical Characteristics of Lake Michigan and its Responses to Applied Forces, 1975.

[8]U. S. Army Corps of Engineers, Report on Great Lakes Open Coast Flood Levels, February 1977.

Figure 2

AVERAGE ANNUAL SURFACE WATER ELEVATION OF LAKE MICHIGAN AT MILWAUKEE: 1860-1980



Source: National Oceanic and Atmospheric Administration.

are average annual surface water elevations while the predicted recurrence interval elevations are derived from maximum instantaneous levels. Prolonged storm periods of several days duration may raise water levels by a foot or more along the county coastline.[9]

Ice formation influences bluff erosion and tends to contribute to a seasonal cycle in erosion. When ice develops along the shore in winter, it serves as a temporary protective barrier against wave action associated with winter storms, thereby reducing bluff erosion. When ice is not stationary against the shore, floating ice chunks can scour the beaches and the bluff toe, thereby reducing the ability of the beach to dissipate wave energy and contributing to toe erosion. Floating ice fields, depending on wind conditions, may develop along the coast. Ice can also cause damage to structures which have been provided to protect the beach and bluff.

Groundwater seepage can also affect bluff stability in several ways. In most areas along the Racine County coast groundwater moves toward the lake and, in some places, discharges either at the toe of the bluff or from the bluff face. Saturated soil conditions decrease the grain-to-grain contact pressure in the soil and reduce the frictional resistance of the material to stress. Groundwater also adds weight to the bluff, further increasing stress on the slope. In addition, groundwater seepage creates a seepage pressure in the direction of water flow. This pressure is especially important in granular soils such as sands and silts and is less important when the content of clay is fairly high. If groundwater actually discharges along the bluff face, some undercutting of materials also occurs. Removal of bluff materials by groundwater is especially important when sand layers are either interbedded with fine grained materials or are present at the bluff top. When present on the top of the bluff, large amounts of water percolate through the sand until a less permeable material is reached and the water then travels laterally towards the bluff face. Sapping of material may occur at the top of this impermeable layer.

Vegetation can also have an effect on bluff stability and erosion. The aboveground portion of the vegetation physically intercepts raindrops, thereby reducing their potential to loosen particles on the bluff face, reducing the impact of wind, and serving to trap windblown sediment. The underground portion of vegetation serves to bind the unconsolidated material in place, to prevent slippage between soil layers parallel to the bluff face, and to retard surface wash and filter out the sediment carried by that wash. The roots of vegetation, however, may induce infiltration by slowing runoff and providing infiltration passages into the bluff face, thereby possibly contributing to a decrease in bluff stability as a result of increased groundwater content and level. Transpiration through vegetation can also help to remove groundwater from the bluff, however, and thereby contribute to its stability. Vegetation on the top of the bluff may serve to intercept and divert some surface runoff, thus preventing it from moving down the bluff face. Probably one of the most significant aspects of the lack of vegetation on a bluff face is that it serves as an effective indicator of recent erosion.

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[9]J. P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, April 1, 1978.

Beach Erosion

The features of a beach and the materials composing the beach are continuously in a state of flux as a result of the onshore or offshore transport of sand and gravel primarily in response to wave action. There is a constantly changing interplay between the forces that bring sand ashore and those that move it lakeward, with the position and configuration of the main mass of sand at any time serving as an index of the dominant forces. High, steep waves--typical of storm events within the coastal area of southeastern Wisconsin--tend to tear beaches down by removing material from them and transporting it in a lakeward direction. In contrast, the small waves--characteristic of periods between storm events--tend to build beaches up through a net landward transport of sediment. Thus, the beaches exhibit a continuous cyclic pattern of erosion and accretion in response to the nature of the waves impinging on the beach. Figure 3 shows the process of beach erosion in response to the impact of high, steep waves. A beach is said to be stable, even though subject to storm and seasonal changes, when the long-term--several years or more--rates of supply and loss of material are approximately equal.

Sediment is also transported parallel to the shoreline along the beach by longshore currents. Longshore currents are currents in the breaker zone running generally parallel to the shoreline and usually caused by waves breaking at an angle to the shoreline. Longshore currents transport sediment and other particulate matter--which is suspended in the current or bounced and rolled along the lake bottom--parallel to the shore. While the longshore currents within the coastal zone of Racine County may move in either a northerly or southerly direction in response the direction of the incident waves, the net sediment transport is to the south. Evidence of this fact is the tendency for beaches to exhibit accretion on the north side of groins, piers, and other structures while erosion occurs on the southerly side of such structures. The U. S. Army Corps of Engineers has estimated that from 50,000 to 75,000 cubic yards of sediment are annually transported along the littoral area of Lake Michigan at the southern boundary of the State of Wisconsin.

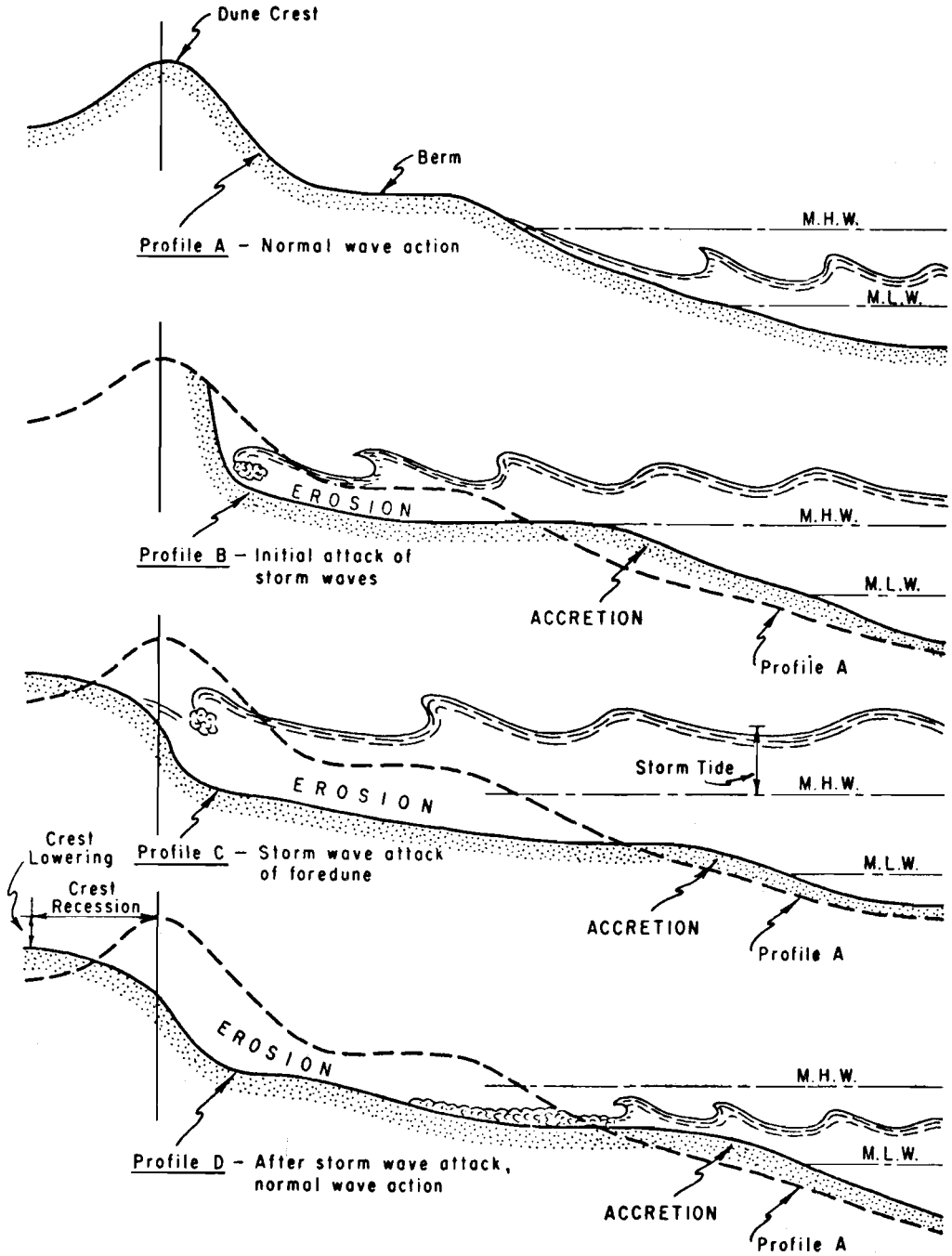
EXISTING REGULATIONS PERTAINING TO SHORELAND DEVELOPMENT

The State of Wisconsin and the federal government have long been involved in the protection of public rights on navigable waters, while more recently water quality has become an important management concern. Of particular concern for coastal erosion management are the means by which state and federal agencies regulate various activities affecting the protection of the Lake Michigan shoreline.

The U. S. Army Corps of Engineers is the primary federal agency responsible for the regulation of structures and work related to surface waters. Initial Corps authority to regulate structures or work in or affecting navigable waters stems from the River and Harbor Act of 1899. Corps regulatory authority was expanded with the passage of the Federal Water Pollution Control Act amendments of 1972. Section 404 of this act authorized the Corps to administer a permit program to regulate the deposition of dredged and fill materials into waters and related wetlands of the United States.

Figure 3

BEACH EROSION IN RESPONSE TO WAVE ACTION



M.H.W. denotes Mean High Water
M.L.W denotes Mean Low Water

Source: U. S. Army Corps of Engineers.

The State of Wisconsin, through the Wisconsin Department of Natural Resources (DNR), regulates shore protection-related activities under the provisions of Chapter 30 of the Wisconsin Statutes. State regulatory authority with respect to shore protection and erosion control projects is largely confined to projects initiated at or below the ordinary high-water mark. For example, Chapter 30 provides for the establishment of bulkhead lines by local units of government and prohibits the deposit of materials or filling at or below the ordinary high-water mark or beyond an established bulkhead line. Under Chapter 30, the installation of riprap and shore protection structures on the bed and bank of the water--or the unbroken slope from the ordinary high-water mark--requires a DNR permit. DNR permits are also required to grade or otherwise remove soil from the bank of any navigable body of water where the area exposed would exceed 10,000 square feet; this provision, it should be noted, affects the grading of the bank below and above the ordinary high-water mark and underscores the importance of county and local management of shore protection activities.

Under Wisconsin Statutes, county and local units of government also have been granted a variety of regulatory powers which can be used to guide development within the Lake Michigan shoreland area in the public interest. Among the most important of these are the shoreland zoning, comprehensive zoning, and land subdivision regulations. The existing zoning and subdivision regulations in Racine County were described previously in this chapter. This section discusses how the regulations pertain to shoreland development and erosion management.

As previously indicated, Racine County presently exercises shoreland zoning powers within statutorily-defined shoreland zoning jurisdiction areas of the Towns of Caledonia and Mt. Pleasant, including the area lying within 1,000 feet of the ordinary high-water mark of Lake Michigan. Certain provisions of the county shoreland zoning ordinance serve to minimize erosion hazards along the Lake Michigan shoreline. Most importantly, the county shoreland ordinance has the effect of making virtually all man-made alterations of a shoreland zoning area a conditional use subject to county review and approval. Specifically, earth movements such as grading, top soil removal, filling, root cutting, construction, altering or enlargement of waterways, removal of stream or lakebed materials, excavation, and soil and water conservation structures--among other activities--are designated as conditional uses within the shoreland area. As a result, conditional use permits must be obtained for the construction of new buildings, the installation of shore protection structures, and most other alterations of the shoreland area. In its shoreland conditional use review process, Racine County attempts to ensure that new structures are safely sited with respect to erosion hazards, that shore protection structures are well designed and environmentally sound, and that alterations of the shoreland, in general, do not increase shore erosion hazards. All applications for conditional use permits within the shoreland area are referred as a matter of course to the Racine County Land Conservation Committee. In addition, Racine County may seek review comments from the Wisconsin Department of Natural Resources, the University of Wisconsin Sea Grant Institute, the U. S. Army Corps of Engineers, the Technical Subcommittee of the Racine County Coastal Management Program Technical Advisory Committee, and the Southeastern Wisconsin Regional Planning Commission.

The county shoreland zoning ordinance also establishes a setback of 400 feet from the ordinary high-water mark for all structures except public utilities,

recreational facilities, single-family homes, and existing water-oriented commercial uses. The residential uses and the water-oriented commercial uses allowed within this 400-foot setback are subject to the 100-foot minimum shore yard requirement of the comprehensive county zoning ordinance. The comprehensive zoning ordinance also specifies, however, that shore yards may be reduced to the average of the shore yards existing on abutting properties, but to not less than 50 feet. The 50-foot minimum also applies to shore yards on substandard lots. The shore yard is defined as the distance between the average annual high-water line and the nearest part of the principal building on a lot.

In addition to shoreland zoning regulations, Racine County has adopted special floodland regulations which serve to limit filling and development within 100-year recurrence interval flood hazard areas. Racine County floodland regulations apply to floodlands throughout the entire unincorporated area of the County. One hundred-year recurrence interval flood hazard areas along the Root River were identified by the Regional Planning Commission under the Root River watershed planning program, while flood hazard areas along other streams in the study area have been delineated under flood insurance studies conducted by private consulting firms for the Federal Emergency Management Agency for the City of Racine, the Village of Wind Point, and the unincorporated areas of Racine County. These flood insurance studies also identify a narrow band along the Lake Michigan shoreline which is subject to inundation by the lake on the average of once every 100 years, and which is also subject to existing county and local floodland regulations.

The zoning ordinances of the City of Racine and the Villages of North Bay and Wind Point are generally devoid of provisions pertaining to Lake Michigan shoreline erosion hazards. These municipalities have not adopted special shoreland zoning regulations, as Racine County has done, nor have they incorporated special erosion hazard regulations into their comprehensive zoning ordinances. The City of Racine and the Village of Wind Point, however, have each adopted floodland zoning regulations which restrict filling and development within 100-year recurrence interval flood hazard areas within the respective communities. The regulations apply to the Lake Michigan shoreline below the highest lake level elevation that may be expected during a 100-year period. These regulations provide a basis for the local regulation of filling or development--including the installation of shore protection devices such as groins or revetments--below this elevation.

There being relatively little undeveloped land within the shoreland area of the City of Racine and the Villages of Wind Point and North Bay, land subdivision regulations have, as a practical matter, little application to the control of erosion hazards in the incorporated portion of the study area. It should be noted, however, that a review of the subdivision control ordinances of the City of Racine and the Village of Wind Point indicates that there are no specific provisions in these ordinances for the minimization of Lake Michigan shoreline erosion hazards.

EXISTING STRUCTURAL EROSION CONTROL MEASURES

Shoreland structural erosion control measures are intended to reduce coastal erosion by providing an artificial protective barrier against direct wave and ice attacks on the beach and bluff toe, by increasing the extent of the beach

to absorb wave energy before the water reaches the bluff, by dissipating wave energy, and/or by stabilizing bluff slopes. However, structural protective measures installed by both public agencies and by private shoreline property owners are costly and have had varying degrees of success. In addition, many structures were not properly designed nor constructed, and many are not properly maintained, resulting in severe deterioration or disappearance within a period of time much shorter than the life of the facilities they were designed to protect.

Onshore protective structures include bulkheads, revetments, and seawalls constructed at or near the base of a bluff. Bulkheads serve primarily as bluff-retaining structures and support the bluff against gravity forces. Seawalls, on the other hand, serve to support a bluff as well as effectively absorb the force of impinging waves. The most common type of onshore protective structure is the revetment--a flattened slope surface armored with erosion-resistive materials, such as concrete or natural rock riprap, and underlaid by filter cloth, or gravel.

A type of onshore and nearshore protective structure is the groin, which is connected to and built perpendicular from the beach and is intended to partially obstruct the longshore current which results in the accumulation of transported sand on the beach up-current of a structure. A similar but temporary result may be achieved with artificial beach nourishment, although this approach is still under study--and not generally permitted--by the Wisconsin Department of Natural Resources. The resulting beach absorbs wave energy and reduces toe erosion along the adjacent bluffs. It should be noted that the installation of groins in the coastal system of southeastern Wisconsin can lead to erosion of the beach and bluff immediately downdrift of groins or groups of groins if there is too much blocking of the littoral drift. Within the Wisconsin shoreline of Lake Michigan, the largest number of groins are located in Racine and Kenosha Counties. Groins, as well as nearly all other shore protection structures, require periodic maintenance, extension, and sometimes replacement.

Breakwaters are protective structures built out from the shore into deeper water and sometimes parallel to the shore. They provide dissipation of wave energy, thus reducing bluff toe erosion while reducing the strength of the longshore current immediately landward of the structures. Like groins, however, breakwaters may accelerate beach and bluff erosion downdrift of the protected areas, as sediments settle in the sheltered water behind the breakwater. Breakwaters currently protect the entrance to the Racine Harbor and are also located parallel to the coast south of the harbor for a distance of about 1.4 miles.

Slope stabilization can be accomplished by using earth-moving equipment to regrade the face of the slope to a flatter, more stable profile, thus accelerating the natural stabilization process. This approach is practical only if sufficient vacant land is available at the top of the bluff. Another slope stabilization procedure involves the installation of internal drains to maintain a lowered water table within the bluff face and thus reduce the likelihood of slippage along bluff surfaces. Slope stabilization can also be accomplished through maintenance of a protective cover of vegetation. Slope stabilization measures usually include a combination of these methods.

A variety of shoreline protection structures have been installed by public agencies and by private property owners, thereby reducing shoreline erosion along certain portions of the Racine County coastal area. For example, the Racine Harbor breakwater and the breakwater south of the harbor serve to minimize erosion problems relating to existing development in the Racine central business district and the portion of the City of Racine to the south. Many structures protecting individual properties have also been installed. For example, about 85 structures, including a number of groins, have been constructed along the coastal reach between the Racine Zoological Gardens and Shoop Park. In contrast, with the exception of the Wisconsin Electric Power Company bulkhead, shoreline protection structures are virtually nonexistent in the northernmost portion of the Racine County coastal area--from Cliffside Park to the Milwaukee County line--the reach which experienced the highest shoreline recession rate in the County in the recent past.[10]

The quality and effectiveness of shoreline protection structures varies considerably. An inventory of shoreline protection structures in existence in 1976 along Lake Michigan, including the Racine County coastal area, was conducted as part of the shoreline erosion study sponsored by the Wisconsin Coastal Management Program.[11] This inventory was supplemented by a Regional Planning Commission staff review of 29 approved shoreline protection structure permits filed with the Wisconsin Department of Natural Resources (DNR) between December 1977 and September 1980. The combined inventories are presented in Appendix A. It should be noted that the DNR permit files do not indicate whether proposed structures were actually constructed, but are based on the applications and plans for such structures.

Appendix A lists a total of 216 shoreline protection structures of which 78, or 36 percent are groins; 71, or about 33 percent are revetments; 39, or about 18 percent are bulkheads; 6, or less than 3 percent are piers; and 1, or less than 1 percent is a breakwater. The remaining 21 structures, or about 10 percent of the total listed as other, include boathouses, boat launching ramps, slag heaps, debris, and concrete sections. Of the total, 136, or about 63 percent of the shoreline protection structures are located in the Town of Caledonia--Township 4 North, Range 23 East--and 80 structures, or about 37 percent of the shoreline protection structures are located in the Town of Mt. Pleasant--Township 3 North, Range 23 East.

Bluff heights at the structure sites range up to 65 feet. The average bluff height at structure sites is 27.4 feet. Bluff slopes range up to 52° for a bluff located in Township 3 North, Range 23 East, Section 32. The average bluff slope is 29°. Beach widths at structure sites range up to 97 feet. The average beach width at structure sites is 14 feet.

Table 9 presents a summary of the condition of various types of shoreland protection structures and the types of failure affecting these structures. The inventory of the condition of structures and failure types was conducted in

[10]D. M. Mickelson, et al., Shore Erosion Study: Technical Report--Shoreline Erosion and Bluff Stability Along Lake Michigan and Lake Superior Shorelines of Wisconsin, 1977.

[11]Ibid.

Table 9

SURVEY OF SHORE PROTECTION STRUCTURE TYPE, CONDITION, AND FAILURE TYPE IN RACINE COUNTY: 1976-1980

Structure Type	Condition[a]					
	Functional		Failing		Nonfunctional	
	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total
Revetment....	35	61.4	9	15.8	13	22.8
Groin.....	50	77.0	6	9.2	9	13.8
Bulkhead.....	34	94.4	--	--	2	5.6
Pier.....	3	50.0	1	16.7	2	33.3
Breakwater...	--	--	--	--	1	100.0
Other.....	7	35.0	1	5.0	12	60.0
Total	129	69.7	17	9.2	39	21.1

Structure Type	Failure Type[b]					
	None		Overtopped		Flanked	
	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total
Revetment....	7	12.3	36	63.2	21	36.8
Groin.....	15	23.1	33	50.8	23	35.4
Bulkhead.....	22	61.1	8	22.2	1	2.8
Pier.....	--	--	2	33.3	--	--
Breakwater...	--	--	--	--	--	--
Other.....	4	20.0	7	35.0	6	30.0
Total	48	25.9	86	46.5	51	27.6

Structure Type	Failure Type[b]					
	Collapsed		Faulty Material		Other	
	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total
Revetment....	13	22.8	14	24.6	7	12.3
Groin.....	13	20.0	--	--	15	23.1
Bulkhead.....	--	--	1	2.8	3	8.3
Pier.....	2	33.3	1	16.7	1	16.7
Breakwater...	--	--	--	--	1	100.0
Other.....	2	10.0	4	20.0	8	40.0
Total	30	16.2	20	10.8	35	18.9

[a] Functional structures are operational and effective, but some portions may be failing. Failing structures are of questionable effectiveness and have moderate structural deficiencies. Nonfunctional structures are ineffective and have major structural deficiencies.

[b] *The failure type percents are calculated from the total number of structures* evaluated. Percents may add up to more than 100 percent because many structures exhibited more than one type of failure.

Source: Wisconsin Coastal Management Program, Wisconsin Department of Natural Resources, and SEWRPC.

1976 under the Wisconsin Coastal Management Program shore erosion study. Table 9 indicates that about 61 percent of the revetments, 77 percent of the groins, 94 percent of the bulkheads, 50 percent of the piers, and 35 percent of the other structures were classified as functional and effective.

Minor portions of many of these functional structures, however, may have been failing; about 63 percent of the functional structures exhibited some form of failure. Approximately 23 percent of the revetments, 14 percent of the groins, 6 percent of the bulkheads, 33 percent of the piers, the only inventoried breakwater, and 60 percent of the other structures were classified as nonfunctional. These nonfunctional structures were ineffective and/or exhibited major failures. The remaining structures, classified as failing, had moderate structural deficiencies, but were still providing some level of structural protection.

Only about 12 percent of the revetments, 23 percent of the groins, 61 percent of the bulkheads, none of the piers and breakwaters, and 20 percent of the other structures exhibited no failure of any kind. The predominant type of structural failure was overtopping, where the water level, or at least wave heights, exceeded the top of the structure. Overtopping affected nearly half of the structures inventoried, including about 63 percent of the revetments, 51 percent of the groins, 22 percent of the bulkheads, 33 percent of the piers, and 35 percent of the other structures. This indicates that many structures have either not been constructed large enough for their intended purpose, or that the structures have settled or partially collapsed. As overtopping occurs, small particles from the structure or its foundation are removed, and the foundation may eventually fail. Other failure types inventoried included flanking--where the sides of the structure are eroded--collapsing, and faulty design and selection of materials.

EXISTING COASTAL EROSION PROBLEMS

The most important Lake Michigan coastal erosion problem existing in Racine County is recession of the bluffs. Of foremost concern regarding bluff recession is the danger to the life of residents of homes located in close proximity to the bluff edge and, therefore, subject to the consequences of major, unexpected, rapid slope failure by sliding or slumping. In addition, bluff recession has, and will continue to, damage or threaten private residences, commercial buildings, streets, parkland, and open natural areas, thereby depreciating or destroying real property values. The erosion or accretion of the beaches is a related process in that the extent of the beach affects the degree of wave erosion at the bluff toe. The failing or nonfunctional status of approximately 30 percent of the existing shoreline protection structures, previously noted in this chapter, is another factor affecting bluff recession rates.

Bluff Recession Rates

The rate of bluff recession in Racine County has been documented in several studies. In particular, a shore erosion study by Schneider, et al.,[12] and

[12]A. F. Schneider, T. Edil, and B. Haas, Shore Erosion Study, Technical Report, Appendix 2, Racine County, February 1977.

a recent study by Keillor and DeGroot[13] of the University of Wisconsin Sea Grant Institute have presented detailed bluff recession rates. Schneider's study presented short-term--10 to 15 year--and long-term--about 110 year--recession rates. The Keillor-DeGroot study documents bluff recession over the period from 1968 through 1971 to 1976. It should be noted that the Keillor-DeGroot study period included the early and mid-1970's when Lake Michigan water levels rose to near record heights. As previously discussed, high lake water levels result in the bluff toes being increasingly susceptible to wave attack. Moreover, the lake level was increasing between 1968 and 1971--the span of the baseline data--and, therefore, several coastal reaches in the County were not observed under identical conditions.

In order to assess the impact of high water levels on bluff recession rates and to verify the Keillor-DeGroot rates, the Regional Planning Commission measured bluff recession rates in Racine County at the specific Keillor-DeGroot measurement sites for the period of 1975 through 1980--generally after the Keiller-DeGroot study period--and for the period of 1963 through 1980--thereby including the Keillor-DeGroot study period. A description of the methodologies used to measure bluff recession rates is presented in Appendix B.

Both the Keillor-DeGroot and the Commission studies presented measured recession rates at 101 locations along the county coastline. The midpoints between each measurement site were used to define the boundaries of coastal erosion analysis reaches which are shown on Map 9. Thus, recession rate data are presented for a total of 101 analysis reaches which cover all but two areas of the coast. These two areas are the southernmost portion of the City of Racine shoreline and the northernmost shoreline--approximately 1,300 feet--of the Town of Caledonia. Recession rates were not measured in these areas because the portion of the City of Racine shoreline concerned is heavily protected by shore protection measures, and the northernmost shoreline of the Town of Caledonia is covered by fly ash and protected by a bulkhead. The shoreline length of the analysis reaches range from 220 feet to 1,160 feet and the combined length of the analysis reaches totals 58,150 feet, or 74 percent of the total Racine County shoreline length of 78,090 feet. The analysis reaches are numbered according to the U. S. Public Land Survey section numbers and the distance between the measurement site within each analysis reach and the south section line. For example, analysis reach 32:05 is located in Section 32 and the measurement site for that reach is located 500 feet north of the southern boundary of Section 32.

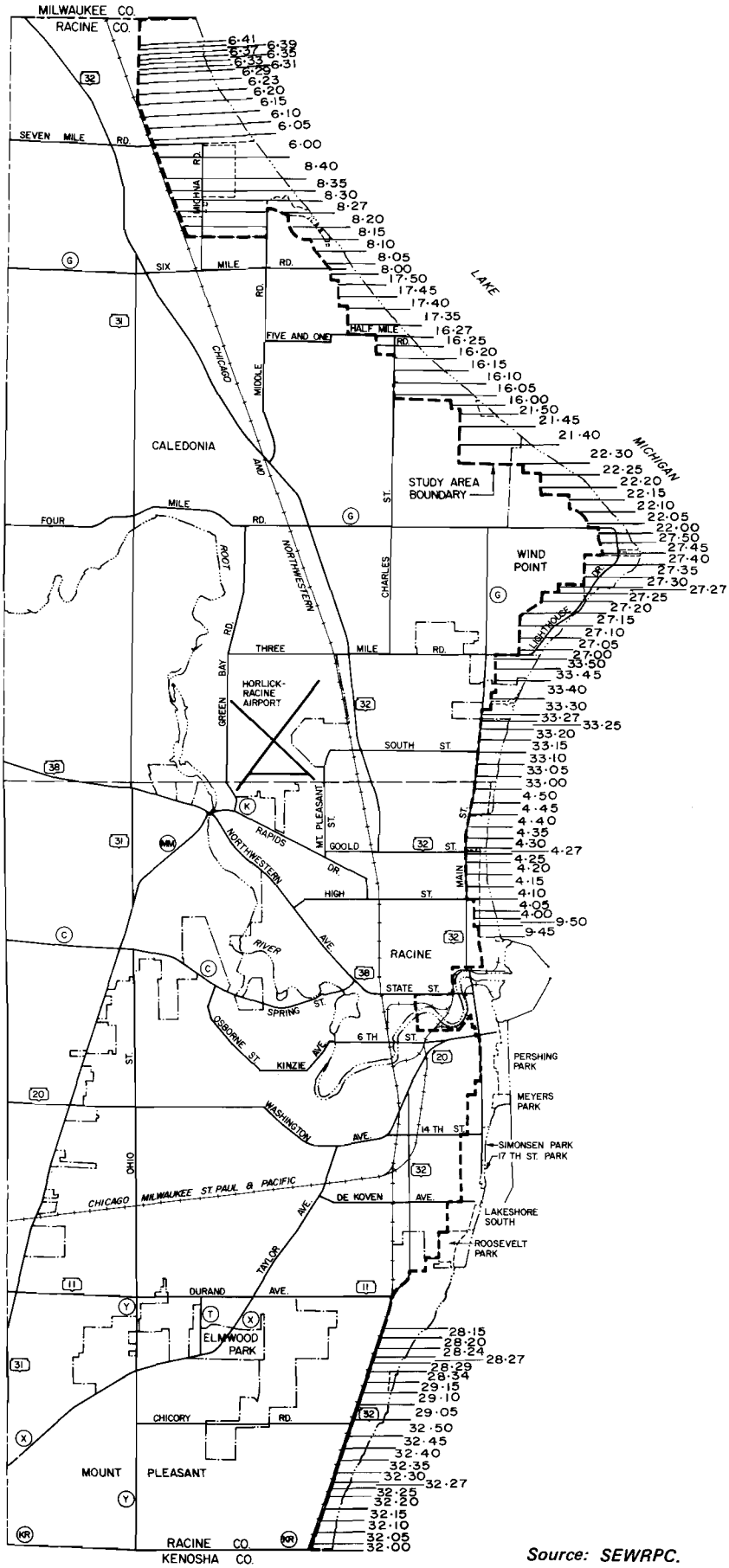
Table 10 sets forth the measured recession rates for each analysis reach as determined by Schneider, et al., Keillor-DeGroot, and the Regional Planning Commission. Shoreline length and the volume of material lost for each reach are also presented. The recession rates are graphically illustrated in Figure 4. The Schneider long-term recession rates range from 0.8 feet per year to 5.0 feet per year, with a shoreline length-weighted mean of 2.1 feet per year. The Schneider short-term recession rates range from 1.0 foot per year to 9.0 feet per year, with a mean of 5.0 feet per year. The highest recession rates reported by Schneider were located within the City of Racine.

The Keillor-DeGroot recession rates range from 3.1 feet per year of accretion to 14.2 feet per year of recession, with a length-weighted mean recession rate

[13]J. P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, and Volume 2, Appendix, 1978.

Map 9

LAKE MICHIGAN COASTAL EROSION ANALYSIS REACHES IN RACINE COUNTY



LEGEND

6·41 COASTAL EROSION ANALYSIS REACH NUMBER

COASTAL EROSION ANALYSIS REACH BOUNDARY

GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

Source: SEWRPC.

