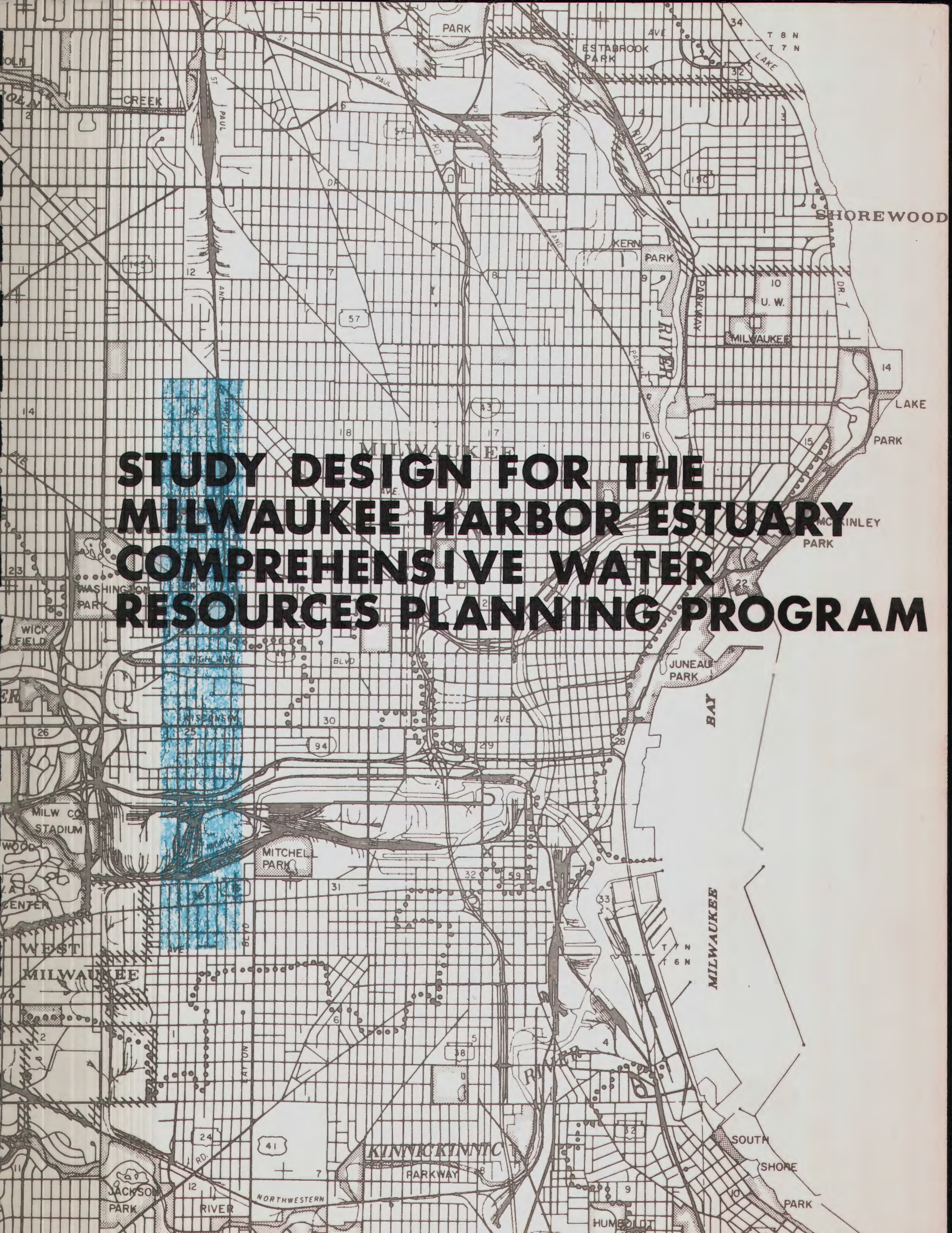
STUDY DESIGN FOR THE MILWAUKEE HARBOR ESTUARY COMPREHENSIVE WATER RESOURCES PLANNING PROGRAM



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Special acknowledgment is due Mr. R. Stephen Grant, Principal Water Resources Engineer, for his effort in the preparation of this document.

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Rudolpho N. Salcedo . . . . Environmental Scientist, Department of City Development, City of Milwaukee

STUDY DESIGN FOR
THE MILWAUKEE HARBOR ESTUARY
COMPREHENSIVE WATER RESOURCES PLANNING PROGRAM

Prepared by the
Southeastern Wisconsin Regional Planning Commission
P.O. Box 769
Old Courthouse
916 N. East Avenue
Waukesha, Wisconsin 53187-1607

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Chapter I

INTRODUCTION

BACKGROUND

The inner and outer harbors of the City of Milwaukee, formed by the confluence of the Milwaukee, Menomonee and Kinnickinnic Rivers with Lake Michigan and the breakwater at the mouth of the Milwaukee River are severely polluted. The water quality in the harbor area creates obnoxious and unaesthetic conditions which impair use of the water for sightseeing, picnicking, fishing, and as a proper aesthetic setting for high-value urban land use development. The pollution of this area threatens the safe use of the Lake Michigan beaches; may threaten the water supply intakes of the City of Milwaukee, the Cities of Cudahy, Oak Creek, and South Milwaukee, and of the tri-community water supply system servicing the City of Glendale and the Villages of Fox Point and Whitefish Bay. The polluted condition limits the potential recreational use of the estuary in the downtown Milwaukee area. The polluted conditions of the Milwaukee Harbor therefore constitute a threat to necessary and desirable forms of water uses in the near-shore zone of Lake Michigan, the inner and outer harbors, and to selected aspects of the fishery of Lake Michigan itself.

The inner and outer harbors constitute a "freshwater estuary" of Lake Michigan. The reaches of the Milwaukee, Menomonee, and Kinnickinnic Rivers comprising the inner harbor, and the outer harbor formed by the breakwater are affected by the backwater effects and water level variation in the main body of Lake Michigan, and are herein referred to in general terms as a freshwater "estuary". This differs from the more common use of the term "estuary," which is used more often with reference to a marine, or saltwater, estuary. A more precise definition of this term is set forth below.

In recognition of the pollution problems of the Milwaukee Harbor, the Common Council of the City of Milwaukee, acting on July 24, 1973, formally requested the Southeastern Wisconsin Regional Planning Commission, upon completion of comprehensive studies of the Milwaukee, Menomonee, and Kinnickinnic River watersheds, to undertake a comprehensive study of the Milwaukee Harbor estuary looking to the ultimate resolution of the serious water pollution problems existing therein. The watershed studies were completed and the reports published in October 1971, October 1976, and December 1978, respectively. With the then-pending completion of the last of these three watershed studies--the comprehensive study of the Kinnickinnic River watershed--the Commission, assisted by its Technical and Citizens Advisory Committee on Coastal Management, prepared a prospectus for a planning program to define and address the problems of the Milwaukee Harbor estuary, as well as the freshwater estuaries of Sauk Creek, Oak Creek, Root River, Pike River, and Pike Creek.[1] This prospectus was published in September, 1978 and transmitted to the concerned units and agencies of government on December 12, 1978 for review and action.

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[1]*See Lake Michigan Estuary and Direct Drainage Areas Subwatershed Planning Program Prospectus, September 1978, SEWRPC.*

On March 20, 1979, the Common Council of the City of Milwaukee acknowledged receipt of the Prospectus transmitted to them by the Commission, and reaffirmed the City of Milwaukee's interest in the conduct of a study looking to the ultimate resolution of the water quality problems in the Milwaukee Harbor estuary. On March 12, 1980, the Wisconsin Department of Natural Resources (DNR), at the request of the U.S. Environmental Protection Agency (EPA), submitted a federal assistance pre-application for a proposed project "Demonstration of the Resident Pollutant Impact on Milwaukee Estuary Water Quality". The letter of intent described a tentative scope of work along with associated work tasks and preliminary cost estimates of $1.7 million for the preliminary proposal, and called for development of a final work plan agreeable to the EPA and cooperating agencies. More recently, the Milwaukee Metropolitan Sewerage District, working in its facilities planning activities through the DNR and the EPA, has considered various alternatives for the control of combined sewer overflows. These alternatives include sewer separation, and conveyance-storage-treatment for the abatement of combined sewer overflows discharging to the Milwaukee Harbor estuary, and measures to resolve the in-place sediment pollution problem of the estuary. In light of the concerns expressed by the City of Milwaukee and the DNR, and the importance of the Milwaukee Harbor as a major source and location of pollution on Lake Michigan; and in view of the need to better understand the water quality effects of alternative water quality management measures in the watersheds draining to the Milwaukee Harbor estuary, the U.S. Environmental Protection Agency on June 12, 1980 requested the Regional Planning Commission to prepare a study design for a water resources planning and management program dealing with the Milwaukee Harbor estuary. Therefore, the major purpose of this study design is to set forth the scope and content of a study to define the water resources management needs of the Milwaukee Harbor estuary, by extracting and refining where necessary the pertinent aspects of the published <u>Lake Michigan Estuary and Direct Drainage Areas Subwatershed Planning Program Prospectus</u>, and by extracting and refining other sources of information concerning point and nonpoint source pollutant effects on the estuarine ecosystem. Thus, this study design is set within the context of the published Prospectus, and provides for the preparation of a major subelement of the overall work program described in that Prospectus. The analysis of the Milwaukee Harbor estuary subwatershed water resources problems is a major undertaking in its own right, because of the technical complexity and magnitude of the problems involved. It should be noted, however, that the undertaking of this project would not preclude the conduct of estuary studies at some future date for the other freshwater estuaries of the Region as they are recommended to be studied according to the published Prospectus. Such study would, however, require an expression of local interest and willingness to help fund the necessary work.

RELATIONSHIP OF REGIONAL PLANNING TO FEDERAL, STATE, AND LOCAL RESOURCE MANAGEMENT PROGRAMS

Regional planning as conducted in southeastern Wisconsin has as one of its principal objectives the integration of the land and water resource management programs of various federal, state, and local units and agencies of government in order to assure a coordinated approach to plan preparation and implementation and to the resolution of areawide problems. For the Milwaukee Harbor estuary comprehensive planning program, the attainment of this objective will require the identification and definition of the pertinent water resources problems, the identification of the sources of those problems, the identification and evaluation of alternative solutions to these problems, the selection and recommendation of the best means of resolving these problems, and the identification of the proper roles of appropriate resource management agencies at all levels of government in the resolution of these problems. By these means, the regional planning function can assist in coordinating the roles of all the parties involved in the resolution of the problems of the estuary. The development of this study design constitutes a first step in the achievement of interagency coordination, on an areawide basis, toward addressing the water resources management problems of the Milwaukee Harbor estuary.

LIMITS OF THE MILWAUKEE HARBOR ESTUARY

Because of the hydraulically complex character of the Milwaukee Harbor estuary, and the engineered subsurface conduit systems which affect it, it is necessary to define with precision certain terms required in any detailed consideration of a water resources management planning program for the Milwaukee Harbor estuary. Accordingly, definitions of key terms used within this study design are set forth in Appendix A. Perhaps the singularly most important definition is that applied to the Milwaukee Harbor estuary. The Milwaukee Harbor estuary is herein defined as the lower reaches of the Kinnickinnic, Milwaukee, and Menomonee Rivers wherein the flow and quality of river waters are influenced by Lake Michigan to create a distinct environment containing characteristics of both the rivers and of Lake Michigan, together with that portion of Milwaukee Bay contained within the Milwaukee Harbor breakwater. This excludes the anchorage area protected by the offshore breakwater south of E. Lincoln Avenue extended. Under this definition, the Milwaukee Harbor estuary--as shown on Map 1--is located entirely within the City of Milwaukee, and is inclusive of the three-mile reach of the Milwaukee River below the North Avenue dam, the 2.2-mile reach of the Menomonee River below the Falk Corporation Dam, and the 1.7-mile reach of the Kinnickinnic River below the Chase Avenue bridge together with the outer harbor. It is recognized that under some conditions the backwater influence of the estuary may extend above the Falk Corporation Dam and Chase Avenue bridge. The harbor itself is bounded by the Becher Street bridge on the Kinnickinnic River, S. 25th Street extended on the Menomonee River, the North Avenue dam on the Milwaukee River, and the breakwater which shelters the outer harbor. The Milwaukee Harbor estuary, as defined, has a total length of stream of 6.9 miles, and a total area of approximately 1,630 acres of surface water. The area draining to this estuary by direct surface runoff, by storm sewer, or by combined storm and sanitary sewer is defined as the Milwaukee Harbor estuary subwatershed. The subwatershed area is delineated on Map 1, and totals 24.9 square miles, or 15,940 acres, in areal extent.

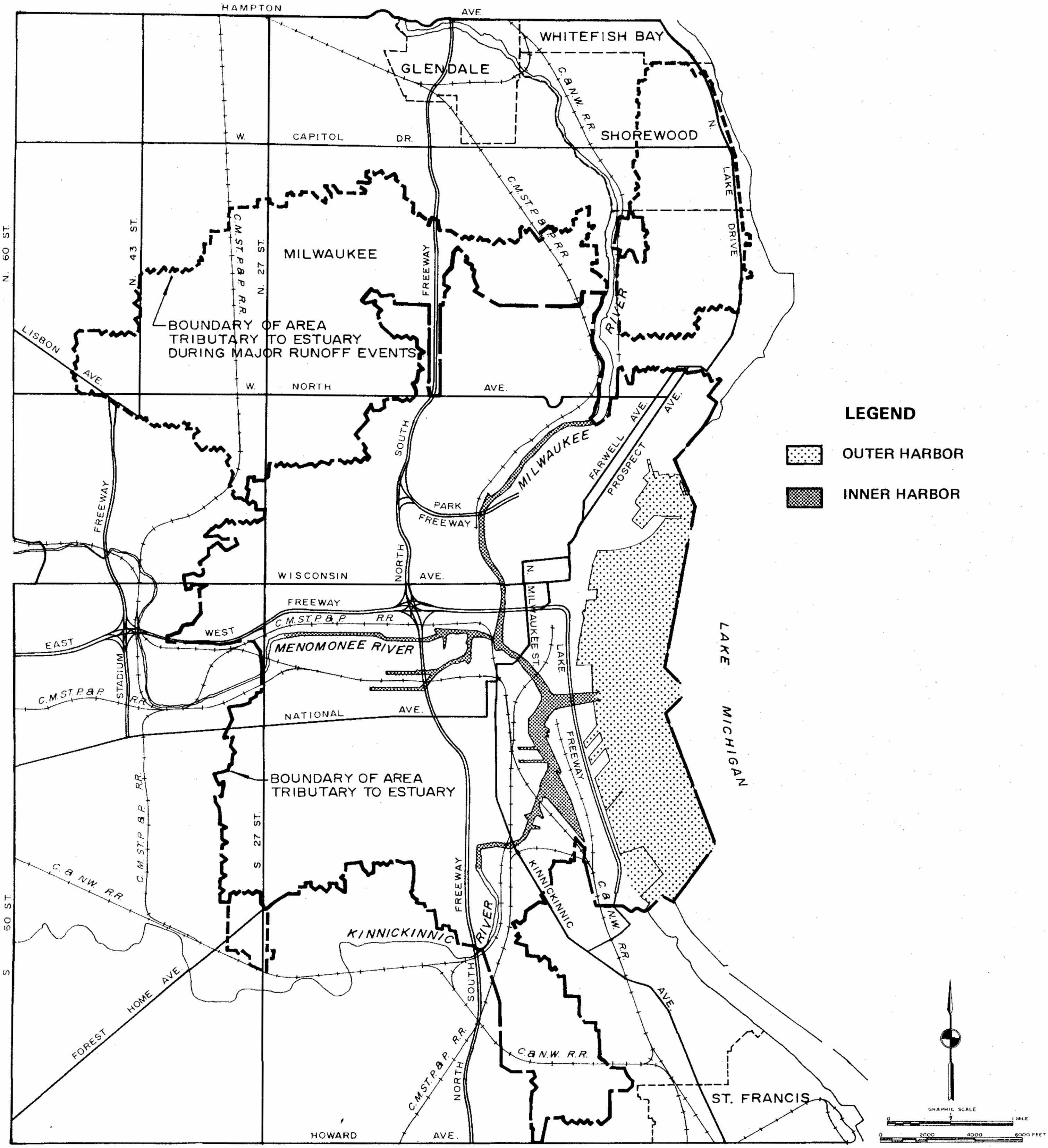
In preparing this definition, there are several important considerations which were recognized by the Commission:

(1) In the conduct of the Commission's previous studies of the Milwaukee, Menomonee, and Kinnickinnic River watersheds, floodland and water quality analyses were conducted for the stream reaches extending as far downstream as the North Avenue dam, the Falk Corporation Dam, and S. Chase Avenue, respectively.

(2) During all conditions the backwater influence of Lake Michigan can extend only to the North Avenue dam which clearly demarks the upper end of the estuary in the Milwaukee River valley. During low-flow and normal flow conditions, the influence of Lake Michigan extends up the Menomonee River to the Falk Corporation Dam. However, during high water conditions of Lake Michigan when the Falk Corporation Dam is overtopped, the U.S. Geological

Map 1

THE MILWAUKEE HARBOR ESTUARY SUBWATERSHED FORMED BY THE CONFLUENCE OF THE MENOMONEE, MILWAUKEE AND KINNICKINNIC RIVERS WITH LAKE MICHIGAN



Source: SEWRPC.

Survey has reportedly observed, during streamflow gaging activities, backwater effects from Lake Michigan as far upstream as 41st Street extended. The Milwaukee Metropolitan Sewerage District during high water conditions has observed backwater effects on the Kinnickinnic River as far upstream as S. 6th Street, about 1.1 miles upstream of W. Becher Street, the normal limits of such effects.

(3) In the development of its facilities plans, the Milwaukee Metropolitan Sewerage District has refined and detailed the delineation of the combined sewer service area. This resulted in the refined Milwaukee Harbor estuary subwatershed boundaries used herein.

Thus, it may be concluded that under most conditions, the navigability, hydraulic backwater pool, and aquatic habitat features of the estuary terminate at the study limits as described above and on Map 1. While the definition of the Milwaukee Harbor estuary, as used in previous SEWRPC studies, together with the boundaries of its subwatershed as described above would be subject to refinement based upon data assembled under the proposed study, they provide an adequate definition for the development of this study design and the initiation of the study. Any redefinition will require substantial further technical analysis of inventory data collected under the water resources management study itself.

PURPOSE AND ORGANIZATION OF STUDY DESIGN

The major purpose of this study design is to provide a working outline for a proposed comprehensive planning study of the Milwaukee Harbor estuary; to serve as a basis for local, state and federal funding for such a study; and to serve as the framework for the initiation and conduct of the work program of the study. This study design addresses the water resources problems of the inner and outer harbors, and recognizes the necessity and importance of identifying and quantifying the impacts of both the riverine and the lake backwater effects on water levels and water quality. In view of the complexities and costs of analyzing conditions in the Lake Michigan near-shore zone, and in view of the broader community of interests involved in and concerned over the conditions of the near-shore zone, such conditions will be addressed in the proposed study only to the extent necessary to properly defind the boundary conditions at the eastern limits of the Milwaukee Harbor estuary study area.

It is not contemplated that this study design will provide complete and detailed guidance for every aspect of the proposed study. Rather the study design is intended to serve as a general work plan which should be followed closely, but which would leave selected details involved in the conduct of tasks to be resolved step by step as the work proceeds. In some cases, such detail is sufficiently tedious to be logically excluded from this study design. In other cases such detail cannot logically be prepared with any degree of confidence until after the initiation of the full technical work to be undertaken in the study itself. In yet other cases, the detail must necessarily be developed by the investigator or contractor for a given work element, in order to provide the final product of each investigation as specified in this study design.

Accordingly, the study design has been prepared in seven chapters. Following this introductory chapter, the second chapter presents a summary of the pertinent studies conducted previously or currently underway which are related to the the water resources problems of the Milwaukee Harbor estuary. The third chapter sets forth the objectives of the proposed comprehensive planning study for the Milwaukee Harbor estuary. The fourth chapter presents the major work elements which need to be undertaken in the study; interrelates those work elements one to another; describes the data which would be obtained, the methods and procedures by which the data would be analyzed, and the resulting product; and groups the work tasks into various logical steps to be undertaken by various participating units or agencies of government. The fifth chapter proposes a logical organization for the conduct of the study, including the relationship and involvement of various agencies and units of government. The sixth chapter presents the estimated costs, by major work element, of the proposed study. The seventh and final chapter summarizes all of the information presented in the study design.

Chapter II

RELATED STUDIES OF THE MILWAUKEE HARBOR ESTUARY

INTRODUCTION

The purpose of this chapter is to present selected pertinent information from all known studies of water quality in the Milwaukee Harbor estuary, published and unpublished. International, federal, state, and local government studies are discussed. Some studies involved multiple agency participation. For each study the period of the study is presented along with a discussion of the objectives, data collected, interpretive analyses made, findings, and conclusions and recommendations. Unpublished material is described in more detail than published material which is more readily accessible. Some published material is also described in additional detail when the level of sophistication is relatively high, and when it is deemed that further work of the same nature may not be necessary to characterize existing conditions in the estuary or a part of the estuary for a given parameter or set of parameters.

The estuary related studies of the U. S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, the U. S. Geological Survey, the U. S. Environmental Protection Agency and its predecessors, the International Joint Commission, the Wisconsin Department of Natural Resources, the Milwaukee County Department of Parks, Recreation, and Culture, the Milwaukee Metropolitan Sewerage District, the City of Milwaukee, the University of Wisconsin at Milwaukee, the University of Wisconsin at Madison, and the Wisconsin Electric Power Company are all addressed as are certain relevant studies of other private and public agencies. Other agencies which were contacted but whose work is not included because of the lack of water quality related activities relevant to the estuary study design include the U.S. Public Health Service, the U.S. Soil Conservation Service, the Wisconsin Department of Transportation, the Wisconsin Public Service Commission and U. S. Bureau of Outdoor Recreation and its successor agency.

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION WORK PROGRAMS

The work of the Southeastern Wisconsin Regional Planning Commission conducted since 1960 has included four programs of importance to the study of water quality conditions in the Milwaukee Harbor estuary. These programs include the comprehensive studies conducted of the Milwaukee, Menomonee, and Kinnickinnic River watersheds, and the regional water quality management planning program. In addition to producing specific elements of the comprehensive regional plan, each of these programs, which are described below, set forth important assumptions and provided valuable information regarding the "boundary conditions" which must of necessity be considered in the development of any study of the Milwaukee Harbor estuary.

Comprehensive Plan for the Milwaukee River Watershed

The comprehensive study of the Milwaukee River watershed was initiated in October 1967 and completed in October 1971. The findings and recommendations were published in SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River

Watershed, Volume One, Inventory Findings and Forecasts, published in September 1970, and Volume Two, Alternative Plans and Recommended Plan, published in October 1971. The planning program was conducted by the Regional Planning Commission with financial assistance from the Wisconsin Department of Natural Resources, U.S. Department of Housing and Urban Development, and the U.S. Environmental Protection Agency. The specific objectives of the planning program included the abatement of flood damage; the protection of floodlands from incompatible development; the abatement of water pollution; the preservation of land for parks and open space; and the promotion of wise and judicious use of the land and water resources of the watershed. Thus, the plan included recommendations for the abatement of flooding and for water quality enhancement. The study specifically did not include the estuary portion of the river except with respect to flooding and combined sewer overflow abatement.

The watershed study, of necessity, addressed the amounts and temporal distribution of streamflow in the river. This resulted in a characterization of both the high flow and low flow hydrology of the Milwaukee River itself throughout the entire watershed upstream from the North Avenue dam. In addition to the characterization of the quantity of water in the Milwaukee River, the watershed study also addressed the quality of streamflow, again upstream from the North Avenue dam. The watershed study relied upon water quality data from the following sources:

1. The Commission monthly stream water quality sampling program conducted at 12 sampling sites in the watershed for the period January 1964 through February 1965. All sampling sites were located upstream from Milwaukee County.

2. The continuing water quality sampling program of the Commission conducted twice a year at 12 stations within the watershed over the period from 1964 through 1970.

3. The Wisconsin Department of Natural Resources water quality surveys conducted in the watershed during the period from 1966 through 1968.

4. The Department of Natural Resources long-term water quality monitoring station on the Milwaukee River at Brown Deer Road, including monthly samples analyzed for 20 indicators taken over the period from May 1961 through 1970.

5. Special intensive water quality sampling efforts conducted by the Commission through its consulting engineers, Harza Engineering Company, during the periods April 29 through May 3, 1968; and July 27 through August 7, 1968.

6. Samples obtained by the Milwaukee Metropolitan Sewerage District (MMSD) laboratory staff during stream surveys along Lincoln Creek and the Milwaukee River within Milwaukee County during the period from May 1 through November 30, of each year from 1946 to 1968.

7. Samples obtained by the City of Milwaukee through its consulting engineers, Consoer, Townsend and Associates, in cooperation with Marquette University water quality sampling efforts conducted at five locations along the Milwaukee River upstream from the North Avenue Dam during 1967

and 1968, as part of a federal water pollution control administration demonstration project which included the evaluation of a combined sewer overflow control system at N. Humboldt Avenue in the City of Milwaukee.

SEWRPC Planning Report No. 13, Volume One in Tables 64, 65, and 66 summarizes the above data listing the total number of samples at each sampling site and maximum, minimum, and average values for water temperature, dissolved oxygen, biochemical oxygen demand (BOD), total and soluble phosphorus, nitrate nitrogen, chloride, and coliforms. Twenty-nine sites were sampled on the main stem of the Milwaukee River, with seven sites in Milwaukee County at County Line Road, Brown Deer Road, Green Tree Road, Silver Spring Drive, upstream and downstream from the Estabrook Park dam, and upstream from the North Avenue dam. Additional details about the SEWRPC water quality monitoring program can be found in Volume One of SEWRPC Planning Report No. 13. The DNR and MMSD water quality monitoring data are further described later in this chapter.

The study indicated that the stream water quality conditions in the watershed varied greatly, with the level of water quality of the watershed being relatively better than that of some of the other watersheds in the Region, particularly the Root and the Fox River watersheds. However, the study indicated that the then-existing stream water quality conditions generally did not meet the standards attendant to the State established water use objectives. The study also indicated that stream water pollution was particularly severe below the Milwaukee County line, and that the Milwaukee River and its tributaries in the County could be considered to be grossly polluted. The study identified, quantified, and evaluated all major sources of stream water pollution. Analyses indicated that a high proportion of the total load of pollutants to the watershed was contributed below the Milwaukee County line and that a substantial amount of pollution was contributed by the sewerage system flow relief devices--both separate and combined--in the watershed. The plan developed recommendations for the cost-effective abatement of both point source and nonpoint source pollution in the watershed.

Analyses were conducted to determine the most cost effective solution to the pollution and public health problems caused by the sewerage system flow relief devices with particular emphasis on the abatement of combined sewer overflows. Based upon the screening and analysis of 15 alternatives, the plan recommended the combination of deep tunnel mined storage/flow-through treatment be implemented as a major water pollution abatement plan element for the watershed. The plan recommended and described a proposed preliminary engineering study which would refine and detail the watershed study recommendation in a subsequent document prepared by the Commission at the request of the Milwaukee Metropolitan Sewerage District. This recommendation was further detailed in a document entitled, Prospectus for Preliminary Engineering Study for the Abatement of Pollution from Combined Sewer Overflow in the Milwaukee Metropolitan Area, published in July of 1973, which provided the basis for the initiation of studies conducted by the Milwaukee Metropolitan Sewerage District starting in 1974.

Comprehensive Plan for the Menomonee River Watershed

The comprehensive study of the Menomonee River watershed was initiated in March 1972 and completed in October 1976. The findings and recommendations were published in SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, Inventory Findings and Forecast; and Volume Two, Alternative Plans and Recommended Plan, published concurrently in October 1976. The planning program was conducted by the Regional Planning Commission with financial assistance from the Wisconsin Department of Natural Resources, the U.S. Department of Housing and Urban Development, and the U.S. Environmental Protection Agency. The specific objectives of the planning program were the abatement of flood damages, the abatement of surface water pollution problems, and the preservation of land for parks and open space. Therefore, the plan included recommendations for the abatement of flooding and water pollution and for natural resource conservation, and park and open space acquisition and development. The study specifically did not include the estuary portion of the river except with respect to flooding and combined sewer overflow abatement.

The watershed study, of necessity, addressed the amounts and temporal distribution of streamflow in the river. This resulted in a characterization of both the high flow and low flow hydrology of the Menomonee River itself throughout the entire watershed upstream from the low head dam owned by the Falk Corporation and located near the 27th Street bridge in the City of Milwaukee. In addition to the quantity of water, the watershed study also addressed the quality of stream flow. The watershed study relied upon water quality data from the following sources:

1. The Commission stream water quality sampling program conducted at 12 sampling sites in the watershed above 70th Street for the period from 1964 through February 1965.

2. The continuing water quality sampling program of the Commission conducted twice a year at 12 stations in the watershed over the period from 1968 through 1974, including a once yearly 24-hour survey starting in 1970.

3. The Wisconsin Department of Natural Resources (DNR) water quality surveys conducted in the watershed in 1951, 1952-1953, 1962, 1966-1967, and 1968-1969. The surveys conducted in the Milwaukee County portion of the watershed are further described later in this chapter.

4. The eutrophic evaluation study conducted from April 1968 to December 1969 by Professor A. Zanoni of Marquette University and published as "Eutrophic Evaluation of a Small Multi Land Use Watershed", a UW Water Resources Center Technical Report in June 1970.

5. A creosote pollution study conducted in 1972 by the Citizens for the Menomonee Restoration, Inc. on the Little Menomonee River.

6. Wisconsin Department of Natural Resources preliminary International Joint Commission Pilot Study of the Menomonee River Watershed for 1973 and 1974.

7. Special synoptic water quality surveys conducted on two 24-hour periods in 1973 and one 24-hour period in 1974, as part of the watershed study by the Commission through the Wisconsin Department of Natural Resources and the U.S. Geological Survey.

The data for the above-listed projects are described in SEWRPC Planning Report No. 26, Volume One in Chapter 7 and Appendices C, D, and E. Data are on file at SEWRPC.

The study indicated that the streams of the watershed were generally polluted as a result of pollutants contributed by municipal sewage treatment plants, sanitary and combined sewerage system flow-relief devices, industrial discharges, urban storm water runoff, and agricultural and other rural runoff. The study indicated the importance of diffuse or nonpoint source pollution and its extensive impact upon the water quality of the watershed. The study further identified the existence of relatively high levels of soil erosion within the watershed, which was attributed in a large part to the urbanizing nature of the watershed, as contributing to problems of water quality, navigation and maintenance, and unstable channel conditions throughout the watershed. Severe pollution in the watershed was found to exist with respect not only to the conventional pollution indicators, such as dissolved oxygen, fecal coliform, and nutrient pollution, but also in the presence of toxic and hazardous materials such as heavy metals and creosote. The study further documented wide variation in water quality conditions as well as the severe limitations in use of the Menomonee River and its tributaries as a result of the water quality problems.

The plan developed recommendations for the cost effective abatement of both point source and nonpoint source pollution in the upper and lower watersheds. The analyses conducted indicated the most cost effective solutions to the pollution and public health problems caused by these pollution sources. The recommended plan proposed the abatement of water pollution problems through the abandonment of four then remaining municipal sewage treatment plants in the watershed, the abatement of combined sewer overflows, the gradual elimination of separate sewer flow relief devices, the gradual elimination of industrial wastewater discharges through the Wisconsin Pollutant Discharge Elimination System, the abatement of the creosote pollution problem in the Little Menomonee River by the excavation of a new channel and filling of existing channel to reestablish a safe and healthy stream channel, the extension of sanitary sewer service to additional urban development during the plan period, and implementation of urban and rural nonpoint source water pollution control measures.

Comprehensive Plan for the Kinnickinnic River Watershed

The comprehensive study of the Kinnickinnic River watershed was initiated in July 1976 and completed in December 1978. The findings and recommendations were published in SEWRPC Planning Report No. 32, A Comprehensive Plan for the Kinnickinnic River Watershed, published in December 1978. The planning program was conducted by the Regional Planning Commission with the local source of funding being provided by the Milwaukee County Board of Supervisors, and with financial assistance from the Wisconsin Department of Natural Resources and the U.S. Department of Housing and Urban Development. The specific objectives of the planning program were the mitigation of existing flood problems and minimization of future flood problems, abatement of existing water quality problems, prevention of future water quality problems, and refinement and adjustment to the regional land use plan to properly relate land use decisions to the water resources system. Therefore, the plan included recommendations for the abatement of flooding and water quality problems and related land and other natural resource conservation problems of the watershed. The study specifically did not include the estuary portion of the river, except with respect to flooding and combined sewer overflow abatement.

The watershed study therefore addressed the amounts and temporal distribution of streamflow in the river resulting in a characterization of high flow and low flow hydrology of the Kinnickinnic River. In addition, the watershed study also addressed the quality of streamflow. The watershed study relied upon water quality data from the following sources:

1. The City of Milwaukee Engineers' reports concerning the Kinnickinnic River flushing tunnel, prepared in 1908 and 1954.

2. The City of Milwaukee Port and Park Commissioners Study published in 1932.

3. The Wisconsin Department of Natural Resources (DNR) River Basin Surveys conducted in 1952-1953 and in 1968.

4. The Commission streamwater quality sampling program conducted at one sampling site in the watershed for the period from April 1964 to February 1975.

5. The continuing water quality sampling program of the Commission conducted twice a year for one station within the watershed over the period from 1968 through 1976, including a once yearly 24-hour survey starting in 1970.

6. Milwaukee Metropolitan Sewerage District (MMSD) survey of 1967.

7. City of Milwaukee Health Department reports concerning the effects of the flushing tunnel prepared in 1970 and 1974.

8. DNR Basin Surveys of Toxic and Hazardous Substances conducted in 1975 and 1976.

9. The Commission special water quality index monitoring program for the areawide water quality management planning program conducted in 1976 and 1977.

10. DNR study of Mitchell Field storm water runoff characteristics in 1977.

11. The City of Cudahy Health Department study conducted in 1977.

The data for the above-listed projects are described in Chapter 7 of Planning Report No. 32 are on file at SEWRPC. Additional discussion of water quality surveys by the DNR and MMSD are provided later in this chapter.

The study indicated that the stream water quality conditions in the watershed varied greatly and were in part attributable to storm water runoff characteristics within the watershed. The study also indicated that the amount of pollutant mass transported during wet weather was significantly greater than was the associated increase in concentrations. The study also indicated the presence of substantial concentrations of heavy metals, as well as indications of the presence of industrial organics and pesticides. The study also indicated that water quality benefits are derived from the operation of the flushing tunnel; that water chemistry parameters indicate substandard water quality conditions for the support of warmwater fish and aquatic life in many reaches during many times of the year; that the biological community in the Kinnickinnic River was indicative of severely polluted conditions, and may be representative of a condition in which toxic substances are sometimes present, therefore precluding the sustained maintenance of a warm water fishery and other aquatic life. The study further indicated that the extensive channelization in the watershed as well as the discharges of raw sanitary sewage were also important factors in the limitations of the water quality conditions of the watershed. The study identified, quantified, and evaluated all major sources of stream water pollution. Analyses indicated the importance of diffused, or nonpoint, sources of water pollution accounting for 20 to 90 percent of the loads of various pollutants to the surface waters of the watershed. The critical role of the combined sewer overflows as a major source of water pollution was noted.

Analyses were also conducted to determine the most cost effective solution to the pollution and public health problems caused by the pollution sources in the watershed including the nonpoint source pollution. The plan recommended elimination of combined sewer overflows, the elimination of separate sanitary sewer system flow relief devices, the gradual abatement of pollution from the 60 industrial discharges, an approximately 25 percent reduction in nonpoint source pollution, implementation measures to control additional sources of toxic and hazardous substances including accidental spills and intermittent discharges of such materials.

Regional Water Quality Management Plan

The regional water quality management planning program was initiated in July 1975 and completed in June 1979. The findings and recommendations were published in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings, Volume Two, Alternative Plans, and Volume Three, Recommended Plan, published in September 1978, February 1979, and June 1979, respectively. The planning program was conducted by the Regional Planning Commission with financial assistance from the Wisconsin Department of Natural Resources and the U.S. Environmntal Protection Agency. The specific objectives of the program were the full integration of water quality management planning with regional land use planning; development of an areawide water quality management planning program as required under Section 208 of Public Law 92-500; extension, revision, and refinement as necessary of the previously adopted watershed and regional sanitary sewerage system plans of the Commission; preparation of a sludge management plan element; coordination and integration of facility planning for municipal wastewater conveyance and treatment facilities; and establishment of a continuing regional water quality management planning program. Of particular importance to the Milwaukee Harbor estuary study is the fact that the regional water quality management planning program did not address Lake Michigan or the fresh water estuaries of the rivers of southeastern Wisconsin.

The regional water quality management planning program addressed the levels, spatial distribution, and temporal distribution of water quality conditions in the 1,180 miles of continuous stream and in 100 major lakes in the Region. This provided characterization of both high-flow and low-flow conditions, particularly in the three rivers tributary to the Milwaukee Harbor estuary and, through the use of a continuous hydrologic-hydraulic water quality simulation model, provided an important characterization of the dynamic conditions of these inflowing rivers. The planning program relied upon water quality data from the following sources:

1. The Commission stream water quality sampling program conducted monthly at 87 sampling sites for the period from January 1964 through February 1965.

2. The continuing water quality sampling program of the Commission conducted two times per year at 87 stations over the period from 1968 through 1976 including a once yearly 24-hour survey starting in 1970.

3. The water quality information developed in previous watershed planning programs of the Commission as discussed under the comprehensive watershed planning studies noted above.

4. The Commission Index Site Sampling Program conducted by the Wisconsin Department of Natural Resources (DNR) in 1976 and 1977 under contract to the Commission as part of the regional water quality management planning program itself.

5. The DNR water quality surveys conducted in the Region's watersheds during the period from 1952 through 1976.

6. The City of Milwaukee Health Department water quality sampling data collected from 1965 through 1975.

7. The Milwaukee Metropolitan Sewerage District (MMSD) water quality sampling data obtained over the period 1965 through 1976.

The data from the above-listed projects are described in SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975 and are on file at SEWRPC. Additional descriptions of water quality surveys by the City of Milwaukee Health Department, the DNR, and MMSD are provided later in this chapter.

The study indicated that the stream water quality conditions in the Region did not generally meet the state and federally established water use objectives and supporting water quality standards. Moreover, the study indicated that over the period since 1964, at which time the Regional Planning Commission sampling programs had been initiated, there had been a subtle but widespread decline in water quality conditions in the Region despite the existence of certain specific stream reaches which had improved as a result of point source pollution control actions. Taken together with the results of the extensive pollution source inventory conducted as part of the planning program, these results indicated that the abatement of nonpoint sources of water pollution is of critical importance in the attainment and maintenance of water quality standards in the lakes and streams in the Region, including the Milwaukee, Menomonee, and Kinnickinnic River watersheds. Studies clearly indicated the relative severity of the pollution in these three rivers at the lower ends of their watersheds both on the basis of in-stream sample data and on the basis of the available pollution source loading estimates. Evaluation of the future actions necessary to abate water pollution in the Region further confirmed the importance and sensitivity of water quality conditions to nonpoint source as well as point source water pollution, both of which must be controlled to improve water quality. In the conduct of analyses to determine the most cost-effective solutions to the water quality problems in the Region, the planning program indicated that various levels of nonpoint source water pollution control would be required in various portions of the three watersheds tributary to the Milwaukee Harbor estuary. For the control of combined sewer overflows and the control of nonpoint sources of water pollution in the combined sewer service area of Milwaukee and Shorewood, the plan assumed the construction of deep tunnel conveyance, storage, and treatment facilities in lieu of land management practices which would otherwise be required to be applied within this area. This recommendation was incorporated into the regional water quality management plan pending the completion and adoption by all parties concerned of the water pollution abatement plan of the Milwaukee Metropolitan Sewerage District.

U.S. DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS

Studies conducted or ongoing that are relevant to the Milwaukee Harbor estuary study design are primarily concerned with harbor dredging and spoils disposal; Great Lakes water level measurements and forecasts; certain research conducted by the Coastal Engineering Research Center; and regulatory activities under Sections 9 and 10 of the federal Rivers and Harbors Act of 1899, under Section 404 of the federal Water Pollution Control Act and under the general and nationwide permit programs of the Corps.

Harbor Dredging and Spoils Disposal

The Federal Navigation Project, Milwaukee Harbor, Wisconsin, is funded by appropriations from Congress, and is an ongoing project. The objective of the project is to provide dredging for navigation purposes, and to maintain and repair the breakwater which forms the outer harbor. Congressionally designated federal channels are authorized for maintenance dredging and are shown on Map 2. Dredging depths are currently maintained to 26 feet. Dredging operations are conducted on the average about two times in every three years. Annual dredging averages about 100,000 cubic yards. Spoils have, since the spring of 1976, been placed in a confined spoils disposal facility located at the south end of the outer harbor. The effluent of this facility, which consists of excess water draining from the spoils placed in the facility, is to be monitored during dredging operations and a short time thereafter to determine chemical quality as requested by the U. S. Environmental Protection Agency. Such a monitoring effort was conducted in the spring of 1976. The data from this sampling program were not published but are on file at SEWRPC. Water quality parameters monitored are listed in Table 1. Plots of concentration versus time throughout the sampling period were prepared by the contract laboratory for each of the water quality parameters for the Corps of Engineers and are on file at SEWRPC. Sediment samples were also taken inside the disposal facility and at numerous locations in the inner harbor. Sediment quality parameters monitored are listed in Table 2. Macroinvertebrate samples were taken in the outer harbor near the spoils disposal facility in June 1976 using an Ekman grab sampler at two sites. Six samples were taken yielding about 14,000 organisms. Table 3 lists the types and numbers of macroinvertebrates found. Map 3 shows the locations of the water quality, sediment quality, and macroinvertebrate sampling sites. PCB water column concentrations ranged from a trace--less than 0.1 part per billion (ppb)--to as high as 7.64 ppb during the sampling period which preceded, coincided with, and followed the dredging period. PCB concentrations in the bottom sediments ranged from 7.58 to 96.3 ppb.

A draft environmental statement prepared by the Chicago District of the Corps in July 1973 for the maintenance dredging program contains bottom sediment sampling data for the inner harbor in the Menomonee and Kinnickinnic River channels collected April 24, 1968.[1] Nine sites were sampled (see Map 3), three sites being in the federal channel in the Kinnickinnic River, and six in the federal channel in the Menomonee River. The Draft Environmental Statement provides detailed descriptions of the sampling site locations and field descriptions of the physical characteristics of the bottom sediments collected at all nine sites, along with water depth at

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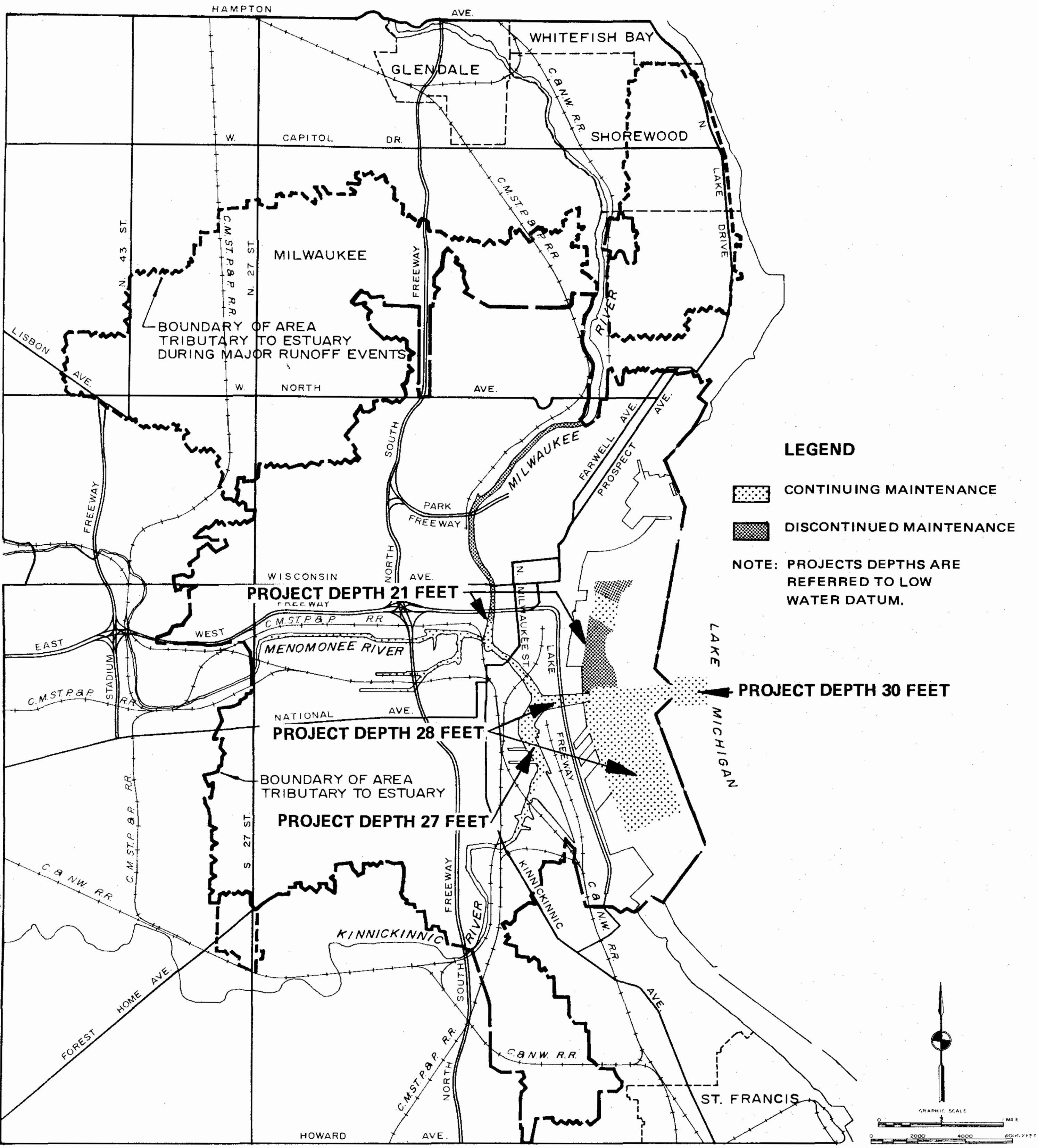
[1] *U.S. Army Corps of Engineers, Chicago District, "Draft Environmental Statement--Maintenance Dredging at Milwaukee Harbor, Wisconsin," July 1973.*

Map 2

LOCATION OF FEDERAL CHANNELS IN MILWAUKEE HARBOR



Source: U.S. Army Corps of Engineers, Chicago District, Review Report--Milwaukee Harbor, Wisconsin, March 1974.

Table 1

LIST OF WATER QUALITY PARAMETERS AND PERIODS MONITORED BY THE U.S. ARMY CORPS OF ENGINEERS IN THE VICINITY OF THE OUTER HARBOR DREDGE SPOILS DISPOSAL FACILITY DURING THE SPRING OF 1976

Parameters Monitored April 12-June 18[a]	
Suspended Solids	Oil and Grease
Turbidity	PCB's[b]
Temperature	Chlorides
Specific Conductance	Sulfates
pH	Zinc
Dissolved Oxygen	Cadmium
5-day Biochemical Oxygen Demand (BOD)	Nickel
Ammonia	Manganese
Total Kjeldahl Nitrogen	Arsenic
Total Inorganic Nitrogen	Chromium
Total Phosphorus	Mercury
Ortho-Phosphorus	Lead
Fecal Coliforms	Copper

[a]*Thirty vertical composite measurements for each of these parameters were made, with sampling intervals averaging 2 to 3 days. Specific dates, times, and locations of sampling are included with the data which are on file at SEWRPC.*

[b]*PCB's were sampled during the period March 25 through June 18, 1976 with a total of 303 samples taken. Specific dates, times, and locations of sampling are on file at SEWRPC.*

Source: U. S. Army Corps of Engineers' unpublished data, on file at SEWRPC.

Table 2

LIST OF SEDIMENT QUALITY PARAMETERS AND PERIODS MONITORED BY THE U.S. ARMY CORPS OF ENGINEERS IN THE INNER HARBOR DURING THE SPRING OF 1976

Parameters Monitored April 14-June 18[a]	
PCB's[b]	Zinc
Total Solids	Cadmium
Volatile Solids	Nickel
Ammonia	Manganese
Total Kjeldahl Nitrogen	Arsenic
Total Inorganic Nitrogen	Chromium
Total Phosphorus	Mercury
Ortho-Phosphorus	Lead
Oil and Grease	Copper
Sulfates	

[a] *A total of 10 measurements were made for each of these parameters with sampling intervals averaging about one week. Specific dates of sampling are on file at SEWRPC. Sampling locations are shown on Map 3.*

[b] *PCB's were sampled during the period April 23 through June 16, 1976. A total of 8 samples were taken at about weekly intervals. Specific dates of sampling are on file at SEWRPC. Sampling locations are shown on Map 3.*

Source: U. S. Army Corps of Engineers, unpublished data, on file at SEWRPC.

Table 3

BENTHIC MACROINVERTEBRATES FOUND IN THE OUTER HARBOR IN THE VICINITY OF THE DREDGE SPOILS DISPOSAL FACILITY JUNE 23, 1976 BY THE U.S. ARMY CORPS OF ENGINEERS

Macroinvertebrate	Number Found Sample Site[a] 3M	7M
DIPTERA (flies)		
Culex	8[b]	0
Chironomus	44[b]	0
CRUSTACEA		
Asellus	48	108
Gammarus	4	0
HIRUDINEA (leeches)	16	1
BIVALVIA (clams)		
Spaerium	112	344
GASTROPODA (snails)		
Bulimus	12	0
Valvata	0	16
OLIGOCHAETA (earthworms)[c]		
Limnodrilus and Potamothrix	6,000	7,200

[a]*See Map 3 for sampling site locations. At each site 6 samples were taken using a 6' x 6' Ekman grab sampler.*

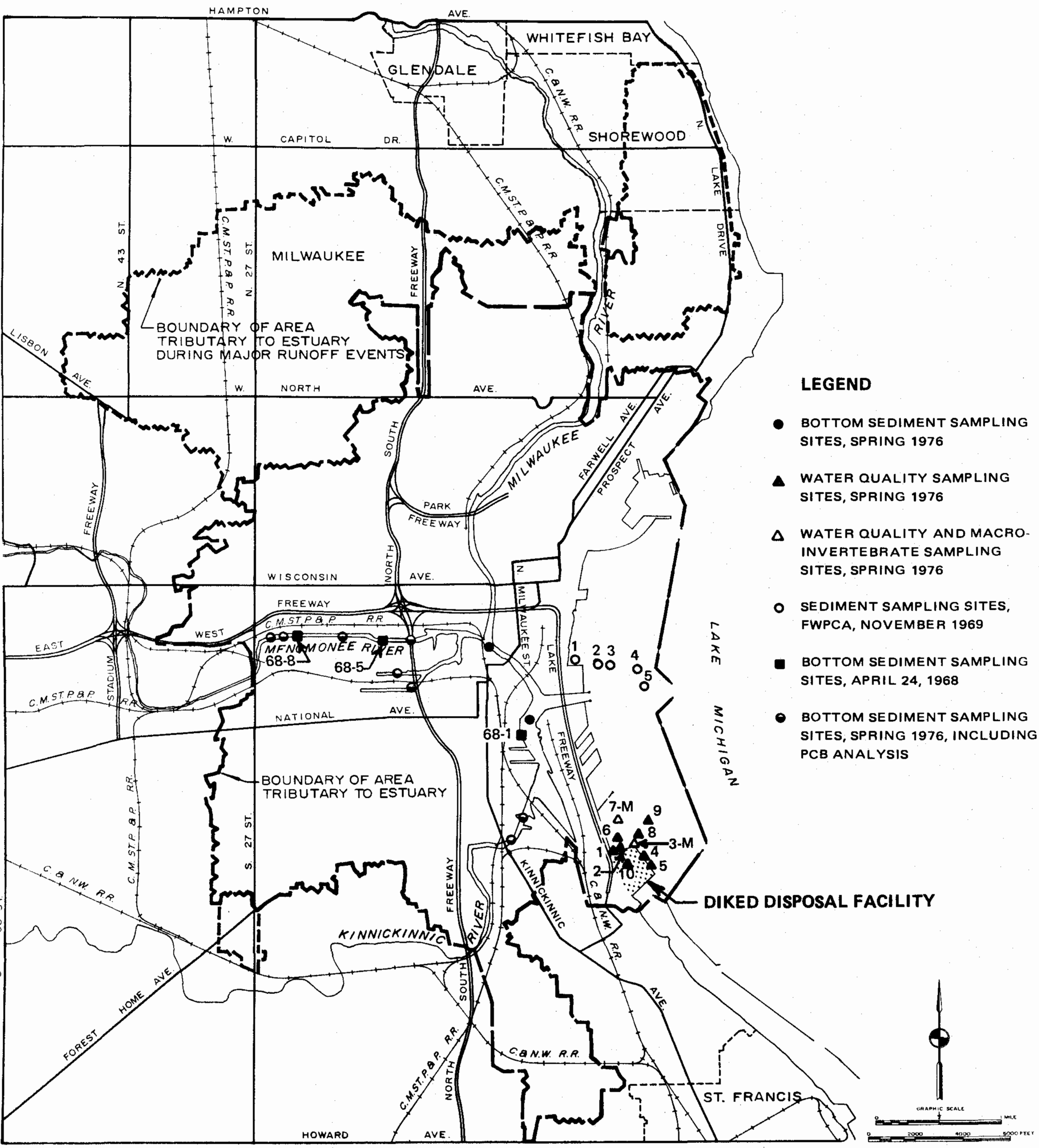
[b]*Larvae.*

[c]*The majority of the oligochaetes were limnodrilus.*

Source: U.S. Army Corps of Engineers' unpublished data, on file at SEWRPC.

Map 3

LOCATIONS OF WATER AND SEDIMENT QUALITY AND BENTHIC MACROINVERTEBRATE MONITORING SITES SAMPLED IN 1968, 1969, AND 1976 FOR DREDGING PERMIT APPLICATIONS BY THE U.S. ARMY CORPS OF ENGINEERS



Source: U.S. Army Corps of Engineers, unpublished data, on file at SEWRPC.

each location. Table 4 presents the results of chemical and physical analyses performed on the bottom sediments at three of the sampling sites for 20 parameters. The Corps of Engineers concluded that the bottom sediments collected in the Kinnickinnic River federal channel were "severely polluted by domestic sewage" and unsuitable for disposal in Lake Michigan. It was concluded that bottom sediments in the Menomonee River federal channel were "severely polluted by oil and domestic sewage" and unsuitable for disposal in Lake Michigan.

An amendment to the Federal Navigation Project was proposed by a report prepared by the Chicago District of the Corps of Engineers in March 1974 entitled Review Report-Milwaukee Harbor, Wisconsin. The study was requested by the City of Milwaukee through the Board of Harbor Commissioners and was authorized and funded by Congress on December 11, 1969. The purpose of the project was to improve commercial navigation in the outer north harbor to provide access to proposed general cargo terminal facilities. Alternative plans were developed for the consideration of the City of Milwaukee and a recommended plan was selected. The recommended plan included a 65-acre contained dredge spoils facility located in the harbor adjacent to the existing shoreline just north of the mouth of the Milwaukee River. A channel to be maintained to a depth of 28 feet would provide access to a proposed terminal facility.

Data collected during this study relevant to the Milwaukee Harbor study design were gathered by the Corps and the federal Water Pollution Control Administration (FWPCA). The Corps made a lead-line sounding survey during July and August of 1971 for the project area, with a total of 39 probings. Contour maps of depth to hard material and depth to point of refusal, that is, the limits of effective ability to drive the probes, were prepared and are included in the Corps report on Plates B-1 and B-2, respectively.[2] The FWPCA in November 1969 took five sediment cores in the project area (see Map 3). The cores sampled the top two and one-half to three feet of the bottom sediments. Table 5 lists the sediment quality parameters and presents the results of the chemical analyses. The Review Report-Milwaukee Harbor, Wisconsin also includes physical descriptions of these sediment cores. The FWPCA described the top silty layer of the sediments as "heavily" polluted and the underlying clay as "moderately" polluted, and consequently ruled that open-lake disposal of dredge materials from the proposed project should not be permitted.

The environmental impacts of the proposed navigation project were reported to be "alteration of bottom sediments, disruption of the benthic community residing on or in the sediments to be excavated, the creation of minor turbidity plumes during excavation operations, reintroduction of some biostimulants and toxic pollutants from existing bottom sediments into the aquatic environment, and conversion of 65 acres of aquatic habitat to terrestrial environment." These impacts were assumed by the Corps of Engineers to be either temporary or minor and therefore not significant enough to jeopardize the proposed project.

The study report concluded that the project was economically justifiable and recommended implementation. The City of Milwaukee, however, concluded that effects upon recreation would be detrimental, primarily because land would be taken from use by the annual "Summerfest" sponsored by the City, and because increased ship traffic

[2] *U.S. Army Corps of Engineers, Chicago District, Review Report-Milwaukee Harbor, Wisconsin, March 1974.*

Table 4

LIST OF BOTTOM SEDIMENT QUALITY PARAMETERS AND CHEMICAL AND PHYSICAL ANALYSES FOR 3 SITES IN THE INNER HARBOR SAMPLED BY THE U.S. ARMY CORPS OF ENGINEERS: APRIL 24, 1968

Parameter	Amount[a] Sampling Sites[b]		
	MILW 68-1	MILW 68-5	MILW 68-8
Percent Total Solids	56.5	48.0	41.9
Percent Volatile Solids	5.7	16.2	19.3
Chemical Oxygen Demand (COD)	108,900	251,500	223,700
Total Soluble Phosphorus	5.01	11.20	2.43
Total Phosphorus	301	354	1,121
NH_3-N	388	281	582
NO_3-N	10.6	8.3	14
Org-N	1,607	6,118	3,157
Phenol	5.85	2.05	3.38
Oil and Grease	4,660	20,850	26,140
Cyanide	--[c]	0.80	1.40
Sulfide	280	1,180	466
Total Iron	12,890	19,890	19,700
Copper	--[c]	22	20
Cadmium	0.69	6.5	10.3
Nickel	41	56	12
Zinc	244	340	--
Lead	165	363	360
Chromium	--	18	40

[a]Chemical analyses presented in milligrams per kilogram. All results reported on a dry weight basis.

[b]Sampling site locations are shown on Map 3.

[c]Not detected within sensitivity of test.

Source: U. S. Army Corps of Engineers, Chicago District, Draft Environmental Statement--Maintenance Dredging at Milwaukee Harbor, Wisconsin, July 1973.

Table 5

LIST OF BOTTOM SEDIMENT QUALITY PARAMETERS AND RESULTS OF LABORATORY ANALYSES FOR SAMPLES COLLECTED BY THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION IN THE OUTER NORTH HARBOR ON NOVEMBER 24 AND 25, 1969

Parameter	Amount at Sampling Sites[a,b]					
	1[c]	3[c]	5[d]	1[e]	2[e]	3[e]
Percent Solids.........	39.7	13.7	47.7	82.7	78.8	86.6
Percent Volatile Solids...............	9.8	12.6	7.7	6.6	7.7	8.9
Total Phosphorus.......	2,007	1,480	4,330	151	512	355
Oil and Grease.........	10,199	8,968	6,672	417	1,021	2,505
Total Iron.............	16,675	29,197	20,500	27,328	20,600	21,478
Zinc...................	657	395	342	56	49	52
Lead...................	201	146	168	35	51	46
Chemical Oxygen Demand (COD)..........	--	--	126,030	--	--	--
Ammonia................	--	--	279	--	--	--

[a] Chemical analyses presented in milligrams per kilogram. All results reported on a dry weight basis.
[b] See Map 3 for locations of sampling sites.
[c] Sample analyzed from top of core.
[d] Petersen grab sampler sample.
[e] Sample analyzed from bottom of core.

Source: U. S. Army Corps of Engineers, Chicago District, Review Report-Milwaukee Harbor, Wisconsin, March 1974.

in the outer north harbor would conflict with recreational boating. The Corps of Engineers, therefore, recommended to Congress that the proposed project be closed out because of lack of local support. As of August 1980, Congressional deauthorization was still pending.

Regulatory Program

The Corps of Engineers Regulatory Program has been funded by Congress since 1899, when the Corps was charged with the responsibility to prevent alteration or obstruction of navigable waters of the United States. Today the regulatory program is concerned not only with navigable channels, but also with the quality of surface waters. Thus, in addition to Section 10 of the River and Harbor Act of 1899, Sections 404 of Public Law 92-500 and 103 of Public Law 92-532 authorized the Corps to regulate through a permit program human activities to protect the quality of the nation's water resources, to maintain water quality by protecting marshes, swamps, and similar environmentally valuable wetland resources, and to control dumping of dredged material into the oceans and the Great Lakes.[3] A Corps permit is required to locate a structure, excavate, or discharge dredged material or place fill material in waterways or in wetlands bordering waterways. Typical activities requiring permits are listed in Table 6. As of July, 1980, the St. Paul District of the Corps of Engineers administered the regulatory program for the entire State of Wisconsin. The permit program is important in its own right, but its particular relevance to the Milwaukee Harbor estuary study design is that much of the water quality data previously collected in the harbor was generated to determine if certain proposed activities would be in compliance with the law as administered under this program.

Coastal Engineering Research Program

The Coastal Engineering Research Program of the Corps of Engineers was authorized by Public Law 166, 79th Congress, July 31, 1945, and supplemented by Public Law 172, 88th Congress, November 7, 1963. The program is ongoing and has been conducted by the Coastal Engineering Research Center (CERC), Fort Belvoir, Virginia, since 1963. The Beach Erosion Board (BEB) was the predecessor of CERC. The objective of the program is to conduct, and publish the results of, coastal research not only for the sea coasts, but also for the coasts of the Great Lakes. The results appear in the form of design manuals, technical reports containing results of research and development efforts, or major engineering studies reports and reports of wide public interest. An annotated bibliography of CERC and BEB publications was published in 1979.[4]

A CERC publication particularly relevant to the Milwaukee Harbor study design was published in July 1977 and is entitled Hydraulics of Great Lakes Inlets.[5] The purpose of the study was to develop a practical methodology for use in the prediction of harbor inlet velocities and water level oscillations developing in response

[3] *U.S. Department of the Army, U.S. Army Corps of Engineers Permit Program--A Guide for Applicants, Office of the Chief of Engineers, Washington, D.C., November 1977.*

[4] *U.S. Army Corps of Engineers, Bibliography of Publications of the Coastal Engineering Board, Coastal Engineering Research Center, Fort Belvoir, Virginia, June 1979.*

[5] *U.S. Army Corps of Engineers, Hydraulics of Great Lakes Inlets, Coastal Engineering Research Center, Technical Paper No. 77-8, Fort Belvoir, Virginia, July 1977.*

Table 6

TYPICAL WATERWAY ACTIVITIES REQUIRING
U.S. ARMY CORPS OF ENGINEERS PERMITS

Activity	
Artificial canals Artificial islands Beach nourishment Boat ramps Breakwaters Bulkheads Dams, dikes, weirs Discharging: Sand Gravel Dirt Clay Stone Dolphins	Dredging Filling Groins and jetties Intake pipes Levees Mooring buoys Ocean dumping Outfall pipes Pipes and cables Piers and wharves Riprap Road fills Signs Tunnels

NOTE: The permit program is authorized by Section 10 of the River and Harbor Act of 1899, Section 404 of Public Law 92-500, and Section 103 of Public Law 92-532.