Table 10

BLUFF RECESSION RATES ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY

Coastal Erosion Analysis Reach	Shoreline Length (feet)	Annual Recession Rates (feet/year)					Annual Volume of Bluff Material Loss (feet^3/year)[b]
		Schneider et al. Short-Term[a] (10-15 years)	Schneider et al. Long-Term[a] (110 years)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
6:41	240	4	4	4.1	4.2	4.5	59,000
6:39	220	4	4	0.9	2.1	2.0	14,300
6:37	360	4	4	8.1	6.5	5.7	233,300
6:35	300	4	4	6.0	5.7	2.8	144,000
6:33	220	4	4	4.4	5.0	3.6	67,800
6:31	220	4	4	7.4	7.9	7.5	130,200
6:29	480	4	4	13.4	9.0	7.2	643,200
6:23	680	6	3	14.2	10.2	8.4	791,800
6:20	480	6	3	10.0	7.1	10.2	384,000
6:15	600	6	3	11.5	7.2	8.3	496,800
6:10	600	6	3	9.8	7.7	9.8	399,800
6:05	820	6	0.8	2.5	2.4	4.4	135,300
6:00	1160	6	0.8	6.8	4.9	3.2	489,100
8:40	1100	6	0.8	8.2	5.7	4.1	541,200
8:35	600	6	0.8	5.7	3.8	2.8	205,200
8:30	540	6	2	3.0	0.9	2.6	100,400
8:27	680	6	2	4.0	3.5	1.8	179,500
8:20	820	6	2	4.1	3.9	2.1	221,900
8:15	700	6	2	1.0	4.1	1.9	37,800
8:10	700	6	2	0.7	0.5	0.8	22,500
8:05	640	6	2	0.5	1.0	0.6	12,800
8:00	460	6	2	0.2	0.0	0.7	3,700
17:50	500	6	2	0.0	0.0	0.3	--
17:45	600	6	1	+ 1.5	+ 0.3	+ 0.7	--
17:40	740	6	1	0.8	0.6	0.5	17,800
17:35	860	6	1	0.6	0.7	0.4	20,600
16:27	700	6	1	4.7	3.9	2.2	125,000
16:25	510	6	1	3.4	3.4	1.9	65,900
16:20	680	6	1	1.5	1.0	1.3	38,800
16:15	740	6	2	3.3	2.0	1.0	83,000
16:10	800	4	2	4.3	2.1	3.1	110,100
16:05	780	4	2	1.4	1.1	1.6	21,800
16:00	450	4	2	0.1	0.9	0.6	900
21:50	480	4	2	0.0	0.0	1.1	--
21:45	740	4	2	0.4	0.8	0.6	3,600
21:40	1100	4	2	+ 0.2	+ 0.1	0.4	--
22:30	1100	4	2	0.7	1.0	0.4	23,100
22:25	840	3	2	0.1	0.7	0.0	2,700
22:20	800	3	0.9	0.4	1.0	0.7	10,200
22:15	780	3	0.9	0.7	0.8	0.4	15,300
22:10	630	3	0.9	+ 0.8	+ 0.3	0.9	--
22:05	640	3	0.9	0.0	+ 0.5	0.2	--
22:00	500	3	0.9	1.6	1.2	1.1	11,200
27:50	490	3	0.9	+ 0.6	0.9	0.7	--
27:45	630	3	0.9	3.8	2.7	0.9	19,200
27:40	560	4	0.9	1.0	0.7	0.8	5,600
27:35	820	4	0.9	1.3	1.3	2.1	10,700
27:30	480	4	0.9	0.1	0.5	+ 0.6	500
27:27	980	4	0.9	+ 0.1	0.4	0.2	--
27:25	530	4	1	0.2	0.0	0.7	1,900
27:20	690	4	1	+ 0.5	+ 0.7	0.1	--
27:15	700	4	1	+ 0.2	+ 0.7	0.0	--
27:10	680	4	1	1.4	1.2	1.1	28,600
27:05	600	4	1	+ 0.4	+ 0.7	+ 2.2	--
27:00	480	3	1	+ 0.3	0.4	1.8	--
33:50	490	3	1	+ 0.9	+ 0.7	+ 0.4	--
33:45	630	3	3	1.2	0.6	0.6	21,200

Table 10 (continued)

Coastal Erosion Analysis Reach	Shoreline Length (feet)	Annual Recession Rates (feet/year)					Annual Volume of Bluff Material Loss (feet^3/year)[b]
		Schneider et al. Short-Term[a] (10-15 years)	Schneider et al. Long-Term[a] (110 years)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
33:40	930	3	3	+ 0.8	0.3	0.0	--
33:30	730	4	3	0.4	0.2	0.4	5,800
33:27	280	4	3	+ 2.1	+ 2.7	0.0	--
33:25	380	4	3	1.6	0.8	1.7	18,200
33:20	530	4	1	+ 0.5	+ 0.4	0.8	--
33:15	520	4	1	5.6	5.1	0.8	87,400
33:10	530	4	1	+ 0.8	0.9	+ 0.2	--
33:05	530	4	1	0.7	0.7	0.7	11,900
33:00	510	4	1	1.4	1.0	0.2	24,300
4:50	490	4	1	+ 0.8	0.2	0.0	--
4:45	530	4	1	0.0	0.0	+ 0.3	--
4:40	540	4	1	0.6	0.1	+ 1.1	9,700
4:35	520	4	1	+ 0.4	+ 1.2	0.0	--
4:30	410	4	1	0.1	0.9	0.0	1,700
4:27	260	9	5	1.0	1.0	0.0	10,900
4:25	360	9	5	0.1	0.0	+ 0.8	1,400
4:20	520	9	5	+ 0.1	+ 0.3	+ 0.7	--
4:15	520	9	5	0.0	0.2	0.6	--
4:10	530	9	5	0.1	+ 0.3	0.0	2,100
4:05	530	9	5	0.2	0.9	+ 0.3	4,200
4:00	440	9	5	0.0	0.0	0.0	--
9:50	430	9	5	0.4	0.6	0.3	6,900
9:45	380	9	5	+ 0.2	+ 0.8	+ 0.2	--
28:15	460	1	2	2.2	3.1	3.2	40,500
28:20	540	1	4	0.3	0.5	2.9	6,500
28:24	400	1	4	1.8	2.2	1.5	28,800
28:27	280	1	4	0.2	0.0	1.1	2,200
28:29	410	1	4	0.6	1.6	0.6	9,800
28:34	490	1	4	+ 0.4	+ 0.4	+ 0.6	--
29:15	480	7	4	2.4	1.4	1.5	46,100
29:10	520	7	4	+ 3.1	+ 2.8	0.7	--
29:05	720	7	2	1.2	0.6	1.3	34,600
32:50	900	7	2	1.8	1.2	3.3	55,100
32:45	550	7	2	1.2	1.6	1.6	25,100
32:40	580	7	2	4.6	4.4	2.0	90,700
32:35	540	7	2	0.7	1.2	2.2	12,100
32:30	500	7	2	2.7	2.5	2.2	40,500
32:27	300	7	3	0.6	0.4	0.4	6,100
32:25	400	7	3	0.3	0.8	0.4	3,600
32:20	560	7	3	0.1	+ 0.1	0.5	1,700
32:15	500	7	3	+ 0.4	+ 0.5	+ 0.4	--
32:10	520	7	3	1.6	2.2	3.5	25,000
32:05	500	7	3	0.8	0.7	2.7	18,200
32:00	250	7	3	1.5	1.9	2.9	14,200
Shoreline Length-Weighted Mean[c]		5	2.1	2.5	2.1	1.5	--

+ - Denotes accretion of the bluff.

[a]It should be noted that Schneider, et al. recession rates shown exclude the portion of the City of Racine and the northernmost 1,300 feet of the Town of Caledonia shoreline, which were not measured in the other studies.

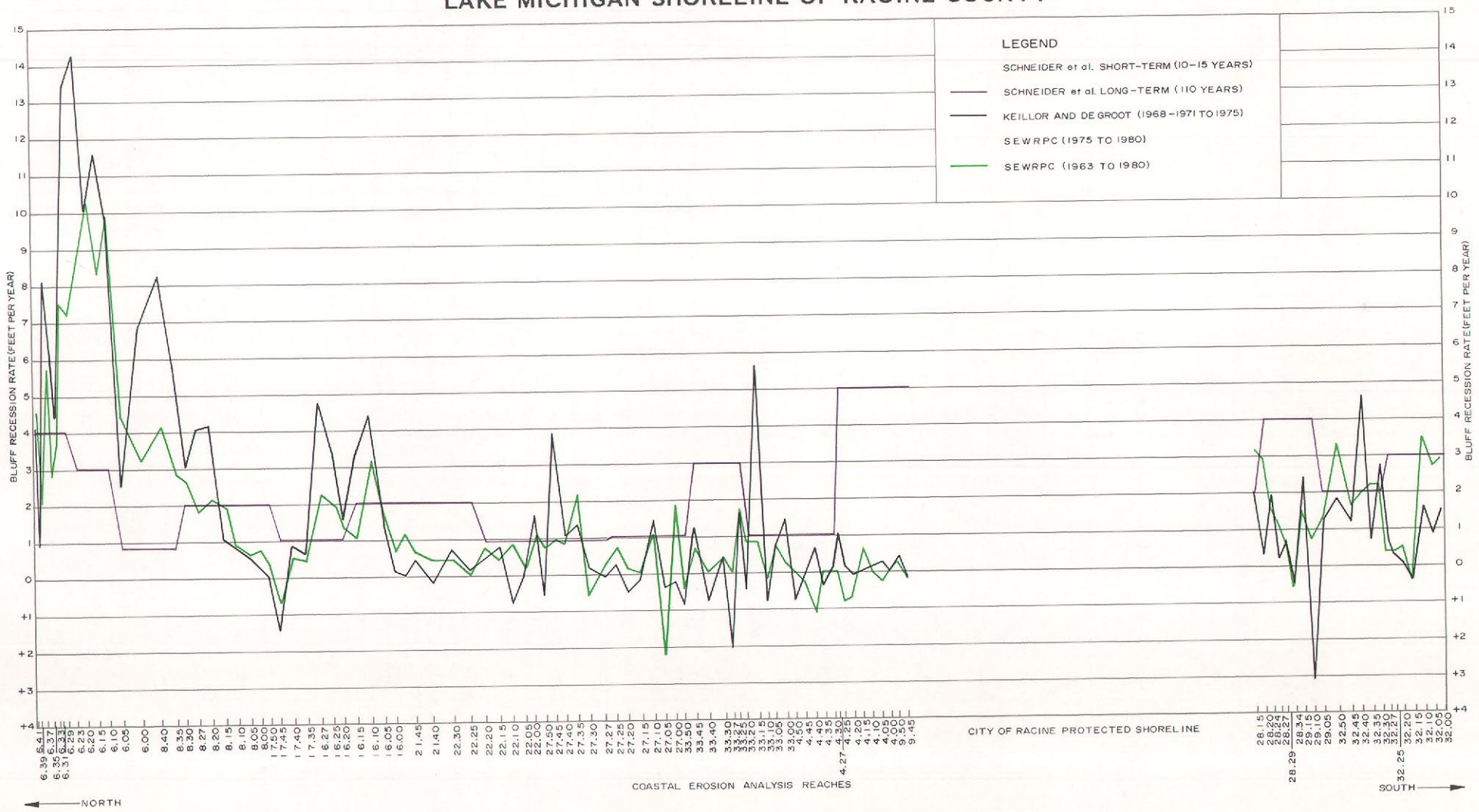
[b]As estimated by Keillor and DeGroot (1978).

[c]Not including reaches which experience accretion.

Source: SEWRPC.

Figure 4

MEASURED BLUFF RECESSION RATES ALONG THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY



Source: SEWRPC.

of 2.5 feet per year. The highest recession rates measured by Keillor-DeGroot were for analysis reaches located in Section 6 of the Town of Caledonia, Township 4 North, Range 23 East. Reaches with consistently low recession rates were located between the City of Racine and Wind Point. The Keillor-DeGroot study indicated that 21 analysis reaches, or 21 percent of the total, apparently exhibited accretion of the bluff over the study period. These apparent accretion areas may represent areas of artifical fill or may indicate errors in the measurements.

The Commission recession rate measurements for the period of 1975 through 1980 ranged from 2.8 feet per year of accretion to 10.2 feet per year of recession, with a mean recession rate of 2.1 feet per year. For the period of 1963 through 1980, the recession rates ranged from 2.2 feet per year of accretion to 10.2 feet per year of recession with a mean recession rate of 1.5 feet per year. Similar to the Keillor-DeGroot results, the highest recession rates measured by the Commission occurred in Section 6 of the Town of Caledonia, Township 4 North, Range 23 East.

The Commission results are generally consistent with the Keillor-DeGroot measured rates. The values derived in the two studies are similar throughout the coast, except in Township 4 North, Range 23 East, Section 6, where the Keillor-DeGroot rates are somewhat higher than those of the Commission. This is to be expected since Section 6 exhibits the most severe bluff erosion, and the high exposed bluffs located in that section would be the most susceptible to the increased wave attack generated during the high lake level period which occurred during the Keillor-DeGroot study.

A summary of measured recession rates and associated shoreline lengths and the volume of material loss to erosion is shown in Table 11. None of the Schneider recession rates were less than 0.5 foot per year; however, about 44 percent of shoreline as measured by Keillor-DeGroot, about 34 percent of the shoreline as measured by the Commission from 1975 through 1980, and about 38 percent of the shoreline as measured by the Commission from 1963 through 1980 had either accretion or recession rates equal to or less than 0.5 foot per year. On the other hand, about 48 percent of the shoreline as measured by Schneider on a short-term basis exhibited a recession rate exceeding 5.0 feet per year. None of the Schneider long-term rates, and only about 12 percent of the shoreline measured by Keillor-DeGroot, 9 percent of the shoreline measured by the Commission for 1975 through 1980, and 6 percent of the shoreline measured by the Commission for 1963 through 1980 exceeded 5.0 feet per year. It should be noted that according to Keillor-DeGroot, although only 12 percent of the shoreline exhibits a recession rate exceeding 5.0 feet per year, that 12 percent of the shoreline accounts for about 69 percent of the total bluff material loss in the County.

These significant levels of bluff recession pose serious problems for both developed and undeveloped portions of the Racine County coastline. Some of the most severe erosion hazards in the coastal area are highlighted below:

1. Lake Park Neighborhood--Town of Mt. Pleasant: Bluff erosion poses a threat to public and private property in the Lake Park neighborhood in the Town of Mt. Pleasant, including several residences; a town park and associated fire station; and street ends, including Larson Street, Kenil-

Table 11

SUMMARY OF BLUFF RECESSION RATES AND VOLUME OF MATERIAL LOSS ALONG THE RACINE COUNTY LAKE MICHIGAN SHORELINE

Recession Rate (feet per year)	Shoreline Extent					
	Schneider, et al. Short-Term (10-15 years)[a]		Schneider, et al. Long-Term (110 years)[a]		Keillor and DeGroot (1968-1971 to 1975)	
	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total
Accretion	--	--	--	--	12,450	21.4
0.0 - 0.50	--	--	--	--	12,820	22.1
0.51 - 2.00	2,580	4.5	40,680	70.0	17,060	29.3
2.01 - 5.00	27,870	47.9	17,470	30.0	8,720	15.0
5.01 - 15.00	27,700	47.6	--	--	7,100	12.2
Total	58,150	100.0	58,150	100.0	58,150	100.0

Recession Rate (feet per year)	SEWRPC (1975 to 1980)		SEWRPC (1963 to 1980)		Annual Volume of Bluff Material Loss[b]	
	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	Cubic Feet Per Year	Percent of Total
Accretion	11,210	19.3	6,550	11.3	--	--
0.0 - 0.50	8,320	14.3	15,460	26.6	72,400	1.1
0.51 - 2.00	21,980	37.8	20,390	35.0	590,300	8.9
2.01 - 5.00	11,300	19.4	12,330	21.2	1,384,900	21.0
5.01 - 15.00	5,340	9.2	3,420	5.9	4,546,000	69.0
Total	58,150	100.0	58,150	100.0	6,593,600	100.0

[a] It should be noted that the Schneider, et al. recession rates shown exclude the portion of the City of Racine and the northernmost 1,300 feet of the Town of Caledonia shoreline, which were not measured in the other studies.

[b] As estimated by Keillor and DeGroot (1978).

Source: SEWRPC.

worth Avenue, Graceland Avenue, Rosalind Avenue, Bryn Mawr Avenue, and Derby Avenue. The Town has had difficulty funding the improvements required to stabilize this area.

2. City of Racine: Two reaches have been identified as particularly subject to shoreline erosion in the City of Racine. One is the coastal reach reach between William Street and Augusta Street, north of the City of Racine Zoo. The City has applied for U. S. Army Corps of Engineers assistance in installing shoreline protection measures along this reach. The second is a reach extending from 14th Street to a point south of 16th Street--the erosion problems here being associated with a gap in the harbor breakwater to the east. Erosion problems in this area are presently under study by the City. The installation of shore protection structures here is contingent upon city acquisition of riparian rights associated with private property immediately south of 16th Street.

3. Town of Caledonia: As previously indicated, the highest recession rates in Racine County in the recent past have been observed in Section 6 of the Town of Caledonia. The Town's shoreland area includes the Town of Caledonia Lake Michigan Park, the Crestview subdivision, Cliffside County Park, the National Guard target range, and private open space land. With respect to property damage, the most imminent problem is the threat posed by the bluff recessing to Lakeshore Drive, to associated utility lines, and, ultimately, to residences within the Crestview subdivision. Bluff recession, if not controlled, would also decrease the area of Cliffside Park and erode the undeveloped open space lands to the north of Cliffside Park. Other significant areas of bluff recession exist; for instance, the road end of Five and One-Half Mile Road is severely eroded.

   The severity of the problem in the northern part of the Town of Caledonia has been attributed to a variety of interrelated factors. The most important factors, not necessarily in the order of importance, are the following:

   a. high lake level;

   b. narrow beaches, which are a direct consequence of a high lake level;

   c. absence of shore protection structures, such as groins, revetments, and seawalls;

   d. constant, or at least repeated, attack on the toe of the bluff by waves, due to both narrow beaches and the general absence of protective structures;

   e. northwest/southeast orientation of the coast and its general concavity to the northeast, which makes it particularly vulnerable to the ravages of winter storm waves from the northeast;

   f. steep and high bluffs, which are susceptible to rapid failure by debris fall and debris slide when undercut by wave action at the toe;

g. high content of fine-grain constituents (silt and clay) in the bluff sediments, which when wet are susceptible to failure by slump and flow processes;

h. presence of coarser-grained and more permeable layers in the bluff sediments, through which water can move laterally and emerge at the bluff face in the form of seeps; and

i. location of the reach (especially the northern portion) just to the south of the Wisconsin Electric Power Company--Oak Creek power plant and its massive groin-like structure that interrupts the north-south longshore current, thereby trapping littoral material to the north and resulting in sediment starvation of the beach area to the south.

SUMMARY

This chapter presents an inventory of certain elements of the natural resource base relevant to coastal erosion, summarizes existing land use and zoning patterns, and sets forth information specific to coastal erosion in Racine County. This information is necessary for the delineation of high-risk erosion areas and for the development of land use regulations based on predicted future coastal erosion rates.

Natural resource data on geology, soils, bluff and beach characteristics, surface water resources, groundwater resources, and climate are presented. The Racine County shoreline is underlain by Precambrian, Cambrian, Ordovician, and Silurian bedrock comprised primarily of dolomite, shale, sandstone, and crystalline rock. The bedrock is covered by unconsolidated glacial deposits which range up to 300 feet in thickness. Glacial till--deposited by glacial ice--is one of the predominant materials comprising the eroding bluff faces along the county's Lake Michigan shoreline.

Soil properties influence the rate of storm water runoff and the severity of surface erosion. About 28 percent of the coastal erosion study area is covered by well-drained or moderately drained soils which generate relatively small amounts of runoff. About 55 percent of the study area is covered by poorly drained soils and the remaining 17 percent of the area is covered by man-made features.

Bluff heights along the shoreline range up to more than 80 feet. Over one half of the shoreline has bluffs ranging from 20 through 40 feet in height. Slightly under 10 percent of the shoreline has bluffs less than 10 feet in height. The most common bluff composition material is till, which is present in about 57 percent of the bluffs surveyed. Other common bluff materials are silt and clay, sand, and gravel. About 65 percent of the bluff faces were at least partially covered or inaccessible.

The most common beach materials are sand and gravel, cobbles, and pebbles. The most extensive beaches, exceeding 75 feet in width, are comprised of sand. About 22 percent of the shoreline has a beach width ranging from one through 10 feet; about 25 percent of the shoreline has a beach width ranging from 11 through 30 feet; about 15 percent of the shoreline has a beach width

ranging from 31 through 75 feet; and about 6 percent of the shoreline has a beach greater than 75 feet wide. About 32 percent of the shoreline has no defined beach.

The Lake Michigan shoreline extends 14.8 miles in length within Racine County. The coastal erosion study area contains 1.6 miles of perennial streams and 5.1 miles of intermittent streams. Bluff erosion along the Racine County coast contributes nearly eight times as much sediment to the Lake as is transported by the Root River at the City of Racine.

Along the Racine County shoreline, groundwater generally flows towards Lake Michigan. Three major aquifers underlie the coastal area; the deep sandstone aquifer, the Niagara dolomite aquifer, and the shallow sand and gravel aquifer. Numerous groundwater discharges and seepages occur from the bluff slopes, contributing to the instability of these slopes.

Climate impacts on coastal erosion include freeze-thaw actions within bluff material, high surface runoff from frozen soils, lake ice effects, and high surface runoff and soil erosion during intense storm events. Frozen ground and snow cover is expected throughout approximately four months each winter season. About 13 percent of the annual precipitation occurs as snowfall and sleet. Lake ice formation begins in late November or December and ice breakup normally occurs in late March or early April.

The study area encompasses a total of 2,552 acres, of which about 1,429 acres, or 56 percent, was devoted to urban land uses in 1980. About half of the urban land area was in residential use.

Zoning ordinances are important land use regulations which are presently in effect in the City of Racine, the Villages of North Bay and Wind Point, and the Town of Mt. Pleasant. The Town of Caledonia has adopted the Racine County zoning ordinance. About 91 percent of the coastal erosion study area has been placed in zoning districts which permit intensive urban development. Such districts cover 13.6 linear miles, or 95 percent of the total Lake Michigan shoreline in Racine County.

Shoreland development and activities are regulated by federal, state, and local agencies and units of government. The U. S. Army, Corps of Engineers is the primary federal agency responsible for certain structures, dredging, and wetland protection. The Wisconsin Department of Natural Resources regulates various shoreland activities, including shore protection structures. A county shoreland zoning ordinance requires county review and approval of virtually all man-made alterations within a specified distance from the shore. Local zoning ordinances regulate land uses within the shoreland area, but are generally devoid of provisions pertaining to Lake Michigan shoreline erosion hazards.

An inventory of shore protection structures indicated that a variety of structures, including bulkheads, revetments, breakwaters, and groins, have been installed along the Racine County coast to provide an artificial protective barrier against direct wave and ice damage, to increase the extent of the beach, to dissipate offshore wave energy, and to stabilize bluff slopes. However, these costly measures, installed by both private shoreline property owners and by public agencies, have had varying degrees of success. An inventory of 216 shore protection structures indicated that, while most structures

were effective and functional, nearly 75 percent of the structures exhibited some type of failure. About 30 percent of the structures were failing overall or were nonfunctional. Causes of failure include overtopping, where the water level, or waves exceeded the top of the structure; flanking, where the sides of the structure were eroded; collapsing; and faulty design and selection of materials.

Bluff erosion may occur as toe erosion, slumping, sliding, flow, surface erosion, and solifluction. Slope failure is often an unpredictable, abrupt process which is constantly being altered by numerous factors. Factors affecting bluff erosion include the physical characteristics of the bluff and beach, wave action at the bluff toe, lake level fluctuations, ice formation, groundwater seepage, surface runoff, and vegetative cover.

The most important Lake Michigan coastal erosion problem in Racine County is recession of the bluffs. Bluff recession threatens human safety, private residences, commercial buildings, streets, parkland, and open natural areas. The rate of bluff recession has been documented in several previous studies. In particular, studies by Schneider, et al., and Keillor-DeGroot have presented detailed bluff recession rates. In order to verify and update the previously measured bluff recession rates, the Regional Planning Commission measured bluff recession rates at the specific Keillor-DeGroot measurements sites for the period of 1975 through 1980--which was generally after the Keillor-DeGroot study period--and for the period of 1963 through 1980--which included the Keillor-DeGroot study period. These updated bluff recession measurement results by the Commission were similar to, and verified, the Keillor-DeGroot results.

During the period of 1963 through 1980, about 38 percent of the Racine County shoreline, as measured by the Commission, had either accretion or recession rates equal to or less than 0.5 foot per year. About 6 percent of the shoreline exceeded 5.0 feet per year in bluff recession. The highest recession rate measured by the Commission during the period of 1963 through 1980 was 10.2 feet per year, which occurred in the Town of Caledonia, Township 4 North, Range 23 East, Section 6. The mean recession rate was 1.5 feet per year. Significant bluff recession problems within the Lake Park neighborhood, Town of Mt. Pleasant, the City of Racine, and the Town of Caledonia are described in this chapter.

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Chapter IV

EVALUATION OF COASTAL EROSION

INTRODUCTION

Shoreline erosion and bluff recession along Lake Michigan is a natural phenomenon which is causing substantial loss of shoreland area in portions of Racine County. The identification of the shoreland areas which are expected to continue to be affected by shoreline erosion and bluff recession is an important basis for any public information and public land use regulatory measures designed to properly relate urban development and redevelopment along the shoreline to anticipated shoreline erosion and bluff recession. Increased public awareness, land use controls, and structural erosion control measures comprise the essential elements of any comprehensive coastal erosion management program. The purpose of this chapter is to describe the extent of shoreline erosion and bluff recession which may be expected to occur over time along the Lake Michigan shoreline of Racine County, to identify erosion risk distances and setback distances related to these erosion risks, and to identify the potential property losses which may result from continued shoreline erosion and bluff recession. The identification of areas subject to a risk of erosion damage is intended to provide information which will enable public officials and private property owners to better assess potential erosion losses and agree upon the management measures recommended in Chapter V of this report.

The first section of this chapter following the introduction describes the analytic procedures and criteria used for identifying and mapping the erosion risk distances and for calculating setback distances. The second section describes the erosion risk distances as identified under alternative time periods for that reach of shoreline which is not recommended to be protected by structural shore protection measures. The third section describes the erosion risk distances for that reach of shoreline which is recommended to be protected by structural shore protection measures. A fourth and final section summarizes the chapter.

ANALYTIC PROCEDURES AND CRITERIA

The delineation of areas with a high risk of erosion involves the prediction--based on analyses of existing and historic conditions and of the pertinent physical characteristics of the shoreline set forth in Chapter III--of future bluff recession rates under both nonstructural and structural shoreland protection measures. The estimated future bluff recession rates were based on the assumption that recession will continue at the same rate as it has historically occurred. High erosion risk areas are delineated by determining the distance from the existing bluff edge which would be affected by recession of the bluff over time, and by the regrading of the bluff slope as required to achieve a stable slope. This distance is referred to herein as the erosion risk distance. The basic information used in the preparation of maps showing the erosion risk distances includes the Racine County cadastre file, the bluff recession rates developed by the Regional Planning Commission from historic data for the period of 1963 through 1980, and the shoreland development stan-

dards developed by the Racine County Technical Subcommittee on Shoreland Development Standards. The bluff recession rates were verified by comparing predicted erosion problem areas to observations reported under the Racine County Coastwatch Program.

The distance required for regrading of the bluff to achieve a stable slope is included in the erosion risk distance for two reasons. First, the stable slope distance serves as a safety factor. It cannot be assumed that the bluff face will remain at its existing slope, and the potential exists for the bluff slope to rapidly, and sometimes catastrophically, recede to a stable slope. The danger of severe damages resulting from this occurrence will increase in future years as the bluff edge recedes closer to the house or facility. Second, the stable slope distance allows the property owner, at some future date, the opportunity to properly construct an adequate shore protection structure, which would include bluff slope stabilization.

Setback distances from the existing bluff edge were identified under both assumed nonstructural and structural management alternatives using methods developed under the study to calculate desirable setback requirements. Setback distances are comprised of the erosion risk distance, plus a minimum facility setback distance. Assumptions concerning the type of management measures to be applied to each reach of shoreline were based on the collective judgment of the Technical Subcommittee on Shoreland Development Standards. The Subcommittee concluded that for the reach of the Racine County shoreline lying north of the southern boundary of Cliffside Park, structural control measures are generally not warranted, and, in most cases, only nonstructural control measures should be implemented. Accordingly, for this reach of shoreline the nonstructural setback distance applies, assuming only nonstructural measures would be implemented. For that reach of the County shoreline lying from the southern boundary of Cliffside Park to the southern boundary of Racine County, the Subcommittee concluded that structural control measures should be considered. Accordingly, the structural setback distance applies for the reach of shoreline located from the southern boundary of Cliffside Park to the southern boundary of the County. One shoreline area was treated as an exception to these general reach assumptions. Structural erosion control measures were found to be appropriate for the extreme northern shoreline of the Town of Caledonia, which is covered by fly ash deposits and protected by a bulkhead. Hence, the structural setback distance applies to this shoreline area.

Nonstructural Erosion Risk Distances and Setback Distances

A procedure was developed for delineating the erosion risk distances from the bluff edge assuming the use of nonstructural erosion control measures only. Nonstructural erosion risk distances are comprised of a bluff recession distance over a given time period, plus the distance required to grade the bluff face to a stable slope. Erosion risk distances were delineated for a 25-year and for a 50-year period of continued bluff recession along the entire shoreline within the County, with two exceptions. Those two exceptions include 1) the shoreline within the City of Racine where major structural shore protection measures are in place; and 2) the northern-most reach of the Town of Caledonia, which is covered by fly ash deposits. The bluff recession rates used for the delineation of erosion risk distances were calculated at 101 sites for the period from 1963 through 1980. The 101 sites are the same as those used by

Keillor-DeGroot.[1] The bluff recession rates so calculated were compared for consistency to the rates calculated for the period from 1968 through 1975 by Keillor-DeGroot. The comparative data are provided in Chapter III of this report. During the 1963 through 1980 period, the elevation of Lake Michigan ranged from record lows to near record highs, thus providing a full range of lake level conditions. The face of the bluffs was assumed to be graded to a stable slope of approximately one on two and one half, or about 22°. This assumption concerning the bluff slope is discussed further below.

Nonstructural setback distances are established as the sum of the nonstructural erosion risk distances and a minimum building or facility setback distance. These minimum setback distances are to be determined by local governmental units within their area of jurisdiction to provide a safety factor, for aesthetics, to allow for installation of surface water and groundwater drainage systems at some future date, and to prevent the location of major facilities too close to the bluff edge, which would increase the shear stress on the bluff slope. Although, for informational purposes, the nonstructural erosion risk distances are mapped for almost the entire county shoreline, the nonstructural setback distances apply only to the county shoreline area located north of the southern boundary of Cliffside Park in the Town of Caledonia. The concepts utilized in the estimation of nonstructural erosion risk distances and attendant facility setback distances are illustrated in Figure 5.

Structural Erosion Risk Distances and Setback Distances

A procedure was also developed for delineating the erosion risk distances from the bluff edge assuming the use of structural shore protection measures. In the reaches assumed to be provided with structural protection measures, the rate of bluff recession was assumed to be zero once the structural measures were in place, the bluff toe protected, and the bluff slope stabilized. A structural erosion risk distance was defined as that distance required to form a stable bluff slope of one on two and one half, or about 22°.

A structural setback distance was established as the sum of the structural erosion risk distance and a minimum facility setback distance. Again, the minimum facility setback distances are to be determined by the local units of government concerned. The structural setback distances apply to those reaches of shoreline located from the southern boundary of Cliffside Park to the southern boundary of the County, including the existing protected shoreline of the City of Racine, and the extreme northern shoreline of the Town of Caledonia--which is covered by fly ash deposits. The procedure utilized to estimate structural erosion risk distances and setback distances is shown in Figure 6.

Stable Slope Angles

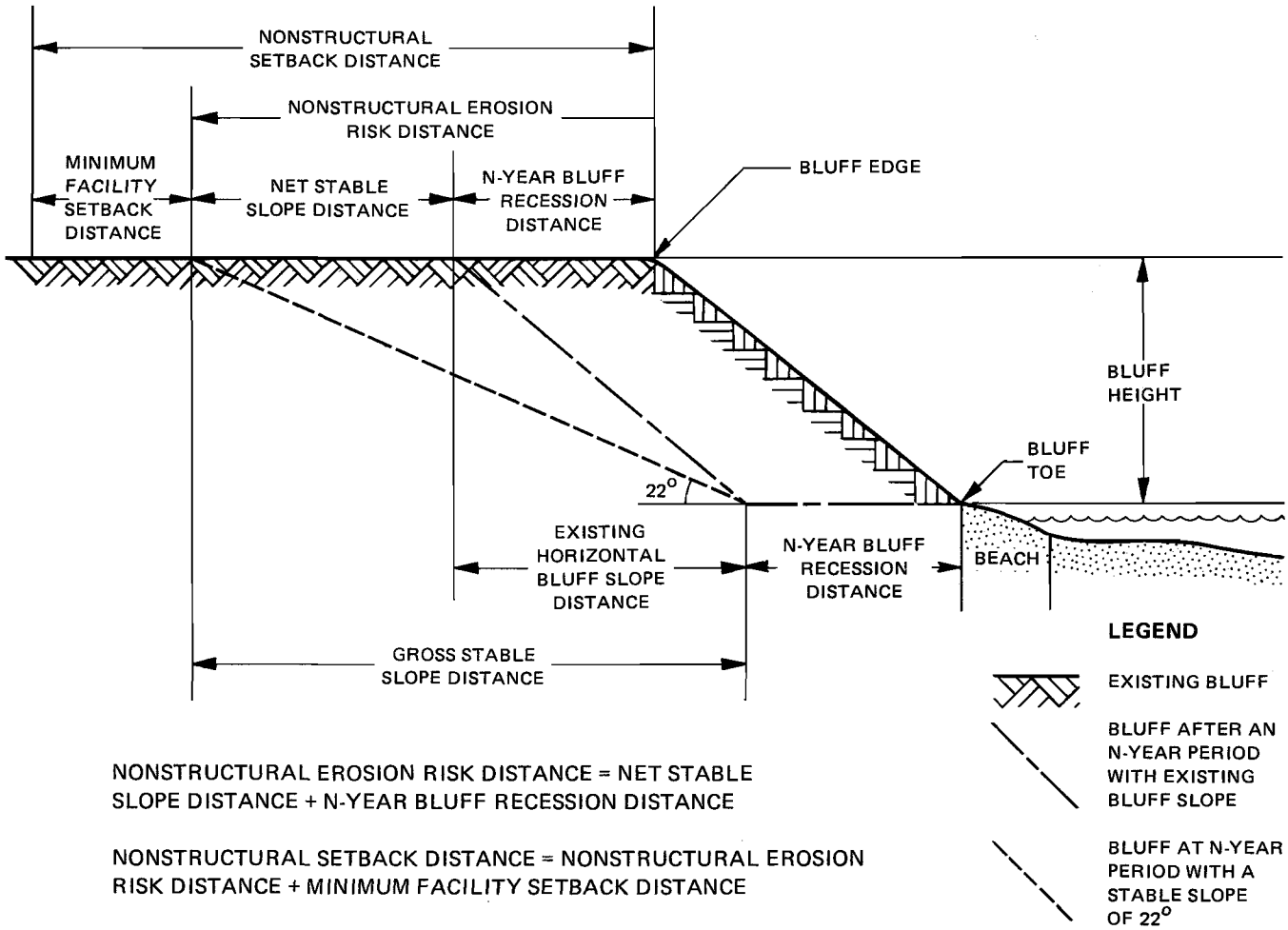
The use of an ultimate stable bluff slope of one on two and one half was recommended by the County Technical Subcommittee on Shoreland Development Standards.[2] This slope was similar to stable slopes along the Lake Michigan

[1]J. P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, and Volume 2, Appendix, 1978.

[2]Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards for the Racine County Land Use Committee, 1982.

Figure 5

PROCEDURE UTILIZED TO ESTIMATE NONSTRUCTURAL EROSION RISK DISTANCE AND NONSTRUCTURAL SETBACK DISTANCE



NONSTRUCTURAL EROSION RISK DISTANCE = NET STABLE SLOPE DISTANCE + N-YEAR BLUFF RECESSION DISTANCE

NONSTRUCTURAL SETBACK DISTANCE = NONSTRUCTURAL EROSION RISK DISTANCE + MINIMUM FACILITY SETBACK DISTANCE

WHERE: NET STABLE SLOPE DISTANCE = GROSS STABLE SLOPE DISTANCE - EXISTING HORIZONTAL BLUFF SLOPE DISTANCE

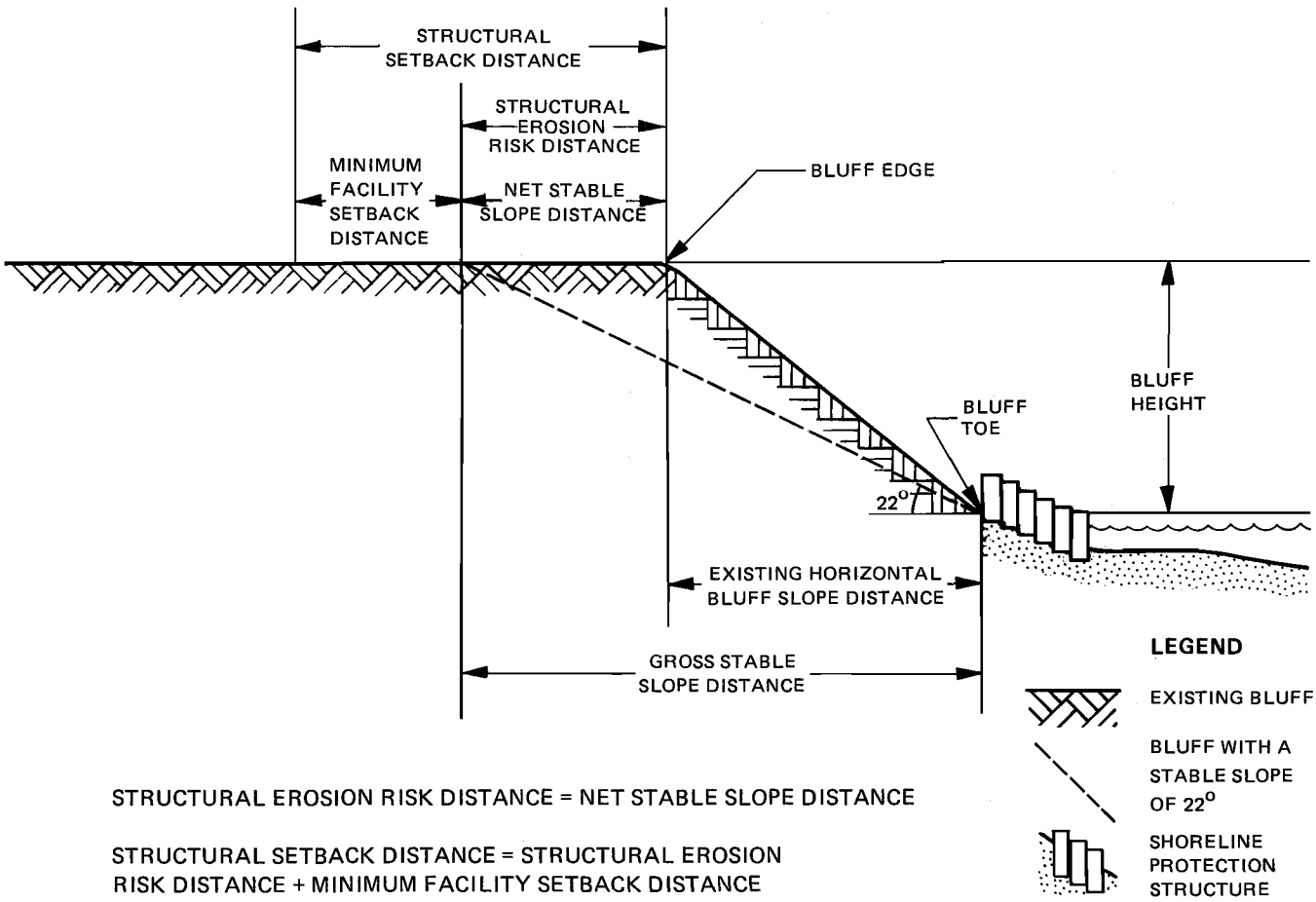
$$\text{GROSS STABLE SLOPE DISTANCE} = \frac{\text{BLUFF HEIGHT}}{\text{TAN } 22^{\circ}} = \frac{\text{BLUFF HEIGHT}}{0.4}$$

MINIMUM FACILITY SETBACK DISTANCE: TO BE DETERMINED BY LOCAL GOVERNMENTAL UNITS WITHIN THEIR AREA OF JURISDICTION TO PROVIDE A SAFETY FACTOR, FOR AESTHETICS, AND FOR PROVISION OF FUTURE SURFACE WATER AND GROUNDWATER DRAINAGE SYSTEMS

Source: SEWRPC.

Figure 6

PROCEDURE UTILIZED TO ESTIMATE STRUCTURAL EROSION RISK DISTANCE AND STRUCTURAL SETBACK DISTANCE



STRUCTURAL EROSION RISK DISTANCE = NET STABLE SLOPE DISTANCE

STRUCTURAL SETBACK DISTANCE = STRUCTURAL EROSION RISK DISTANCE + MINIMUM FACILITY SETBACK DISTANCE

WHERE: NET STABLE SLOPE DISTANCE = GROSS STABLE SLOPE DISTANCE - EXISTING HORIZONTAL BLUFF SLOPE DISTANCE

$$\text{GROSS STABLE SLOPE DISTANCE} = \frac{\text{BLUFF HEIGHT}}{\text{TAN } 22^{\circ}} = \frac{\text{BLUFF HEIGHT}}{0.4}$$

MINIMUM FACILITY SETBACK DISTANCE: TO BE DETERMINED BY LOCAL GOVERNMENTAL UNITS WITHIN THEIR AREA OF JURISDICTION TO PROVIDE A SAFETY FACTOR, FOR AESTHETICS, AND FOR PROVISION OF FUTURE SURFACE WATER AND GROUNDWATER DRAINAGE SYSTEMS

Source: SEWRPC.

bluffs reported by Edil and Vallejo.[3] Another report by Vallejo[4] and Edil noted that, given certain physical soil characteristics, the ultimate stable slope may be expected to vary in relation to the height of the groundwater level--measured from the base of the bluff--to the height of the bluff. For the Racine County shoreline, the ultimate stable slopes may be expected to range from a minimum of 16°, if the height of the groundwater is three fourths or more of the height of the bluff, to a minimum of 30°, if no groundwater is contained within the bluff. This information could be used to develop differing stable slopes along the shoreline. However, this refinement in the calculation of stable slopes for specific reaches of the shoreline was not applied in this study because:

1. Groundwater levels, and specifically seepage zones, are highly variable on a seasonal and annual basis.

2. Surveys of groundwater seepage zones have been conducted at only a few relatively select sites along the county coast.

3. Within the Racine County shoreline, the overall phreatic surface of the groundwater is beneath the bluffs. Within the bluffs, only localized seepage zones, or seasonally high groundwater levels exist. Thus, different stable slopes would exist for different portions of the same bluff.

4. Groundwater conditions can change significantly as the bluff recedes and strata of permeable bluff materials are eroded, covered, or disturbed.

Therefore, a stable slope angle of one on two and one-half, or approximately 22°, is used in this study for the coastal reaches evaluated. This stable slope angle represents the approximate average of stable slopes expected under a full range of groundwater conditions.

EROSION RISK DISTANCES CONSIDERING NONSTRUCTURAL SHORE PROTECTION MEASURES

The delineation of the nonstructural erosion risk distances identifies the shoreland areas of Racine County that may be expected to be affected by shoreline erosion and bluff recession over time, where proper shore protection structures are not implemented. With the use of the county cadastre file and attendant cadastral maps, erosion risk distances can be determined for individual parcels of land.

Table 12 indicates, for each coastal erosion analysis reach, the distance the top of the bluff may be expected to recede over a 25-year and 50-year period. These distances were determined by multiplying the average annual recession rates established for the period from 1963 through 1980 by the period of recession being evaluated. The table also indicates the gross stable slope dis-

[3]T. B. Edil and L. E. Vallejo, "Mechanics of Coastal Landslides and the Influence of Slope Parameters," Engineering Geology, Volume 16, 1980. pp. 83-96.

[4]L. E. Vallejo and T. B. Edil, "Design Charts for Development and Stability of Evolving Slopes," Journal of Civil Engineering Design, Volume 1, No. 3, 1979, pp. 231-252.

Table 12

NONSTRUCTURAL EROSION RISK DISTANCES FOR THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY

Coastal Erosion Analysis Reach	Estimated Bluff Recession Distance[a] (feet)		Bluff Height (feet)	Gross Horizontal Stable Slope Distance[b] (feet)	Existing Horizontal Slope Distance (feet)	Net Horizontal Stable Slope Distance[c] (feet)	Nonstructural Erosion Risk Distance[d] (feet)	
	25-Year	50-Year					25-Year	50-Year
6:41	112	225	60	150	95	55	167	280
6:39	50	100	72	180	88	92	142	192
6:37	142	285	80	200	35	165	307	450
6:35	70	140	80	200	60	140	210	280
6:33	90	180	70	175	60	115	205	295
6:31	188	375	80	200	90	110	298	485
6:29	180	360	100	250	110	140	320	500
6:23	210	420	82	205	106	99	309	519
6:20	255	510	80	200	80	120	375	630
6:15	208	415	72	180	110	70	278	485
6:10	245	490	68	170	75	95	340	585
6:05	110	220	66	165	90	75	185	295
6:00	80	160	62	155	58	97	177	257
8:40	102	205	60	150	70	80	182	285
8:35	70	140	60	150	90	60	130	200
8:30	65	130	62	155	68	87	152	217
8:27	45	90	66	140	50	90	135	180
8:20	52	105	66	165	70	95	147	200
8:15	48	95	54	135	57	78	126	173
8:10	20	40	46	115	87	28	48	68
8:05	15	30	40	100	60	40	55	70
8:00	18	35	40	100	50	50	68	85
17:50	8	15	40	100	55	45	53	60
17:45	0	0	38	95	80	15	15	15
17:40	12	25	30	75	60	15	27	40
17:35	10	20	40	100	60	40	50	60
16:27	55	110	38	95	40	55	110	165
16:25	48	95	38	95	45	50	98	145
16:20	32	65	38	95	45	50	82	115
16:15	25	50	34	85	33	52	77	102
16:10	78	155	32	80	38	42	120	197
16:05	40	80	20	50	40	10	50	90
16:00	15	30	20	50	32	18	33	48
21:50	28	55	34	85	35	50	78	105
21:45	15	30	12	30	30	0	15	30
21:40	10	20	20	50	60	0	10	20
22:30	10	20	30	75	30	45	55	65
22:25	0	0	32	80	60	20	20	20
22:20	18	35	32	80	72	8	26	43
22:15	10	20	28	70	33	37	47	57
22:10	22	45	24	60	40	20	42	65
22:05	5	10	20	50	28	22	27	32
22:00	28	55	14	35	26	9	37	64
27:50	18	35	8	20	0	20	38	55
27:45	22	45	8	20	0	20	42	65
27:40	20	40	10	25	0	25	45	65
27:35	52	105	10	25	0	25	77	130
27:30	0	0	10	25	0	25	25	25
27:27	5	10	16	40	20	20	25	30
27:25	18	35	18	45	25	20	38	55
27:20	2	5	24	60	30	30	32	35
27:15	0	0	26	65	28	37	37	37
27:10	28	55	30	75	28	47	75	102
27:05	0	0	24	60	38	22	22	22
27:00	45	90	22	55	35	20	65	110
33:50	0	0	20	50	40	10	10	10
33:45	15	30	28	70	30	40	55	70
33:40	0	0	20	50	30	20	20	20
33:30	10	20	20	50	40	10	20	30

Table 12 (continued)

Coastal Erosion Analysis Reach	Estimated Bluff Recession Distance[a] (feet)		Bluff Height (feet)	Gross Horizontal Stable Slope Distance[b] (feet)	Existing Horizontal Slope Distance (feet)	Net Horizontal Stable Slope Distance[c] (feet)	Nonstructural Erosion Risk Distance[d] (feet)	
	25-Year	50-Year					25-Year	50-Year
33:27	0	0	28	70	45	25	25	25
33:25	42	85	30	75	38	37	79	122
33:20	20	40	28	70	58	12	32	52
33:15	20	40	30	75	28	47	67	87
33:10	0	0	30	75	40	35	35	35
33:05	18	35	32	80	37	43	61	78
33:00	5	10	34	85	28	57	62	67
4:50	0	0	34	85	30	55	55	55
4:45	0	0	38	95	30	65	65	65
4:40	0	0	30	75	60	15	15	15
4:35	0	0	38	95	60	35	35	35
4:30	0	0	42	105	61	44	44	44
4:27	0	0	42	105	50	55	55	55
4:25[e]	0	0	40	--	--	--	0	0
4:20[e]	0	0	38	--	--	--	0	0
4:15[e]	0	0	38	--	--	--	0	0
4:10[e]	0	0	40	--	--	--	0	0
4:05[e]	0	0	40	--	--	--	0	0
4:00[e]	0	0	40	--	--	--	0	0
9:50[e]	0	0	40	--	--	--	0	0
9:45[e]	0	0	40	--	--	--	0	0
28:15	80	160	40	100	35	65	145	225
28:20	72	145	40	100	55	45	117	190
28:24	38	75	40	100	30	70	108	145
28:27	28	55	40	100	38	62	90	117
28:29	15	30	40	100	38	62	77	92
28:34	0	0	40	100	60	40	40	40
29:15	38	75	40	100	25	75	113	150
29:10	18	35	40	100	27	73	91	108
29:05	32	65	40	100	55	45	77	110
32:50	82	165	34	85	40	45	127	210
32:45	40	80	38	95	45	50	90	130
32:40	50	100	34	85	43	42	92	142
32:35	55	110	32	80	45	35	90	145
32:30	55	110	30	75	40	35	90	145
32:27	10	20	34	85	40	45	55	65
32:25	10	20	30	75	35	40	50	60
32:20	12	25	30	75	35	40	52	65
32:15	0	0	30	75	25	50	50	50
32:10	88	175	30	75	35	40	128	215
32:05	68	135	38	95	40	55	123	190
32:00	72	145	38	95	45	50	122	195

[a] Calculated by multiplying the annual recession rates measured by the Regional Planning Commission for the period of 1963 through 1980 by either 25 years or 50 years.

[b] Calculated by dividing the bluff height by a factor of 0.4.

[c] The Net Horizontal Stable Slope Distance represents the additional horizontal distance required for the bluff to attain a stable slope angle. It is calculated by subtracting the Existing Horizontal Slope Distance from the Gross Horizontal Stable Slope Distance.

[d] The Nonstructural Erosion Risk Distance is calculated by the following formula:

Nonstructural Erosion Risk Distance = Net Stable Slope Distance + N-Year Bluff Recession Distance

[e] Slopes have been stabilized by engineering measures.

Source: SEWRPC.

tances, or the horizontal distances required to obtain a stable slope for the specified bluff heights, assuming a slope of one on two and one-half. Since most bluff slopes are not vertical, the existing horizontal distance of the bluff slope was subtracted from the gross horizontal stable slope distance to estimate the net stable slope distance--or the additional horizontal distance the top of the bluff would need to recede, or be regraded, to form a stable slope. In Table 12, the bluff recession distance--determined from historic measured rates of recession--and the net stable slope distance are added to establish the nonstructural erosion risk distance for a 25-year and 50-year period of time.

Areas within the nonstructural erosion risk distances from the existing bluff edge are shown on 1 inch = 400 feet scale topographic maps in Appendix E contained in the back of this report. The maps show the 25-year and 50-year erosion risk distances for the entire county shoreline except for the City of Racine shoreline where major structural shore protection measures are in place, and for the northern-most shoreline reach of the Town of Caledonia, which is covered by fly ash deposits and protected by a bulkhead. Thus, nonstructural erosion risk distances are also shown for the shoreline from the southern boundary of Cliffside Park to the southern boundary of the County for informational purposes, even though the structural setback distance would apply to this reach. The nonstructural erosion risk distances indicate the future bluff edge location if shore protection structures are not implemented. Real property boundaries, as described in the county cadastre file, are also shown on the maps. Finally, the coastal erosion analysis reaches are shown on the maps so that the user may determine the bluff recession rate used at any site, as well as the assumed bluff height.

The land area and number of existing facilities contained within the 25-year and 50-year nonstructural erosion risk distances as delineated in Appendix E are set forth in Table 13. The 25-year nonstructural erosion risk distance contains approximately 141 acres of land, or about 6 percent of the coastal erosion study area. One hundred and three buildings or facilities lie, in whole

Table 13

EXTENT AND ECONOMIC VALUE OF LAND AREA AND FACILITIES LYING WITHIN THE 25-YEAR AND 50-YEAR NONSTRUCTURAL EROSION RISK DISTANCES FROM THE LAKE MICHIGAN SHORELINE OF RACINE COUNTY: 1980 [a]

Nonstructural Erosion Risk Distance Period	Land				Facilities			Total Economic Value[b] (million dollars)
	Extent (acres)	Percent of Coastal Erosion Study Area	Economic Value[b] (million dollars)	Percent of Total Economic Value	Number	Economic Value[b] (million dollars)	Percent of Total Economic Value	
25-Year	141	6	2.9	31	103	6.4	69	9.3
50-Year	199	8	4.0	31	143	8.9	69	12.9

[a] Applies to the entire county shoreline except for the protected shoreline in the City of Racine, and the fly ash-covered reach in the Town of Caledonia.

[b] Economic values are in 1981 dollars.

Source: SEWRPC.

or in part, within the 25-year risk distance. About 199 acres of land, or about 8 percent of the study area, and 143 facilities lie, in whole or in part, within the 50-year erosion risk distance.

The potential economic losses resulting from continued bluff recession may be estimated by determining the market value of the land and facilities located within the nonstructural erosion risk area. The potential value of land and facilities which are expected to be lost due to bluff recession and to the formation of a stable bluff slope was based upon the values presented in the Racine County statistical report of property valuations for 1981.[5] It was assumed that the value of each land parcel or facility is equal to the average market value of similar land or facilities within each civil division.

These potential land values were then applied to the acreage that may be expected to be lost to shoreline erosion in the form of bluff recession and slope stabilization. The classification of a land parcel as developed or undeveloped is based on planned year 2000 land use patterns in the study area. The value of the facilities and related improvements affected by shoreline erosion was determined by applying the average market value of facilities within each civil division to the number of facilities located within the 25-year and 50-year nonstructural erosion risk distances.

The approximate value of the land and facilities contained within the 25-year and 50-year nonstructural erosion risk distances are also set forth in Table 13. These values apply to the entire county shoreline, except for the protected shoreline of the City of Racine, and the fly ash-covered reach in the Town of Caledonia. Within the 25-year erosion risk distance, the total economic value of land and facilities is approximately $9.3 million, of which about $2.9 million, or 31 percent represents the value of the land, and about $6.4 million, or 69 percent, represents the value of the facilities or improvements. The 50-year erosion risk distance has an approximate land and facility economic value of about $12.9 million, of which $4.0 million, or 31 percent, represents the land value and about $8.9 million, or 69 percent, the facility value. The economic values presented above do not include the value of public utilities and improvements such as streets and sewers.

EROSION RISK DISTANCES CONSIDERING STRUCTURAL SHORE PROTECTION MEASURES

The erosion risk distance for those shoreline reaches currently protected by adequate shore protection structures, and for those reaches within which the provision of new shore protection structures is recommended to be considered, was defined as the distance from the existing bluff edge needed to establish a stable slope. The structural erosion risk distances are used to calculate structural setback distances, which apply to the county shoreline located south of the southern boundary of Cliffside Park, and also the northernmost reach of shoreline in the Town of Caledonia, which is covered by fly ash deposits and protected by a bulkhead.

[5]Robert E. Wood, 1981 Statistical Report of Property Valuations, Racine County, Wisconsin, Southeast District--Bureau of Property Tax, Wisconsin Department of Revenue, 1981.

The maintenance of existing development within the nonstructural erosion risk distances may require the provision of structural shore protection measures, or facility relocation to prevent or delay the potential loss of such development to bluff recession. Studies have indicated that the majority of structural shore protection measures installed to prevent Lake Michigan erosion have been at least partially unsuccessful[6] (see Appendix A). Structural measures that are known to be effective require a substantial capital investment and entail a substantial maintenance cost. Proper consideration of structural alternatives and relocation requires detailed, site-specific, evaluations of the physical characteristics of the bluff and beach, the causes of erosion, the intended use of the shoreline, the degree of hazard posed by erosion, the existing investment or value of the property, and the resources which can be committed to the undertaking. In addition, the selection of structural protection measures must consider the initial cost of the structure, the availability of needed materials and expertise, and the frequency, cost, and convenience of maintenance. A description of different types of structural shore protection measures was provided in Chapter III. Appendix A presents an inventory of existing shore protection structures located along the Lake Michigan shoreline of Racine County.

The Racine County Technical Subcommittee on Shoreland Development Standards concluded that effective shore protection requires a combination of bluff stabilization, surface water and subsurface water control, and bluff toe protection. The Subcommittee concluded that a building within a high-risk area should be considered for relocation if the building can be moved by conventional methods at a cost equal to, or less than, 30 percent of the value of an equivalent building located on secure ground.[7]

The Subcommittee recommended that structural shore protection measures should be provided if it can be shown that such measures will effectively reduce shoreline erosion and not adversely affect adjacent sections of the shoreline or impair public rights in navigable waters; that there will be no significant reduction in public access, use, and enjoyment of the shoreline environment; and that any adverse impacts on fish and wildlife resources caused by the structure will be compensated for by providing fish and wildlife preservation measures. It was recommended that, south of Cliffside Park, such shore protection structures should be required to protect new facilities within the 50-year nonstructural erosion risk distance which are not readily relocatable. The Subcommittee recommended that all shore protection structures should meet a set of minimum criteria and be based on sound engineering design. The criteria recommended by the Subcommittee are presented in Table 14.

The maps contained in Appendix E show the reaches of shoreline which, based on a field survey conducted by the Regional Planning Commission staff in October 1982, were observed to be adequately protected by shore protection structures based upon the degree of bluff toe protection provided. The long-term stability

[6]Coastal Zone Laboratory, University of Michigan, Engineering-Economic Analysis of Shore Protection Systems: A Benefit/Cost Model, May 1976.

[7]Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee Shoreland Development Standards for the Racine County Land Use Committee, 1982.

Table 14

MINIMUM CRITERIA FOR SHORE PROTECTION STRUCTURES ADAPTED FROM CRITERIA RECOMMENDED BY THE RACINE COUNTY TECHNICAL SUBCOMMITTEE ON SHORELAND DEVELOPMENT STANDARDS[a]

Category	Criteria Required to be Met
Support Information	1. Determine lake bottom profiles offshore of proposed structure and 300 feet on both sides of the structure, from the structure out to a water depth of at least 12 feet 2. Identify existing and planned septic tank systems on the property to be protected and on adjacent properties, and consider the impact of the systems on bluff stability 3. Consider design wave height, wave direction, and the erosive impacts of wave action on the proposed structure
Structural Design	1. Size the structure for design waves expected for a 50-year recurrence interval high lake level, or 583.6 feet above the National Geodetic Vertical Datum 2. Provide measures to protect the base of the structure against wave scouring 3. Design loose rubble revetment structures with a slope no greater than one vertical on two horizontal 4. Avoid structural damage or erosion on the landward side of the structure by preventing the overtopping of the structure by storm waves, or by providing for the positive drainage of any water which overtops the structure 5. Provide measures to prevent excessive erosion along the flanks of the structure 6. Provide adequate bedding materials to prevent undercutting of the structure
Bluff Stabilization	1. Regrade the bluff to a one on two and one half slope; unless detailed site-specific engineering analyses indicate that a different slope would be stable 2. If the groundwater level is occasionally higher than the lake level and threatens bluff stability, provide subsurface drainage facilities to intercept the groundwater, if necessary 3. If necessary, provide for interception drainage of surface water runoff to prevent surface erosion and saturation of the soils in the bluff 4. Provide adequate vegetative cover of the bluff slope after regrading

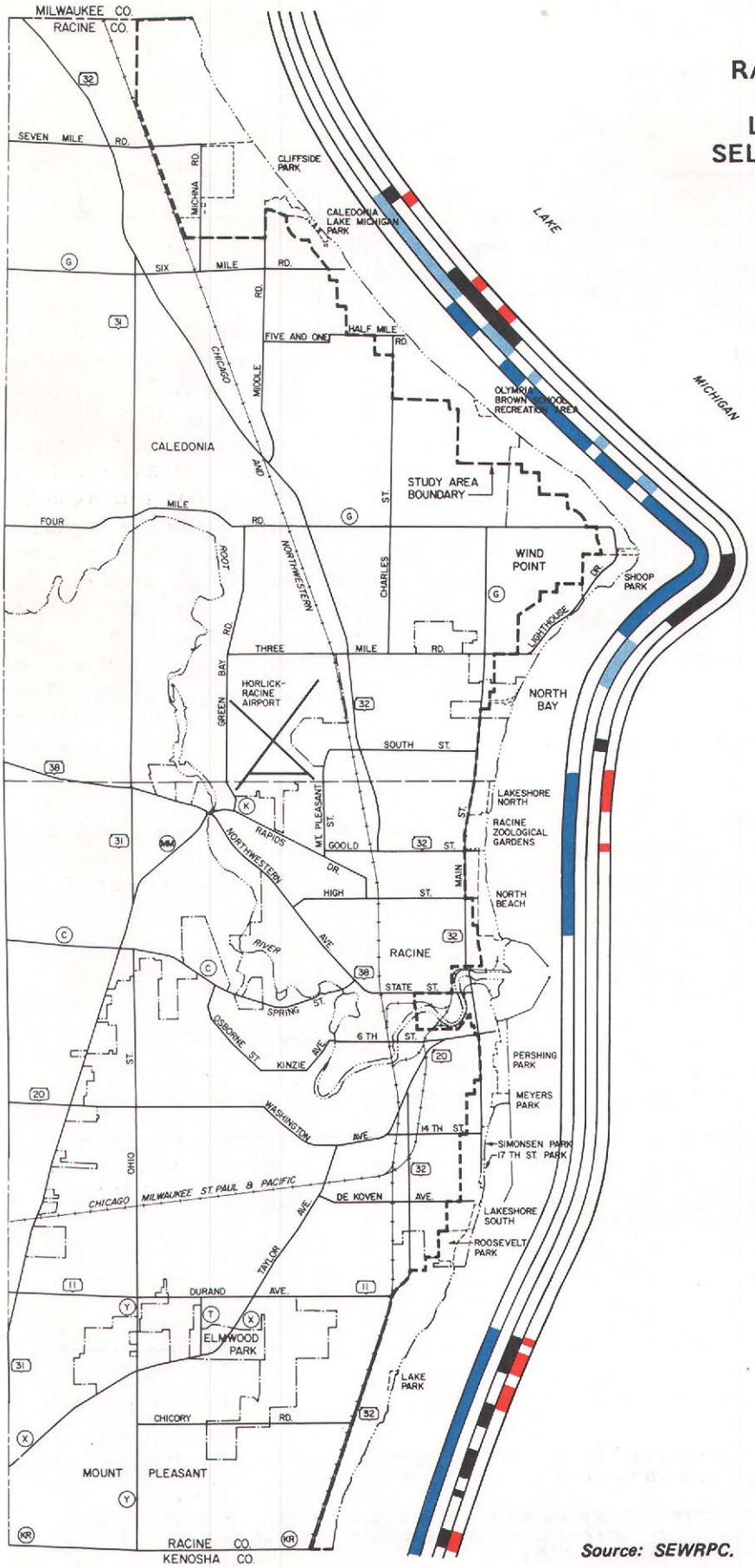
[a]See Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards for the Racine County Land Use Committee, 1982.