Source: U.S. Department of the Army, U.S. Army Corps of Engineers Permit Program--A Guide for Applicants, Office of the Chief of Engineers, Washington, D.C., November 1977.

to lake seiche phenomena. Data were collected at 13 locations in the Great Lakes, eight sites being on the east shore of Lake Michigan, to evaluate the applicability of analytical methods and computer models. The study concluded, in part, that high quality harbor water-level records along with harbor and inlet geometry data could be utilized in a relatively simple procedure to determine harbor inlet velocities, which in turn could be converted to estimate inflow or outflow between the harbor and the lake.

Great Lakes Water Level Forecasting

Great Lakes water levels are published and forecast by the Corps of Engineers, in cooperation with the National Ocean Survey (NOS) of the U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), under the auspices of the International Coordinating Committee on Great Lakes Basin Hydraulics and Hydrologic Data, by Environment Canada and the Detroit District of the Corps. Water level data are available from 1860 to the present and are collected as a public service by NOS. A publication released monthly presents recorded levels for the previous year and current year to date, along with the probable levels for the next six months.[6] Mean, maximum, and minimum lake level data are presented in tabular and graphical form for the gaging station at Harbor Beach, Michigan, monitoring Lakes Michigan-Huron, as well as for gaging stations monitoring the other Great Lakes and Lake St. Clair. A complete description of Great Lakes water level monitoring by the NOS is presented with the discussion of programs conducted by the U. S. Department of Commerce, NOAA, in the next section of this chapter.

Lake Michigan Open-Coast Flood Levels

At the request of the Federal Insurance Administration, the Corps of Engineers prepared a report on flood levels for the Great Lakes.[7] Instantaneous annual peak levels recorded at monitoring stations on the Great Lakes, adjusted to present diversion and outflow control conditions, were utilized in frequency analyses to estimate 10-, 50-, 100-, and 500-year levels at each monitoring station. These data were then used to represent flood levels for segments of shoreline near each monitoring station. For Lake Michigan at Milwaukee the frequency analyses were based on water level records of the National Ocean Survey for the period 1906-1974. The 10-, 50-, 100-, and 500-year flood stages for this site are tabulated in the Report on Great Lakes Open-Coast Flood Levels in both the National Geodetic and the International Great Lakes Datums. Effects of short period wave height and wave runup are not reflected in the analysis.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Three subsidiary agencies of the National Oceanic and Atmospheric Administration (NOAA) have Great Lakes programs relevant to the Milwaukee Harbor study design: the Great Lakes Environmental Research Laboratory (GLERL), the National Ocean Survey (NOS), and the National Weather Service (NWS).

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[6] *U.S. Army Corps of Engineers, Detroit District, Monthly Bulletin of Lake Levels for the Great Lakes, published monthly.*

[7] *U.S. Army Corps of Engineers, Report on Great Lakes Open-Coast Flood Levels, Detroit, Michigan, 1977.*

Great Lakes Environmental Research Laboratory

GLERL was established in April 1974 to conduct environmental research for NOAA in the Great Lakes Region to increase knowledge of environmental processes for the purposes of solving environmental problems in the Great Lakes basin. GLERL programs particularly pertinent to the Milwaukee Harbor Study design include Lake Michigan water temperature monitoring, operation of wave gages in Lake Michigan, and near-shore and offshore limnological investigations in southern Lake Michigan.

Lake Michigan Water Temperature Monitoring: Great Lakes water temperatures have been systematically monitored by GLERL and predecessor agencies since 1966. The objectives of the monitoring program are to provide a continuous record of water temperature at 10 stations on the Great Lakes to quantify short-term, seasonal, annual, and long-term temperature variation; to provide data for the development of relationships between water temperature characteristics and limnological and meteorological phenomena; and to provide a continuous long-term record to be used for comparative purposes with short-term records collected during miscellaneous local or large-scale studies. Stations are at near-shore locations where conditions are such that water temperatures reflect fluctuations in the main lake mass. Temperature probes are set at about 10 feet below International Great Lakes Datum (1955) to minimize the effects of surface layer heating and cooling on the temperature record. Two stations have been operated in Lake Michigan, one at the north breakwater of Milwaukee Harbor for the periods 1966-1968, and 1970-1972, and the other on the coal dock at the Oak Creek Harbor from 1973 to the present.

A report describing the monitoring program entitled Great Lakes Water Temperatures, 1966-1975, was published by NOAA and contains a sample monthly summary of hourly average water temperatures.[8] A complete set of the hourly data is available on microfiche from the National Technical Information Service, however, an annual summary of daily mean water temperatures and a frequency distribution of daily mean water temperatures is contained in the report for the Lake Michigan stations. Periods of water temperature data available are shown in Figure 1. As the graph indicates, the temperature records are not continuous, with significantly long periods of "no record", because of station malfunctions.

The report concluded that many more years of record are necessary to define long-term temperature trends. The temperature records define short-term events such as initiation of spring warm-up and winter freeze-up, and the upwelling and downwelling periods.

Wave Monitoring in Lake Michigan: Surface wave data was collected by GLERL in Lake Michigan at two locations--near Muskegon, Michigan during 1973 and 1975-77, and near Milwaukee, Wisconsin during 1976 and 1977. The data were collected for the purpose of making detailed analyses of storm events, studies of wave growth and decay, studies correlating wave data with meteorological data, and wave prediction studies. The Milwaukee wave station was located at three sites about 6, 12, and 19 miles offshore, and almost due east from the Village of Fox Point, Wisconsin. Periods of wave record and other pertinent data for the Milwaukee station are presented in Table 7. A waverider buoy was used to collect the Milwaukee and Muskegon data.

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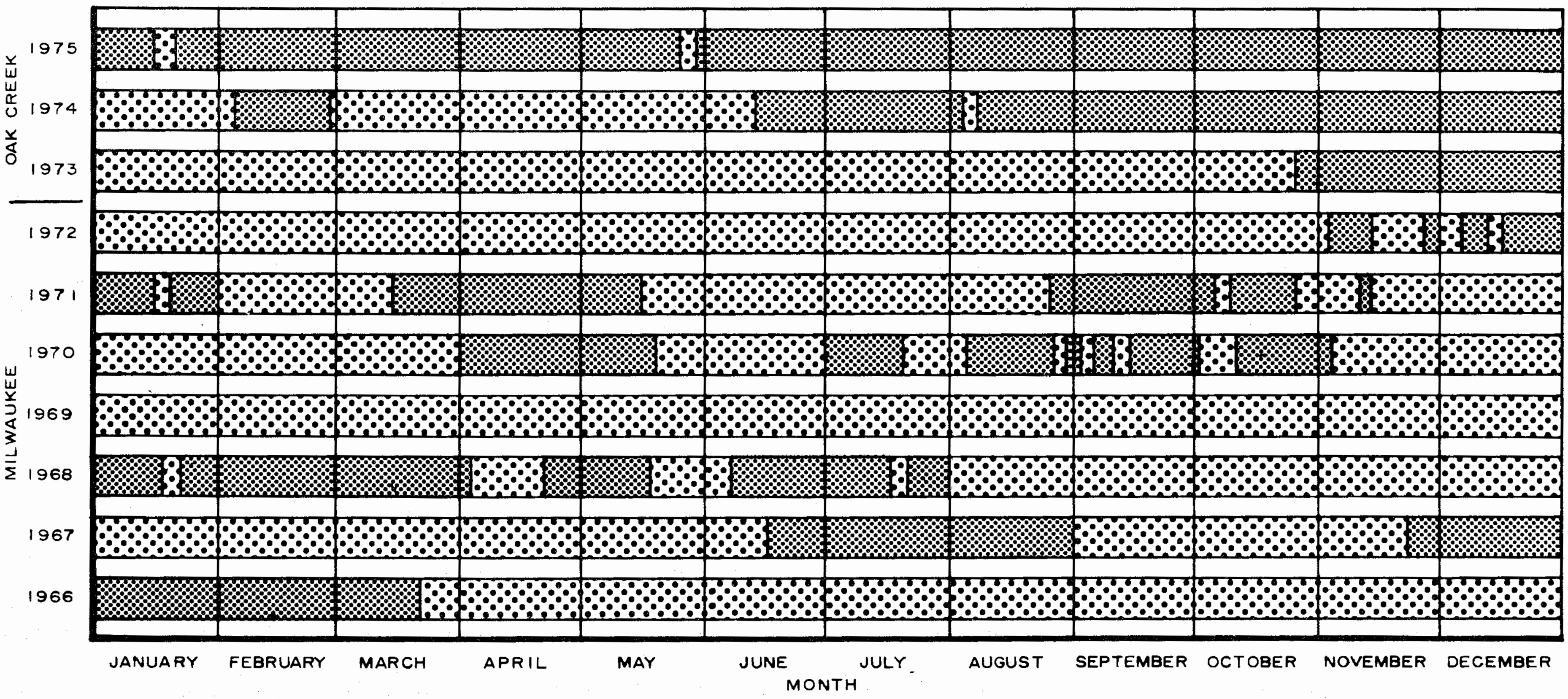
[8] *John L. Grumblatt, Great Lakes Water Temperatures 1966-1975, National Oceanic and Atmospheric Administration Technical Memorandum ERL GLERL-11-1, August 1976.*

Figure 1

PERIODS OF RECORD OF LAKE MICHIGAN HOURLY WATER TEMPERATURE DATA COLLECTED AT MILWAUKEE AND OAK CREEK FROM 1966-1975 BY THE GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY



LEGEND

RECORD OF WATER TEMPERATURE

NO RECORD OF WATER TEMPERATURE

NOTE: AVERAGE DAILY TEMPERATURES ARE SUMMARIZED FOR THE PERIOD OF RECORD IN THE REPORT <u>GREAT LAKES WATER TEMPERATURES 1966-1975,</u> NOAA TECHNICAL MEMORANDUM ERL GLERL-11-1, 1976. HOURLY DATA ARE SUMMARIZED ON MICROFICHE AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).

Source: John L. Grumblatt, Great Lakes Water Temperatures 1966-1975, National Oceanic and Atmospheric Administration Technical Memorandum ERL GLERL-11-1, August 1976.

Table 7

WAVE MONITORING PERIODS AND OTHER PERTINENT INFORMATION FOR THE LAKE MICHIGAN STATION NEAR MILWAUKEE OPERATED IN 1976 AND 1977 BY THE GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

Period of Record	Gage Location	Water Depth (feet)
Sept. 22 - Oct. 12, 1976	Lat. 43.17°N, Long. 87.52°W	230
June 13 - July 14, 1977	Lat. 43.20°N, Long. 87.77°W	245
June 16 - Nov. 29, 1977	Lat. 43.20°N, Long. 87.64°W	295

NOTE: Wave monitoring stations were about 6, 12, and 19 miles offshore almost due east from the Village of Fox Point.

Source: Blondell C. Doughty, Timothy A. Kessnick, and Paul C. Liu, Surface Wave Data Recorded in Lake Michigan During 1973 and 1975-77, National Oceanic and Atmospheric Administration Technical Memorandum ERL GLERL-19, 1978.

Table 8

NAUTICAL CHARTS PREPARED FOR THE MILWAUKEE HARBOR VICINITY: 1902 TO 1978

Edition/Date[a]	
1st/March 1902[b]	12th/March 1951
2nd/November 1907[b]	13th/May 1954
3rd/September 1912[b]	14th/June 1957
4th/January 1916[c]	15th/May 1959
5th/December 1928[c]	16th/March 1960
6th/April 1931[c]	17th/July 1963
7th/March 1936	18th/February 1966
8th/June 1939	19th/February 1969
9th/May 1942	20th/June 1972
10th/September 1944	21st/July 1975
11th/November 1947	22nd/August 1978

[a]*Chart 14924 (formerly LS743) is for Milwaukee Harbor and vicinity, and has been published at a scale of 1:10,000 starting with the seventh edition.*

[b]*Published at a scale of 1:12,000.*

[c]*Published at a scale of 1:15,000.*

Source: National Ocean Survey (written communication, August 28, 1980)

Wave statistics were summarized in NOAA Technical Memorandum ERL GLERL-19, based on 10 minutes of data per hour. The data are presented on microfiche, included with the report, and are in the form of hourly wave statistics which are summarized daily. These statistics include standard deviations, significant and average wave heights, and associated wave periods.[9] Digital tapes containing raw data are available from GLERL.

Limnological Studies in Southern Lake Michigan: Other ongoing GLERL efforts relevant to the Milwaukee Harbor study design include studies of coastal currents in southern Lake Michigan, water level oscillation and flooding studies in Lake Michigan, ecological modeling of sediment-water column interactions, dynamics of material movements in the near-shore zone, and development of simulation models for near-shore zone applications. Additional description of these studies is available from GLERL.

National Ocean Survey

National Ocean Survey (NOS) activities pertinent to the Milwaukee Harbor study design include the preparation of nautical charts of Lake Michigan and moniitoring water levels in Lake Michigan.

Nautical Chart Mapping: NOS activities in the Milwaukee vicinity of Lake Michigan include the preparation of nautical charts which contain detailed sounding data. The latest Milwaukee Harbor chart was published in 1978 as Chart 14924 and is a 1:10,000 scale map of the inshore area, outer harbor, and inner harbor.[10] Detailed sounding data are plotted on the map along with associated depth contours. Another chart published in September 1979 at a scale of 1:120,000--Chart 14904--covers the near-shore zone between Belgium, Wisconsin and Waukegan, Illinois.[11] Charting in the Milwaukee vicinity was begun early in the 19th century by the U. S. Coast and Geodetic Survey, working within the coastal zone only. The U.S. Lake Survey of the Army Corps of Engineers began preparation of nautical charts later in the 19th century, for offshore, as well as near-shore, areas of the Great Lakes. Their first chart of the Milwaukee Harbor was published in 1902. All charting activities since 1970 have been be conducted by NOS. Charts of Milwaukee Harbor are normally updated at three-year intervals. A listing of nautical charts prepared in the Milwaukee Harbor vicinity is presented in Table 8.

Lake Michigan Water Level Monitoring: The NOS records hourly water levels at numerous locations in the Great Lakes. During 1979, nine monitoring stations were operated in Lake Michigan at the locations shown on Map 4. NOS publishes the recorded water levels annually in tabular form on a calendar-year basis showing daily and monthly average water levels referred to the International Great Lakes datum of 1955. In addition, the annual report for each gage includes maximum and

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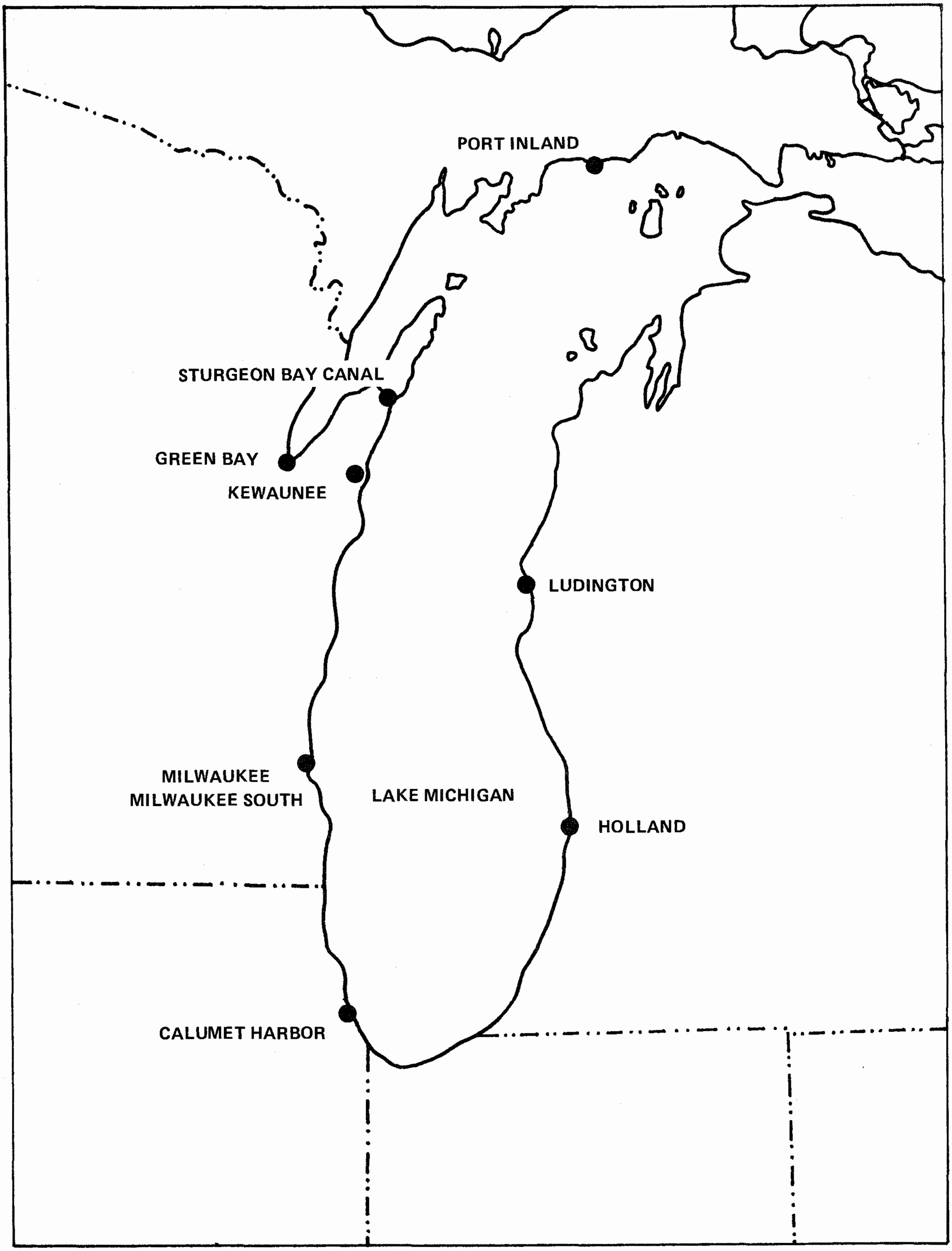
[9]*Blondell C. Doughty, Timothy A. Kessenick, and Paul C. Liu, Surface Wave Data Recorded in Lake Michigan During 1973 and 1975-77, National Oceanic and Atmospheric Administration Technical Memorandum ERL GERL-19, 1978.*

[10]*National Ocean Survey, Nautical Chart of Milwaukee Harbor, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Washington, D.C. Nautical Chart 14924, August 1978.*

[11]*National Ocean Survey, Nautical Chart - Port Washington to Waukegan, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Washington, D.C., Nautical Chart 14904, September 1979.*

Map 4

LOCATION OF LAKE MICHIGAN WATER LEVEL MONITORING STATIONS
OPERATED BY THE NATIONAL OCEAN SURVEY IN 1979



Source: *National Ocean Survey, Great Lakes Water Levels, 1979, U.S. Department of Commerce, National Ocean Survey, Rockville, Maryland, 1980.*

minimum average daily water level each month, maximum and minimum hourly water levels for the year and each month, a frequency distribution of daily average levels for the year, and the mean water level for the year. A table is also provided summarizing water levels from the year 1900 to the present for the Lakes Michigan-Huron monitoring station at Harbor Beach, Michigan. This table includes mean water levels for each month for the period since 1900, along with the highest and lowest mean monthly water levels. The report is divided into two sections, the first containing water level data in feet, and the second in meters.

At five-year intervals, NOS publishes a report summarizing monthly and annual average water levels for the period since 1860 for all monitoring stations, presently active or inactive, operated in the Great Lakes. The last summary report was published in 1976 with the next scheduled in calendar year 1981.[12] The report presents monthly and annual average water levels for each permanent gage for the period of record, average monthly levels for the period of record, average monthly levels for the period 1966-1975, and the maximum and minimum monthly average levels for the period of record. Table 9 presents the periods of record for monitoring stations operated on Lake Michigan.

As Table 9 indicates, water level records for Lake Michigan at Milwaukee have been collected since 1860. The monitoring station was located on the breakwater near the main entrance to the outer harbor through December 1969. The station was then relocated at the U.S. Coast Guard Station at the south end of the outer harbor near the dredge spoils disposal facility. Hourly data for this station and the other Lake Michigan stations is available in magnetic tape form.

National Weather Service

The National Weather Service (NWS) collects meteorological and hydrological data and provides forecasts and warnings for meteorological, riverine, and limnological events. NWS has operated a long-term weather station at the City of Milwaukee since the late 19th century. Types of meteorological data collected are listed in Table 10. Records for the parameters in Table 10 have been summarized periodically since 1950 by the NWS.[13] Data collected prior to 1950 and since 1871 are less readily available, but can be obtained from the NWS or the Meteorology Department of the University of Wisconsin at Milwaukee.

U.S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY

The U. S. Geological Survey (USGS) is currently involved in two programs relevant to the Milwaukee Harbor estuary planning program. The USGS is participating in the National Urban Runoff Pollution Study (NURPS) under the auspices of the U. S. Environmental Protection Agency, and is operating eight gaging stations monitoring storm sewers draining small urban basins in the Milwaukee and Menomonee River watersheds. Locations of the NURPS gaging sites are shown on Map 5. The study began in October

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[12] *National Ocean Survey, Great Lakes Water Levels, 1860-1975, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Rockville, Md., 1976.*

[13] *National Weather Service, Environmental Data Service, Local Climatological Data - Milwaukee, Wisconsin - Monthly Summary, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, North Carolina, published monthly.*

Table 9

WATER LEVEL MONITORING ON LAKE MICHIGAN BY THE NATIONAL OCEAN SURVEY SINCE JANUARY 1860

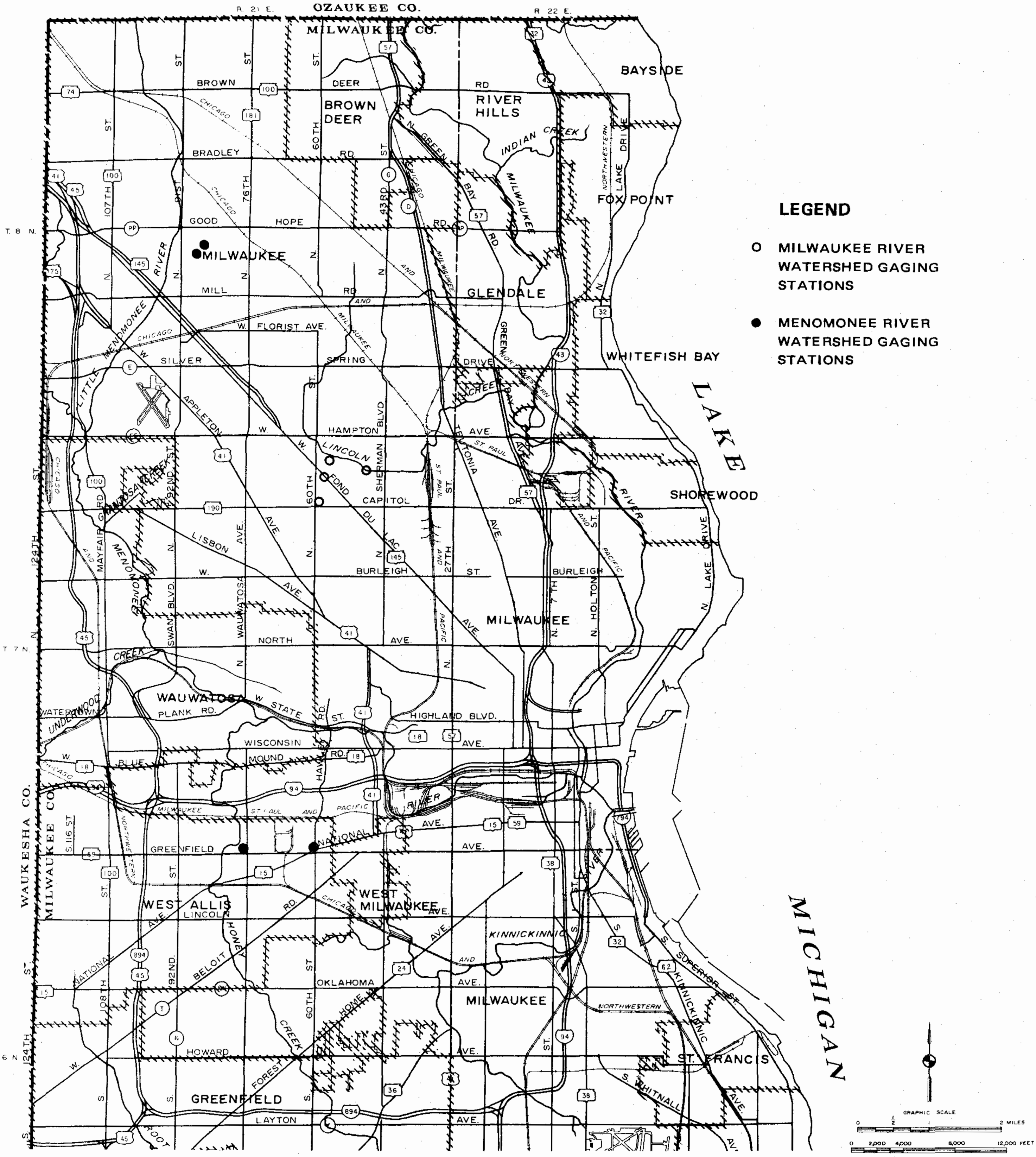
Station Number[a]	Station Name	Latitude North	Longitude West	Period of Record
7023	Ludington, Michigan	43° 56'48"	86° 26'30"	Complete records since August, 1950 Partial records in years 1895-97, 1900, 1902-1904, 1906, 1908, 1935-37, 1939, 1944-47.
7031	Holland, Michigan	42° 46'05"	86° 12'06"	Complete records since May, 1959. Partial records in years 1894, 1895-97, 1899, 1900, 1903, 1905-08, 1935, 1941-42, 1956.
7044	Calumet Harbor, South Chicago, Illinois	41° 43'48"	87° 32'18"	Complete records since April, 1903.
7057	Milwaukee South, Wisconsin	43° 00'05"	87° 53'13"	Complete records since January, 1970.
7058	Milwaukee, Wisconsin	43° 01'36"	87° 52'54"	Complete records from January, 1860-December, 1969.
7068	Kewaunee, Wisconsin	44° 27'48"	87° 30'00"	Complete records since October, 1973.
7072	Sturgeon Bay Canal, Wisconsin	44° 47'40"	87° 18'48"	Complete records since January, 1928. Complete records from January, 1905-March, 1919. Partial records in years 1922, 1925, 1927.
7078	Green Bay, Wisconsin	44° 32'27"	88° 00'30"	Complete records since July, 1954. Partial records in years 1953-54.
7096	Port Inland, Michigan	45° 58'10"	85° 52'20"	Complete records since December, 1964.

[a]See Map 4 for locations of monitoring stations operated in 1979.

Source: National Ocean Survey, Great Lakes Water Levels, 1860-1975, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Rockville, Maryland, 1976.

Map 5

LOCATIONS OF URBAN STORM RUNOFF QUALITY MONITORING STATIONS OPERATED BY THE U.S. GEOLOGICAL SURVEY FOR THE NATIONAL URBAN RUNOFF POLLUTION STUDY: 1980-1981



Source: SEWRPC.

1979 with a planned monitoring effort of three years duration, and includes the collection of storm event flow and water quality data. Water quality constituents to be sampled are listed in Table 11. Data will be published annually in the USGS Water Resources Data for Wisconsin reports.

The USGS also currently operates, in cooperation with the Regional Planning Commission and local units of government, nine other continuous record gaging stations in the watersheds tributary to the estuary, monitoring at all sites streamflow and at some sites water quality constituents. Data collected at these active stations as well as deactivated stations have been published in the USGS annual report series Water Resources Data for Wisconsin.

Previous USGS programs of relevance to the Milwaukee Harbor planning program are concerned with a sediment discharge study, and three hydrogeologic investigations. Measurement and prediction of sediment yields in the watershed tributary to Milwaukee Harbor are described in Measurement and Prediction of Sediment Yields in Wisconsin Streams, which includes a table of sediment yield, concentration, and particle size for both bed and suspended material for 18 monitoring sites in the watershed. A predictive equation for estimating average annual long-term suspended sediment yield is presented.[14] Descriptions of the hydrogeology of the estuary watershed can be found in the following reports:

1. F.C. Foley, W.C. Walton, and W.J. Drescher, Groundwater in the Milwaukee-Waukesha Area, Wisconsin, U.S. Geological Survey Water Supply Paper 1229, 1953.

2. J.H. Green and R.D. Hutchinson, Groundwater Pumpage and Water Level Changes in the Milwaukee-Waukesha Area, Wisconsin, U.S. Geological Survey Water Supply Paper 1809-I, 1965.

3. U.S. Geological Survey, Digital-Computer Model of the Sandstone Aquifer in Southeastern Wisconsin, Southeastern Wisconsin Regional Planning Commission Technical Report No. 16, April 1976.

U.S. DEPARTMENT OF TRANSPORTATION

The U.S. Department of Transportation has conducted a study in the Milwaukee Harbor watershed which is considered relevant to the estuary study design. That study is described below.

Freeway Runoff Quality Study, 1975-1978

To assist in the evaluation of environmental impact of future freeways, the Federal Highway Administration contracted with Envirex, Inc., of Milwaukee to conduct a nationwide study of freeway runoff quality, including preparation of a procedures manual for monitoring such runoff, description of runoff characteristics, development of a data storage program and users manual, and development of predictive methods for determining pollutant loadings from freeways. Of six sites studied, three were in the Milwaukee Harbor watershed. A 106-acre site along U.S. Highway 45 extending 9,500 feet north from the interchange with Interstate Highway 94 was monitored from the spring of 1976 to the fall of 1977, along with a 2.1-acre site of

[14] *S.M. Hindall, Measurement and Prediction of Sediment Yields in Wisconsin Streams, U.S. Geological Survey Water Resources Investigations 54-75, January 1976.*

Table 10

LIST OF METEOROLOGICAL PARAMETERS
CURRENTLY MONITORED IN MILWAUKEE
BY THE NATIONAL WEATHER SERVICE

Parameters	
Air Temperature Wet Bulb Temperature Wind Speed and Direction Precipitation	Daily Sunshine Daily Skycover Relative Humidity Barometric Pressure

NOTE: The data collected since 1950 are published in summary form on an hourly, daily, monthly, and annual basis.

Source: National Weather Service, Environmental Data Service, Local Climatological Data--Milwaukee, Wisconsin--Monthly Summary, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, North Carolina, published monthly.

Table 11

WATER QUALITY PARAMETERS MONITORED
BY THE NATIONAL URBAN RUNOFF POLLUTION
STUDY IN MILWAUKEE COUNTY

Parameters	
Total Solids Suspended Solids Volatile Suspended Solids Volatile Solids Total Phosphorus Soluble Phosphorus Available Phosphorus Nitrate and Nitrite Nitrogen Total Kjeldahl Nitrogen Ammonia Nitrogen	Total Lead Soluble Lead Multi-element Scan Chemical Oxygen Demand 5-day BOD 30-day BOD Fecal Coliform Fecal Streptococci Chloride

NOTE: See Map 5 for sampling site locations.

Source: U.S. Geological Survey.

Interstate Highway 794 between W. 2nd and W. 3rd Streets. Runoff quality from a 2.5-acre grass covered area adjacent to an uncurbed section of U.S. 45 at Bluemound Road was also monitored to determine the effects of pervious areas upon runoff quality. Water quality parameters monitored are listed in Table 12. Federal Highway Administration Report No. FHWA-RD-78-194 presents equations for estimating pollutant accumulation rates, and pollutant wash-off.[15] The study concluded, in part, that completely paved monitoring areas showed the highest pollutant loadings for most constituents. Lowest rates were monitored from the grass covered areas bordering uncurbed pavement. Total solids correlated significantly with most constitutents monitored. A six-volume report is scheduled for publication by the middle of 1981.

U.S. ENVIRONMENTAL PROTECTION AGENCY

The U. S. Environmental Protection Agency (USEPA) and its predecessor agency, the Federal Water Pollution Control Administration (FWPCA) have sponsored or participated in a number of water quality studies and programs relevant to the Milwaukee Harbor estuary study design. Programs funded by USEPA but carried out by local units of government are discussed in other sections of this chapter. More direct USEPA involvement, as discussed in this section, includes bottom sediment sampling activities in the Milwaukee Harbor for purposes of evaluating a dredging permit application; and a study of the impacts of combined sewer overflows on receiving water quality in the City of Milwaukee and environs, which was conducted for the USEPA by Envirex, Inc.

Milwaukee Harbor Sediment Quality Sampling

The USEPA and its predecessor, the Federal Water Pollution Control Administration (FWPCA), have been involved in bottom sediment sampling in Milwaukee Harbor for the evaluation of dredge spoil disposal alternatives. It should be noted that the results of a number of these surveys were included in reports by the U. S. Army Corps of Engineers and are discussed, therefore, in the Corps of Engineers section of this chapter. The remaining USEPA sediment survey results are discussed in the following paragraphs.

On June 21, 1973, the USEPA collected 15 bottom sediment samples for chemical analysis in the Milwaukee, Menomonee, and Kinnickinnic River estuaries and the outer harbor at the locations shown on Map 6. Twenty-seven other stations were also sampled. Only field observations were made on the characteristics of these samples. Locations of these sampling sites are described in USEPA unpublished data, "Survey of Bottom Sediment Samples--Milwaukee Harbor, Milwaukee, Wisconsin--June 21, 1973," on file at SEWRPC, along with the recorded field observations. Parameters analyzed for the 15 sediment quality samples are listed in Table 13. The table also compares the results of the chemical analyses to the maximum allowable standard for each parameter as established by the USEPA Commissioner of Operations, Water Quality Office, Washington, D.C., January 11, 1971. The data indicate many samples which exhibited levels much greater than maximum allowable standards. The USEPA concluded

[15] *M.K. Gupta, Constituents of Highway Runoff--Executive Summary, Federal Highway Administration Report. No. FHWA-RD-78-194, September 1978.*

Table 12

WATER QUALITY PARAMETERS MONITORED
IN MILWAUKEE DURING 1976 AND 1977
FOR THE HIGHWAY RUNOFF QUALITY STUDY
BY THE FEDERAL HIGHWAY ADMINISTRATION

Parameters	
Total Coliforms	Pesticide/Herbicide
Fecal Coliforms	Oil and Grease
Fecal Streptococci	Asbestos
5-day BOD	PCB
Chemical Oxygen Demand	Lead
Total Phosphorus	Zinc
Ammonia Nitrogen	Iron
Nitrate and Nitrite Nitrogen	Copper
Total Solids	Cadmium
Total Volatile Solids	Chromium
Suspended Solids	Nickel
Volatile Suspended Solids	Mercury
	Discharge

Source: Federal Highway Administration.

Table 13

SEDIMENT QUALITY PARAMETERS AND RESULTS OF
CHEMICAL ANALYSES OF SAMPLES COLLECTED JUNE 21, 1973
IN THE INNER AND OUTER MILWAUKEE HARBORS BY
THE U.S. ENVIRONMENTAL PROTECTION AGENCY

	Parameter, Maximum Allowable Standard,[b] and Sampled Concentration[c]							
Sampling Station[a]	Chemical Oxygen Demand 50,000	Total Kjeldahl Nitrogen 1,000	Mercury 10	Lead 50	Zinc 50	Total Volatile Solids (percent) 6	Oil and Grease 1,500	Total Solids (percent) --
1	15,600	314	0.9	54	111	3.7	260	84.5
4	180,000	4,530	1.5	431	510	14.4	7,120	40.9
8	29,100	1,020	0.4	45	130	3.5	482	73.5
9	205,000	1,520	1.8	470	1,100	22.0	19,100	34.1
11	161,000	300	0.6	120	220	8.3	3,460	50.6
14	136,000	5,660	0.4	25	70	12.8	4,080	35.5
20	44,300	2,850	0.9	160	390	8.6	2,300	43.4
24	49,000	3,670	0.4	220	460	8.9	5,000	49.8
26	71,700	4,460	0.4	340	230	11.6	7,420	43.8
30	79,100	3,260	0.6	350	390	12.6	9,830	48.3
33	64,900	3,490	0.4	280	270	10.2	10,200	49.0
35	55,200	2,360	0.4	150	130	8.0	2,400	58.3
39	82,200	4,150	0.5	320	310	12.4	7,910	39.2
41	136,000	2,300	0.4	370	340	11.9	7,030	56.2
42	113,000	3,660	0.4	410	550	13.0	7,090	45.2

[a]Sampling site locations are shown on Map 6.

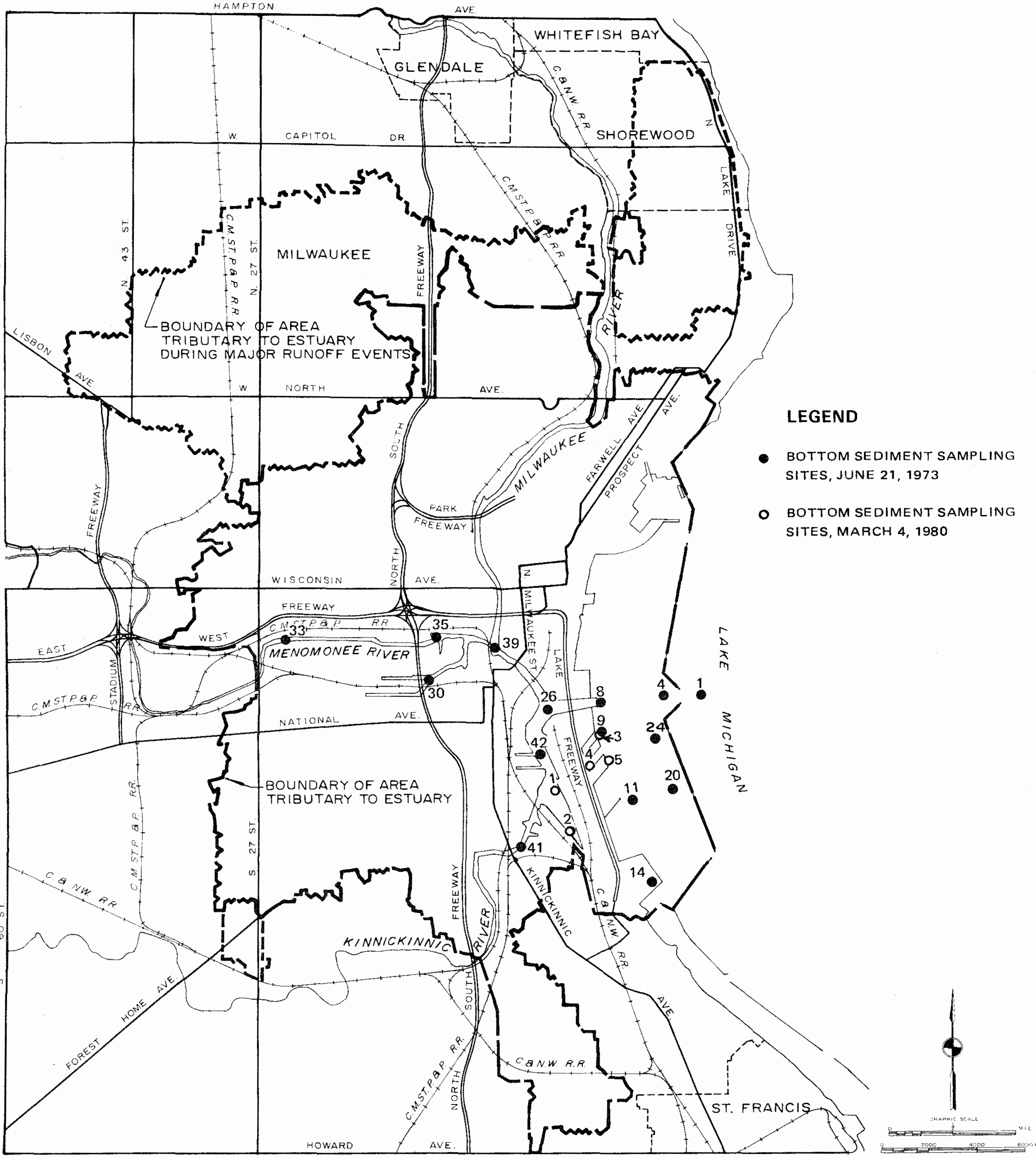
[b]From "Criteria for Determining the Acceptability of Dredged Spoil Disposal to the Nation's Waters " January 11, 1971.

[c]Concentrations are in milligrams per kilogram on an oven dry basis unless otherwise specified.

Source: U.S. Environmental Protection Agency, "Survey of Bottom Sediment Samples--Milwaukee Harbor, Milwaukee, Wisconsin--June 21, 1973," Surveillance and Analyses Division, Chicago, Illinois, unpublished data, on file at SEWRPC.

Map 6

LOCATIONS OF BOTTOM SEDIMENT QUALITY SAMPLING SITES IN THE INNER AND OUTER HARBORS SAMPLED IN 1973 AND 1980 FOR DREDGE SPOIL DISPOSAL ANALYSIS BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY



Source: U.S. Environmental Protection Agency, unpublished data on file at SEWRPC and U.S. Army Corps of Engineers, reference number NCSCO-RF (80-915-12) March 26, 1980.

that the outer harbor and the three estuaries were "grossly polluted" and that no dredging spoils from these areas should be disposed of in Lake Michigan.[16]

Another U.S. Army Corps of Engineers permit application to the EPA prompted recent sediment sampling activities in the Milwaukee Harbor. Two samples of bottom sediments in the Kinnickinnic River estuary between Becher Street and First Street were taken on March 16, 1979, by Sommer-Frey Laboratories, Inc., for the Milwaukee Harbor Commission. The parameters analyzed and results of the laboratory analyses are presented in Table 14. The Harbor Commission had further chemical analyses performed for support of a dredging permit application on March 4, 1980. Five sediment samples were taken in the inner and outer harbor at the locations shown on Map 6. Sediment quality parameters were analyzed, and the laboratory results are presented in Table 15.

Impact of Combined Sewer Overflows

A study of the effects of combined sewer overflows (CSO) upon receiving water quality was conducted for the Milwaukee River for the U. S. Environmental Protection Agency (USEPA) by Rexnord, Inc. (Envirex), from August, 1976 to October 1978.[17] The study complemented an ongoing project entitled Milwaukee Combined Sewer Overflow Abatement Project, conducted by Stevens, Thompson, & Runyan under contract to the Milwaukee Metropolitan Sewerage District. The CSO project had found large differences between simulated and observed dissolved oxygen concentrations in the lower Milwaukee River, and concluded that a more detailed analysis of CSO effects on receiving water quality was necessary. Accordingly, the study by Rexnord, Inc. was commissioned.

The primary purpose of the Rexnord study was to use real-time data to quantify the effects of CSO's upon the dissolved oxygen sag which was grossly under simulated during wet-weather events. It was suspected that CSO's somehow were causing a very rapid reduction in dissolved oxygen in the lower Milwaukee River, and detailed study of this phenomenon was carried out. Hydraulic studies, intensive water quality surveys, continuous monitoring of dissolved oxygen and water temperature, sediment studies and water quality modeling studies were conducted. Data collected during these studies are discussed in the following paragraphs, with findings summarized at the conclusion of this section.

Hydraulic Studies: Hydraulic studies conducted included dye studies and current meter measurement of speed and direction of flow. Dye studies were conducted to determine the hydraulic characteristics of the river for a wide range of flow conditions in two distinct reaches of the river--an upper reach between Estabrook Park and the North Avenue dam, and a lower reach from the dam downstream to St. Paul Avenue. Complete dye curves from leading to trailing edges were sampled.

A slug injection of fluorescent dye was made in the upper reach on November 8, 1976 when streamflow was about 90 cubic feet per second (cfs). "Slug" injections were

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[16] *U.S. Environmental Protection Agency, "Survey of Bottom Sediment Samples--Milwaukee Harbor, Milwaukee, Wisconsin--June 21, 1973:" Surveillance and Analyses Division, Chicago, Illinois. Unpublished data on file at SEWRPC.*

[17] *U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979.*

Table 14

BOTTOM SEDIMENT QUALITY PARAMETERS AND LABORATORY RESULTS FOR SAMPLES TAKEN MARCH 16, 1979 IN THE KINNICKINNIC RIVER ESTUARY BETWEEN BECHER STREET AND FIRST STREET FOR THE MILWAUKEE HARBOR COMMISSION

Parameter	Sample Site and Concentration[a,b]	
	1	2
Volatile Solids[c]	4.334	7.691
Chemical Oxygen Demand	83,055	16,941
Oil and Grease	3,047	2,517
Phenols	69.6	15.7
PCB[d]	10.7	11.1
Mercury	0.249	0.093
Ammonia	958	362
Organic Nitrogen	1,477	1,327
Total Phosphorus	475	293
Lead	374	351
Zinc	467	410
Copper	61.3	56.2
Iron	11,630	9,600
Nickel	33.2	29.3
Manganese	332	201
Arsenic	2.93	2.56
Cadmium	3.7	4.0
Chromium	57	64
Barium	3,115	1,756
Cyanide	0.53	0.67

[a] *Sample Site 1 - downstream from Becher Street, Sample Site 2 - upstream from First Street.*

[b] *Total concentration in milligrams per kilogram unless otherwise specified.*

[c] *Percent weight.*

[d] *PCB is referenced to Arochlor 1242.*

Source: Sommer-Frey Laboratories, Inc., "Bottom Sediment Analyses--Kinnickinnic River between Becher Street and First Street, March 16, 1979," Project 9214, March 19, 1979, on file at SEWRPC.

Table 15

BOTTOM SEDIMENT QUALITY PARAMETERS AND LABORATORY RESULTS FOR SAMPLES TAKEN MARCH 4, 1980 AT FIVE SITES IN THE INNER AND OUTER HARBORS FOR THE MILWAUKEE HARBOR COMMISSION

Parameter	Sampling Site and Concentration[a,b]				
	1	2	3	4	5
Chemical Oxygen Demand.....	66,705	34,984	23,174	53,114	41,855
Total Kjeldahl Nitrogen....	942	580	597	877	675
Total Volatile Solids......	5,532	222	242	389	333
Oil and Grease............	5,610	5,483	2,524	2,537	2,003
Arsenic....................	5.95	2.73	3.73	5.39	2.41
Mercury....................	0.45	0.18	0.16	1.05	0.12
Lead.......................	159	122	69	80	70
Zinc.......................	258	158	135	345	228
PCB's......................	73.3	55.6	4.07	5.14	38.0

[a]Sampling site locations are shown on Map 6.
[b]Total concentration in milligrams per kilogram.

Source: U.S. Army Corps of Engineers, "Notice of Application for Permit by the Milwaukee Board of Harbor Commission," Reference Number NCSCO--RF (80-915-12) March 26, 1980, on file at SEWRPC.

made in the lower reach on two dates, March 30, 1978 and June 13, 1978 when streamflows were 1,700 and 215 cfs, respectively. Mean velocities, travel times, and dispersion coefficients were computed for two segments of each reach and are tabulated in the USEPA report Verification of the Water Quality Impacts of Combined Sewer Overflow.[18] It was concluded that dispersion effects would not have to be modeled because coefficients were very small in both the upper and lower reaches.

Current speed and direction were monitored 300 feet downstream from St. Paul Avenue to determine if velocities sufficient to cause sediment scour were occurring at that location. These data were not tabulated in the report; however, velocities reportedly ranged from 0 to 0.25 feet per second (fps) near the river bottom for a range in flow from about 100 to 500 cfs. Current direction was found to be highly variable. Current velocities were also measured near CSO outfalls. Velocities measured about one foot above the river bottom were as high as 12 fps, but generally ranged from 1 to 5 fps, indicating significant scour potential of bottom sediments near these outfalls.

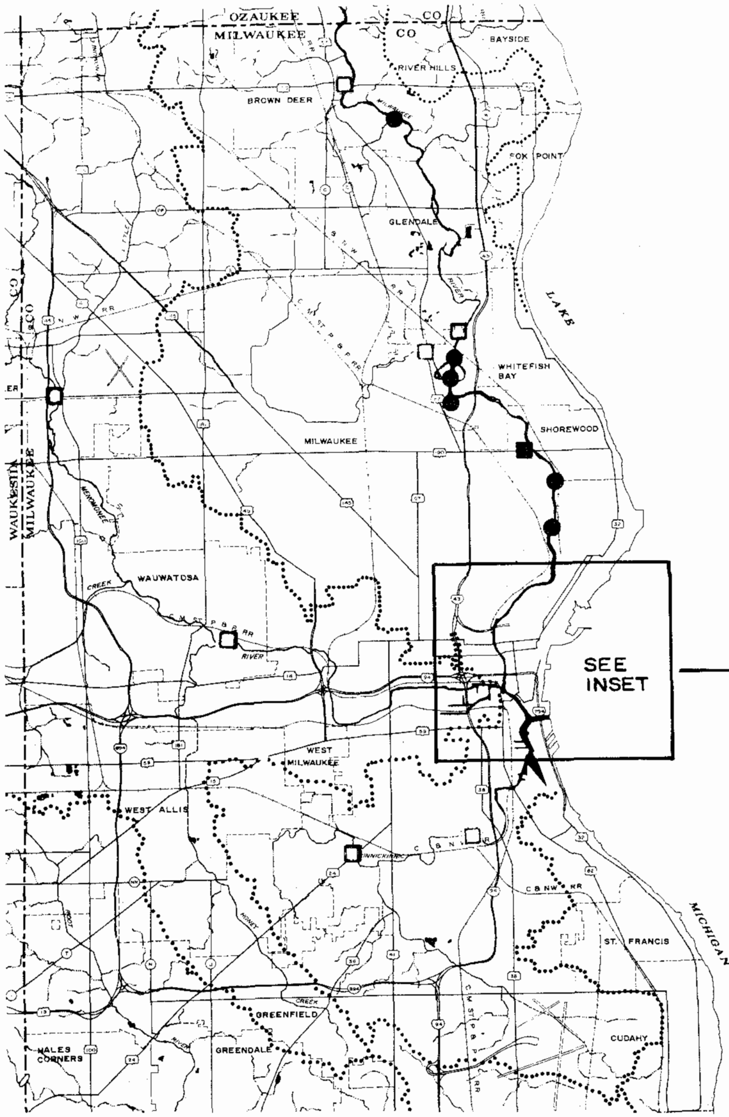
During the wet- and dry-weather intensive water quality surveys of 1975, described in the next topic in this chapter, "Intensive and Weekly Water Quality Surveys", intensive monitoring of current speed, current direction, dissolved oxygen (DO), and water temperature was conducted in the inner harbor. Measurements were made at 3-hour intervals at depth intervals of 3 feet. During intensive water quality surveys of the Menomonee River, currents, DO, and water temperature were monitored at mid channel of the Menomonee River at Muskego Avenue, the Milwaukee River at the Chicago & North Western Transportation Company railroad bridge (about 1200 feet upstream from the confluence with the Kinnickinnic River), and in the Kinnickinnic River just downstream from the University of Wisconsin Center for Great Lakes Studies. During the intensive water quality surveys of the Kinnickinnic and Milwaukee Rivers, currents were not monitored at the Muskego Avenue site, however. During the 1975 wet-weather survey of the Milwaukee River, currents, DO, and temperature were also monitored at St. Paul Avenue at a 30-minute time interval and a 3-foot depth interval for 72 hours. A complete listing of the current data, DO data, and water temperature data is presented in the appendix of the Envirex, Inc. unpublished report "River Monitoring Program."

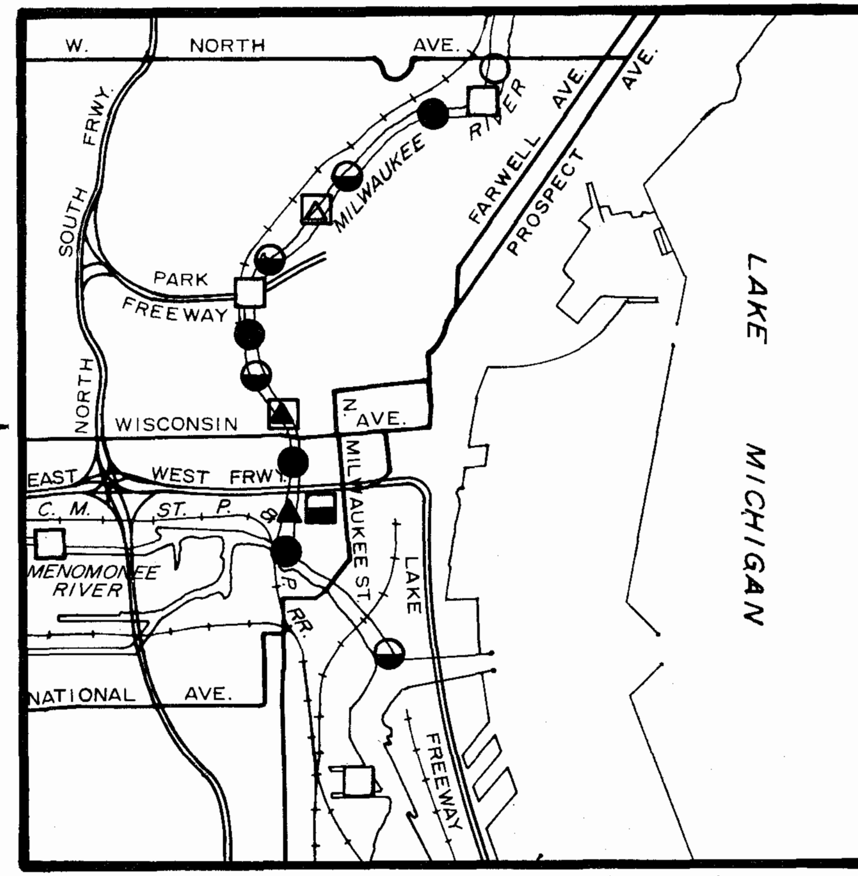
Intensive and Weekly Water Quality Surveys: Eight intensive water quality surveys were conducted at the eight locations on the Milwaukee River and one site on Lincoln Creek shown on Map 7. The surveys were made in the summers of 1975, 1976, 1977, and 1978, with two surveys representing dry weather conditions and six surveys representing wet weather conditions. In addition, one wet-weather survey and one dry-weather survey were made in 1975 on the Menomonee and Kinnickinnic Rivers at the locations shown on Map 7. During the 1975 surveys, current speed and direction, along with DO and water temperature were monitored in the inner harbor as described in the previous section under "Hydraulic Studies". Sampling intervals for the wet-weather surveys ranged from 3 to 6 hours, conducted over periods of from 3 to 5 days. Dry-weather samples were collected every three hours over a 72-hour period. Integrated samples were taken from bridges and composited for chemical analysis. Data summaries for the surveys conducted in 1976, 1977, and 1978 are tabulated in the appendix of the USEPA report, Verification of the Water Quality Impacts of Combined Sewer Overflow. Survey data collected in 1975 are presented in the unpub-

[18] *Ibid.*

Map 7

LOCATIONS OF INTENSIVE WATER QUALITY SURVEY AND BOTTOM SEDIMENT QUALITY SAMPLING SITES ON THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS IN MILWAUKEE COUNTY FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY: 1975-1978

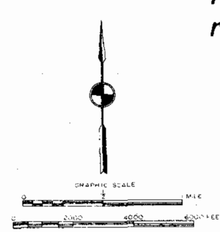




LEGEND

- ■ WATER QUALITY SAMPLING SITES, 1976 THROUGH 1978
- ● BOTTOM SEDIMENT SAMPLING SITES, MAY AND JUNE 1977
- ◒ BOTTOM SEDIMENT SAMPLING SITES, JANUARY 21, 1976
- △ WATER QUALITY AND BOTTOM SEDIMENT SAMPLING SITES, 1976 THROUGH 1978, MAY AND JUNE 1977, AND JANUARY 21, 1976
- ○ WATER QUALITY AND BOTTOM SEDIMENT SAMPLING SITES, 1976 THROUGH 1978, AND MAY AND JUNE 1977
- ▲ WATER QUALITY AND BOTTOM SEDIMENT SAMPLING SITES, 1976 THROUGH 1978, AND JANUARY 21, 1976
- □ DRY AND WET WEATHER INTENSIVE SURVEY SITES, 1975
- ⬓ WET WEATHER INTENSIVE SURVEY SITES, 1975

Source: *U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979, and Envirex, Inc., "River Monitoring Program," unpublished report.*



lished report, "River Monitoring Program" by Envirex, Inc. Water quality parameters analyzed are listed in Table 16. Dates of these surveys were as follows:

Milwaukee River		*Menomonee River*	
June 9-12, 1975	(dry weather)	July 17-19, 1975	(dry weather)
October 15-21, 1975	(wet weather)	September 5-8, 1975	(wet weather)
September 21-23, 1976	(dry weather)		
May 31-June 2, 1977	(wet weather)	Kinnickinnic River	
June 18-June 21, 1977	(wet weather)		
August 3-8, 1977	(wet weather)	July 14-17, 1975	(dry weather)
June 15-18, 1978	(wet weather)	August 16-18, 1975	(dry weather)
July 26-29, 1978	(wet weather)		

During May-November, 1975, weekly grab sampling was carried out at six sites on the Milwaukee River (Map 7) to provide baseline data for evaluation of effects of implementation of future pollution control efforts. Water quality parameters analyzed are presented in Table 16.

Continuous Dissolved Oxygen and Water Temperature Monitoring: Three continuous record stations at the North Avenue dam, Cherry Street, and St. Paul Avenue have monitored dissolved oxygen (DO) and water temperature at mid-channel and mid-depth since October, 1975. These stations were operated by the Milwaukee Metropolitan Sewerage District (MMSD). In addition, another monitoring site was operated at Rangeline Road from October through December 1975 by Envirex. The data collected at these sites were used in the CSO impact study to characterize dry-weather variations in DO, DO decline during and after rainfall events, and subsequent DO recovery. Continuous DO data are presented graphically for selected periods in the USEPA report Verification of the Water Quality Impacts of Combined Sewer Overflow. The unpublished report "River Monitoring Program" by Envirex presents DO and water temperature data at 15-minute intervals for the Rangeline Road and North Avenue monitoring sites for the period October-December, 1975. St. Paul Avenue data are presented only for October and November, 1975. Further description of the continuous DO and temperature monitoring program is provided in the discussion of MMSD programs in this chapter.

Bottom Sediment Quality: Sediment sampling was conducted in the Milwaukee, Menomonee, and Kinnickinnic Rivers to characterize the sediments so that: 1) an understanding could be developed of the mechanism causing rapid dissolved oxygen decline after runoff events; 2) sources of these sediments could be identified and quantified; and 3) a determination of sediment oxygen demand values for water quality modeling purposes could be made. Sediment samples were taken in the summer of 1977 at 12 locations on the Milwaukee River (see Map 7). Four sites were upstream from the Combined Sewer Overflow (CSO) area, three more were upstream from the North Avenue dam, and five were downstream from the dam. Twenty-inch cores were sampled when possible, with separate analyses being conducted for the top and bottom halves of each core. The sampled parameters are listed in Table 17. Cores were taken at mid-channel and grab samples were taken mid-way between the coring site and the edge of the river on both sides. Results of the chemical analyses are tabulated for each sample in the appendix of the USEPA report Verification of the Water Quality Impacts of Combined Sewer Overflow. A summary of the ranges observed for each

Table 16

LIST OF WATER QUALITY PARAMETERS ANALYZED IN DRY- AND WET-WEATHER INTENSIVE WATER QUALITY SURVEYS AND WEEKLY SURVEYS OF THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS IN MILWAUKEE, BY REXNORD, INC. FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY: 1975-1978

Parameters[a]	
Dissolved Oxygen[d]	Total Organic Carbon[d]
Water Temperature[d]	Ammonia Nitrogen[b,d]
Total Solids	Nitrite and Nitrate Nitrogen
Suspended Solids	Organic Nitrogen
Volatile Suspended Solids	Total Phosphorus[d]
5-day BOD[d]	Fecal Streptococci[c,d]
Chemical Oxygen Demand	Fecal Coliforms[d]
	Specific Conductance[c,d]

NOTE: Sampling site locations are shown on Map 7.

[a] *Average, minimum, and maximum dissolved oxygen and minimum and maximum water temperature for each intensive survey sampling day are tabulated in the appendix of the U.S. Environmental Protection Agency research report. Daily averages are reported for the remaining parameters. The 1975 survey data are listed completely in the appendix of the unpublished Envirex Inc. report.*

[b] *Analyzed for wet-weather samples in 1975 only.*

[c] *Analyzed for wet- and dry-weather samples in 1975 only.*

[d] *Also analyzed in 1975 weekly surveys of the Milwaukee River. Weekly surveys of the Menomonee and Kinnickinnic Rivers were not conducted.*

Source: U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979, and Envirex, Inc., a division of Rexnord, Inc., "River Monitoring Program," unpublished report.

Table 17

BOTTOM SEDIMENT QUALITY PARAMETERS FOR SAMPLES TAKEN AT 12 SITES IN THE MILWAUKEE RIVER IN MILWAUKEE COUNTY FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY: MAY AND JUNE 1977

Parameters[a]	
Total Solids	Iron
Total Volatile Solids	Cadmium
Chemical Oxygen Demand	Zinc
Nitrite and Nitrate Nitrogen	Lead
Ammonia Nitrogen	Copper
Total Phosphorus	pH

NOTE: Sampling site locations are shown on Map 7.

[a]Results of chemical analyses for each sample are tabulated in the appendix of USEPA research report.

Source: U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979.

Table 18

LIST OF BOTTOM SEDIMENT QUALITY PARAMETERS FOR SAMPLES TAKEN AT SEVEN SITES IN THE MILWAUKEE RIVER DOWNSTREAM FROM THE NORTH AVENUE DAM FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY: JANUARY 21, 1976

Parameters[a]	
pH	Nitrite Nitrogen
Oxidation-reduction Potential	Nitrate Nitrogen
Total Solids	Total Phosphorus
Volatile Solids	Iron
20-day BOD	Cadmium
Chemical Oxygen Demand	Lead
Total Organic Carbon	Copper
Ammonia Nitrogen	Zinc

NOTE: Sampling site locations are shown on Map 7.

[a]Results of chemical analyses for each sample are tabulated on page 18 of the USEPA research report.

Source: U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979.

parameter for the reach below the North Avenue dam, the reach from the dam to Capitol Drive, and the reach upstream from Capitol Drive is tabulated on page 60 of the report.

Another sediment survey was conducted January 21, 1976 in the Milwaukee River downstream from the North Avenue dam at seven locations shown on Map 7. Parameters analyzed for these samples are listed in Table 18. Three of these sediment samples were also analyzed to determine if pollutants were associated with the solids or the interstitial water. It was found that ammonia-nitrogen was the only readily soluble pollutant and that all other pollutants were associated almost completely with the solids.

Laboratory tests of settling velocity were conducted for suspended sediments from the Milwaukee River, sampled in January 1977. It was found that, in general, more than 90 percent of the suspended sediment settling velocities were greater than 20 inches per hour with less than 3 percent remaining in suspension after 15 hours. Another test, for samples taken in February 1979, however, showed continued settling after 40 hours with only slightly lower settling rates. The differences between these two settling tests were considered insignificant. The settling tests were conducted to estimate scouring velocity. Scouring velocity based on these data was estimated to range from 0.01 to 0.1 foot per second for 10 to 20 percent of the Milwaukee River sediments. Summer scouring velocities may be somewhat higher, however, because of temperature effects.