Source: SEWRPC.

of the bluff slope and the adequacy of surface and subsurface drainage were generally not surveyed. In addition, the effectiveness of shore protection structures can be maintained only if proper structure repair and maintenance is conducted. About 38,600 feet of county shoreline, or about 49 percent of the total county shoreline, were observed to have adequate structural bluff toe protection. Based on this survey, those shoreline reaches which are most likely to benefit from certain types of shore protection measures can be identified. Map 10 identifies those portions of the Racine County shoreline developed for intensive urban uses and located south of the southern boundary of Cliffside Park which are most likely to benefit from certain types of structural shore protection measures. As shown on the map, and quantified in

Map 10

RACINE COUNTY DEVELOPED SHORELINE AREAS MOST LIKELY TO BENEFIT FROM SELECTED STRUCTURAL SHORE PROTECTION MEASURES



LEGEND

- SUBSURFACE WATER DRAINAGE MEASURES
- SURFACE WATER DRAINAGE MEASURES
- SHORE PROTECTION STRUCTURES SUCH AS GROINS, REVETMENTS, AND BULKHEADS
- BLUFFS REQUIRING REGRADING OF MORE THAN 50 FEET

GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

Source: SEWRPC.

Table 15, about 2.1 miles of the shoreline, or about 14 percent of the total County shoreline, are most likely to require surface water drainage improvements, based on the distribution of poorly and very poorly drained soils in the study area. About 5.7 miles of shoreline, or about 38 percent of the County total, are most likely to require subsurface drainage improvements. Soils in these areas are better drained, resulting in greater water infiltration and potentially more groundwater seepage. Those shoreline areas, totaling about 1.5 miles, or about 10 percent of the county total, which are developed for intensive urban uses and are currently exhibiting a bluff recession rate in excess of one foot per year and were not observed to have adequate bluff toe protection in 1982, would most likely benefit from the provision of properly designed and constructed shore protection structures such as groins and revetments. Map 10 also shows which shoreline areas developed for intensive urban uses and located south of Cliffside Park would require regrading for a distance of 50 feet or more from the top of the bluff in order to achieve a stable slope. These shoreline areas total about 1.3 miles, or about 9 percent of the county total. It should be recognized that the specific structural protection measures required at any particular site can be determined only on the basis of detailed engineering analyses. Such structural measures should only be employed following a careful evaluation of the economic costs and benefits of nonstructural measures, building relocation, and structural alternatives. The decision to invest in a shore protection structure is influenced by a number of variables, including property values, intended development, and degree of erosion.

Protective structures could be installed to substantially reduce land and facility losses resulting from erosion in many reaches of the Lake Michigan shoreline of Racine County. Shore protection structures may be expected to

Table 15

RACINE COUNTY DEVELOPED SHORELINE EXTENT MOST LIKELY TO BENEFIT FROM SELECTED STRUCTURAL SHORE PROTECTION MEASURES

Structural Shore Protection Measure	Shoreline Length (miles)	Percent of Total County Shoreline
Surface Water Drainage.....	2.1[a]	14
Subsurface Water Drainage.....	5.7[b]	38
Revetment, Groin, or Other Major Structure.....	1.5[c]	10
Bluff Slope Regrading of >50 feet.....	1.3[d]	9

[a]Consists of those developed shoreline areas covered by poorly drained or very poorly drained soils.

[b]Consists of those developed shoreline areas covered by moderate to well-drained soils. Bluffs in these areas are more likely to contain groundwater seepage zones.

[c]Consists of those developed shoreline areas which exhibit an existing bluff recession rate of more than one foot per year and which were not observed to have adequate bluff toe protection in October 1982.

[d]Consists of those developed shoreline areas with a net stable slope distance of more than 50 feet.

Source: SEWRPC.

have a capital cost, in 1982 dollars, ranging from $100 per foot of shoreline for temporary protection structures, to more than $300 per foot of shoreline for protection structures with a life expectancy of 25 years or more, and an annual maintenance cost ranging from $2 to $30 per foot of shoreline.[8]

The capital cost of new shore protection structures with a life expectancy of 25 years, if installed at all developed locations south of Cliffside Park with an existing bluff recession rate exceeding one foot per year, and presently unprotected as shown on Map 10, is estimated to be $2.4 million, with an annual maintenance cost of up to $240,000. During a 50-year period, those structures would be replaced once on the average, resulting in a doubling of the capital cost to $4.8 million. The 50-year present worth of these shore protection structures, including capital cost and annual operation and maintenance cost, and assuming an interest rate of 10 percent, is approximately $5.0 million. These costs represent high estimates of the total cost of structural shore protection because the upper range of known unit costs was used in the calculations.

The costs for shore protection structures can be compared to the value of potential property losses expected for that portion of the county shoreline recommended for structural shore protection if those recommended structural controls are not implemented. Failure to implement structural shore protection measures where recommended would result in an estimated property loss of approximately $12.7 million over a 50-year period. Hence, based on this generalized comparative analysis, the implementation of shore protection structures, where recommended, would be less costly than the value of property lost to shore erosion over a 50-year period if such structures are not implemented.

However, for that portion of the county shoreline lying north of the southern boundary of Cliffside Park, where shore protection structures were not recommended, such shore protection structures are not cost-effective on a general basis. During a 50-year period, the value of land expected to be lost to bluff recession and stable slope formation is approximately $200,000. No facilities lying north of the southern boundary of Cliffside Park would be affected by bluff recession during a 50-year period. Implementation of shore protection structures within this reach, however, would involve a total capital cost of about $2.6 million, an average annual maintenance cost of up to $260,000, and a 50-year present worth of about $5.4 million. Hence, shore protection structures are generally not warranted for this reach of shoreline.

SUMMARY

The identification of the shoreland areas which may be expected to continue to be affected by shoreline erosion and bluff recession enables public officials and private property owners to better assess potential erosion losses and evaluate alternative erosion management measures. Erosion risk distances and facility setback distances from the existing bluff edge were identified for each of 101 coastal analysis shoreline reaches. The erosion risk distances and facility setback distances were developed under assumed nonstructural and

[8]S. N. Hanson, et al., Great Lakes Shore Erosion Protection, Structural Design Examples, Owen, Ayres & Associates, Wisconsin Coastal Management Program, August 1978.

structural management alternatives. The erosion risk distance is the distance from the existing bluff edge which would be affected by recession of the bluff over time, and by the regrading of the bluff slope as required to achieve a stable slope of 22°. The facility setback distance is comprised of the erosion risk distance plus a minimum facility setback distance. This minimum distance is to be determined by the local units of government.

Nonstructural erosion risk distances were presented for the entire County shoreline, with two exceptions. These exceptions are: 1) the City of Racine shoreline which is currently protected by shore protection structures, and 2) the northern-most reach in the Town of Caledonia, which is covered by fly ash deposits and protected by a bulkhead. The nonstructural setback distance applies to the reach of the Racine County shoreline lying from the southern boundary of Cliffside Park to the northern boundary of the County, except for the fly ash covered reach in the Town of Caledonia. The structural setback distance applies to the county shoreline extending from the southern boundary of Cliffside Park to the southern boundary of the County, as well as to the fly ash-covered reach in the northern portion of the Town of Caledonia.

Nonstructural erosion risk distances are shown in Appendix E at the end of this report, for a 25-year and 50-year period. Real property boundaries, as delineated in the county cadastre file, are also shown on the maps. The area contained within the 25-year nonstructural erosion risk distance from the existing bluff edge includes about 141 acres of land, or about 6 percent of the study area, and 103 buildings or facilities. About 199 acres of land, or about 8 percent of the study area, and 143 facilities lie within the 50-year nonstructural erosion risk distance. Most of the facilities lying within the nonstructural erosion risk distances are located between the southern boundary of Cliffside Park and the southern boundary of the County. The Racine County Technical Subcommittee on Shoreland Development Standards recommended that the shoreline from the southern boundary of Cliffside Park to the southern county boundary be protected by shore protection structures, wherever feasible. Hence, the structural setback distance applies to the shoreline reach south of Cliffside Park.

The economic value of the land and facilities located within the 25-year nonstructural erosion risk distance is approximately $9.3 million. The economic value of the land and facilities located within the 50-year erosion risk distance is about $12.9 million. These economic values doe not include the value of public utilities and improvements such as streets and sewers.

Effective shore protection requires a combination of bluff stabilization, surface water and subsurface water control, and bluff toe protection. Specific structural protection measures required at any particular site can be determined only on the basis of detailed engineering analyses and the consideration of a number of variables, including property values, the intended development, and the degree of erosion expected. The installation of new shore protection structures with a life expectancy of 25 years at all developed shoreline reaches having an existing bluff recession rate exceeding one foot per year, located south of Cliffside Park to the southern boundary of the County, and which were not observed to have adequate bluff toe protection would entail a capital cost of about $2.4 million, and an annual maintenance cost of up to $240,000, and a 50-year present worth of about $4.8 million.

Chapter V

RECOMMENDATIONS AND CONCLUSIONS

INTRODUCTION

The primary purpose of this Racine County coastal erosion management study is to identify erosion risk distances and develop facility setback distances from the existing bluff of the Lake Michigan shoreline of Racine County, and to develop public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to these erosion risk delineations. The location and extent of the erosion risk distances as delineated in Chapter IV of this report provide the primary basis for the formulation of these public informational and regulatory measures. The delineation of the erosion risk distances prepared under this study, coupled with the findings and recommendations of companion coastal zone studies and the County Coastwatch Program, make it possible to implement new nonstructural erosion control measures, as well as to refine the need for further structural shore protection measures, in order to reduce shoreline erosion damages.

The first section of this chapter suggests important public informational and educational uses of the findings and recommendations of this study. The second section sets forth required changes in the county shoreland zoning ordinance to implement certain recommendations of this study, changes which could also be incorporated into local municipal ordinances as may be required. The third section describes a proposed procedure for modifying the extent of the erosion risk and setback distances. The fourth section describes a proposed procedure for periodically updating the delineation of the erosion risk and setback distances. The fifth and final section summarizes the chapter.

PUBLIC INVOLVEMENT IN COASTAL EROSION MANAGEMENT

Public involvement in the management of the Lake Michigan shoreland area of Racine County is essential to obtain the political support required for the success of that management effort. Such involvement requires that pertinent information concerning the problems and opportunities existing in the shoreland area be made available to interested and concerned citizens. The findings and recommendations of this study provide a valuable reference which can help to inform the general public and key interest groups about the distance from the existing bluff edge which is subject to a risk of erosion along the Lake Michigan shoreline, and of actions that can help to reduce that risk.

Placing findings and recommendations, such as those set forth in this report, before the public allows affected parties to act more judiciously and responsibly of their own accord with respect to development and redevelopment of the shoreland area--thereby relieving the burden of regulation and enforcement to some extent. The findings and recommendations set forth in this report can serve as a "fair warning" guide for, and a valuable service to, groups such as realtor-brokers, shoreline property owners, developers, lending institutions,

and prospective buyers. It is crucial that groups such as these be fully cognizant of the potential problems and hazards associated with coastal shoreline development.

With the information made available particularly through the mapping element of this study, all of the directly impacted groups will have ready access to information helpful in addressing issues such as: the appropriate use of shoreland areas within the erosion risk distances; the need for special setbacks for buildings, special development techniques, or structural shore protective measures in certain areas; and the attainment of a better understanding by groups involved in real estate transactions of the threat of shoreline erosion to the real property being transferred. Public information and understanding also affords individuals a better opportunity to choose from an educated standpoint actions or measures which are more protective, more safe, or more compatible with the existing land uses and resource features than the minimum requirements which may be dictated by public regulations.

The projections made herein of erosion and bluff recession may be regarded by some as a potential threat to real property values, such values being related to existing and potential uses of the shoreland areas contained within the erosion risk distances. It is not the study findings, however, which create a threat in this respect, but rather the forces in the natural environment which conflict with certain existing and intended uses of the land. To openly and extensively communicate the risk entailed to the general public would be a responsible course of action by the public agencies concerned.

RECOMMENDED ORDINANCE AMENDMENTS

Racine County currently has a shoreland zoning ordinance which regulates the location of facilities, and certain land uses and land management practices, within a specified distance to the Lake Michigan shoreline. These regulations can be made more effective by including provisions directly related to the erosion hazards which threaten specific reaches of the shoreline. The use of zoning ordinances to reduce the physical and economic impacts of bluff erosion constitutes one viable tool for protecting new development and redevelopment along the affected shoreline area.

Regulations can be developed which protect proposed development from excessive shoreline erosion and bluff recession by identifying the distance from the existing bluff edge which is subject to a risk of erosion, and by specifying a setback distance which restricts or prohibits the location of buildings and other land uses which are vulnerable to damages or destruction from erosion. These regulations can be readily incorporated into the existing county zoning ordinance, which regulates the use of land, the area and dimensions of lots, and the location of structures on such lots. Zoning can also control grading, filling, vegetation removal, and certain other land management practices. To be constitutionally valid, however, regulation of the land use within the setback distances must serve valid public objectives, have a reasonable basis for the classification of uses subject to the regulations, leave the property owner with some reasonable use of his property, and provide sufficient standards to prevent arbitrary decision-making.

Recommended amendments to the Racine County shoreland zoning ordinance which, in the public interest, would regulate land uses, activities, and facility locations within the specified setback distances are set forth in Appendix D. The amendments include provisions defining pertinent terms, designating the lands to be regulated, specifying the necessary regulation of land use and facility location, specifying the regulation of certain land disturbance activities, and describing procedures for modifying the location and extent of the designated setback distances. Such provisions, with appropriate adaptation, may also be incorporated into local municipal zoning ordinances. The Regional Planning Commission will, upon request, assist municipal units of government in the incorporation of provisions related to erosion risk and associated setback distances along the Lake Michigan shoreline of Racine County into local ordinances.

Identification of Erosion Risk Distances and Setback Distances

The setback distance for buildings and other facilities from the edge of the bluff along shoreline areas currently--or proposed to be--protected by properly designed, constructed, and maintained structural shore protection measures should be estimated for each property by the following formula--graphically illustrated in Figure 6 of Chapter IV of this report. It is recommended that the structural setback distance apply to the entire county shoreline south of the southern boundary of Cliffside Park, and to the northernmost reach of the Town of Caledonia, which is covered by fly ash deposits and protected by bulkhead. This structural setback distance from the bluff edge should apply over the entire length of shoreline of a property.

Structural Setback Distance = Structural Erosion Risk Distance + Minimum Facility Setback Distance

Where: Structural Erosion Risk Distance = Net Stable Slope Distance = Distance Required to Achieve a One on Two and One-Half Bluff Slope

The distance required to achieve a one on two and one-half bluff slope is set forth for each coastal erosion analysis reach in Table 12 of Chapter IV of this report. The property boundaries, as shown on the cadastral maps, contained within each analysis reach are shown in Appendix E at the end of this report.

The minimum facility setback distance is intended to provide a safety factor which helps to prevent damages which could be caused by major storms or protective structure failure, and to provide an open space area which can be effectively utilized for surface water and subsurface water drainage and control. The minimum setback distance prevents the weight of facilities from being placed too close to the bluff edge, which could reduce slope stability. Benefits of a minimum setback distance also include maintenance of the aesthetic amenities of the bluff edge, human safety factors, and the prevention of public utilities from being located too close to the bluff edge. It is recommended that, based on the above considerations, minimum facility setback distances be determined by each local unit of government within its jurisdictional area. For the Racine County shoreland zoning ordinance, which regulates land uses and activities within the unincorporated shoreland areas, it is recommended that the following minimum facility setback distances be applied:

- 200 feet for all permanent facilities except public utilities, public recreation facilities, and single-family residential units.

- 100 feet for public utilities, public recreational facilities, and single-family residential units, except that the minimum setback distance may be reduced to the average distance from the bluff edge of adjacent facilities located within 100 feet of the proposed facility, although the minimum setback distance cannot be less than 50 feet.

A shore protection structure may be considered effective and properly designed if it meets the criteria established by the Racine County Technical Subcommittee on Shoreland Development Standards, as set forth in Table 14 of Chapter IV of this report. The proposed ordinance amendments require that proposed development along the shoreline south of Cliffside Park be protected by shore protection structures meeting the criteria set forth by the Technical Subcommittee.

The nonstructural setback distance for all portions of the coastline not proposed to be protected by proper shore protection structures should consist of the nonstructural erosion risk distance--defined as the 50-year total bluff recession rate distance from the existing bluff edge, as presented in Table 12 of Chapter IV of this report, plus a net stable slope distance, plus a minimum facility setback distance--as defined above. The nonstructural erosion risk distance is shown in Appendix E for the entire county shoreline except for the protected portion of the City of Racine shoreline and the extreme northern shoreline in the Town of Caledonia, for which bluff recession rates were not determined. These maps should be used for general information purposes. The nonstructural setback distance applies to the entire county shoreline north of the southern boundary of Cliffside Park, except for the northern-most reach of the Town of Caledonia. The required nonstructural distance for each property should be calculated, over the entire length of shoreline, by the following formula--graphically illustrated in Figure 5 of Chapter IV of this report:

Nonstructural Setback Distance = Nonstructural Erosion Risk Distance + Minimum Facility Setback Distance

Where: Nonstructural Erosion Risk Distance = 50-Year Bluff Recession Distance + Net Stable Slope Distance

Prohibited, Conditional, and Permitted Uses

Within the calculated structural and nonstructural setback distances, the recommended county shoreland zoning ordinance amendments would prohibit the development or redevelopment of major facilities and buildings. Buildings and facilities which may be relocated are also prohibited, but under certain conditions, may be granted a variance from the ordinance provisions. These variances for relocatable buildings should be reviewed on a case-by-case basis to determine the impact on the property owner, the erosion risk involved, and alternatives for development. Although not included in the shoreland zoning amendments, it is also recommended that the county sanitary ordinance be amended to prohibit new onsite sewage disposal systems within the structural and nonstructural setback distances because such systems contribute moisture and weight to the bluff soils which may create unstable slope conditions and because such systems are unlikely to be removed if, or when, the bluff erodes at the site, thereby contributing to pollution of the shoreline environment.

The recommended shoreland zoning ordinance amendments specify as conditional uses within the calculated structural and nonstructural setback distances, land disturbance activities, tree cutting or other vegetation removal, and the construction of structural shore protection measures. Such conditional uses require, for approval, that certain specified criteria or provisions be met.

Permitted uses within the structural and nonstructural setback distances, unless restricted by other zoning ordinance provisions, include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor facilities such as driveways, sidewalks, patios, and fences. Permitted uses thus include the placement of materials and supplies which can be readily moved prior to erosion damage, minor facilities with a relatively low economic value, and uses which will not increase stresses on the bluff which could increase slope instability.

MODIFICATION OF THE STRUCTURAL AND NONSTRUCTURAL SETBACK DISTANCE

The calculated structural and nonstructural setback distances may be modified upon submittal by an applicant or property owner of acceptable engineering studies which indicate that the actual recession rate is different than that set forth in this report for the appropriate coastal erosion analysis reach (for the nonstructural setback distance only), that the stable slope conditions are different than indicated herein, or that the height of the bluff is different. In addition, the requirement for structural protection measures south of Cliffside Park may be waived if the applicant or property owner presents acceptable evidence that the proposed facility and adjacent property can be adequately protected without the shore protection structure.

Although the provision of the required technical information is the responsibility of the landowner, various governmental agencies can supply useful maps and data. Historic recession rates for any specific shoreland parcel can be measured from aerial photographs available from the Southeastern Wisconsin Regional Planning Commission for the years 1963, 1967, 1970, 1975, and 1980, or from similar suitable information available over a relatively long time period. The bluff height at any specific parcel may be measured by a field survey, or on the large-scale topographic maps available from the Racine County Planning and Zoning Department. The evaluation of the stability of the slope and the identification of the specific stable slope angle will, in most cases, require a field survey and technical assistance from a qualified professional geologist, soil scientist, or engineer.

PERIODIC UPDATING OF STRUCTURAL AND NONSTRUCTURAL EROSION RISK DISTANCES AND SETBACK DISTANCES

It is recommended that the structural and nonstructural erosion risk distances be refined periodically to reflect changes in the bluff characteristics and to incorporate new bluff recession rates into the long-term average rate. The formula for establishing setback distances can and should continue to be used with the new recession rates and bluff characteristics. Bluff heights should

be redefined at approximately 10-year intervals, as updated large-scale topographic maps become available for the shoreline. Similarly, bluff recession rates should be remeasured, at approximately 10-year intervals, as appropriate aerial photography becomes available. The 1963 aerial photographs by the Regional Planning Commission should continue to be used as the base period for measuring recession. Updated topographic maps may also be used to refine and update bluff recession rates. A stable slope of 22° should continue to be used unless new technical studies indicate that an alternative angle is more appropriate, or where site-specific studies have indicated a stable slope different than 22°. Appendix E, provided at the end of this report, should be updated at approximately 10-year intervals, to reflect the revisions in bluff characteristics and recession rates.

SUMMARY

The identification of erosion risk distances and the development of facility setback distances from the existing Lake Michigan bluffs provides a basis for public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to the risk of erosion. This chapter includes a description of recommended amendments to the county shoreland zoning ordinance which relate development to the risk of erosion. Similar provisions may be incorporated into local municipal zoning ordinances.

Public involvement in coastal erosion management and the availability of pertinent shoreline erosion information to the public helps obtain political and public support for the recommended management measures, permits affected parties to practice sound coastal management on their own accord, and identifies coastal erosion problems for affected parties and potential property buyers. Importantly, the findings and recommendations of this study provide a valuable reference and educational resource to inform the public about the process and effects of coastal erosion, the area potentially affected by that erosion, and actions to reduce the effects of that erosion.

The current Racine County shoreland zoning ordinance regulates the location of facilities and certain land uses within a specified distance to the Lake Michigan shoreline. On the basis of the erosion risk distances presented in Chapter IV, setback distances were specified to protect those areas potentially subject to erosion within a 50-year period of time. The setback distances also contain a minimum facility setback. These setback distances were incorporated into amendments to the county shoreland zoning ordinances. A nonstructural setback distance was recommended for the county shoreline north of the southern boundary of Cliffside Park. A structural setback distance was recommended for the county shoreline south of Cliffside Park to the southern boundary of the County, as well as for the reach of shoreline in the Town of Caledonia which is covered by fly ash.

For the county shoreland zoning ordinance, a minimum facility setback of 50 to 100 feet for public utilities, public recreational facilities, and single-family residential units, and a setback of 200 feet for other major permanent facilities was recommended. Outside of the jurisdiction of the county zoning ordinance, local units of government should determine the minimum facility setback distance.

Prohibited uses within the specified nonstructural and structural setback distances include the development or redevelopment of major facilities and buildings. Conditional uses include land disturbance activities, tree cutting, and the construction of shore protection structures. Uses permitted within the setback distances include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor facilities such as driveways, sidewalks, patios, and fences.

Provisions of the shoreland zoning ordinance are recommended which would allow property owners or applicants the opportunity to present information which could be used to modify the required setback distance. In addition, it was recommended that the erosion risk and setback distances be refined and updated at approximately 10-year intervals.

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Chapter VI

SUMMARY

INTRODUCTION

The erosion and recession of the coastal bluffs along the Lake Michigan shoreline of Racine County constitutes a serious loss of valuable natural resources and of real property and improvements thereto. Bluff recession rates in Racine County range up to 14 feet per year, averaging almost two feet per year along the unprotected reaches of the shoreline. This bluff recession results in the loss of approximately three acres of land each year, and 6.6 million cubic feet of shore material.

The erosion and bluff recession along the Lake Michigan shoreline of Racine County may be managed by a coordinated set of structural and nonstructural measures which reduce shoreline erosion and the damages which result from such erosion. Structural shore protection measures include groins, breakwaters, revetments, bulkheads, piers, and surface water and groundwater drainage and control techniques. Nonstructural measures include land use regulations, building setback requirements and restriction of certain land management practices, and public acquisition of shoreland areas. Currently, shoreland development in the unincorporated portions of Racine County is regulated by a shoreland zoning ordinance. Because of the high value of shoreland resources and the varying degrees of shore erosion there is a need to establish more refined building setback requirements and related regulations which are more specifically linked to expected future bluff recession rates and slope conditions.

Several previous studies on coastal erosion in Racine County have established an extensive data base which permitted the prediction of future shoreline conditions and the formulation of regulations which can assist in more rational adjustments of rural and urban development and redevelopment of these expected future conditions. These studies have been conducted by the Racine County Coastwatch Program, the University of Wisconsin Sea Grant Program and Extension Service, and Racine County with financial and technical assistance from the federally supported Wisconsin Coastal Management Program.

PURPOSE

The primary purpose of this coastal erosion management study was to delineate and map erosion and bluff recession risk distances from the existing bluff edge along the Lake Michigan shoreline of Racine County, and to develop a set of land use regulations properly related to the existing and probable future shoreline erosion and bluff recession rates. The study identifies the extent of shoreline erosion and bluff recession which may be expected to occur over time along the Lake Michigan shoreline of Racine County; identifies erosion risk distances and recommends associated setback distances for buildings along shoreline reaches protected by proper shore protection structures, as well as along reaches not so protected; quantifies the potential property losses which may be expected to result from continued shoreline erosion and bluff recession

in the absence of a sound management program; and recommends a set of provisions which may be incorporated into existing shoreland regulations to restrict certain land uses and practices, as well as to guide the placement of new buildings, within those shoreland areas susceptible to erosion and bluff recession. Recommendations for both structural and nonstructural coastal erosion control measures previously made by the Racine County Technical Subcommittee on Shoreland Development Standards were adapted and incorporated into the findings and recommendations of this study.

ORGANIZATIONAL STRUCTURE

The purpose, scope, and content of the study was developed under the guidance of the Coastal Erosion Technical Advisory Committee, comprised of persons who have knowledge and experience related to the technical aspects of coastal zone management, as well as of persons who are intimately familiar with the Racine County coastal environment. The composition of this Committee, given on the inside front cover of this report, includes representatives from the University of Wisconsin Sea Grant Program, the City of Racine, the Town of Caledonia, the Racine County Coastwatch Program, the Racine Board of Realtors, the Wisconsin Department of Natural Resources, the Sierra Club, and private engineering consulting firms. The study itself was subsequently carried out cooperatively by the staffs of the Regional Planning Commission and the Racine County Planning and Zoning Department.

INVENTORY FINDINGS

A coastal erosion study area was defined and delineated under the study, being that area of Racine County lying within approximately 1,000 feet of the ordinary high water mark of Lake Michigan. The study area thus includes all lands subject to existing county shoreland zoning regulations. The study area is comprised of those lands which most directly affect, or are most directly affected by, Lake Michigan erosion processes. The study area encompasses 2,552 acres of land and 14.8 miles of Lake Michigan shoreline.

Elements of the natural resource base of the study area pertinent to the understanding of coastal erosion include the geology, soils, bluff and beach composition and topography, surface water resources, groundwater resources, and climate of the coastal area. The study area is underlain by, in successively descending order, dolomite, shale, sandstone, and crystalline layers of bedrock. Up to 300 feet of unconsolidated glacial deposits cover the dolomite. About 28 percent of the study area is covered by well-drained and moderately drained soils, and about 55 percent of the study area is covered by poorly drained and very poorly drained soils.

Although some bluff heights in Racine County exceed 80 feet, most of the shoreline has bluffs ranging from 20 to 40 feet. The bluffs are comprised of till, silt, clay, sand, and gravel. Nearly one-third of the shoreline has no beach. Most of the shoreline with a beach has a beach width ranging from one to 30 feet, although the maximum beach width exceeds 300 feet.

Along the Racine County shoreline, groundwater generally flows toward Lake Michigan. Three major aquifers underlie the coastal area: the deep sandstone

aquifer, the Niagara dolomite aquifer, and the shallow sand and gravel aquifer. Numerous groundwater discharges and seepages occur on the bluff slopes, contributing to the instability of these slopes.

The type, degree, and extent of shore erosion damage is determined by the interrelationship of the natural and man-made features of the study area. About 56 percent of the study area was devoted to urban land uses in 1980. About half of the area in urban land use was devoted to residential use. Land use in the study area is currently regulated by County and municipal zoning ordinances. Municipal zoning ordinances are in effect in the City of Racine, and in the Villages of North Bay and Wind Point. The Town of Caledonia has adopted the Racine County zoning ordinance. The Town of Mt. Pleasant has adopted its own zoning ordinance, but that ordinance is a joint town-county ordinance. The county has jurisdiction over the shoreland areas of the Town of Mt. Pleasant. About 91 percent of the study area has been placed in zoning districts which permit intensive urban development. The zoning ordinances are generally devoid of provisions pertaining to the regulation of development and redevelopment in relation to Lake Michigan shoreline erosion hazards.

Numerous types of shore protection structures are currently present along the Racine County shoreline. These structures, which include groins, bulkheads, revetments, and breakwaters, have had varying degrees of success. An inventory of 216 shore protection structures indicated that nearly 75 percent of all structures exhibited some type of failure. About 30 percent of all structures were failing overall, or were nonfunctional.

The most important Lake Michigan coastal erosion problem in Racine County is recession of the bluffs. Bluff recession is caused by the sliding and slumping, as well as the surface erosion, of bluff slopes. Factors affecting bluff erosion include wave action at the bluff toe; lake levels; the physical characteristics of the beach and bluff, including the configuration and soil types; ice activity; groundwater seepage; and surface runoff. The rate of bluff recession has been documented in several previous studies. During the period from 1963 through 1980, bluff recession along the unprotected reaches of shoreline, as measured by the Regional Planning Commission, averaged 1.5 feet per year. About 38 percent of the unprotected reaches of shoreline had a bluff recession rate equal to or less than 0.5 foot per year. The highest recession rate, measured by the Regional Planning Commission for the period 1963 through 1980, was 10.2 feet per year. During periods of high water elevation, recession rates as high as 14 feet per year have been measured in Racine County.

EVALUATION OF COASTAL EROSION

The identification of the shoreland areas which may be expected to continue to be affected by shoreline erosion and bluff recession enables public officials and private property owners to better assess potential erosion losses and evaluate alternative erosion management measures. Erosion risk and setback distances from the existing bluff edge were identified for each of 101 coastal analysis shoreline reaches. The erosion risk and setback distances were developed under assumed nonstructural and structural management alternatives. The erosion risk distance is the distance from the existing bluff edge which would be affected by recession of the bluff over time, and by the regrading of the

bluff slope, as required, to achieve a stable slope of 22°. (See Figures 5 and 6 of Chapter IV of this report for the procedure used to calculate erosion risk and setback distances).

The formula used to calculate the nonstructural erosion risk distances is as follows:

Nonstructural Erosion Risk Distance = 50-Year Bluff Recession Distance + Net Stable Slope Distance

Where: 50-Year Bluff Recession Distance = Annual Recession Rate Measured for Period of 1963 to 1980 x 50 Years

Net Stable Slope Distance = Gross or Total Horizontal Distance of 22° Slope for the Specific Bluff Height - Existing Horizontal Distance of the Bluff Slope

The nonstructural erosion risk distances were presented for the entire county shoreline, with two exceptions. These exceptions are: 1) the City of Racine shoreline which is currently protected by shore protection structures; and 2) the northern-most reach in the Town of Caledonia which is covered by fly ash deposits. The sum of the nonstructural erosion risk distance, plus a minimum facility setback distance is referred to as the nonstructural setback distance. The minimum facility setback distance should be determined by the local units of government. The nonstructural setback distances apply to the reach of the Racine County shoreline lying north of the southern boundary of Cliffside Park, except for the fly ash-covered reach in the Town of Caledonia.

Nonstructural erosion risk distances are shown in Appendix E at the end of this report for a 25-year and 50-year period. Real property boundaries, as delineated in the county cadastre file, are also shown on the maps. The area contained within the 25-year nonstructural erosion risk distance from the existing bluff edge includes about 141 acres of land, or about 6 percent of the study area, and 103 buildings or facilities. About 199 acres of land, or about 8 percent of the study area, and 143 facilities lie within the 50-year nonstructural erosion risk distance.