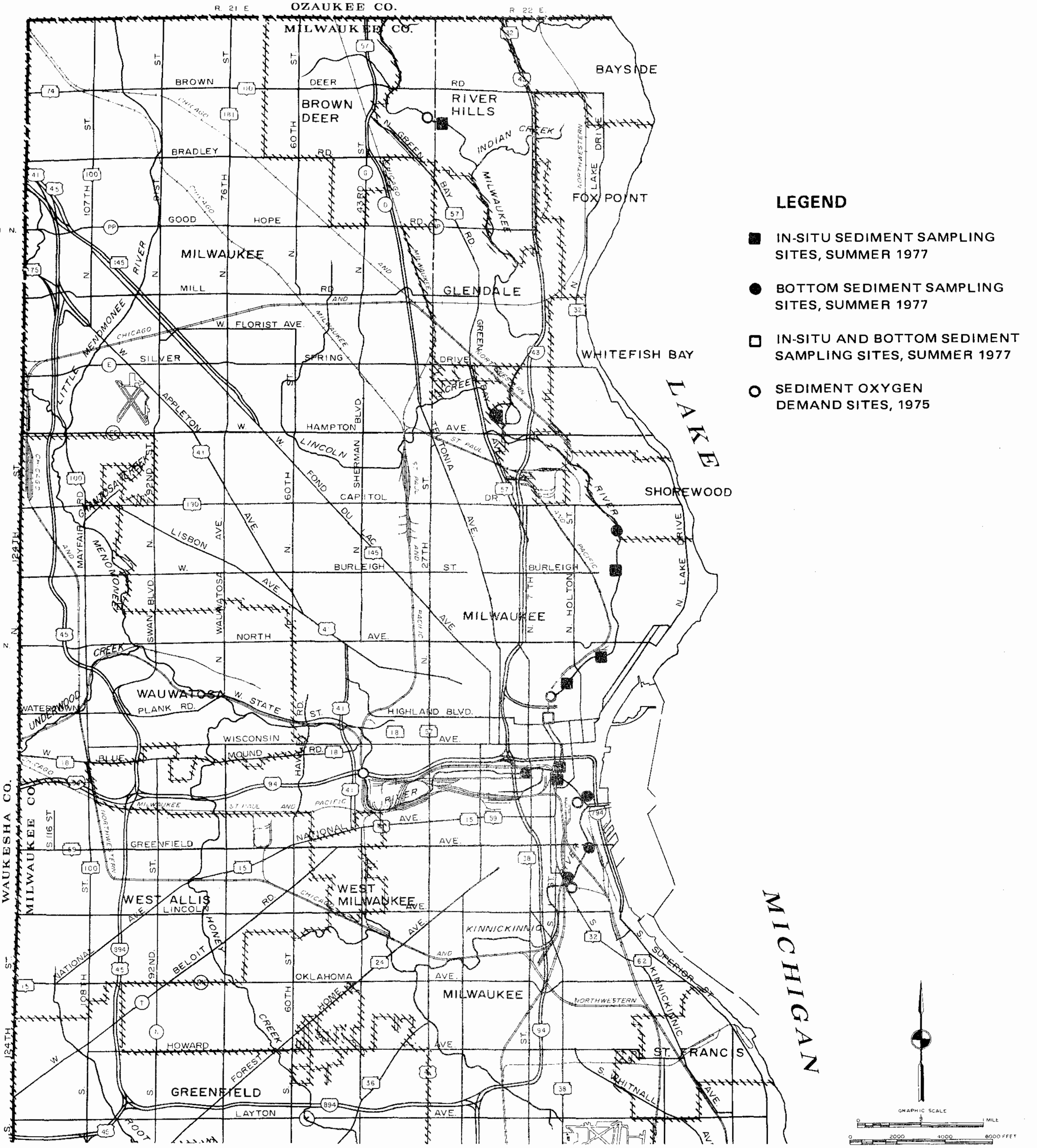
Sediment oxygen demand (SOD) was measured in 1977 "in situ" on the bed of the Milwaukee River, in the laboratory under quiescent conditions, and in the laboratory under agitated conditions. In situ SOD measurements were made twice at five sites downstream from the North Avenue dam, and once at three sites upstream from the dam. Laboratory measurements of SOD under quiescent conditions were made in part to relate the results to the field measurements, since the techniques applied were newly developed. Samples for laboratory analysis were taken from the Milwaukee, Menomonee, and Kinnickinnic Rivers at the locations shown on Map 8. USEPA report Verification of the Water Quality Impacts of Combined Sewer Overflow tabulates the SOD values for the 1977 in-situ and laboratory measurements. In-situ SOD in the Milwaukee River ranged from 0.0 to 6.7 grams per square meter per day in 1977. Laboratory SOD for agitated conditions ranged from 66 to 1,370 grams per square meter per day by comparison.

In-situ SOD was measured in 1975 at three sites in the Milwaukee River, and one site each in the Menomonee and Kinnickinnic Rivers (Map 8). One measurement was reported for each site in "River Monitoring Program" by Envirex with SOD ranging from 0.0 in the Milwaukee River at Rangeline Road to 9.8 in the Milwaukee River at Cherry Street.

Simulation Model Calibration: The U. S. Army Corps of Engineers Storage-Treatment-Overflow-Runoff-Model (STORM) was used to simulate suspended solids, carbonaceous BOD (CBOD), and fecal coliforms in combined and separate storm sewers discharging to the Milwaukee River. To calibrate the model, water quality samples were taken at outfalls during runoff events, along with in-stream water quality samples from the Milwaukee River, Lincoln Creek, and the Kinnickinnic River at the sites shown on Map 9. Six CSO outfalls, three storm sewer outfalls, and seven instream sites were monitored for numerous events in the summer of 1977. The USEPA report Verification of the Water Quality Impacts of Combined Sewer Overflow lists

Map 8

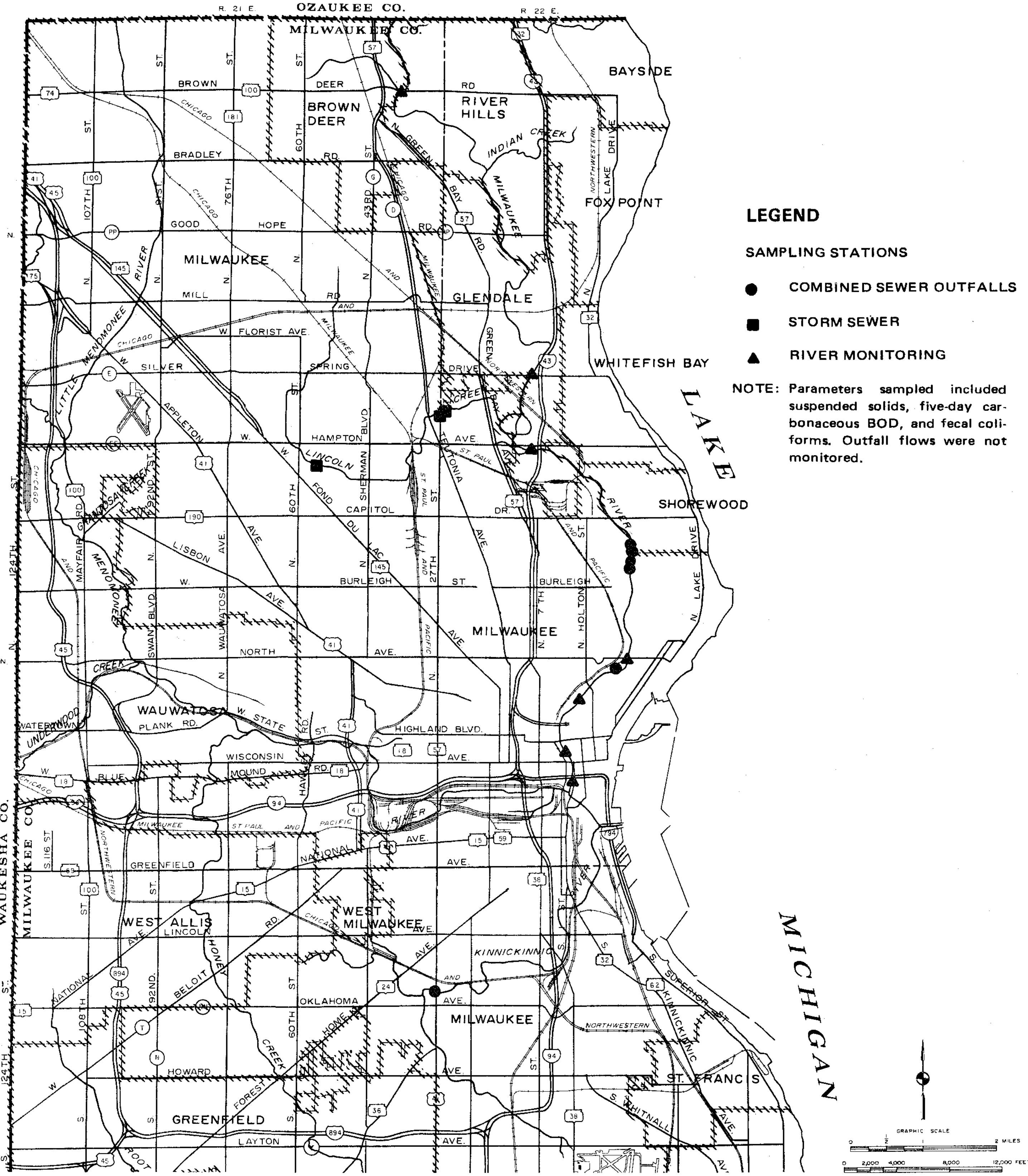
LOCATIONS OF SEDIMENT OXYGEN DEMAND, IN-SITU, AND LABORATORY ANALYSIS SAMPLE SITES FOR THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS IN MILWAUKEE COUNTY FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY: 1975 AND 1977



Source: U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/ 2-79-144, December 1979, and Envirex, Inc., "River Monitoring Program," unpublished report.

Map 9

LOCATIONS OF WATER QUALITY SAMPLING SITES AT COMBINED SEWER OUTFALLS, STORM SEWER OUTFALLS, AND IN THE MILWAUKEE RIVER, LINCOLN CREEK, AND THE KINNICKINNIC RIVER USED FOR CALIBRATION OF STORM FOR THE COMBINED SEWER OVERFLOW IMPACT STUDY



Source: U.S. Environmental Protection Agency, Verification of the Water Quality Impacts of Combined Sewer Overflow, Research Report EPA-600/2-79-144, December 1979.

the calibration data and dates of sampling for each CSO and storm sewer monitoring site and compares these data with simulated values. CSO and storm sewer flow were not monitored, however.

Harper's water quality model was used to simulate instream water quality using a time-varying rate of sediment oxygen demand during runoff events and constant Lake Michigan inflow to the Milwaukee River. The USEPA report cited above provides a description of this model.

Conclusions: The study concluded that approximately 40 to 50 percent of the oxygen demanding bottom sediments in the Milwaukee River are discharged at CSO outfalls. Sediment oxygen demand was reported to have been increased more than ten times, compared to quiescent conditions, by the sediment scouring action of more than 40 submerged outfalls along both sides of the Milwaukee River in the CSO study area. The scouring effect contributed about 40 to 70 percent of the dissolved oxygen impact, with BOD loadings from CSO's contributing most of the remainder. Fecal coliform impacts upon the Milwaukee River were reported to be solely attributable to combined sewer overflows.

PCB Fish Survey of the Milwaukee and Kinnickinnic Rivers

In 1980 the USEPA conducted a fish survey of Region V to determine total PCB's on a whole fish basis. The Milwaukee and Kinnickinnic Rivers were two of the streams sampled and for which preliminary estimates of fish PCB content are provided below:

Sampling Location	Total PCB (Microgram/gram-wet weight)
Milwaukee River at North Avenue Dam	25.1
Milwaukee River at North Avenue Dam	11.0
Kinnickinnic River at Milwaukee	21.5

Refined values of PCB content will be determined for the samples taken from the above locations using improved methods of gas chromatograph and mass spectometer analysis.

Comprehensive Water Pollution Control Study-Milwaukee Area

The Federal Water Pollution Control Administration (FWPCA) published a report in 1966 describing a comprehensive water pollution study of the Milwaukee rivers, Milwaukee Harbor, and adjacent Milwaukee Bay.[19] Municipal, industrial, combined sewer overflow, and nonpoint source pollutant loads to the Milwaukee Harbor were estimated. Continuous monitoring of Lake Michigan currents near Milwaukee was carried out over a 33-month period from 1962 to 1964 and included use of recording current meters, anemometers, and thermographs. Nearly 20,000 current meter observations were made at the monitoring station near Milwaukee. In the fall of 1962 and the summer of 1963 water quality surveys were made of the lower inner harbor, the outer harbor, and adjacent Milwaukee Bay with more than 2,400 samples collected.

[19] *Federal Water Pollution Control Administration, Comprehensive Water Pollution Control Program for the Lake Michigan Basin-Milwaukee Area, Wisconsin: Great Lakes-Illinois River Basins Project, Chicago, Illinois, June 1966.*

Water quality parameters analyzed are listed in Table 19. Distribution of coliform bacteria in the outer harbor, adjacent Milwaukee Bay, and offshore Lake Michigan are shown on a map in the FWPCA report. Benthic fauna and phytoplankton data were also collected during the study and population counts are presented in map-form in the report for the lower Milwaukee, Menomonee, and Kinnickinnic River estuaries, the outer harbor, adjacent Milwaukee Bay, and offshore Lake Michigan.

The study concluded that physical, chemical, biological, and microbiological data indicated degraded water quality in the lower Milwaukee River, Milwaukee Harbor, and adjacent Lake Michigan. Actions to alleviate water pollution problems were recommended.

INTERNATIONAL JOINT COMMISSION

The International Joint Commission (IJC) was formed to implement the Boundary Waters Treaty of 1909 for the purpose of coordinating activities of both nations in the boundary waters to prevent and solve disputes, and to prepare rules and agreements concerning activities by both nations. During the period 1973-1978 the IJC carried out an intensive pilot study of the water quality of the Menomonee River watershed, as one of eight watersheds studied in the Great Lakes basin. The principal objectives of the study were to qualify and quantify major and trace pollutants in the urbanized and urbanizing portions of the watershed, including but not limited to nutrients, pesticides, and sediments moving in the stream systems; to identify sources of these pollutants from areas of major urban development; to evaluate the behavior of these pollutants in response to the activities of man and the influences of nature; and to develop a means for transferring the acquired knowledge to other urban settings throughout the Great Lakes Basin. The Wisconsin Department of Natural Resources (DNR) was the lead agency for the Menomonee River portion of the IJC study. A report summarizing the pilot watershed study was published in 1978 which summarizes studies described in 11 separate volumes.[20] Volume 10 of this series deals specifically with the effects of the Milwaukee Harbor upon reduction of pollutant loadings to Lake Michigan.[21]

Summary Report IJC Menomonee River Pilot Watershed Study

Water quality monitoring was conducted at 16 locations in the Menomonee River watershed. The monitoring stations were operated by the U.S. Geological Survey and the DNR and locations are shown on Map 10. Data collected at these stations are summarized in the International Joint Commission Menomonee River Pilot Watershed Study, Volume 3, Surface Water Monitoring Data, which contains tables showing seasonal mean concentrations, standard deviations, and sampling frequencies during normal and high flow periods for the water quality parameters listed in Table 20. Similar data for dissolved oxygen and conductance are presented for normal flow periods. Bacteria counts for normal flow periods are also included in the IJC Study, Volume 3, Surface

[20] *John G. Konrad, Gordon Chesters, and Kurt W. Bauer, Summary Pilot Watershed Report, Menomonee River Basin, Wisconsin, International Joint Commission, International Reference Group on Great Lakes Pollution from Land Use Activities, May 1978.*

[21] *R. Bannerman, J.G. Konrad, and D. Becker, International Joint Commission Menomonee River Pilot Watershed Study, Volume 10, Effects of Tributary Inputs on Lake Michigan During High Flows, October 1979.*

Table 19

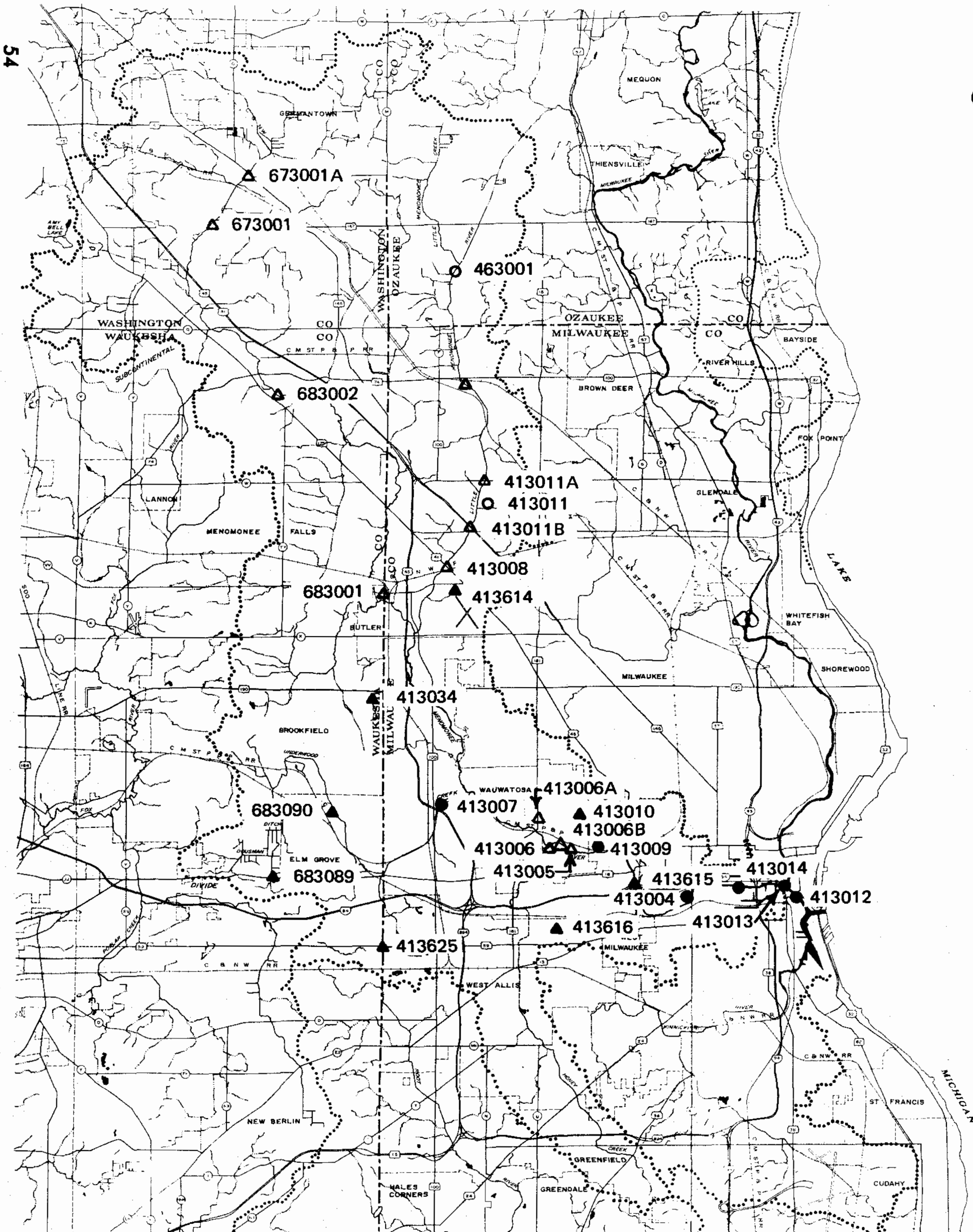
WATER QUALITY PARAMETERS ANALYZED FOR SAMPLES COLLECTED IN THE INNER HARBOR, OUTER HARBOR, AND ADJACENT MILWAUKEE BAY FOR THE WATER POLLUTION CONTROL STUDY OF THE MILWAUKEE AREA BY THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION: 1962 AND 1963

Parameters	
Phenol	Silica
Ammonia Nitrogen	Chloride
Nitrate Nitrogen	Sulfate
Total Soluble Phosphate	Dissolved Solids
Dissolved Oxygen	Alkalinity
Water Temperature	Calcium
Biochemical Oxygen Demand	Magnesium
Total Coliform Bacteria	pH
Fecal Streptococci	

Source: Federal Water Pollution Control Administration, Comprehensive Water Pollution Control Program for the Lake Mighican Basin--Milwaukee Area, Wisconsin, Great Lakes-Illinois River Basins Project, Chicago, Illinois, June 1966.

Map 10

LOCATIONS OF STREAMFLOW, WATER QUALITY, AND AQUATIC MACROINVERTEBRATE SAMPLING SITES MONITORED FOR THE INTERNATIONAL JOINT COMMISSION MENOMONEE RIVER PILOT WATERSHED STUDY: 1975-1977



LEGEND

▲ PREDOMINANT LAND USE DRAINAGE AREA MONITORING SITES

● MULTI-LAND USE DRAINAGE AREA MONITORING SITES

△ BIOLOGICAL SAMPLING SITES

○ PREDOMINATE LAND-USE DRAINAGE AREA SITES, AND BIOLOGICAL SAMPLING SITES

413006 B STORET NUMBER

Source: John G. Konrad, Gordon Chesters, and Kurt W. Bauer, Summary Pilot Watershed Report, Menomonee River Basin, Wisconsin, International Joint Commission, International Reference Group on Great Lakes Pollution from Land Use Activities, May 1978.

Table 20

WATER QUALITY PARAMETER LIST FOR NORMAL AND HIGH-FLOW PERIODS FOR THE MENOMONEE RIVER SUMMARIZED IN THE STUDY BY THE INTERNATIONAL JOINT COMMISSION FOR THE PERIOD 1975 TO 1977

Parameter[a]	
Total Solids	Bacteria
Suspended Solids	Chlorides
Volatile Suspended Solids	Lead
Alkalinity for Total Solids	Cadmium
Hardness for Total Solids	Copper
Dissolved Oxygen	Zinc
Total Phosphorus	Chromium
Soluble Phosphorus	Nickel
Organic Nitrogen	Iron
Ammonia Nitrogen	Aluminum
Nitrite and Nitrate Nitrogen	Mercury
Total Carbon	Calcium
Conductance	Magnesium

NOTE: Locations of sampling sites are shown on Map 10.

[a]Seasonal mean concentration, standard deviation, and sampling frequency are summarized in Volume 3 of the IJC study. Raw data are in the U.S. Environmental Protection Agency data system (STORET). Dissolved oxygen and conductance are summarized similarly in Volume 3 of the IJC study for normal flow periods only. Bacteria counts are presented for normal and high-flow periods.

Source: John G. Konrad, Gordon Chesters, and Kurt W. Bauer, IJC Menomonee River Pilot Watershed Study, Volume 3, Surface Water Monitoring Data, September 1978.

Water Monitoring Data.[22] Raw data are in the the U. S. Environmental Protection Agency data system (STORET) and are available from the DNR. Particle size distribution, total phosphorus, and metals concentrations in the various size fractions were determined for the soils in the watershed as well as for streambed material--14 sites-- and suspended sediment--11 sites. Metals measured were zinc, iron, chromium, nickel, and manganese. In addition, particle size distributions and concentrations of suspended sediments at 11 sites were tabulated for different positions on sampled storm hydrographs and on seasonal hydrographs. Data on the dispersibility of soils and clay-sized particles were also collected.

Stormwater runoff and snowmelt quality were monitored at 10 sites. Three of the sites were drainage areas of one predominant land use, allowing for the calibration and verification of an overland flow quantity-quality simulation model (LANDRUN) to be used for evaluation of the effects of projected land use changes on pollution loadings. Thirteen land use classifications were developed for the watershed area; and areas for each land use category in each monitored basin were tabulated. Soil types and physical characteristics of 48 subwatersheds were determined for use in LANDRUN. Seasonal, annual, event, and unit area pollutant loadings were generated and are presented for nonpoint sources of suspended sediment, total phosphorus, and lead. Point source pollutant loadings are presented for suspended sediment and total phosphorus. Loadings of other toxic and organic materials were found to be small.

The important effect of sediment characteristics on pollutant availability was investigated, so that appropriate management strategies could be developed. Groundwater and atmospheric pollutant loadings at 5 sites were measured, and their impacts upon water quality evaluated. Biological data collected during the IJC study included data from two macroinvertebrate surveys. Locations of the 14 sampling sites are shown on Map 10. A table showing diversity index and biotic index at each sampling site indicate moderate to heavy pollution, with only one sample at an agricultural site indicating clean conditions by the diversity index.

The study concluded that, in rural areas, row crops and feed lots were two major sources of suspended solids and phosphorus that could be controlled cost effectively. In urban areas the management practice considered most cost-effective was keeping pollutants from entering stormwater by carefully timed street sweeping during spring cleanup and seed-fall, leaf pickup during the autumn, limiting street salting in the winter, covering salt stockpiles and prewetting them with liquid calcium chloride, curtailment of accelerated streambank erosion, and paving or covering of other readily erodible surfaces. In combined sewer service areas, conveyance, storage and treatment were generally identified as preferable to sewer separation. However, dry weather street and sewer flushing was recommended, until sewer separation or storage and treatment of stormwater runoff can be implemented as a result of further study. In urbanizing areas, control of construction-related erosion was emphasized, along with maximizing infiltration. The study indicated benefits of decreased pollutant washoff, stream bank erosion, and downstream flooding. It was found that, although only 2.6 percent of the watershed was undergoing urban development as of 1970, this part of the watershed contributed about 37 percent of the

[22]*John G. Konrad, Gordon Chesters, and Kurt W. Bauer, International Joint Commission Menomonee River Pilot Watershed Study, Volume 3, Surface Water Monitoring Data, September 1978.*

suspended solids and 48 percent of the total phosphorus loading at the mouth of the Menomonee River, thereby documenting the need for controls in developing urban areas.

Lake Michigan Tributary Loadings Study

An ancillary study was included as Volume 10 of the IJC Menomonee River Pilot Watershed Study entitled Effects of Tributary Inputs on Lake Michigan During High Flows. The purpose of the study was twofold: 1) to determine effects of high-flow river loadings on water quality in the harbor vicinity; and 2) to document dispersion of these pollutant materials in Lake Michigan. The study was conducted by DNR personnel. An extensive amount of water sampling was carried out in the inner and outer harbors, as well as in the near-shore zone of Lake Michigan during base-flow and precipitation runoff periods. Current measurements were also made at the entrances to the inner and outer harbors. Bottom sediments were sampled at 13 locations in the inner and outer harbors and in Lake Michigan. Remotely sensed imagery was used to monitor harbor and near-shore surface sediment plumes. Loadings to the inner harbor, outer harbor, and Lake Michigan were estimated.

Water quality surveys were conducted in 1976 and 1977 during eight high-flow periods, during two normal-flow periods, and during a normal-flow period when a sediment plume, originating updrift from Milwaukee, passed by the harbor. Samples were collected at the surface and at 23-foot (7-meter) depths in the harbor, and at surface and 33-foot (10-meter) depths in the near-shore zone. Parameters sampled and sampling dates are listed in Table 21. Sampling locations are shown on Map 11, and, as the table shows, not all locations were sampled in every survey. Volume 10 of the IJC study contains maps of sampling sites for each survey, however. Raw data for each of the water quality surveys is tabulated in Volume 10 along with a baseflow water quality summary for three of the harbor sites.[23]

Bottom sediments were sampled in the harbor and Lake Michigan during April 1976. Site locations were selected to represent different sediments and rates of sedimentation. Bottom sediment sampling site locations are shown on Map 11. Table 22 lists the sediment quality parameters analyzed.

Mid-channel measurements of current speed and direction and water temperature at 5-foot (1.5 meter) depth intervals, along with supplemental surface and 23-foot (7-meter) readings, were made at the entrance to the inner harbor and at the main entrance of the outer harbor during one normal-flow period and on three days of high runoff. Similar data were collected at the Broadway bridge during one normal-flow survey. Normally, vertical velocity and temperature profiles were measured numerous times at each sampling station on a given day. Table 23 lists current sampling dates, locations, and other pertinent data collected.

An estimate of annual pollutant loading rates was made for the inner and outer harbors and Lake Michigan using loading estimates for the Milwaukee, Menomonee, and Kinnickinnic Rivers, and for the Jones Island sewage treatment plant, along with estimates of residence time; and using a mass balance procedure. Generalized estimates indicated that river loadings passing through the harbor to Lake Michigan were

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[23]*R. Bannerman, J.G. Konrad, and D. Becker, International Joint Commission Menomonee River Pilot Watershed Study, Volume 10, Effects of Tributary Inputs on Lake Michigan During High Flows, October 1979.*

Table 21

WATER QUALITY PARAMETERS AND FREQUENCY OF SAMPLING IN THE INNER AND OUTER HARBORS AND THE NEARSHORE ZONE OF LAKE MICHIGAN DURING THE TRIBUTARY LOADINGS STUDY OF THE IJC MENOMONEE RIVER PILOT WATERSHED STUDY: 1976 AND 1977

Parameter	Sampling Dates and Number of Samples											Total Number of Samples
	2/13/76[a]	2/25/76[a]	4/8/76[c]	7/28/76[a]	8/28/76[a]	9/9/76[a]	5/11/77[b]	5/19/77[b]	6/28/77[a]	6/30/77[a]	7/18/77[a]	
Total Solids	12	18	30	22	32	22	--	--	--	--	--	136
Suspended Solids	12	18	30	22	32	22	18	41	20	20	14	249
Total Phosphorus	12	18	30	22	32	22	18	41	20	20	14	249
Soluble Phosphorus	--	18	30	22	32	22	18	41	20	20	14	237
Organic Nitrogen	--	18	30	22	32	22	--	--	--	--	--	124
Nitrite and Nitrate Nitrogen	--	18	30	22	32	22	--	--	--	--	--	124
Ammonia Nitrogen	--	--	--	--	--	--	--	--	--	--	--	-0-
Chloride	12	18	30	22	--	--	--	--	--	8	14	104
Alkalinity	12	--	--	22	32	22	--	--	--	--	--	88
Total Organic Carbon	--	--	4	--	--	--	--	--	--	--	--	4
Lead	--	11	30	22	32	--	--	--	--	--	--	95
Zinc	--	11	30	22	32	--	--	--	--	--	--	95
Cadmium	--	11	--	22	32	--	--	--	--	--	--	65
Chromium	--	11	30	22	32	--	--	--	--	--	--	95
Nickel	--	--	--	--	26	--	--	--	--	--	--	26
Copper	--	11	30	22	32	--	--	--	--	--	--	95
Temperature	--	18	30	20	32	22	18	79	136	111	135	601
Dissolved Oxygen	--	18	26	20	32	22	18	39	20	16	14	225
Secchi Depth	--	--	--	--	--	--	--	5	--	--	6	11
Iron	--	--	26	--	--	--	--	--	--	--	--	26
Conductivity	--	--	--	--	--	--	18	20	--	--	--	38

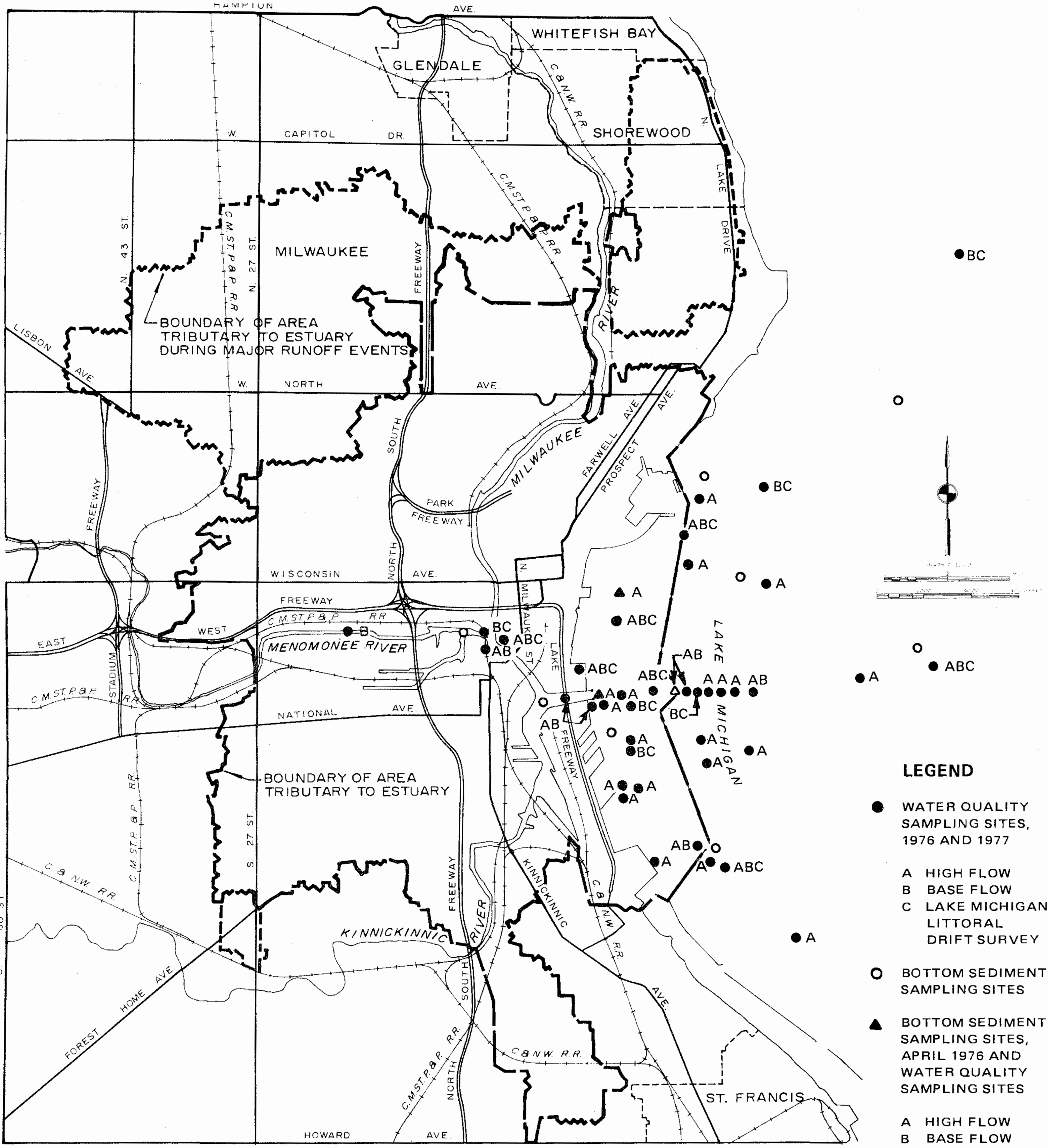
NOTE: See Map 11 for the locations of sampling stations.

[a] High-flow period
[b] Normal flow period but high littoral drift
[c] Normal flow period

Source: IJC Menomonee River Pilot Watershed Study, Volume 10, Effects of Tributary Inputs on Lake Mighican During High Flows, October 1979.

Map 11

LOCATIONS OF WATER QUALITY AND BOTTOM SEDIMENT SAMPLING SITES IN THE INNER AND OUTER HARBORS AND LAKE MICHIGAN SAMPLED FOR THE TRIBUTARY LOADINGS STUDY OF THE INTERNATIONAL JOINT COMMISSION MENOMONEE RIVER PILOT WATERSHED STUDY: 1976 AND 1977



Source: <u>IJC Menomonee River Pilot Watershed Study</u>, Volume 10, <u>Effects of Tributary Inputs on Lake Michigan During High Flows</u>, October 1979.

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Table 23

CURRENT AND WATER TEMPERATURE MEASUREMENT AT THREE LOCATIONS IN MILWAUKEE HARBOR IN 1977 FOR THE TRIBUTARY LOADINGS STUDY OF THE IJC MENOMONEE RIVER PILOT WATERSHED STUDY

Location[a]	Date and Number of Vertical Profiles			
	May 19	June 28	June 30	July 18
Broadway Bridge	2[b]	--	--	--
Inner Harbor Entrance	7[b]	11[b]	7[b]	1[c]
	--	4[c]	3[c]	--
Outer Harbor Main Entrance	8[b]	11[b]	9[b]	--
	--	4[c]	3[c]	--

NOTE: Current speed and direction along with water temperature were measured at designated vertical intervals, and each vertical profile also contained surface readings.

[a]*Data were collected at mid-channel at each sampling site.*

[b]*1.5-meter vertical sampling interval.*

[c]*7-meter vertical sampling interval.*

Source: IJC Menomonee River Pilot Watershed Study, Volume 10, Effects of Tributary Inputs on Lake Michigan High Flows, October 1979.

reduced to 45 percent for suspended solids, 61 percent for total phosphorus, and 35 percent for soluble phosphorus.

Evaluation of the dispersion of large event runoff plumes reaching Lake Michigan was inhibited by the lack of large runoff events during the study period. One large event occurred July 18, 1977 and was photographed by LANDSAT and by two overflights by the DNR. The data from this imagery has not yet been interpreted.

The tributary loadings study concluded that, for most runoff events, only suspended solids and total organic nitrogen concentrations increased significantly in the inner harbor above normal flow levels. The harbor complex serves as a buffer between the rivers and Lake Michigan for most runoff events, because near-shore zone water quality usually was not affected significantly during high-flow periods. The relatively large runoff event of July 18, 1977, however, caused significant increases in concentrations of suspended solids and chlorides in the near-shore zone. The transport of pollutants between the rivers and the near-shore area reportedly appeared to be dominated, during most runoff events, by lake and harbor water-level oscillations, with pollutants apparently pulsing at intervals into Lake Michigan, perhaps once each oscillation period of a seiche event. Stratified multi-directional flow was observed during the high-flow events monitored, except for the largest event of July 18, 1977 when surface velocities did not reverse direction.

The tributary loadings study recommended that pollutant concentrations should be monitored seasonally in the free-flowing rivers, at 3 sites in the inner harbor, at 5 sites in the outer harbor, and at 5 sites in the near-shore zone near the breakwater. Runoff event sampling would require additional sampling sites to determine accurate loadings. The study also recommended that remote sensing imagery obtained near the end of the study should be evaluated, and that future investigations utilize remote sensing. Continuous monitoring of flow velocity and water quality at the breakwater openings was also recommended for determinations of loadings to Lake Michigan.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Studies or programs of the Department of Natural Resources (DNR) and its predecessor agencies which have been conducted or are ongoing, and are relevant to the Milwaukee Harbor Estuary Study Design are the Milwaukee County river basin assessment, the inner harbor water quality monitoring program, the statewide PCB fish monitoring program, the toxic substance surveys of Lake Michigan and its tributaries, the statewide ambient surface water quality monitoring program, the toxic metals studies in the lower Milwaukee River and Milwaukee Harbor, the water quality surveys of the lower Milwaukee Harbor watershed, the sediment and water quality surveys of the Burnham Canal, the study of benthic macroinvertebrates in the Milwaukee Harbor, the Milwaukee County surface water pollution surveys of 1952-1953, and a statewide assessment of chemical loadings to Lake Michigan by large rivers. These studies or programs are discussed in the following sections of this chapter, in the order given above.

Milwaukee County River Basins Study

During the period 1975-1977, the DNR conducted water quality surveys within Milwaukee County for the lower Milwaukee River, the Kinnickinnic River, and Oak Creek as part of the DNR water quality surveillance programs conducted statewide. The Menomonee River was not included in this monitoring program because data were already being collected by the then ongoing International Joint Commission (IJC) Menomonee River Pilot Watershed Study. The DNR conducted a one-year synoptic water quality survey of the Milwaukee County basins and intensive surveys in selected water quality problem areas. Chemical, physical, and biological water quality data, including hazardous substances data, were collected. Fish data collected during these surveys and previous surveys since 1967 were collated and included in the study. Records of spills of toxic and hazardous substances were collated and summarized in the report. An intensive low-flow water quality survey was made of the Kinnickinnic River watershed for demonstration purposes to determine the feasibility of conducting similar surveys in other basins. Runoff from Milwaukee Mitchell Field was monitored to characterize the quality because little such data was then available. A draft report titled "Milwaukee County River Basins Study" was prepared in two volumes--the "Chemical and Physical Chapter," and the "Biological Chapter"--and is on file at SEWRPC. The following sections describe the data DNR collected and the study conclusions.

Chemical and Physical Water Quality: A physical and chemical water quality survey was conducted from May 1975 through April 1976 in the lower Milwaukee River basin in Milwaukee County and the entire Kinnickinnic River and Oak Creek basins. Because the Oak Creek watershed is not tributary to the Milwaukee Harbor estuary, the Oak Creek portion of the study will not be discussed. Data was collected monthly at nine sites in the lower Milwaukee River basin and five sites in the Kinnickinnic River basin. The sites are described in Table 24 and shown on Map 12. Sampling procedures are described in the "Chemical and Physical Chapter."[24] Water quality parameters analyzed are listed in Table 25. Data were placed in STORET and are available from the DNR.

Chemical and physical data are summarized in tables containing instantaneous monthly chemical concentrations and discharge results, seasonal and period of record mean concentrations of total phosphorus, total nitrogen, and total suspended solids with standard deviations, instantaneous monthly chemical loadings by station, and stream loadings in pounds per day. These tables are available from the DNR.

The water quality of the streams studied exhibited violations of the state and federal water quality standards and criteria as shown on Table 26.

All dissolved oxygen levels violating standards reportedly were associated with increased levels of oxygen demanding materials, and occurred during periods of warm water and low streamflow. These oxygen deficiencies were recorded in areas of the lower Milwaukee and Kinnickinnic Rivers influenced by combined sewer overflow discharge. The impoundment upstream from the North Avenue dam on the Milwaukee River reportedly encouraged oxygen depletion immediately upstream, and anaerobic conditions resulted periodically.

A strong relationship between the pollutant load to the rivers and the urban land use drained was indicated by both discharge and concentration trends which were reflected by the pollution loading rates in the Milwaukee County rivers. In most in-

[24] DNR draft report, "Milwaukee County River Basins Study," "Chemical and Physical Chapter," Wisconsin Department of Natural Resources, Southeast District, Milwaukee, Wisconsin (draft copy on file at SEWRPC).

Table 24

DESCRIPTION OF MONTHLY CHEMICAL AND PHYSICAL WATER QUALITY SAMPLING SITES AND STREAMFLOW MEASURING SITES IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: MAY 1975-APRIL 1976

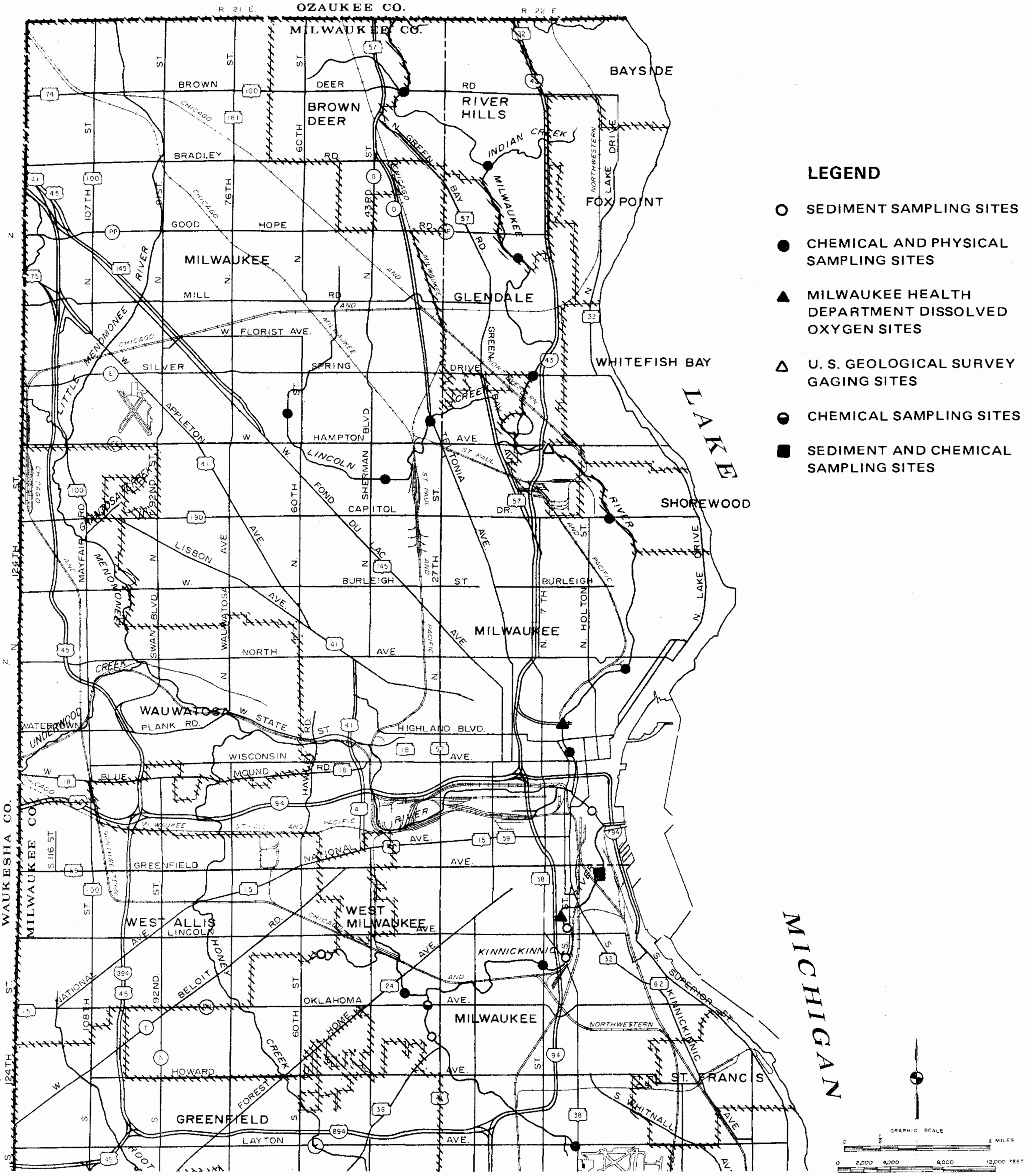
Location	DNR Station Number	STORET Number	Water Quality Site	Streamflow Measured Site
Milwaukee River Basin				
Lower Milwaukee River				
Brown Deer Road..........	LMR-1	413063	Yes	Yes
Green Tree Road..........	LMR-2	413066	Yes	Yes
Silver Spring Drive	LMR-3	413080	Yes	Yes
Capitol Drive..............	LMR-4	413072	Yes	Yes
Below North Avenue Dam..	LMR-5	413073	Yes	No
Wells Street	LMR-6	413067	Yes	No
Lincoln Creek				
Villard Avenue	LC-1	413071	Yes	Yes
N. 40th Street	LC-2	413079	Yes	Yes
Teutonia Avenue	LC-3	413070	Yes	Yes
Indian Creek				
Bradley Road..............	IC-1	413065	Yes	Yes
Kinnickinnic River Basin				
Kinnickinnic River				
S. 35th Street............	KK-1	413077	Yes	Yes
S. 6th Street..............	KK-2	413069	Yes	Yes
C&NW Railroad	KK-3	413078	Yes	No
Wilson Park Creek				
Howell Avenue.............	WPC-1	413082	Yes	Yes
Okalhoma Avenue..........	WPC-2	413075	Yes	Yes

NOTE: See Map 12 for sampling site locations.

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Map 12

LOCATIONS OF CHEMICAL, PHYSICAL, AND SEDIMENT QUALITY SAMPLING SITES AND STREAMFLOW MONITORING SITES IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER WATERSHEDS FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: MAY 1975-APRIL 1976



Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 25

LIST OF CHEMICAL AND PHYSICAL WATER QUALITY PARAMETERS ANALYZED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES IN THE MILWAUKEE COUNTY RIVER BASINS STUDY: MAY 1975-APRIL 1976

Parameters
Solids: Total, total volatile, total suspended, and volatile suspended solids
Phosphorus: Total and dissolved phosphorus
Nitrogen: Total organic, nitrite, nitrate, and ammonia nitrogen
Biochemical oxygen demand (BOD_5)
Dissolved oxygen[a]
Temperature[a]
pH[b]

NOTE: See Map 12 for sampling site locations.

[a]Dissolved oxygen and temperature profiles were simultaneously recorded at the time of water sampling with a model 54, YSI meter, which was air calibrated daily prior to use.

[b]pH of the composited water sample was measured in the field with a Rasher and Betzold colormetric kit.

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 26

NUMBER OF VIOLATIONS OF STATE AND FEDERAL WATER QUALITY STANDARDS IN THE LOWER MILWAUKEE AND KINNICKINNIC RIVER WATERSHEDS ACCORDING TO THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: MAY 1975-APRIL 1976

Sampling Station	Parameter				
	Water Temperature[a]	Dissolved Oxygen[b]	Total Phosphorus[c]	Un-ionized Ammonia[d]	pH[e]
Milwaukee River Basin					
Lower Milwaukee River					
LMR-1.	0	0	12	1	0
LMR-2.	0	0	12	1	0
LMR-3.	0	0	11	0	0
LMR-4.	0	0	13	1	0
LMR-5.	0	0	12	1	0
LMR-6.	0	3	12	1	0
Lincoln Creek					
LC-1.	0	0	2	1	0
LC-2.	0	0	10	0	0
LC-3.	0	1	7	1	0
Indian Creek					
IC-1.	0	0	5	0	0
Kinnickinnic River Basin					
Kinnickinnic River					
KK-1.	0	0	11	--	0
KK-2.	0	0	9	1	0
KK-3.	0	19	9	1	0
Wilson Park Creek					
WPC-1.	0	0	6	--	0
WPC-2.	0	0	7	--	0

[a]*The water temperature standard is temperature change less than 5°F at the edge of the mixing zone.*

[b]*Dissolved oxygen standard is 5.0 mg/l. The variance standard is 2.0 mg/l.*

[c]*The total phosphorus standard is 0.1 mg/l.*

[d]*The un-ionized ammonia standard is 0.02 mg/l.*

[e]*The pH standard is equal to or greater than 6.0 standard units and equal to or less than 9.0 standard units.*

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

stances, the mean annual total phosphorus and total nitrogen levels represented levels reported for other urban rivers. The urban nature of the watershed was also reflected in the predominantly inorganic nature of the solid material in the rivers.

The downstream, most-urbanized sections of the Milwaukee County rivers generated the highest concentrations and the greatest loadings of water pollutants, especially within the combined sewer service area. Pollutant loadings also increased as the river discharge increased, indicating that the rivers of Milwaukee County were most strongly influenced by wet-weather-induced urban runoff and, in some reaches, sanitary sewer overflow.

A significant portion of the mean annual discharge measured from Lincoln Creek, the Kinnickinnic River, and Wilson Park Creek, was contributed by point source discharges, excluding combined sewer overflows. Point sources were not generally sampled for all stream parameters because some dischargers did not routinely cause water quality stream violations. The pollutant loads from the lower Milwaukee River and the Kinnickinnic River to Lake Michigan were approximated by using data from the downstream-most sampling stations where both flow and chemical concentrations were measured: sampling stations LMR-4 (Capitol Drive) and KK-2 (S. 6th Street), respectively (see Map 12). The mean annual loading to Lake Michigan, based on twelve instantaneous samples, is given in Table 27.

<u>Aquatic Biology</u>: Included in the DNR Milwaukee County River Basins Study was a biological investigation described in the draft copy titled "Biological Chapter." Studies were made of benthic macroinvertebrates, primary producers, fish, and fecal coliform contamination.

<u>Benthic Macroinvertebrates:</u> Benthic macroinvertebrate data were collected by the DNR October 27-31, 1975, in the lower Milwaukee River and the Kinnickinnic River. Quantitative samples were taken in riffle areas with qualitative data being taken from other characteristic aquatic habitats. These data were collected because benthic macroinvertebrates are relatively good short- and long-term water quality indicators and because of their relative abundance, lack of mobility, quick response to water contamination, long lifespan, and ease of collection and identification. Locations of the sampling sites are shown on Map 13 for the lower Milwaukee River and Kinnickinnic River watersheds. Descriptions of sampling sites are presented in Table 28. Man-modified stream reaches were assumed to be habitat-limited and were not sampled for water quality interpretation purposes. Field and laboratory procedures are described in detail in the "Biological Chapter."[25]

Statistical analyses were conducted on the sampling data to determine hierarchical diversity by tolerance classification, Simpson's similarity index, Hilsenhoff's biotic index, and variance. Mean number of individuals for each taxon at each station per square foot, along with corresponding standard deviations, were computed for the lower Milwaukee and Kinnickinnic River watersheds. In addition, "mean number of individuals and taxa per square foot in each tolerance classification; community diversity of the taxa and diversity contributed by the tolerance classifications as

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[25]*DNR draft report, "Milwaukee County River Basins Study," "Biological Chapter," Wisconsin Department of Natural Resources, Southeast District, Milwaukee, Wisconsin (draft copy on file at SEWRPC).*

Table 27

ESTIMATED MEAN ANNUAL LOADING TO LAKE MICHIGAN
FROM THE MILWAUKEE AND KINNICKINNIC RIVERS
ACCORDING TO THE MILWAUKEE COUNTY RIVER BASINS STUDY
BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Parameter	Mean Annual Loading to Lake Michigan (pounds per day)[a]	
	Lower Milwaukee River[b]	Kinnickinnic River[c]
Total Phosphorus	755	25
Total Nitrogen	9,300	188
Suspended Solids	250,000	5,400
Biochemical Oxygen Demand (BOD_5)	16,000	810

[a]*Mean annual loading to Lake Michigan based on twelve instantaneous samplings.*

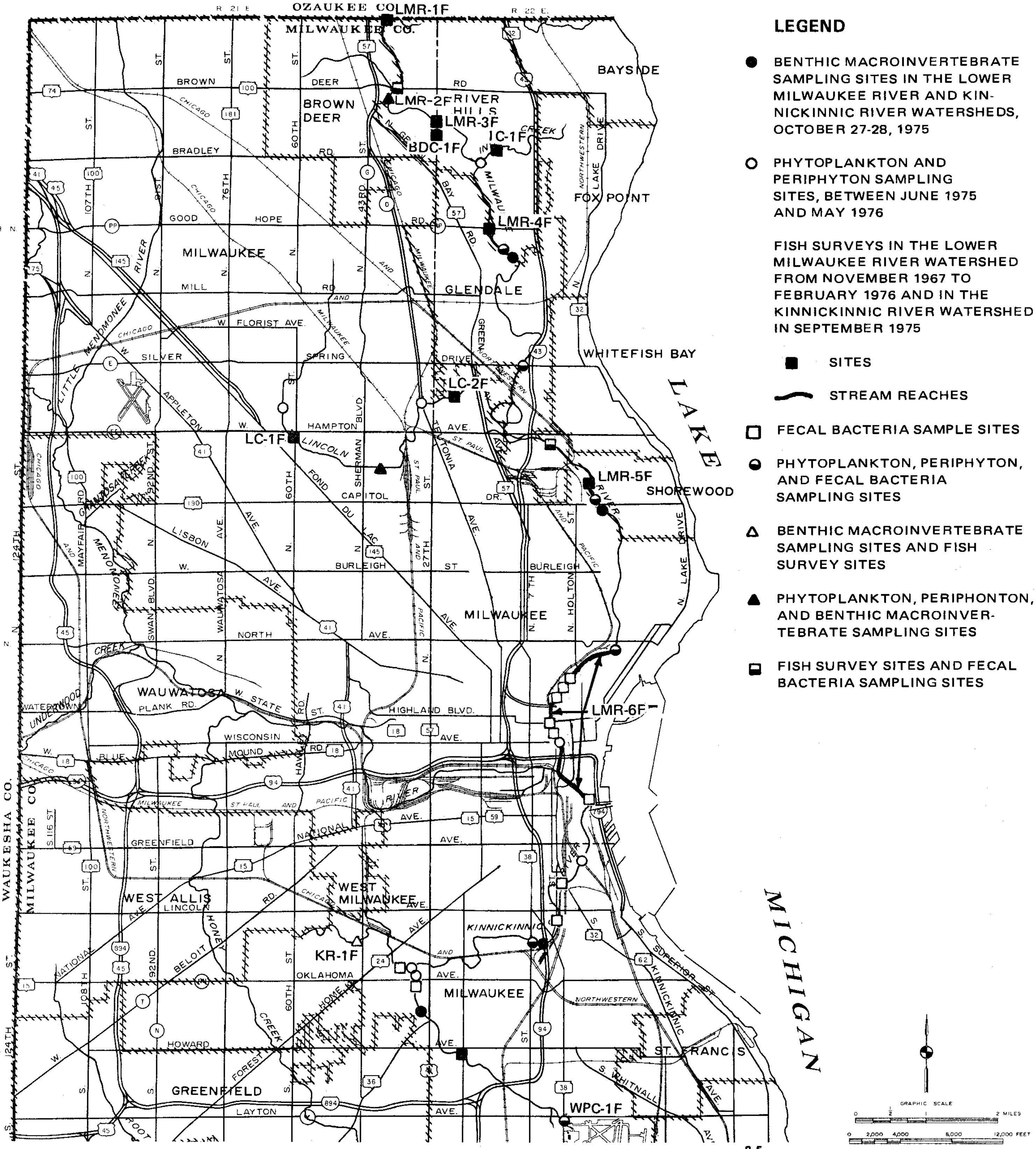
[b]*Over 37 percent of the mean pollutant annual load from the Milwaukee River was contributed from within Milwaukee County. Based on the difference between the mean annual pollutant load at LMR-1 and LMR-4 (see Table 24), 19 percent of the total phosphorus, 26 percent of the total nitrogen, 66 percent of the total suspended solids, and 38 percent of the biochemical oxygen demand originated in the Milwaukee County portion of the Milwaukee River Basin.*

[c]*The upstream station, KK-1, contributed about 27 percent of the mean annual load, while Wilson Park Creek contributed 31 percent.*

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Map 13

LOCATONS OF BIOLOGICAL SAMPLING SITES IN THE LOWER MILWAUKEE RIVER AND THE KINNICKINNIC RIVER WATERSHEDS FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: MAY 1975-OCTOBER 1976



Source: *DNR draft report, "Biological Chapter," on file at SEWRPC.*[25]

Table 28

DESCRIPTIONS OF BENTHIC MACROINVERTEBRATE SITES SAMPLED ON OCTOBER 27-31, 1975 IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER WATERSHEDS FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Location	DNR Station Number	Site Characteristics
Lower Milwaukee River Brown Deer Road, 200 yards downstream	LMR-1M	Riffle current over sand, gravel, and rock bar. Myriophyllum upstream from site.
Greentree Road, 200 yards downstream	LMR-2M	Riffle current over gravel and rock bar. Myriophyllum and filamentous blue-green algae on substrate.
Capitol Drive, 75 yards downstream	LMR-3M	Riffle current over sand, gravel, rock and boulder bar. Myriophyllum upstream from site. Downstream of combined sewer overflow outfall.
Lincoln Creek 40th Street footbridge, 20 yards downstream	LC-1M	Riffle current over detritus, sand, gravel, and rock bar. Elodea and filamentous algae present. Oil film on water surface. Abundant debris.
Kinnickinnic River S. 43rd Street, 300 yards upstream	KR-1M	Riffle current over sand, gravel, and rock bar. Leaves abundant on substrate.
S. 4th Street	KR-2M	Riffle over sand, gravel, and rock bar. Rocks covered with green slime and tarlike material. Salmon swimming upstream.
Wilson Park Creek Morgan Avenue, 100 yards downstream	WPC-1M	Riffle over sand, gravel, and rock bar. Abundant filamentous algae on rock substrates. Substrate oil laden. Oil on water surface.

[a]See Map 13 for sampling site locations.

Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

a whole and individually; biotic index values of the streams; and Simpson's similarity index"[26] were tabulated and are presented in the "Biological Chapter".

The macroinvertebrate study found 53 taxa in the lower Milwaukee River, 22 taxa in Lincoln Creek, 27 taxa in the Kinnickinnic River, and 19 taxa in Wilson Park Creek. In the lower Milwaukee River, the community diversity index ranged from 2.22 to 2.47. No dominant taxa were found and most taxa were found at each sampling station. In Lincoln Creek, as in the lower Milwaukee River, no dominant taxa were found. In the Kinnickinnic River most of the taxa found were present at both sampling stations. In Wilson Park Creek 13 taxa were found which also were found in the Kinnickinnic River.

The study concluded that the data were statistically valid for station comparison purposes. The benthic macroinvertebrate community reportedly indicated that water quality of the lower Milwaukee River was fair to poor, with quality decreasing in a downstream direction. Figure 2 presents biotic index values for each of the four lower Milwaukee River watershed sampling stations illustrating the downstream decrease in water quality. Lincoln Creek water quality was judged poor, based on the biotic index shown in Figure 2, the dominance of very pollution tolerant organisms, low population densities, and low diversity. Benthic macroinvertebrates in the Kinnickinnic River and Wilson Park Creek were found to be severely limited by water quality, as indicated by the biotic index shown in Figure 3. Sampling sites were occupied primarily by pollution tolerant organisms with low population densities and low diversity. The extent of human-modified habitat, and the erratic streamflow conditions were also considered limiting factors.

Phytoplankton and Periphyton: During the period June 1975 to May 1976, the DNR collected phytoplankton and periphyton data with major emphasis on diatoms in the periphyton community. Populations were evaluated based on community diversity, biomass, and pollution tolerance. Periphyton, phytoplankton, and chlorophyll-a samples were collected at six sites on the lower Milwaukee River, three on Lincoln Creek, and five on the Kinnickinnic River. Sampling site locations are shown on Map 13. Physical and chemical water quality data, discussed previously, were collected in conjunction with the biological sampling. The "Biological Chapter" of the draft report "Milwaukee County River Basins Study" describes field and laboratory procedures in detail.

Artificial substrates were used for periphyton with occasional samples taken from the stream bottom when artificial substrates were lost. Samples were taken at approximately one-month intervals. Diatoms were generally identified to the generic level and counted. Community diversity at the generic level was determined using the Shannon-Weaver index. Maximum possible diversity and community evenness were also determined along with hierarchical diversity at the generic and family levels, and the mean diversity within families.

Families and genera of periphyton and phytoplankton found in each stream are listed in Table 29. The number of individuals of periphytic and planktonic diatoms, diversity indices, and chlorophyll-a values were tabulated in the Appendices of the "Biological Chapter." Summary descriptions of these data follow to demonstrate that

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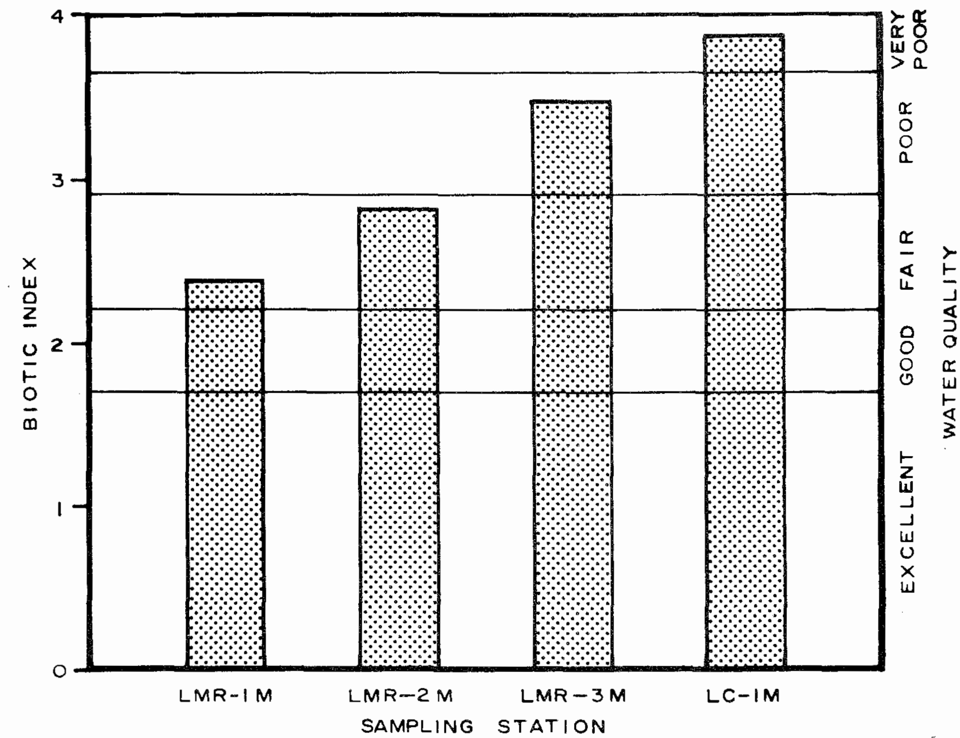
[26] *Ibid.*

Figure 2

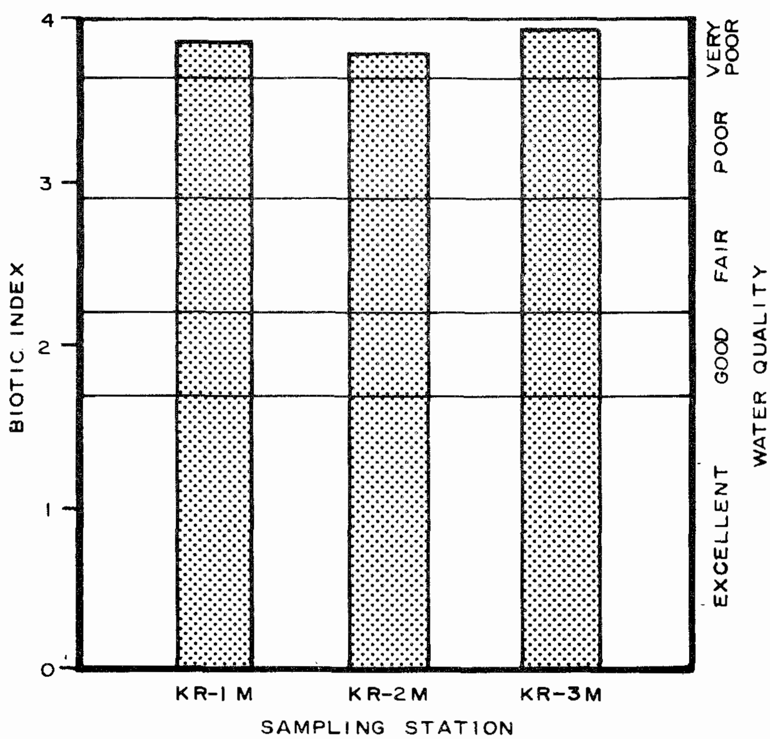
BIOTIC INDEX VALUES FOR THE MACROINVERTEBRATE COMMUNITY IN THE LOWER MILWAUKEE RIVER WATERSHED FOR SAMPLES COLLECTED OCTOBER 27-31, 1975 BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY



Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Figure 3

BIOTIC INDEX FOR THE MACROINVERTEBRATE COMMUNITY IN THE KINNICKINNIC RIVER WATERSHED FOR SAMPLES COLLECTED OCTOBER 27-31, 1975 BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY



Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Table 29

FAMILIES AND GENERA OF PERIPHYTIC AND PLANKTONIC DIATOMS COLLECTED IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER WATERSHEDS BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY: MAY 1975-APRIL 1976

Family	Genera
Lower Milwaukee River Watershed	
Coscinodiscaceae	Melosira,[a] Cyclotella
Fragilariaceae	Tabellaria,[b] Diatoma,[a] Fragilaria, Synedra
Naviculaceae	Navicula, Gyrosigma
Cymbellaceae	Amphora,[a] Cymbella[c]
Gomphonemaceae	Gomphonema
Achnanthaceae	Cocconeis, Achnanthes, Rhoicosphenia
Nitzschiaceae	Nitzschia
Surirellaceae	Surirella,[c] Cymatopleura[a,c,]
Kinnickinnic River Watershed	
Coscinodiscaceae[d]	Melosira,[d] Cyclotella[d]
Fragilariaceae	Tabellaria,[d] Diatoma,[d] Fragilaria, Synedra
Naviculaceae	Navicula, Pinnularia[d]
Nitzschiaceae	Nitzschia
Gomphonemaceae	Gomphonema
Achnanthaceae	Cocconeis, Achnanthes, Rhoicosphenia[d]
Cymbellaceae	Cymbella, Amphora[d]
Surirellaceae	Surirella, Cymatopleura[d]

[a]*Not represented in Lincoln Creek.*

[b]*Planktonic only.*

[c]*Periphytic only.*

[d]*Not represented in Wilson Park Creek.*

Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

adequate data and analyses of periphyton and phytoplankton may already exist to characterize these parameters in the Milwaukee and Kinnickinnic Rivers for existing conditions.

Eight families of periphyton and phytoplankton combined, including 16 genera, were found in the lower Milwaukee River. Cocconeis and Navicula were the most prevalent genera. Community diversity ranged from 0.25 to 0.81 during the study period. In Lincoln Creek, 8 families and 11 genera were found. Achnanthes and Gomphonema were the most common genera. Diversity ranged from 0.22 to 0.68. In the Kinnickinnic River, 8 families, including 17 genera, were found. Gomphonema, Surirella, and Nitzschia were the most common genera. Diversity ranged from 0.16 to 0.75. In Wilson Park Creek, 7 families, including 9 genera, were found with Achnanthes being the most dominant genera in almost every sample. Diversity ranged from 0.14 to 0.56. Chlorophyll-a ranged from 1.8 to 216 milligrams per square meter in the lower Milwaukee River, 5.5 to 350 in Lincoln Creek, 0.0 to 97 in the Kinnickinnic River, and 0.0 to 40 in Wilson Park Creek.

In the lower Milwaukee River, phytoplankton were specifically sampled in October 1975, for identification and counting. Seven families, including 14 genera, were found. Cyclotella was the most common genera. Community diversity ranged from 0.71 to 0.88. Chlorophyll-a concentrations in the lower Milwaukee River and Lincoln Creek, based on 74 phytoplankton samples, were very small or undetectable, as was the case in the Kinnickinnic River basin as indicated by 22 samples.

Tolerant to very tolerant genera were dominant in the periphyton samples in the lower Milwaukee River. The more tolerant genera found were Navicula, Nitzschia, and Cyclotella. Stations LMR-2P, LMR-4P, and LMR-6P (Map 13) had relatively high values of diversity and evenness. Phytoplankton samples also indicated relatively high values of diversity and evenness, indicating that no one genus was dominant at these locations.

Periphyton biomass, based on chlorophyll-a data, was about the same at all the lower Milwaukee River stations, and in general was relatively low. Optical density ratios and pheophytin indicated that periphyton communities were in poor physiological condition. Phytoplankton biomass was also low at all sampling stations.

In Lincoln Creek pollution tolerant genera also dominated in the periphyton samples collected, and included in part Nitzschia, Navicula, and Gomphonema. Community diversity, however, was low in all the samples taken, as was evenness. Biomass was relatively low in most samples and the physiological condition of the community was poor. Phytoplankton biomass was considered negligible.

In the Kinnickinnic River, pollution tolerant genera dominated in the periphyton samples collected. Station KK-3P (Map 13) data suggested much influence by Lake Michigan at this site containing lower numbers of pollution tolerant genera. The more pollution tolerant genera found included Gomphonema, Nitzschia, and Surirella. Diversity and evenness were generally low except at the lower site affected by Lake Michigan where these values were much higher. Periphyton biomass was low as was that for phytoplankton.

In Wilson Park Creek, pollution tolerant organisms again dominated. However, only 9 of the 17 genera found in the Kinnickinnic River were found in Wilson Park Creek with a large number of facultative genera being found in all samples. Nitzschia and

Surirella were the dominant nonfacultative pollution tolerant genera, with Achnanthes being the dominant facultative genera. Community diversity and evenness were low, as was biomass. The periphyton community was in poor physiological condition.

The report concluded that the algae data indicated generally fair water quality in the lower Milwaukee River. The quality of upper Lincoln Creek was considered relatively good, with poor quality in the most downstream reaches having a detrimental effect on the Milwaukee River. Phytoplankton in the lower Milwaukee River watershed was considered insignificant and not useful as a water quality indicator. Water quality in the Kinnickinnic River was considered generally poor, with somewhat better quality indicated in Wilson Park Creek. Phytoplankton in these two streams were insignificant and considered useless as a water quality indicator.

Fish: Fish population data from DNR surveys and surveys of others in Milwaukee County rivers and streams were collated by the DNR and evaluated in the "Milwaukee County River Basins Study." The data were collected at the sites shown on Map 13 for the lower Milwaukee and Kinnickinnic River watersheds. The lower Milwaukee River fish surveys were made from November 1967 to February 1976, with the Kinnickinnic River survey being made in September 1975. Table 30 lists the dates of each individual fish survey, the sampling station locations, and the collection methods. Fish data collected by the Wisconsin Electric Power Company in 1976, and discussed later in this chapter, at the Commerce Street Power Plant were included with the data evaluated by the DNR. Fish collection techniques are discussed in detail in the "Biological Chapter" of the study. Fish species found are listed in Table 31. The "Biological Chapter" of the study presents tables listing the number of individuals of fish species collected, corresponding sampling stations, and sampling dates in the lower Milwaukee River watershed. Only one fish--a goldfish--was found in the Kinnickinnic River watershed in Wilson Park Creek.

The report concluded that generally good water quality was found in the lower Milwaukee River upstream from the combined sewer outfall area and industrialized areas as indicated by the fish species found there, many of which are intolerant to turbidity and siltation. The greater redhorse (Moxostoma valenciennesi), normally found in large, clear sand and gravel streams, was found in September 1969 at Site LMR-2F (Map 13), and is indicative of good water quality at that location and time. Numerous other species, intolerant of turbidity and siltation, were also found in the lower Milwaukee River upstream from combined sewer outfall areas and industrialized areas. Fish populations in the Kinnickinnic River watershed were noted to be severely limited by habitat and streamflow regime. Additional fish surveys in this watershed were recommended to determine if populations are habitat or water quality limited.

Fecal Bacteria: Fecal coliform and fecal streptococcus bacteria data collected by the DNR, the City of Milwaukee Health Department, and the U. S. Geological Survey were used in the "Milwaukee County River Basins Study" to qualify and quantify bacterial conditions in the lower Milwaukee River and Kinnickinnic River watershed. Bacteria sampling site locations are shown on Map 13 for the lower Milwaukee River and Kinnickinnic River watersheds. Fecal coliform sampling data were collected by the DNR at about one-month intervals in 1975 and 1976, beginning in May 1975, and were discontinued in either April or October 1976 at each site. City of Milwaukee Health Department fecal coliform samples collected in June, July and August in the years 1974-1977, inclusive, were included with the data evaluated, along with fecal coliform and fecal streptococcus data collected monthly from October 1973 to Septem-

Table 30

FISH SURVEY LOCATIONS, DATES, AND COLLECTION METHODS IN THE LOWER MILWAUKEE AND KINNICKINNIC RIVER WATERSHEDS INCLUDED IN THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: NOVEMBER 1967-SEPTEMBER 1975

Sample Station Number and Location		Collection Date	Collection Method[a]
Lower Milwaukee River			
LMR-1F	County Line Road	10/70	1
LMR-2F	Brown Deer Road...........	11/67	1
	Brown Deer Road...........	9/69	1
LMR-3F	Range Line Road	10/70	1
LMR-4F	Green Tree Road	9/69	1
	Good Hope Road............	10/70	1
	Green Tree Road	9/75	2
LMR-5F	Estabrook Parkway	9/75	2
LMR-6F	North Avenue Dam to the Milwaukee Bay.........	5/72	4
Brown Deer Creek			
BDC-1F	Range Line Road	9/75	3
Indian Creek			
IC-1F	River Road.................	9/75	2
Lincoln Creek			
LC-1F	60th Street.................	9/75	2
LC-2F	23rd and Villard Avenue....................	9/75	2
Kinnickinnic River			
KR-1F	43rd Street.................	9/75	2
Wilson Park Creek			
WPC-1F	Howard Avenue.............	9/75	2

NOTE: Fish data utilized in the study but collected by the Wisconsin Electric Power Company (WEPCO) in 1976, are presented in the WEPCO section of this chapter for the intake monitoring study at the Commerce Street Power Plant on the Milwaukee River.

[a] *1-small mesh seine; 2-stream shocker; 3-long line shocker; 4-boomshocker.*

Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Table 31

FISH SPECIES FOUND IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER WATERSHEDS INCLUDED IN THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: NOVEMBER 1967-FEBRUARY 1976

Lower Milwaukee River			
Common Name	Scientific Name	Common Name	Scientific Name
Common shiner	Notropis cornutus	Shorthead redhorse	Moxostoma macrolepidotum
Striped shiner	Notropis chrysocepahlus	Greater redhorse	Moxostoma valenciennesi
Spottail shiner	Notropis hudsonius	Black bullhead	Ictalurus melas
Spotfin shiner	Notropis spilopterus	Yellow bullhead	Ictalurus natalis
Sand shiner	Notropis stramineus	Brown bullhead	Ictalurus nebulosus
Emerald shiner	Notropis atherinoides	Stonecat	Noturus flavus
Stoneroller	Campostoma anomalum	Channel catfish	Ictalusus punctatus
Longnose dace	Rhinichthys cataractae	Tadpole madtom	Noturus gyrinus
Large scale stoneroller	Campostoma anomalum oligolepis	Rock bass	Ambloplites rupestris
Carp	Cyprinus carpio	Black crappie	Pomoxis nigromaculatus
Bluntnose minnow	Pimephales notatus	Green sunfish	Lepomis cyanellus
Fathead minnow	Pimephales promelas	Pumpkinseed	Lepomis gibbosus
Mud minnow	Umbra limi	Bluegill	Lepomis macrochirus
Hornyhead chub	Nocomis biguttatus	Largemouth bass	Micropterus salmoides
Golden shiner	Notemigonus crysoleucas	Johnny darter	Etheostoma nigrum
Goldfish	Carassius auratus	Log perch	Percina caprodes
Carp x goldfish	--	Yellow perch	Perca flavescens
Common x striped shiner	--	Blackside darter	Percina maculata
Brook stickleback	Culaea inconstans	Alewife	Alosa pseudoharengus
Northern pike	Esox lucius	Smelt	Osmerus mordax
		Gizzard shad	Dorosoma cepedianum
		White sucker	Catostomus commersoni

Lower Milwaukee River Tributaries[a]	
Common Name	Scientific Name
Northern Pike	Esox lucius
Carp	Cyprinus carpio
Common shiner	Notropis cornutus
Spottail shiner	Notropis hudsonius
Spotfin shiner	Notropis spilopterus
Sand shiner	Notropis stamineus
Bluntnose minnow	Pimephales notatus
Fathead minnow	Pimephales promleas
Goldfish	Carassius auratus
Creek chub	Semotilus atromaculatus
White sucker	Catastomus commersoni
Yellow bullhead	Ictalurus natalis
Green sunfish	Lepomis cyanellus
Pumpkinseed	Lepomis gibbosus
Largemouth bass	Micropterus salmoides
Logperch	Percina caprodes

Kinnickinnic River	
Goldfish	Carassius auratus

[a]Brown Deer Creek, Indian Creek, and Lincoln Creek.

Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

ber 1976 by the U. S. Geological Survey (USGS) at the gaging station on the Milwaukee River at Estabrook Park. Sampling dates and bacteria counts are listed in the "Biological Chapter" of the study for the DNR samples. USGS data are also summarized in the "Biological Chapter" which presents sampling dates, fecal coliform and fecal streptococcus counts, and ratios of fecal coliforms to fecal streptococci.

City of Milwaukee Health Department data are also summarized in the "Biological Chapter" which presents monthly geometric mean fecal coliform counts, monthly ranges, and the percentage of samples violating fecal bacteria standards. The chapter also includes a discussion on field and laboratory methods, which were the same for all three agencies.

The DNR compared the sample data to fecal coliform standards for Milwaukee County surface waters which are presented in Table 32. The study concluded that "surface waters within Milwaukee County were grossly contaminated by fecal material" as evidenced by Figures 4, 5, and 6, which show the percentage of violations of the fecal coliform standards in the lower Milwaukee River, Lincoln Creek, and the Kinnickinnic River during the summer recreation season. Annual data collected by the DNR and USGS indicated that the entire lower Milwaukee River, Lincoln Creek, and the Kinnickinnic River were unfit for any water-based recreation. The major sources of fecal coliform contamination were reported to be sanitary sewage flow-relief devices and combined sewer outflows. This was based in part upon the ratios of fecal coliform to fecal streptococci for the USGS samples, which indicate that a majority of the fecal material was of human origin rather than from nonpoint sources. Fecal coliform counts were high not only in the stream reaches draining combined sewer service areas, but in upstream reaches containing outfalls for sanitary sewer flow-relief devices.

Hazardous Substances: An investigation was conducted in 1975-1976 of the hazardous materials within the Milwaukee County river basins as a component of the "Milwaukee County River Basin Study", reported in the "Chemical and Physical Chapter."

The primary objectives for conducting this survey were to identify the toxic and hazardous contaminants and document their concentrations within the rivers of Milwaukee County. Hazardous and toxic material concentrations within the water samples were compared with USEPA recommended criteria for fish and other aquatic life (Table 33). Instream sediments were classified according to EPA pollution severity guidelines (Table 34).

Data collected included monthly water samples taken from locations throughout Milwaukee County, and muck type sediment samples taken from areas of recent sediment deposition. Sampling stations were selected to reflect changing land use.

Ten water quality and eight sediment quality sampling stations were established on the lower Milwaukee River and its tributaries, while the Kinnickinnic River and its tributaries had five water and six sediment sampling stations. The sites are shown on Map 12.

Fresh snowfall samples were collected for PCB analysis from six sites during 1975 and four sites in 1976 at sites in the City of Milwaukee, and the Counties of Fond du Lac, Kenosha, Ozaukee, Racine and Washington. Table 35 presents PCB concentrations, sampling dates and sampling location descriptions.

Table 32

FECAL COLIFORM STANDARDS FOR SURFACE WATERS IN MILWAUKEE COUNTY

Stream	Standards	
	30-Day[a]	10 Percent[b]
Lower Milwaukee River		
Above North Avenue Dam..	200	400
Below North Avenue Dam..	1,000	--
Lincoln Creek	1,000	2,000
Kinnickinnic River...........	1,000	2,000

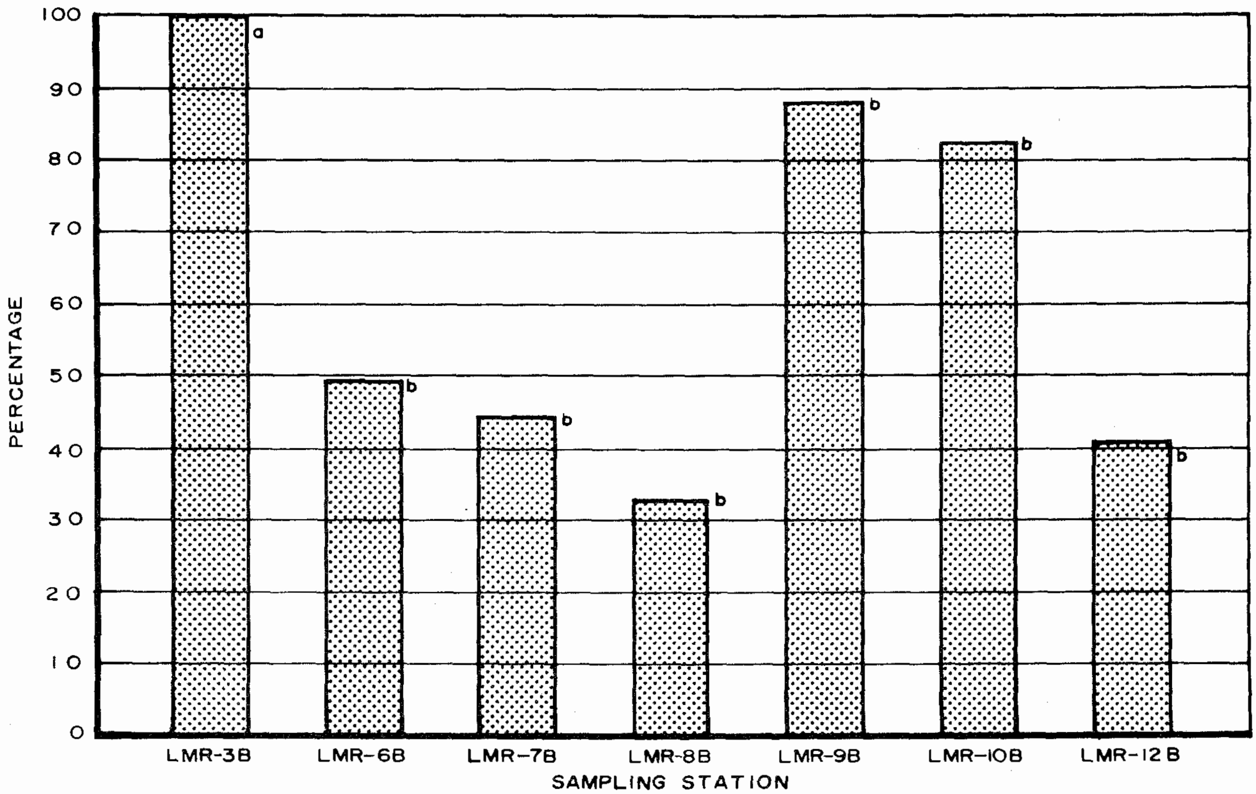
[a] *Maximum 30-day geometric mean of fecal coliform per 100 milliliters.*

[b] *Maximum count of fecal coliforms per 100 milliliters in highest 10 percent of monthly samples.*

Source: DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Figure 4

PERCENTAGE OF SUMMER MONTHLY GEOMETRIC MEANS IN VIOLATION OF FECAL COLIFORM STANDARDS IN THE LOWER MILWAUKEE RIVER: 1974-1977

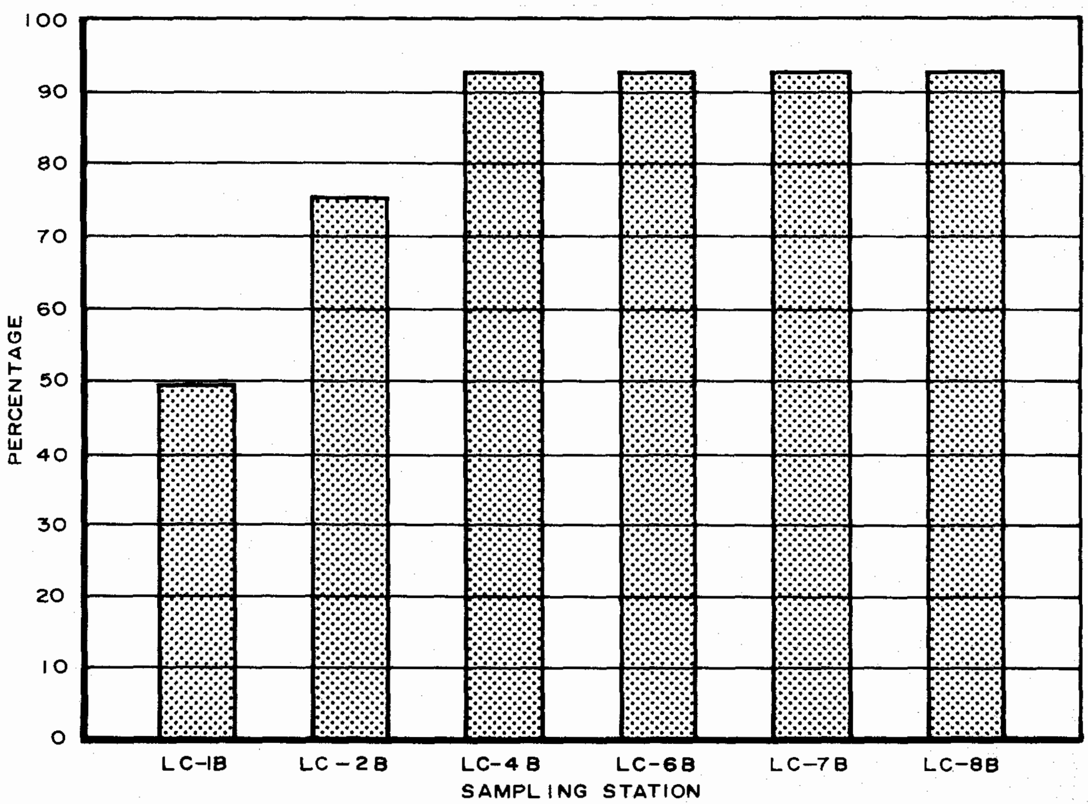


a STANDARD 30-DAY GEOMETRIC MEAN NOT TO EXCEED 200 FECAL COLIFORM PER 100 MILLILETERS
b STANDARD 30-DAY GEOMETRIC MEAN NOT TO EXCEED 1000 FECAL COLIFORM PER 100 MILLILETERS

Source: City of Milwaukee Health Department and DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Figure 5

PERCENTAGE OF SUMMER MONTHLY GEOMETRIC MEANS IN VIOLATION OF FECAL COLIFORM STANDARDS IN LINCOLN CREEK: 1974-1977

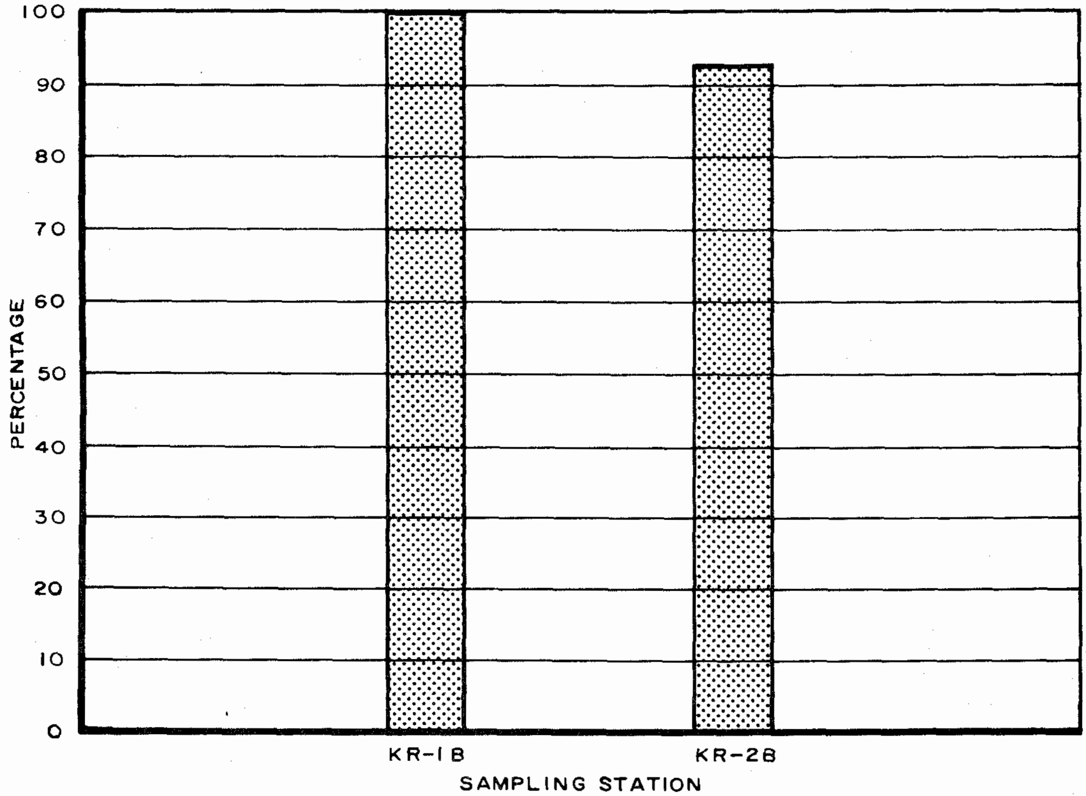


STANDARD: 30-DAY GEOMETRIC MEAN NOT TO EXCEED 1,000 FECAL COLIFORM PER 100 MILLILETERS. 10% OF SAMPLES NOT TO EXCEED 2,000 PER 100 MILLILETERS.

Source: City of Milwaukee Health Department and DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Figure 6

PERCENTAGE OF SUMMER MONTHLY GEOMETRIC MEANS IN VIOLATION OF FECAL COLIFORM STANDARDS IN THE KINNICKINNIC RIVER: 1974-1977



STANDARD: 30-DAY GEOMETRIC MEAN NOT TO EXCEED 1,000 FECAL COLIFORM PER 100 MILLILETERS. 10% OF SAMPLES NOT TO EXCEED 2,000 PER 100 MILLILETERS

Source: City of Milwaukee Health Department and DNR draft report, "Biological Chapter," on file at SEWRPC.[25]

Table 33

U.S. ENVIRONMENTAL PROTECTION AGENCY RECOMMENDED WATER QUALITY CRITERIA FOR MATERIALS TOXIC AND HAZARDOUS TO FISH AND OTHER AQUATIC LIFE

Parameter	EPA Recommended Criteria (μg/l)[a]	Parameter	EPA Recommended Criteria (μg/l)
PCB.........	.001	Heptachlor	0.001
Cadmium	12 μg/l hard water 4 μg/l soft water	Aldrin-Dieldrin ..	0.003/0.01
		DDT	0.001
Chromium ...	100	DDE.............	0.001
Copper......	47	Methoxychlor	0.03
Lead	4,820	DDD	--
Zinc.........	82	Heptachlor-epoxide	0.001[b]
Nickel.......	100		
Mercury.....	0.05	Diethylhexyl phthalate.......	3.00
Lindane	0.01		

[a]*References: U.S. Environmental Protection Agency, Quality Criteria for Water, July 1976.*

[b]*U.S. Environmental Protection Agency, Quality Criteria for Water, March 1973.*

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 34

U.S. ENVIRONMENTAL PROTECTION AGENCY SEDIMENT POLLUTION CATEGORIES USING BULK SEDIMENT ANALYSIS

Parameter	Concentration (mg/kg)		
	Nonpolluted	Moderately Polluted	Highly Polluted
Cadmium[a]	--	--	6
Chromium	25	25-75	75
Copper.................	25	25-50	50
Lead	40	40-60	60
Zinc...................	90	90-200	200
Nickel.................	20	20-50	50
Mercury...............	1.0	N/A	10
PCB...................	10	10	N/A

NOTE: N/A indicates data are not available.

[a]*Lower limits not established.*

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 35

PCB CONCENTRATIONS IN SNOW SAMPLES COLLECTED FOR THE MILWAUKEE COUNTY RIVER BASINS STUDY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1975 AND 1976

Location	Date Sampled	PCB µg/l
Milwaukee County		
(1) Milwaukee River at Confluence with Kinnickinnic River	--	0.10
(2) Juneau Park at Milwaukee Lake Front	2/26/75	0.12
(3) Juneau Park at Milwaukee Lake Front	12/03/76	--[a]
(4) Underwood Creek Parkway	12/03/76	--[a]
Racine County		
(1) 16th and Main at Racine Lake Front	2/26/75	0.17
(2) East High Street, Racine	12/03/76	--[a]
Kenosha County		
(1) 5th Avenue Branch at Kenosha Lake Front	2/26/75	0.22
(2) Alford Park at Highway 32 in Kenosha	12/06/76	--[a]
Washington County		
(1) Jct. Highways 45 and 60, South of West Bend	3/06/75	--[a]
Fond du Lac County		
(1) Morraine Bridge East Branch of Milwaukee River, Northeast of Kewaskum	3/06/75	--[a]
Ozaukee County		
(1) Grafton High School	2/26/75	--[a]

[a] *Below detectability levels.*

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Occasionally, the concentrations of toxic and hazardous substances in water samples from the rivers of Milwaukee County exceeded levels documented as toxic to aquatic life (Table 36). It should be noted that EPA water quality criteria concentrations (Table 33) in some cases are below the analytical testing limits. This circumstance precluded total documentation of the occurrence of hazardous levels of mercury, aldrin, dieldrin, DDT and PCB's.

The water sampling dates were selected for convenience in DNR work scheduling, and therefore the samples were collected under a wide variety of conditions. Runoff induced by rainfall and snowmelt influenced toxicant concentrations and loadings within the riverine systems. A comparison was made between an instantaneous dry weather toxicant load and a wet weather load, and demonstrated greatly increased toxicant stream loadings due to urban nonpoint source runoff, resuspension of previously deposited materials, and, in some areas, combined sewer overflows (see Table 37).

The sediments in the rivers of Milwaukee County were generally moderately to heavily polluted with heavy metals and PCB's (See Tables 38 and 39). In many cases, several toxicants simultaneously exceeded heavily polluted levels, which increased the potential for interactive effects of the pollutants. PCB's and all heavy metals were present in every sediment sample. Downstream industrialized river sections, especially those in the combined sewer service area, contained the most severe levels of sediment contamination.

Toxicant contamination reportedly was a function of increasing urbanization and industrial activity. There were 47 known industrial wastewater discharges to the lower Milwaukee River and its tributaries within Milwaukee County. Many of these were potential dischargers of hazardous and toxic materials. Urban nonpoint source runoff and the combined and sanitary sewer flow relief devices were considered by the DNR to be the two most significant sources of hazardous and toxic contamination to the Milwaukee rivers. Instantaneous loading rates during wet weather showed a large increase in heavy metals compared to dry weather results. This increase was especially pronounced in the more urbanized areas and the combined sewer service area. Industrial centers were typically most prone to spill hazardous and toxic materials. Recorded spills of toxic and hazardous substances in the Milwaukee County river basins are described in the draft report, "Milwaukee County River Basins Study," "Chemical and Physical Chapter," which also discusses the types of recorded spill materials, causes and sources of spills, spill-prone areas, and methods for spill prevention and management. Maps of recorded spill sites are included in the report, with numerous such sites being located in the Milwaukee Harbor estuary. It was estimated that up to 90 percent of spills are unreported, undetected, and, therefore, unrecorded.

Kinnickinnic River Watershed Intensive Water Quality Survey: As part of the "Milwaukee County River Basins Study," the DNR on October 22-24, 1975, conducted an intensive water quality survey of Wilson Park Creek and the Kinnickinnic River. This study was made in part to evaluate the effectiveness of intensive surveys for river basin assessment purposes. Sampling sites for this low-flow survey are shown on Map 14. Water quality and physical parameters sampled are listed in Table 40. Data collected at each sampling site for each parameter are tabulated in the "Chemical and Physical Chapter." Instream loadings for each water quality parameter were calculated and tabulated in the chapter, as were percentages of loadings contributed to and assimilated by each stream reach. Apparent assimilation was estimated between

Table 36

NUMBER OF VIOLATIONS OF U.S. ENVIRONMENTAL PROTECTION AGENCY WATER QUALITY CRITERIA FOR TOXIC AND HAZARDOUS SUBSTANCES AT SAMPLING STATIONS IN THE LOWER MILWAUKEE RIVER AND KINNICKINNIC RIVER WATERSHEDS: 1975 AND 1976

		Station[a]														
		Lower Milwaukee River Basin										Kinnickinnic River Basin				
Parameters	Criteria µg/l	LMR-1	LMR-2	LMR-3	LMR-4	LMR-5	LMR-6	LC-1	LC-2	LC-3	IC-1	KR-1	KR-2	KR-3	WPC-1	WPC-2
Cadmium.....	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chromium....	100	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copper......	47	--	--	1	1	1	--	--	--	--	--	1	--	1	--	--
Lead........	4,820	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mercury.....	0.05	1	2	1	1	2	1	1	2	1	1	1	2	1	1	1
Nickel......	100	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zinc........	82	1	--	--	1	1	1	1	1	1	1	3	2	3	--	1
PCB.........	0.001	--	--	--	1	1	1	--	--	--	--	1	--	--	--	--
Lindane.....	0.01	--	--	--	--	--	--	--	1	1	1	--	--	--	--	--
Heptachlor-Epoxide....	0.001	--	--	--	--	--	--	--	--	--	--	--	1	1	--	1
Heptachlor..	0.001	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--

[a] See Map 12 for water sampling station locations. Samples were collected monthly.

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 37

INSTANTANEOUS DISCHARGE OF HEAVY METALS DURING SEPTEMBER 1975
(DRY-WEATHER FLOW) AND FEBRUARY 1976 (WET-WEATHER FLOW)
IN THE LOWER MILWAUKEE AND KINNICKINNIC RIVER WATERSHEDS

Water Column Parameter	Date	Sampling Site and Concentration[a] (pounds per day)											
		Lower Milwaukee River Basin								Kinnickinnic River Basin			
		LMR-1	LMR-2	LMR-3	LMR-4	LC-1	LC-2	LC-3	IC-1	KR-1	KR-2	WPC-1	WPC-2
Cadmium	Sept.	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
	Feb.	--[b]	--[b]	3.7	5.2	--[b]	1.3	0.1	--[b]	--[b]	0.1	--[b]	--[b]
Copper	Sept.	20.3	28.9	14.0	--[b]	0.3	0.1	0.6	--[c]	0.2	0.5	0.02	0.1
	Feb.	163.5	143.2	238.1	506.2	1.3	3.7	4.8	0.3	0.5	1.3	0.20	0.9
Chromium	Sept.	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	0.8	--[c]	--[b]	2.3	--[b]	--[b]
	Feb.	--[b]	--[b]	--[b]	226.9	--[b]	--[b]	1.1	--[b]	--[b]	0.5	0.1	0.6
Lead	Sept.	6.4	7.2	3.7	--[b]	0.1	--[b]	1.9	--[c]	0.3	--[b]	0.04	--[b]
	Feb.	238.0	156.2	398.9	2,443.5	3.4	25.2	31.8	0.6	0.9	3.4	0.3	2.3
Zinc	Sept.	209.0	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[c]	0.9	3.1	--[b]	2.3
	Feb.	223.0	--[b]	357.2	174.4	12.7	23.6	28.4	2.9	21.6	9.7	0.8	6.7
Nickel	Sept.	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[c]	--[b]	--[b]	--[b]	--[b]
	Feb.	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Mercury	Sept.	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[c]	--[b]	--[b]	--[b]	--[b]
	Feb.	1.5	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]

[a] See Map 12 for water sampling station locations.
[b] Below detectability.
[c] No streamflow.

Source: DNR draft report "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 38

BOTTOM SEDIMENT CHEMICAL QUALITY IN THE LOWER MILWAUKEE RIVER WATERSHED: 1975 AND 1976

Parameter	Sampling Site[a] and Recording Date With Concentrations in Milligrams per Kilogram									
	LMR-1CS 2/10/76	LMR-2C 5/8/75	LC-4S 5/8/75	LMR-3CS 2/10/76	LMR-4CS 5/8/75	LMR-4CS 2/10/76	LMR-5CS[b] 5/8/75	LMR-5CS[b] 2/10/76	LMR-6CS 2/10/76	LMR-75 5/8/75
PCB..............	0.150	1.1	3.2	7.5	3.5	345(P)	21.3	13.6	9.6	26(P)
Cadmium..........	0.5	--	--	2.0	--	7.25(HP)	--	6.75(HP)	6.25(HP)	--
Chromium.........	6.5	--	--	38(MP)	--	172(HP)	--	93(HP)	16.5	--
Copper...........	8.5	--	--	45(MP)	--	272(HP)	--	100(HP)	125(HP)	--
Lead.............	35	--	--	250(HP)	--	625(HP)	--	550(HP)	775(HP)	--
Nickel...........	5	--	--	20(MP)	--	62(HP)	--	28(MP)	30(MP)	--
Zinc.............	95(MP)	--	--	275(HP)	--	775(HP)	--	525(HP)	600(HP)	--
Mercury..........	.07	--	--	0.21	--	0.69	--	0.11	1.06(P)	--
EPA Pollution Classification..	MP	ID	ID	HP	ID	HP	P(PCB)	HP	HP	P(PCB)
Land Use[c]........	A,L,B	L	R	R,I,T	R,I	R,I	R,I	R,I	C,T	C,T

[a] See Map 12 for sampling site locations.
[b] Sample taken in impounded area.

Pollution classifications:
P - Polluted.
MP - Moderately polluted.
HP - Heavily polluted.
ID - Insufficient data.

[c] Land Use Categories: Agricultural (A), Commercial (C), Industrial (I), Residential (R), Low-Density Residential (L), Transportation (T), and Base Line Data (B).

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 39

BOTTOM SEDIMENT CHEMICAL QUALITY IN THE
KINNICKINNIC RIVER WATERSHED: 1975 AND 1976

Parameter	Sampling Site[a] and Recording Date with Concentrations in Milligrams per Kilogram						
	WMD-IS 2/10/76	KR-ICS 5/8/75	WPC-2CS 2/2/76	KR-2CS 2/10/76	KR-3S 5/8/75	KR-3CS 5/8/75	KR-3CS 2/10/76
PCB...............	2.7	1.1	0.11	11.0(P)	3.6	5.5	9.7
Cadmium...........	3.5	--	1.25	3.5	--	--	11.2(HP)
Chromium..........	22	--	16	37.5(MP)	--	--	530(HP)
Copper............	49(MP)	--	36(MP)	78(MP)	--	--	118(HP)
Lead..............	670(HP)	--	375(HP)	650(MP)	--	--	670(MP)
Nickel............	15	--	12	25(MP)	--	--	32(MP)
Zinc..............	750(HP)	--	250(HP)	825(HP)	--	--	850(HP)
Mercury...........	0.31	--	0.25	0.34	--	--	0.55
EPA Pollutional Classification....	HP	ID	HP	HP	ID	ID	HP
Land Use[b]..........	I,R	R	R,T	R	R	R,T	R,T

[a]See Map 12 for sampling site locations.

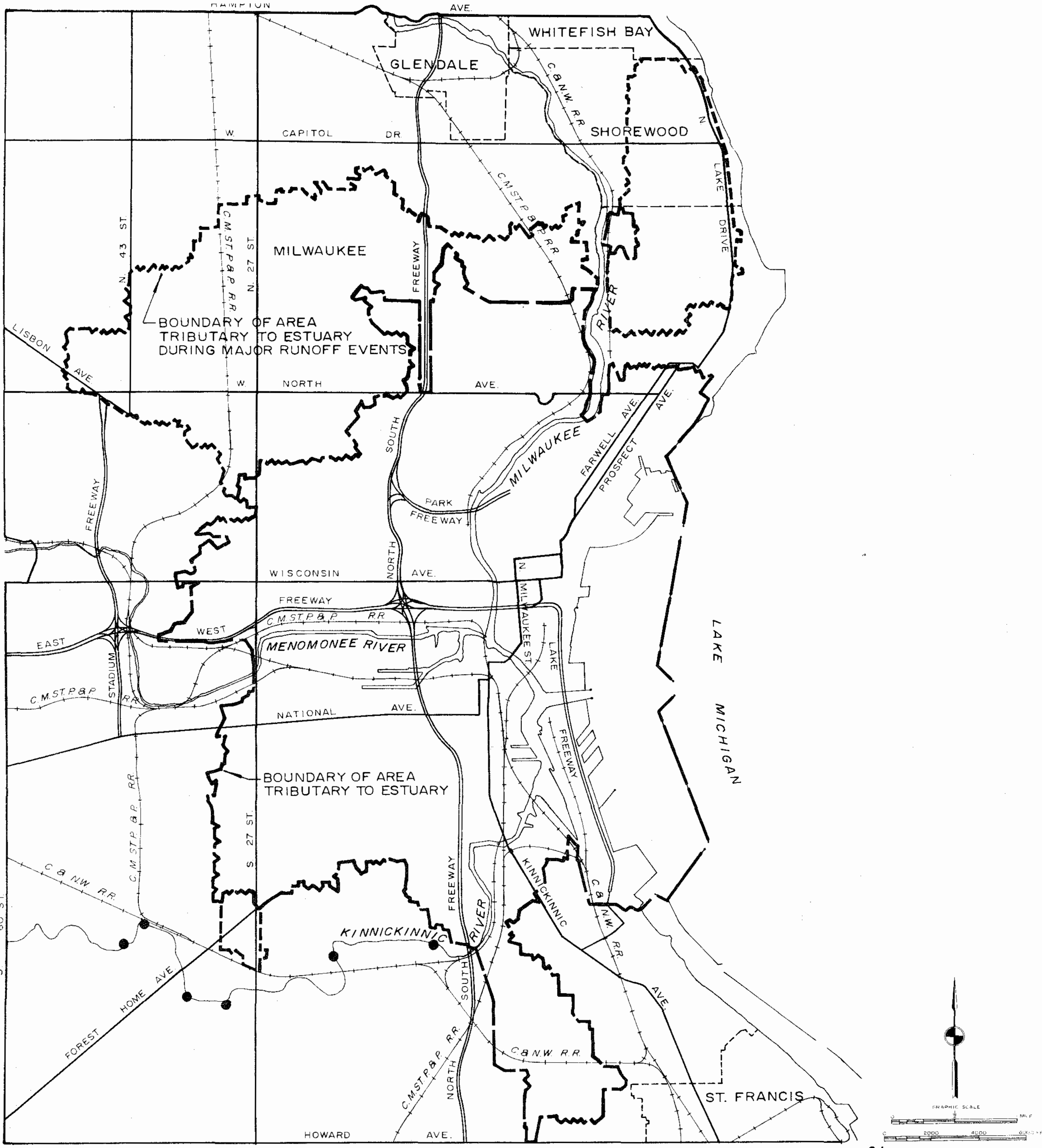
Pollution Classifications:
P - Polluted.
MP - Moderately Polluted.
HP - Heavily Polluted.
ID - Insufficient Data.

[b]Land Use Categories: Industry (I), Residential (R), Transportation (T).

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Map 14

SAMPLING STATION LOCATIONS FOR THE KINNICKINNIC RIVER WATERSHED INTENSIVE WATER QUALITY SURVEY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: OCTOBER 22-24, 1975



Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 40

WATER QUALITY AND PHYSICAL PARAMETERS MONITORED DURING THE INTENSIVE WATER QUALITY SURVEY OF THE KINNICKINNIC RIVER WATERSHED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES ON OCTOBER 22-24, 1975

Parameters	
Water Temperature	Total Organic Nitrogen
Dissolved Oxygen	Ammonia Nitrogen
Hardness	Nitrite and Nitrate Nitrogen
pH	Un-ionized Ammonia
Alkalinity	Total Nitrogen
Suspended Solids	Chlorides
Volatile Solids	Heavy Metals
Fixed Solids	Cadmium
Total Solids	Chromium
Total Phosphorus	Copper
Ortho-phosphorus	Lead
Total Organic Carbon	Mercury
Time of Travel	Nickel
Stream Discharge	Zinc
5-day BOD	Iron

NOTE: See Map 14 for sampling site locations.

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

Table 41

WATER QUALITY PARAMETERS MONITORED AT GENERAL MITCHELL FIELD BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: JANUARY-DECEMBER 1977

Parameters	
Total Solids	Chemical Oxygen Demand
Total Volatile Solids	pH
Suspended Solids	PCB
Suspended Volatile Solids	
Total Phosphorus	Heavy Metals:
Soluble Phosphorus	Mercury
Organic Nitrogen	Lead
Ammonia Nitrogen	Copper
Nitrite and Nitrate Nitrogen	Chromium
Chlorides	Cadmium
Total Organic Carbon	Zinc
5-Day BOD	Nickel

Source: DNR draft report, "Chemical and Physical Chapter," on file at SEWRPC.[24]

sampling stations for each parameter by comparison of upstream and downstream instantaneous loadings. In some cases, apparent assimilation was negative, indicating that loadings increased rather than decreased.

Dissolved oxygen, temperature, and pH were compared to applicable water quality criteria set forth in the Wisconsin Administrative Rules. Total phosphorus, un-ionized ammonia, suspended solids, and heavy metals were compared with U.S. Environmental Protection Agency (USEPA) recommended water quality criteria. The DNR concluded that the waters of the Kinnickinnic River and its tributaries generally met state and federal water quality standards and recommendations on October 22-24, 1975.

The primary sources of discharge water and chemical loadings to the Kinnickinnic River were the West Milwaukee ditch and the Wilson Park Creek tributaries. Point sources were the principal discharge and chemical loading sources to these tributaries. The Kinnickinnic River reportedly displayed poor pollution assimilative capacities. Only total solids were effectively reduced. The uniform, concrete cunette river channel excluded pools to trap the suspended load and inhibited development of stable aquatic communities resulting in poor assimilative capacity. Wilson Park Creek, however, was effective in reducing much of its chemical loading prior to the confluence with the Kinnickinnic River. The creek's slow movement over natural substrate reportedly allowed deposition of suspended material and seepage from the creek channel. The mass-balance type of survey was found to be an effective technique for assessing water quality of a river system at low flow.

General Mitchell Field Nonpoint Source Pollution Study: Studies attempting to characterize water quality runoff from airport land uses are limited. Therefore, a water quality study of airport runoff from General Mitchell Field was undertaken by the DNR from January 1, 1977 to December 31, 1977.

The primary objectives in undertaking this study were to characterize airport land-use-water-quality relationships, determine annual and seasonal pollutant yields from precipitation induced runoff, and generate transfer information for other similar land uses.

General Mitchell Field drains into two watersheds, the Kinnickinnic River and Oak Creek. The study area drained to the headwaters of Wilson Park Creek, a tributary of the Kinnickinnic River, and comprised 11 percent of the Kinnickinnic River basin. The study area is relatively flat (e.g., a four-foot drop per 9,000 feet E-W) with clay-filled soils. Approximately 50 percent of the study area is impervious. A complete discussion of the sampling sites, sampling procedures, and results, including data tables, can be found in the "Chemical and Physical Chapter" of the "Milwaukee County River Basins Study." Table 41 is a list of the parameters sampled.

The study concluded that runoff from a medium hub airport is a significant source of pollutants. Nutrients, solids, heavy metals, and oxygen demanding materials display concentrations and loadings similar to those reported for urban roadway and parking lot storm waters. State water quality standards and USEPA recommended criteria were routinely exceeded in airport stormwater runoff.

Pollution potential was not only determined by the amount of discharge, but also by other seasonal factors, such as length of antecedent non-runoff periods, airport maintenance practices (de-icing practices and grounds maintenance), and storm characteristics. The major sources of pollution were associated with drainage from paved auto parking and airport terminal areas. The lowest pollutant concentrations were characteristically from water drained from runway and infield areas which had large plots covered with grass.

Inner Harbor Water Quality Monitoring Program

During the International Joint Commission (IJC) Menomonee River Pilot Watershed Study, the Wisconsin Department of Natural Resources collected some physical and water quality data in the inner harbor which were not published or summarized in the IJC volumes. Vertical profiles of water temperature and dissolved oxygen (DO) concentration were measured weekly or bi-weekly from August 1974 to May 1977 in the inner harbor at the Broadway Street bridge over the Milwaukee River, and at the South 2nd Street bridge and 13th Street (the Muskego Avenue bridge) over the Menomonee River. In addition, water temperature and DO profiles were taken at these three locations on March 10, 1973. These site locations are shown on Map 15.

Water temperature and DO were sampled at mid-channel at either one-meter or 2-foot intervals throughout the water column using a Yellow Springs Instrument Company (Y.S.I.) DO and temperature meter. At least 65 profiles were taken at each station during the 33-month period from August 1974 to May 1977. Visual observations of current speed and direction were recorded during each survey along with observations of boat and ship traffic, meteorological conditions, and apparent water quality. Dissolved oxygen concentrations ranged from a minimum of 0.0 to 15 milligrams per liter with DO of less than 5 milligrams per liter being observed 23 times at the Broadway bridge; 30 times at 2nd Street, and 36 times at the Muskego Avenue bridge. DO levels dropped to nearly zero on numerous occasions, but most frequently at the Muskego Avenue bridge sampling site. The DO and water temperature data are on file at SEWRPC.[27]

Other water quality data collected by the DNR during the IJC study at the Broadway Street, 2nd Street, and Muskego Avenue bridges were plotted on unpublished graphs for the years 1975 and 1976. Surface, mid-depth, and bottom concentrations, or values, were plotted against time on one graph for each site, for each year for water temperature, DO, pH, conductance, organic nitrogen, ammonia nitrogen, nitrate nitrogen, total phosphorus, dissolved reactive phosphorus, chloride, total solids and suspended solids. Figure 7 is a typical plot, showing, in this case, dissolved oxygen at the 2nd Street bridge in 1975. These unpublished DNR graphs are compiled in "Water Quality Calcomp Plots--Inner Harbor--for Calendar Years 1975 and 1976," on file at SEWRPC. The harbor base flow data were placed in STORET and are obtainable from the DNR. Hard copy of the STORET raw harbor base flow data for the Broadway Street, South 2nd Street, and Muskego Avenue sampling sites for calendar years 1975 and 1976 (collected during the IJC Menomonee River Pilot Watershed Study) are on file at SEWRPC.

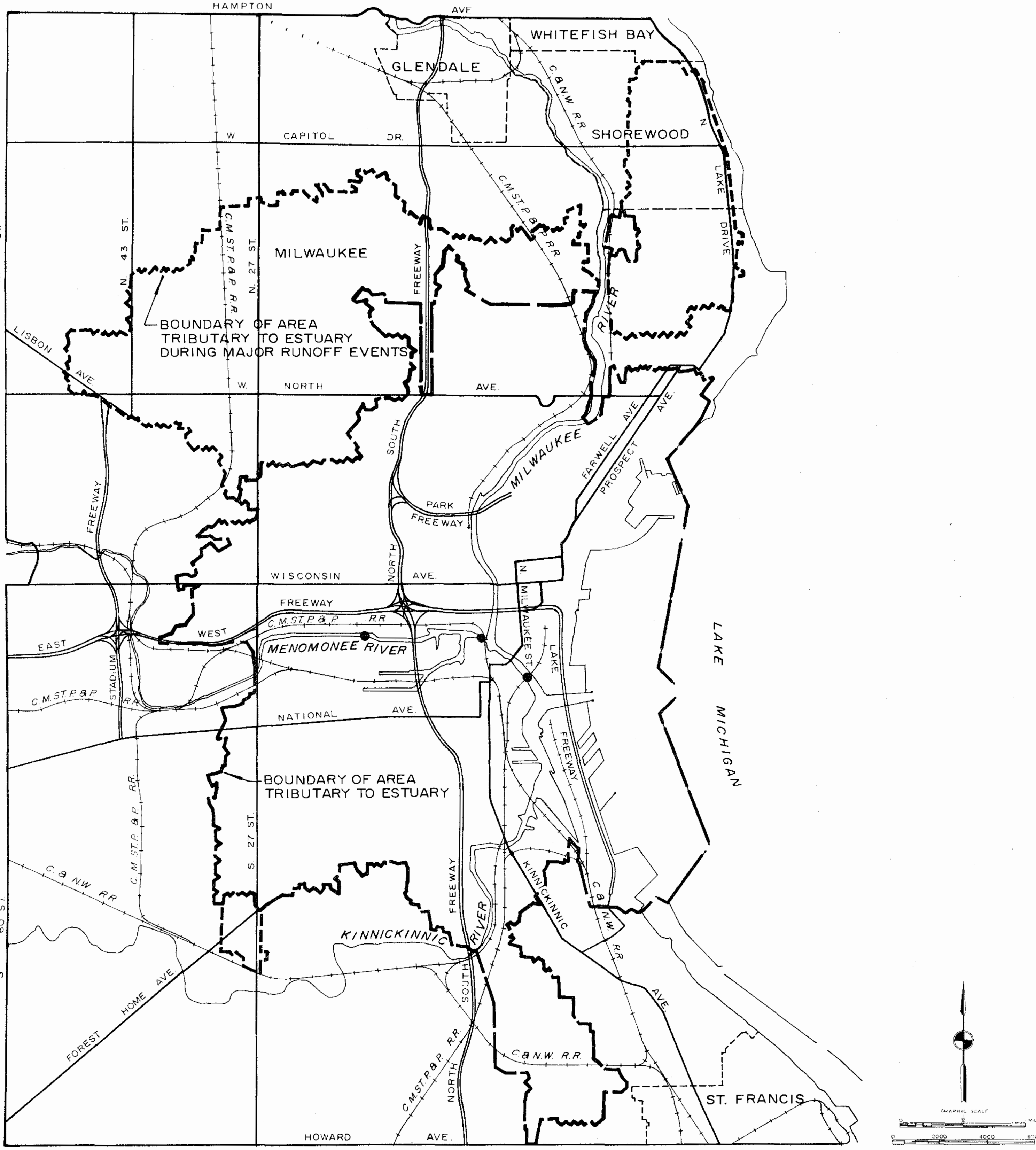
Statewide PCB Fish Monitoring Program

The current U.S. Food and Drug Administration PCB tolerance level for fish sold for human consumption is 2 parts per million (ppm). The DNR conducts annual statewide surveys for determination of PCB concentrations in fish. The DNR monitoring data have served as a basis for the preparation of fish consumption advisories by the State Department of Health and Social Services since 1971. The data are pub-

[27] *DNR unpublished data, "Dissolved Oxygen and Water Temperature Profiles Monitored at Broadway Street, 2nd Street, and 13th Street (Muskego Avenue bridge) March 1973 and August 1974-May 1977," on file at SEWRPC.*

Map 15

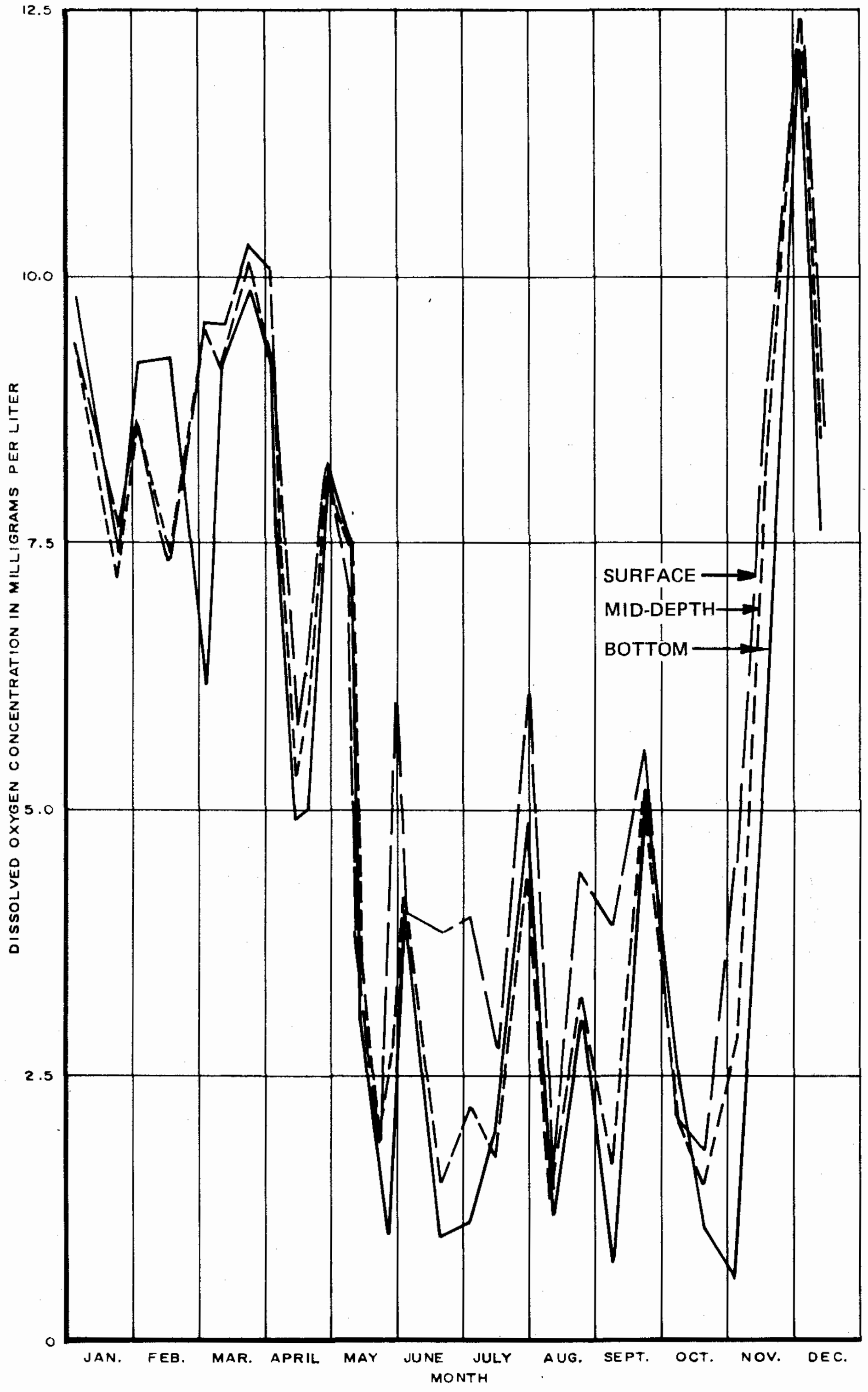
WATER TEMPERATURE AND DISSOLVED OXYGEN VERTICAL PROFILE MONITORING LOCATIONS IN THE INNER HARBOR SAMPLED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: MARCH 1973 AND AUGUST 1974-MAY 1977



Source: DNR unpublished data, "Dissolved oxygen and water temperature profiles monitored at Broadway Street, Second Street, and Thirteenth Street, March 1973 and August 1974-May 1977," on file at SEWRPC.

Figure 7

DISSOLVED OXYGEN CONCENTRATIONS FOR THE MENOMONEE RIVER AT SECOND STREET AT THE SURFACE, MID-DEPTH, AND BOTTOM, MONITORED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1975



Source: DNR unpublished data, "Water Quality Calcomp Plots--Inner Harbor--for Calendar Years 1975 and 1976," on file at SEWRPC.

lished annually by the DNR in a tabular form that lists sampling locations, number of fish sampled, species, length, PCB concentration, and percent fat. The 1979 survey found PCB concentrations as high as 43 ppm in carp in the Milwaukee River at Thiensville and as high as 31 ppm at USH 141 in Milwaukee. No Milwaukee River samples were taken downstream from this point. In the lower Kinnickinnic River, PCB concentrations as high as 18 ppm were found in goldfish. Just outside the Milwaukee Harbor breakwater in Lake Michigan, PCB concentrations as high as 61 ppm were found in lake trout.[28]

Toxic Substances Survey of Lake Michigan and Tributaries

The DNR conducted a toxic substances survey in 1979 for the Wisconsin Coastal Management Program to assist in the identification of problem areas. Fish samples were collected and analyzed for the parameters listed in Table 42. Sampling sites near the Milwaukee Harbor estuary were located in the Milwaukee River at North Avenue, the Menomonee River at South 27th Street, the Kinnickinnic River at South 7th Street, and offshore in Lake Michigan at a point east of the Milwaukee Harbor. Data from the survey were scheduled for publication in October 1980.