The economic value of the land and facilities located within the 25-year nonstructural erosion risk distance is approximately $9.3 million, of which $2.9 million, or 31 percent represents the value of the land, and $6.4 million, or 69 percent, the value of the facilities and improvements thereto. The economic value of the land and facilities located within the 50-year erosion risk distance is about $12.9 million, of which $4.0 million, or 31 percent, is the value of the land, and $8.9 million, or 69 percent, is the value of the facilities.

The structural erosion risk distances were defined as the net stable slope distances, since it was assumed that the shore protection structures would be properly constructed and maintained, and would therefore essentially prevent any further bluff recession. The structural setback distance consisted of the structural erosion risk distance plus a minimum facility setback distance. It was recommended that the structural setback distance apply to the County shoreline lying from the southern boundary of Cliffside Park to the southern boundary of the County, as well as to the fly ash-covered reach in the Town of Caledonia. The Racine County Technical Subcommittee on Shoreland Development Standards recommended that the shoreline from the southern boundary of Cliffside Park to the southern county line be protected by shore protection structures, wherever feasible.

Effective shore protection requires a combination of bluff stabilization, surface water and subsurface water control, and bluff toe protection. Specific structural protection measures required at any particular site can be determined only on the basis of detailed engineering anlyses and the consideration of a number of variables, including property values, the intended development, and the degree of erosion expected. The installation of new shore protection structures with a life expectancy of 25 years at all currently inadequately protected developed shoreline reaches having an existing bluff recession rate exceeding one foot per year and located south of Cliffside Park would entail a capital cost of about $2.4 million, an annual maintenance cost of up to $240,000, and a 50-year present worth of about $4.8 million.

RECOMMENDATIONS

The findings of this coastal erosion management study provide a basis for developing public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to the associated risk of shoreline erosion and bluff recession. The findings of the study provide a valuable reference which can help to inform the general public and concerned special interest groups about the location and extent of the Lake Michigan shoreline area subject to a risk of erosion, and actions that can help to reduce that risk. Public land use regulations can be developed which protect proposed development and redevelopment from excessive shoreline erosion and bluff recession risk by identifying erosion risk distances from Lake Michigan and establishing facility setback distances from the shoreline. Recommended amendments to the Racine County shoreland zoning ordinance which would regulate land uses, activities, and facility locations within the setback distances are set forth in Appendix D of this report. With proper adaptation, these provisions may also be incorporated into local municipal zoning ordinances. The ordinance amendments designate distances from the existing bluff edge within which certain land uses and management practices, and the placement of permanent facilities are restricted or prohibited.

The current Racine County shoreland zoning ordinance regulates the location of facilities and certain land uses within a specified distance of the Lake Michigan shoreline. On the basis of the erosion risk distances presented in Chapter IV, setback distances were specified to protect those areas potentially subject to erosion within a 50-year period of time. The setback distances consist of the erosion risk distance plus a minimum facility setback distance. Setback distances were developed under the nonstructural alternative, and under the structural alternative. A nonstructural setback distance was recommended for the county shoreline north of the southern boundary of Cliffside Park, except for the reach of shoreline in the Town of Caledonia which is covered by fly ash. A structural setback distance was recommended for the county shoreline from the southern boundary of Cliffside Park to the southern county line, as well as for the reach of shoreline in the Town of Caledonia which is covered by fly ash.

For the county shoreland zoning ordinance, a minimum facility setback of 50 to 100 feet for public utilities, public recreation facilities, and single-family residential units, and of 200 feet for other major permanent facilities was

recommended. Outside of the jurisdiction of the county zoning ordinance, it is recommended that local units of government determine the minimum facility setback distance.

Prohibited uses within the specified nonstructural and structural setback distances include the development or redevelopment of major facilities and buildings. Conditional uses include land disturbance activities, tree cutting, and the construction of shore protection structures. Uses permitted within the setback distances include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor facilities such as driveways, sidewalks, patios, and fences.

The established setback distances may be modified upon submittal by an applicant or property owner of the findings of engineering studies showing that the actual shoreline erosion and bluff recession rate is different than that set forth in this report for the appropriate coastal erosion analysis reach, that the stable slope conditions are different than indicated herein, or that the height of the bluff is different. It is recommended that the erosion risk and the setback distances be refined at approximately 10-year intervals to reflect changes in the bluff characteristics and to incorporate new bluff recession rates into the long-term average rates.

The adoption and implementation of the management measures herein recommended for the Lake Michigan shoreland area of Racine County will help reduce the serious and costly erosion and bluff recession problems affecting the county shoreline. The implementation of these recommended measures may thus be expected to provide a safer, more healthful and more pleasant, as well as more orderly and efficient environment within the shoreland area, promoting the public health, safety, and general welfare.

APPENDICES

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Appendix A

SHORE PROTECTION STRUCTURE INVENTORY FOR RACINE COUNTY: 1976-1980

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Groin	4N	23E	6	65	31	25	--	--	Stone/steel	Functional	None	None	6/76	Wall around Oak Creek Power Plant
Revetment	4N	23E	6	65	39	10	12	540	Broken concrete	Nonfunctional	Overtopped/ flanked/ collapsed	Rebuild	6/76	Concrete chunks along bluff
Revetment	4N	23E	8	35	25	60	5	120	Wire/stone	Failing	Overtopped/ collapsed/ vandalism	Rebuild	6/76	Small, poorly constructed gabion
Revetment	4N	23E	8	50	33	10	20	--	Stone	Functional	Flanked	Minor	6/76	Dolomite block structure with some beach erosion
Groin	4N	23E	17	25	15	95	37	15	Stone	Functional	Overtopped	None	6/76	Recently installed small groin
Other	4N	23E	17	--	--	--	55	120	Broken concrete	Functional	Other	None	6/76	Concrete sidewalk sections at gully mouth
Bulkhead	4N	23E	17	30	37	95	74	270	Stone	Functional	None	None	6/76	Four groins and a dolomite bulkhead
Groin	4N	23E	16	40	37	95	30	190	Stone/broken concrete	Functional	Flanked/ collapsed	Minor	6/76	Some erosion in back of groin
Groin	4N	23E	16	40	37	95	30	92	Stone/poured concrete	Functional	Flanked	Minor	6/76	Fairly stable and effective
Revetment	4N	23E	16	25	31	25	42	320	Stone/broken concrete	Failing	Faulty material/ collapsed	Rebuild	6/76	Concrete fragments, concrete and dolomite riprap at bluff toe
Groin	4N	23E	16	35	47	5	23	275	Stone/tires	Functional	None	None	6/76	Conjoined with above structure
Revetment	4N	23E	16	25	44	5	27	1,320	Stone/broken concrete	Functional	Flanked/ overtopped	Major	6/76	Low and overtopped near south end
Revetment	4N	23E	16	30	--	5	--	210	Wire/stone	Failing	Other	Major	6/76	Failing due to ice shove
Groin	4N	23E	16	25	33	90	41	55	Stone	Functional	Overtopped	None	6/76	--
Revetment	4N	23E	21	25	33	95	40	1,056	Stone	Functional	None	None	6/76	--
Revetment	4N	23E	21	15	20	98	53	900	Stone	Functional	Overtopped	None	6/76	Appears to cause accretion
Revetment	4N	23E	22	20	25	95	41	800	Stone	Functional	Overtopped	None	6/76	Bluff failing due to high winter wave action
Bulkhead	4N	23E	22	25	35	5	29	215	Poured concrete	Functional	None	None	6/76	Large dolomite reinforcements
Bulkhead	4N	23E	22	18	35	95	41	148	Poured concrete	Functional	None	None	6/76	--
Bulkhead	4N	23E	22	18	--	99	26	178	Poured concrete/ broken concrete	Functional	None	Minor	6/76	Reinforced with dolomite blocks
Revetment	4N	23E	22	20	20	95	34	700	Stone	Functional	None	None	6/76	--
Revetment	4N	23E	22	20	20	95	37	245	Stone	Functional	Overtopped	None	6/76	--
Other	4N	23E	22	25	32	10	35	240	Broken concrete/ asphalt	Functional	None	Rebuild	6/76	Terraced bluff
Revetment	4N	23E	22	20	20	95	28	250	Stone	Functional	Collapsed/ faulty material	Major	6/76	Dolomite revetment, groin at north end
Revetment	4N	23E	22	10	--	95	11	350	Stone/poured concrete	Functional	None	None	6/76	Dolomite block revetment
Bulkhead	4N	23E	22	--	--	95	20	300	Stone/poured concrete	Functional	None	None	6/76	Some dolomite riprap and concrete support

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Revetment	4N	23E	22	--	--	95	--	550	Stone/broken concrete	Functional	Overtopped/ collapsed	Major	6/76	--
Bulkhead	4N	23E	22	25	28	80	58	126	Poured concrete	Functional	None	None	6/76	Recently poured concrete bulkhead
Revetment	4N	23E	22	18	25	90	48	250	Stone	Functional	Overtopped	Major	6/76	Groins at both ends
Revetment	4N	23E	22	20	25	95	6	525	Stone	Functional	Overtopped/ other	None	6/76	Widely spaced dolomite blocks
Bulkhead	4N	23E	27	6	--	90	31	303	Stone	Functional	None	None	6/76	Convex dolomite bulkhead
Bulkhead	4N	23E	27	18	33	90	8	150	Poured and precast concrete	Functional	Faulty material	Minor	6/76	Attached to previous two structures
Revetment	4N	23E	27	12	15	95	--	122	Stone	Nonfunctional	Overtopped/ flanked	None	6/76	--
Revetment	4N	23E	27	15	30	50	12	169	Stone/ asphalt	Functional	Overtopped	Major	6/76	Blocks should be added
Revetment	4N	23E	27	25	35	95	16	225	Broken concrete	Functional	Overtopped	None	6/76	Scattered concrete chunks on shore
Groin	4N	23E	27	20	33	60	35	76	Poured concrete	Functional	Overtopped	Minor	6/76	--
Revetment	4N	23E	27	20	33	60	10	200	Steel/broken concrete	Functional	Overtopped/ collapsed	Rebuild	6/76	--
Bulkhead	4N	23E	27	20	33	85	23	43	Poured concrete	Nonfunctional	Overtopped	Minor	6/76	Small bulkhead
Groin	4N	23E	27	15	35	95	55	92	Poured concrete	Functional	Collapsed	Major	6/76	End of groin broken off
Bulkhead	4N	23E	27	15	35	90	25	45	Poured concrete	Functional	Overtopped	None	6/76	--
Revetment	4N	23E	27	20	33	75	20	350	Broken concrete	Functional	Faulty material/ overtopped	Rebuild	6/76	--
Groin	4N	23E	27	15	30	--	20	65	Stone	Functional	Overtopped	None	6/76	--
Revetment	4N	23E	27	15	30	75	5	350	Broken concrete	Functional	Collapsed/ faulty material	Rebuild	6/76	--
Groin	4N	23E	27	25	35	--	--	35	Stone	Nonfunctional	Overtopped/ flanked	Rebuild	6/76	--
Revetment	4N	23E	27	25	42	50	--	--	Stone/broken concrete	Functional	Overtopped	None	6/76	Has two attached groins
Groin	4N	23E	27	25	42	50	--	30	Poured concrete	Nonfunctional	Flanked/ collapsed/ overtopped	Rebuild	6/76	Below lake level and ineffective
Groin	4N	23E	27	25	42	50	--	30	Poured concrete	Nonfunctional	Flanked/ collapsed/ overtopped	Rebuild	6/76	Slumping of bluff behind structure
Bulkhead	4N	23E	27	10	--	95	17	150	Stone	Functional	None	None	6/76	--
Bulkhead	4N	23E	27	10	--	90	17	48	Stone	Functional	None	None	6/76	--
Other	4N	23E	27	10	--	90	17	73	Poured concrete	Functional	None	Minor	6/76	Boat launching ramp
Bulkhead	4N	23E	27	6	--	95	23	143	Poured concrete	Functional	None	None	6/76	Recently poured bulkhead
Pier	4N	23E	27	4	--	90	27	200	Steel/timber	Nonfunctional	Collapsed	Rebuild	6/76	--
Pier	4N	23E	27	6	15	90	25	250	Precast concrete	Nonfunctional	Overtopped/ collapsed	Minor	6/76	40 feet of pier collapsed
Pier	4N	23E	27	20	22	95	97	380	Precast concrete	Functional	None	Minor	6/76	Partial cause of much accretion

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Pier	4N	23E	27	20	22	95	70	226	Precast concrete	Functional	None	Minor	6/76	--
Pier	4N	23E	27	20	22	95	53	105	Precast concrete	Functional	None	Major	6/76	--
Bulkhead	4N	23E	27	20	20	95	--	133	Stone/poured concrete	Functional	None	Minor	6/76	Solid buttressed seawall
Groin	4N	23E	27	20	2	95	--	46	Poured concrete	Functional	None	None	6/76	Attached to previous structure
Bulkhead	4N	23E	27	20	20	95	--	103	Poured concrete	Functional	None	Minor	6/76	Seawall
Other	4N	23E	27	20	31	--	--	150	Broken concrete	Nonfunctional	Overtopped	Rebuild	6/76	--
Bulkhead	4N	23E	27	18	35	80	15	76	Poured and precast concrete	Functional	Overtopped	Minor	6/76	Seawall with small buttresses
Pier	4N	23E	27	18	35	90	15	35	Timber/ poured concrete	Failing	Overtopped/ faulty material/ other	Major	6/76	Small boat launching pier
Groin	4N	23E	34	20	41	90	48	35	Stone	Nonfunctional	Overtopped/ flanked	Rebuild	6/76	--
Groin	4N	23E	34	20	41	95	48	80	Stone	Functional	Overtopped/ flanked	Major	6/76	Requires additional material
Other	4N	23E	34	18	14	95	48	12	Wire/stone	Nonfunctional	Other	None	6/76	Small ineffective gabion
Revetment	4N	23E	34	18	14	95	17	65	Stone	Functional	Overtopped	None	6/76	--
Groin	4N	23E	34	20	14	95	15	65	Stone	Functional	Overtopped	Minor	6/76	--
Other	4N	23E	34	20	15	95	15	12	Wire/stone	Nonfunctional	Other	None	6/76	Not effective
Revetment	4N	23E	34	20	14	95	9	110	Broken concrete	Functional	Toe undermined	Minor	6/76	Damaged by ice shove
Groin	4N	23E	34	20	15	95	9	60	Stone	Functional	Flanked/ overtopped	Major	6/76	--
Other	4N	23E	34	25	39	95	23	60	Wire/stone	Functional	None	None	6/76	--
Groin	4N	23E	34	25	39	75	51	51	Stone	Functional	Toe undermined/ flanked/ overtopped	Rebuild	6/76	Caused beach accretion
Other	4N	23E	34	22	35	99	53	12	Stone/wire	Functional	None	None	6/76	Four small stone-filled gabions
Groin	4N	23E	34	15	15	--	64	116	Poured concrete	Functional	Overtopped	Minor	6/76	--
Groin	4N	23E	34	18	25	99	44	55	Stone	Functional	Overtopped/ flanked/ collapsed	Rebuild	6/76	Caused some sand accretion
Groin	4N	23E	34	--	--	95	62	98	Stone/poured concrete	Functional	Overtopped/ collapsed	Major	6/76	East end eroded and collapsed
Bulkhead	4N	23E	34	16	10	95	10	625	Stone	Functional	None	None	6/76	--
Groin	4N	23E	34	18	15	95	10	40	Stone	Nonfunctional	Overtopped/ flanked/ collapsed	Rebuild	6/76	--
Groin	4N	23E	34	20	15	95	15	115	Stone	Functional	Overtopped/ flanked	Minor	6/76	Accretion of sand and gravel
Bulkhead	4N	23E	33	15	25	90	8	300	Stone	Functional	None	None	6/76	--
Other	4N	23E	33	15	13	95	--	59	Poured concrete/ other	Functional	Other	Minor	6/76	Accretion of sand on south side
Bulkhead	4N	23E	33	25	18	95	--	136	Stone	Functional	None	None	6/76	--
Groin	4N	23E	33	20	25	95	--	60	Poured concrete/ stone	Functional	None	None	6/76	Shore section is concrete

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Revetment	4N	23E	33	25	30	90	--	315	Broken concrete	Functional	Collapsed	Rebuild	6/76	Shore of broken concrete slabs
Groin	4N	23E	33	25	30	95	--	115	Poured concrete/ stone	Functional	Overtopped/ flanked/ collapsed	Major	6/76	--
Other	4N	23E	33	25	32	75	22	115	Broken concrete/ asphalt	Nonfunctional	Faulty material/ collapsed overtopped	Rebuild	6/76	Pile of debris
Other	4N	23E	33	25	32	75	5	55	Broken concrete/ asphalt	Nonfunctional	Overtopped/ flanked/ collapsed	Rebuild	6/76	Debris strewn randomly
Groin	4N	23E	32	20	27	90	29	85	Stone	Functional	Overtopped	Major	6/76	--
Bulkhead	4N	23E	33	20	26	90	36	150	Poured concrete	Functional	Flanked	None	6/76	Has outside nine-foot buttresses
Groin	4N	23E	33	20	26	90	36	52	Stone	Functional	None	Major	6/76	--
Groin	4N	23E	33	20	25	95	35	80	Stone	Functional	None	None	6/76	Substantial dolomite block groin
Groin	4N	23E	33	18	20	60	26	70	Poured concrete	Functional	Overtopped/ flanked/ other	Major	6/76	Slight erosion on both ends
Revetment	4N	23E	33	18	20	95	10	135	Broken concrete	Nonfunctional	Overtopped/ flanked collapsed	Rebuild	6/76	Bluff erosion is occurring
Groin	4N	23E	33	18	20	95	10	100	Poured concrete	Functional	Other	Minor	6/76	Is fairly strong and effective
Revetment	4N	23E	33	25	24	95	--	48	Broken concrete	Functional	Faulty material/ flanked/ overtopped	Rebuild	6/76	--
Groin	4N	23E	33	25	24	95	10	35	Stone	Nonfunctional	Overtopped/ flanked	Rebuild	6/76	Back area eroding at toe
Groin	4N	23E	33	25	25	95	21	120	Stone/poured concrete	Functional	None	None	6/76	--
Bulkhead	4N	23E	33	25	29	95	15	110	Poured concrete	Functional	Other	Minor	6/76	Bluff is very stable
Groin	4N	23E	33	25	29	95	20	80	Stone	Functional	Overtopped	None	6/76	--
Groin	4N	23E	33	25	28	95	15	75	Stone	Functional	None	None	6/76	--
Bulkhead	4N	23E	33	30	30	95	10	110	Poured concrete	Functional	None	None	6/76	Five-foot thick bulkhead
Groin	4N	23E	33	25	28	95	--	60	Stone/poured concrete	Functional	None	Major	6/76	Dolomite block extension into lake
Bulkhead	4N	23E	33	30	25	95	8	100	Poured concrete	Functional	None	Minor	6/76	Erosion on south end of wall
Groin	4N	23E	33	30	25	95	8	65	Stone/poured concrete	Functional	Overtopped	Minor	6/76	More stone needed
Bulkhead	4N	23E	33	30	25	95	5	105	Poured concrete	Functional	Overtopped	None	6/76	--
Groin	4N	23E	33	30	33	95	5	65	Poured concrete	Functional	None	None	6/76	--
Revetment	4N	23E	33	30	30	95	--	130	Stone	Functional	Toe undermined/ flanked	None	6/76	Some erosion in back of structure
Bulkhead	4N	23E	33	25	39	60	15	35	Poured concrete	Functional	None	None	6/76	Riprap on bluff slope
Other	4N	23E	33	25	25	80	10	60	Stone/broken concrete	Nonfunctional	Toe undermined/ flanked/ overtopped	Rebuild	6/76	--

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Groin	4N	23E	33	28	32	95	5	75	Poured concrete	Failing	Collapsed	Rebuild	6/76	Permeable groin of concrete
Groin	4N	23E	33	30	28	95	5	50	Stone	Nonfunctional	Overtopped/ flanked	Rebuild	6/76	Erosion has removed seaward end
Groin	4N	23E	33	25	33	95	17	65	Stone	Failing	Overtopped/ flanked	Minor	6/76	Should add dolomite to flank area
Groin	4N	23E	33	25	25	75	5	45	Stone	Failing	Toe undermined/ flanked/ overtopped	Rebuild	6/76	Considerable erosion by bluff slumping
Groin	4N	23E	33	25	28	95	15	120	Stone/poured concrete	Functional	Toe undermined/ flanked	Major	6/76	--
Groin	4N	23E	33	25	25	95	17	35	Stone	Failing	Overtopped/ other	Rebuild	6/76	Bluff slumping behind beach
Bulkhead	4N	23E	33	25	25	95	--	160	Poured concrete	Functional	None	None	6/76	Two-foot thick wall
Groin	4N	23E	33	30	35	95	--	60	Stone	Failing	Overtopped/ flanked	Major	6/76	Needs more height
Other	4N	23E	33	30	35	10	--	60	Broken concrete	Nonfunctional	Other	None	6/76	Dangerous, falling concrete
Revetment	3N	23E	21	40	30	90	--	1,200	Stone	Functional	None	None	6/76	Large dolomite revetment
Bulkhead	3N	23E	21	38	16	5	--	500	Steel/broken concrete	Functional	Overtopped	None	6/76	Bluff has been graded
Bulkhead	3N	23E	21	40	20	--	--	1,450	Stone/steel	Functional	Overtopped	None	6/76	Protects sewage treatment plant
Revetment	3N	23E	21	45	25	90	--	165	Stone	Failing	Overtopped/ flanked	Rebuild	6/76	Poorly constructed
Revetment	3N	23E	21	45	8	95	--	1,200	Stone	Functional	Overtopped	Minor	6/76	Some bluff erosion occurring
Bulkhead	3N	23E	28	--	--	--	--	120	Steel/poured concrete	Functional	None	None	6/76	Iron bulkhead-- J. I. Case Plant
Other	3N	23E	28	--	--	--	--	80	Stone	Functional	None	None	6/76	--
Bulkhead	3N	23E	28	--	--	--	--	175	Steel	Functional	None	None	6/76	No beach
Revetment	3N	23E	28	25	18	80	--	1,400	Dolomite block	Functional	Overtopped	None	6/76	Overtopped by high water
Breakwater	3N	23E	28	35	36	20	--	200	Stone/timber	Nonfunctional	Other	Rebuild	6/76	Old wooden pilings
Other	3N	23E	28	35	35	20	--	90	Other	Functional	Overtopped/ flanked	None	6/76	Pile of slag on bluff toe
Other	3N	23E	28	36	41	5	5	158	Broken concrete/ asphalt	Nonfunctional	Toe undermined/ flanked/ overtopped	Rebuild	6/76	--
Revetment	3N	23E	28	35	34	20	--	170	Stone/broken concrete	Failing	Faulty material/ other	Minor	7/76	Poorly constructed
Bulkhead	3N	23E	28	35	34	50	--	88	Poured concrete	Nonfunctional	Overtopped/ flanked/ other	Rebuild	7/76	In six sections, spaced apart
Revetment	3N	23E	28	35	35	--	--	425	Stone/broken concrete	Nonfunctional	Overtopped/ flanked/ collapsed	Rebuild	7/76	Severe bluff erosion, dangerous
Groin	3N	23E	28	38	37	80	8	65	Stone	Functional	Overtopped/ collapsed	Minor	7/76	Eroded considerably on lake end
Revetment	3N	23E	28	38	35	80	--	400	Stone/broken concrete	Functional	Overtopped/ flanked	Rebuild	7/76	Randomly piled debris

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Other	3N	23E	28	38	37	--	--	120	Stone/broken concrete	Nonfunctional	Faulty material/ other	Rebuild	7/76	Debris piled on bluff slope
Revetment	3N	23E	28	38	35	50	--	264	Stone/wire	Functional	None	None	7/76	--
Revetment	3N	23E	28	38	37	--	--	800	Stone/broken concrete	Functional	None	Minor	7/76	--
Other	3N	23E	28	38	35	40	--	130	Poured and broken concrete	Failing	Faulty material/ flanked/ overtopped	Rebuild	7/76	Four-foot diameter concrete cylinders
Other	3N	23E	28	38	35	--	--	130	Stone/broken concrete	Nonfunctional	Flanked/ faulty material	Rebuild	7/76	Debris strewn on slope
Bulkhead	3N	23E	28	38	35	--	--	--	Stone	Functional	Other	None	7/76	--
Revetment	3N	23E	28	35	35	--	--	--	Stone/broken concrete	Failing	Overtopped/ faulty material/ other	Rebuild	7/76	Material piled along shore
Groin	3N	23E	29	38	35	--	--	75	Stone/timber	Nonfunctional	Collapsed	Rebuild	7/76	--
Revetment	3N	23E	29	35	35	--	--	60	Stone/broken concrete	Functional	Overtopped	Rebuild	7/76	--
Groin	3N	23E	29	38	35	--	--	30	Stone	Functional	None	None	7/76	New structure
Revetment	3N	23E	29	38	35	80	5	175	Stone/steel	Nonfunctional	Overtopped	Rebuild	7/76	--
Groin	3N	23E	29	38	39	50	18	55	Stone	Functional	Overtopped/ other	Major	7/76	Failing by slide, flow, and slump
Revetment	3N	23E	29	38	39	80	5	90	Stone/broken concrete	Nonfunctional	Overtopped/ flanked/ collapsed	Rebuild	7/76	--
Groin	3N	23E	29	38	38	80	--	45	Broken and poured concrete	Failing	Overtopped/ flanked/ collapsed	Rebuild	7/76	Needs reinforcement
Revetment	3N	23E	29	38	39	80	12	110	Broken concrete	Nonfunctional	Overtopped/ flanked collapsed	Rebuild	7/76	--
Groin	3N	23E	32	38	35	95	--	60	Stone/broken concrete	Functional	Overtopped	Minor	7/76	--
Revetment	3N	23E	32	38	38	95	--	250	Stone/other	Functional	Faulty material/ flanked overtopped	Rebuild	7/76	--
Revetment	3N	23E	32	38	35	5	--	300	Stone/broken concrete	Failing	Faulty material	Rebuild	7/76	Dangerous pile of concrete
Bulkhead	3N	23E	32	38	38	--	--	650	Stone	--	--	--	7/76	Bluff failing by slump and slide
Revetment	3N	23E	32	38	37	90	--	70	Stone/broken concrete	Functional	Faulty material/ flanked/ overtopped	Rebuild	7/76	Dangerous, unsightly, ineffective
Groin	3N	23E	32	37	32	50	15	60	Stone	Functional	Overtopped/ flanked	Rebuild	7/76	Could use additional blocks
Revetment	3N	23E	32	37	32	90	10	130	Stone/broken concrete	Nonfunctional	Faulty material/ flanked/ overtopped	Rebuild	7/76	Too small to be effective
Groin	3N	23E	32	37	35	25	7	50	Stone	Functional	Other	Rebuild	7/76	Needs to be higher
Revetment	3N	23E	32	38	35	20	--	200	Stone/broken concrete	Failing	Faulty material	Major	7/76	Bluff failing by slump and slide

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Groin	3N	23E	32	36	35	75	10	55	Stone/tires	Functional	Other	Major	7/76	--
Bulkhead	3N	23E	32	38	36	60	--	30	Stone	Functional	None	Minor	7/76	--
Revetment	3N	23E	32	30	39	90	17	72	Stone	Failing	Flanked/ overtopped	Rebuild	7/76	--
Groin	3N	23E	32	30	25	90	21	100	Stone	Functional	None	Minor	7/76	Considerable accretion at south end
Groin	3N	23E	32	30	25	95	20	90	Stone	Functional	Collapsed/ other	Major	7/76	--
Groin	3N	23E	32	30	25	95	37	150	Poured concrete	Functional	Other	Minor	7/76	Erosion at south end of structure
Revetment	3N	23E	32	30	25	95	--	225	Concrete	Functional	Overtopped/ flanked	Major	7/76	--
Groin	3N	23E	32	30	38	25	--	50	Stone	Functional	None	Minor	7/76	--
Revetment	3N	23E	32	30	40	20	10	58	Steel/broken concrete	Nonfunctional	Faulty material/ collapsed	Rebuild	7/76	Dangerous pipes, twisted iron
Groin	3N	23E	32	30	40	60	15	75	Poured concrete	Functional	Other	Major	7/76	Bluff failing by slump, slide, and flow
Revetment	3N	23E	32	28	22	95	28	40	Stone	Nonfunctional	Overtopped/ flanked other	Rebuild	7/76	--
Groin	3N	23E	32	28	32	90	40	65	Stone	Functional	None	Mionr	7/76	Bluff fairly stable
Groin	3N	23E	32	30	32	95	25	75	Stone	Functional	None	Minor	7/76	Accretion to north, erosion to south
Revetment	3N	23E	32	30	35	80	5	180	Stone	Nonfunctional	Overtopped/ flanked	Rebuild	7/76	Bluff failing considerably
Groin	3N	23E	32	30	52	--	5	80	Steel/poured concrete	Nonfunctional	Other	Rebuild	7/76	Very severely eroded area
Revetment	3N	23E	32	30	52	--	5	211	Stone/poured concrete	Nonfunctional	None	None	7/76	Submerged
Revetment	3N	23E	32	30	32	--	--	240	Stone	Functional	None	Minor	7/76	New large seawall
Other	3N	23E	32	30	32	--	--	320	Stone/broken concrete	Nonfunctional	None	None	7/76	Dangerous pile of concrete and iron
Revetment	3N	23E	32	28	42	10	10	185	Broken concrete/ asphalt	Nonfunctional	Faulty material/ flanked/ overtopped	Rebuild	7/76	Bluff failing by large slumps
Other	3N	23E	32	28	40	10	--	120	Broken concrete/ asphalt	Nonfunctional	None	Rebuild	7/76	Bluff failing by slump and slide
Groin	3N	23E	32	28	32	40	40	65	Stone/poured concrete	Functional	Other	Major	7/76	Boathouse with dolomite groin
Bulkhead	3N	23E	32	22	35	90	25	60	Poured concrete	Functional	None	None	7/76	Bulkhead mostly buried in beach gravel
Revetment	3N	23E	32	15	13	95	25	150	Stone	Functional	Overtopped/ flanked	Major	7/76	--
Groin	3N	23E	32	15	13	90	26	60	Stone	Functional	Other	Minor	7/76	Substantial beach to north and south
Groin	3N	23E	32	25	25	80	33	75	Stone/poured concrete	Functional	None	Minor	7/76	Concrete reinforced with dolomite
Bulkhead	3N	23E	32	25	25	85	10	200	Stone/other	Functional	Overtopped	Minor	7/76	--
Groin	3N	23E	32	25	25	50	--	65	Stone	Functional	None	Minor	7/76	Considerable slumping to south

Appendix A (continued)

Structure Type	U. S. Public Land Survey Location			Physical Setting				Length of Structure (feet)	Material Composition of Structure	Condition of Structure	Types of Failure	Maintenance Required	Date Inventoried	Comments
	Township	Range	Section	Bluff Height (feet)	Bluff Slope (degrees)	Percent of Bluff Vegetated	Beach Width (feet)							
Groin	3N	23E	32	20	25	10	--	60	Stone/poured concrete	Functional	None	Minor	7/76	Concrete reinforced with dolomite
Revetment	4N	23E	16	30	34	--	20	146	Stone	--	--	--	1/78	Placed landward of existing riprap
Revetment	3N	23E	28	30	29	--	--	115	Broken concrete	--	--	--	9/78	Bluff graded and filled
Groin	4N	23E	16	30	31	--	--	60	Stone	--	--	--	11/78	First of a series at 100-foot intervals
Groin	4N	23E	16	30	31	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	30	31	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	30	31	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	28	29	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	25	27	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	24	26	--	--	60	Stone	--	--	--	11/78	Part of series
Groin	4N	23E	16	26	27	--	--	60	Stone	--	--	--	11/78	Last of series
Revetment	4N	23E	21	30	29	--	--	760	Stone	--	--	--	12/77	--
Groin	4N	23E	21	30	29	--	--	50	Stone	--	--	--	12/77	First of a series
Groin	4N	23E	21	30	29	--	--	50	Stone	--	--	--	12/77	Part of series
Groin	4N	23E	21	30	29	--	--	50	Stone	--	--	--	12/77	Part of series
Groin	4N	23E	21	30	29	--	--	50	Stone	--	--	--	12/77	Part of series
Groin	4N	23E	21	30	29	--	--	50	Stone	--	--	--	12/77	Last of series
Bulkhead	4N	23E	8	5	4	--	--	160	Stone	--	--	--	12/79	For nearby urban development
Revetment	4N	23E	6	80	39	--	--	1,200	Stone	--	--	--	4/80	Large chunks of riprap
Bulkhead	4N	23E	16	25	16	--	--	110	Stone	--	--	--	6/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	First in a series
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	Good design
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	Good design
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	t0	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--
Revetment	3N	23E	29	60	41	--	--	60	Stone	--	--	--	9/80	--

Source: Wisconsin Department of Natural Resources, Wisconsin Coastal Management Program, and SEWRPC.

Appendix B

METHODS OF BLUFF RECESSION MEASUREMENT

INTRODUCTION

For the purposes of the Racine County Lake Michigan coastal erosion study, shoreline erosion and bluff recession were estimated by measuring the change in the location of the edge of the bluff along the Lake Michigan shoreline, as shown on topographic maps or aerial photographs, over a specified time period. Bluff recession rates presented in this report were estimated by Keillor-DeGroot,[1] Schneider, et al.,[2] and the Southeastern Wisconsin Regional Planning Commission. All measured recession distances were converted to annual recession rates by dividing by the measured recession period.

KEILLOR-DEGROOT

Bluff recession rates as reported by Keillor-DeGroot were measured from large-scale topographic maps prepared for Racine County by the firm of Alster and Associates, Inc., Madison, Wisconsin, to standards and specifications promulgated and prepared by the Southeastern Wisconsin Regional Planning Commission. These maps have a scale of 1:2400 (1" = 200'), and a vertical contour interval of two feet. One set of maps was compiled from aerial photography taken at several different times from April 4, 1968, through December 1, 1971. A second set of maps was compiled from aerial photography taken in 1976. The maps are based upon a monumented control survey network and meet National Map Accuracy Standards. The control survey network combined the U. S. Public Land Survey system with the Wisconsin State Plane Coordinate System so that cadastral and earth science data shown on the maps would be precisely and accurately correlated, a characteristic of the maps that is important to this study. The two sets of maps permitted the use of comparative measurements for determining the recession which had occurred during the given time intervals. Measurements were made at 101 locations by determining the distance from the bluff edge to a stationary landmark.

The maps sets were reproduced on translucent polyester film with a 0.1 inch interval grid system placed beneath the maps to facilitate the measurements. Each map set was oriented with its south U. S. Public Land Survey section or quarter section line parallel to and coincident with a lateral line on the grid system. Measurements were made along these grid lines and, therefore, were parallel to the south section or quarter section line.

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[1]J. P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 2, Appendix, March 1, 1978.

[2]A. F. Schneider, et al., Shore Erosion Study Technical Report, Appendix 1 and Appendix 2, February 1977.

Measurements were made with a glass scale (a Bausch and Lomb Microline Super Gage) graduated to 0.001 inch. A 40-power microscope mounted on the instrument allowed accurate reading of the scale. Mounted on the 40-power microscope was a 10-power spotting microscope which was used for precise location of the measurement sites.

Bluff edge recession was defined as the linear retreat measured perpendicular to the bluff edge. Since the majority of measurements were not made perpendicular to the bluff edge, a correction factor was used to standardize the measurements. The acute angle between the bluff edge and the measurement line was determined. The measured recession rate multiplied by the sine of the angle gave the corrected recession rate; that is, the recession rate perpendicular to the bluff edge.

An analysis of the error which could have occurred during the bluff recession measurement procedure applied by Keillor-DeGroot identified seven sources of possible error:

1. Instrument accuracy,
2. Operator error,
3. Map reproduction,
4. Cartographic procedures,
5. Bluff edge location,
6. Obscured bluff edge, and
7. Human intervention or modification of the bluff.

Instrument accuracy, operator error, and map reproduction were found to produce a very small (+0.05 percent) error and were not considered of major concern. An obscured bluff edge and human modification of the bluff could cause inconsistencies in the recession measurements, but these factors are readily identified. Cartographic procedures and the proper location of the bluff edge were found to be a potential source of substantial error, with the maximum error probable for any measured recession rate being + 0.8 feet per year.

SCHNEIDER, ET AL

Both long-term and short-term bluff recession rates were reported by Schneider, et al. The long-term erosion rates were developed from a variety of sources of data--including the original U. S. Public Land Survey notes and maps--by the U. S. Army Corps of Engineers. Short-term recession rates were measured from aerial photographs at a scale of 1:12000 (1" = 1000') to 1:20000 (1" =1667') that were taken over a period of 10 to 15 years. The measurements were made by plotting shoreline positions from the older photograph onto the most recent photograph and measuring the distance of recession with a Bausch and Lomb Microline Super Gage. Recession distances were measured on the maps to the nearest 0.0005 inch.

REGIONAL PLANNING COMMISSION

The Regional Planning Commission measured bluff recession for the period of 1963 through 1980, and for 1975 through 1980. Measurements were made on ratioed and rectified aerial photographs having a scale of 1" = 400' and 1" = 2000'.

The distance from a stationary landmark nearest to the Keillor-DeGroot measurement sites to the bluff edge was determined on each set of photographs. On the photographs having a scale of 1" = 400', measurements to the nearest 1/60th of an inch were made using an engineering scale and a magnifying lens. On the photographs having a scale of 1" = 2000', measurements were made with a glass scale graduated to 0.001 inch (a Bausch and Lomb Microline Super Gage). A 40-power microscope mounted on the instrument allowed accurate reading of the scale. All measurements were made parallel to the south section or quarter section line. These measurements were corrected, using the same procedure applied by Keillor-DeGroot, to calculate the bluff recession rate perpendicular to the bluff edge.

The aerial photographs were corrected for tilt and vertical distortion by the ratio and rectification procedures. However, minor variations in scale and relief displacement errors occurred on the maps. Therefore, minor variations in scale were corrected by determining the exact scale of the map within each coastal erosion analysis reach. Exact scale was determined by comparing the distance between two known points on the map to the same distance as measured on a large-scale (1" = 200') topographic map. Relief displacement errors could be significant if the elevation of the top edge of the bluff changed by more than six meters (approximately 19.7 feet) over the measurement period.[3] However, the change in the elevation of the bluff edge was found to be very minor, generally less than four feet. Consequently, relief displacement errors are not significant. Other errors related to instrument use, operator procedures, and cartogrpahic procedures would be similar to those analyzed byKeillor-DeGroot.

[3]C. H. Everts and D. C. Wilson, Base Map Analysis of Coastal Changes Using Aerial Photography, U. S. Army Corps of Engineers. Technical Paper No. 81-4, November 1981.

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Appendix C

GLOSSARY OF SHORELINE EROSION-RELATED TERMS

BEACH: An area of unconsolidated material which extends landward from the ordinary low-water line to the line marking a distinct change in physiographic form or the beginning of permanent terrestrial vegetation.

BLUFF: A high, steep bank or cliff located to the landward side of a beach.

BLUFF RECESSION RATE: The rate at which the bluff recedes because of erosion by the water body and because of unstable slope conditions.

BREAKWATER: An offshore barrier which breaks the force of waves and provides shelter from wave action.

BULKHEAD: A structure of wood, stone, concrete, or steel erected along and parallel to a portion of a shoreline primarily to prevent erosion and other damage by wave action. Also called a seawall.

FLANKING: A cause of failure of shore protection structures where the sides of the structure are eroded by wave action.

GROIN: A structure projecting outward from the shore designed to protect the shore from erosion and to arrest sand movement along the shore, thereby encouraging the formation of increased beach widths.

GROSS STABLE SLOPE DISTANCE: The total horizontal distance of a bluff with a stable slope. In Racine County, a stable bluff slope along the Lake Michigan shoreline may be assumed to have an angle with the horizonal of approximately 22°. This bluff slope would result in a gross stable slope distance which is about two and one-half times the bluff height.

GROUNDWATER SEEPAGE: The movement of water--through cracks, pores, and interstices--out of a material body. Groundwater seepage from bluff faces may decrease the grain-to-grain contact pressure in the soil, reduce the frictional resistance of the soil to stress, and add weight to the bluff. Groundwater seepage may result in soil flow.

HYDROLOGIC SOIL GROUP: A soil classification system based on soil infiltration capacity, permeability, and drainage. Well-drained soils may have higher levels of groundwater seepage, which contribute to bluff slope instability. Poorly-drained soils generate higher levels of surface water runoff which increase surface soil erosion.

INTERMITTENT STREAMS: A stream that flows only in direct response to precipitation, and the channel of which may be dry during portions of the year.

LONGSHORE CURRENTS: Water currents running generally parallel to the shoreline and usually caused by waves breaking at an angle to the shoreline. Longshore currents transport sediment parallel to the shore.

NET STABLE SLOPE DISTANCE: The gross stable slope distance minus the existing horizontal distance of the bluff slope. It represents the distance that the top of the bluff would need to recede, or be regraded, to form a stable bluff slope which would not likely be affected by major bluff recession processes such as slumping or sliding.

NONSTRUCTURAL EROSION RISK DISTANCE (RACINE COUNTY): The distance from the existing bluff edge which is expected to be affected by continued bluff recession, or by regrading of the bluff face to a stable slope (the net stable slope distance). This distance applies to those shoreline areas which are not protected, or planned to be protected, by shore protection structures.

NONSTRUCTURAL SETBACK OVERLAY DISTRICT DISTANCE (RACINE COUNTY): For Lake Michigan shoreland areas not recommended to be protected by properly designed, constructed, and maintained shore protection structures, the distance from the existing bluff edge which is expected to be affected by shoreline erosion and bluff recession over a 50-year period, or by regrading of the bluff slope as needed to achieve a stable slope. The nonstructural setback distance also includes a minimum facility setback distance.

OVERTOPPING: A condition where the water level, or wave heights, exceed the top of a shore protection structure. Overtopping can remove small particles from the foundation of a structure thereby weakening that foundation.

PERENNIAL STREAMS: A stream which flows continuously at all seasons of the year. Perennial streams are usually fed by groundwater.

PHREATIC: The upper boundary of the water table in soils, which may contribute to springs, seeps, and wells.

REVETMENT: A facing of stone, concrete, or other material placed to protect a shore from erosion by wave action.

RILL AND GULLY FLOW: The concentrated, channelized flow of water over the soil surface during and following a rainfall.

SEAWALL: A structure of wood, stone, concrete, or steel erected along and parallel to a portion of a shoreline primarily to prevent erosion and other damage from wave action. Also called a bulkhead.

SHEAR STRENGTH: The greatest shear stress which can be resisted by a material.

SHEAR STRESS: The tendency of adjacent soil particles, when under stress, to slide past each other. When shear stress exceeds shear strength, the slope becomes unstable.

SHEETWASH: The unconfined flow of water over the soil surface during and following a rainfall.

SHORE PROTECTION STRUCTURES: Structures which are intended to reduce shoreline erosion and bluff recession by providing an artificial protective barrier against direct wave and ice attacks on the beach and bluff toe, by increasing

the extent of the beach available to absorb wave energy before the water reaches the bluff, by dissipating wave energy, and/or by stabilizing the bluff slope. Shore protection structures include bulkheads or seawalls, revetments, groins, breakwater, and slope stabilization measures.

SLIDING: A type of slope failure where material moves along a single slide plane.

SLUMPING: A type of rapid slope failure where a fairly large soil mass slides on a curved surface, usually rotating so that the top of the slump block is tilted back and toward the slope.

SOIL FLOW: A type of slope failure where the soil becomes saturated with water and the soil mass actually liquifies and moves like a fluid. Flows may be caused by surface water runoff, groundwater seepages, and the melting of intergranular ice.

SOLIFLUCTION: Soil flow resulting from freeze and thaw activity which saturates the soil and reduces shear strength.

STRUCTURAL EROSION RISK DISTANCE (RACINE COUNTY): The distance from the existing bluff which is expected to be affected by regrading the bluff to a stable slope (the net stable slope distance). This distance applies to those shoreline areas which are protected, or planned to be protected, by shore protection structures.

STRUCTURAL SETBACK OVERLAY DISTRICT DISTANCE (RACINE COUNTY): For Lake Michigan shoreland areas recommended to be protected by properly designed, constructed, and maintained shore protection structures, the distance from the existing bluff edge which would be lost by regrading the bluff slope as needed to achieve a stable slope. The structural setback distance also includes a minimum facility setback distance.

WAVE REFRACTION: The bending of waves near the shoreline due to variations in the water depth.

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Appendix D

SUGGESTED AMENDMENTS TO THE RACINE COUNTY ZONING ORDINANCE TO INCORPORATE SPECIAL REGULATIONS FOR EROSION RISK SETBACK DISTANCES ALONG THE LAKE MICHIGAN SHORELINE

1. Repeal and recreate Section 7.016 to read as follows:

7.016 Severability and Nonliability

If any section, clause, provision, or portion of this Ordinance is adjudged unconstitutional or invalid by a Court of competent jurisdiction, the remainder of this Ordinance shall not be affected thereby.

The County does not guarantee, warrant, or represent that only those areas designated as floodlands will be subject to periodic inundation and hereby asserts that there is no liability on the part of the County Board of Supervisors, its agencies, or employees for any flood damages that may occur as a result of reliance upon, and conformance with, this Ordinance.

The nonstructural setback distance provisions for the Lake Michigan shoreland are considered the minimum reasonable requirements necessary to reduce bluff recession damages to facilities for an anticipated 50-year hazard period. These requirements are based upon engineering, geological, and other scientific studies and principles. Higher rates of erosion may occur. Erosion rates may be increased by natural causes such as major storms or high lake levels or by man-made causes such as construction activities. Similarly, compliance with the structural setback distances set forth in this Ordinance is assumed to provide reasonable protection from further bluff recession if the shore protection structures are properly designed, constructed, and maintained. However, even proper protection structures meeting all of the required criteria may fail during major storm events or other natural occurrences.

These regulations do not guarantee or warrant that development in compliance with its terms will be protected from all erosion damage. Reliance on these regulations shall not create liability on the part of the County Board of Supervisors, its agencies, or employees for any erosion damages that may occur as a result of reliance upon, and conformance with, this Ordinance.

2. Repeal and recreate Section 7.028 to read as follows:

7.028 Shoreland Regulations

In addition to any other applicable use, site, or sanitary regulations, the following restrictions, and regulations shall apply to shorelands:

Tree cutting and shrubbery clearing are prohibited except for home and park site development, access roads, customary trimming, dead tree removal, stream and drainage projects approved by the County Land Use Committee, and managed timber harvesting under a state district forester's plan within the following distance from high-water elevation:

Lakes 50 acres or more in area	300 feet
Lakes less than 50 acres in area	200 feet
Navigable streams	100 feet
All other streams	50 feet

Within the Lake Michigan shoreland area, such tree cutting and shrubbery clearing, except for the permitted uses noted above, shall be prohibited within the Structural Setback Overlay District and the Nonstructural Setback Overlay District, as defined in Section 7.031.

Site, road (except roads used primarily for agricultural purposes), path, and trail development and all other cutting and trimming within the shoreland area may be conditional uses requiring review, public hearing, and approval by the County Land Use Committee or may be subject to review and approval by the Zoning Administrator in accordance with Section 7.040 of this Ordinance.

Earth movements and soil disturbance activities such as grading, topsoil removal, filling, road cutting, construction, altering, or enlargement of waterways, removal of stream or lakebed material, excavation, channel clearing, ditching, dredging, lagooning, and soil and water conservation structures may be conditional uses requiring review, public hearing, and approval by the County Land Use Committee or may be subject to review and approval by the Zoning Administrator in accordance with Section 7.040 of this Ordinance, in addition to the permit required from the state agency having jurisdiction under Sections 30.11, 30.12, 30.19, 30.195, and 30.20 of the Wisconsin Statutes.

All structures, except public utilities; public recreation facilities; one-family dwellings in the R-1, R-2, R-3, and R-8 Residential Districts; and all structures in the B-6 Business District, shall be not closer than the following distances from the high-water elevation:

Lakes 50 acres or more in area	300 feet
Lakes less than 50 acres in area	200 feet
Navigable streams	100 feet
All other streams	50 feet

Within the Lake Michigan shoreland area, the construction of new permanent residential, institutional, commercial, industrial, agricultural, and transportation structures is prohibited within the SSO Structural Setback Overlay District and the NSO Nonstructural Setback Overlay District, as defined in Section 7.031.

Within the NSO Nonstructural Setback Overlay District, relocatable structures may be allowed as a conditional use provided that, 1) the property extends sufficiently outside the NSO Nonstructural Setback Overlay District so that the structure can be relocated outside the NSO District in the future, and 2) the structure is certified by a professional building moving contractor as being relocatable at a cost not exceeding 30 percent of the estimated equalized value of the structure. This conditional use requires review, public hearing, and approval by the County Land Use Committee or may be subject to review and approval by the Zoning Administrator in accordance with Section 7.040 of this Ordinance. Relocatable structures are not allowed as conditional uses within the SSO Structural Setback Overlay District.

Grazing, livestock watering and feeding, and application of fertilizers shall be prohibited unless conducted in accordance with the County's Conservation Standards, as such standards are formulated and adopted by the County Land Use Committee.

Where State Statutes (Section 30.18, 144.025(2) and 144.555) require a state permit for surface waters withdrawal, diversion or discharge for irrigation, processing, cooling or any other purpose, then such activities may be a conditional use requiring review, public hearing and approval by the County Land Use Committee or may be subject to review and approval by the Zoning Administrator in accordance with Section 7.040 of this Ordinance. The County Land Use Committee shall advise the state agency having jurisdiction of the results of the public hearing or the Zoning Administrator's review and whether the conditional use was approved.

In order to help prevent and control further erosion and consequent sedimentation of the surface waters of Racine County, crop production on lands that are severely eroded is prohibited, and such lands shall be planted to permanent vegetation. For the purposes of this Ordinance, all lands designated by the U. S. Soil Conservation Service as having an erosion factor of three or more, as shown on the operational soil survey maps on file with the Zoning Administrator, shall be considered as being severely eroded. An erosion factor of three means that three-fourths or more of the surface soil has been removed by erosion.

With respect to the application of this section during such time period, if any, when any Racine County town shall not have adopted this Ordinance and related zoning map, see Section 7.017 of this Ordinance.

3. Repeal and recreate Section 7.031 to read as follows:

7.031 Establishment

For the purpose of this Ordinance, the County of Racine, Wisconsin, is hereby divided into 27 basic use districts and five overlay districts, as follows:

R-1	Country Estate District
R-2	Suburban Residential District (unsewered)
R-3	Suburban Residential District (sewered)
R-3A	Suburban Residential District (sewered)
R-4	Urban Residential District I
R-5	Urban Residential District II
R-6	Two-Family Residential District
R-7	Multifamily Residential District
R-8	Planned Residential District
P-1	Institutional Park District
P-2	Recreational Park District
C-1	Resource Conservancy District
B-1	Neighborhood Business District
B-2	Community Business District
B-3	Commercial Business District
B-4	Planned Business District
B-5	Highway Business District
B-6	Water-Oriented Business District
A-1	General Farming District I
A-2	General Farming and Residential District II
A-3	General Farming District III
A-4	Truck Farming District
M-1	Light Industrial and Office District
M-2	General Industrial District
M-3	Heavy Industrial District
M-4	Quarrying District
FW	Urban Floodway District
FCO	Urban Floodplain Conservancy Overlay District
FFO	Urban Floodplain Fringe Overlay District
GFO	General Floodplain Overlay District
SSO	Structural Setback Overlay District
NSO	Nonstructural Setback Overlay District

Boundaries of these districts, except for the floodplain and structural and nonstructural setback districts, are hereby established as shown on a series of maps entitled "Zoning Maps, County of Racine, Wisconsin," dated _____ 19__, which accompany and are a part of this Ordinance. Unless otherwise noted on the zoning map, such boundaries shall be construed to follow: corporate limits; U. S. Public Land Survey lines; lot or property lines, centerlines of streets, highways, alleys, easements, and railroad rights-of-way or such lines extended. Where a C-1 Resource Conservation District is delineated on the zoning district map in a linear form along a perennial or intermittent watercourse, the district boundaries shall be construed to be the following unless otherwise noted on the zoning district map:

a. 100 feet from the ordinary high water mark of perennial streams.

b. 50 feet from the ordinary high water mark of intermittent streams.

Boundaries of the floodland zoning districts shall be determined as follows: The boundaries of the GFO General Floodplain Overlay District shall be determined through the use of flood profiles published in the Flood Insurance Study--Racine County, Wisconsin Unincorporated Areas by the Federal Emergency Management Agency (FEMA), Flood Insurance Administration and dated October 1, 1981. The information contained in the flood insurance study is further illustrated on the FEMA Flood Insurance Rate Maps and Floodway and Flood Boundary Maps, dated April 1, 1982, and the boundaries are depicted on the large scale topographic mapping of Racine County. The boundaries of the FW Urban Floodway District shall be determined by use of the scale contained on the "Supplementary Floodland Zoning Map, County of Racine, Wisconsin," dated April 1, 1982, which accompanies and is made a part of the Ordinance. The boundaries of the FCO Urban Floodplain Conservancy Overlay District and the FFO Urban Floodplain Fringe Overlay District shall be determined by the floodland limits shown on the Supplementary Floodland Zoning Map. Where a conflict exists between the floodland limits as shown on the map and actual field conditions, the elevations from the 100-year recurrence interval flood profiles contained in the Flood Insurance Study shall be the governing factor in locating the regulatory floodland limits.

Vacation of public streets and alleys shall cause the land vacated to be automatically placed in the same district as the abutting side to which the vacated land reverts.

Boundaries of the structural and nonstructural setback overlay districts shall be determined as follows. The boundaries of the SSO Structural Setback Overlay District shall be determined through the use of the following equation establishing a setback distance from the existing Lake Michigan bluff edge:

$$\begin{bmatrix}\text{SSO Structural Setback}\\ \text{Overlay District Distance}\end{bmatrix} = \begin{bmatrix}\text{Horizontal distance required to achieve}\\ \text{one on two and one-half stable bluff slope}\end{bmatrix} + \begin{bmatrix}\text{Minimum facility}\\ \text{setback distance}\end{bmatrix}$$

The stable slope distance and the minimum facility setback distance are described in Section 7.0310.

The boundaries of the NSO Nonstructural Setback Overlay District shall be determined through the use of the following equation establishing a setback distance from the existing Lake Michigan bluff edge:

$$\begin{bmatrix}\text{NSO Nonstructural Setback}\\ \text{Overlay District Distance}\end{bmatrix} = \begin{bmatrix}\text{Horizontal distance required to achieve}\\ \text{a one and two and one-half stable bluff slope}\end{bmatrix} + \begin{bmatrix}\text{(Average annual bluff}\\ \text{recession rate x 50 years)}\end{bmatrix} + \begin{bmatrix}\text{Minimum facility}\\ \text{setback distance}\end{bmatrix}$$

4. Create Section 7.0310 to read as follows:

7.0310 Structural and Nonstructural Setback Overlay Districts

SSO Structural Setback Overlay District

The SSO Structural Setback Overlay District is intended to be used to protect people and property from shore erosion damage in Lake Michigan shoreland areas which are recommended

to be protected by properly designed, constructed, and maintained shore protection structures. This overlay district applies to those Lake Michigan shoreline areas which are located south of the northern one-half of Township 4 North, Range 23 East, Section 8, in the Towns of Caledonia and Mt. Pleasant. In addition, the SSO district applies to the northernmost 1,300 feet of Lake Michigan shoreline in Section 6 of the Town of Caledonia, Township 4 North, Range 23 East, which is covered by fly ash deposits. All new development within this overlay district shall be adequately protected by properly designed, constructed, and maintained shore protection structures or measures. Such structural protection measures shall meet the criteria established in Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards to the Racine County Land Use Committee, 1982. In delineating the SSO district, the required recession or regrading of the bluff needed to form a stable slope, plus a minimum facility setback distance, shall be computed. The provision of the stable slope provides protection against further major bluff recession, as long as the shore protective structures are effective. This stable slope distance is measured from the existing bluff edge. The minimum facility setback distance is then measured from the edge of the regraded bluff needed to form a stable slope. The minimum facility setback distance provides a safety factor against possible failure of the protective structures during extreme storm events or other natural occurrences, and provides a buffer area which helps protect the regarded bluff edge from excessive surface water runoff and from the potential bluff instability which could be caused by the additional weight of buildings being placed close to the bluff edge. In addition, the minimum facility setback distance provides an area which may be effectively utilized to facilitate surface water and subsurface water drainage and control.

The distance required to achieve a one on two and one-half stable slope is set forth in Table 12, page 65 of SEWRPC Community Assistance Planning Report No. 86, A Lake Michigan Coastal Erosion Management Study for Racine County, Wisconsin, and shall be used to determine the stable slope distance. Minimum facility setback distances measured from the edge of the net stable slope distance shall be as follows:

a. 200 feet for all structures except public utilities, public recreational facilities, and single-family residential units.

b. 100 feet for public utilities, public recreational facilities, and single-family residential units. The minimum setback distance shall be reduced in areas of existing facility development to the average distance

from the edge of the net stable slope distance to adjacent structures within 100 feet of the structure, although the minimum setback distance shall not be less than 50 feet from the edge of the net stable slope distance.

The calculated structural setback overlay district distance may be modified upon submittal by an applicant or property owner of acceptable engineering analyses which indicate that the required distance for a stable slope is different than as defined in SEWRPC Community Assistance Planning Report No. 86, or that the height of the bluff is different than the assumed height.

Principal Uses
Surface and subsurface water drainage and control; general farming activities, not including the erection of structures; open space; outdoor recreation; yard; storage of portable equipment and supplies; accessory buildings such as storage sheds; and minor structures such as driveways, sidewalks, patios, and fences.

Conditional Uses (See Section 7.0413)
Tree cutting and shrubbery clearing, land disturbance and earth movements, and shore protection structures.

Structures Prohibited
New, permanent or relocatable residential, institutional, commercial, industrial, and agricultural structures designed for human habitation or the confinement of animals.

NSO Nonstructural Setback Overlay District
The NSO Nonstructural Setback Overlay District is intended to be used to protect people and property from shore erosion damage in Lake Michigan shoreland areas which are not protected by properly designed, constructed, and maintained shore protection structures. This overlay district applies to those Lake Michigan shoreline areas which are located north of the southern one-half of Township 4 North, Range 23 East, Section 8, the Town of Caledonia, except for the northernmost 1,300 feet of Lake Michigan shoreline in Section 6 of the Town of Caledonia, which is covered by fly ash deposits. In delineating the NSO district, the expected bluff recession over a 50-year period, plus the required recession, or regrading of the bluff needed to form a stable slope, plus a minimum facility setback distance from the regraded bluff edge, shall be computed. The NSO district thus includes those Lake Michigan shoreline areas which, based on historical bluff recession rates, are expected to be lost due to bluff recession, and the formation of a stable slope, over a 50-year period, plus a minimum facility setback distance.

The distance required to achieve a one on two and one-half stable slope is set forth in Table 12, page 65 of SEWRPC Community Assistance Planning Report No. 86, A Lake Michigan Coastal Erosion Management Study for Racine County, Wisconsin, and shall be used to determine the stable slope distance. Minimum facility setback distances measured from the edge of the net stable slope entrance shall be as follows:

a. 200 feet for all structures except public utilities, public recreational facilities, and single-family residential units.

b. 100 feet for public utilities, public recreational facilities, and single-family residential units. The minimum setback distance shall be reduced in areas of existing facility development to the average distance from the regraded bluff edge to adjacent structures within 100 feet of the structure, although the minimum setback distance shall not be less than 50 feet from the edge of the net stable slope distance.

The calculated nonstructural setback overlay district distance may be modified upon submittal by an applicant or property owner of acceptable engineering analyses which indicate that the actual bluff recession rate is different than as set forth in SEWRPC Community Assistance Planning Report No. 86, that the required distance for a stable slope is different, or that the height of the bluff is different than the height presented in the report.

Principal Uses

General farming activities, not including the erection of structures; open space, outdoor recreation; yard; storage of portable equipment and supplies; accessory buildings such as storage sheds; and minor structures such as driveways, sidewalks, patios and fences.

Conditional Uses (See Section 7.0413)

Tree cutting and shrubbery clearing, land disturbance and earth movements, shore protection structures, and the placement of structures or buildings which may be relocated at a cost not to exceed 30 percent of the equalized value of the structure. Although shore protection structures are, in general, not recommended for this overlay district, such structures may be allowed in certain areas.

Structures Prohibited

New, permanent residential, institutional, commercial, industrial, and agricultural structures designed for human habitation or the confinement of animals.

5. Repeal and recreate Section 7.0413 to read as follows:

7.0413 Shoreland Uses

The following may be conditional uses requiring review, public hearing, and approval by the County Land Use Committee:

Tree cutting and shrubbery clearing not prohibited in Section 7.029 of this Ordinance, provided that such cutting and clearing shall not exceed thirty (30) percent of the lot or tract and shall be so regulated as to prevent erosion and sedimentation, preserve and improve scenic qualities, and during foliation substantially screen any development from stream or lake users. Paths and trails shall not exceed ten (10) feet in width and shall be so designed and constructed as to result in the least removal and disruption of shoreland cover and the minimim impairment of natural beauty.

The County Land Use Committee or the Zoning Administrator shall request a review of such tree cutting and shrubbery clearing in excess of one (1) acre by the State Department of Natural Resources and await their recommendations before taking final action but not to exceed sixty (60) days.

Earth movements, such as grading, topsoil removal, stream course changing, road cutting, waterway construction or enlargement, removal of stream or lakebed materials, excavation, channel clearing, ditching, dredging, lagooning, and soil and water conservation structures, provided that such uses are so regulated as to prevent erosion and sedimentation and to least disturb the natural fauna, flora, watercourse, water regimen, and topography.

The County Land Use Committee or the Zoning Administrator shall request a review of such earth movement by the U. S. Soil Conservation Service District Conservationist and the State District Fish and Game Manager and a review of each such cutting and clearing from the State District Forester and await their recommendations before taking final action, but not to exceed sixty (60) days of such decision.

A copy of the land use committee's or the zoning administrator's decision on such application shall be forwarded to the Department of Natural Resources and the Region 2 Water Resources Advisory Board within ten (10) days of such decision.

Shore protection structures for the Lake Michigan shoreline such as groins, revetments, breakwaters, bulkheads and piers. All such structures shall meet the criteria set forth in Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards to the Racine County Land Use Committee, 1982.

The County Land Use Committee or the Zoning Administrator shall request a review of such shore protection structures by the County Technical Subcommittee on Shoreland Development Standards and await their recommendations before taking final action, but not to exceed sixty (60) days.

The placement of relocatable structures or buildings within the NSO District.

The property owner shall submit a report from a professional building moving contractor certifying that the structure can be feasibly moved at a cost not to exceed thirty (30) percent of the equalized value of the structure. In addition, the property shall extend sufficiently outside the NSO District so that the structure can be relocated in the future outside the NSO District. Relocatable structures are not permitted within the SSO Structural Setback Overlay District.

6. Add to Section 7.0120

7.0120 Add to the following definitions, in the appropriate alphabetical order, to Section 7.0120, DEFINITIONS:

Bluff
The often steeply sloped land area located to the landward side of the Lake Michigan beach. The edge of the bluff is shown on the county topographic maps as "Edge of Cliff" at a scale of one inch equals 200 feet.

Bluff Recession Rate
The rate at which the bluff recedes because of erosion by the waters of Lake Michigan and because of unstable slope conditions.

Minimum Facility Setback Distance
A component of the structural and nonstructural setback overlay district distances which represents a setback distance measured from the regraded stable sloped bluff edge which provides a safety factor against possible failure of shore protection structures or the occurrence of higher than expected bluff recession rates, provides a buffer area which helps protect the regraded bluff edge from excessive surface runoff and from the potential bluff slope stresses resulting from the additional weight of buildings being placed close to the bluff edge, and provides an area which may be effectively utilized for surface water and subsurface water drainage and control.