A follow-up toxic substances survey was scheduled to be conducted during the period July 1, 1980 through June 30, 1983 in the problem areas identified by the 1979 survey, to assist in the identification and elimination of illegal discharges, and to document concentration changes of toxic substances in the coastal zone. Fish, sediment, industrial effluent and water column samples will be taken in 1980 and analyzed for PCB's, DDT, Chlordane, and Dieldrin. The 1979 survey indicated that the other parameters listed in Table 42 were low and, therefore, no further analyses of these parameters were called for. The 1980 sampling sites were located near industrial and municipal wastewater outfalls and storm sewer outfalls. Sediment sampling was done at these sites in locations where organic deposits could be found. Three sites were sampled in the Milwaukee Harbor estuary, one on the Milwaukee River at Wisconsin Avenue, and two on the Kinnickinnic River at Kinnickinnic Avenue and Chase Avenue. A list of the toxic subtances survey sampling site locations for the 1979 and 1980 surveys is presented in Table 43. Publication of the 1980 survey data is scheduled for the spring of 1981.

Ambient Surface Water Quality Monitoring

In 1961, the Wisconsin Department of Natural Resources (DNR) initiated an ambient surface water quality monitoring effort in response to federal programs which then called for such data to be collected along the periphery of each state, as a basis for interstate water pollution control programs. Since that time, the original 1961 sampling network has been revised with the addition of some and deletion of other sampling stations. In an unpublished report dated July 1977, the DNR Surface Water Quality Monitoring Work Group, based in Madison, reviewed the ambient water quality monitoring network and revised it again to meet current needs. This report recommended collection of additional water quality data for the Kinnickinnic River at South 7th Street in Milwaukee for the parameters and sampling intervals listed in Table 44. This sampling program was initiated in 1977 and is currently ongoing. Sampling stations on the Milwaukee River at Brown Deer Road, the Milwaukee River at its confluence with the Kinnickinnic River, and Lake Michigan near Oak Creek at the Peter Cooper Corporation intake were discontinued in 1976, and are shown on Map 16,

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[28] *T.B. Sheffy and T.M. Aten, 1979 Annual Summary of PCB Levels in Wisconsin Fish, DNR Bureau of Water Quality, Surveillance Section, Madison, Wisconsin, 1979.*

Table 42

LIST OF PARAMETERS ANALYZED IN THE TOXIC SUBSTANCES SURVEYS CONDUCTED BY DNR FOR THE WISCONSIN COASTAL MANAGEMENT PROGRAM: 1979-1980

Parameters[a]	
Arsenic	Chlordane[b]
Cadmium	Endrin
Chromium	PCB[b]
Copper	Percent Fat
Lead	Hexachlorobenzene
Mercury	Pentachlorophenol
Aldrin	Hexachlorocycohexane
Dieldrin[b]	Methoxychlor
DDT[b]	

[a]*This list of parameters is designated as the "EPA series." The 1979 survey included fish sample analyses only.*

[b]*To be sampled in 1980 only for each fish, sediment, industrial effluent, and water column sample.*

Source: Wisconsin Department of Natural Resources.

Table 43

LOCATIONS OF TOXIC SUBSTANCES SURVEY SAMPLING SITES IN THE MILWAUKEE HARBOR VICINITY USED BY DNR FOR THE WISCONSIN COASTAL MANAGEMENT PROGRAM: 1979-1980

Locaton	Year of Sampling
Milwaukee River	
At Mequon Road........................	1980
At Brown Deer Road	1980
Above Silver Spring Drive.............	1980
Above North Avenue	1980
At North Avenue	1979
Above Wisconsin Avenue...............	1980
Menomonee River	
At STH 57 (27th Street)...............	1979
Kinnickinnic River	
At Pulaski Park	1980
At South 7th Street	1979
At STH 38 (Chase Avenue)	1980
At Kinnickinnic Avenue.................	1980

NOTE: Parameters analyzed in each survey are listed in Table 42.

Source: Wisconsin Department of Natural Resources.

Table 44

WISCONSIN AMBIENT WATER QUALITY MONITORING NETWORK PARAMETERS AND SAMPLING PERIODS FOR THE KINNICKINNIC RIVER AT SOUTH 7TH STREET IN MILWAUKEE SINCE JANUARY 1977

Parameter	Sampling Period[a]			
	1977	1978	1979	1980
Total Nonfiltered Residue	x	x	x	x
Total Residue	x	x	--	--
Fish Tissue Analysis	--	--	x	x
Hardness	x	--	x	--
Water Temperature	x	x	x	x
pH	x	x	x	x
Dissolved Oxygen	x	x	x	x
Conductivity	--	x	x	x
5-Day BOD	x	x	--	--
Organic Nitrogen	x	x	x	x
Ammonia Nitrogen (dissolved)	x	x	x	x
Nitrite and Nitrate Nitrogen (dissolved)	x	x	x	x
Total Phosphorus	x	x	x	x
Ortho Phosphorus (dissolved)	--	x	x	--
Chlorides	x	--	x	x
Fecal Coliform	x	x	x	x
COD	--	x	x	--
Arsenic	x	x	x	--
Cadmium	x	x	x	x
Chromium	x	x	x	x
Copper	x	x	x	x
Lead	x	x	x	x
Mercury	x	x	x	--
Streamflow	x	x	x	x
Time of Day Sampling	x	x	x	x

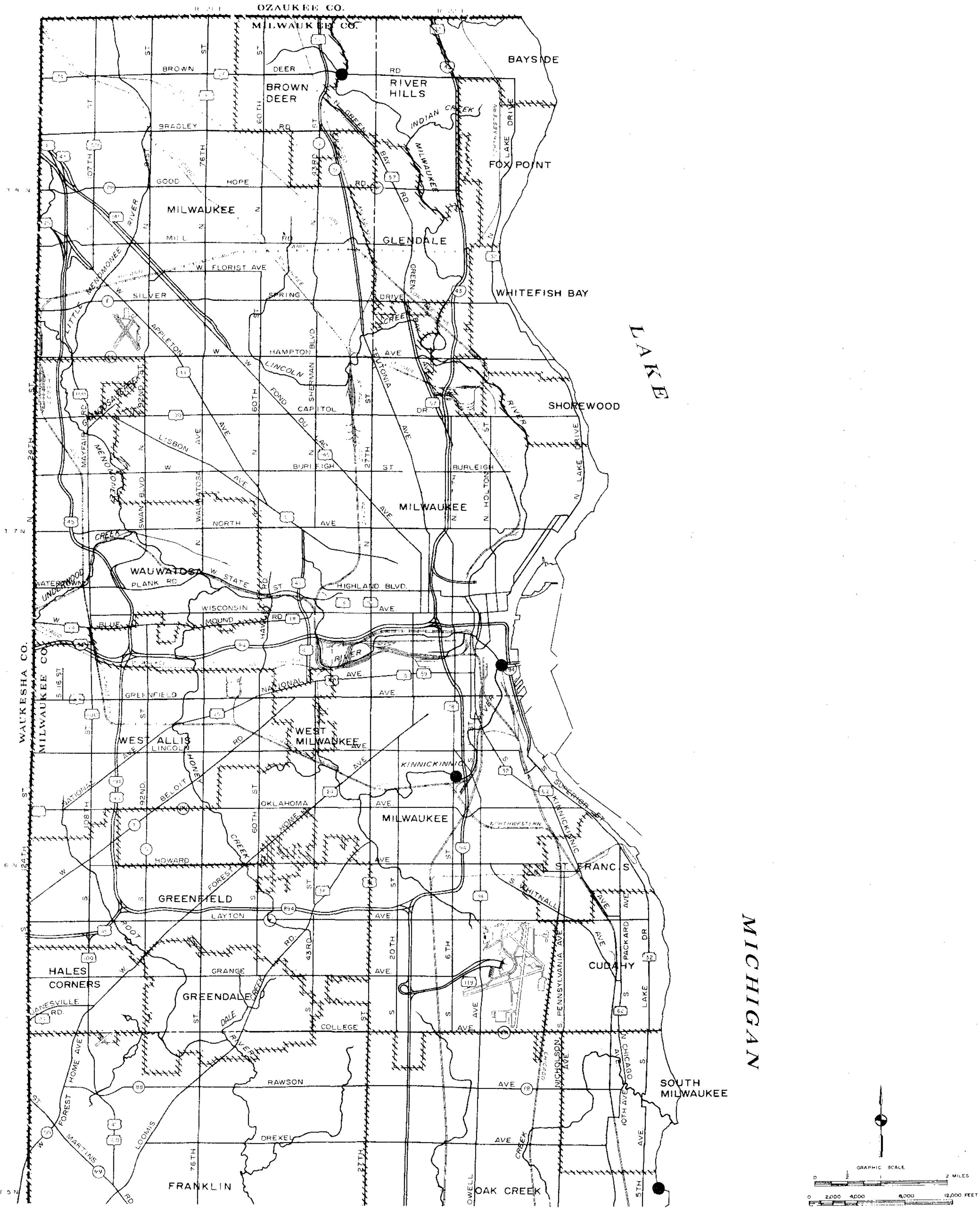
NOTE: Continuous record streamflow data are also collected at this site by the U.S. Geological Survey.

[a]*Samples are collected monthly.*

Source: DNR, State of Wisconsin Surface Water Quality Monitoring Data, 1977 and State of Wisconsin Surface Water Quality Monitoring Data, 1978, Bureau of Water Quality, Madison, Wisconsin, 1980. 1979 and 1980 information provided by Jerome R. McKersie, DNR Water Quality Evaluation Section Chief, October 15, 1980.

Map 16

LOCATION OF AMBIENT WATER QUALITY MONITORING SAMPLE SITES IN THE MILWAUKEE HARBOR WATERSHED AND LAKE MICHIGAN IN MILWAUKEE COUNTY USED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND OTHERS SINCE 1961



Source: DNR unpublished report by the Surface Water Quality Monitoring Work Group, Madison, Wisconsin, on file at SEWRPC.

which also shows the ongoing Kinnickinnic River sampling site which is located at the U. S. Geological Survey gaging station. Table 45 lists the water quality parameters and sampling periods for the discontinued sites operated from 1961 to 1976. Data collected since 1961 are summarized in these reports:

- Wisconsin Committee on Water Pollution, Wisconsin Surface Water Quality, 1961-1964, Madison, Wisconsin, July 1965.

- Wisconsin Department of Natural Resources, State of Wisconsin Surface Water Quality Monitoring Data, 1965-1968, Division of Environmental Protection, Madison, Wisconsin, 1969.

- Wisconsin Department of Natural Resources, State of Wisconsin Surface Water Quality Monitoring Data, 1969-1972, Division of Environmental Protection, Madison, Wisconsin, 1973.

- Wisconsin Department of Natural Resources, State of Wisconsin Surface Water Quality Monitoring Data, 1973-1976, Bureau of Water Quality, Madison, Wisconsin, June 1980.

- Wisconsin Department of Natural Resources, State of Wisconsin Surface Water Quality Monitoring Data, 1977, Bureau of Water Quality, Madison, Wisconsin, July 1980.

- Wisconsin Department of Natural Resources, State of Wisconsin Surface Water Quality Monitoring Data, 1978, Bureau of Water Quality, Madison, Wisconsin, July 1980.

Laboratory methods are also described in each of these reports. Raw data are available from STORET.

Toxic Metals In Waters, Sediments, and Aquatic Life in the Lower Milwaukee River and Milwaukee Harbor, 1970 and 1972

From May to October 1970, the Wisconsin Department of Natural Resources conducted a statewide survey of mercury levels in surface waters, bottom sediments, public water supplies, and municipal wastewater treatment plant effluents to locate mercury deposits and determine the background levels in sediments. In the Milwaukee Harbor watershed, samples were taken on the main stem of the Milwaukee River, and in the inner and outer harbors. Locations of sampling sites in Milwaukee County are shown on Map 17. Mercury content in all water column samples was found to be less than 0.0005 part per million (ppm), but in the sediments, it ranged from 0.6 ppm above the North Avenue dam to 1.70 ppm at the turning basin in the inner harbor. Data are tabulated in DNR Research Report 74.[29]

In 1970 the DNR also began a statewide survey of mercury levels in fish, sampling both streams receiving industrial and municipal wastes and relatively pristine streams. The Milwaukee River was sampled at Thiensville and in Milwaukee above North

[29] *John G. Konrad, Mercury Content of Various Bottom Sediments, Sewage Treatment Plant Effluents, and Water Supplies in Wisconsin--A Preliminary Report, Wisconsin Department of Natural Resources Research Report 74, 1971.*

Table 45

WATER QUALITY PARAMETERS AND PERIODS OF RECORD FOR AMBIENT WATER QUALITY MONITORING SITES ON THE MILWAUKEE RIVER AT THE CONFLUENCE WITH THE KINNICKINNIC RIVER, THE MILWAUKEE RIVER AT BROWN DEER ROAD, AND NEAR-SHORE LAKE MICHIGAN AT THE CITY OF OAK CREEK: 1961-1976

Parameter	Period[d]					Parameter	Period[d]				
	1961 - 62	1963 - 64	1965 - 68	1969 - 72	1973 - 76		1961 - 62	1963 - 64	1965 -68	1969 - 72	1969 - 76
Total Solids[a]	x	x	x	x	x	Soluble Phosphorus	x	x	x	--	--
Total Volatile Solids	x	x	x	--	--	Ortho-Phosphorus	--	--	--	--	x[h]
Suspended Solids[b]	x	x	x	x	x	Bacteria	x	x	x	--	--
Suspended Volatile Solids[c]	x	x	x	x	x	Fecal Coliforms	--	--	x[i]	x	x
Water Temperature	x	x[e]	x	x	x	Alkyl Benzene Sulfonate (ABS)	--	x	--	--	--
pH	x	x	x	x	x	Methylene Blue Active Substances (MBAS)	--	--	x	--	--
Total Alkalinity	x	x	x	x	x	Chlorides	x	x	x	x	x
Total Hardness	x	x	x	x	x	Fluoride	--	--	--	--	x
Color	x	x	x	x	x	Chromium	--	--	--	--	x
Dissolved Oxygen	x	x	x	x	x	Copper	--	--	--	--	x
5-day Biochemical Oxygen Demand (BOD)	x	x	x	x	x	Lead	--	--	--	--	x
Total Organic Nitrogen	x	x	x	x	x	Manganese	--	--	--	--	x
Free Ammonia	x	x	x	x	--	Zinc	--	--	--	--	x
Nitrates	x	x	x	x	--	Gross Radioactivity	x[j]	x[j]	x[j]	x[j]	--
Ammonia Nitrogen (dissolved)	--	--	--	--	x	Alpha Radioactivity	x[j]	x[j]	x[j]	x[j]	x[j]
Nitrate Nitrogen (dissolved)	--	--	--	--	x[f]	Beta Radioactivity	--	--	--	--	x[j]
Nitrite and Nitrate Nitrogen (dissolved)	--	--	--	--	x[g]	Time of Day	--	--	--	--	x
Total Phosphorus	x	x	x	x	x						

NOTE: See Map 16 for sampling site locations. All sampling at these sites was discontinued after 1976.

[a]Reported as Total Residue after 1972.

[b]Reported as Total Nonfilterable Residue after 1972.

[c]Reported as Volatile Nonfilterable Residue after 1972.

[d]Data are in STORET and can also be found in those DNR references listed in the text for the time period 1961-1976. The Milwaukee River sites were sampled monthly, and the Lake Michigan site weekly.

[e]Lake Michigan only.

[f]Data only for 1973 and 1974.

[g]No data in 1973. No data for Milwaukee River at Brown Deer Road.

[h]No data for Lake Michigan in 1976.

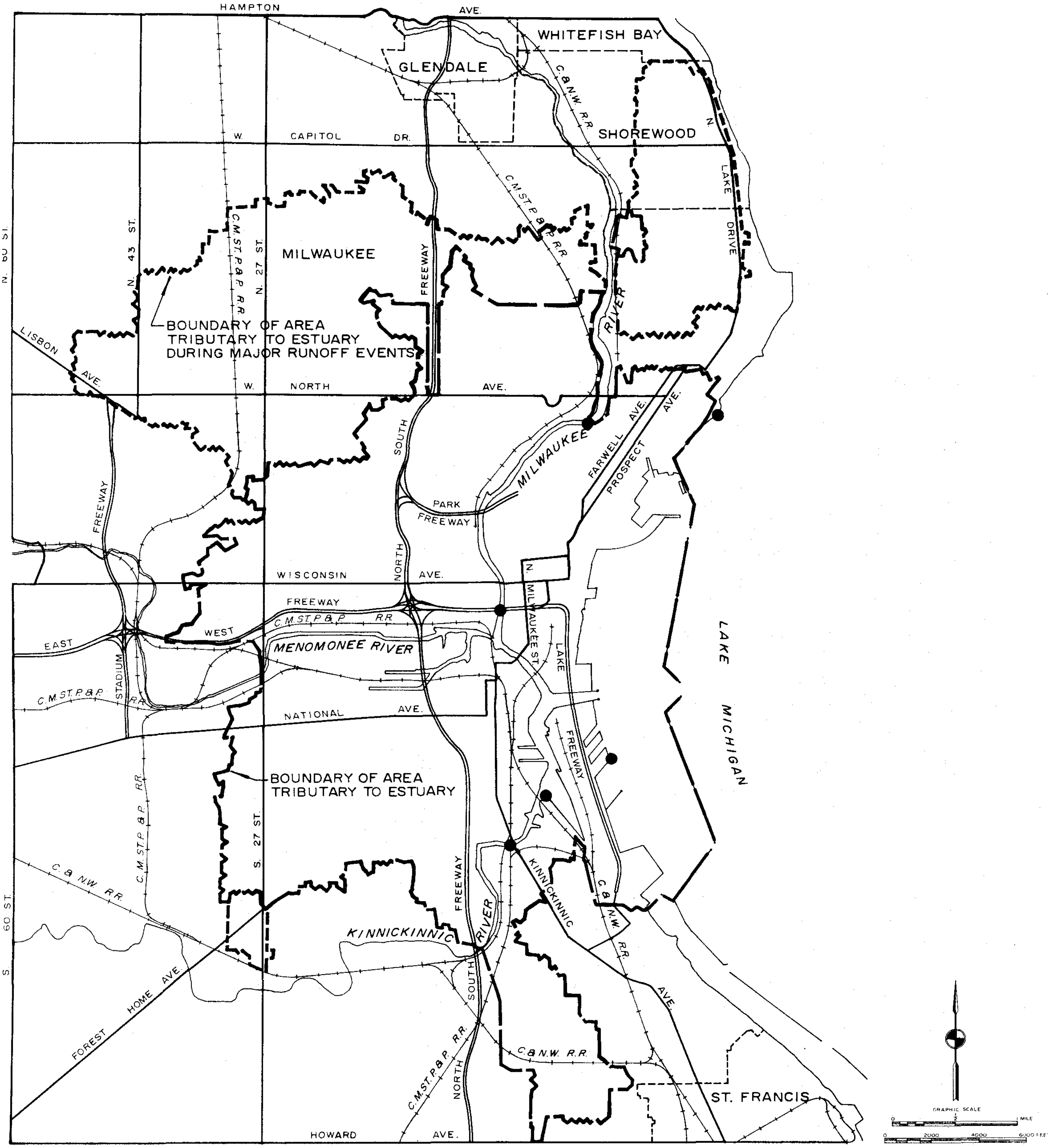
[i]No data for Lake Michigan in 1964 and 1965.

[j]No data for Lake Michigan.

Source: Wisconsin Department of Natural Resources

Map 17

LOCATON OF WATER COLUMN AND BOTTOM SEDIMENT SAMPLING SITES ANALYZED FOR MERCURY CONTENT IN THE LOWER MILWAUKEE HARBOR WATERSHED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1970



Source: *John G. Konrad,* *__Mercury Content of Various Bottom Sediments, Sewage Treatment Plant Effluents, and Water Supplies in Wisconsin--A Preliminary Report__, Wisconsin Department of Natural Resources Research Report 74, 1971.*

Avenue in July 1970, and in Milwaukee Harbor in May 1970. Mercury content in fish filets ranged from 0.11 to 0.35 ppm at Thiensville, 0.11 to 0.18 ppm above North Avenue, and 0.05 to 0.22 ppm in Milwaukee Harbor. Data are tabulated in DNR Technical Bulletin No. 52 and Table 46.[30]

In a report published in 1974, the DNR presented data from surveys for toxic metals in fish and in Wisconsin municipal wastewater treatment plant influents, effluents, and sludges. Fish samples analyzed were those collected in the mercury study discussed above. Parameters analyzed in addition to mercury, were chromium, zinc, cadmium, arsenic and lead. Table 46 summarizes the data collected. Additional details and data are presented in DNR Technical Bulletin No. 74.[31] This report concluded that concentrations for the metals analyzed were not hazardous to fish consumers anywhere in Wisconsin.

In 1972 the statewide survey of the municipal wastewater treatment plants was made with samples being taken also at the Milwaukee Metropolitan Sewerage District South Shore and Jones Island plants. DNR Technical Bulletin No. 74 lists concentrations found in the influent, effluent, and sludge.[32] Table 47 presents data for the effluent only at the Jones Island plant. The report concluded that, based upon influent-effluent correlations, heavy metal contamination is possible in surface waters receiving effluent from wastewater treatment plants accepting wastes high in heavy metals.

Lower Milwaukee Harbor Watershed Water Quality Survey, 1968

The Wisconsin Department of Natural Resources in 1968 made chemical and biological surveys in Milwaukee County of the Milwaukee River, Lincoln Creek, Menomonee River, Little Menomonee River, Underwood Creek, Honey Creek, Wood Tributary, Kinnickinnic River, and Wilson Park Creek to compliment a pollution investigation study made in 1967 of the Milwaukee River outside Milwaukee county. Samples for chemical and bacteriological analysis were taken for point source discharges, as well as at instream locations at the sites shown on Map 18. Water quality parameters analyzed are listed in Table 48. Sampling dates are presented in the DNR report published in May 1969 for each site along with the results of the chemical and bacteriological analyses.[33] Two synoptic water quality surveys were made in 1968 of the lower Milwaukee River and the Little Menomonee River, three for the Menomonee River and the Kinnickinnic River, and one for Lincoln Creek. The remaining streams monitored were sampled only once at one location on each stream except for the Wilson Park Creek station which was sampled three times in 1968.

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[30] *Stanton J. Kleinert and Paul E. Degurse, Mercury Levels in Wisconsin Fish and Wildlife, Wisconsin Department of Natural Resources Technical Bulletin No. 52, Madison, Wisconsin, 1972.*

[31] *Stanton J. Kleinert, Paul E. Degurse, and J. Ruhland, "Concentrations of Metals in Fish," Wisconsin Department of Natural Resources Technical Bulletin No. 74, Surveys of Toxic Metals in Wisconsin, Madison, Wisconsin, 1974.*

[32] *John G. Konrad and Stanton J. Kleinert, "Removal of Metals from Waste Waters by Municipal Sewage Treatment Plants," Wisconsin Department of Natural Resources, Technical Bulletin No. 74, Surveys of Toxic Metals in Wisconsin, Madison, Wisconsin, 1974.*

[33] *Wisconsin Department of Natural Resources, Report on an Investigation of the Pollution of the Milwaukee River, Its Tributaries, and Oak Creek Made During 1968 and 1969, Division of Environmental Protection, Madison, Wisconsin, May 1969.*

Table 46

SUMMARY DATA FOR TOXIC METALS IN FISH SAMPLES COLLECTED IN MILWAUKEE HARBOR AND THE MILWAUKEE RIVER BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1970

Location	Parameter and Range in Concentration (ppm)					
	Chromium	Zinc	Cadmium	Arsenic	Lead	Mercury
Milwaukee River Above Thiensville[a]..........	--[c]	4.2-10.6	--[c]	--[c]	0.05-0.30	0.11-0.35
Milwaukee River Above North Avenue[a].........	--[c]	18.3[d]	--[c]	0-0.10	0.27-0.30	0.11-0.18
Milwaukee Harbor[b]......	0-0.42	4.6-6.9	--[c]	--[c]	--[c]	0.05-0.22

[a]Samples were collected in July 1970

[b]Samples were collected in May 1970.

[c]No trace of this metal was found at this location.

[d]Only one concentration was reported for this location.

Source: Wisconsin Department of Natural Resources Technical Bulletins No. 52 and No. 74.

Table 47

CONCENTRATIONS OF HEAVY METALS FOUND IN THE EFFLUENT OF THE JONES ISLAND MUNICIPAL WASTEWATER TREATMENT PLANT BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1972

Parameter	Concentrations (milligrams per liter)
Chromium	0.1
Copper	0.05
Lead	0.08
Zinc	0.16
Cadmium	0.02
Mercury	0.0008
Nickel	0.05

Source: Wisconsin Department of Natural Resources Technical Bulletin No. 74.

Table 48

LIST OF CHEMICAL AND BIOLOGICAL WATER QUALITY PARAMETERS FOR THE 1968 WATER POLLUTION SURVEY OF THE LOWER MILWAUKEE HARBOR WATERSHED IN MILWAUKEE COUNTY BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

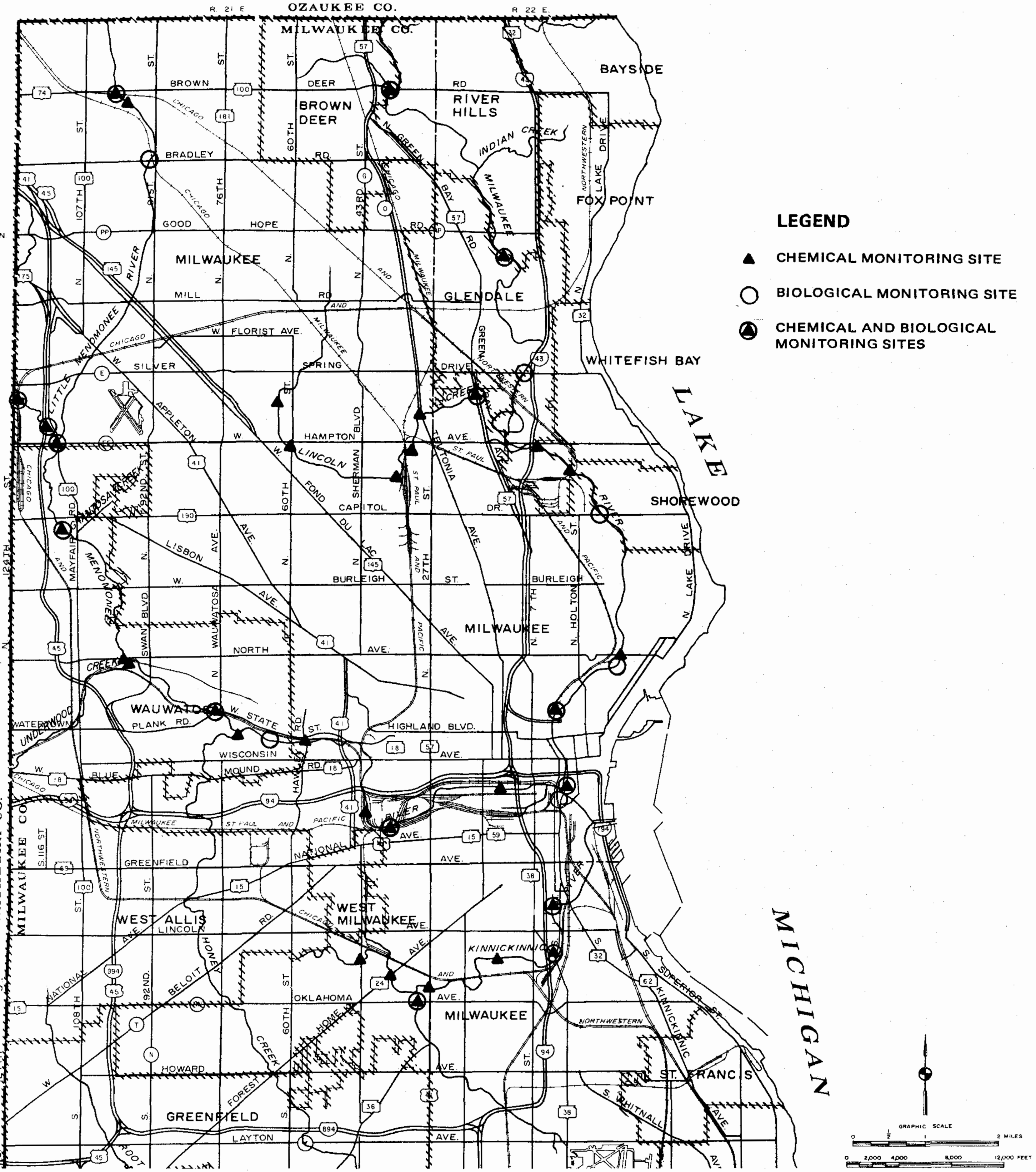
Parameters[a]
Water Temperature
pH
Dissolved Oxygen
5-Day BOD
Fecal Coliform Bacteria
Numbers of Pollution Intolerant Species and Individuals
Numbers of Pollution Tolerant Species and Individuals
Numbers of Very Pollution Tolerant Species and Individuals

[a]*For sampling data see source and for sampling locations see Map 18.*

Source: Wisconsin Department of Natural Resources, Report on An Investigation of the Pollution of the Milwaukee River, Its Tributaries, and Oak Creek Made During 1968 and 1969, Division of Environmental Protection, Madison, Wisconsin, May 1969.

Map 18

LOCATION OF CHEMICAL AND BIOLOGICAL WATER QUALITY MONITORING SITES IN THE LOWER MILWAUKEE HARBOR WATERSHED IN MILWAUKEE COUNTY SAMPLED BY THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES: 1968



Source: Wisconsin Department of Natural Resources, Report on an Investigation on the Pollution of the Milwaukee River, Its Tributaries, and Oak Creek Made During 1968 and 1969, Division of Environmental Protection, Madison, Wisconsin, May 1969.

One biological survey was made in the study area in 1968. Twenty-seven sites were inspected and the aquatic habitat was described qualitatively. Counts were made of the number of species present at each site along with the number of individuals in each species. The species were grouped in classifications according to pollution tolerance--intolerant, tolerant, and very tolerant. These data are tabulated by sampling site in the DNR report publsihed in May of 1969.[34] Sampling sites are shown on Map 18 along with the chemical and bacteriological sampling sites. This report also contains daily summer coliform and fecal coliform data for 1968 for eight Lake Michigan beaches in the Milwaukee area, based upon data provided by the Milwaukee Metropolitan Sewerage District.

Chemical, Biological, and Sediment Survey of the Burnham Street Canal, 1968

On April 4, 1968, the Wisconsin Department of Natural Resources, acting upon a request by the Milwaukee Metropolitan Sewerage Commission and the port of Milwaukee made a survey of the Burnham Street Canal prior to dredging, to identify biological organisms inhabiting the bottom sediments and to determine if the quality of these sediments was suitable for open-lake disposal in Lake Michigan. Water column and bottom samples were taken to determine physical, chemical, and biological characteristics for a reach of the canal extending from 900 feet west of the South 11th Street bridge to a point 150 feet east of the bridge. Parameters analysed and corresponding data are presented in Table 49. The Army Corps of Engineers granted a permit for openlake disposal despite opposition by the Sewerage Commission.

Benthic Macroinvertebrate Study of Milwauke Harbor, 1964

In 1962 a survey of biological conditions in the major harbors of Lake Michigan was begun by the Wisconsin Committee on Water Pollution. The purpose of the study was to qualify and quantify pollution tolerant and intolerant benthic macroinvertebrates to assess long-term water quality conditions in the harbors. The survey of Milwaukee Harbor was made in 1964. Samples were taken using a Petersen dredge in hard-bottom habitats and an Ekman dredge in soft-bottom habitats. Organism identifications were made to the most specific level possible. The report, however, only listed the numbers of individuals in each of three pollution tolerance categories--intolerant, tolerant, and very tolerant.[35] Benthic samples were taken in the lower Milwaukee, Menomonee, and Kinnickinnic Rivers, as well as in the outer harbor and Lake Michigan. Sampling site locations are shown on Map 19. General physical observations of sediment and water quality were tabulated along with the number of organisms per square foot in each tolerance category and the water depth at each sampling site.

Only tolerant to very tolerant organisms were found even one-quarter mile east of the three main breakwater entrances. Very tolerant organisms dominated the counts in both the inner and outer harbors.

Lower Milwaukee Harbor Watershed Water Quality Survey, 1952-1953

Physical, chemical, biological, and bacteriological data were collected to characterize water quality in Milwaukee County streams, the inner harbor, Lake Michigan at the City of Milwaukee water supply intake and the Lake Michigan Shoreline near

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[34] *Ibid.*

[35] *James M. Helm, A Biological Evaluation of Wisconsin Harbors on Lake Michigan, Wisconsin Committee on Water Pollution, Madison, Wisconsin, May 1966.*

Table 49

WATER QUALITY AND SEDIMENT DATA COLLECTED
IN THE BURNHAM CANAL ON APRIL 4, 1968

Parameter	Sampling Site and Parameter Quantity[a]			
	1	2	3	4
Water Column:[c]				
Dissolved Oxygen (mg/l)	5.3	--	--	5.1
Water Temperature (°C)	12.0	--	--	10.5
pH	8.0	--	--	7.8
Chlorides as Cl (mg/l)	70	--	--	70
Turbidity Units	32	--	--	28
5-Day BOD (mg/l)	10.0	--	--	10.3
Total Coliforms (count/ml)	4,400	--	--	4,500
Fecal Coliforms (count/ml)	120	--	--	360
Bottom Sediments:				
Total Nitrogen as N (percent)	0.4	0.8	0.6	0.4
pH	7.2	7.4	7.2	7.1
Loss on Ignition (dry basis percent)	14.24	17.02	19.94	20.20
Total Phosphorus as PO_4 (percent)	0.50	0.56	0.83	0.86
Total Oil-Hexane Extraction (dry basis, percent)	1.2	2.1	4.1	4.6
Sand (percent)[b]	52.0	62.0	62.0	52.0
Silt (percent)[b]	35.2	27.2	27.2	33.2
Clay (percent)[b]	12.8	10.8	10.8	14.8
Number of Benthos (per square foot)	--[d]	--[d]	16	--[d]
Pollution Tolerancy of Benthos	--[d]	--[d]	Very Tolerant	--[d]

NOTE: -- indicates no sample taken.

[a] Station 1--150 feet east of South 11th Street bridge; Station 2--150 feet west; Station 3--450 feet west; Station 4--900 feet west.

[b] Mechanical analysis on ash basis.

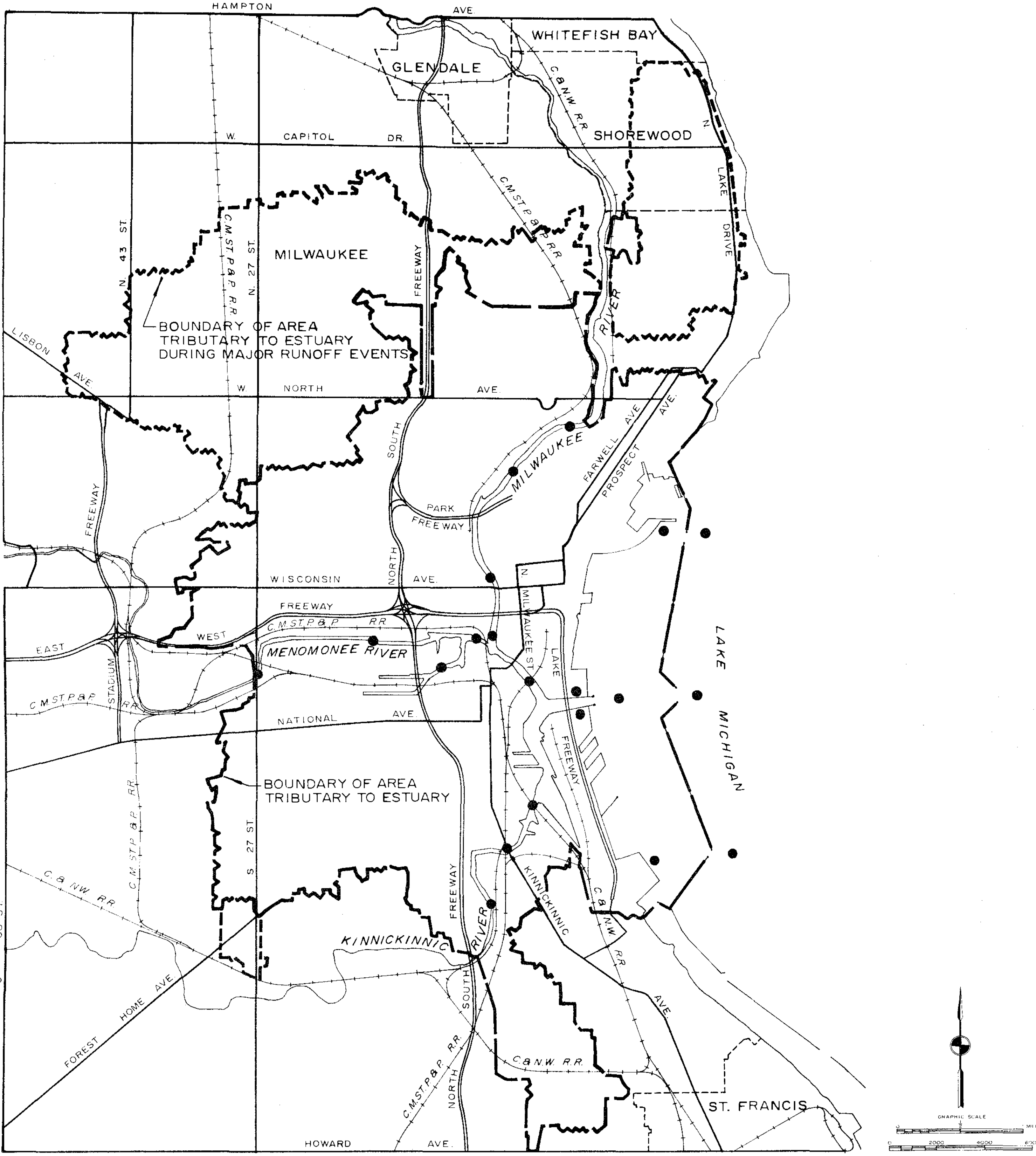
[c] Surface samples.

[d] No organisms found.

Source: Henry Dedinsky, "Menomonee River Bottom Sampling, Burnham Canal," DNR Memorandum to the Milwaukee Metropolitan Sewerage Commission, April 15, 1968, (unpublished); and John B. Conway, "Biological Survey of the Burnham Canal," DNR State Division of Resource Development letter to the Milwaukee Metropolitan Sewerage Commission, April 15, 1968 (unpublished).

Map 19

LOCATION OF BENTHIC MACROINVERTEBRATE SAMPLING SITES IN THE LOWER MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS, THE OUTER HARBOR, AND LAKE MICHIGAN SAMPLED FOR THE WISCONSIN COMMITTEE ON WATER POLLUTION: JULY 1964



Source: James M. Helm, *A Biological Evaluation of Wisconsin Harbors on Lake Michigan,* *Wisconsin Committee on Water Pollution (DNR), Madison, Wisconsin, May 1966, on file at SEWRPC.*

Milwaukee beaches in 1952 and 1953.[36] Streams sampled for physical, chemical and bacteriological water quality included the Milwaukee River (6 sites, 65 samples), Lincoln Creek (15 sites, 35 samples), South Branch Lincoln Creek (2 sites, 3 samples), North Branch Lincoln Creek (1 site, 3 samples), Menomonee River (17 sites, 68 samples), Little Menomonee River (6 sites, 17 samples), Butler ditch (1 site, 6 samples), Underwood Creek (5 sites 9 samples), Honey Creek (8 sites, 32 samples), Wood Creek (2 sites, 3 samples), Kinnickinnic River (8 sites, 50 samples), Jackson Park Drain (3 sites, 11 samples), and Wilson Park Creek (3 sites, 6 samples). Parameters analyzed were biochemical oxygen demand (BOD), temperature, pH, dissolved oxygen, and B. coli index.

Benthic macroinvertebrates were sampled in 1953 in the Milwaukee River (6 sites), the Menomonee River (8 sites), the Little Menomonee River (3 sites), Honey Creek (1 site), and the Kinnickinnic River (5 sites). Species sampled were classified by pollution tolerance, and the number of species found at each sampling site for each tolerance classification are presented along with an overall rating for each sampling site describing it as either clean, semi-polluted, or polluted.

Beach survey data for coliform bacteria were collected for this study by the Milwaukee Metropolitan Sewerage District, and also by the State. Data are presented in this report for the Atwater, North Bradford, South Bradford, South Shore, and Grant Park beaches. Water intake bacteria data for the period 1929-1953 are also summarized in the report. Average bacteria counts in the effluent of the Jones Island wastewater treatment plant for the years 1949-1953 are also presented along with average suspended solids, average 5-day BOD, and average flow.

Lake Michigan Tributary Loadings Program

At the request of the U.S. Environmental Protection Agency, the DNR in 1980 began a water quality monitoring program of large rivers tributary to Lake Michigan to improve upon previous estimates of chemical loadings to the lake. Monitoring of the Milwaukee River at the U.S. Geological Survey gaging station at Estabrook Park commenced in April 1980. Water samples were collected once daily during high flow periods and analyzed for suspended solids, total and soluble phosphorus, dissolved silica, lead, and chloride. A total of 60 samples was collected in 1980. Results of chemical analyses are on file at DNR. Continued monitoring in 1981 and 1982 is planned, pending availability of funding.

MILWAUKEE COUNTY DEPARTMENT OF PARKS, RECREATION AND CULTURE

The Milwaukee County Department of Parks, Recreation and Culture administers the Milwaukee County Park System, including the public marinas within the Milwaukee Harbor estuary. However, as water quality monitoring programs have been conducted in the harbor by other agencies, only limited water quality data have been collected by the Park Commission.

In response to a Department request for a proposal concerning the water quality effects of marina development, a consulting firm collected limited water quality

[36] *Ralph H. Scott, Kenneth M. Mackenthun, Lawrence A. Ernst, and George F. Bernauer, Report on the Investigation of Pollution of Surface Waters in Milwaukee County, Wisconsin Department of Natural Resources, 1954, on file at SEWRPC.*

data on April 6, 1972, for the Park Commission at two stations, one in the McKinley Marina mooring area and one near the flushing tunnel intake located at the Milwaukee Yacht Club. The complete study was never undertaken, but the water quality data were provided by the consulting firm, and represent an independent sampling of water quality conditions in a limited portion of the outer harbor. The results of the chemical analysis for 21 parameters are presented in Table 50. As the table indicates, coliform counts near the flushing tunnel intake were an order of magnitude higher than in the mooring area.

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

The Milwaukee Metropolitan Sewerage District (MMSD) has conducted or sponsored numerous studies and programs relevant to the study design for the Milwaukee Harbor estuary water quality management planning study. These studies and programs include studies of the cost-effectiveness of alternate methods and levels of combined sewer overflow abatement, ambient river water quality sampling, ambient outer harbor and near-shore Lake Michigan water quality sampling, monitoring of Jones Island wastewater treatment plant effluent and overflows, bottom sediment analyses at the proposed Jones Island lakefill site, and continuous meteorological data collection in the Milwaukee Harbor. The following paragraphs summarize these studies and programs.

Cost-Effectiveness Studies for Alternative Water Quality Improvement Strategies for the Milwaukee Rivers (PG-61)

As part of the Milwaukee Combined Sewer Overflow Abatement Project, the U.S. Environmental Protection Agency (USEPA) required an analysis of the cost-effectiveness of alternative approaches to improvement of water quality conditions in the reaches of the Milwaukee, Menomonee, and Kinnickinnic Rivers currently receiving combined sewer overflows. Such analysis was done in the Rexnord report[37] as prescribed by the USEPA Program Guidance Memorandum No. 61(P.G. 61) prepared in 1977, and later reissued as USEPA Program Requirements Memorandum (PRM) 35-74. It should be noted that, theoretically, a cost-effectiveness analysis should consider only the relative cost of alternatives which would meet all of the state and federally prescribed water quality standards for the estuary. By contrast, a "cost-benefit analysis" would assess the values of water quality--and other--benefits associated with a full range of abatement alternatives against the cost of those alternatives.

For consistency with previous USEPA and MMSD reports and discussions, this description uses the term "cost-effectiveness" in describing the PG-61 analysis, but the analysis would be better described as a very limited and strangely narrow cost-benefit evaluation. Costs for water quality improvement--based on milligrams per liter per day for dissolved oxygen impact, and on the number of days of fecal coliform violations--were to be determined and compared. The alternatives evaluated were for 1) the existing combined sewer overflow (CSO) network; 2) partial and complete sewer separation; 3) treatment and discharge of CSO out of the watershed for up to a 5-year level of protection; 4) end-of pipe CSO treatment; 5) complete elimination of

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[37] *Thomas L. Meinholz, William A. Kreutzberger, Nicholas P. Kobriger, and Martin E. Harper, Water Quality Analysis of the Milwaukee River to Meet PRM 35-74 (PG-61) Requirements, Rexnord Environmental Research Center, Milwaukee, Wisconsin, report for the Milwaukee Metropolitan Sewerage District, February 8, 1979.*

Table 50

RESULTS OF WATER QUALITY ANALYSES FOR SAMPLES TAKEN AT THE MCKINLEY MARINA AND THE MILWAUKEE YACHT CLUB FOR THE MILWAUKEE COUNTY DEPARTMENT OF PARKS, RECREATION AND CULTURE: APRIL 6, 1972

Parameter	Concentration (milligrams per liter except as indicated)	
	Marina[a]	Yacht Club[b]
pH[c]	8.05	8.14
Specific Conductance[d]	410	505
Alkalinity (as $CaCO_3$)	125	156
Turbidity[e]	18	12
Total Solids	214	293
Total Suspended Solids	15.8	6.45
Total Dissolved Solids	116	173
Ammonia Nitrogen	0.03	0.03
Organic Nitrogen	0.55	0.85
Nitrate Nitrogen	1.04	0.68
Nitrite Nitrogen	0.02	0.02
Soluble Orthophosphorus	0.045	0.12
Total Phosphorus	0.14	0.215
Chloride	28	33
Sulfate	30	46
Calcium	25	30
Magnesium	16	24
Sodium	14	16
Potassium	2.6	2.8
Total Coliform[f]	340	8,400
Fecal Coliform[f]	72	1,170

[a] *Sampling location near the middle of the marina about 150 yards off of the boat ramp.*

[b] *Sampling location at the Yacht Club slip near the flushing tunnel intake.*

[c] *pH standard units.*

[d] *Micro-ohms per square centimeter.*

[e] *JTU*

[f] *Count per 100 milliliters.*

Source: Limnetics, Inc.

combined sewer overflow with conveyance, treatment, and discharge at a point outside the Milwaukee, Menomonee, and Kinnickinnic River watersheds; and 6) instream water quality enhancement measures.

To make the required analysis, previous studies based on discrete event water quality modeling were not deemed appropriate. A continuous simulation method was applied to determine the frequency with which instream dissolved oxygen (DO) and fecal coliform standards would be violated for each of the alternatives to be evaluated. For this purpose, Harpers water quality model was modified from a discrete-event to a continuous-process instream simulation model. The Army Corps of Engineers Storage Treatment Overflow Runoff Model (STORM) was used to simulate continuous loadings from the CSO outfalls, these loadings being inputs to Harper's instream simulation model for the Milwaukee River from Brown Deer Road to the confluence with the Menomonee River, which was used as the prototype study reach. Four years of typical rainfall data were selected from the 37-year record available to minimize costs for simulation during ice-free and unfrozen ground conditions. The analysis did not include the spring thaw and the associated snowmelt runoff. Hourly flow and water quality conditions were generated for use in enumeration of standards violations for the alternatives studied.

To evaluate whether the results of the Milwaukee River CSO study were transferable to the CSO outfall reaches of the Menomonee and Kinnickinnic Rivers, sediments in the estuaries of these three rivers were characterized along with sediments from the outer harbor and near-shore Lake Michigan. Sediments were sampled in the summer of 1977 for chemical analysis; and sediment oxygen demand (SOD) rates were measured in the laboratory for both quiescent and agitated conditions. Map 20 shows the locations of the sediment chemistry sampling sites. Table 51 lists the parameters analyzed. In most cases samples were taken at the mid- and quarter-point locations in river channels, with chemical analyses being conducted for the top and bottom of each mid-channel core, and for the grab samples taken at the quarter points. The Rexnord report appendix tabulates the results of each of the sediment chemistry analyses for the 29 sites sampled, and presents maps for each of nine selected parameters showing concentrations measured.

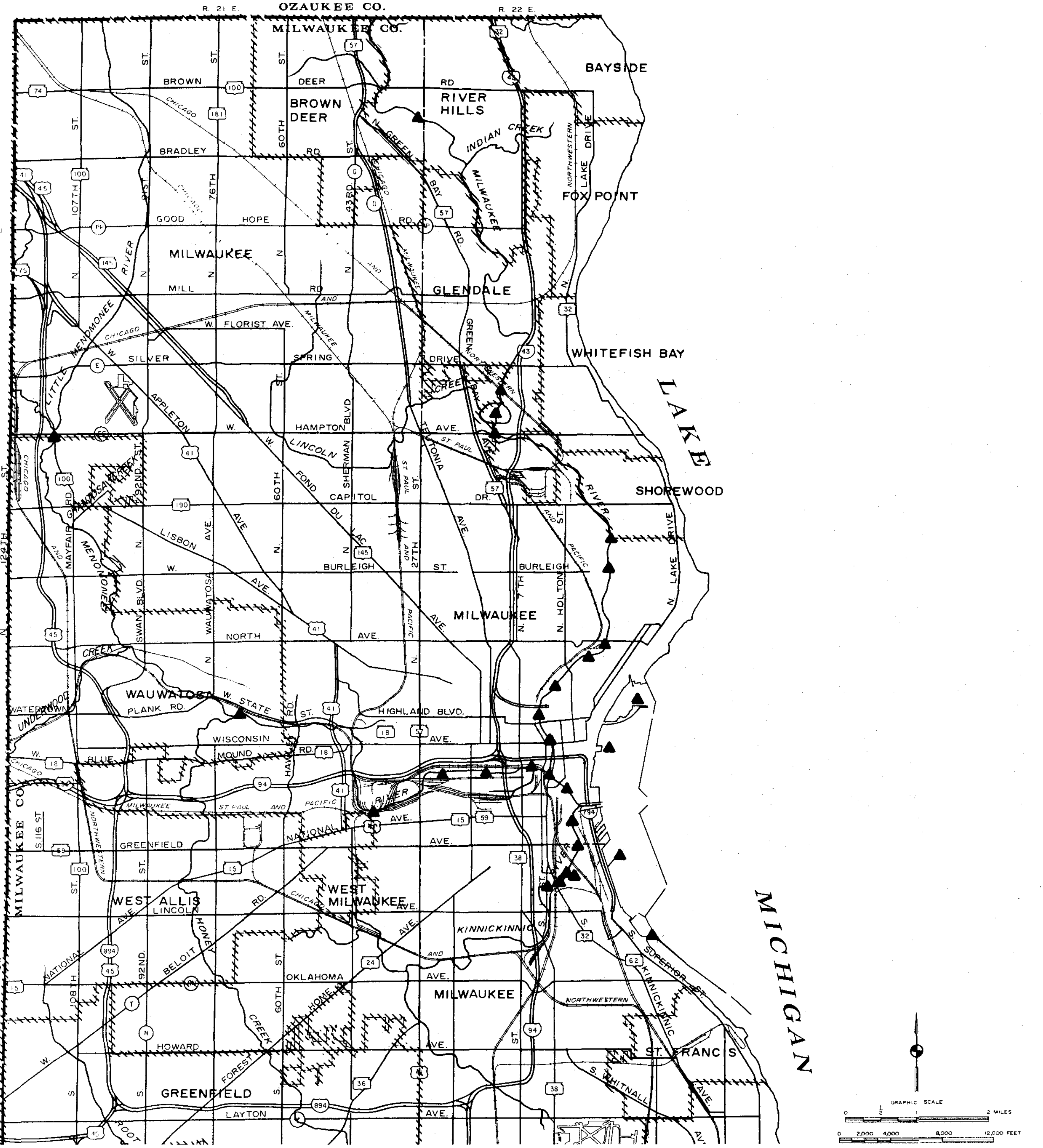
In-situ sediment oxygen demand (SOD) was measured at sites 1 through 26, shown on Map 20, in the summer of 1977 at least once, and up to three times at some locations. The Rexnord report, in Table 5, tabulates 20-day SOD for each measurement along with the date of sampling for each of the 26 sites. Average SOD at each site is also set forth in summary form on maps in this report.

It was concluded that sediment chemistry in the estuary upstream from the outer harbor was chemically quite similar in each of the river estuary reaches, except for lead and zinc concentrations in the Kinnickinnic estuary, which were two to three times larger than those found in the Milwaukee and Menomonee Rivers. In-situ SOD at 20°C was determined more than once at 15 of the 26 sites and did not change significantly with time. Because of these similarities, the study concluded that the results of the Milwaukee River simulation modeling could also be considered indicative of conditions in the Menomonee and Kinnickinnic estuaries.

Stream water quality surveys made during the USEPA combined sewer overflow study--described in the USEPA section of this chapter--for wet and dry weather periods were used to calibrate the continuous-process simulation model. Dissolved oxygen (DO) levels data recorded at continuous monitoring sites in the Milwaukee River estuary at

Map 20

LOCATIONS OF BOTTOM SEDIMENT CHEMISTRY SITES SAMPLED IN THE SUMMER OF 1977 IN THE MILWAUKEE HARBOR WATERSHED AND NEAR-SHORE LAKE MICHIGAN FOR THE WATER QUALITY IMPROVEMENT COST-EFFECTIVENESS STUDY (PG-61) FOR THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT



Source: Thomas L. Meinholz et.al., Water Quality Analysis of the Milwaukee River to Meet PRM 35-74 (PG-61) Requirements, Rexnord Environmental Research Center, Milwaukee, Wisconsin, report for MMSD.

Table 51

BOTTOM SEDIMENT CHEMISTRY PARAMETERS ANALYZED FOR SEDIMENT SAMPLES TAKEN IN THE SUMMER OF 1977 IN THE MILWAUKEE HARBOR WATERSHED AND NEAR-SHORE LAKE MICHIGAN FOR THE WATER QUALITY IMPROVEMENT COST-EFFECTIVENESS STUDY (PG-61) FOR THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

Parameters[a]	
Total Solids	Density
Total Volatile Solids	pH
5-Day BOD	Oxidation-Reduction Potential
Chemical Oxygen Demand	Iron
Nitrite and Nitrate Nitrogen	Cadmium
Ammonia Nitrogen	Zinc
Total Phosphorus	Lead
Sediment Oxygen Demand[b]	Copper

NOTE: See Map 20 for sampling site locations.

[a]The source cited below presents the results of each chemical analysis.

[b]SOD was measured in-situ at sites 1-26 only.

Source: Thomas L. Meinholz et.al., Water Quality Analysis of the Milwaukee River to Meet PRM 35-74 (PG-61) Requirements, Rexnord Environmental Research Center, Milwaukee, Wisconsin, report for MMSD.

St. Paul Avenue, Cherry Street, and North Avenue for the period May through September 1977, are summarized in the Appendix of the Rexnord report. Chlorophyll-a data used for model calibration were collected at seven sites on the Milwaukee River, at one site in the inner harbor, and at one site in the outer harbor during the summer of 1977. Locations and sampling dates are presented in Table 52.

Output data from the calibrated model for each of the four years of continuous simulation at North Avenue, Walnut Street, and St. Paul Avenue were then used to determine the frequency of violations of DO and fecal coliform standards for the alternatives studied. Each alternative was then compared on the basis of a selected set of cost-effectiveness measures.

The study concluded that dredging would be the most effective alternative to improve dissolved oxygen levels in the three rivers, and would be expected to result in an immediate improvement. Complete sewer separation was reported to best reduce the number of fecal coliform violations expected, with a cost similar to the out-of-basin alternative at the one-year level of protection, i.e., sized to accommodate a maximum overflow not exceeded on the average more than once a year. CSO impacts on short-term dissolved oxygen levels were found to be primarily associated with sediment scour, and DO levels were only marginally affected by the direct CSO pollutant loads. In other words, if sediment scour did not occur, CSO effects on dissolved oxygen would be marginal. None of the CSO abatement alternatives evaluated would, in themselves, significantly improve dissolved oxygen levels at North Avenue.

The study recommended that a study of the feasibility of sediment removal be conducted; that a more detailed analysis of the combinations of alternatives evaluated be made, along with a review of the water quality assumptions that were made; that studies should be made concerning the effects of improved water clarity upon algal blooms; and that a comprehensive water quality monitoring program should be implemented to improve upon the data base for existing conditions, and to provide a basis for comparison of the effects upon water quality of future CSO abatement actions.

The recommended water quality monitoring program, as described in the Rexnord report, included additional monitoring of sediment oxygen demand and sediment chemistry on a monthly basis and prior to and after dredging operations, as well as monitoring the effects of the submerged CSO discharges upon sediment scour in the Menomonee and Kinnickinnic Rivers as well as in the Milwaukee River. The study also recommended measurement of sediment depths to determine deposition rates and sediment transport load in the rivers. Continuous water quality monitoring in the lower reaches of each of the three rivers was recommended for at least dissolved oxygen and water temperature, and should also include other parameters such as conductivity, pH, and ammonia nitrogen. Weekly or bi-weekly grab sampling was also recommended, as well as development of a rainfall data storage and retrieval system for the City of Milwaukee raingage network. Grab sampling was recommended at the following locations:

1) at the upstream ends of the Milwaukee and Menomonee Rivers within the Milwaukee Metropolitan Sewerage District boundaries,

2) just upstream from the combined sewer outfall affected areas, and

3) within the Milwaukee Harbor estuary generally.

Table 52

CHLOROPHYLL-A SAMPLING LOCATIONS AND SAMPLING DATES FOR THE MILWAUKEE RIVER IN MILWAUKEE, AND THE INNER AND OUTER HARBORS DURING THE SUMMER OF 1977 USED IN THE WATER QUALITY IMPROVEMENT COST-EFFECTIVENESS STUDIES (PG-61) FOR THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

	Sampling Date							
Location	6/24	7/8	7/15	7/20	7/28	8/8	8/30	9/27
Brown Deer Road......	X	X	X	X	--	X	X	X
Silver Spring Drive..	X	X	X	X	--	X	--	X
Port Washington......	X	X	X	X	--	X	X	X
North Avenue.........	--	X	X	X	X	X	--	X
Walnut Street........	--	X	X	X	X	X	X	X
Wells Street.........	--	X	X	X	X	--	--	X
St. Paul Avenue......	X	X	X	X	X	X	X	X
Inner Harbor.........	--	--	--	--	--	--	X	--
Outer Harbor.........	--	--	--	--	--	--	X	--

Source: Thomas L. Meinholz et. al., Water Quality Analysis of the Milwaukee River to Meet PRM 35-74 (PG-61) Requirements, Rexnord Environmental Research Center, Milwaukee, Wisconsin, report for MMSD.

Table 53

WATER QUALITY PARAMETERS ANALYZED FOR THE MILWAUKEE RIVER (1946-1968), THE MENOMONEE RIVER (1963-1968), AND THE KINNICKINNIC RIVER (1946-1968) BY THE RIVER QUALITY MONITORING PROGRAM OF THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

Parameters	
Water Temperature Dissolved oxygen 5-Day BOD	Coliform Bacteria pH Chlorides Turbidity

NOTE: Sampling site locations are shown on Map 21.

Source: Stevens, Thompson & Runyan, Inc., Combined Sewer Overflow Pollution Abatement--Phase One, Volume Three, Appendix, MMSD, 1975.

Fecal coliform sampling in the rivers, the harbor, and near the beaches was also recommended following CSO discharge events to provide a basis for comparison of benefits attributable to CSO abatement projects.

River Water Quality Sampling Program

The Milwaukee Metropolitan Sewerage District collected samples for water chemistry analyses during non-winter periods on a weekly basis in the Milwaukee, Menomonee, and Kinnickinnic Rivers. Data are available for a total of 21 sites for the period 1946 through 1968 for the Milwaukee and Kinnickinnic Rivers, and for the period 1963 through 1968 for the Menomonee River. The water quality parameters analyzed are listed in Table 53. The sampling site locations are shown on Map 21. All sampling sites were not monitored concurrently, some sites being operated for shorter periods of time than others. A listing of the parameters analyzed at each station along with the period of record is presented in a water quality data review included in the Stevens, Thompson & Runyan, Inc., report.[38]

In 1979, MMSD, acting in fulfillment of a staff agreement with SEWRPC, began a river water quality sampling program to supplement an outer harbor sampling effort conducted by the University of Wisconsin-Milwaukee. The program objective was to define water quality conditions for five characteristic periods: 1) a spring runoff event, 2) a summer dry period, 3) a summer large storm runoff event, 4) a fall dry period, and 5) a fall runoff event. This sampling program was carried out in 1980 and sampling data were input to a computer file by MMSD. The data are scheduled to be available early in 1981. Water quality parameters analyzed are listed in Table 54 and sampling site locations are presented in Table 55. Samples are taken at mid-stream at the surface, mid-depth, and near the bottom when depths exceeded three meters. For depths less than three meters, samples were taken at mid-depth.

In addition, to complement outer harbor and near-shore water quality sampling efforts by the University of Wisconsin at Milwaukee (UWM)--described under the UWM section of this chapter--the MMSD collected concurrent samples at North Avenue, the Menomonee River above the Falk Corporation Dam, and the Kinnickinnic River at S. 7th Street. During 1979, samples were collected weekly starting in April, with weekly sampling also being conducted in 1980. Water quality parameters analyzed are presented in Table 56. Data are on the computer file at MMSD.

Since 1975, the MMSD has also been operating continuous dissolved oxygen monitoring stations on the Milwaukee River just above the North Avenue dam, at Cherry Street, and at St. Paul Avenue. Continuous water temperature was also monitored, but the data are not considered reliable because temperature recorder calibration was not maintained during the monitoring period. Data are on file at MMSD in computer readable form.

Outer Harbor and Near-Shore Sampling Program

During 1979, MMSD collected water samples for chemical and physical analyses in the outer harbor and also near the South Shore wastewater treatment plant to provide documentation of existing conditions for the facilities planning studies of the Jones Island and South Shore sewage treatment plants. Eleven locations were sampled

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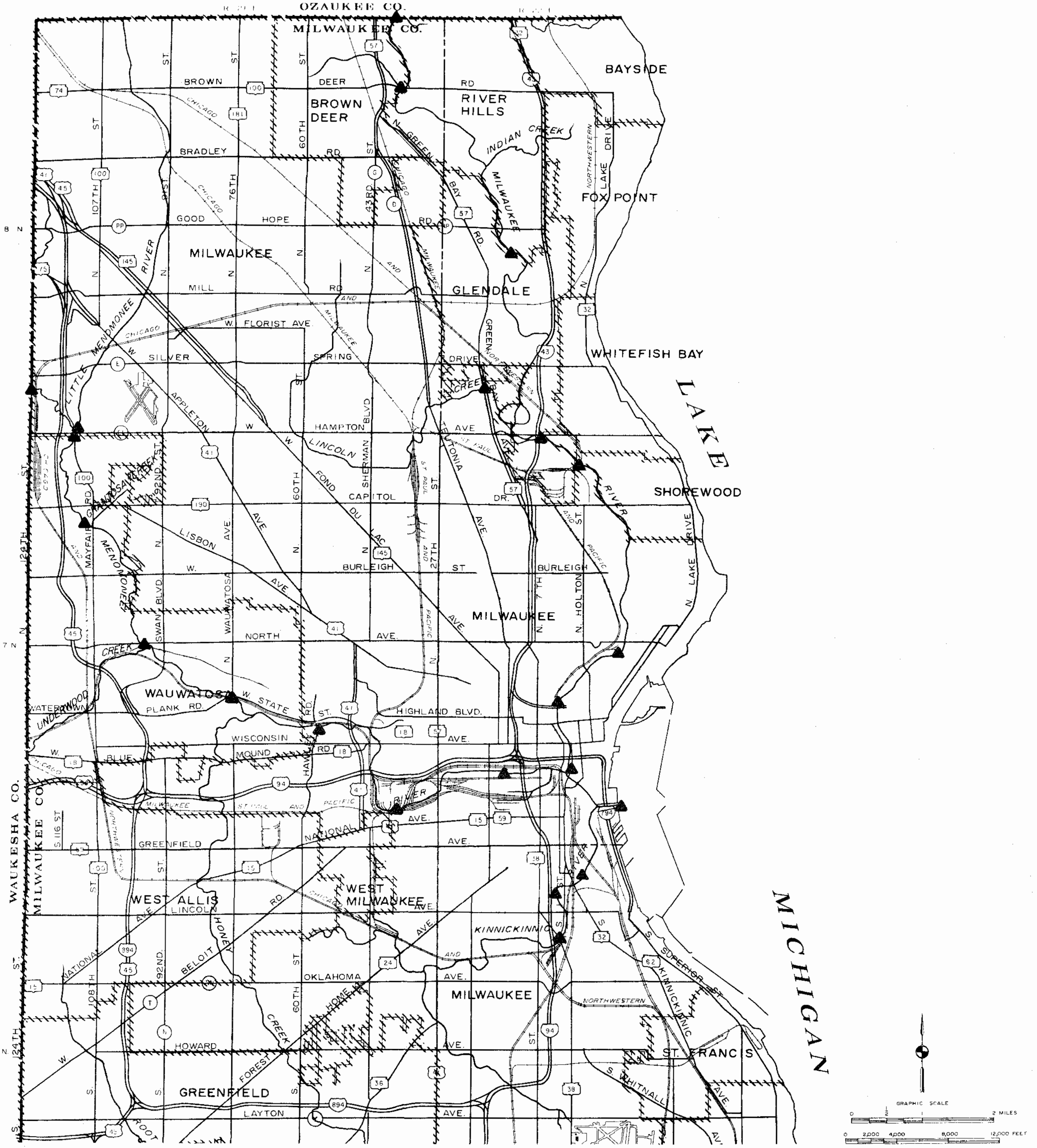
[38] *Stevens, Thompson & Runyan, Inc.,* *__Combined Sewer Overflow Pollution Abatement--Phase One__, Volume Three, __Appendix__, Milwaukee Metropolitan Sewerage District, 1975.*

Map 21
LOCATION OF WATER QUALITY SAMPLING SITES MONITORED BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT FOR THE RIVER QUALITY MONITORING PROGRAM FOR THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS: 1946-1968



Source: Stevens, Thompson & Runyan, Inc., Combined Sewer Overflow Pollution Abatement--Phase One, Volume Three, Appendix, MMSD, 1975.

Table 54

WATER QUALITY PARAMETERS ANALYZED FOR SEASONAL WET AND DRY WEATHER SAMPLING PERIODS IN THE LOWER MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT: 1980

Parameters	
Dissolved Oxygen	Chlorophyll-a
Temperature	Dissolved Silica
pH	Chlorides
Specific Conductance	Cadmium
Ammonia Nitrogen	Chromium
Total Kjeldahl Nitrogen	Lead
Total Solids	Zinc
Total Phosphorus	Mercury
Fecal Coliform Bacteria	Water Depth

NOTE: Sampling site locations are listed in Table 55.

Source: SEWRPC

Table 55

LOCATION OF WATER QUALITY MONITORING SITES SAMPLED DURING SEASONAL WET AND DRY WEATHER PERIODS IN THE LOWER MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVERS BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT: 1980

Sampling Locations	
Milwaukee River	North Avenue Dam Walnut Street Wells Street Milwaukee Avenue
Menomonee River	Second Street Muskego Avenue Falk Corporation Dam
Kinnickinnic River	First Street Seventh Street

NOTE: Water quality parameters analyzed are listed in Table 54.

Source: SEWRPC.

Table 56

WATER QUALITY PARAMETERS ANALYZED FOR SAMPLES TAKEN NEAR THE UPSTREAM ENDS OF THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVER ESTUARIES BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT: 1979-1980

Parameter	
Ammonia Nitrogen	Chlorophyll-a
Nitrate Nitrogen	Chloride
Nitrite Nitrogen	Turbidity[b]
Total Kjeldahl Nitrogen	Total Suspended Matter
Total Phosphorus	Specific Conductance
Total Filterable Phosphorus[a]	Dissolved Oxygen
Silica	Temperature
Dissolved Silica[a]	Fecal Coliform Bacteria

[a] *Analyzed in 1980 only.*

[b] *Analyzed in 1979 only.*

Source: SEWRPC

on a weekly basis with nine sites in the outer harbor and two sites just east of the breakwater in Milwaukee Bay[39] beginning in April 1979. Samples were taken at surface, mid-depth, and near the bottom. During 1980, the outer harbor sampling network was expanded to 14 bi-weekly sampling stations with the three additional sites being outside the breakwater in Milwaukee Bay, as shown on Map 22 which shows the locations of all the sites sampled in 1979 and 1980. Water quality parameters analyzed are listed in Table 57. Meteorological parameters were also monitored at two sampling sites--the outer harbor entrance and the South Shore sewage treatment plant. In 1980, the zooplankton and phytoplankton populations were also sampled for identification and quantification at six sites in the outer harbor and one site outside the harbor in Milwaukee Bay.

In 1980 the MMSD also began bi-weekly sampling at 15 locations further offshore between Fox Point and Wind Point to complement the outer harbor and Milwaukee Bay sampling program. The outer harbor near-shore sampling program is proposed to be continued indefinitely to provide lacking background water quality data for existing conditions.[40]

Jones Island Effluent and Overflow Sampling

The Milwaukee Metropolitan Sewerage District samples the influent and effluent of the Jones Island wastewater treatment plant to evaluate plant efficiency and to determine if effluent standards are being met. Effluent characteristics for 20 parameters are currently sampled by MMSD, with sampling intervals ranging from daily to once every 23 days for the various parameters analyzed. Table 58 lists the parameters analyzed and the corresponding sampling frequencies, which were taken from Table 4-20 of the Jones Island Facility Plan Element, Volume 1, Planning Report.[41]

The Wisconsin Pollution Discharge Elimination System (WPDES) permit also requires that MMSD monitor overflows in the Jones Island sewage collection network. Currently, eight overflow points are monitored continuously by MMSD and ten overflow points are monitored by the City of Milwaukee for flow, 5-day biochemical oxygen demand (BOD), suspended solids, pH, and fecal coliform. Locations of these monitoring sites are listed in Table 59.

Wastewater discharge from the Jones Island plant is monitored continuously by MMSD. During wet weather periods, total effluent flows monitored include treated flow and in-plant bypasses and overflows.

During wet weather flow periods, however, accuracy of the flow record was noted to be questionable because of the limited capacity of the total effluent meter. The Planning Report, in Table 4-1, presents daily, weekly, and monthly flows for each of the years 1975-1978.[42]

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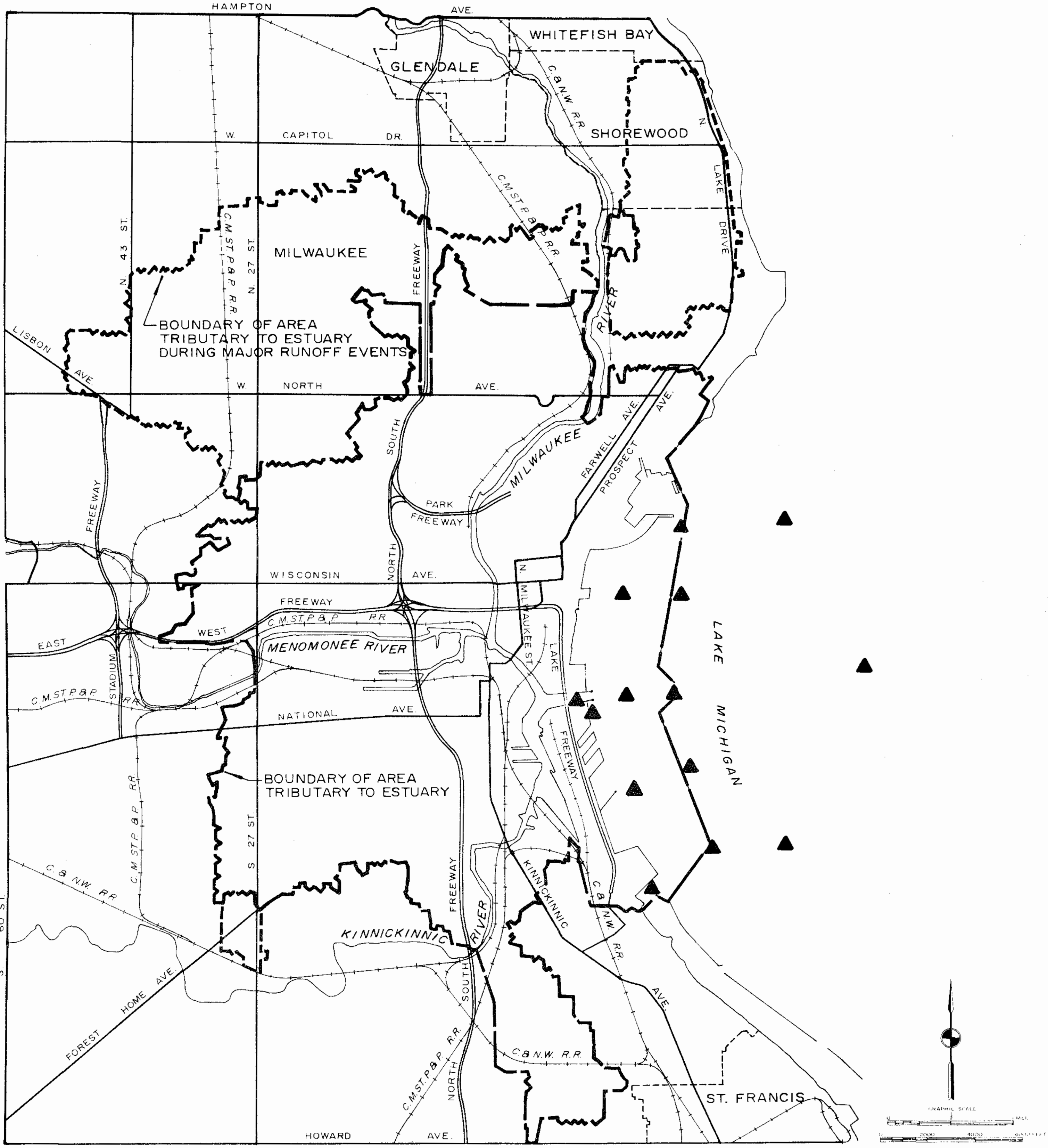
[39] *Milwaukee Bay is used in this study design to mean those portions of the area of Lake Michigan situated west of a line between the North Point filtration plant and the Lakeside power plant inclusive of the outer harbor.*
[40] *Information provided by David A. Gruber, Water Quality Data Coordinator, MMSD, December 22, 1980.*
[41] *MMSD, Jones Island Facility Plan Element, Volume 1, Planning Report, Milwaukee Water Pollution Abatement Program, Program Management Office, June 1, 1980.*
[42] *Ibid.*

Map 22

LOCATONS OF WATER QUALITY SAMPLING SITES IN THE OUTER HARBOR AND MILWAUKEE BAY MONITORED BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT: 1979-1980



Source: SEWRPC.

Table 57

WATER QUALITY PARAMETERS ANALYZED FOR SITES IN THE OUTER HARBOR AND MILWAUKEE BAY OUTSIDE THE BREAKWATER SAMPLED BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT: 1979-1980

Parameters	
Specific Conductance	Total Dissolved Silica[a]
Depth	Suspended Solids[a]
Temperature	Volatile Suspended Solids[a]
pH[a]	Total Solids[a]
Dissolved Oxygen	Cadmium
Fecal Coliform Bacteria	Chromium
Total Kjeldahl Nitrogen[a]	Copper
Ammonia Nitrogen	Lead
Nitrate Nitrogen[a]	Zinc
Nitrite Nitrogen[a]	Chlorophyll-a
Chlorides[a]	Free, Mono-, and Di-Chlorine
Total Phosphorus	Total Organic Carbon[a]
Dissolved Phosphorus[a]	Total Dissolved Organic Carbon[a]
Total Silica	

NOTE: Sampling site locations are shown on Map 22.

[a]Not analyzed in 1979.

Source: SEWRPC

Table 58

CURRENT EFFLUENT QUALITY PARAMETERS AND SAMPLING FREQUENCIES FOR THE JONES ISLAND WASTEWATER TREATMENT PLANT

Parameter	Sampling Frequency	Type of Sample[a]
5-Day BOD....................	Daily	C
5-Day BOD (carbonaceous)......	Twice weekly	C
Soluble 5-Day BOD............	Twice weekly	C
Soluble 5-Day BOD (carbonaceous)...............	Daily	C
Total Solids..................	Daily	C
Total Volatile Solids.........	Daily	C
Suspended Solids..............	Daily	C
Volatile Suspended Solids.....	Daily	C
Total Kjeldahl Nitrogen.......	Daily	C
Ammonia Nitrogen..............	Weekly[c]	C[c]
Nitrate Nitrogen..............	Weekly	C
Nitrite Nitrogen..............	Weekly	C
Total Phosphorus..............	Daily	C
Soluble Phosphorus............	Daily	C
Heavy Metals[b]................	Weekly	C
Fecal Coliforms...............	Thrice weekly	W
Total Plate Count.............	Twice weekly	G
pH............................	Six times daily	G
Temperature...................	Four times daily	G
Chlorine Residual.............	Twelve times daily	G

NOTE: Total effluent sampling program is different than individual outfall sampling program.

[a] C-daily composite; G-grab sample; W-weekly composite.
[b] Heavy metals include iron, aluminum, cadmium, zinc, nickel, chromium, copper, and lead.
[c] Sampled and analyzed separately for the east and west outfalls.

Source: MMSD, Jones Island Facility Plan Element, Volume 1, Planning Report, Milwaukee Water Pollution Abatement Program, Program Management Office, June 1, 1980.

Table 59

LOCATIONS OF SANITARY SEWAGE OVERFLOW MONITORING SITES CURRENTLY SAMPLED BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT AND THE CITY OF MILWAUKEE

Location
MMSD:
W. Hampton Avenue at N. Lydell Avenue
W. Villard Avenue at N. 27th Street
W. Hampton Avenue at N. 32nd Street
W. Roosevelt Drive at N. 35th Street
N. Richard Street at E. Congress Street extended
N. Range Line Road at north side of Milwaukee River
N. Lydell Avenue at W. Lancaster Avenue
Point 800 feet west of N. Humboldt Avenue
City of Milwaukee:
N. Milwaukee River Parkway at W. Wilson Drive
N. Milwaukee River Parkway at W. Lawn Avenue
N. 19th Place at W. Fairmont Avenue
N. 49th Street at W. Luscher Avenue
N. 61st Street at W. Lawn Avenue
5344 N. 60th Street
N. 60th Street at W. Custer Avenue
N. 58th Street at W. Sheridan Avenue
S. 72nd Street at W. Honey Creek Drive
S. 46th Street at W. Cleveland Avenue

Source: MMSD and the City of Milwaukee Bureau of Engineers.

Table 60

JONES ISLAND EFFLUENT POLLUTANT LOADINGS: 1978

Parameter	Loading
Biochemical Oxygen Demand.....	8,440 x 10^3 pounds per year
Total Suspended Solids........	9,600 x 10^3 pounds per year
Total Phosphorus..............	169 x 10^3 pounds per year
Ammonia Nitrogen..............	2,130 x 10^3 pounds per year
Fecal Coliform................	5 x 10^{13} per year
Average Flow..................	132 million gallons per day

Source: MMSD, Jones Island Facility Plan Element, Volume 2, Environmental Assessment, Milwaukee Water Pollution Abatement Program, Program Management Office, June 1, 1980.

Pollutant loadings for 1978 from the Jones Island combined sewer outfalls to the outer harbor are presented in Table 60 for five parameters. Jones Island Facility Plan Element, Volume 2, Environmental Assessment, in its Table 4-9, also presents estimates of pollutant loadings from combined sewer overflows and bypasses, industrial discharges, and the Milwaukee River at its mouth.[43]

An annual summary of the effluent quality data is presented in the annual reports of the MMSD. The 1974 annual report includes summary data for each of the years 1969 through 1974 for wastewater flow; pH; total, dissolved, and suspended solids; phosphorus, 5-day BOD; total nitrogen; and nitrite and nitrate nitrogen. Plant effluent chlorination data are also presented.[44] Effluent quality data for other parameters and other years are available from MMSD.

Sediment Sampling at the Proposed Jones Island Lakefill

During the summer of 1980, the MMSD collected bottom sediment samples from the outer harbor just east of the Jones Island wastewater treatment plant for cemical analysis to determine if the sediments at this location were technically categorized as "hazardous" according to U.S. Environmental Protection Agency criteria. Samples were analyzed for PCB content, with one sample also being analyzed for "priority" pollutants--the full range of pollutants classified as hazardous, according to federal regulations. During the same period, samples were also taken for PCB testing from locations in the Kinnickinnic River at Lincoln Avenue and at the confluence with the Milwaukee River, and the Menomonee River at its confluence with the Milwaukee River. Core samples were taken to determine PCB concentration as a function of depth.[45]

Meteorological Data Collection

During 1979, the MMSD began operation of a meteorological data collection station to provide assistance to the UW-Milwaukee (UWM) outer harbor near-shore Lake Michigan dispersion study, which is described in the UWM section of this chapter. The weather station is located on the breakwater at the main entrance to Milwaukee Harbor. The station is equipped with telemetry to transmit the data directly to MMSD offices. The station records precipitation, wind speed, wind direction, air temperature, relative humidity, and solar insolation. A computerized data management system records these data at 5-minute intervals. Another weather station--not equipped with telemetry--is operated at the South Shore wastewater treatment plant and records the same parameters except for solar insolation. This station is equipped with analog recorders only.[46]

CITY OF MILWAUKEE

City of Milwaukee programs and studies relevant to the Milwaukee Harbor estuary study design include the river stage monitoring program of the Department of Public

[43]*MMSD, Jones Island Facility Plan Element, Volume 2, Environmental Assessment, Milwaukee Water Pollution Abatement Program Management Office, June 1, 1980.*
[44]*Annual Report of the Sewerage Commission of the City of Milwaukee and of the Metropolitan Sewerage Commission of the County of Milwaukee for the Year 1974, January 2, 1975.*
[45]*Information supplied by David A. Gruber, Water Quality Data Coordinator, MMSD, December 22, 1980.*
[46]*Ibid.*

Works, Bureau of Engineers; operation and monitoring of the effectiveness of the Milwaukee River and Kinnickinnic River flushing tunnels by the Bureau of Engineers and the City of Milwaukee Health Department, beach pollution monitoring, dye tracer studies, and alewife studies by the City Health Department; and the Humboldt Avenue combined sewer overflow detention tank study conducted by a consultant for the City of Milwaukee and the U.S. Environmental Protection Agency. These programs are described in the following sections of this chapter.

River Stage Monitoring

The City of Milwaukee, Department of Public Works, Bureau of Engineers, currently operates four continuous record water level recorders in the Milwaukee Harbor estuary at the locations shown on Map 23. The gages were placed in operation April 21, 1975, and SEWRPC was informed of their placement in a letter dated April 30, 1975. The Menomonee River estuary gage was initially at Canal Street and 26th Street (extended). This site was deactivated in November 1977, and the gage was moved to 24th Street and reactivated in April 1978. Data for these stations are available from the Bureau of Engineers.

In addition to the continuous stage record, the City of Milwaukee has operated numerous other nonrecording river stage monitoring stations in the estuary. Locations of these gages, along with periods of record, are listed in Table 61. Gages were read by observers on a twice daily basis, with more frequent readings during periods of rapid water level fluctuation. Data for the Kinnickinnic River at Kinnickinnic Avenue for the period 1968-1974 are on file at SEWRPC. Remaining data for this gage and the other gages are on file at the City of Milwaukee Records Center.

On a 5-day per week basis, the Port of Milwaukee currently reads a staff gage located in the Kinnickinnic River estuary at the former C & O Railway car ferry pier. Readings are not taken during periods of ice cover. Data have been collected since 1965 and are on file at the Port of Milwaukee field office on Jones Island.

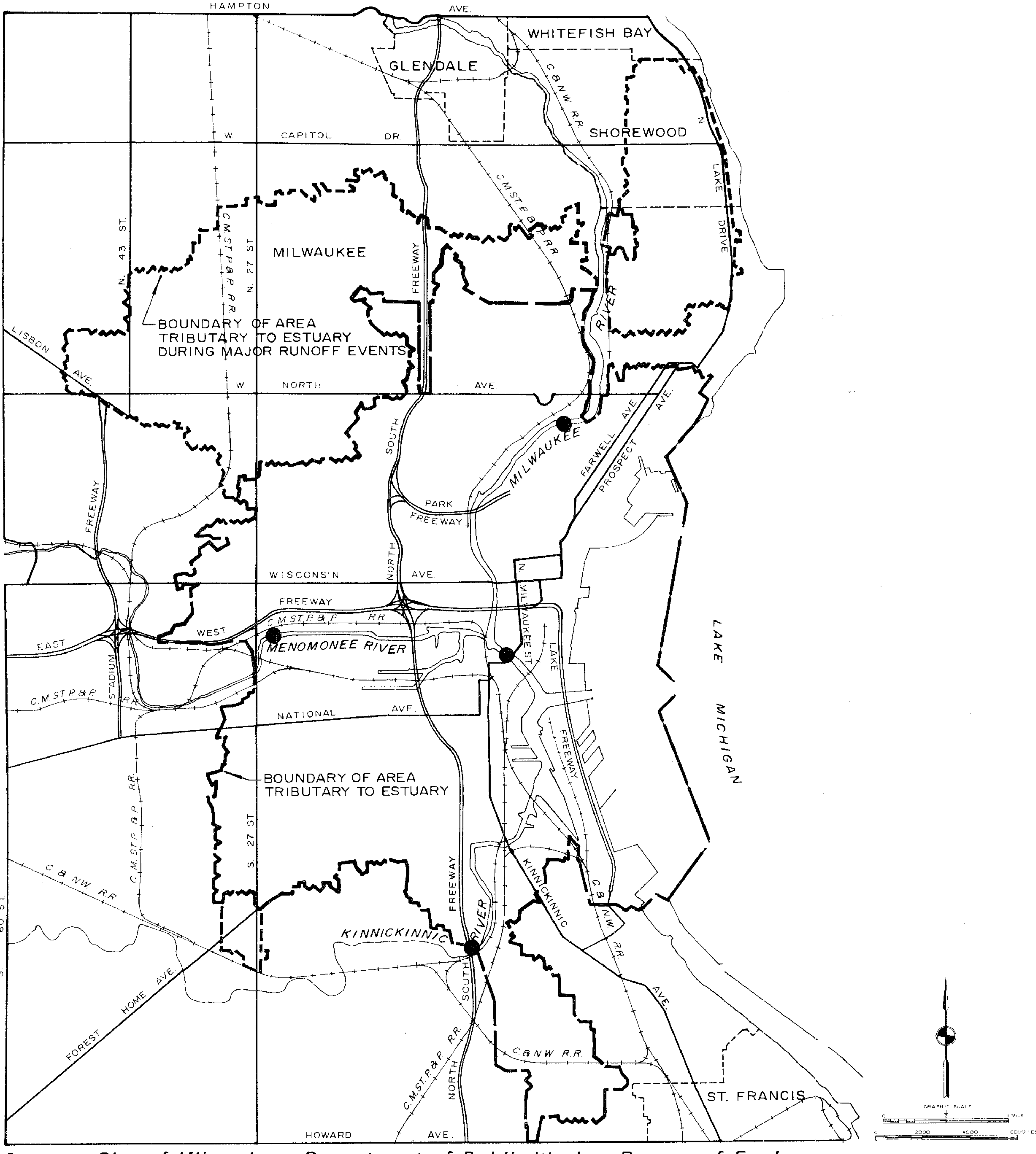
Milwaukee River and Kinnickinnic River Flushing Tunnels

To enhance the water quality of the Milwaukee and Kinnickinnic River estuaries, the City of Milwaukee constructed tunnels from Lake Michigan to the upper reaches of these two estuaries to supply lake water to flush pollutants from these estuaries into Lake Michigan. The Milwaukee River flushing tunnel was built in 1888 with the outlet being placed downstream from the North Avenue dam at the foot of N. Warren Avenue and E. Boylston Place. The tunnel discharge capacity is about 420 cubic feet per second (cfs). Until 1964, the tunnel was operated on a flexible schedule from May through November. In 1964, the flushing tunnel operation was transferred to the Milwaukee Metropolitan Sewerage District (MMSD) which operated the tunnel about 80 hours per week from May through October. During critical periods, 24-hour operation for up to seven days a week occurs. Hours of operation since 1964 are on file at MMSD.

The Kinnickinnic River flushing tunnel was built in 1907 with the outlet being placed immediately downstream from Chase Avenue. The pumping mechanism is rated at 410 cfs. In 1975 the tunnel was operated from June through November, seven hours per day, five days per week, for the most part. Operating schedules for the tunnel were included in the annual reports of the Bureau of Engineers of the City of Milwaukee. Since 1980, MMSD has been operating the Kinnickinnic River flushing tunnel. Flushing tunnel design details are summarized in the City of Milwaukee Bureau of Engineers

Map 23

LOCATIONS OF CONTINUOUS RECORD WATER LEVEL RECORDERS IN THE MILWAUKEE HARBOR ESTUARY OPERATED BY THE CITY OF MILWAUKEE SINCE APRIL 1975



Source: City of Milwaukee, Department of Public Works, Bureau of Engineers.

Table 61

LOCATIONS AND PERIODS OF RECORD FOR NONRECORDING RIVER STAGE MONITORING STATIONS IN THE MILWAUKEE HARBOR ESTUARY OPERATED BY THE CITY OF MILWAUKEE

River	Gage Location	Period of Record	Gage Number[a]
Milwaukee River	Broadway Street	1941-63	1
	Water Street	1901-74	2
	Buffalo Street	1930-65	3
	Clybourn Street	1930-60	4
	Michigan Street	1930-65	5
	Wisconsin Avenue	1930-62	6
	Wells Street	1930-62	7
	Kilbourn Street	1930-61	8
	State Street	1930-55	9
	Juneau Avenue	1930-55	10
	Cherry Street	1930-55	11
	Pleasant Street	1930-55	12
	Holton Street	1930-55	13
Menomonee River	Plankinton Avenue	1930-58	1
	Sixth Street	1941-47	2
	Sixteenth Street	1940-55	3
	Muskego Avenue	1941-67	4
Kinnickinnic River	Kinnickinnic Avenue	1941-67	1
	C & O Car Ferry		--[b]

NOTE: Data on file in city of Milwaukee Records Center.

[a] *City of Milwaukee gaging station identification number.*
[b] *Staff gage operated by the Port of Milwaukee.*

Source: City of Milwaukee, Department of Public Works and Port of Milwaukee.

report Data Pertaining to Milwaukee's Two River Flushing Stations, published in 1953. SEWRPC also has this information on file.[47]

The City of Milwaukee Health Department in 1970 submitted a report to the Common Council of the City concerning water quality effects of the Kinnickinnic River flushing tunnel.[48] The report included an analysis of the quality of water discharged from the flushing tunnel outlet immediately east of S. Chase Avenue; analysis of water quality conditions in the Kinnickinnic River upstream of the flushing tunnel at S. 6th Street; and water quality conditions downstream of the flushing tunnel at the W. Lincoln Avenue and W. Becher Street crossings of the Kinnickinnic River estuary. Sampling was carried out during the summers of 1967, 1969, and 1970. Water quality parameters measured are listed in Table 62.

In addition to the above report, a letter dated January 11, 1974 from the City of Milwaukee Health Department to the City Engineer of Milwaukee, transmits dissolved oxygen data for the Kinnickinnic River at S. First Street bridge, just downstream from the flushing station. The dissolved oxygen values were taken at one- to seven-day intervals for the period September through December 1973.

The report on the flushing station provided an opportunity to compare Kinnickinnic River water quality in the estuary downstream of the flushing tunnel with that in the Kinnickinnic River upstream of the flushing tunnel. Furthermore, because the tunnel was not in operation during the 1969 sampling period, the water quality investigations provided an opportunity to evaluate the effectiveness of the tunnel in enhancing estuary water quality.

A summary of all of the physical, chemical, and biological analyses conducted during the three summers at the four locations is set forth in Table 63. Dissolved oxygen levels for all locations during the summers of 1967 and 1969 are presented in graphic form on page 152 of SEWRPC Planning Report No. 32, A Comprehensive Plan for the Kinnickinnic River Watershed. Based on data presented in the City of Milwaukee Health Department Report of November 1970,[49] some of which is presented in Table 63, certain conclusions may be drawn concerning the effectiveness of the flushing tunnel in enhancing estuary water quality.

- When the flushing tunnel is in operation:

    1. estuary water quality approximates that of the water being pumped from Lake Michigan into the estuary.

    2. estuary water quality is superior to that of the Kinnickinnic River upstream of the estuary for biochemical oxygen demand, chlorides, and total and fecal coliform bacteria.

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[47] *On file at SEWRPC in the "Kinnickinnic River Watershed Inventory Memorandum No. 5," Book 1, Exhibit K.*
[48] *E.R. Krumbiegel and Roger H. Hulbert, Report on Operation of the Kinnickinnic River Flushing Station and Its Effect on Downstream Water Quality, City of Milwaukee Health Department Report, November 1, 1970. On file at SEWRPC, "Kinnickinnic Watershed Study Inventory Memorandum No. 5," Book 1, Exhibit B.*
[49] *Ibid.*

Table 62

LIST OF WATER QUALITY PARAMETERS MONITORED IN THE INNER HARBOR FOR THE KINNICKINNIC RIVER FLUSHING TUNNEL STUDY DURING THE SUMMERS OF 1967, 1969, AND 1970 BY THE CITY OF MILWAUKEE HEALTH DEPARTMENT

Parameters[a]	
Water Temperature Dissolved Oxygen Biochemical Oxygen Demand Chloride	Total Coliforms Fecal Coliforms pH Turbidity

[a]Sampling site locations are S. 6th Street (above flushing tunnel), flushing tunnel outlet, W. Lincoln Avenue, and W. Becher Street.

Source: City of Milwaukee Health Department Report, November 1, 1970, on file at SEWRPC.

Table 63

DRY WEATHER WATER QUALITY IN THE KINNICKINNIC RIVER UPSTREAM AND DOWNSTREAM OF THE FLUSHING TUNNEL WITH AND WITHOUT OPERATION OF THE FLUSHING TUNNEL: SUMMERS OF 1967, 1969, AND 1970

Sampling Station Location	River Mile	Number of Samples	Arithmetic Mean of All Analyses							
			Temperature (°F)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (mg/l)	Chloride (mg/l)	Total Coliform (MFFCC per 100 ml)	Fecal Coliform (MFFCC per 100 ml)	pH (standard units)	Turbidity (standard units)
Summer 1967--Flushing Station Operated										
S. 6th Street.	2.81	26	69.8	10.8	8.7	59.7	395,200	58,700	7.88	50.8
Flushing Station Outlet. .	2.35	26	62.8	8.5	4.1	20.5	73,300	1,900	7.98	25.4
W. Lincoln Avenue.	1.96	26	63.9	8.0	5.5	23.6	244,900	22,000	7.89	30.8
W. Becher Street	1.67	26	64.9	7.3	5.0	24.3	352,900	15,500	7.92	46.1
Summer 1969--Flushing Station Not Operated										
S. 6th Street.	2.81	14	70.0	9.4	8.0	44.5	833,600	57,000	8.00	27.8
Flushing Station Outlet. .	2.35	14	68.5	5.1	6.1	43.9	214,700	22,300	7.71	21.2
W. Lincoln Avenue.	1.96	14	71.2	2.6	6.2	44.6	293,500	14,200	7.70	26.5
W. Becher Street	1.67	14	70.2	1.3	6.4	38.3	361,700	8,200	7.61	30.0
Summer 1970--Flushing Station Operated										
S. 6th Street.	2.81	13	77.9	12.8	6.5	62.1	154,900	18,800	8.53	15.1
Flushing Station Outlet. .	2.35	13	63.5	9.9	4.1	20.4	48,400	4,200	8.16	16.1
W. Lincoln Avenue.	1.96	13	61.7	10.1	3.6	19.9	36,900	2,400	8.18	15.2
W. Becher Street	1.67	13	65.3	9.8	3.9	19.1	50,800	3,900	8.05	16.9

NOTE: Underlining indicates substandard water quality based on the following criteria associated with the support of recreation and warmwater fishery use objectives:

Temperature--Maximum of 89°F.
Dissolved Oxygen--Minimum of 5.0 mg/l.
Fecal Coliform--Maximum of 400 MFFCC per 100 ml.
pH--6.0 to 9.0.

Source: City of Milwaukee Health Department

3. the dissolved oxygen concentration in the estuary is less than that of the Kinnickinnic River immediately upstream of the estuary; however, the dissolved oxygen levels in the estuary are well above the 5.0 milligrams per liter (mg/l) minimum standard associated with maintenance of a full warm-water fishery and recreational use.

- When the flushing tunnel is not operating, the most significant water quality effects are low to substandard dissolved oxygen levels in the estuary and increased chloride levels, approximating those of the Kinnickinnic River immediately upstream of the estuary.

The 1967 through 1970 City of Milwaukee Health Department investigation did include an examination of relationships between wet weather flow and water quality in the lower Kinnickinnic River. However, the report concluded that "no significant or invariable relationship between wet weather flow and downstream water quality was established."

The City of Milwaukee Health Department performed dissolved oxygen determinations in the Kinnickinnic River estuary at the S. First Street bridge at one- to seven-day intervals during the period September 18, 1973 to December 6, 1973. Dissolved oxygen values ranged from a low of 4.8 mg/l to a high of 9.7 mg/l, with an average of 7.5 mg/l. Thus the range and the average are generally well above the concentration standard of 5.0 mg/l. The flushing tunnel was in operation intermittently during most of this sampling period, with operations discontinued for the season on November 21, 1973.

The principal objective used to establish the operating schedule of the flushing tunnel is maintenance of a minimum dissolved oxygen concentration of 2.0 mg/l in the estuary at the S. First Street crossing. The City of Milwaukee Health Department data suggest that the tunnel operation was successful in satisfying this dissolved oxygen standard.

Beach Pollution Monitoring

The City of Milwaukee Health Department closely monitors fecal coliform levels near city beaches. Daily beach water samples are collected during the summer season, and records since 1961 are kept at the City of Milwaukee Health Department. Intermittent data are available for the period since 1945. Beaches monitored are Bradford, McKinley, South Shore, and Bay View. Numerous studies have been conducted by the Health Department concerning beach pollution since 1945, and are briefly discussed in a previous data review for the Milwaukee Metropolitan Sewerage District.[50] Correlations of rainfall with fecal bacteria at beaches was made for beach closing and duration of closing purposes. Bacteria samples have also been collected intermittently in the inner and outer harbors.

Dye and Drogue Studies

The Milwaukee Department of Health in 1962 conducted numerous dye tracer and drogue studies in the outer harbor and near-shore Lake Michigan to determine natural flow patterns under a range of wind and flow conditions. It had been found that wind and rainfall strongly correlated with fecal bacteria counts at city beaches located on Lake Michigan outside the outer harbor breakwater.

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[50] *Milwaukee Metropolitan Sewerage District, Combined Sewer Overflow Pollution Abatement--Phase One, Volume Three, Appendix, 1975.*

Five dye studies were conducted in 1962 and two in 1963, for a range in wind directions. Rhodamine B fluorescent dye was injected in the Milwaukee River upstream from the outer harbor to achieve complete mixing at the mouth of the river. Instantaneous injections were used in some cases with a line injection used in at least one study.

A flow-through fluorometer with a continuous recorder and a submersible pump was used to collect samples at different depths in some of the studies. Water temperature was recorded at each sampling station, with wind speed and direction recorded at Mitchell Field as part of the National Weather Service station located there. Sampling station locations are shown on Map 24. Detailed time, fluorometer readings, and water temperature data were tabulated for each sampling station. Dates of dye studies, predominant wind direction, and average wind speed are listed for comparison in Table 64. Additional details for each dye study are available from the Health Department and SEWRPC files.[51] It was reported that in some of the studies the dye occasionally moved against the wind.

During July and August, 1962, seven drogue studies were conducted in the outer harbor for a range of wind speeds and directions. Drogue release locations varied from study to study, but for each individual study, all drogues were released at approximately the same time and location. Surface drogues were used in only a few studies, while in other studies drogues set at surface, four-foot, and ten-foot depths were tracked by using triangulation. In most studies six to eight drogues were utilized, with one study utilizing as few as two drogues. Drogue path maps were prepared for some studies, but for others only the raw data are available. These data would allow for construction of drogue path maps for the remaining studies. In some studies drogue velocities were also computed and tabulated along with time of travel between observed locations. The data and the drogue path maps are on file at the Health Department.[52] Dates of drogue studies, predominant wind direction, and average wind speed are listed for comparison in Table 65. It was found in some studies that the deep drogues sometimes moved in significantly different directions than the shallow drogues, which generally moved in the same direction as the wind.

Lake levels during the dye and drogue studies of the summer of 1962 were about two feet lower than those for the summer of 1980, during which time dye studies were conducted in the harbor by the University of Wisconsin at Milwaukee. The summer 1962 levels were about 1.0 foot lower than normal lake levels; while the summer 1980 levels were about 1.0 foot higher than normal summer levels. The summer 1963 levels were about 3.0 feet lower than during the summer of 1980, and about 2.0 feet below normal summer levels. Therefore, the data developed from these two lake level conditions should be helpful in understanding the hydraulic circulation characteristics for a range of lake levels.

Humboldt Avenue Combined Sewer Overflow Detention Tank Study

The City of Milwaukee, in cooperation with the U.S. Environmental Protection Agency (USEPA), conducted a demonstration project evaluating the merits of a detention tank for combined sewer overflows (CSO).[53] A detention tank for intercepting and

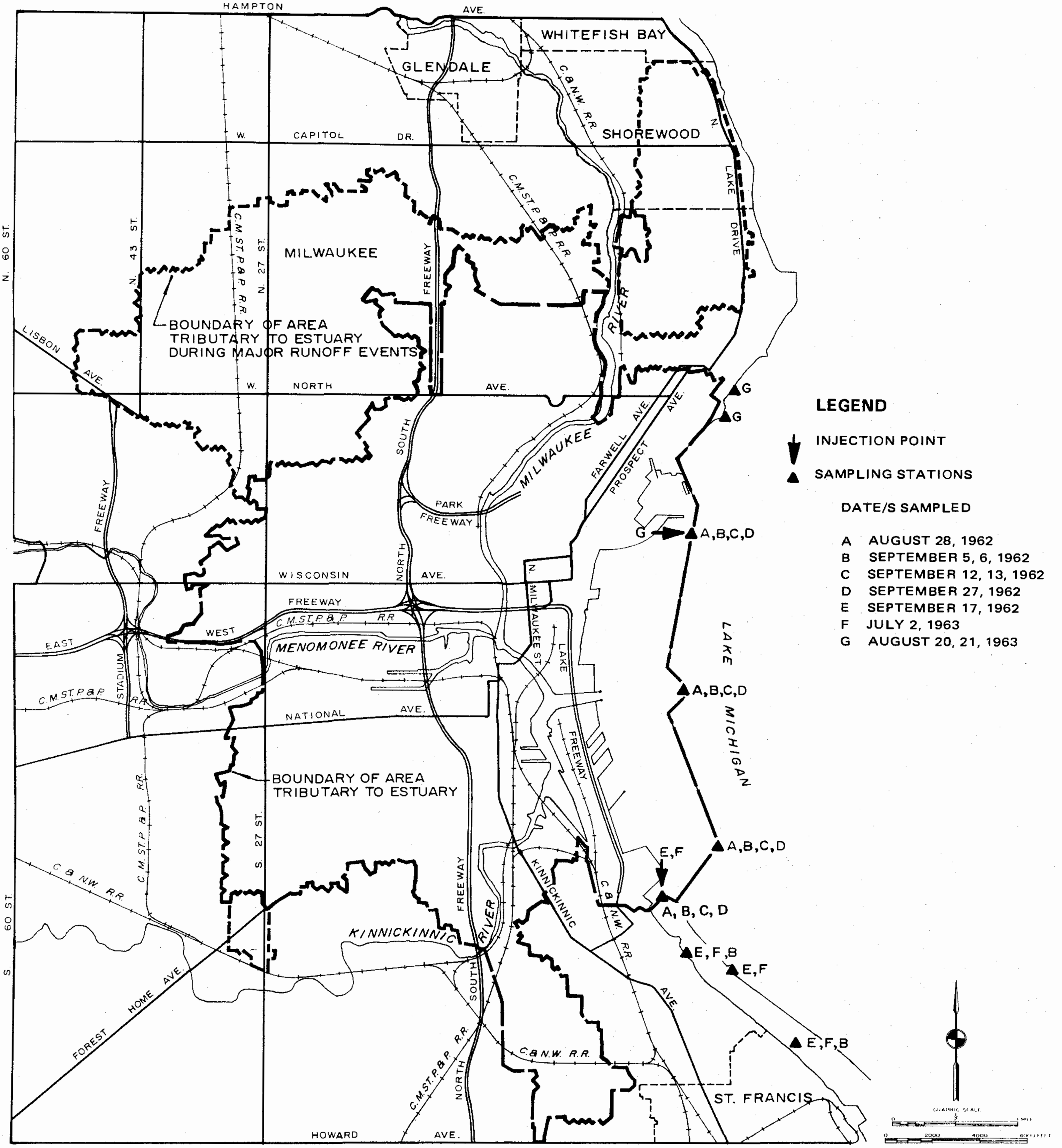
[51] *City of Milwaukee Health Department, "Dye Studies," 1962, Water Pollution Research Studies file, Room 105, Municipal Building.*

[52] *City of Milwaukee Health Department, "Drogue Studies," 1962, Water Pollution Research Studies file, Room 105, Municipal Building.*

[53] *U.S. Environmental Protection Agency, Detention Tank for Combined Sewer Overflow--Milwaukee, Wisconsin, Demonstration Project, Office of Research and Development, Research Report EPA-600/2-75-071, December 1975.*

Map 24

LOCATION OF SAMPLING STATIONS FOR FLUORESCENT DYE TRACER STUDIES IN MILWAUKEE HARBOR AND NEAR-SHORE LAKE MICHIGAN CONDUCTED BY THE CITY OF MILWAUKEE HEALTH DEPARTMENT: SUMMERS OF 1962 AND 1963



Source: SEWRPC.

Table 64

DATES, WIND DIRECTION, AND WIND SPEED FOR DYE STUDIES IN THE OUTER HARBOR CONDUCTED BY THE CITY OF MILWAUKEE HEALTH DEPARTMENT: 1962 AND 1963

Date	Predominant Wind Direction	Average Wind Speed (miles per hour)
August 28, 1962	SW	--
September 5-6, 1962	NW-N	10
September 12-13, 1962	SSW	15
September 17, 1962	W-WNW	18
September 27, 1962	N	16
July 2, 1963	NW	15
August 20-21, 1963	SW-SE	--

Source: City of Milwaukee Health Department and SEWRPC.

Table 65

DATES, WIND DIRECTION, AND WIND SPEED FOR DROGUE STUDIES IN THE OUTHER HARBOR CONDUCTED BY THE CITY OF MILWAUKEE HEALTH DEPARTMENT: JULY AND AUGUST 1962

Date	Predominant Wind Direction	Average Wind Speed (Miles per Hour)
July 5 and 6	--	--
July 17	NNE-NE	9
July 19	S	12
July 24	SW	10
July 26	NW-NNW	14
August 2	SE	11
August 7	W and E	8

Source: City of Milwaukee Health Department and SEWRPC.

storing CSO from a 570 acre area was built at Humboldt Avenue and the Milwaukee River. Data for the study were collected intermittently from July 1967, through November 1972, and included monitoring of rainfall, combined sewers and CSO, the Lake Michigan flushing tunnel discharge, and the Milwaukee River for pre- and post-construction periods. Characterization of dry and wet weather sewer and river flow quantity and quality was deemed necessary to fully evaluate the effectiveness of the detention tank upon river water quality. For simulation modeling purposes, water quality boundary conditions in the Menomonee and Kinnickinnic River estuaries required collection of some data in these reaches also. Locations of river quality sampling stations are shown on Map 25. Water quality parameters analyzed are listed in Table 66. Periods for which sampling was conducted at each monitoring site are presented in Table 67. A complete chronological listing of daily water quality data collected is presented in Volume III of Humboldt Avenue Pollution Abatement Project, which also groups data for a 48-hour intensive water quality sampling survey made September 12-14, 1970; an eight-day dry weather sampling survey made May 17-24, 1972; and a nine-day wet weather survey made August 16-24, 1972.[54] Volume III also organizes data collected by season, e.g., all data collected during spring months are grouped together, as are data for the other seasons--except winter--for the period 1967-1972. The last section of Volume III sets forth all dissolved oxygen (DO) measurements. Continuous DO and temperature monitoring was done automatically at stations established at Cherry Street, St. Paul Avenue, and on both the upstream and downstream sides of the North Avenue dam. Only a limited amount of useful DO data was collected at these four sites, however, because of chronic probe malfunctions due in large part to periphyton growths.

To evaluate factors affecting water quality in the Milwaukee River, a two dimensional (lateral and longitudinal) water quality simulation model was applied and included not only the Milwaukee River study reach, but also the Menomonee and Kinnickinnic River estuaries, the outer harbor, and Lake Michigan near the main entrance to the outer harbor. Simulation model segments are shown on a map in the USEPA Research Report (page 207). Good model verification was reported for dry weather conditions, but for wet weather conditions, significant differences between simulated and observed dissolved oxygen occurred at St. Paul Avenue and downstream. The modeling study concluded that factors having a significant influence upon the quality of the Milwaukee River downstream from the North Avenue dam included upstream water quality variation, algal and macrophyte activity above and below the dam, flushing tunnel operation, benthic oxygen demand, urban nonpoint source pollutant loads, combined sewer overflows, and water quality and pollutant loadings from the Menomonee River during wet weather conditions.

Milwaukee River Alewife Air Curtain Experiment

Because of problems with large numbers of dead alewives floating in the Milwaukee River between the North Avenue dam and the confluence with the Menomonee River, the City of Milwaukee Health Department conducted an experiment in the summer of 1964 to determine the feasiblity of inhibiting alewife migration into the Milwaukee rivers from Lake Michgan by the use of an air bubble curtain. The study was initiated by the Milwaukee River Technical Study Committee, at the request of the Mayor of the City of Milwaukee on July 5, 1963. The committee was comprised of city and county officials, and the study report is contained in its entirety in "The Effectiveness of an Air Bubble Curtain in Stopping, Reducing, or Redirecting Migration of Alewives

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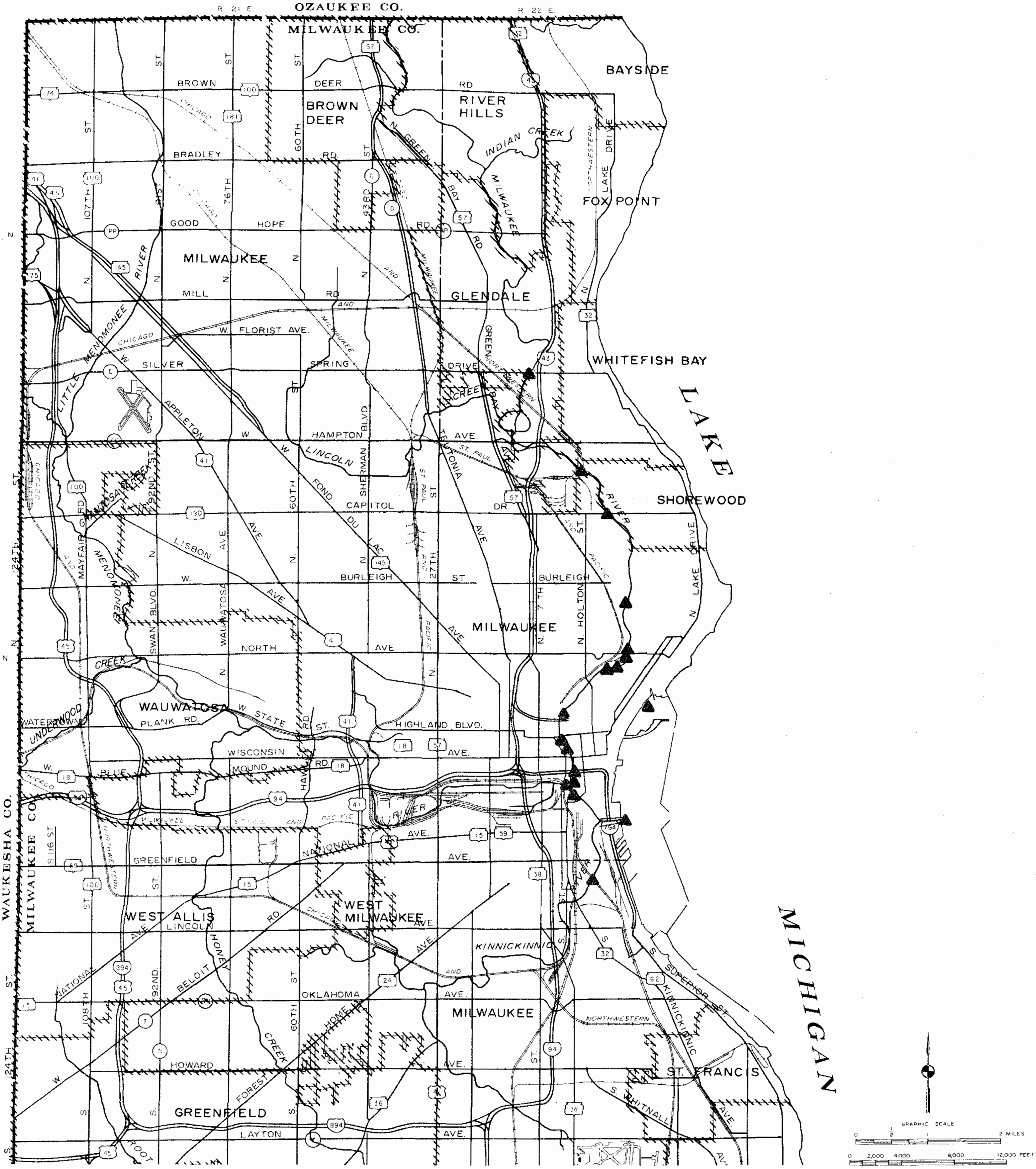
[54] *Consoer, Townsend and Associates, Humboldt Avenue Pollution Abatement Project, Volume III, "Appendix II" and "Appendix III," September 1974.*

Map 25

LOCATION OF WATER QUALITY SAMPLING STATIONS IN THE MILWAUKEE HARBOR ESTUARY SAMPLED FOR THE HUMBOLDT AVENUE COMBINED SEWER OVERFLOW DETENTION TANK STUDY FOR THE CITY OF MILWAUKEE: 1967-1972



Source: U.S. Environmenal Protection Agency, Office of Research and Development, Research Report EPA-600/2-75-071, December 1975.

Table 66

LIST OF WATER QUALITY PARAMETERS MONITORED IN THE MILWAUKEE HARBOR ESTUARY FOR THE COMBINED SEWER OVERFLOW DETENTION TANK STUDY FOR THE CITY OF MILWAUKEE: 1967-1972

Parameters	
Water Temperature	Kjeldahl Nitrogen
pH	Ammonia Nitrogen
Conductivity	Nitrite Nitrogen
Chemical Oxygen Demand	Ortho Phosphate
Dissolved Oxygen	Total Phosphate
Chlorides	Total Solids
Total Coliform	Total Suspended Solids
Fecal Coliform	Total Volatile Solids

NOTE: Sampling site locations are shown on Map 25. Sampling periods for each site are listed in Table 67.

Source: U.S. Environmental Protecion Agency, Office of Research and Development, Research Report EPA-600/2-75-071, December 1975.

Table 67

SAMPLING STATION MONITORING PERIODS IN THE MILWAUKEE HARBOR ESTUARY FOR THE COMBINED SEWER OVERFLOW DETENTION TANK STUDY FOR THE CITY OF MILWAUKEE

Sampling Station[a]	Year and Season[b] of Sampling				
	1967	1968	1969	1970	1972
40............	A,W	Su,A	--	--	S,Su
47............	--	--	--	--	S,Su
50............	Su,A,W	S,Su,W	--	--	--
52............	--	Su,A,W	S,A,W	S,A	S,Su
53............	--	Su,A,W	S	--	--
54............	Su,A	--	--	--	--
58............	Su,A	Su,A,W	S,Su,A	S,A	S,Su
59............	--	--	--	--	S,Su
62............	--	S,Su,A,W	S	--	S,Su
64............	--	--	A	A	--
65............	--	--	--	--	S,Su
66............	--	--	--	S	Su
68............	Su,A	--	--	--	--
70............	Su,A	Su,W	--	--	--
72............	Su,A	--	S,W	--	--
74............	--	S,W	--	--	--
81............	--	--	--	--	S,Su
82............	--	--	--	--	S,Su

[a] *Sampling station locations are shown on Map 25.*

[b] *S-Spring (March, April, May); Su-Summer (June, July, August); A-Autumn (September, October, November); W-Winter (December, January, February)*

Source: U.S. Environmental Protection Agency, Office of Research and Development, Research Report EPA-600/2-75-071, December 1975.

Up the Milwaukee Rivers."[55] The experiment utilized a perforated plastic tube laid across the bottom of the Milwaukee River at the confluence with the Menomonee River. A compressor pumped air through the tube, emitting a curtain of bubbles across the river in an effort to deter alewives from crossing the bubble barrier into the upper reaches of the estuary. The experiment was run for about seven weeks, beginning May 11 and ending June 30, 1964. The Milwaukee River flushing tunnel was not operated during the study period until June 16, when water quality conditions became critical. As part of the study, water quality data were collected for dissolved oxygen, water temperatures, pH, and turbidity. Samples were taken on 22 days for both 6-foot and 15-foot depths and both upstream and downstream from the air curtain three days per week. Occasional samples were taken in the Menomonee and Kinnickinnic Rivers, as well as further upstream on the Milwaukee River up to the North Avenue dam. This report in The Milwaukee River tabulates the water quality data for each individual sample taken at the Milwaukee River sites near the air curtain, and also provides mean and median values for each parameter measured. Remaining water quality data are on file at the health department. Of the 22 days sampled, 17 days represented natural flow conditions, and five days represented conditions with flow augmentation. The data indicated that dissolved oxygen levels just downstream from the air curtain were slightly lower than just upstream. The study found that the air bubble barrier had a significant effect upon lowering alewife populations upstream from the barrier.

UNIVERSITY OF WISCONSIN-MILWAUKEE

The University of Wisconsin at Milwaukee (UWM) has conducted or participated in numerous studies of near-shore Lake Michigan and Milwaukee Harbor. Pertinent UWM studies described in the following paragraphs concern urban freeway runoff pollution, the ongoing Milwaukee Harbor and near-shore Lake Michigan study initiated in 1979 for the Milwaukee Metropolitan Sewerage District, two Lake Michigan bibliographies prepared by UWM, and eight other studies related to Lake Michigan near the Milwaukee area, which are relevant to the design and conduct of a Milwaukee Harbor estuary water resources management planning study.

Urban Freeway Stormwater Runoff Quality Study

In 1972 and 1973 UWM faculty and staff collected storm water runoff samples from two urban freeway catchment areas for chemical analyses in a study to quantify and qualify pollutant loadings from these catchments to receiving waters. The catchments monitored were a 34-acre site discharging into the Menomonee River at State Street, and an 8-acre site discharging to the Menomonee River at the Milwaukee County Stadium interchange. A total of 98 samples were collected during the 13-month period from June 1972 to July 1973, and were analyzed for chemical and bacteriological content. Parameters analyzed are listed in Table 68. Tables in the appendices of Quality of Urban Freeway Stormwater present raw data, and a summary

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[55] *George A. Kupfer, "The Effectiveness of an Air Bubble Curtain in Stopping, Reducing, or Redirecting Migration of Alewives up the Milwaukee Rivers," The Milwaukee River, Milwaukee River Technical Study Committee, 1968.*

Table 68

WATER QUALITY PARAMETERS ANALYZED FOR MILWAUKEE FREEWAY STORM RUNOFF SAMPLES COLLECTED BY THE UNIVERSITY OF WISCONSIN-MILWAUKEE: 1972-1973

Parameters	
5-Day BOD	Phosphate-Phosphorus[a]
Water Temperature	Total Solids
Air Temperature	Volatile Total Solids
Dissolved Oxygen	Suspended Solids
Total Organic Nitrogen	Volatile Suspended Solids
Ammonia Nitrogen	Chlorides
Nitrate Nitrogen	Calcium Chloride
Nitrate and Nitrite Nitrogen	Lead
Fecal Coliforms	Calcium[a]
pH	Magnesium[a]
Total Phosphorus	Sodium[a]

[a] *Analyzed for February 1972 samples only.*

Source: James Jodie, Quality of Urban Freeway Stormwater, University of Wisconsin-Milwaukee, Department of Systems Design, Masters Thesis, June 1974.

table presents the average and the range of the values observed for each of the water quality parameters.[56] Runoff quantity was not monitored.

The study found very high concentrations of sodium chloride and total solids, found that nitrogen compounds and total phosphorus were "nominal" in concentration, and that dissolved oxygen in freeway runoff was very near or equal to the saturation concentrations. Chloride concentrations occurred at high levels in the winter and spring and were influenced by road salting, snow or rain, and air temperature patterns. Five-day biochemical oxygen demand (BOD) was generally much higher than the effluent from the Jones Island wastewater treatment plant, and suspended solids concentrations were similar to those of raw sewage. Total organic nitrogen and total phosphorus in the freeway runoff was much lower than that of the Jones Island effluent, however.

Fecal coliform counts were much higher than levels suitable for recreational water use, and lead concentrations were much higher than the allowable drinking water standard. A "first slug" of contaminants was generally observed in the form of high concentrations during the first hour of a storm. During snowstorms, high concentrations of pollutants--such as lead--associated with snow contamination from vehicle exhausts were reportedly observed, as well as pollutants associated with roadway salting. In general, pollutants in freeway runoff were found to occur at levels well above the 1968 Wisconsin water quality standards for preservation and enhancement of aquatic life and recreational use.

Wastewater Management Study of Milwaukee Harbor and Near-Shore Lake Michigan

At the request of the Milwaukee Metropolitan Sewerage District, UWM in 1979 initiated a study of Milwaukee Harbor and near-shore Lake Michigan to: 1) provide biological and chemical water quality data against which future data could be compared; 2) determine mixing and transport patterns of MMSD effluent plumes from the Jones Island and South Shore wastewater treatment plants for a range of meteorological conditions; 3) determine dispersion and dieoff characteristics of indicator pathogenic bacteria, and evaluate the utility of indicator viruses; and 4) to mathematically model the effluent plume characteristics. The study was scheduled for completion of field work by January 1981, and report preparation by October 1981.

Baseline Water Quality Monitoring: Beginning in March 1979, an initial network of 65 sampling stations in Milwaukee Harbor and near-shore Lake Michigan was established to develop an optimized water quality monitoring network for future sampling and to provide data for evaluation of pollutant gradients and direction of pollutant transport. Numerous such stations were sampled in the outer harbor, the anchorage area south of the outer harbor, along the outer periphery of the breakwater protected areas, and further offshore between Fox Point and Wind Point. Parameters suitable for automated shipboard analysis and for tracing sewage effluent plumes were measured at all 65 stations by drawing water continuously from a depth of two meters as the UWM research vessel, USS Neeskay, moved from station to station. Water quality data were recorded at two second intervals by an onboard computer. Vertical profiles of the same chemical parameters were also taken at selected locations, as were complete chemical analyses. Sampling cruises were made every other month beginning in March 1979, with additional cruises conducted during episodic storm events or

[56] *James Jodie, Quality of Urban Freeway Stormwater, University of Wisconsin-Milwaukee, Department of Sytems Design, Masters Thesis, June 1974.*

other hydrologic events. The chemical water quality parameters analyzed are listed in Table 69. Water quality data are stored on magnetic tape at UWM and at MMSD. A description of sampling and laboratory procedures is provided in the study proposal submitted to MMSD.[57] The 1979 data were used in part to design an efficient long-term monitoring network containing fewer sampling stations, but with more complete chemical analyses.

Mixing and Dispersion Study of MMSD Effluents: During the first year of the UWM Milwaukee Harbor and near-shore Lake Michigan study, dye and current studies were initiated near the outfalls of the Jones Island and South Shore wastewater treatment plants to provide a "quantitative description of the mixing, dilution, and dispersion characteristics of the existing MMSD sewage outfalls"[58] These studies were also intended to identify the locations of the effluent plumes for concurrent chemical and biological sampling. More specifically, the objectives of this phase of the UWM study were: 1) "to determine the horizontal extent of the effluent dispersion from the Jones Island and South Shore outfalls and their relation to the horizontal circulation in the harbor and lake;" 2) "to determine the vertical distribution of the effluents at both outfalls;" 3) "to determine the rate of mixing and dilution of the effluents and the nature of its transport in the Milwaukee Harbor and at the South Shore plant;" and 4) "to provide field identifications of effluent distribution for subsequent guidance for water quality monitoring locations."

Rhodamine WT dye was injected into the Jones Island effluent on June 21, August 21, and October 9, 1979, and the dispersion through the outer harbor was monitored horizontally and vertically. A shipboard computer plotted the plume to guide the sampling effort. Water temperatures were measured at multiple depths during the dye tracing periods, as were current speed and direction. Dye studies were coordinated with biological and chemical sampling efforts. Additional dye studies were scheduled for 1980. Computer programs were developed to edit, correct, and plot the extensive dye sampling and current meter data for use in statistical and graphical analyses. Data are on computer file at UWM and are being transferred to MMSD.

Microbiological Studies: The objectives of the UWM Milwaukee Harbor and Near-shore Lake Michigan microbiological study were: 1) to provide baseline bacteriological water quality data; 2) to determine die-off rates of indicator bacteria originating in MMSD effluents; and 3) to isolate and identify polioviruses and closely related enteroviruses from samples collected in the Milwaukee Harbor and adjacent Lake Michigan, and, because man is the only known host of poliovirus, to quantify their presence for use in detection of potential human pathogens.