Net Stable Slope Distance
The horizontal distance that the top of the bluff would need to recede, or be regraded, to form a stable bluff slope, which would not likely be affected by major bluff recession processes such as slumping or sliding. The stable slope distance is one component of the structural and nonstructural setback overlay district distances.

Nonstructural Setback Overlay District Distance
For Lake Michigan shoreland areas not recommended to be protected by properly designed, constructed, and maintained shore protection structures, the distance from the existing bluff edge which is expected to be affected by shoreline erosion and bluff recession over a 50-year period, or by regrading of the bluff slope as needed to achieve a stable slope. The nonstructural setback distance also includes a minimum facility setback distance.

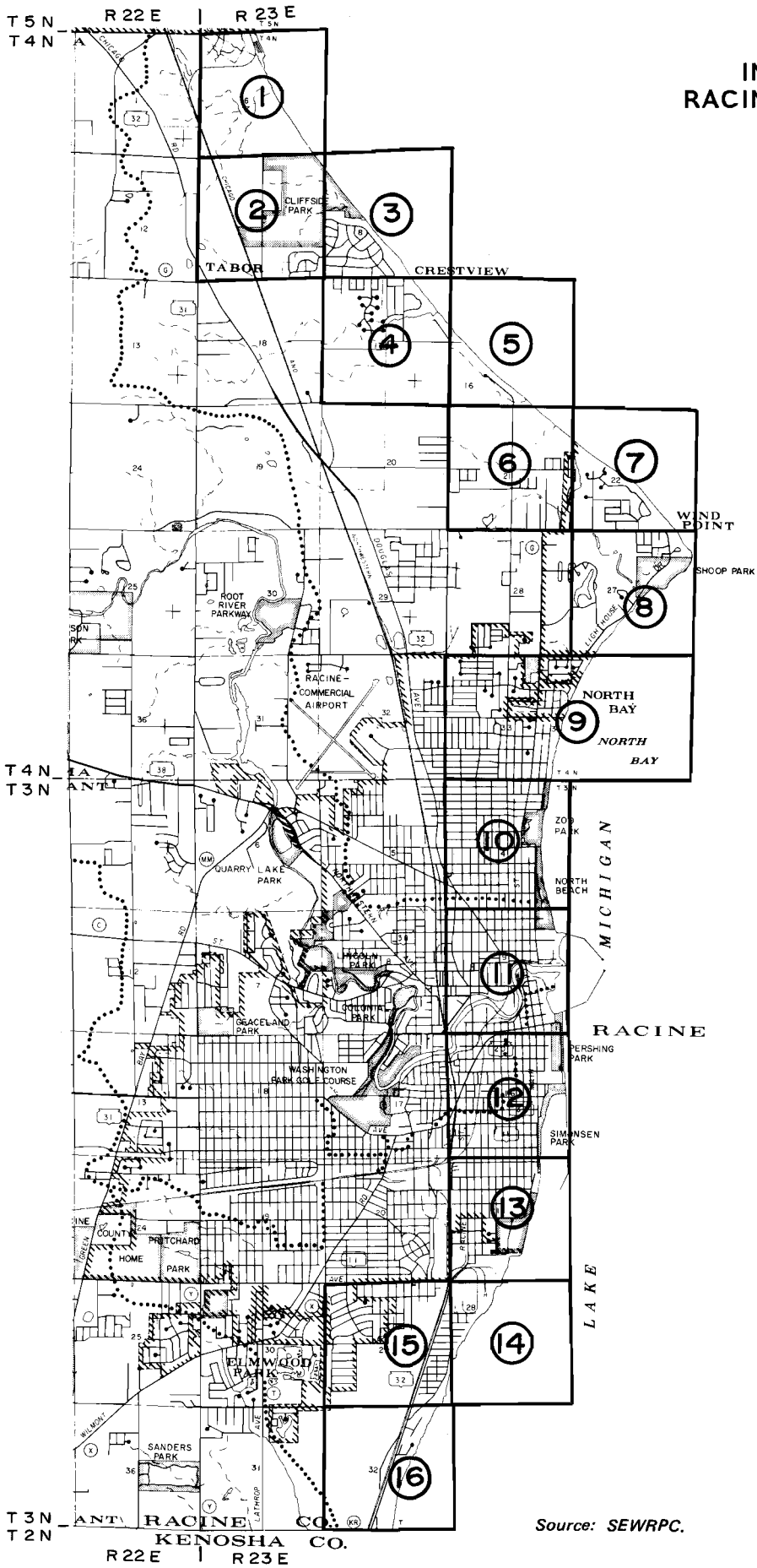
Relocatable Structure
A structure or building which can be moved by a professional building moving contractor to its desired location at a cost not to exceed thirty (30) percent of the equalized value of the structure.

Shore Protection Structures
Structures which are intended to reduce shoreline erosion and bluff recession by providing an artificial protective barrier against direct wave and ice attacks on the beach and bluff toe, by increasing the extent of the beach available to absorb wave energy before the water reaches the bluff, by dissipating wave energy, and/or by stabilizing the bluff slope. Shore protection structures include bulkheads, revetments, seawalls, groins, breakwater, and slope stabilization measures.

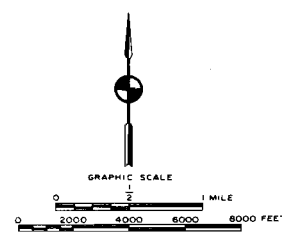
Structural Setback Overlay District Distance
For Lake Michigan shoreland areas recommended to be protected by property designed, constructed, and maintained shore protection structures, the distance from the existing bluff edge which would be lost by regrading the bluff slope as needed to achieve a stable slope. The structural setback distance also includes a minimum facility setback distance.

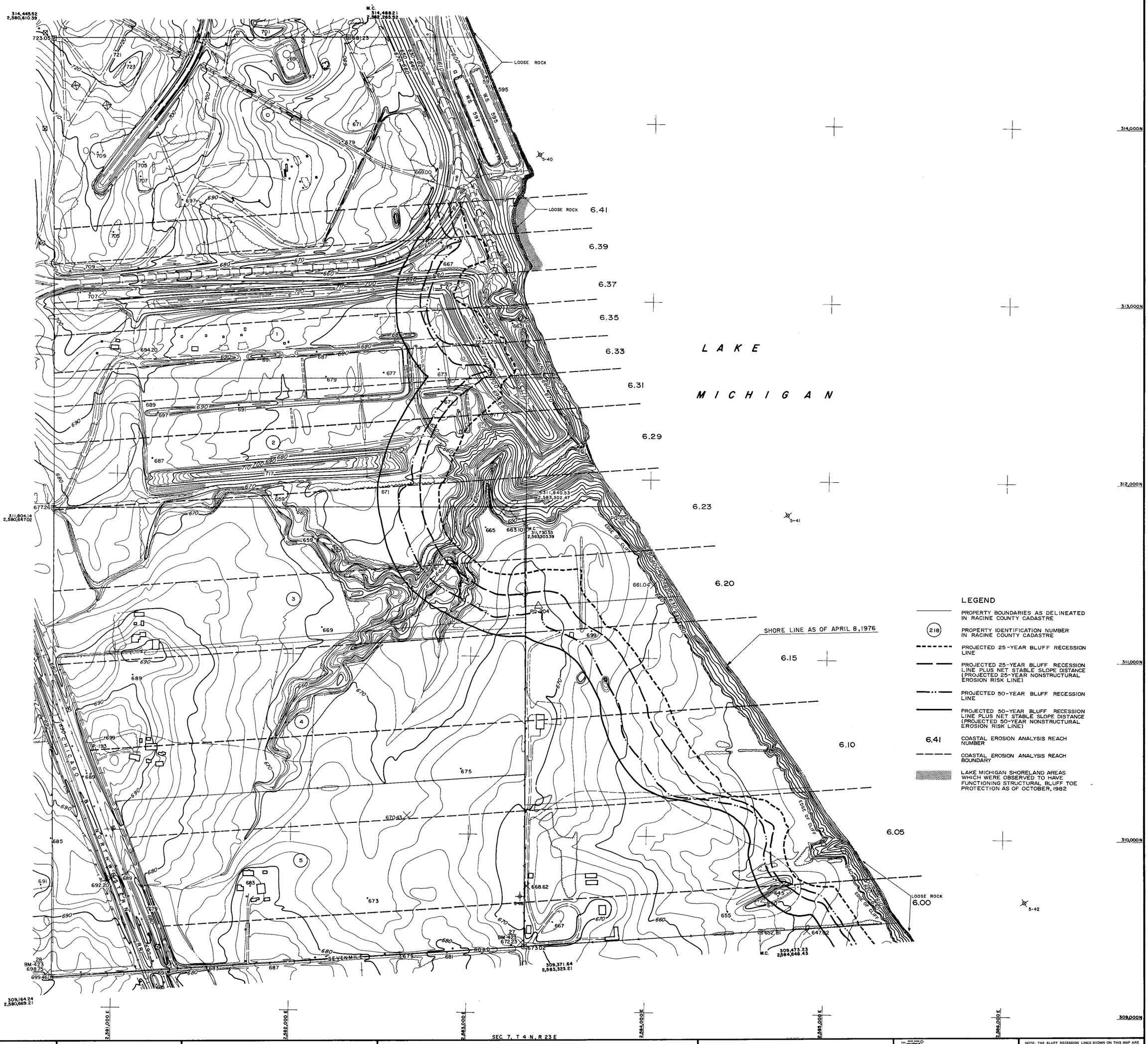
Appendix E

INDEX OF MAPS SHOWING RACINE COUNTY LAKE MICHIGAN EROSION RISK AREAS



Source: SEWRPC.





LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999513

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1968
DATE OF MAPPING: WINTER 1968-1969
REVISED: APRIL 1976

1°E 0°N
+0°01' 29" 40"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 6, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

BY THE

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MAP NO. 1

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

SEC. 6, T 4 N, R 23 E

SEC. 12, T 4 N, R 22 E

SEC. 8, T 4 N, R 23 E

SEC. 18, T 4 N, R 23 E

2,580,000E | 2,581,000E | 2,582,000E | 2,583,000E | 2,584,000E | 2,585,000E | 2,586,000E

309,000N | 308,000N | 307,000N | 306,000N | 305,000N | 304,000N

309,164.24
2,580,669.21

309,371.64
2,583,323.21

309,473.23
2,584,648.43

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2,580,709.91

306,737.78
2,583,376.91

306,966.21
2,586,051.84

304,105.49
2,583,404.79

304,303.52
2,586,075.64

303,904.48
2,580,740.46

6.00

8.40

8.35

SEVENMILE ROAD

SIX MILE ROAD

NORTHWESTERN

CHICAGO

LAKE MICHIGAN

LOOSE ROCK

RIDGE OF CLIFF

SUB-STATION

ELDERBERRY

MEADOW LARK LANE

ELVA

ROBOLINK RD.

LAMBERTON ROAD

BM-423 698.75 699.46

BM-423 672.23

BM-423 688.20

BM-423 687.36

BM-423 654.29

BM-423 643.25

BM-423 666.62

M.C. 308,517.29 2,586,037.97

Q-202

Q-199

WS. 651

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
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- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR 0.99995113

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1968
DATE OF MAPPING: SUMMER 1969
REVISED: APRIL 1976

TN GN +01°29'39"

SCALE. 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 7, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

BY THE

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MAP NO. 2

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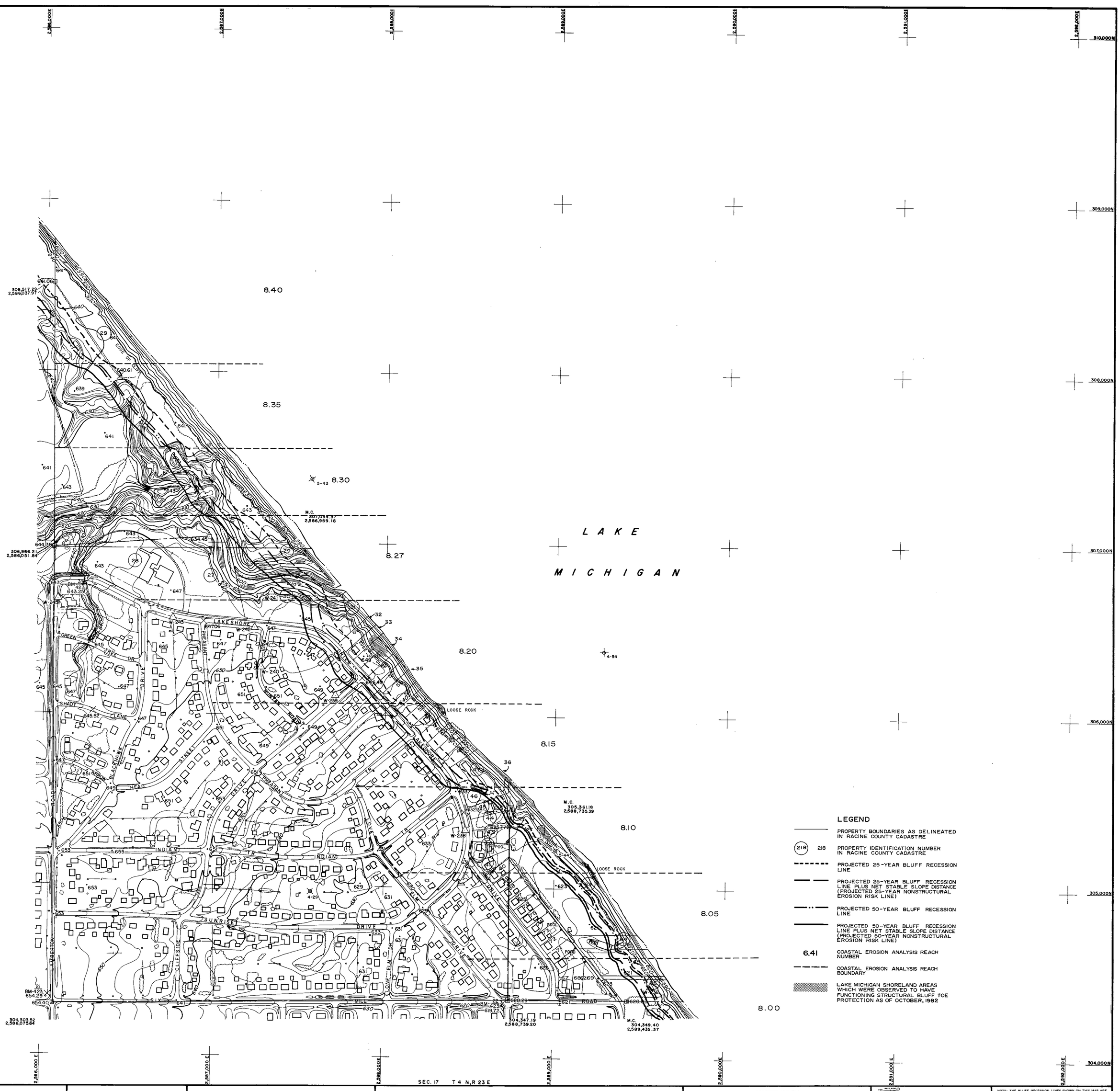

LEGEND

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LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999513

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VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1968
DATE OF MAPPING: SPRING 1969
REVISED: APRIL 1976

TN GN +01°30' 28"

SCALE 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 8, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
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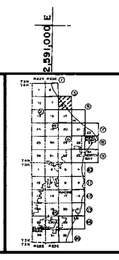

MAP NO. 3

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SEC. 8, T 4 N, R 23 E

SEC. 18, T 4 N, R 23 E

SEC. 20, T 4 N, R 23 E

SEC. 16 T 4 N, R 19 E

2,586,000E 2,587,000E 2,588,000E 2,589,000E 2,590,000E 2,591,000E 2,592,000E

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301,690.98 2,591,464.71

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299,004.49 2,588,807.45

299,034.10 2,591,483.70

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
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- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

8.00 17.50 17.45 17.40 17.35 16.27 16.25 16.20

LAKE MICHIGAN

SIX MILE ROAD

FIVE AND ONE HALF MILE ROAD

CHARLES STREET

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999513

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1968
DATE OF MAPPING: SUMMER 1969
REVISED: APRIL 1976, & 1979 FROM PHOTOGRAPHY FLOWN APRIL 23, 1979

TN ON +01° 30' 28"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 17, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

BY THE

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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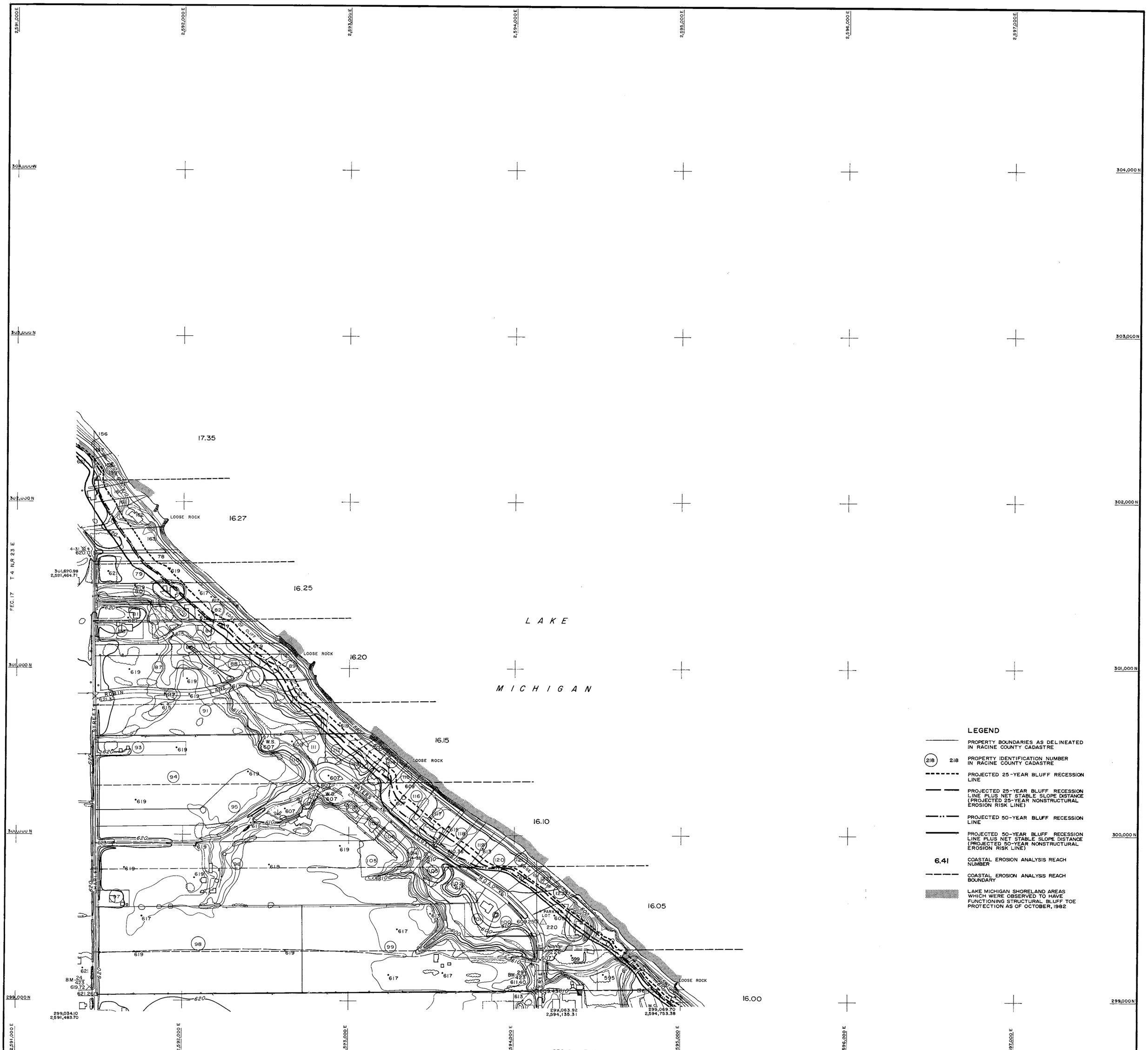

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
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LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR 0.999513

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 9, 1970
DATE OF MAPPING: WINTER 1970-71
REVISED: APRIL 1976

TR 6N +01° 31' 16"

SCALE 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 16, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
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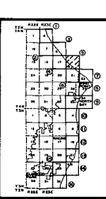
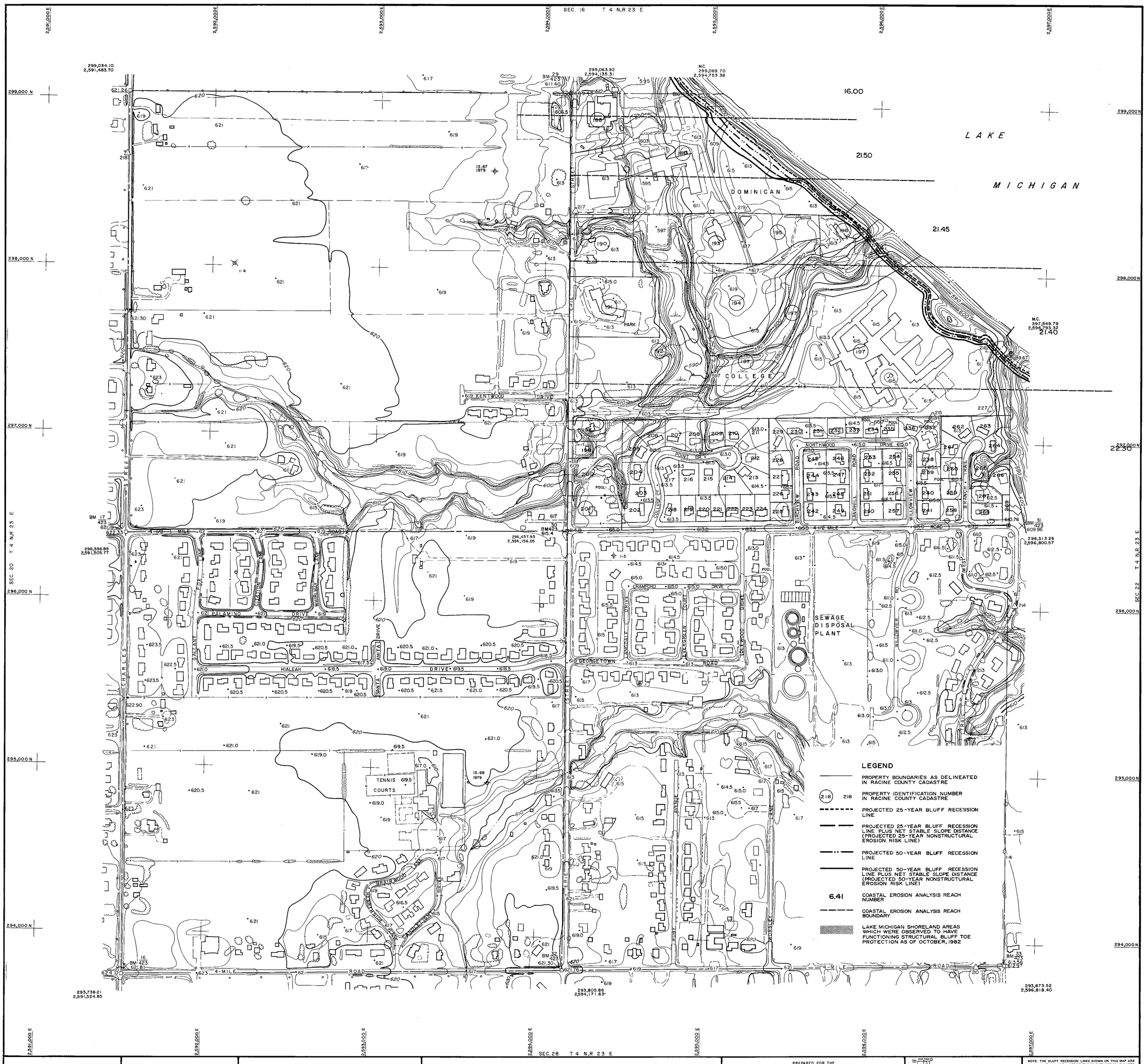


MAP NO. 5

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999513

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 9, 1970
DATE OF MAPPING: WINTER 1970-71
REVISED: 1979 FROM PHOTOGRAPHY FLOWN APRIL 23, 1979

TN GN +01°31' 16"

SCALE: 1"=200' CONTOUR INTERVAL 4'

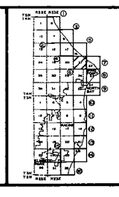
SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 21, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 6

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

2,597,000 E | 2,598,000 E | 2,599,000 E | 2,600,000 E | 2,601,000 E | 2,602,000 E

299,000 N

298,000 N

297,000 N

296,000 N

295,000 N

294,000 N

SEC. 21 T 4 N,R 23 E

21.40

22.30

22.25

22.20

22.15

22.10

22.05

22.00

L A K E

M I C H I G A N

LOOSE ROCK

M.C. 297,549.79 2,596,793.32

296,513.26 2,596,800.57

296,533.30 2,597,566.95

M.C. 295,543.08 2,599,457.06

293,873.52 2,596,818.40

293,944.39 2,599,467.85

M.C. 293,964.29 2,600,779.90

RAVEN TURN

WINDY POINT

OLD PINE CIRCLE

PARK PLACE ROAD

WHITE SAND LANE

MILE ROAD

SEC. 27 T 4 N,R 23 E

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 — COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999513

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS

DATE OF PHOTOGRAPHY: APRIL 9, 1970

DATE OF MAPPING: WINTER 1970-71

REVISED: APRIL 1976

TN ON +01°31'47"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800

SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 22, TOWNSHIP 4 NORTH, RANGE 23 EAST

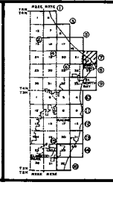
PREPARED FOR THE

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

BY THE

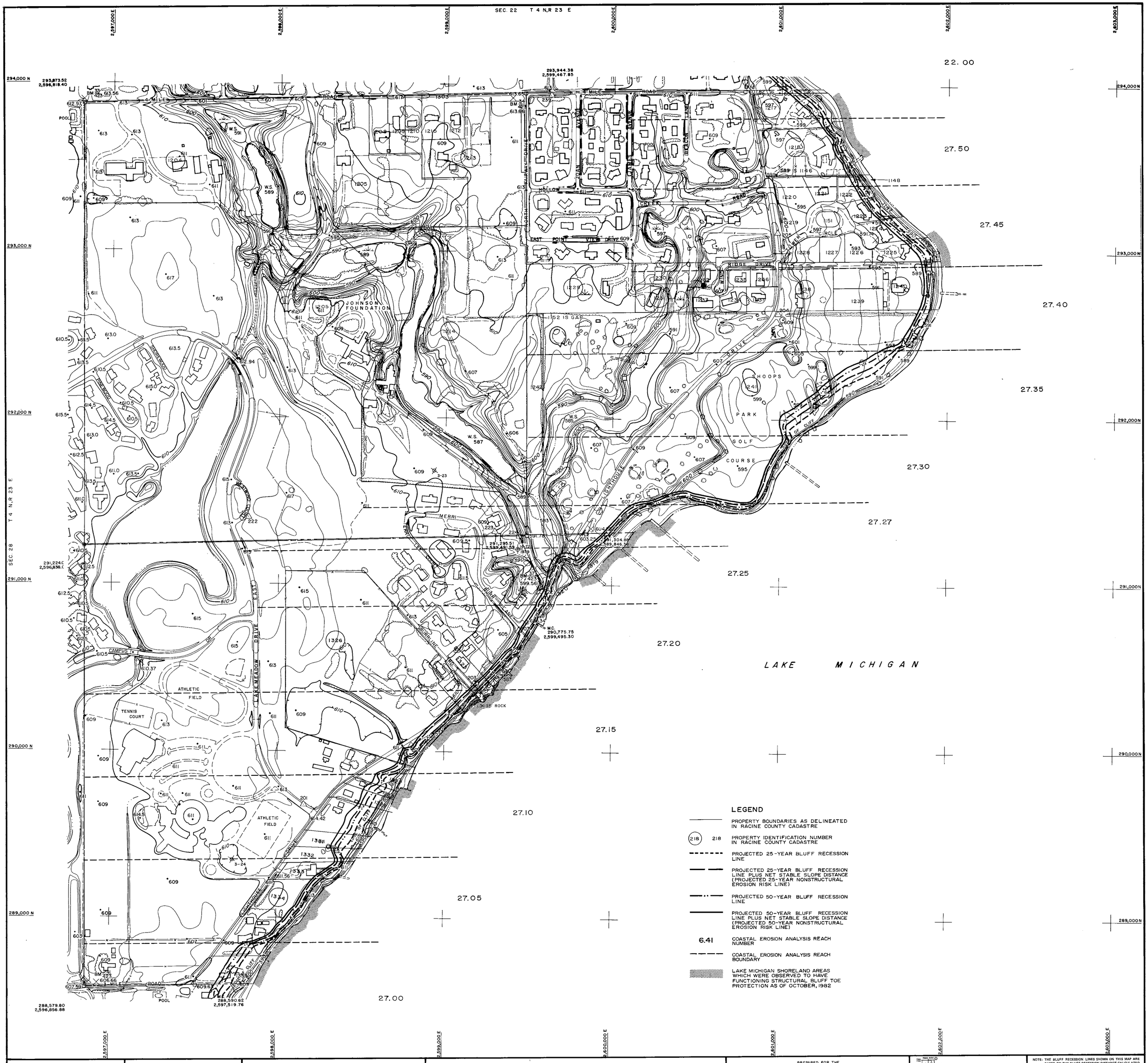
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 7

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 — COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.99995113

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 9, 1970
DATE OF MAPPING: WINTER 1970-71
REVISED: APRIL 1976

TN GN +01°32'04"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 27, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MAP NO. 8

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1903 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

SEC. 28 T4N, R23E

SEC. 32 T4N, R23E

SEC. 4 T3N, R23E

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 — COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR 0.999913

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: DEC 1, 1971
DATE OF MAPPING: SPRING 1972
REVISED: APRIL 1976

TN 6N +0°31'14"