For the bacteriological studies samples were collected in May 1979, and monthly from July through December, 1979, in areas exhibiting typical overall water quality and under a range of weather conditions. In addition, sampling was conducted in May 1979, after a heavy rainfall event, and during an extremely dry period in October 1979. Samples were collected at discrete depths along with bottom sediment samples for bacterial counts. Bacteria die-off kinetics for each season of the year were scheduled for study in 1980. Bacteria monitored were total coliforms, fecal coli-

[57]*University of Wisconsin-Milwaukee, "An Investigation of the Biological and Chemical Water Quality and the Dispersion of Sewage Effluents in Milwaukee Harbor and Adjacent Lake Michigan," Study Proposal submitted to MMSD, January 1979.*
[58]*Ibid.*

Table 69

BASELINE WATER QUALITY PARAMETERS ANALYZED IN MILWAUKEE HARBOR AND NEAR-SHORE LAKE MICHIGAN BETWEEN FOX POINT AND WIND POINT BY THE UNIVERSITY OF WISCONSIN-MILWAUKEE: 1979-1980

Parameters	
Ammonia Nitrogen	Total Suspended Matter
Nitrite Nitrogen	Total Organic Carbon
Nitrate Nitrogen	Area
Total Kjeldahl Nitrogen	Turbidity[a]
Ortho-Phosphate	Conductivity[a]
Total Phosphorus	Chemical Oxygen Demand
Silica	Water Temperature[a]
Chlorophyll-a[a]	Dissolved Oxygen[a]
Total Alkalinity	pH[a]
Chloride	Fluorescence[a]

[a]*Monitored at all 60 sampling stations and continuously between sampling stations.*

Source:

UWM, "An Investigation of the Biological and Chemical Water Quality and the Dispersion of Sewage Effluents in Milwaukee Harbor and Adjacent Lake Michigan," Study Proposal submitted to MMSD, January 1979.

forms, Escherichia coli, fecal streptococcus, and Clostridium perfringens. For the virus studies, technical problems necessitated the development and testing of a methodology for detection and quantification. Quantification of viruses in Jones Island influent was successfully achieved in 1979 for two samples.

Effluent Plume Modeling: For design of a water quality monitoring program and for water quality assessment, UWM research staff will characterize Jones Island and South Shore effluent plume parameters using multiple linear regression analysis and dye tracer study data for a range in environmental and effluent conditions. Historical weather and lake conditions data were collected and analyzed to identify a set of typical conditions for preparation of a field sampling schedule. Rhodamine WT dye will be injected into the effluent streams of the two treatment plants and traced in the receiving waters. Resulting dye plumes will be mapped, and plume characteristics determined therefrom using step-wise regression. Stochastic models will be developed for a set of typical conditions and verified with independent sets of data for each typical condition. The verified models will then be used to simulate effluent plumes for a range of hypothetical effluent conditions and environmental conditions.

Milwaukee Harbor Bathymetric Mapping, 1980: A high-resolution bathymetric map of the outer harbor and the lower inner harbor was prepared in early 1980 to assist in ongoing hydraulic and water quality studies by UWM. The M/V Neeskay used sonic and leadline sounding methods, radar for horizontal location, and an onboard computer to prepare continuous sounding data for mapping by a Calcomp Plotter. A map was prepared at the same scale as the Army Corps of Engineers harbor map, based on conventional methods. Significant differences were noted. Using computer plotting, the UWM bathymetric map can be prepared in a variety of scales, depending on user requirements. A copy of the map can be examined at the UWM Civil Engineering Department.

Benthic Sediment and Biota Survey of Milwaukee Harbor, 1973

An intensive survey of the outer harbor and the lower inner harbor was carried out in July, 1973, by UWM in a thesis study of the distribution of Sphaeriidae (fingernail clams) in the harbor. One hundred sites were sampled using a Ponar grab sampler for benthic biota and bottom sediment characteristics with ten of the sites being in the inner harbor and the remainder of the sites being spaced in a grid network in the outer harbor, but excluding the McKinley Marina mooring area. Study of the distribution of Sphaeriids in relation to bottom sediment characteristics was based on a two-day sampling effort during which sediments were also collected for determination of grain size distribution, organic content, and sediment oxygen demand (SOD). SOD was measured at fifty of the sampling sites in the laboratory using fresh sediment and lake water and a dark incubation period of 30 minutes. Statistical analyses were performed on the biota identified and the 100 sediment samples collected. Philip J. Emmling's Masters Thesis contains maps showing sampling site locations and contours of organic content of sediments, percent sand, water depth, surface water temperature, living sphaeriids, and relict sphaeriids, along with numerous other maps, tables, and figures.[59] Data collected at each of the 100 sampling stations are contained in the Appendix of the Thesis.

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[59] *Philip J. Emmling, Factors Affecting the Distribution of Sphaeriidae (Mollusca: Pelecypoda) in the Milwaukee Harbor, Lake Michigan, University of Wisconsin-Milwaukee, Department of Zoology, Masters Thesis, 1976.*

The study found populations of living sphaeriids in the northern and southern near-shore portions of the outer harbor exceeding 500 per square meter. Poor habitats contained more than 40 percent silt-clay. SOD varied directly with organic content. Sphaeriid data indicated moderately enriched conditions rather than grossly polluted conditions in some areas of the harbor having sand substrates with low organic content.

Lake Michigan Bibliographies

UWM has prepared two bibliographical reports useful in preparation of the design and conduct of the Milwaukee Harbor estuary water quality management planning study. The "Bibliography of Lake Michigan Shore Erosion and Near-Shore Process Studies" is a partially annotated bibliography containing references concerning shoreline erosion and near-shore processes conducted on the Great Lakes and the coastal system of southeastern Wisconsin.[60] The references are subdivided into the following topics: topographic map references and Great Lakes Bathymetric charts; general geology, geomorphology, and physiography; lake currents, water levels, and general water quality; physical processes; shoreline protection; bibliographies; general studies of Lake Michigan; and examples of shore erosion studies from areas other than Lake Michigan.

Another bibliography on plankton investigations cites the sources of information concerning plankton from all five of the Great Lakes and St. Clair, Nipigon, and Nipissing Lakes.[61] The information cited specifically addresses plankton in water quality investigations, and as food for fishes.

Miscellaneous Studies

Eight additional studies conducted by UWM, and of particular relevance to the Milwaukee Harbor estuary study design, are briefly summarized below. Additional details are available in the cited references.

1. A study of the general physical limnology of Lake Michigan was published in 1975 and describes the physical characteristics of Lake Michigan, including basin geomorphology, water budget, light penetration and heat budget. In addition, wind-driven currents and typical circulation patterns, gravitational and frictional forces acting upon the lake, seasonal cycles, stratification, and heat distribution are described. This report also identifies and discusses theoretical models which estimate and describe dispersal, local concentrations, mixing rates, and other physical processes involved in pollution diffusion and dispersion.[62]

2. Another physical limnology study of near-shore lake currents and temperatures was also published in 1975 and describes the variability of near-

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[60] *Norman P. Lasca, D. Baier, P. Curth, W. Bauman, and J.H. Smith, "Bibliography of Lake Michigan Shore Erosion and Near-Shore Process Studies," funded by the University of Wisconsin-Extension and by the Center for Great Lakes Studies, University of Wisconsin-Milwaukee, SEWRPC Technical Record Volume 4-No. 2, March 1981.*

[61] *John E. Gannon, Great Lakes Plankton Investigations: A Bibliography, University of Wisconsin-Milwaukee, Center for Great Lakes Studies Special Report No. 7, 1969.*

[62] *C.H. Mortimer, "Physical Characteristics of Lake Michigan and Its Responses to Applied Forces," Environmental Status of the Lake Michigan Region, Volume 2, Part I, Argonne National Laboratory, June 1975.*

shore current regimes and temperature fields in the area of the Wisconsin Electric Power Company's fossil-fuel power plant at the City of Oak Creek. The results are discussed from studies of ambient lake motions into which the plumes were discharged and the characteristics of sinking plumes in winter. Current, temperature, and wind data collected at inshore and offshore stations are included along with a descriptive text on the characteristics of coastal currents and lake stratification in coastal regions of Lake Michigan.[63]

3. A study describing phytoplankton pigments and nutrients was published in 1977 and contains a detailed discussion and supportive data from investigations conducted on the water quality and phytoplankton standing crop productivity of the inner and outer portions of the Milwaukee Harbor.[64]

4. A report on temporal and spatial changes in primary production and nutrients in Lake Michigan was published in 1976 and contains a discussion of the results from investigations conducted to determine the spatial and temporal distribution of primary production as well as several physical and chemical parameters in Lake Michigan. Differences between inshore and offshore areas were observed for several measures of physical and chemical productivity. Seasonal variations were also observed for phytoplankton populations, and for various physical and chemical parameters.[65]

5. In 1974 a paper was published on temporal and spatial distribution of planktonic rotifers in Milwaukee Harbor and adjacent Lake Michigan The data indicate that significant inshore-offshore differences in abundance and species composition exist in the Lake Michigan rotifer populations.[66]

6. A paper on the horizontal distribution of crustacean zooplankton across Lake Michigan was published in 1975 and discusses large-scale variations in horizontal distribution of crustacean zooplankton in Lake Michigan. The inshore-offshore variations in 1969 and 1970 were recorded. Zoo-

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[63]*S.K. Sato and C.H. Mortimer, Lake Currents and Temperatures Near the Western Shore of Lake Michigan, University of Wisconsin-Milwaukee, Center for Great Lakes Studies Special Report No. 22, March 1975.*
[64]*Max L. Bothwell, Studies on the Distribution of Phytoplankton Pigments and Nutrients in the Milwaukee Harbor Area, University of Wisconsin-Milwaukee, Center for Great Lakes Studies Special Report No. 25, 1977.*
[65]*D.C. Rousar, "Seasonal and Spatial Changes in Primary Production and Nutrients in Lake Michigan," University of Wisconsin-Milwaukee, Center for Great Lakes Studies Contribution No. 82, and in Water, Air, and Soil Pollution, Volume 2, 1976.*
[66]*Richard S. Stemberger, "Temporal and Spatial Distributions of Planktonic Rotifers in Milwaukee Harbor and Adjacent Lake Michigan," University of Wisconsin-Milwaukee, Center for Great Lakes Studies Contribution No. 121, and the Proceedings of the 17th Conference, Great Lakes Research, International Association for Great Lakes Research, 1974.*

plankton populations were observed to be generally uniform during all seasons except summer.[67]

7. A study of the effects of harbor dredge materials on plankton and benthos was published in 1969, and describes methods developed and results obtained concerning the physical and chemical characteristics and the effects on the biota of dredge sediments from harbors located on the Great Lakes. Milwaukee Harbor sediments were sampled in May of 1968 as part of this investigation. Specific data concerning bioassays of benthic organisms, benthic algae, phytoplankton and daphnia in culture are included.[68]

8. A report on the effects of chlorine and sulfite reduction on Lake Michigan invertebrates was published in 1976 and describes both laboratory studies and field studies in the Milwaukee Outer Harbor and adjacent Lake Michigan. The study found that significant reductions in benthic organisms occurred in a small area near the Jones Island effluent plume, and attributed these reductions to the effects of chlorination.[69]

WISCONSIN ELECTRIC POWER COMPANY

The Wisconsin Electric Power Company (WEPCO) has collected water quality data in the Milwaukee River Harbor estuary for use in the operation of their power plants, as well as for environmental studies concerning the effects of exisiting and proposed power plant operations. Three WEPCO plants are located in the inner harbor, and three others are located on Lake Michigan at St. Francis (Lakeside), at Oak Creek, and at Port Washington. Map 26 shows the locations of the plants. Data collected by WEPCO for the Milwaukee River Harbor estuary include physical, biological, and chemical water quality. These will be useful in the preparation of the study design. The studies and projects pertinent to a comprehensive Milwaukee Harbor estuary subwatershed planning program include intake and outfall water temperature data, water intake impact on aquatic organisms, intake water chlorination studies, and thermal discharge effects on the aquatic community. The specific data collected by WEPCO, which may be used as part of the proposed planning program, are discussed in the following sections of this chapter.

Intake and Outfall Water Temperature Monitoring

Long-term intake water temperature data have been collected at the Valley Power Plant on the Menomonee River, the Commerce Street power plant on the Milwaukee River, and the Lakeside, Oak Creek, and Port Washington power plants on Lake Michigan. These data were originally collected for optimization of power plant operations. However, since 1972, the intake water temperature data have been required by

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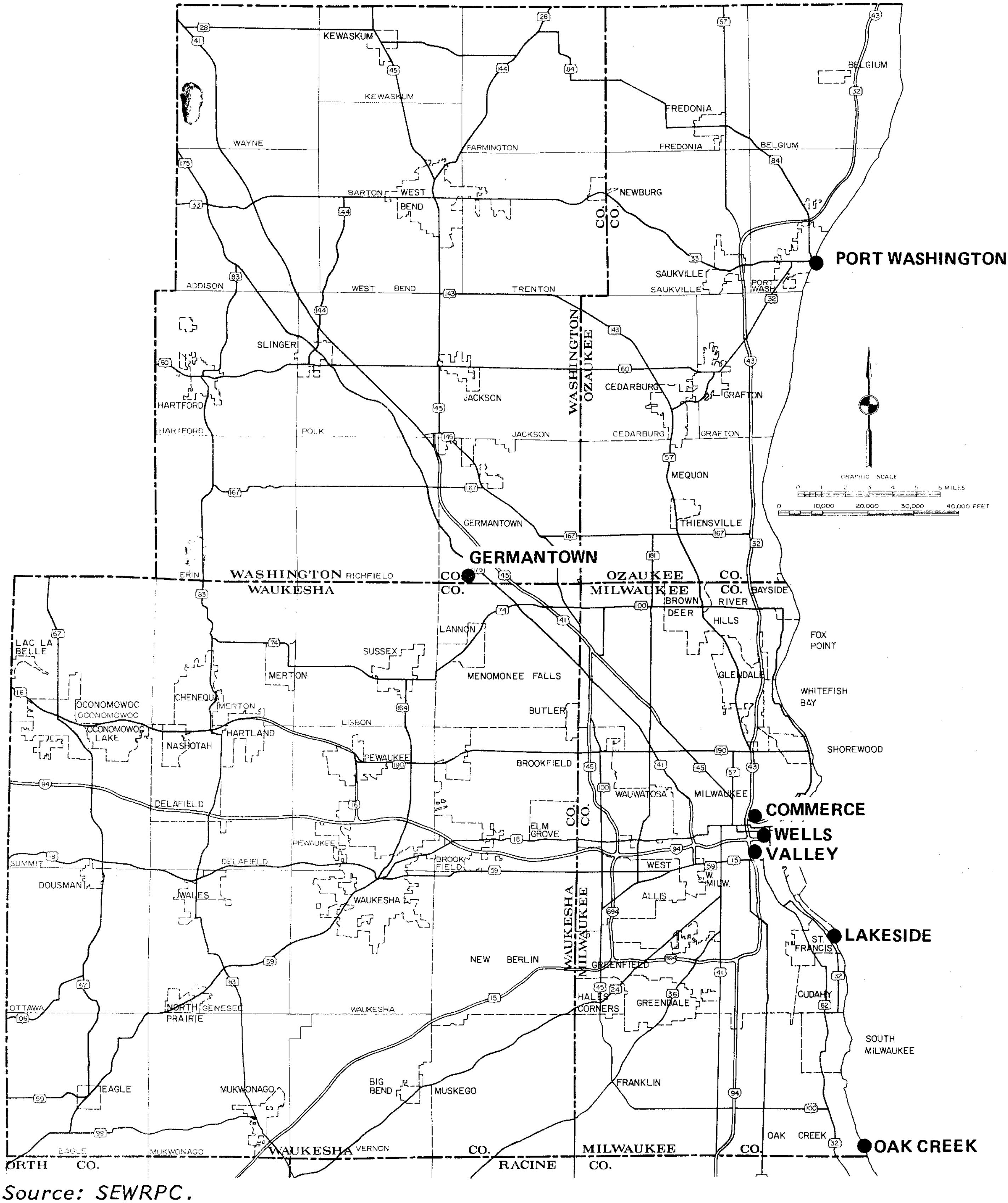
[67]John E. Gannon, "Horizontal Distribution of Crustacean Zooplankton Along A Cross-Lake Transect in Lake Michigan," University of Wisconsin-Milwaukee, Center for Great Lakes Studies Contribution No. 136, and the Journal of Great Lakes Research, Volume I, October 1975.

[68]John E. Gannon, and A.M. Beeton, Studies on the Effects of Dredged Materials from Selected Great Lakes Harbors on Plankton and Benthos, University of Wisconsin-Milwaukee, Center for Great Lakes Studies Special Report No. 8, 1969.

[69]A.M. Beeton, P.K. Kovacic, and A.S. Brooks, Effects of Chlorine and Sulfite Reduction on Lake Michigan Invertebrates, U.S. Environmental Protection Agency Research Report No. EPA-600/3-76-036, April 1976.

Map 26

LOCATIONS OF POWER PLANTS OPERATED BY THE WISCONSIN ELECTRIC POWER COMPANY IN THE LAKE MICHIGAN BASIN IN SOUTHEASTERN WISCONSIN



Source: SEWRPC.

the Wisconsin Department of Natural Resources as part of the Wisconsin Pollution Discharge Elimination System (WPDES) program. The intake temperature data collected since 1972 have been computerized and daily summaries are available for maximum, minimum, and mean water temperature for intake and outfall discharges. Prior to 1972, only intake temperature data were available. Intake temperatures represent not only ambient water temperatures, but also may be useful for identification of intrusions by Lake Michigan waters into the inner harbor, upwellings and downwellings, and seiche effects on near-shore and estuarine water temperature variability and duration.

Water Intake Impact on Aquatic Organisms

A one-year intake monitoring study required under the WPDES program at the Commerce Street power plant was undertaken from March 1975 through February 1976. The purpose of the study was to determine the environmental impact of the intake system with the inlet being two adjacent openings, each measuring 9.5 feet wide by 12 feet high and covered by a steel bar trash rack with 5-inch gaps. Maximum daily intake is about 83 cubic feet per second. Studies of fish impingement on one-half inch mesh intake screens, and egg and larvae entrainment in the intake water were made. Map 27 shows the location of the Commerce Street power plant in the Milwaukee River estuary along with the locations of the Valley, Wells Street, and Lakeside power plants.

Fish samples were collected on 45 days throughout the study year with 1,063 fish representing 17 species collected. Of the fish collected, 81 percent were alewife and 8 percent were goldfish. The remaining were all warmwater and Lake Michigan species referred to as "pollution tolerant". A summary of the fish impingement data is presented in Table II-1 of the Commerce Street Power Plant Final Report. The data included are sampling date, percent volume sampled, species, number, mean weight, mean length, range in length, and breeding state. Sampling methods are also detailed in the report.[70]

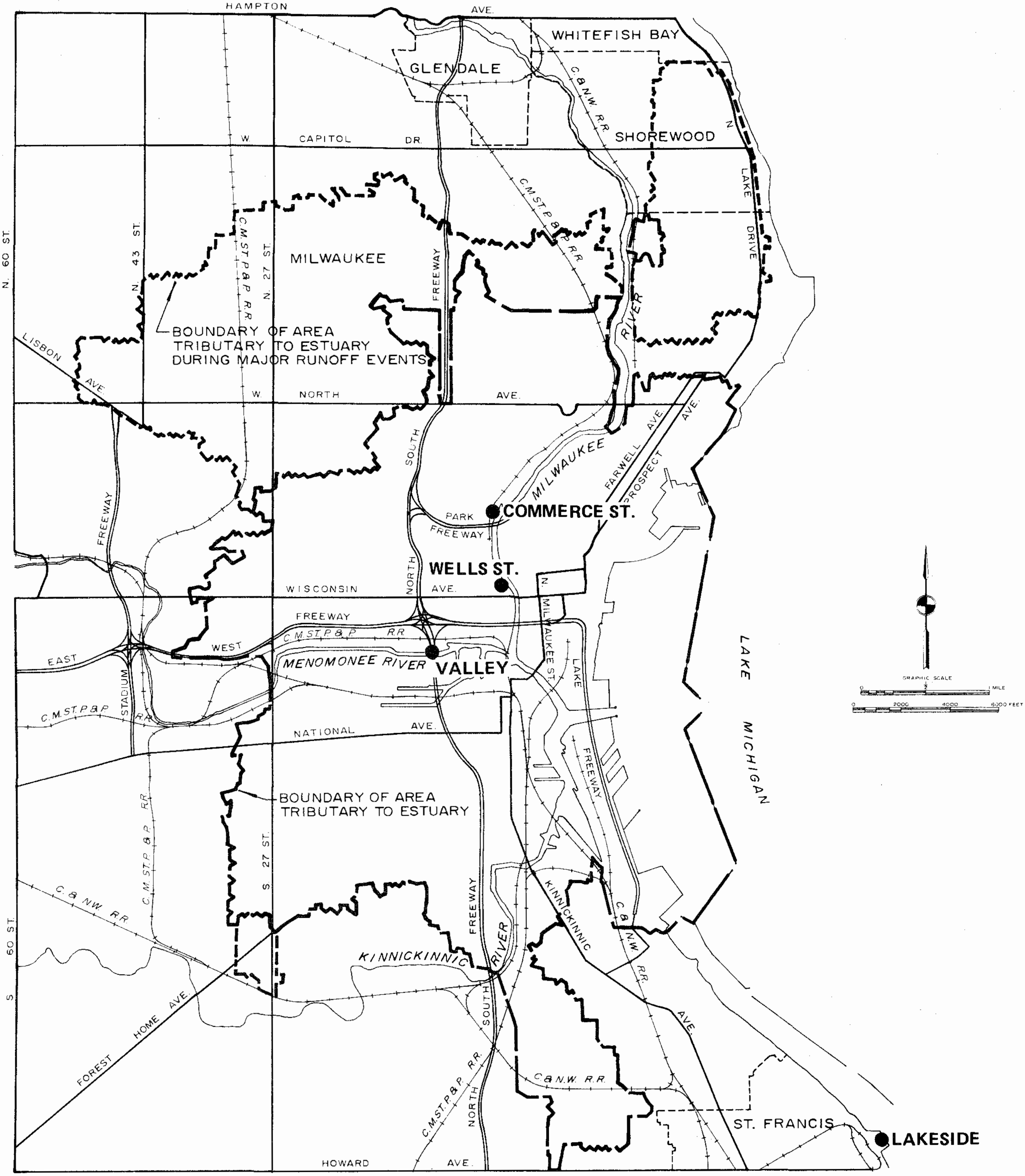
Entrainment sampling was conducted from April through October 1975 when 23 samples were taken. The samples contained a total of 89 fish fry of which 76 were goldfish and 13 were fathead minnow. Fertilized eggs collected were 2,282 alewife, nine goldfish, and one golden shinner. A summary of the fish egg and fish fry data is represented in the Commerce Street Power Plant Final Report, Table II-2. The data included are sampling date, water volume sampled, percent of intake volume species, and number per cubic meter. Sampling methods are also detailed in the report.

The study concluded that about 6,150 fish were impinged at the power plant during the sampling year, with alewife comprising about 81 percent by number (60 percent by weight) and rough fish about 9 percent (30 percent by weight). Intake velocities were low enough that nearly all viable fish could avoid being drawn into the intake. It was estimated that about 240,000 fish fry were entrained during the April to October study period, and almost three million fertilized fish eggs, nearly all of which were alewife. Fish egg entrainment was estimated to represent that produced by a total of about 275 females. The report concluded that a negligible impact on the fish population was caused by the intake system because the species sampled were prolific and undesirable.

[70]*Wisconsin Electric Power Company, Commerce Street Power Plant Final Report, WPDES Intake Monitoring Studies, June 1, 1976.*

Map 27

LOCATIONS OF THE COMMERCE STREET, VALLEY, WELLS STREET, AND LAKESIDE POWER PLANTS OPERATED BY THE WISCONSIN ELECTRIC POWER COMPANY



Source: SEWRPC.

A one-year intake monitoring study was also conducted at the Valley power plant on the lower Menomonee River with the same study period and purpose as that for the Commerce Street power plant study. Studies of fish impingement upon a 3/8 inch mesh screen, and egg and fry entrainment were made; the water intake is a slot about 40 feet long and two feet high located about two feet above the river bottom where the depth is about 23 feet. The study is described in the Valley Power Plant Final Report, which stated that it is probable that most fish avoid the Valley plant intake because of its location near the bottom below the photic zone.

Fish samples were collected on 90 days throughout the study year, with 2,979 fish representing more than 15 species collected. Of the fish collected, 78 percent were alewife, 10 percent were goldfish and 0.3 percent were trout. The remainder were all warmwater and Lake Michigan species, none of which were threatened or endangered species. A summary of the fish impingement data is presented in Table II-1 of the Valley Power Plant Final Report. Sampling methods are detailed in the report.[71]

Entrainment sampling was conducted from April through October 1975 when samples were collected on 50 days. Six goldfish fry in one sample were all that was found entrained in the intake water. Sampling methods are detailed in the report.

The study concluded that about 18,500 fish were impinged on the intake screen during the study year, with alewife comprising about 77 percent by number (33 percent by weight), rough fish 14 percent (44 percent by weight), and smelt 5 percent (8 percent by weight). Trout comprised only about 0.3 percent (3.0 percent by weight). Relative to the size of the Lake Michigan fishery from which the more desirable species originate, the impact of the intake system was considered negligible. Because only six fry were entrained during the study period, the impact of the intake system was considered negligible upon egg and fry survival.

Intake Water Chlorination Study

An evaluation of environmental effects of chlorination of intake water at the Valley power plant and the Oak Creek plant was conducted by WEPCO during 1977 and 1978. The purpose of the study was to determine optimal chlorination rates of intake water for control of condensor biofouling with resulting outfall concentrations not in excess of chlorine effluent limitations. Chlorination rates were varied to evaluate the effect upon biofouling rates of test condenser tubes. Total residual chlorine effluent concentrations averaging less than two milligrams per liter were maintained during the study period. Free available chlorine comprised, on the average, 70 percent of the total residual chlorine in the effluent. Intake water quality was sampled weekly during 4 one-month study periods. Parameters analyzed are listed in Table 70, which also summarizes the data collected. Influent and effluent water temperature data are summarized in Table 71.[72]

Weights of total particulate solids (TPS) accumulating on the walls of the test condenser tubes were monitored along with concentrations of adenosine triphosphate (ATP) for use in quantification of the biofouling community. These data are sum-

[71] *Wisconsin Electric Power Company, Valley Power Plant Final Report, WPDES Intake Monitoring Studies, June 1, 1976.*

[72] *P.D. Schumacher and J.W. Lingle, "Chlorine Minimization Studies at the Wisconsin Electric Power Company Valley and Oak Creek Power Plants," Electric Power Research Institute, Inc., Condenser Biofouling Control Symposium Proceedings EPRI CS1450, Ann Arbor Science, 1980.*

Table 70

WATER QUALITY PARAMETERS, SAMPLING PERIODS, AND SUMMARY DATA FOR INTAKE WATER AT THE VALLEY POWER PLANT FOR WEPCO CHLORINE MINIMIZATION STUDY: 1977-1978

Parameter	Sampling Period and Observed Values[a]							
	October 18, 1977 to November 18, 1977		December 5, 1977 to January 13, 1978		January 20, 1978 to July 18, 1978		August 18, 1978 to September 11, 1978	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
Total Suspended Solids . . .	18	44	13	20	23	63	39	113
Turbidity.	2.1	3.5	2.1	3.0	2.1	3.0	1.8	3.5
Ammonia.	0.31	0.37	0.33	0.58	0.50	1.17	0.49	0.69
Total Kjeldahl Nitrogen. . .	1.4	2.0	1.4	2.5	--	--	--	--
Total Organic Nitrogen . . .	1.0	1.7	1.0	2.4	1.1	1.7	1.0	2.0
Total Organic Carbon	10.1	13.0	11.3	20.0	10.3	15.0	5.4	9.0
5-day BOD.	2.6	7.0	1.7	3.0	4.0	7.0	4.0	7.0
Dissolved Oxygen	3.5	4.2	--	--	2.5	5.8	3.1	6.9
Chlorine Demand.	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3
Phosphorus	0.18	0.32	0.11	0.13	0.16	0.24	0.13	0.20
pH[b]	7.6	8.2	7.8	8.2	7.3	7.8	7.2	7.9
Silica	9.5	12.0	6.4	10.0	6.5	9.9	3.7	7.1

[a]All values have units of milligrams per liter except pH, expressed in standard units, and turbidity, which is expressed in Jackson Turbidity Units (JTU).
[b]pH values given as Means are actually minimum values.

Source: Wisconsin Electric Power Company.

Table 71

INFLUENT AND EFFLUENT WATER TEMPERATURE DATA AT VALLEY POWER PLANT
COLLECTED DURING THE WEPCO CHLORINE MINIMIZATION STUDY: 1977-1978

Study Period	Average Influent Temperature (°F)	Effluent Temperature (°F)					
		East Condenser Area			West Condenser Area		
		Average	Maximum	Minimum	Average	Maximum	Minimum
October 18, 1977 to November 18, 1977	61	88	101	67	87	104	61
December 5, 1977 to January 13, 1978	44	70	81	44	69	82	43
June 20, 1978 to July 18, 1978	68	87	103	71	86	103	67
August 18, 1978 to September 11, 1978	74	89	109	71	92	110	71

NOTE: The water intake is in the Menomonee River and the outfall is in the South Menomonee Canal.

Source: Wisconsin Electric Power Company.

marized on a weekly basis in the "Chlorine Minimization Studies".[73] Although the water velocity in the condenser tubes was estimated to be 6.9 feet per second (fps) for a flow rate of 124 cubic feet per second (cfs), a biofouling layer formed and increased in thickness with time. The initial layer was composed primarily of biological slime, and as the thickness increased, diatoms and algae, along with sand and silt particles, also were accumulated on the layer.

The study concluded that the use of ATP alone for quantification of the biofouling rate was not adequate because of the accumulation of significant quantities of abiotic material after the initial layer of biological slime was formed. The use of total particulate solids along with ATP was recommended for quantification of condenser tube biofouling. To maintain a design "cleanliness" of the condenser tubes at 85 percent, total residual chlorine and free available chlorine dosages of 24 and 14 chlorine-min twice each operating day were recommended. Correlation of biofouling potential with ambient water quality was sought but not achieved.

Thermal Discharge Effects on the Aquatic Community

At the request of the Wisconsin Department of Natural Resources, WEPCO conducted a demonstration study on the thermal effects of the Valley, Commerce, and Wells Street power plants on aquatic communities present in the Menomonee and Milwaukee Rivers to serve as a model for similar studies to be conducted under Section 316(a) of Public Law 92-500. The primary intent of the study was to determine if significant differences in water quality and aquatic populations could be found between locations upstream from the water intake and downstream from the heated water outfall. Conclusions were drawn solely on that basis, although other water quality implications could be drawn from the data. The report describes the physiochemical studies, chemistry, bacteriology, phytoplankton, zooplankton, periphyton, macroinvertebrates, and fishery studies conducted. Field, laboratory, statistical, and other analytical procedures are described in the volume which was never published as a Section 316(a) report. Sampling station locations are shown on Map 28.

Physiochemical Studies: Six stream surveys were made during the study period in which physiochemical water data were collected. Vertical profiles for many of these parameters were surveyed at three transects across each channel near the sampling stations shown on Map 28. Surface and transect isopleths were drawn for dissolved oxygen and water temperature, and vertical profiles for other parameters are plotted in the CDM/Limnetics Report to WEPCO for each sampling station for each survey.[74] Parameters sampled and dates of sampling are listed in Table 72. During the surveys, bottom sediment samples were collected at the transect locations and only physical descriptions were recorded.

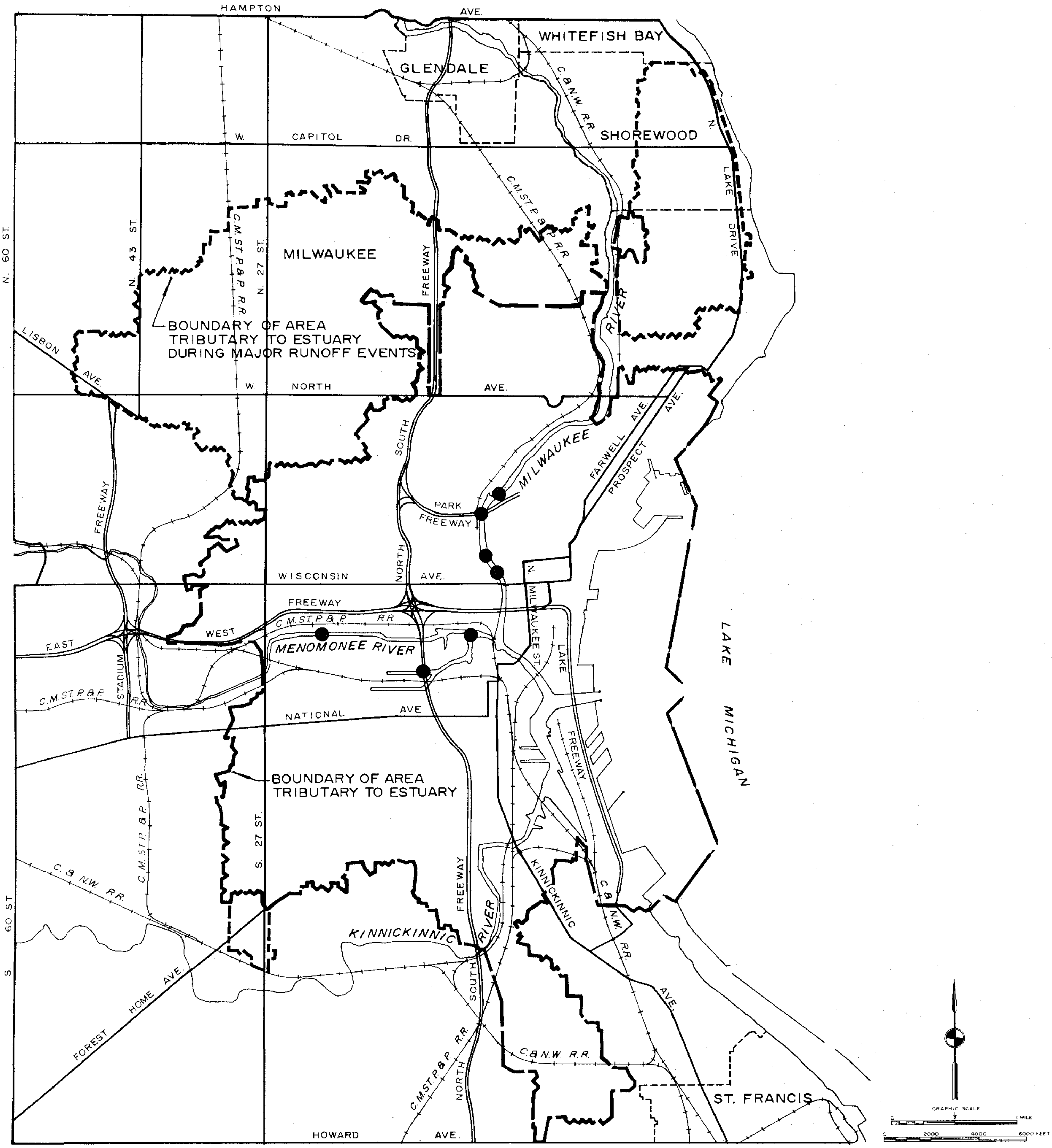
The CDM/Limnetics Report to WEPCO also includes a summary discussion of the results of each survey. The physiochemical study found that in the Menomonee River and the South Menomonee Canal, all Secchi depths were 0.8 meter or less. Current speeds ranged from less than 0.1 to 2.8 feet per second during spring runoff. Considerable variation in current direction occurred when speeds were low, but current direction

[73] *Ibid.*

[74] *CDM/Limnetics, "Report to Wisconsin Electric Power Company--Milwaukee, Wisconsin--Aquatic Studies at Valley, Commerce Street, and Wells Street Power Plants," Unpublished report, 1976.*

Map 28

LOCATIONS OF SAMPLING STATIONS IN THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976



Source: SEWRPC.

Table 72

PHYSIOCHEMICAL WATER PARAMETERS AND SAMPLING FREQUENCY IN THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY OF JANUARY-MAY 1976[a]

Parameter	Dates and Locations[b]					
	1/20-21/76	2/13/76	3/9/76	4/7/76	4/21/76	5/1/76
Secchi Depth[c]	VC	C	VC	VC	VC	VC
Water Depth[d]	VC	C	VCW	VCW	VCW	VC
Current Speed[e]	VC	C	VCW	VCW	VCW	VC
Current Direction[e] . .	VC	C	VCW	VCW	VCW	VC
Dissolved Oxygen[f] . .	VC	C	VCW	VCW	VCW	VC
Conductance[f]	VC	C	VCW	VCW	VCW	VC
Air Temperature[c] . . .	VC	C	VC	VC	VC	VC
Water Temperature[f] . .	VC	C	VCW	VCW	VCW	VC
pH[f]	VC	C	--	VCW	VCW	VC

[a]Monitoring data collected at all sampling sites shown on Map 28.
[b]Locations at which parameters are available are symbolized by V (Menomonee River near Valley power plant), C (Milwaukee River near Commerce Street power plant) and W (Milwaukee River near Wells Street power plant).
[c]Data tabulated in CDM/Limnetics Report, Chapter 2, pp. 29 and 31.
[d]Data presented in form of depth contours near power plant outfalls in CDM/Limnetics Report, Chapter 2.
[e]Collected at one-meter depth intervals. Data tabulated in CDM/Limnetics Report, Chapter 2, pp. 30, 32-41.
[f]Vertical profile plot for each sampling station for each survey is presented in CDM/Limnetics Report, Chapter 2.

Source: CDM/Limnetics, "Report to Wisconsin Electric Power Company--Milwaukee Wisconsin--Aquatic Studies at Valley, Commerce Street, and Wells Street Power Plants," unpublished report, 1976.

at other times was predominantly downstream. Dissolved oxygen (DO) was generally lower at the outfall sampling station, presumably because of warmer water temperatures and associated lower DO saturation levels. No clear pattern in conductivity at the three sampling stations was discernible, and very little variation in pH was found between the stations.

In the Milwaukee River Secchi depths were, again, 0.8 meter or less, except during the January survey when a reading of 2.0 meters was taken, indicative, perhaps, of the presence of intruding Lake Michigan waters. Current speeds ranged from less than 0.1 to 1.9 feet per second during spring runoff when the direction was predominantly downstream. At other times--unlike the Menomonee River--there was considerable variation in flow direction. Conductivity generally increased in the downstream direction. Variation in pH with location and time was small. Between January and May, a loss of detritus and silt from the bed of the river in the sampling area was found, presumably caused by high velocities during spring runoff.

Chemical Studies: Water chemistry and sediment chemistry data were collected during three surveys near the Valley and Commerce Street power plants, and during one survey near the Wells Street plant during the period January through May 1976. Sampling site locations are shown on Map 28. A list of the water chemistry parameters monitored, sampling dates, and summary data are provided in Table 73. Lists of sediment chemistry and interstitial water chemistry parameters monitored, sampling dates, and data summaries are provided in Table 74 and Table 75, respectively.

Water samples were taken one foot below the surface, at mid-depth, and one foot above the bottom at each station. In many cases, 6 to 8 samples were taken at each sampling depth during each survey for evaluation of statistical differences. For each survey a summary table is presented showing station means or ranges, multiple range test results, and analysis of variance for each parameter. Sediment samples were taken where possible with a Ballchek gravity corer. Otherwise, an Ekman sampler was used. No statistical analyses were applied to the sediment data because multiple samples were not taken at each station.

The study concluded, in part, that phosphorus and sulfate concentrations and total hardness in the Menomonee River upstream from the Valley power plant were consistently higher than downstream from the plant. Concentrations for sulfate and hardness for surface waters, generally warmer, were consistently greater than those in bottom waters which were generally colder.

For the Milwaukee River nutrient concentrations and total hardness were generally greater upstream from the Commerce Street power plant than downstream. No consistent significant differences were observed between depths for the parameters samples.

The summary data presented in Tables 73, 74, and 75, show that of the 86 maximum observations listed in the Milwaukee Harbor estuary for chemical and physical characteristics, 59 were made on the Menomonee River with only 18 on the Milwaukee River exceeding Menomonee River levels, suggesting generally poorer water and sediment quality in the Menomonee River estuary.

Bacteriological Studies: During the water and sediment chemistry sampling surveys of January 20-21, March 9, and May 1, 1976, bacteria samples were also collected in the Menomonee and Milwaukee River estuaries near the Valley, Commerce Street, and

Table 73

WATER CHEMISTRY PARAMETERS, SAMPLING FREQUENCY, AND DATA SUMMARY FOR THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Parameter	Dates and Locations[a]			Range in Observed Values[c]			
				Menomonee River[f]		Milwaukee River[g]	
	January 20-21	March 9	May 1	Minimum	Maximum	Minimum	Maximum
Turbidity[d]	VC	VCW	VC	10	26	8	13
Total Inorganic Nitrogen	VC	VCW	VC	1.8	3.0	1.08	2.2
Ammonia Nitrogen	VC	VCW	VC	0.19	1.32	0.14	0.52
Nitrate Nitrogen	VC	VCW	VC	1.4	2.6	0.91	2.1
Nitrite Nitrogen	VC	VCW	VC	0.022	0.05	0.012	0.042
Organic Nitrogen	VC	VCW	VC	0.63	1.27	0.44	1.05
Total Carbon	VC	VCW	VC	48	61	42	62
Total Inorganic Carbon	VC	VCW	VC	45	53	35	49
Total Organic Carbon	VC	VCW	VC	4	9	4	15
5-day BOD	VC	VCW	VC	2.5	3.7	1.5	3.0
Chemical Oxygen Demand	VC	VCW	VC	22	36	14	36
Chlorine Demand	VC	VCW	VC	0.2	0.4	0.2	0.6
Total Residual Chlorine	VC	VCW	VC	0.01	0.01	0.01	0.01
Free Available Chlorine	VC	VCW	VC	0.01	0.01	0.01	0.01
Total Phosphorus	VC	VCW	VC	0.193	0.298	0.160	0.179
Soluble Phosphorus	VC	VCW	VC	0.124	0.195	0.088	0.152
Oil and Grease	VC	VCW	VC	1	1.9	1	1
Sulfate	VC	VCW	VC	95	147	44	59
Sulfite	VC	VCW	VC	0.5	0.5	0.5	0.5
Sulfide	VC	VCW	VC	0.05	0.05	0.05	0.08
Silica	VC	VCW	VC	0.65	7.6	0.55	5.8
Hardness	VC	VCW	VC	327	443	230	320
Alkalinity	VC	VCW	VC	205	274	155	255
Color[e]	VC	VCW	VC	18	100	13	90
Calcium	VC	VCW	VC	62	123	43	74
Sodium	VC	VCW	VC	44	247	14	60
Magnesium	VC	VCW	VC	34	40.5	26	34
Potassium	VC	VCW	VC	4.9	6.9	3.2	3.7
Fluoride	VC	VCW	VC	0.2	0.5	0.1	0.2
Mercury[b]	VC	VCW	VC	0.0002	0.0006	0.0002	0.0011
Boron[b]	VC	VCW	VC	0.2	0.25	0.2	0.2
Arsenic[b]	VC	VCW	VC	0.001	0.001	0.001	0.001
Iron[b]	VC	VCW	VC	0.47	1.63	0.1	0.67
Hexavalent Chromium[b]	VC	VCW	VC	0.005	0.006	0.005	0.009
Nickel[b]	VC	VCW	VC	0.005	0.011	0.005	0.006
Lead[b]	VC	VCW	VC	0.002	0.006	0.002	0.003
Manganese[b]	VC	VCW	VC	0.055	0.097	0.018	0.040
Copper[b]	VC	VCW	VC	0.004	0.010	0.003	0.006
Cadmium[b]	VC	VCW	VC	0.0002	0.0009	0.0001	0.0012
Zinc[b]	VC	VCW	VC	0.017	0.065	0.010	0.020

[a]Locations at which parameters were sampled are symbolized by V (Menomonee River near Valley power plant), C (Milwaukee River near Commerce Street power plant), and W (Milwaukee River near Wells Street power plant). Sampling locations are shown on Map 28.

[b]Total and dissolved analyses were both conducted.

[c]Values are expressed in milligrams per liter unless otherwise specified.

[d]Turbidity values are given in Formazin units.

[e]Color values are given in APHA units.

[f]Ranges are presented only for the Menomonee River sampling station upstream from the intake of the Valley power plant.

[g]Ranges are presented only for the Milwaukee River sampling station upstream from the intake for the Wells Street power plant.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 74

BOTTOM SEDIMENT CHEMISTRY PARAMETERS, SAMPLING FREQUENCY, AND DATA SUMMARY FOR THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Parameter	Sampling Dates and Locations[a]			Range in Observed Values[b]			
				Menomonee River[c]		Milwaukee River[d]	
	January 20-21	March 9	May 1	Minimum	Maximum	Minimum	Maximum
pH (in situ)[e]	VC	VCW	VC	5.2	7.4	6.6	7.3
Redox Potential (in situ)[f]	VC	VCW	VC	-40	-425	-130	-325
Benthic Oxygen Uptake[g]	VC	VCW	VC	599	713	334	560
COD	VC	VCW	VC	47,000	85,600	50,000	76,200
Aluminum	VC	VCW	VC	12,000	16,000	11,000	19,000
Arsenic	VC	VCW	VC	0.04	0.04	0.04	0.04
Boron	VC	VCW	VC	0.05	0.10	0.04	0.06
Cadmium	VC	VCW	VC	10	23	8.0	12
Copper	VC	VCW	VC	120	170	88	130
Hexavalent Chromium	VC	VCW	VC	0.05	0.05	0.05	0.05
Iron	VC	VCW	VC	22,000	24,000	17,000	30,000
Manganese	VC	VCW	VC	550	700	520	760
Nickel	VC	VCW	VC	68	78	40	66
Lead	VC	VCW	VC	150	660	140	560
Zinc	VC	VCW	VC	440	590	420	560
Total Carbon	VC	VCW	VC	57,000	75,000	74,000	77,000
Total Inorganic Carbon	VC	VCW	VC	15,000	23,000	21,000	25,000
Total Organic Carbon	VC	VCW	VC	41,000	60,000	50,000	56,000

[a] Locations at which parameters were sampled are symbolized by V (Menomonee River near Valley power plant), C (Milwaukee River near Commerce Street power plant), and W (Milwaukee River near Wells Street power plant). Sampling locations are shown on Map 28.

[b] Values are expressed in milligrams per kilogram unless otherwise specified.

[c] Ranges are presented only for the Menomonee River sampling station upstream from the intake of the Valley power plant.

d Ranges are presented only for the Milwaukee River sampling station upstream from the intake for the Wells Street power plant.

[e] Expressed as the logarithm of the hydrogen ion concentration.

[f] Expressed in MV.

[g] Expressed in units of milligrams per square centimeter.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 75

INTERSTITIAL WATER CHEMISTRY PARAMETERS, SAMPLING FREQUENCY, AND DATA SUMMARY FOR THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Parameter	Sampling Dates and Locations[a]			Range in Observed Values[b]			
				Menomonee River[c]		Milwaukee River[d]	
	January 20-21	March 9	May 1	Minimum	Maximum	Minimum	Maximum
Ammonia Nitrogen	VC	VCW	VC	2.6	100	28	42
Nitrate Nitrogen	VC	VCW	VC	0.42	1.2	0.32	0.92
Nitrite Nitrogen	VC	VCW	VC	0.01	0.021	0.004	0.01
Total Carbon	VC	VCW	VC	259	1100	137	340
Total Inorganic Carbon	VC	VCW	VC	120	210	93	230
Total Organic Carbon	VC	VCW	VC	50	1000	34	120
Total Phosphorus	VC	VCW	VC	0.174	0.288	0.081	0.115
Ortho-Phosphate	VC	VCW	VC	0.014	0.052	0.012	0.016
Silica	VC	VCW	VC	0.44	25	0.38	34
Sulfate	VC	VCW	VC	1	33	1	18
Sulfite	VC	VCW	VC	0.5	1	0.5	1
Sulfide	VC	VCW	VC	0.05	0.05	0.05	0.05
Alkalinity	VC	VCW	VC	364	1030	455	664
Calcium	VC	VCW	VC	80	460	83	170
Magnesium	VC	VCW	VC	41	110	34	52
Sodium	VC	VCW	VC	34	160	33	50
Potassium	VC	VCW	VC	5.8	30	7.2	9.1
Aluminum	VC	VCW	VC	0.1	0.3	0.1	0.6
Arsenic	VC	VCW	VC	0.001	0.001	0.001	0.002
Boron	VC	VCW	VC	0.2	0.53	0.2	0.2
Cadmium	VC	VCW	VC	0.0001	0.0001	0.0001	0.0002
Copper	VC	VCW	VC	0.002	0.01	0.001	0.005
Hexavalent Chromium	VC	VCW	VC	0.005	0.008	0.005	0.005
Iron	VC	VCW	VC	0.70	32	0.20	7.4
Manganese	VC	VCW	VC	1.2	98	0.80	8.1
Nickel	VC	VCW	VC	0.012	0.094	0.009	0.030
Lead	VC	VCW	VC	0.001	0.009	0.001	0.008
Zinc	VC	VCW	VC	0.062	0.16	0.056	0.100

[a] Locations at which parameters were sampled are symbolized by V (Menomonee River near Valley power plant), C (Milwaukee River near Commerce Street power plant), and W (Milwaukee River near Wells Street power plant). Sampling locations are shown on Map 28.

[b] Values are expressed in milligrams per liter.

[c] Ranges are presented only for the Menomonee River sampling station upstream from the intake of the Valley power plant.

d Ranges are presented only for the Milwaukee River sampling station upstream from the intake of the Wells Street power plant.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Wells Street power plants. Sampling locations are shown on Map 28, and are the same sites sampled for water chemistry. Three replicate samples for fecal coliform, fecal streptococci, and total bacteria were taken one foot above the bottom and one foot below the surface at each sampling station. Station means and depth means were statistically analyzed for significant differences and trends. Table 76 summarizes the results of the three bacteria surveys. The data show that the fecal coliform counts in the Menomonee and Milwaukee River estuaries greatly exceed human contact limits of 200 to 400 colonies per 100 milliliters.

Phytoplankton Studies: During the sampling surveys of January 20-21, March 9, and May 1, 1976, phytoplankton were sampled in the Menomonee and Milwaukee River estuaries near the Valley, Commerce Street, and Wells Street power plants at the locations shown on Map 28. Three replicate samples were taken at each station for the entire water column by pumping through a hose traversing the vertical at a constant rate. Phytoplankton were identified and quantified by a modification of the Utermohl method similar to that described by Lund and others.[75] The CDM/Limnetics Report to WEPCO describes these reporting units in detail along with other details on sampling and laboratory procedures. Station means were statistically analyzed for significant differences and trends.

Phytoplankton found in the Menomonee and Milwaukee River estuaries during the three surveys are listed in Tables 77 and 78, respectively. The CDM/Limnetics Report to WEPCO contains tables summarizing statistical analyses, diversity, and evenness indices for each sampling station for each survey. The report concluded that in general, phytoplankton populations in the Menomonee River upstream from the Valley power plant intakes were different from those downstream. On the Milwaukee River, however, no such differences were noted. The data indicate a generally higher diversity index at the Milwaukee River stations than at the Menomonee River stations.

Periphyton Studies: During the physiochemical surveys made once each month from January through May 1976, periphyton was removed from permanent substrates, such as sheet pilings and bridge supports, near each of the sampling stations shown on Map 28. Periphyton contained in these samples were merely identified and are listed in Tables 79 and 80. All identifications were made to the lowest practical taxon using laboratory procedures described in detail in the CDM/Limnetics Report to WEPCO. Artifical styrofoam substrates were also placed at each sampling station on January 20-21 to be used for quantitative periphyton determinations. The identification of the periphyton from the artificial substrates was taken only to major groups. Detailed descriptions of the field and laboratory procedures involved are also provided in the CDM/Limnetics Report to WEPCO. The quantitative periphyton data are summarized in tabular form in the report for each sampling station for each survey. The tables include major periphyton groups, abundance per unit area, and biomass and percent composition. Because a month was required for adequate periphyton build up, quantitative data are presented for the period beginning in February. The data indicate significantly larger periphyton biomass in the Menomonee River estuary, as compared to the Milwaukee River estuary, during all months sampled. The report concluded that there were no apparent effects of the thermal discharge from the Valley

[75] *S.W.G. Lund, C. Kipling, and E.D. LeGren, "The Inverted Microscope Method of Estimating Algal Numbers and the Statistical Basis of Estimations by Counting," Hydrobiologia 11:143-170.*

Table 76

BACTERIOLOGICAL SAMPLING PARAMETERS, SAMPLING FREQUENCY, AND SUMMARY DATA FOR THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES FOR WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Location[b]	Parameter	Mean Bacteria Counts[a]					
		January 20-21		March 9		May 1	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Menomonee River near Valley Power Plant	Fecal Coliform	298	1,773	4,467	6,033	1,095	1,640
	Fecal Streptococci	68	576	1,600	2,350	950	1,677
	Total Bacteria	43,667	328,330	260,000	363,300	578,300	840,000
Milwaukee River near Wells and Commerce Street Power Plants	Fecal Coliform	2,283	12,683	3,317	5,400	4,433	5,367
	Fecal Streptococci	593	3,613	1,112	1,467	1,367	1,483
	Total Bacteria	61,333	658,500	130,000	273,300	343,300	398,300

[a]Mean counts reported in number of colonies per 100 milliliters.

[b]Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 77

PHYTOPLANKTON FOUND IN THE MENOMONEE RIVER ESTUARY NEAR THE VALLEY POWER PLANT IN JANUARY, MARCH, AND MAY DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

- CHLOROPHYTA
  - Volvocales
    - *Carteria* Diesing
      - spp.
    - *Chlamydomonas* Ehrenberg
      - spp.
    - *Chloroqonium* Ehrenberg
      - spp.
  - Tetrasporales
    - *Gloeocystis* Naegeli
      - spp.
  - Chlorococcales
    - *Tetraedron* Kuetzing
      - *caudatum* (Corda) Hansgirg
      - *minimum* (A. Braun) Hansgirg
    - *Ankistrodesmus* Corda
      - *Falcatus* (Corda) Ralfs
    - *Closteriopsis* Lemmermann
      - spp.
    - *Kirchneriella* Schmidle
      - *obesa* Schmidle
      - *subsolitaria* G. S. West
      - spp.
    - *Oocystis* Naegeli
      - spp.
    - *Dictyosphaerium* Naegeli
      - *pulchellum* Wood
    - *Coelastrum* Naegeli
      - *microporum* Naegeli
    - *Crucigenia* Morren
      - *tetrapedia* (Kirch.) West and West
    - *Scenedesmus* Meyen
      - *abundans* (Kirchner) Chodat
      - *dijuga* (Turpin) Lagerheim
      - *denticulatus* Lagerheim
      - *dimorphus* Kuetzing
      - *quadricauda* (Turpin) Brebisson
      - *longus* Meyen
      - spp.

Table 77 (continued)

Tetrastrum Chodat
staurogeniaeforme (Schroeder) Lemmermann
Pediastrum Meyen
boryanum (Turp.) Meneghini
tetras (Enrenb.) Ralfs
spp.
Elakatothrix Wille
gelatinosa Wille
Chaetophorales
Stigeoclonium Kuetzing
spp.
EUGLENOPHYTA
Euglenales
Euglena Ehrenberg
spp.
Phacus Dujardin
spp.
PYRRHOPHYTA
Dinophycae
Gymnodinium Stein
spp.
CRYPTOPHYTA
Chroomonas Hansgirg
spp.
Cryptomonas Ehrenberg
spp.
Katablepharis Skuja
spp.
CHRYSOPHYTA
Chrysophyceae
Ochromonas Wyssotzki
spp.
Dinobryon Ehrenberg
divergens Imhof
sertularia Ehrenberg
sociale Ehrenberg
spp.

Table 77 (continued)

Mallomonas Perty
spp.
Synura Ehrenberg
spp.
Erkenia Skuja
spp.
Stelexomonas Lackey
dicotoma Lackey
Aulomonas Lackey
purdyi Lackey
Diatomaceae
Centrales
Melosira Agardh
granulata (Ehrenberg) Ralfs
islandica O. Muller
varians Agardh
spp.
Cyclotella Kuetzing
spp.
Stephanodiscus Ehrenberg
astraea (Ehrenberg) Grunow
niagarae Ehrenberg
spp.
Pennales
Asterionella Hassall
formosa Hassall
Fragilaria Lyngbye
crotonensis Kitton
pinnata Ehrenberg
Synedra Ehrenberg
spp.
Tabellaria Ehrenberg
fenestrata (Lyngbye) Kuetzing
Achnanthes Bory
spp.
Rhoicosphenia Grunow
curvata (Kuetzing) Grunow
Navicula Bory
cryptocephala Kuetzing
tripunctata O. Muller
spp.
Pinnularia (Ehrenberg)
spp.

Table 77 (continued)

Gomphonema Agardh
olivaceum (Lyngbye) Kuetzing
Nitzschia Hassall
acicularis W. Smith
dissipata (Kuetzing) Grunow
palea (Kuetzing) W. Smith
parvula Levis
spp.
Surirella Turpin
ovata Kuetzing
ovalis Brebisson
spp.
CYANOPHYTA
Chroococcales
Aphanothece Naegeli
spp.
Anacystis Meneghini
spp.
Chroococcus Naegeli
dispersus G. M. Smith
spp.
Merismopedia Meyen
spp.
Oscillatoriales
Oscillatoria Vaucher
agardhii Gomont
pseudogeminata Schmid
tenuis Agardh
spp.

NOTE: Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 78

PHYTOPLANKTON FOUND IN THE MILWAUKEE RIVER ESTUARY NEAR THE WELLS AND COMMERCE STREET POWER PLANTS IN JANUARY, MARCH, AND MAY DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

- CHLOROPHYTA
  - Volvocales
    - *Chlamydomonas* Ehrenberg
      - spp.
    - *Chloroqonium* Ehrenberg
      - spp.
  - Tetrasporales
    - *Gloeocystis* Naegeli
      - *gigas* (Kuetzing) Lagerheim
      - spp.
  - Chlorococcales
    - *Tetraedron* Kuetzing
      - *minimum* (A. Braun) Hansgirg
      - *penta edricum* West and West
      - *asymetricum* Prescott
      - spp.
    - *Ankistrodesmus* Corda
      - *falcatus* (Corda) Ralfs
    - *Closteriopsis* Lemmermann
      - spp.
    - *Kirchneriella* Schmidle
      - *contorta* (Schmidle) Bohlan
      - *elongata* G. M. Smith
      - *obesa* Schmidle
      - spp.
    - *Lagerheimia* (DeTomi) Chodat
      - spp.
    - *Oocystis* Naegeli
      - *pusilla* Hansgirg
      - spp.
    - *Quadrigula* Printz
      - spp.
    - *Treubaria*
      - *setigerum* (Archer) G. M. Smith
    - *Dictyosphaerium* Naegeli
      - *pulchellum* Wood
    - *Coelastrum* Naegeli
      - spp.

Table 78 (continued)

Crucigenia Morren
tetrapedia (Kirch.) West and West
retangularis (A. Braun) Gay
Scenedesmus Meyen
abundans (Kirschner) Chodat
bijuga (Turpin) Lagerheim
denticulatus Lagerheim
dimorphus Kuetzing
quadricauda (Turpin) Brebisson
longus Meyen
spp.
Tetrastrum Chodat
staurogeniaeforme (Schroeder) Lemmermann
Pediastrum Meyen
boryanum (Turpin) Meneghini
tetras (Ehrenberg) Ralfs
spp.
Zygnematales
Mougestia Agardh
spp.
Cosmarium Corda
spp.
Closterium Nitzsch
spp.
Chaetophorales
Stigeoclonium Kuetzing
EUGLENOPHYTA
Euglenales
Euglena Ehrenberg
spp.
PYRRHOPHYTA
Dinophycae
Gymnodinium Stein
spp.
Peridinium Ehrenberg
spp.
CRYPTOPHYTA
Chroomonas Hansgirg
spp.
Cryptomonas Ehrenberg
spp.
Katablepharis Skuja
spp.

Table 78 (continued)

CHRYSOPHYTA
Chrysophyceae
Dinobryon Ehrenberg
divergens Imhof
sertularia Ehrenberg
sociale Ehrenberg
spp.
Mallomonas Perty
spp.
Synura Ehrenberg
spp.
Erkenia Skuja
spp.
Stelexomonas Lackey
dicotoma Lackey
Aulomonas Lackey
purdyi Lackey
Centrales
Melosira Agardh
granulata (Ehrenberg) Ralfs
islandica O. Muller
italica (Ehrenberg) Kuetzing
varians Agardh
spp.
Cyclotella Kuetzing
bodanica Eulenst
spp.
Stephanodiscus Ehrenberg
astraea (Ehrenberg) Grunow
niagarae Ehrenberg
spp.
Rhizosolenia Ehrenberg
eriensis H. L. Smith
longiseta Zacharias
Pennales
Asterionella Hassall
formosa Hassall
Diatoma Bory
tenne Agardh
Fragilaria Lyngbye
crotonensis Kitton
leptostauron (Ehrenberg) Hustedt
pinnata Ehrenberg
vaucheriae (Kuetzing) Peters

Table 78 (continued)

- *Syndedra* Ehrenberg
  - *acus* Kuetzing
  - spp.
- *Achnanthes* Bory
  - spp.
- *Cocconeis* Ehrenberg
  - *pediculus* Ehrenberg
  - spp.
- *Rhoicosphenia* Grunow
  - *curvata* (Kuetzing) Grunow
- *Navicula* Bory
  - *cryptocephala* Kuetzing
  - *tripunctata* O. Muller
  - *capitata* Ehrenberg
  - spp.
- *Gomphonema* Agardh
  - *olivaceum* (Lyngbye) Kuetzing
  - spp.
- *Amphora* Ehrenberg
  - *ovalis* Kuetzing
- *Cymbella* Agardh
  - spp.
- *Nitzschia* Hassall
  - *acicularis* W. Smith
  - *denticula* Grunow
  - *dissipata* (Kuetzing) Grunow
  - *linearis* W. Smith
  - *palea* (Kuetzing) W. Smith
  - *sigmoidea* (Ehrenberg) W. Smith
  - spp.
- *Cymatopleura* W. Smith
  - *solea* (Brebisson) W. Smith
- *Surirella* Turpin
  - *angustata* Keutzing
  - *ovata* Kuetzing
  - spp.

CYANOPHYTA

- Chroococcales
  - *Aphanocapsa* Naegeli
    - *delicatissima* West and West
    - spp.

Table 78 (continued)

Aphanothece Naegeli
spp.
Anacystis Meneghini
spp.
Chroococcus Naegeli
dispersus G. M. Smith
spp.
Coelosphaerium Naegeli
naegelianum Unger
Microcystis Kuetzing
aeruginosa Kuetzing
Merismopedia Meyer
spp.
Oscillatoriales
Lyngbya Agardh
spp.
Oscillatoria Vaucher
agardhii Gomont
geminata Meneghini
pseudogeminata Schmid
tenuis Agardh
spp.

NOTE: Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 79

PERIPHYTON FOUND ON NATURAL[a] SUBSTRATES IN THE MENOMONEE RIVER NEAR THE VALLEY POWER PLANT DURING THE WEPCO THERMAL DISCHARGE STUDY OF JANUARY-MAY 1976[b]

CHLOROPHYTA
- Volvocales
  - Chlamydomonas Ehrenberg
    - spp.
- Tetrasporales
  - Gloeocystis Naegeli
    - vasiculosa (Naegeli)
    - spp.
- Chlorocooccales
  - Grucigenia Morren
    - quadrata Morren
  - Scenedesmus Meyden
    - abundans (Kirschner) Chodat
    - bijuga (Turpin) Lagerheim
    - quadricauda (Turpin) Brebisson
    - spp.
- Ulotrichales
  - Ulothrix Kutzing
    - spp.
- Zygnematales
  - Mougeotai Agardh
    - spp.
- Chaetophorales
  - Stigeoclonium Kuetzing
    - spp.