SCALE 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

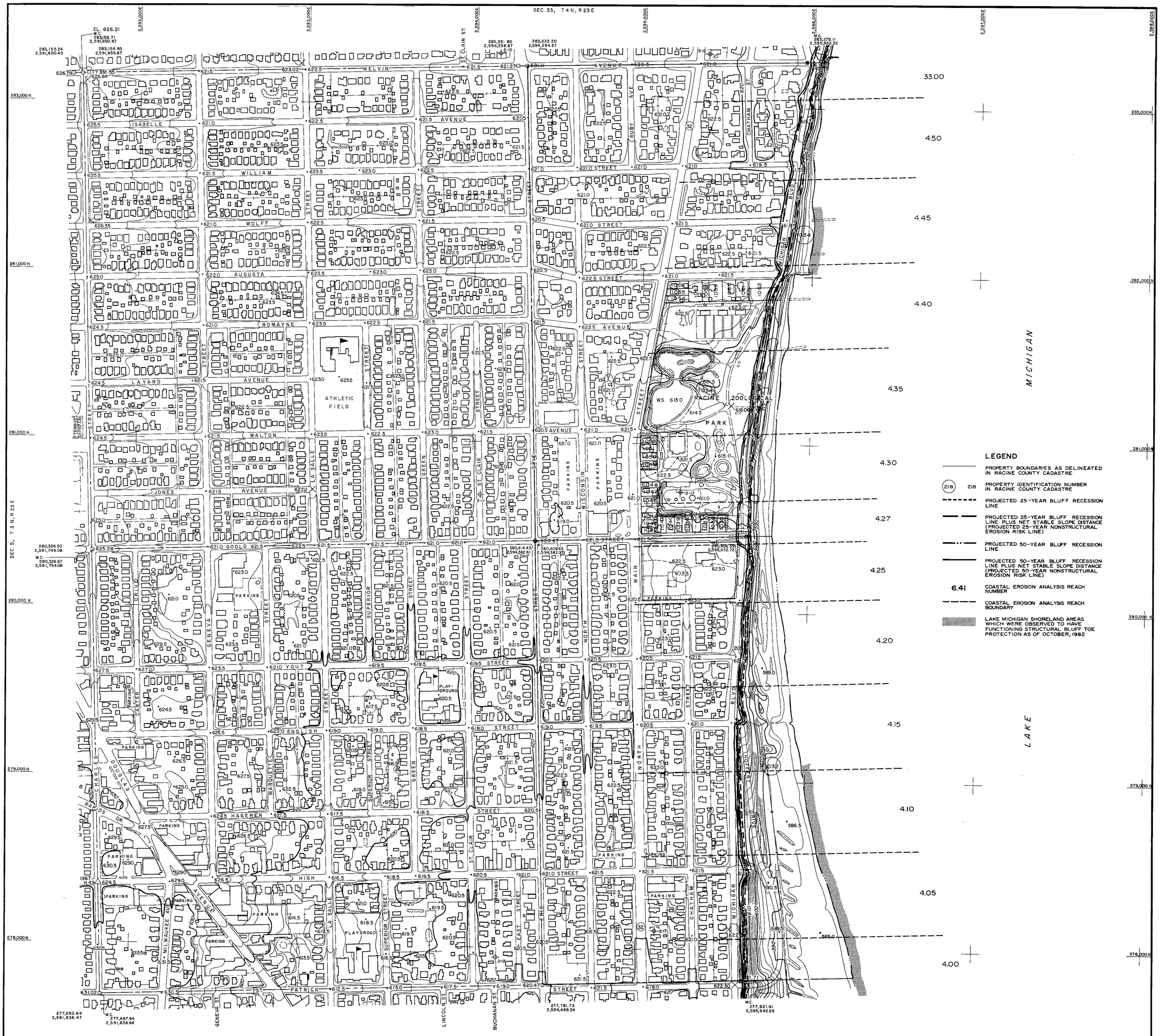
RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTIONS 33&34, TOWNSHIP 4 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MAP NO. 9

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999716

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: DEC. 1, 1971
DATE OF MAPPING: SPRING 1972
REVISED: APRIL 1976

1° GN + 01° 31' 14"

SCALE: 1"=200' CONTOUR INTERVAL 4'

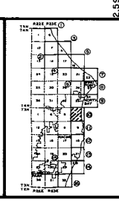
SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 4, TOWNSHIP 3 NORTH, RANGE 23 EAST

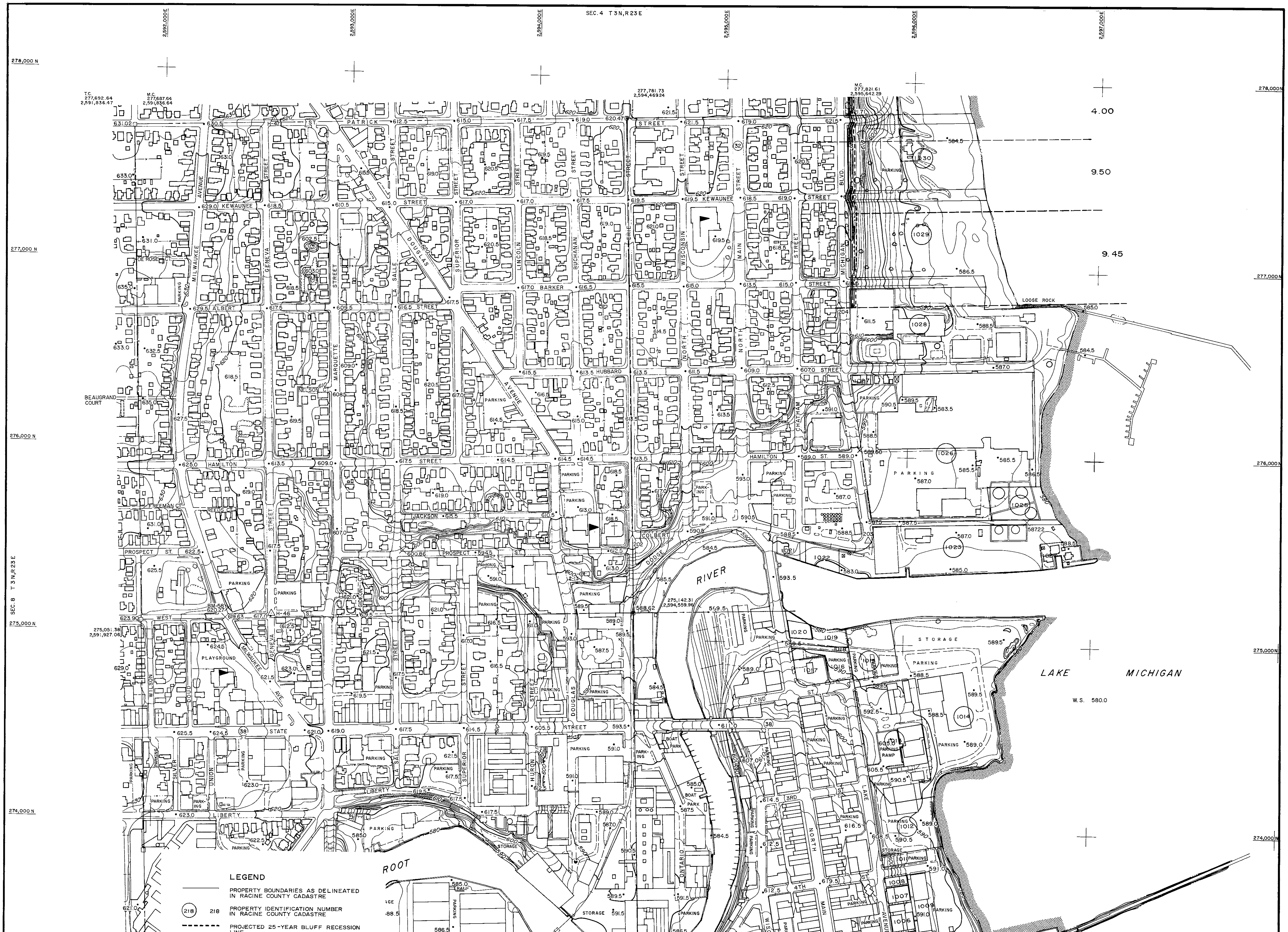
PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LIMITS SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

MAP NO. 10


SEC.4 T3N,R23E
SEC.16 T3N,R23E
SEC.8 T3N,R23E
LAKE MICHIGAN
W.S. 580.0
ROOT
RIVER
LEGEND
PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
218 PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
PROJECTED 25-YEAR BLUFF RECESSION LINE
PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
PROJECTED 50-YEAR BLUFF RECESSION LINE
PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
6.41 COASTAL EROSION ANALYSIS REACH NUMBER
COASTAL EROSION ANALYSIS REACH BOUNDARY
LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982
4.00
9.50
9.45
LOOSE ROCK
STORAGE
PARKING

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999716

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: DEC. 1, 1971
DATE OF MAPPING: SPRING 1972
REVISED: APRIL 1976

TN GN + 01° 31' 13"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 9, TOWNSHIP 3 NORTH, RANGE 23 EAST

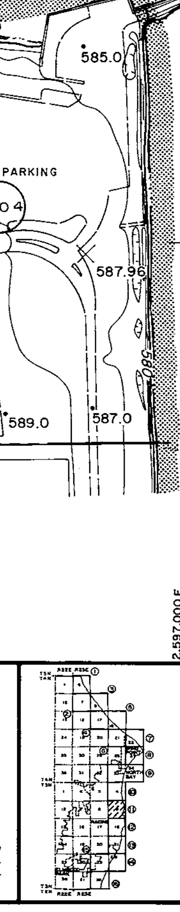
PREPARED FOR THE

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

BY THE

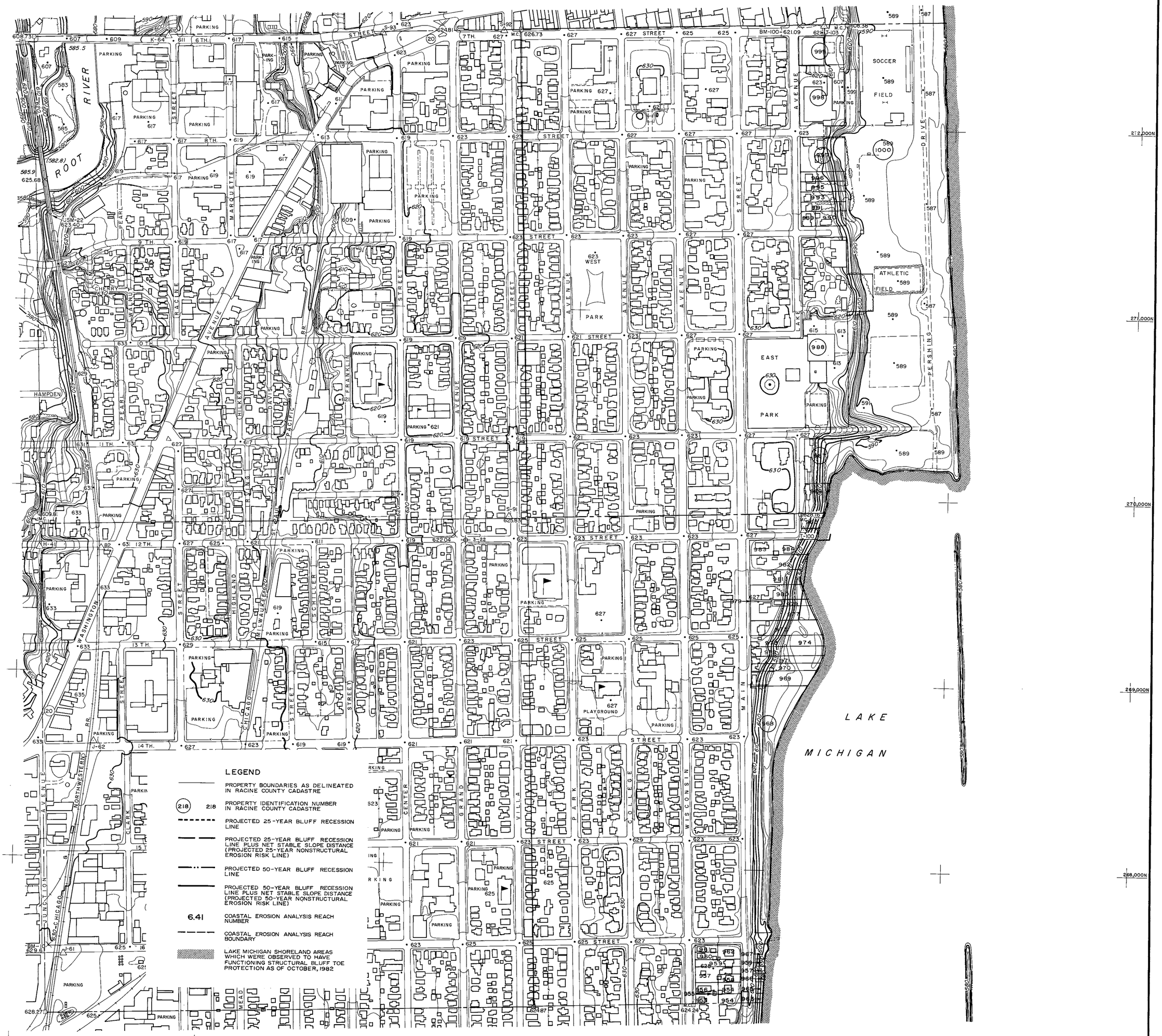
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 11

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999716

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1969
DATE OF MAPPING: FALL 1969
REVISED:

TR 6N — +01°31'15" — 1R 23E

SCALE: 1"=200' CONTOUR INTERVAL 4'

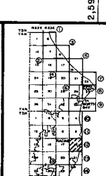
SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 16, TOWNSHIP 3 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 12

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH, FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

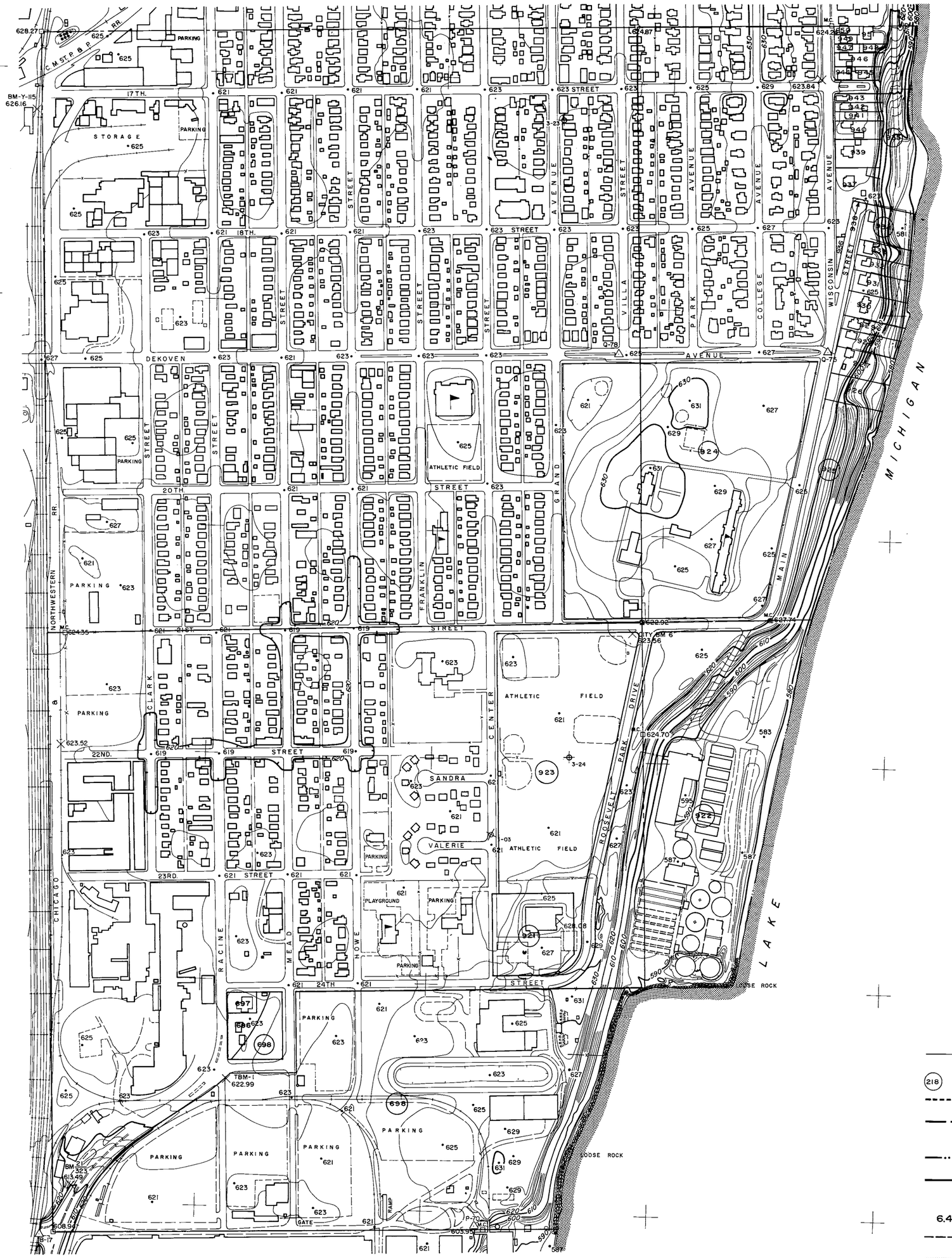
SEC. 16, T 3 N, R 23 E

SEC. 20, T 3 N, R 23 E

SEC. 28, T 3 N, R 23 E

2,592,000 E | 2,593,000 E | 2,594,000 E | 2,595,000 E | 2,596,000 E | 2,597,000 E | 2,598,000 E

267,000 N | 266,000 N | 265,000 N | 264,000 N | 263,000 N | 262,000 N



LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- (218) 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 — COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.99997716

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS.

DATE OF PHOTOGRAPHY: APRIL 1969
DATE OF MAPPING: FALL 1969
REVISED: APRIL 1976

+01° 31' 15"

SCALE 1"=200' CONTOUR INTERVAL 4'

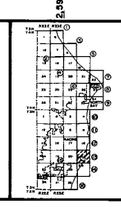
SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 21, TOWNSHIP 3 NORTH, RANGE 23 EAST

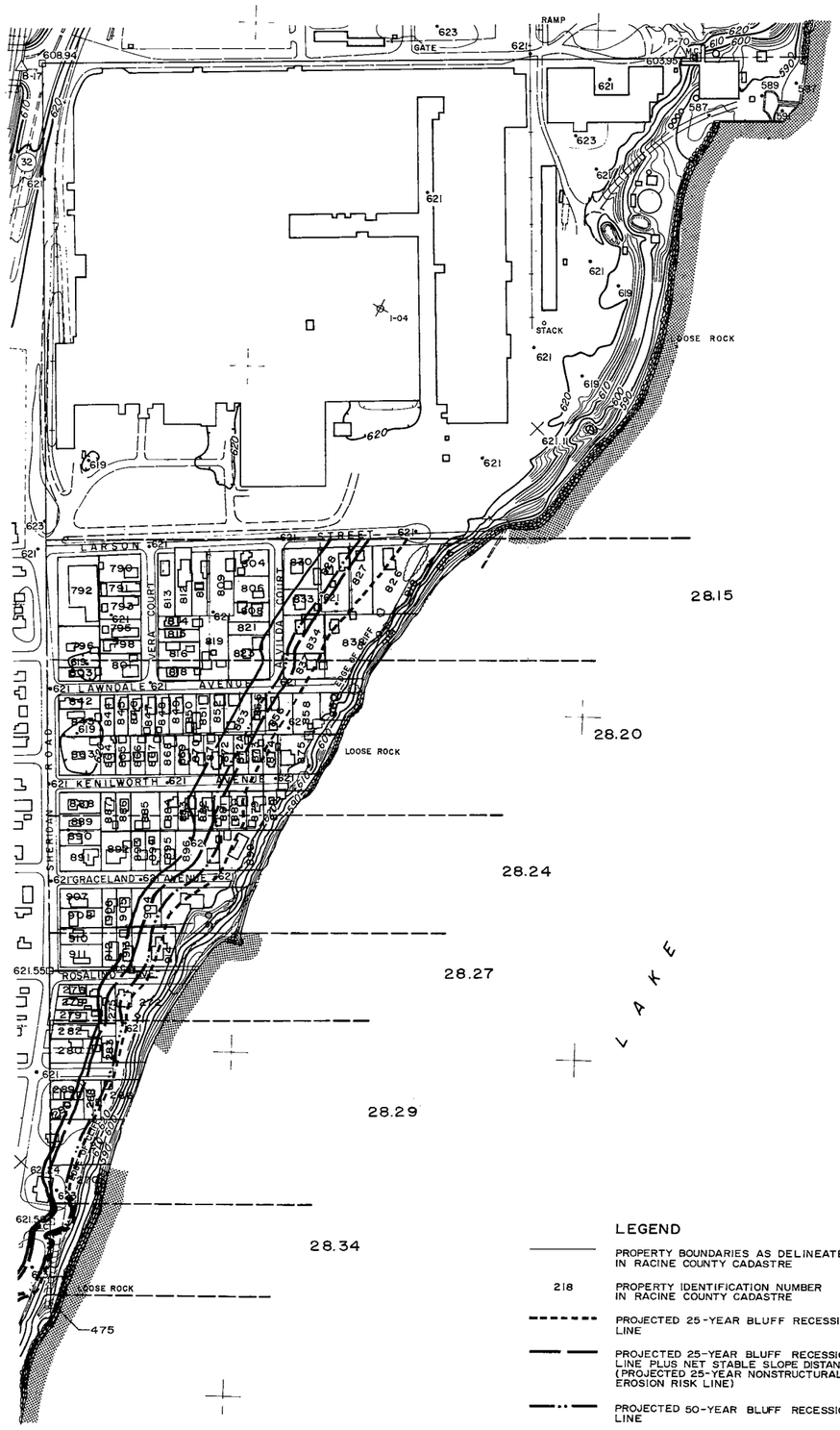
PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 13

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
- PROJECTED 50-YEAR BLUFF RECESSION LINE
- PROJECTED 50-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 50-YEAR NONSTRUCTURAL EROSION RISK LINE)
- 6.41 — COASTAL EROSION ANALYSIS REACH NUMBER
- COASTAL EROSION ANALYSIS REACH BOUNDARY
- LAKE MICHIGAN SHORELAND AREAS WHICH WERE OBSERVED TO HAVE FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION AS OF OCTOBER, 1982

2,592,000E · 2,593,000E · 2,594,000E · 2,595,000E · 2,596,000E · 2,597,000E · 2,598,000E

262,000 N · 261,000 N · 260,000 N · 259,000 N · 258,000 N · 257,000 N

SEC. 28, T 3 N, R 23 E

LEGEND
- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
- PHOTO CENTER
- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR:0.9999716

HORIZONTAL DATUM IS BASED ON THE WISCONSIN PLANE COORDINATE SYSTEM, SOUTH ZONE.

VERTICAL DATUM IS MEAN SEA LEVEL, 1929 ADJUSTMENT

COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY STEREOPHOTOGRAMMETRIC METHODS

DATE OF PHOTOGRAPHY: APRIL 1969
DATE OF MAPPING: FALL 1969
REVISED: APRIL 1976

TR 6N · +01° 31' 15"

SCALE: 1"=200' CONTOUR INTERVAL 4'

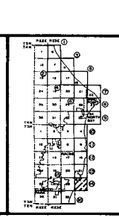
SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 28, TOWNSHIP 3 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

FINANCIAL ASSISTANCE FOR THE PREPARATION OF THIS MAP HAS BEEN PROVIDED THROUGH THE WISCONSIN COASTAL MANAGEMENT PROGRAM UNDER THE COASTAL ZONE MANAGEMENT ACT OF 1972, ADMINISTERED BY THE FEDERAL OFFICE OF COASTAL ZONE MANAGEMENT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



MAP NO. 14

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED, STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.

SEC. 20, T 3 N, R 23 E

SEC. 30, T 3 N, R 23 E

SEC. 28, T 3 N, R 23 E

SEC. 32, T 3 N, R 23 E

262,000 N

261,000 N

260,000 N

259,000 N

258,000 N

257,000 N

256,000 N

2,587,000 E

2,588,000 E

2,589,000 E

2,590,000 E

2,591,000 E

2,592,000 E

2,593,000 E

262,000N

261,000N

260,000N

259,000N

258,000N

257,000N

256,000N

DURAND AVENUE

GLENDALE

WINTHROP ST

CARPENTER AVE

PINEHURST

DELAWARE

RIDGEWOOD AVE

MARYLAND AVE

ROSALIND

BRENTWOOD

FLEETWOOD

LINCOLNWOOD

CHICKORY ROAD

PARKING

MASON ST

GATES ST

HAMLIN ST

DEBRA LANE

KEARNEY AVE

GROVE AVE

HICKORY COURT

PHILLIPS AVE

PACKARD AVE

HAMILTON AVE

CAPITOL DR

TRAILER COURT

TANK

JUNK YARD

NORTHWESTERN R.R.

CHICAGO

VIRGINIA

PLAINFIELD

BRYN MAWR AVE

ENOS AVE

WALTER AVE

RICHARD AVE

PRATT AVE

LAKEWOOD AVE

ATHALEEN AVE

DERBY

K-51 AVE

LOOSE ROCK

LAKE MICHIGAN

BM RU-74 622.79

BM RU-73 622.91

BM 19 323 625.39

BM 16 323 622.378

BM 17 323 622.45

J-47

C-22

2-16

28.34

29.15

29.10

29.05

32.50

LEGEND

- PROPERTY BOUNDARIES AS DELINEATED IN RACINE COUNTY CADASTRE
- 218 — PROPERTY IDENTIFICATION NUMBER IN RACINE COUNTY CADASTRE
- PROJECTED 25-YEAR BLUFF RECESSION LINE
- PROJECTED 25-YEAR BLUFF RECESSION LINE PLUS NET STABLE SLOPE DISTANCE (PROJECTED 25-YEAR NONSTRUCTURAL EROSION RISK LINE)
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LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
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COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR 0.9999716

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DATE OF PHOTOGRAPHY: APRIL 1969
DATE OF MAPPING: FALL 1969
REVISED: APRIL 1976

TR 6N +01°30' 26"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 29, TOWNSHIP 3 NORTH, RANGE 23 EAST

PREPARED FOR THE
RACINE COUNTY PLANNING AND ZONING DEPARTMENT
BY THE
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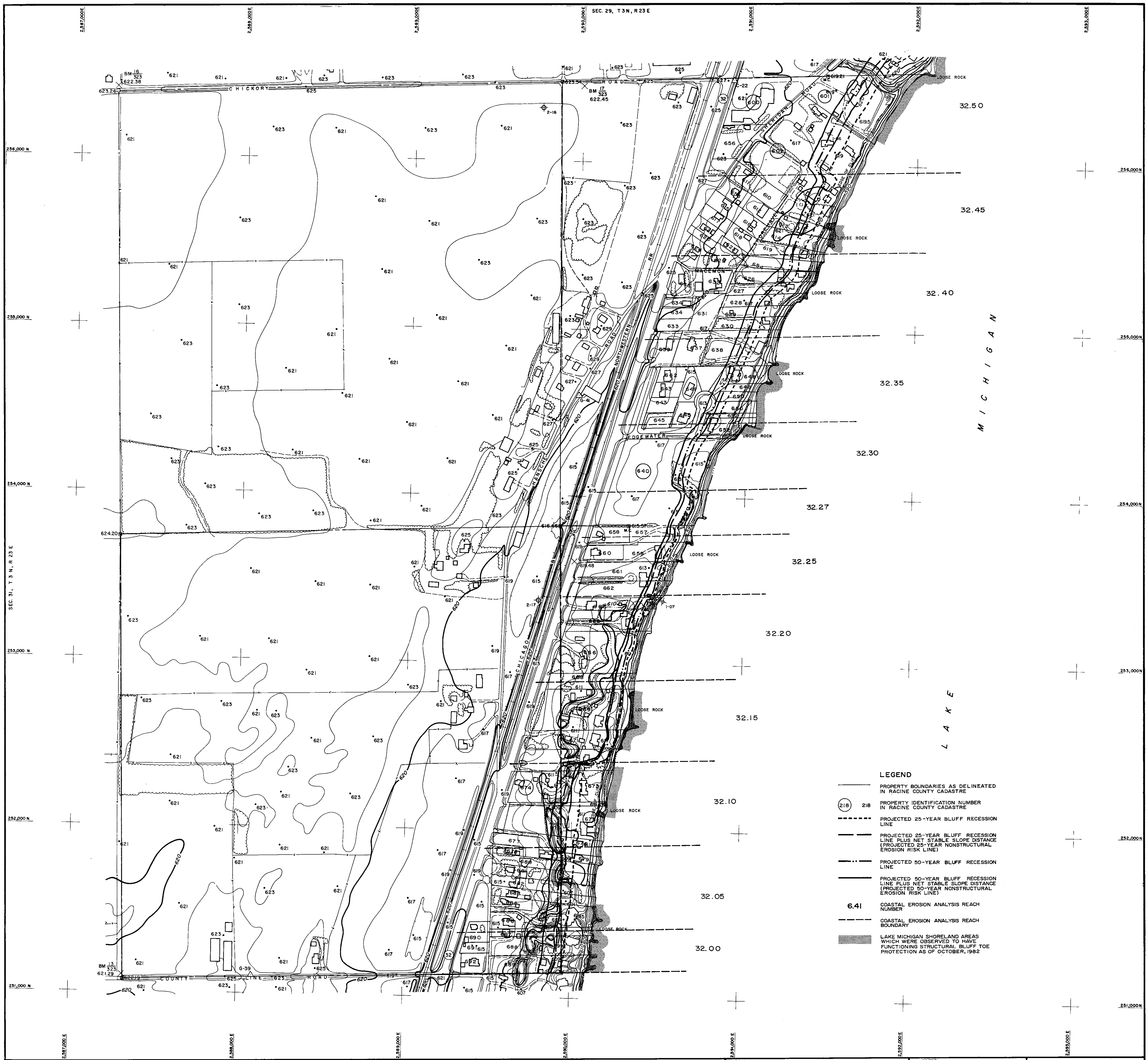
MAP NO. 15

NOTE: THE BLUFF RECESSION LINES SHOWN ON THIS MAP ARE BASED ON THE BLUFF RECESSION DISTANCE CALCULATED FOR THE PERIOD OF 1963 THROUGH 1980 FOR EACH COASTAL EROSION ANALYSIS REACH. FOR THOSE SHORELINE REACHES WHICH WERE OBSERVED IN OCTOBER 1982 AS HAVING FUNCTIONING STRUCTURAL BLUFF TOE PROTECTION, AS SHOWN ON THIS MAP, THE FUTURE BLUFF RECESSION DISTANCE FROM THE EXISTING BLUFF EDGE MAY BE ZERO, PROVIDING THAT THE SHORE PROTECTION STRUCTURES ARE MAINTAINED. STORM DAMAGE IS REPAIRED, AND FLANKING OF ISOLATED STRUCTURES IS PROTECTED AGAINST. SHOULD THE PROTECTIVE STRUCTURES NOT BE ADEQUATELY MAINTAINED AND FAIL, BLUFF RECESSION DISTANCES UP TO THE LINES SHOWN ON THIS MAP COULD APPLY. THE NET STABLE SLOPE DISTANCE APPLIES TO SHORELINES WHICH ARE ADEQUATELY PROTECTED BY SHORELINE STRUCTURES, AS WELL AS THOSE SHORELINES NOT PROTECTED, EXCEPT WHERE SPECIAL BLUFF STABILIZATION TECHNIQUES HAVE BEEN APPLIED.



LEGEND

- USC&GS TRIANGULATION STATION
- MONUMENTED LAND SURVEY CORNER
- TRAVERSE STATION
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- BM OR TBM (LABELLED)

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.9999716

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TN GN +01° 31' 26"

SCALE: 1"=200' CONTOUR INTERVAL 4'

SUPPLEMENTARY 2 FOOT CONTOURS COMPILED BY STEREOPHOTOGRAMMETRIC INTERPOLATION BETWEEN BASIC 4 FOOT CONTOURS.

200 0 200 400 600 800
SCALE IN FEET

RACINE COUNTY
LAKE MICHIGAN EROSION RISK AREAS
SECTION 32, TOWNSHIP 3 NORTH, RANGE 23 EAST

PREPARED FOR THE

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BY THE

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MAP NO. 16

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INTERAGENCY STAFF

LAKE MICHIGAN COASTAL EROSION MANAGEMENT STUDY FOR RACINE COUNTY

RACINE COUNTY PLANNING AND ZONING DEPARTMENT

Arnold L. Clement . . . . . Planning Director and Zoning Administrator

Frank A. Risler . . . . . Assistant Planning Director and Zoning Administrator

Betty J. Gruning . . . . . Coastal Management Project Coordinator

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION STAFF

Kurt W. Bauer, P.E., AICP . . . . . Executive Director

Philip C. Evenson . . . . . Assistant Director

Kenneth R. Yunker, P.E. . . . . Assistant Director

Robert P. Biebel, P.E. . . . . Chief Environmental Engineer

John W. Ernst . . . . . Data Processing Manager

Leland H. Kreblin . . . . . Chief Planning Illustrator

Donald R. Martinson . . . . . Chief Transportation Engineer

Frederick J. Patrie . . . . . Administrative Officer

Thomas D. Patterson . . . . . Chief of Planning Research

Bruce P. Rubin . . . . . Chief Land Use Planner

Roland O. Tonn, AICP . . . . . Chief Community Assistance Planner

Special acknowledgement is due Mr. David B. Kendziorski, Senior Planner, for his contribution to the preparation of this report.