CHRYSOPHYTA
- Chrysophyceae
  - Dinobryon Ehrenbert
    - divergens Imhof
  - Bicosoeca J. Clark
    - spp.
- Diatomaceae
  - Centrales
    - Melosira Agardh
      - varians C. A. Agardh
      - granulata (Ehrenberg) Ralfs
      - spp.
    - Cyclotella Kuetzing
      - atomus Hustedt
      - meneghiniana Kuetzing
      - ocellata Pantocsek
      - spp.

Table 79 (continued)

- *Stephanodiscus* Ehrenberg
  - *astraea* (Ehrenberg) Grunow
  - *hantzschii* Grunow
- Pennales
  - *Diatoma* Bory
    - *valgare* Bory
    - spp.
  - *Fragilaria* Lyngbye
    - *leptostauron* (Ehrenberg) Hustedt
    - *pinnata* Ehrenberg
    - *vaucheriae* (Kuetzing) Peters
    - spp.
  - *Synedra* Ehrenberg
    - *acus* Kuetzing
    - *amphicephala*
    - *fascicalata* (Agardh) Kuetzing
    - *pulchella* Ralf ex Kuetzing
    - *rumpens* Kuetzing
    - *ulna* (Nitzsch) Ehrenberg
    - spp.
  - *Achnanthes* Bory
    - *lanceolata* Brebisson
  - *Cocconeis* Ehrenberg
    - *plasentual* Ehrenberg
    - spp.
  - *Rhoicosphenia* Grunow
    - *curvata* (Kuetzing) Grunow
  - *Navicula* Bory
    - *binodis* Ehrenberg
    - *angasta* Grunow
    - *cryptocephala* Kuetzing
    - *salinarum* Grunow
    - *tripunctata* O. Muller
    - *ratica* Kuetzing
    - *pupula* Kuetzing
    - *capitata* Ehrenberg
    - spp.
  - *Gomphonema* Agardh
    - *angustastum* (Kuetz.) Rabenhorst
    - *olivaccum* (Lyngbye) Kuetzing
    - *parvulum* (Kuetz.) Kuetzing
    - spp.
  - *Amphora* Ehrenberg
    - *ovalis* Kuetzing
  - *Cymbella* Agardh
    - *prostrata* (Berkeley) Cleve
  - *Nitzschia* Hassall
    - *acicularis* W. Smith

Table 79 (continued)

- *amphibia* Grunow
- *apiculata* (Gregory) Grunow
- *denticula* Grunow
- *dissipata* (Kuetzing) Grunow
- *filiformis* (Wm. Smith) Schutt
- *fonticola* Grunow
- *hungarica* Grunow
- *palea* (Kuetzing) W. Smith
- *sigma* (Kuetzing) W. Smith
  - spp.
- *Cymatopleura* W. Smith
  - spp.
- *Surirella* Turpin
  - *angustata* Kuetzing
  - *ovata* Kuetzing
  - *oralis* Brebisson
- *Caloneis* Cleve
  - *bacillum* (Grunow) Cleve
  - *hyalina* Bustedt
- *Pinnularia* Ehrenberg
  - *microstauron* (Ehrenberg) Cleve
  - spp.
  - *obscura* Krasske

CYANOPHYTA
- Chroococcales
  - *Chroococcus* Naegeli
    - *dispersus* minor G.M. Smith
    - spp.
- Oscillatoriales
  - *Lynabya* Agardh
    - *taylorii* Drouet & Strickland in Strickland
  - *Oscillatoria* Varcher
    - *acutissima* Kufferath
    - *agardhii* Gomont
    - *tenuis* C.A. Agardh
    - *pseudogeminata* Schmid
    - spp.

CHLOROMONADOPHYTA
- *Gonyostomum* Diesing
  - spp.

[a] *Defined in the CDM/Limnetics Report as sheet pilings and bridge supports, as distinguished from artificial (styrofoam) substrates placed in the river for quantitative periphyton sampling purposes.*

[b] *Sampling locations are near the sites shown on Map 28.*

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 80

PERIPHYTON FOUND ON NATURAL[a] SUBSTRATES IN THE MILWAUKEE RIVER NEAR THE WELLS STREET AND COMMERCE STREET POWER PLANTS DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976[b]

- CHLOROPHYTA
  - Tetrasporales
    - *Glococystis* Naegeli
      - *gigas* (Kuetzing) Lagerheim
      - spp.
  - Chlorococcales
    - *Tetraedron* Kuetzing
      - *caudatum* (Corda) Hansgirg
    - *Crucigenia* Morren
      - spp.
    - *Scenedesmus* Meyen
      - *abundans* (Kirschner) Chodat
      - *bijuda* (Turpin) Lagerheim
      - *dimorphus* Kuetzing
      - *quadricauda* (Turpin) Brebisson
      - spp.
    - *Pediastrum* Meyen
      - *loryanum* (Turpin) Meneghini
      - *tetras* (Ehrenberg) Ralfs
  - Ulotrichales
    - *Ulothrix* Kutzing
      - spp.
  - Oedogoniales
    - *Oedogonium* Link
      - spp.
  - Chaetophorales
    - *Stigeoclonium* Kuetzing
      - spp.
  - Diatomaceae
    - Centrales
      - *Melosira* Agardh
        - *granulata* (Ehrenberg) Ralfs
        - *islandica* O. Muller
        - *varians* C. A. Agardh
        - spp.
      - *Cyclotella* Kuetzing
        - *atomus* Hustedt
        - *glomarata* Backmann
        - *meneghiniana* Kuetzing
        - spp.
      - *Stephanodiscus* Ehrenberg
        - *astraea* (Ehrenberg) Grunow
        - *invisitatus* Hohn and Hellerman
        - spp.

Table 80 (continued)

Pennales
- *Asterionella* Hassall
  - *formosa* Hassall
  - *gracillima* (Hantz.) Heiberg
- *Diatoma* Bory
  - *anceps* (Ehr.) Grunow
  - *hiemale* (Roth) Heiberg
  - *tenue* Agardh
  - *vulgare* Bory
  - spp.
- *Fragilaria* Lynbye
  - *construens* (Ehr.) Grunow
  - *leptostauron* (Ehrenberg) Hustedt
  - *pinnata* Ehrenberg
  - *vaucheriae* (Kuetzing) Peters
  - *inflata* Pantocsek
  - spp.
- *Synedra* Ehrenberg
  - *fasciculata* (Agardh) Kuetzing
  - *rumpens* Kuetzing
  - *ulna* (Nitzsch) Ehrenberg
  - spp.
- *Achnanthes* Bory
  - *lanceolata* Brebisson
  - *linearis* (Wm. Smith) Grunow
  - spp.
- *Cocconeis* Ehrenberg
  - *diminuta* Pantocsek
  - *pediculus* Ehrenberg
  - *placentula* Ehrenberg
  - spp.
- *Rhoicosphenia* Grunow
  - *curvata* (Kuetzing) Grunow
- *Navicula* Bory
  - *capitata* Ehrenberg
  - *cryptocephala* Kuetzing
  - *exigua* Gregory ex Grunow
  - *mutica* Kuetzing
  - *placcatual* (Ehrenberg) Kuetzing
  - *pupula* Kuetzing
  - *rhyachocephala* Kuetzing
  - *salinarum* Grunow
  - *scutelloides* Wm. Smith ex Gregory
  - *tripunctata* O. Muller
  - spp.

Table 80 (continued)

Gomphonema Agardh
angustatum (Kuetzing) Rabenhorst
olivaceum (Lyngbye) Kuetzing
parvulum (Kuetzing) Kuetzing
spp.
Amphora Ehrenberg
ovalis Kuetzing
spp.
Cymbella Agardh
sinuata Gregory
spp.
Nitzschia Hassall
acicularis W. Smith
amphibia Grunow
denticula Grunow
dissipata (Kuetzing) Grunow
filiformis (Wm. Smith) Schutt
fonticola Grunow
gracilis Hantzsch
hungarica Grunow
linearis W. Smith
microcephala Grunow
palea (Kuetzing) W. Smith
spp.
Surirella Turpin
ovata Kuetzing
spp.
Caloneis Cleve
bacillum (Grunow) Cleve
Gyrosigma Hass
spp.
Meridion Agardh
circulare (Grev.) Agardh
Pinnularia Ehrenberg
microstauron (Ehrenberg) Cleve
spp.
CYANOPHYTA
Chroococcales
Aphanothece Naegeli
spp.
Anacystis Meneghini
spp.

Table 80 (continued)

<u>Chroococcus</u> Naegeli
<u>dispersus</u> (Keissl.) Lemmermann
<u>turgidus</u> (Kuetzing) Naegeli
spp.
<u>Glococapsa</u> Kuetzing
spp.
Oscillatoriales
<u>Lyngbya</u> Agardh
<u>nordgaardii</u> Wille
<u>taylorii</u> Drouet & Strickland in Strickland
spp.
<u>Oscillatoria</u> Vaucher
<u>agardhii</u> Gomont
<u>pseudogeminata</u> Schmid
<u>subbrevis</u> Schmidle
<u>tenius</u> C. A. Arardh
spp.
<u>Phormidium</u> Kuetzing
spp.

[a] *Defined in the CDM/Limnetics Report as sheet pilings and bridge supports, as distinguished from artificial (styrofoam) substrates placed in the river for quantitative periphyton sampling purposes.*

[b] *Sampling locations are near the sites shown on Map 28.*

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

power plant on periphyton species composition in the Menomonee River. In the Milwaukee River there were no apparent trends in the abundance, species composition, or biomass attributable to thermal discharges from the Wells or the Commerce Street power plants.

Zooplankton Studies: During the sampling surveys of January 20-21, March 9, and May 1, 1976, zooplankton were sampled in the Menomonee and Milwaukee River estuaries near the Valley, Commerce Street, and Wells Street power plants at the locations shown on Map 28. Three replicate samples were taken at each station for the entire water column by pumping through a hose traversing the vertical at a constant rate. All zooplankton were identified to the lowest possible taxon, including immature microcrustacea. Zooplankton species counts were made, and diversity and evenness values were determined along with statistical evaluations of differences and trends. Zooplankton found in the Menomonee and Milwaukee River estuaries during the the three surveys are listed in Tables 81 and 82, respectively. The CDM/Limnetics Report to WEPCO contains tables summarizing statistical analyses, diversity, and evenness indices for each sampling station for each survey. The report concluded that, in general, zooplankton populations during all three surveys were often significantly higher in the Menomonee River downstream from the Valley power plant outfall than upstream from the intakes. A higher abundance of zooplankton populations found in the South Menomonee Canal, which receives the thermal discharge directly from the power plant, may be an effect of the thermal discharge. On the Milwaukee River, no consistent statistically significant differences in zooplankton populations were found between sampling stations for each survey.

Macroinvertebrate Studies: During the stream surveys made during January, March, and May 1976, benthic macroinvertebrate samples were collected at the sampling sites shown on Map 28. The site near the Wells Street power plant, however, was only sampled during the March survey. Two replicate samples were taken at each site with an Ekman grab sampler. Substrate type for each sample was visually characterized and recorded. In the laboratory, organisms were identified to the lowest possible taxonomic level. Computations were made of benthic macroinvertebrate densities per unit area, species diversity, and evenness. Evenness mathematically expresses the numerical distribution of individual organisms within the taxa found. Evenness is greatest when there is an even distribution of individual organisms among the taxa. Statistical analyses of differences and trends were also conducted, but only for oligochaetes, since this subclass composed at least 97 percent of the total macroinvertebrates sampled. Table 83 lists the benthic macroinvertebrate species found at the Menomonee and Milwaukee River estuary sampling stations during the study period. Summary data tables in the CDM/Limnetics Report to WEPCO present macroinvertebrate densities, and diversity and evenness indices for each sampling station for each survey. The report indicated that tubificids composed more than 97 percent of the total benthic fauna sampled; that soft, mucky substrate was found at all sampling stations; that many of the great abundance of tubificids found are commonly associated with eutrophic environments; and that thermal discharges had no apparent effect on the benthic communities in the Menomonee and Milwaukee River estuary study reaches.

Fisheries Studies: Five fish surveys were made near the Valley, Commerce Street, and Wells Street power plants in the Menomonee and Milwaukee River estuaries from January to May 1976. Fish were collected using both electro-shocking and net trawling methods near each of the sampling stations shown on Map 28. Fish fry were also sampled using a plankton net towed just below the water surface. In the field, fish

Table 81

ZOOPLANKTON FOUND IN THE MENOMONEE RIVER ESTUARY NEAR THE VALLEY POWER PLANT IN JANUARY, MARCH, AND MAY DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

- CLADOCERA
  - *Bosmina* (Baird 1845)
    - *longirostris* (O. F. Muller 1785)
  - *Ceriodaphnia* (Dana 1853)
    - spp.
  - *Chydotus* (Leach 1843)
    - *sphaericus* (O. F. Muller 1785)
  - *Daphnia* (O. F. Muller 1785)
    - immature
  - *Eubosmina*
    - *coregoni* (Baird 1857)
  - *Macrothrix* (Baird 1843)
    - *laticornis* (Jurine 1820)

- COPEPODA
  - Nauplii
  - Calanoida
    - copepodids
    - *Diaptomus* (G.O. Sars 1903)
      - *ashlandi* (Marsh 1893)
      - *minutus* (Lilljeborg 1889)
      - *oregonensis* (Lilljeborg 1889)
      - spp.
    - *Limnocalanus*
      - *macrurus* (Sars 1863)
  - Cyclopoida
    - copepodids
    - *Cyclops* (O. F. Muller 1776)
      - *bicuspidatus* *thomasi* (S. A. Forbes 1882)
      - *vernalis* (Fischer 1853)
    - *Eucylops*
      - *agilis* (Koch 1838)
      - *prionophorus* (Kiefer 1931)
      - *speratus* (Lilljeborg 1901)
    - *Mesocyclops* (Kiefer 1927)
      - *edax* (S. A. Forbes 1891)
    - *Tropocyclops*
      - *prasinus* (Fischer 1860)
    - Harpacticoida
      - spp.

Table 81 (continued)

- ROTIFERA
  - spp.
  - Bdelloidea
    - spp.
  - Monogononta
    - *Asplanchna* (Gosse 1850)
      - spp.
    - *Brachionus* (Pallas 1766)
      - *angularis* (Gosse 1851)
      - *calyciflorus* (Pallas 1766)
      - *caudatus* (Barrois and Daday 1894)
      - *quadridentatus* (Hermann 1783)
      - *urceolaris* (O. F. Muller 1773)
      - spp.
    - *Cephalodella* (Bory de St. Vincent 1826)
      - spp.
    - *Conochilus* (Ehrenberg 1834)
      - *unicornis* (Rousselet 1892)
    - *Dicranophorus* (O. F. Muller 1773)
      - spp.
    - *Encentrum* (Ehrenberg 1838)
      - spp.
    - *Epiphanes* (Ehrenberg 1832)
      - spp.
    - *Euchlanis* (Ehrenberg 1832)
      - spp.
    - *Filinia* (Bory de St. Vincent 1824)
      - *brachiata* (Rousselet 1901)
      - *longiseta* (Ehrenberg 1834)
      - spp.
      - *terminalis* (Plate 1886)
    - *Kellicottia* (Ahlstrom 1938)
      - *bostoniensis* (Rousselet 1908)
      - *longispina* (Kellicott 1879)
    - *Keratella* (Bory de St. Vincent 1822)
      - *quadrata* (O. F. Muller 1786)
      - spp.
    - *Lecane* (Nitzsch 1827)
      - spp.
    - *Lepadella* (Bory de St. Vincent 1826)
      - spp.
    - *Monostyla* (Ehrenberg)
      - spp.

Table 81 (continued)

Mytilina (Bory de St. Vincent 1826)
spp.
Notholca (Gosse 1886)
spp.
Pleurotrocha (Ehrenberg 1830)
spp.
Polyarthra (Ehrenberg 1834)
spp.
Proales (Gosse 1886)
spp.
Synchaeta (Ehrenberg 1832)
spp.
Testudinella (Bory de St. Vincent 1826)
mucronata (Gosse 1886)
Trichocerca (Lamarck 1801)
mucosa (Stokes 1896)
Trichotria (Bory de St. Vincent 1827)
tetractis (Ehrenberg 1830)

NOTE: Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 82

ZOOPLANKTON FOUND IN THE MILWAUKEE RIVER ESTUARY NEAR THE WELLS STREET AND COMMERCE STREET POWER PLANTS IN JANUARY, MARCH, AND MAY DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

CLADOCERA
- *Alona* (Baird 1850)
  - *circumfibriata* (Megard 1967)
    - immature
- *Bosmina* (Baird 1845)
  - *longirostris* (O. F. Miller 1785)
- *Ceriodaphnia* (Dana 1853)
  - spp.
- *Chydorus* (Leach 1843)
  - *sphaericus* (O. F. Muller 1785)
- *Daphnia* (O. F. Muller 1785)
  - *pulex* (Leydig 1860 emend. Richard 1896)
- *Ilyocryptus* (Sars 1861)
  - *spinifer* (Herrick 1884)
- *Leydigia* (Kurz 1874)
  - *quadrangularis* (Leydig 1860)
- *Macrothrix* (Baird 1843)
  - immature
  - *laticornis* (Jurine 1820)

COPEPODA
- Nauplii
- Calanoida
  - copepodids
  - *Diaptomus* (G. O. Sars 1903)
    - *ashlandi* (Marsh 1893)
    - *minutus* (Lilljeborg 1889)
    - *oregonensis* (Lilljeborg 1889)
  - *Limnocalanus*
    - *macrurus* (Sars 1863)
- Cylopoida
  - copepodids
  - *Cyclops*
    - *bicuspidatus* *thomasi* (S. A. Forbes 1882)
  - *Eucyclops*
    - *agilis* (Koch 1838)
    - *prionophorus* (Kiefer 1931)
    - *speratus* (Lilljeborg 1901)
  - *Tropocyclops*
    - *prasinus* (Fischer 1860)
- Harpacticoida
  - spp.

Table 82 (continued)

ROTIFERA
    spp.
  Bdelloidea
    spp.
  Monogononta
    Brachionus (Pallas 1766)
      angularis (Gosse 1851)
      calyciflorus (Pallas 1766)
      quadridentata (Hermann 1783)
      urceolaris (O. F. Muller 1773)
    Cephalodella (Bory de St. Vincent 1826)
      spp.
    Collurella (Bory de St. Vincent 1824)
      spp.
    Conochilus (Ehrenberg 1834)
      unicornis (Rousselet 1892)
    Dicranophorus (O. F. Muller 1773)
      spp.
    Encentrum (Ehrenberg 1838)
      spp.
    Epiphanes (Ehrenberg 1832)
      spp.
    Euchlanis (Ehrenberg 1832)
      spp.
    Filinia (Bory de St. Vincent 1824)
      longiseta (Ehrenberg 1834)
    Kellicottia (Ahlstrom 1938)
      bostoniensis (Rousselet 1908)
      longispina (Kellicott 1879)
    Keratella (Bory de St. Vincent 1822)
      quadrata (O. F. Muller 1786)
      spp.
    Lecane (Nitzsch 1827)
      spp.
    Lepadella (Bory de St. Vincent 1826)
      spp.
    Lopocharis (Ehrenberg 1838)
      salpina (Ehrenberg 1834)
    Monostyla (Ehrenberg)
      spp.

Table 82 (continued)

Notholca (Gosse 1886)
foliacea (Ehrenberg 1838)
spp.
Pleurotrocha (Ehrenberg 1830)
spp.
Polyarthra (Ehrenberg 1834)
spp.
Proales (Gosse 1886)
spp.
Synchaeta (Ehrenberg 1832)
spp.
Trichocerca (Lamarck 1801)
mucosa (Stokes 1896)

NOTE: Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Table 83

BENTHIC MACROINVERTEBRATE SPECIES FOUND IN THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES IN JANUARY, MARCH, AND MAY DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Species	Location	
	Menomonee River	Milwaukee River
Class: Clitellata		
Subclass: Oligochaeta		
Family: Enchytraeidae		
Enchytraeidae spp.		X
Family: Haididae		
Dero digitata (Muller)	X	
Nais cf. variabilis	X	
Ophidonais serpentina (Muller)		
Family Tubificidae		
Limnodrilus cervix (Brinkhurst)	X	X
L. cervix variant	X	X
L. claparedianus	X	X
L. hoffmeisteri (Claparede)	X	X
L. manmeensis (Brinkhurst and Cook)	X	
L. polfondicola (Verrill)	X	X
L. spiralis (Eisen)	X	X
L. udekemianus (Claparede)	X	X
Peloscolex multisetosus longidentus (Brinkhurst and Cook)	X	X
P. multisetosus multisetosus (Smith)	X	X
Tubifex tubifex (Muller)	X	X
Unindentified Immature Oligochaeta with capilliform chaetae	X	X
Unindentified Immature Oligochaeta without capilliform chaetae	X	X
Class: Hirudinea		
Family: Erpobdellidae		
Erpobdellidae spp.	X	X
Class: Crustacea		
Order: Ispopoda		
Family: Asellidae		
Asellus spp.	X	
Class: Insecta		
Order: Dipera		
Family: Chironomidae		
Subfamily: Tanypodinae		
Procladius sp.	X	X
Tanypus sp.		X
Pentaneurini sp.	X	

Table 83 (continued)

Species	Location	
	Menomonee River	Milwaukee River
Subfamily: Chironominae		
Chironomus sp.		X
Glypotendipes sp.		X
Microtendipes sp.	X	
Parachironomus sp.		X
Rheotanytarsus sp.	X	X
Subfamily: Orthocladiinae		
Cricotopus spp.	X	X
Microcricotopus sp.	X	
Family: Dolichopodidae		
Dolichopodidae spp.	X	
Family: Psychodidae		
Pericoma spp.		X
Psychoda spp.	X	
Psychodidae spp		X
Order: Hemipter		
Family: Corixidae		
Corixidae spp.		X
Order: Coleoptera		
Family: Elmidae		
Dubiraphia spp.		X
Family: Helodidae		
Cyphon spp.		X
Class: Pelecypoda		
Family: Sohaeriidae		
Sphaerium spp.	X	X
Class: Gastropoda		
Family: Planorbidae	X	
Armiger sp.	X	

NOTE: Sampling locations are shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

were separated by species, counted, weighed, and measured. Growths or diseases on any of the fish were noted. Detailed discussion of the fish collection procedures is presented in the CDM/Limnetics Report to WEPCO.

In the laboratory, fish fry were identified to the lowest possible taxon, and total fry and species densities were determined. Statistical analyses were conducted to test for differences in fish length, weight, and condition, when more than five fish from the same species were collected at a given station. Adult and juvenile fish number were also statistically analyzed.

During the five surveys, a total of 133 fish representing 15 species were collected. A list of these species is provided in Table 84. Tables presented in the report list the catch for each species at each sampling station during each survey along with fish measurements, sex, and other pertinent data. Fish fry sampling conducted on three dates found no fish fry whatsoever in the Menomonee River. Fish fry from two species were found in the Milwaukee River and included Osmeridae (Rainbow smelt) and Catastomidae.

The report concluded that determination of indigenous fish species in the Menomonee and Milwaukee River estuaries near the WEPCO power plants was difficult because some of the species found were obviously transients from Lake Michigan, some species could have drifted into the estuary from upstream locations, and goldfish may have been discharged into the estuary from combined sewer outfalls. Species composition could vary significantly from day to day, as fish locations depend upon water quality conditions which are highly variable.

STUDIES RELATED TO FLOODING AND STORM DAMAGE IN THE MILWAUKEE HARBOR ESTUARY

Studies of flooding in the Milwaukee Harbor estuary relevant to the study design have been conducted by the Regional Planning Commission, the Milwaukee Department of City Development of the City of Milwaukee, and the U.S. Army Corps of Engineers. The Regional Planning Commission analyses comprised elements of the comprehensive watershed studies discussed above and were conducted only for the estuarine reaches of the Milwaukee, Menomonee, and Kinnickinnic Rivers, but did not address the outer harbor. Studies relevant to flooding and storm damage in the outer harbor, however, have been carried out by the Milwaukee Department of City Development and the Army Corps of Engineers.

As part of SEWRPC Planning Reports Nos. 13, 26, and 32 for the Milwaukee, Menomonee, and Kinnickinnic River watersheds published by the Regional Planning Commission in 1971, 1976, and 1978, respectively, flooding problems in the estuarine reaches of the three rivers were addressed using historic flood information--including City of Milwaukee water level records since 1906--along with hydrologic and hydraulic analyses. Recommendations for the management of inner harbor flooding were described in these three planning reports.

The U.S. Army Corps of Engineers, at the request of the Federal Insurance Administration of the U.S. Department of Housing and Urban Development, prepared stage-frequency relationships for open-coast reaches of the Great Lakes in a study titled Report on Great Lakes Open-Coast Flood Levels.[76] Long-term stage data for Lake

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[76] *U.S. Army Corps of Engineers, Report on Great Lakes Open-Coast Flood Levels, Detroit, Michigan, prepared for Federal Insurance Administration, February 1977.*

Table 84

FISH SPECIES FOUND IN THE MENOMONEE AND MILWAUKEE RIVER ESTUARIES DURING THE WEPCO THERMAL DISCHARGE STUDY: JANUARY-MAY 1976

Species		Location[b]	
Common Name	Scientific Name[a]	Milwaukee River	Menomonee River
Alewife	*Alosa pseudoharengus* (Wilson)	X	X
Gizzard Shad	*Dorosoma copedianum* (Lesueur)		X
Brown Trout	*Salmo trutta* (Linnaeus)		X
Rainbow Trout	*Salmo gairdneri* (Richardson)	X	X
Goldfish	*Carassius auratus* (Linnaeus)	X	X
Carp	*Cyprinus carpio*		X
Golden Shiner	*Notomigonus crysoleucas* (Mitchell)		X
Common Shiner	*Notropis cornutus* (Mitchell)	X	X
Emerald Shiner	*Notropis atherinoides* (Refinesque)	X	
Spotfin Shiner	*Notropis spilopterus* (Cope)		X
Spottail Shiner	*Notropis hudsonius* (Clinton)	X	
Brassy Minnow	*Hybognathus hunkinsoni* (Hubbs)		X
White Sucker	*Catostomus commersoni* (Lacepede)	X	
Shorthead Redhorse	*Moxostoma macrolepidotum* (Lesueur)	X	
Banded Killifish	*Fundulus diaphanus* (Lesueur)	X	

[a]R.M. Bailey, et.al. "A List of Common and Scientific Names of Fishes from the United States and Canada," 3rd Edition, American Fishery Society, Special Publication No. 6, 1970.

[b]Sampling locations encompass the sites shown on Map 28.

Source: Wisconsin Electric Power Company, CDM/Limnetics Report.[74]

Michigan, collected at Milwaukee at the main entrance to the outer harbor were adjusted to the existing outlet control conditions for use in the frequency analysis of instantaneous annual peak stages at that monitoring location, as well as at other locations on Lake Michigan and the other Great Lakes. The report presents the 10-, 50-, 100-, and 500-year recurrence interval lake stages for the Milwaukee area at both the International Great Lakes and National Geodetic Vertical Datums. These data are intended for use in flood insurance studies prepared by the Federal Insurance Administration, but are also useful for analysis of flooding problems of the outer harbor.

The Department of City Development of the City of Milwaukee in 1980 contracted for a study of wave conditions in the outer harbor. Storm damages in the Harbor have been caused in part by waves associated with wind set-up and wave reflection, strong oscillating currents associated with harbor surge, and wind-blown spray from breaking waves. Piers and pleasure craft in McKinley Marina have been damaged repeatedly by wave action. The strong oscillating currents in commercial slips in the outer harbor periodically make mooring conditions unsafe and, on December 26, 1979, caused the sinking of a ship, the E.M. Ford, owned by the Huron Cement Company, due to damage by repeated collisions with an adjacent pier. A severe storm on April 9, 1973 caused waves that overtopped the outer harbor breakwater, causing wave heights of up to 13 feet, washing out the revetment protecting the Summerfest grounds, and damaging pierside buildings and the Jones Island wastewater treatment plant. The storm caused about $500,000 in damages, mostly attributable to high winds and spray from breaking waves, as the tops of stationary waves in the outer harbor slips were blown into adjacent structures, causing additional damage. Offshore wave data were utilized to estimate outer harbor wave heights which will be useful for the design of outer harbor protective structures.

SUMMARY AND CONCLUSIONS

A total of 63 studies relevant to water quality conditions in the Milwaukee Harbor estuary were found to have been conducted since 1952. These studies were conducted by 13 public and quasi-public agencies--at the local, state, and federal levels of government. The studies included the collection, analysis, and interpretation of data concerning wet- and dry-weather water quality conditions, hydrologic and hydraulic processes, biological conditions, suspended sediment and bottom sediment conditions, point and nonpoint sources of pollution, bathymetry, and climatology. The available studies present a fragmented and sometimes contradictory picture of the phenomena and conditions in the estuary. Any meaningful analysis of the significance of the findings of these studies taken as a whole will require supplemental data collection and substantial technical analysis.

While other types of data will be required, in addition to water quality data, for the conduct of a comprehensive assessment of estuary water quality conditions and related water resource management needs, such data--described in Chapter IV--are generally available in a routine manner for use in areawide planning studies. This type of data includes base maps and aerial photography; data on terrestrial natural resource features; data on the locations and sizes of storm sewers; sanitary sewers, and combined sewer outfalls and overflows; data on industrial wastewater sources; data on harbor operations; data on existing and planned land uses; data on population and economic activity levels; data on public utilities; data on water use; and data on existing land management practices.

Table 85 summarizes the temporal and spatial extent of the available water quality related studies and also indicates the general types of data collected. Study locations are designated as either estuarine or non-estuarine subwatersheds, or as outer harbor or near-shore Lake Michigan locations. As Table 85 indicates, the time period with the most comprehensive data available for the entire Milwaukee Harbor estuary is the three-year period 1975 through 1977.

This chapter is intended to provide a basic familiarity with the data and studies already available, to summarize the findings and recommendations of the completed studies, and to provide a basic literature search resource for use in the design, as well as in the conduct, of a Milwaukee Harbor estuary water resources planning program. This chapter, together with the study objectives described in the the next chapter, provides the basis for the recommendations made in Chapter IV concerning the additional data collection and analyses needed for development of a comprehensive water resource management plan for the estuary.

An overview of the studies described in this chapter indicates that some data are useful as general "benchmark" information, providing a frame of reference, or norm, for the evaluation of other data available. These studies can assist in the characterization of ambient conditions. Other studies are useful for more detailed analysis of the behavior of certain water quality and water quality-related conditions, thereby providing insight into important phenomena. It is important to note, however, that none of the studies, taken individually, provides the necessary information to support the preparation of a comprehensive water resources management plan for the Milwaukee Harbor estuary. Moreover, even when considered collectively, the available studies do not adequately characterize the existing conditions or the major phenomena which underlie those conditions and which would require explicit consideration in the development of a plan for the estuary. This problem is the result of at least three factors: 1) many studies were conducted for relatively narrow, single purpose objectives and either did not generally address interactions between the physical, chemical, and biological sub-systems or were limited in their geographic scope to only portions of the estuary or both; 2) the differences in timing of the studies preclude integrated use of the data gathered and the associated findings because the estuary is not a static system or even a highly predictable system; and 3) the methodologies employed varied over time, with individual investigators often applying differing study techniques making data comparisons difficult or impossible. For these major reasons, the available studies present a fragmented characterization of the dynamics of the estuary, and must be recognized as a piecemeal basis for the conduct of a comprehensive study of the important water resource and water resource-related problems of the estuary. The utility of the available data for accomplishing the study objectives presented in Chapter III will be discussed in Chapter IV of this study design.

The review of the available studies indicated eight factors which must be considered in any sound analysis of estuary water quality management alternatives. These factors are discussed in summary fashion below and include the meteorology; bathymetry; hydrology and hydraulics; ambient water quality conditions; physical and water chemistry response to extreme conditions, i.e., "events" or "episodes"; biologic conditions; pollution sources; and sediment characteristics of the estuary.

With respect to meteorologic data, long term data for characterization of historic and existing conditions have been collected in Milwaukee by the National Weather Service and are either published or already on a computer file at SEWRPC for the

Table 85

SELECTED FEATURES OF WATER QUALITY STUDIES RELEVANT TO THE MILWAUKEE HARBOR ESTUARY STUDY DESIGN: 1950-1980

Year	Locaton and Data Type[a]							
	Nonlake Affected Reaches			Estuaries				
	Milwaukee River	Menomonee River	Kinnickinnic River	Milwaukee River	Menomonee River	Kinnickinnic River	Outer Harbor	Near-shore Zone
1950	H	--	--	H	H	H	ABHS	H
1951	H	--	--	H	H	H	ABDHS	DH
1952	ABH	AB	AB	ABH	ABH	ABH	ABHS	BH
1953	ABHS	ABHS	ABHS	ABHS	ABHS	ABHS	ABHS	BH
1954	H	--	--	H	H	H	DH	DH
1955	H	--	--	H	H	H	H	H
1956	H	--	--	H	H	H	H	H
1957	H	--	--	H	H	H	DH	DH
1958	H	--	--	H	H	H	H	H
1959	H	--	--	H	H	H	DH	DH
1960	H	--	--	DH	DH	DH	DH	DH
1961	AHS	H	--	AHS	H	H	H	ABHS
1962	AHS	H	--	AHS	H	H	CH	ABCHS
1963	AHS	H	--	ADHS	DH	DH	CDH	ABCDHS
1964	AHS	H	--	ABHS	ABH	ABH	BH	ABHS
1965	AHS	H	--	AHS	H	H	H	ABHS
1966	AHS	H	--	ADHS	DH	DH	ADH	ABDHS
1967	ABHS	H	--	ABHS	ABHS	ABH	AH	ABHS
1968	ABH	ABH	AB	ABHS	ABS	ABS	AH	ABHS
1969	ABHS	H	--	ABDHS	ABDS	ABDS	DHS	ABDHS
1970	ABHS	H	--	ABHS	ABS	ABS	ABHS	ABHS
1971	AHS	H	--	ABHS	ABS	ABS	ADH	ABHS
1972	AEHS	H	--	ABDEHS	ABDS	ABDS	ABDHS	ABDHS
1973	AHS	ABHS	--	AHS	ABS	AS	ABHS	ABHS
1974	AHS	ABHS	--	AHS	ABHS	--	AH	ABHS
1975	AHS	ABHS	ABHS	ABDS	ABDHS	ABDS	ADH	ABDHS
1976	ABHS	ABHS	ABHS	ABDHS	ABDHS	ABS	ABHS	ABHS
1977	ABEHS	ABHS	AEH	ABES	ABEHS	AEHS	AEH	H
1978	ABHS	ABHS	H	ABDHS	ABDS	ABH	ADH	DH
1979	HNS	H	H	AB	AB	ABHS	ABCH	H
1980	H	H	H	ABNS	ABNS	ABHS	ACHS	H

[a]Data types are as follows:
A - Ambient water quality
B - Biological
C - Climatological
D - Depth soundings
E - Event sampling
H - Hydraulic-hydrologic
N - Nonpoint Source
S - Suspended and/or bottom sediments

Source: SEWRPC

period from 1940 through 1979. Data from the existing City of Milwaukee network of 16 rain gages, and the Milwaukee Metropolitan Sewerage District weather station on the breakwater at the main harbor entrance, together with the National Weather Service weather station records, should provide adequate meteorological data for the purposes of the Milwaukee Harbor estuary water quality management study, if these data collection activities are maintained.

With respect to bathymetry, sounding data collected by the University of Wisconsin-Milwaukee, the National Ocean Survey and the U.S. Army Corps of Engineers in the inner and outer harbors and the near-shore zone of Lake Michigan, at relatively frequent time intervals, appear to be adequate for residence time computations and for the conduct of certain hydraulic analyses. Because of the need for additional sediment data--as discussed below--and in light of the age and geographic scope of the bathymetric data available, it is anticipated that additional bathymetric mapping will be needed concurrent with the sediment studies.

With respect to hydrologic and hydraulic data, past and ongoing continuous-record streamflow monitoring for the Menomonee and Milwaukee River estuaries is inadequate for determination of pollutant loadings to the harbor estuary from upstream sources. The gaging station on the Kinnickinnic River at S. 7th Street is located relatively close to the upstream limit of the Kinnickinnic estuary, but the streamflow record--collected only since September, 1976--is relatively short. Implementation of more sophisticated methods of streamflow monitoring at the upstream limits of the Menomonee and Milwaukee River estuaries will be necessary for a successful water quality management study of the Milwaukee Harbor estuary since changes in the type of sewer system, and in the resultant runoff quality and quantity, occur between the upstream limits of the estuaries and the existing gaging stations on the Menomonee River at 70th Street and on the Milwaukee River at Estabrook Park. Although attempts have been made to monitor streamflow near the upstream limits of the Menomonee River and Milwaukee River estuaries, these attempts were made using conventional methods which proved to be inadequately suited for the hydraulic conditions existing at those locations.

Only a limited amount of current-velocity and current-direction data have been collected in the inner and outer harbors. These data were generally obtained for only portions of the estuary in any given study. Unfortunately, these data are inadequate for characterization of inner harbor circulation, of the hydraulic interrelationships of the inner and outer harbors, and of the outer harbor circulation over a full range of lake level, wind, and seiche conditions. Some of those topics may be addressed by the University of Wisconsin-Milwaukee study scheduled for completion by mid-1981. The City of Milwaukee continuous record water level gages in the estuary could also provide data which would be useful for inner harbor hydraulic analyses, if these gages were upgraded for more precise water level monitoring, and if the gages were tied to National Geodetic Vertical Datum by at least second-order vertical control surveys. Pollutant budgets and transport of pollutants between and within the outer harbor and the inner harbor cannot be quantified until hydrologic-hydraulic data are available which can support the development of the water budget relationships of these two harbor sub-systems.

With respect to ambient water quality conditions, the review of the studies indicated that adequate water column quality data exist for conventional pollutants--and for most hazardous substances--to characterize generally the current conditions in the Milwaukee, Menomonee, and Kinnickinnic Rivers and their tributaries in both

Milwaukee County and upstream from Milwaukee County. This data base will be useful as benchmark information for comparison of "before and after" conditions in the future evaluation of the effects of water quality management activities. These data, however, do not provide adequate baseline information on the ambient water quality conditions in the estuary or on the temporal and spatial effects of bottom sediments on water column quality, because insufficient water column chemical gradient data near the sediment-water interface have been collected for various hydrologic and hydraulic events.

With respect to wet- and dry-weather event river sampling, numerous intensive water quality surveys conducted in the estuarine and non-estuarine reaches of the Milwaukee River in Milwaukee County have been completed within the last two decades for use in studies of dissolved oxygen and bacteriological conditions. The Humboldt Avenue Detention Tank Study was the source of the oldest such evaluations. A lesser amount of data on hazardous substances has been collected, especially during wet-weather events. However, taken together, the past programs and the Milwaukee Metropolitan Sewerage District water quality sampling program currently being conducted should provide much of the water column data needed for identification of hazardous substances in not only the Milwaukee, but also in the Menomonee and Kinnickinnic River estuaries. Event sampling data currently available for the Menomonee and Kinnickinnic Rivers and estuaries, for the outer harbor, and for near-shore Lake Michigan are limited, and are useful as background information only. In addition, lack of streamflow data in the estuaries and at the outer harbor entrances severely restricts the usefulness of these data.

With respect to aquatic biology, the phytoplankton, zooplankton, benthic macroinvertebrate, and bacteriological data collected are of sufficient detail in the estuarine and non-estuarine reaches of the Milwaukee Harbor estuary subwatershed and in near-shore Lake Michigan to identify and in some cases to quantify the extant aquatic fauna and flora under existing conditions. It should be noted that periphyton data adequate to characterize the existing conditions has also been proposed to be collected in the ongoing Milwaukee Metropolitan Sewerage District baseline data monitoring effort. The available data on existing game fish species are also considered generally adequate. However, the minnow and forage fishes are not well documented or studied for the full geographic extent of the estuary.

With improvements in chemical and physical water quality characteristics, it may be expected that biological characteristics will also change. As in most biological systems, forecasting such changes quantitatively is not a well-developed science. The changes, however, may not necessarily be improvements, especially if conditions are enhanced for production and propagation of large amounts of aquatic plant growth. Such growths can be aesthetically undesirable and can create dissolved oxygen problems. Further study of these phenomena is therefore necessary to determine if indeed such problems could develop with physical and chemical water quality enhancement. It is anticipated that existing data and methodology can be utilized to make these determinations, and the nature of these determinations is set forth below in Chapter IV of this study design.

Review of the available studies indicates that with respect to pollutant sources, extensive data are available through state and federal regulatory programs for qualifying and quantifying point source loadings of conventional pollutants to the Milwaukee Harbor estuary. It must be understood that most point sources of water pollution to the estuary are discharged through the public sewer systems, which are unusually complicated in this particular area. Depending on the study objectives, it is possible that the point sources of hazardous pollutants are not adequately quantified, and that supplemental pollution source surveys will be necessary for selected point sources. This is also true with respect to the combined sewer overflows, since--as noted above--many industrial wastewater and cooling water discharges ultimately reach the receiving waters as elements of the combined sewer overflow.

A dearth of locally sampled nonpoint source pollutant data exists, thus precluding full qualification and quantification of nonpoint source pollutant loads. The ongoing Nationwide Urban Runoff Pollution Study project of the Wisconsin DNR and SEWRPC should provide some of the necessary data, but only for residential land uses. The Federal Highway Administration study will provide useful information on quality and loading rates of freeway storm water runoff from the Milwaukee area. The nonpoint source loadings in storm water runoff, snowmelt, and dryfall from other land uses--in particular the commercial, industrial, and transportation land uses, and harbor facilities--in the estuary subwatershed will also be needed in order to evaluate the significance of pollutants from these land uses upon the biological, sediment, and water quality characteristics of the estuary. Effects of ship movement and associated waste disposal and bilge water discharges upon water quality, as well as pollutant loadings from marinas in the Milwaukee Harbor are not documented and will require further investigation.

With respect to sediment studies, sediment loading rates to the Milwaukee Harbor estuary from the three inflowing rivers have not been adequately defined, because of a lack of systematic suspended sediment monitoring and because of inadequate streamflow monitoring. Suspended sediment loadings to the estuaries from upstream sources and from nonpoint sources within the estuary subwatershed, as well as the associated sediment chemistry, are necessary in the evaluation of the severe sediment pollution problem that exists within the estuarine reaches. The bottom sediments apparently exert very high sediment oxygen demands, particularly during high flow periods, and have been reported to be contaminated with substances characteristic of sediments classified by the U.S. Environmental Protection Agency as "hazardous" in nature. Under such categorization, the disposal of dredge spoils from the Milwaukee Harbor estuary would therefore require costly transfer to hazardous waste disposal facilities.

Existing suspended sediment data are lacking in part because long-term and event sediment transport rates have not been adequately quantified at the upstream limits of the estuaries, within the estuaries, and within the outer harbor. Chemical quality data for suspended sediments are also lacking since most suspended sediment data report only the total organic and inorganic proportions, and the particle-size distribution. Therefore, quantification of pollutant transport associated with suspended sediments in the estuarine system is inadequate for a full understanding of the pollutant sources, budgets, and exchanges at work.

Interstitial water quality in bottom sediments was characterized in 1976 in studies by Wisconsin Electric Power Company and the study on "Verification of Water Quality Impacts of Combined Sewer Overflow", published in 1979, provided some baseline information on nutrients, metals, total organic carbon, chemical oxygen demand, and volatile solids in interstitial water in the Milwaukee and Menomonee estuaries and the Menomonee canals. To better understand sediment-water interactions, additional interstitial water chemistry data collected in coordination with sediment and water quality sampling efforts will be necessary.

Bottom sediment samples have been collected in at least 17 different studies at about 250 locations in the free-flowing streams, the estuaries, the outer harbor, and adjacent waters of Lake Michigan since 1968. In many of these samples, nutrients, metals, and total and volatile solids were quantified with a limited number of samples being analyzed for chlorinated hydrocarbons. Such data are useful for identification of pollutants occurring in the bottom sediments in the Milwaukee Harbor estuary. These data collectively are not adequate, however, for determination of the quantitative effects of bottom sediments upon water column quality because, in part, the mechanisms by which undesirable substances are released from the sediments are not well understood; and because water quality gradients in the water column near the sediment-water interface generally have not been measured concurrent with sediment sampling. Because the role of bottom sediments as sources and sinks of pollutants has not been well defined, and because of the lack of adequate suspended sediment and chemical budgets for the rivers, estuaries, and the outer harbor, it appears that, in order to quantify the effects of sediments upon water quality, an extensive, systematic, coordinated sampling effort of the locations and physical characteristics of bottom sediments--including thickness, the bottom sediment chemistry, interstitial water quality, sediment oxygen demand, near-sediment water-column chemical gradients, suspended sediment quantity and quality, and water flow--is necessary for the Milwaukee Harbor estuary study.

For dredge spoil disposal analysis, qualification and quantification of hazardous substances in the estuary sediments is necessary to identify appropriate management actions and any appropriate disposal methods. To evaluate the feasibility and relative effectiveness of natural purification of the estuarine system, and of artificial purification measures, such as aeration, dredging, and flow-augmentation, the mechanism and duration of sediment oxygen demand and the sources of oxygen consuming materials must be identified along with the natural rates of mechanical flushing, and the rates of biological and chemical degradation of these polluted sediments from the Milwaukee Harbor, in order to determine whether any form of disturbance would be desirable or feasible.

With respect to flooding problems in the estuary, a review of available studies indicated five principal sources of information. These sources provide background information for both the inner and outer harbors, and quantify the extent and severity of flooding problems in the inner harbor. Together with conventional data sources used in floodland management studies, the available data in these reports may be expected to provide an adequate basis for the proposed planning effort.

Although this chapter has presented general conclusions regarding the adequacy of the data already available, further data collection efforts should not be specified without consideration of the study objectives presented in Chapter III. The applicability of certain existing data described in this chapter to the various elements of the proposed Milwaukee Harbor Estuary Planning Study will be addressed in Chapter IV, "Major Elements of the Milwaukee Harbor Estuary Comprehensive Water Resources Management Planning Program ". In that chapter, the quantity and quality of data necessary or already available for the conduct of the study will be addressed, with existing data fully utilized wherever possible and appropriate.

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Chapter III

PURPOSE AND OBJECTIVES OF A COMPREHENSIVE STUDY OF THE MILWAUKEE HARBOR ESTUARY

It is fundamental that the objectives of any undertaking be clearly established, in order that the work may be carried to a satisfactory conclusion. Accordingly, this chapter is intended to set forth explicitly the purpose and the objectives of the proposed Comprehensive Study of the Milwaukee Harbor Estuary.[1]

The purpose of the proposed comprehensive study is to identify a practical, cost-effective set of water resources management actions which will achieve agreed-upon local, areawide, state, and federal objectives for the management of the water resources of the Milwaukee Harbor estuary. These objectives--which would be explicitly identified and documented in the planning process--would include specific water use and floodland management objectives and related general land use development and redevelopment objectives.

In identifying the best water resource management plan for the estuary and its direct tributary areas, it will be necessary to:

1. Qualitatively and quantitatively assess the existing and historic water quality conditions and problems of the estuary;

2. Qualitatively and quantitatively assess the existing and historic flooding conditions and problems of the estuary;

3. Qualitatively and quantitatively identify all sources of pollution to the estuary, and to the extent practicable, assess the effects of those sources on water quality conditions and problems;

4. Evaluate specifically the role of in-place pollutant sources on water quality conditions;

5. Formulate practical and achievable water use objectives and supporting water quality standards for the estuary;

6. Formulate and evaluate alternative means of abating, to the extent necessary, the sources of pollution of the estuary, thereby achieving the agreed upon water use objectives and supporting water quality standards; and to identify from among the alternatives the most cost-effective means to achieving those objectives, identifying any water quality management measures needed in the tributary watersheds over and beyond those recommended in the adopted areawide water quality management plan, as well as the measures required to abate the in-place pollutant sources in accordance with concerns expressed by the Wisconsin Department of Natural

[1] *It should be noted that these objectives of the proposed study are not to be confused with the water quality management objectives, principles, and standards which are sought to be achieved for the estuary as a water body.*

Resources and the Milwaukee Metropolitan Sewerage District representatives in a series of interagency meetings held over the period from June 1979 through July 1980.

7. Recommend from among the water resources management alternatives the most cost-effective means of achieving the agreed-upon objectives for the estuary;

8. Extend the adopted regional water quality management plan by the amendment of that plan to include the most effective means of abating the water quality problems in the estuary;

9. Identify the specific actions necessary to implement the recommended plan, and identify the units and agencies of government which can best carry out those actions, including any required in-stream pollutant abatement measures;

10. Provide a basis for state and federal review of water quality standards for, and of required water quality enhancement actions in, the Milwaukee Harbor estuary;

11. Fulfill the request of the City of Milwaukee set forth in a resolution adopted by the Common Council of the City of Milwaukee on July 24, 1973, and reaffirmed by a resolution adopted by that body on March 20, 1979, that the Regional Planning Commission conduct a comprehensive study of the water resources and problems in the Milwaukee Harbor estuary as soon as practicable, following completion of comprehensive plans for the tributary watersheds; and

12. Assist the Wisconsin Department of Natural Resources and the Milwaukee Metropolitan Sewerage District in addressing the problem of in-place pollutants in the harbor estuary as called for in the resolution adopted by the Sewerage Commission of the City of Milwaukee and by the Milwaukee Metropolitan Sewerage Commission on May 24, 1979.

The study recommended in this document has been designed to meet the above-stated objectives. As noted in Chapter IV, a specific step for the identification of water resource management objectives is provided for in the proposed study. This particular step will be of particular importance to the management decisions applicable to the estuary, since the choice of water uses and floodland management objectives may be expected to have a significant impact upon plan design. Accordingly, the potential for reconsideration of the currently established state and federal water quality standards and floodland management objectives must be recognized in the proposed study.

For the Milwaukee Harbor estuary, the inherent complexity of water resources management is exacerbated by the complicated hydraulics; by the importance of sediment-water interaction; by the planned major actions for water pollution control of combined sewer overflows; by the high proportion of the tributary land dedicated to vital industrial, commercial, and high-density residential land uses; by the important implications of the estuary as a location for major public recreational and cultural facilities along the lake front and the waterway of the downtown area; and by the presence of the estuary as a major feature of the urban structure of the City of Milwaukee, and as a water resource of Regional and statewide importance. Only through a properly conceived and well executed comprehensive water resources management study can the objectives of the federal, state and local units and agencies of government be met in a practicable cost-effective manner.

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Chapter IV

MAJOR ELEMENTS OF THE MILWAUKEE HARBOR ESTUARY COMPREHENSIVE WATER RESOURCES PLANNING STUDY

INTRODUCTION

This chapter sets forth the major elements of a comprehensive study required to address the water resource and water resource-related problems of the Milwaukee Harbor estuary. The chapter is intended to establish the general scope and content of the planning program required to produce a comprehensive water resource management plan for the estuary subwatershed, and to thereby provide recommendations for the abatement of water pollution from both point and nonpoint sources so that the established water use objectives and supporting water quality standards will be met in a timely manner, and for the abatement of damages caused by floods, strong harbor currents, and storms on Lake Michigan. The work program has been prepared in sufficient detail to permit the development of initial cost estimates for budgetary and grant application purposes; to establish a practical time sequence and schedule for the necessary work; and to develop an organizational structure for the proposed work, including a determination of staff requirements. The outline is intended to constitute the initial plan of work as required for contracts between the funding agencies and the agencies involved in the conduct of the studies. As indicated in Chapter I, however, it is envisioned that the plan of work may need to be refined and revised from time-to-time during the actual conduct of the work program.

The chapter is based upon the following assumptions:

1. That the primary purpose of the Milwaukee Harbor estuary comprehensive water resources planning study will be the development of a sound and workable plan to control water pollution from both point and nonpoint sources within the Milwaukee Harbor estuary watershed, which will meet established water use objectives and supporting water quality standards in a cost-effective manner and will further the protection and wise use of the natural resource base; and to abate damages caused by flooding, fluctuating water levels, strong currents and wave action. In addition, the estuary planning program should provide, insofar as practicable, planning and engineering data which can contribute to planning efforts for the other estuaries in the Region, as well as to the preparation of a plan specifically for the Milwaukee Harbor estuary.

2. That the comprehensive water resource management plan to be produced for the Milwaukee Harbor estuary will be in sufficient depth to provide a sound basis for the review and approval, by the agencies concerned, of federal grant applications for flood control structures, navigation and associated transportation improvements, and water quality related facility improvements; to provide a basis for the review of the plans and designs for private and municipal flood control and navigation and associated transportation facilities; and to provide a basis for review of pertinent state and federalregulatory permit applications.

3. That effective solutions to the water resource problems of the estuary and full realization of its development potential can be achieved only by considering all important aspects of the natural resource base, together with

all significant human modifications and uses thereof. This requires that the estuary planning program be comprehensive in both functional scope and geographic area, fully recognizing the interrelationship of the land and water use problems of the estuary subwatershed, as well as the need to consider the entire Milwaukee Harbor watershed as a rational planning unit.

4. That the program will utilize the latest planning and engineering techniques in developing a comprehensive, coordinated water resources management and flood control plan for the Milwaukee Harbor estuary.

5. That the task of establishing a comprehensive water resource management and flood control planning program, collection and analysis of basic data under such a program, the formulation of individual plan elements, the synthesis of the recommended plan, and plan implementation all require close and continuing cooperation among the various levels and agencies of government concerned with, and involved in, land and water use problems of the Milwaukee Harbor estuary watershed.

6. That full use will be made of all existing and available surveys, studies, reports, and other data which may influence or affect the proposed work program; and that additional data collection activities will be conducted only as necessary to develop original data essential to preparation of a sound water resources management and flood control plan for the estuary. Thus, to the maximum extent possible, emphasis in the program will be on problem analysis and on plan formulation, testing, and evaluation.

7. That the abatement of pollution and public health hazards from the separate sewer flow relief devices and the combined sewer overflows which affect the Milwaukee Harbor estuary will be accomplished by the construction of a system to provide for the conveyance, storage, and subsequent treatment and discharge of wet-weather flows. Subsequent to the U.S. Supreme Court action of April 28, 1981 overturning the orders of the U.S. District Court of Northern Illinois--which required control of combined sewer overflows for conditions up to and including the largest storm in 37 years of record, the so-called "37-year level of protection"--the Milwaukee Metropolitan Sewerage District (MMSD) has indicated that a conveyance-storage-treatment system at a lesser level of protection would be selected to meet the requirements of the May 25, 1977 Dane County Circuit Court Stipulation, which established the State regulatory controls.

   In the event that a full or partial sewer separation alternative or a combination sewer separation and conveyance-storage-treatment alternative is ultimately selected for abatement of pollution from combined sewer overflows, the number and types of nonpoint pollution sources which would need to be sampled, and the control alternatives to be considered in a water resources planning study of the estuary would be significantly different from the assumed conveyance-storage-treatment alternative; and it would be necessary to amend this study design and the costs. Necessary amendments may include--but not be limited to--the inventory and analysis of the details of the proposed separation scheme itself; the amounts, types and locations of nonpoint sources of water pollution; the water quality characteristics of the runoff from selected types of land use; and the potential methods of redesign and modification of the existing combined sewer overflows and storm sewer outfalls, as well as data for any proposed new storm sewer outfalls.

8. That, a) a complete understanding of the dynamics of pollutant behavior in sediment-water interactions, and b) a complete and accurate simulation of the dynamics of the hydraulics and associated water quality phenomena of the Milwaukee Harbor estuary and its interaction with Lake Michigan are both highly complex technical issues which will ultimately require basic research efforts which transcend the scope of the proposed planning study. It is expected, however, that it will be possible to conduct, as part of the planning study, necessary functional analyses in support of a practical development and comparison of water resource management alternatives for the Milwaukee Harbor estuary.

9. That, although time is of importance, the breadth of the study and its intensity must not be sacrificed for the expediency of affecting temporary, short-range solutions to the problems of the estuary.

It is intended that the proposed Milwaukee Harbor estuary planning program will culminate in the preparation and adoption of a comprehensive water resources management plan providing for the abatement of pollution and flooding and related damage problems. In addition, it is intended that the plan will include specific recommendations for the designation of implementing agencies as required for any meaningful plan to be converted to reality. In this respect, it is intended that the estuary plan will serve as an extension and amendment to the adopted areawide water quality management plan, and will supercede those portions of the adopted comprehensive watershed plans which deal directly with the flooding problems in the Milwaukee, Menomonee, and Kinnickinnic estuaries. The estuary plan will also serve to refine and extend the sewerage facilities plan developed and adopted by the Milwaukee Metropolitan Sewerage District.

The proposed program will employ a seven-step process developed by the Regional Planning Commission, through which the principal functional relationships existing in the Milwaukee Harbor watershed that affect water quality and flooding in both the estuary and outer harbor can be accurately described both graphically and numerically; flows and quality conditions in the surface water system can be analyzed; and the effect of different courses of action with respect to land use and water quality management can be tested and evaluated. The seven steps involved in this planning process are: 1) study organization and design; 2) formulation of objectives, principles, and standards; 3) inventory, or data collection; 4) analyses and forecasts; 5) preparation, testing, and public evaluation of alternative plans; 6) plan selection and adoption; and 7) plan implementation. It should be understood that these steps may overlap to some degree, as in the case of inventory or data collection which may be ongoing for selected information, and, therefore, concurrent with the development of other phases of the planning study.

STUDY ORGANIZATION AND DESIGN

The basic design of the proposed Milwaukee Harbor estuary study is set forth in this volume. However, two additional and important tasks will be required during the conduct of the study itself. These are the organization and support of a suitable advisory committee structure, and the preparation of selected refinements to the plan of work.

Advisory Committee Structure and Citizen Participation

Since its inception, the Commission has striven to achieve active and constructive citizen participation in all its work programs. This established policy, coupled with requirements for citizen participation under the federal Water Pollution Control Act, will require an effective citizen participation element in the Milwaukee Harbor estuary work program. Primary citizen participation is intended to be obtained through citizen representation on a technical and citizen advisory committee, as described below. In addition, the Commission proposes to conduct public informational meetings and public hearings on the work, as well as to disseminate information concerning the program through the Commission Newsletter and annual report and through supplementary information-type documents, such as news releases. Major public hearings or meetings would be held at the outset of the study, in order to help achieve agreement on problem definition; at the point of significant development of alternative plans; and upon completion of the initially proposed plan. Conferences or workshops will also be scheduled as required. Because of its importance, citizen participation is envisioned as an ongoing work element to be continued throughout the life of the program.

It is proposed that the Milwaukee Harbor estuary planning program be guided and monitored by a reconstituted Technical and Citizens Advisory Committee on Coastal Management in Southeastern Wisconsin. If it is to have a meaningful role, the committee will require considerable staff service, including administrative services such as preparation of meeting agendas and meeting minutes; technical orientation, in terms of written briefings as to prior local decisions and programs and their relationship to the proposed Milwaukee Estuary planning program; and assistance in the dissemination of information concerning the estuary planning program throughout the Milwaukee Harbor watershed. The function of advisory committee service will continue throughout the life of the Milwaukee Harbor estuary planning program.

Final Plan of Work

It is envisioned that the study staff will work with the staffs of the Wisconsin Department of Natural Resources, the U.S. Environmental Protection Agency, the U.S. Geological Survey, and other agencies of government and members of the Advisory Committee in preparing a final plan of work and in initiating actual work on the program. It is important that the technical staffs of the various local, state and federal agencies concerned develop a common understanding as to the specific purposes of the work program, the way in which the work program is to be conducted, and the specific work program outputs. For this reason it is anticipated that considerable staff work will be expended, once the Milwaukee estuary planning program is funded, in preparing a final plan of work. This work step will be accomplished by those key Commission staff personnel who will actually be responsible for the conduct of the work program.

FORMULATION OF OBJECTIVES AND STANDARDS

Since planning is a rational process of formulating and meeting objectives, the formulation of agreed-upon development objectives is a necessary and essential task which must be undertaken before plans can be prepared, evaluated, and adopted. The objectives to be defined must not only be clearly stated and be logically sound, but must also be related in a demonstrable way to alternative plan proposals and system management programs. Only if the objectives are clearly related to physical development and subject to objective tests can a choice be made from among alternatives in order to select that plan which best meets the agreed-upon objectives. To accomplish this, logically conceived and well expressed objectives must be translated into detailed design standards to provide the basis for plan preparation, testing, and evaluation. The formulation of such objectives and supporting standards is a matter of public policy, and as such is dependent upon many non-engineering, as well as engineering, considerations.

It is envisioned that under the Milwaukee Harbor estuary planning program the work element dealing with the formulation of objectives, principles and standards will include two subelements: 1) the review of previously formulated pertinent resource conservation and development objectives under prior Commission work programs; and 2) the formulation of new water resource management objectives relating to the harbor estuary.

Review of Previous Objectives

Prior Commission planning programs for land use development, sewerage system development, comprehensive watershed development, and areawide water quality management have each contributed toward the formulation of a body of regional and subregional land use and water resources development objectives together with supporting principles and standards. It will be essential that under the estuary planning program all of the previously formulated pertinent objectives, principles, and standards be reviewed and reconsidered in light of the federal water quality objectives expressed in the federal Water Pollution Control Act Amendments of 1972, and in any resulting programs undertaken by local, state, or federal government in the implementation of the national goals. Of particular importance in this respect are those objectives and supporting standards specifically relating to water use and water quality and to flood damage abatement.

Formulation of Additional Objectives

It is envisioned that it will be necessary to formulate new water resource management objectives and supporting principles and standards under the Milwaukee Harbor estuary planning program to deal with those substantive areas not previously dealt with under Commission land and water resources planning programs. Of particular importance in this respect are the formulation of additional objectives relating to the control of water pollution from nonpoint sources and to water quality enhancement measures; to the importance of the estuary to the sound development and redevelopment of the adjacent land areas, and particularly of the central business district of Milwaukee; and to the abatement of damages from flooding, high or fluctuating water levels, strong currents, and wave action.

CONDUCT OF INVENTORIES

Reliable basic engineering and planning data available on a uniform, areawide basis is essential to the formulation of workable water resource management plans. Inventory, consequently, becomes the first operational step in any water resource planning effort evolving from the final plan of work. The data may either have to be obtained by direct measurement as part of the planning program, or may have to be acquired from secondary sources--that is, obtained from another agency which has originally collected the information. The basic inventory operations described below will have to be conducted as part of the proposed estuary water quality management planning program.

Base Maps and Aerial Photography

Essential to any consideration of water resource management planning for the harbor area is a definitive knowledge of the topographic and cultural features of the estuary subwatershed. Such knowledge can be best derived from large-scale topographic and cadastral (property boundary) maps. Information will be required on such features as ground relief; areas subject to inundation; areas subject to erosion; and such man-made features as real property boundary lines, highways, railroads, loading areas and docks, storm and combined sewer outfalls, and related catchments; materials stock piles; and principal buildings and bridges. Small scale, general base maps of the estuary subwatershed will also be required to provide a medium for recording and presenting in graphic form the results of the planning studies, as well as the natural and man-made features of the area.

Planning base maps have been prepared by the Commission for the entire Region and are available for the study. These maps portray Milwaukee County at four scales: 1:24,000, 1:48,000, 1:62,500, and 1:96,000. These base maps can be used to prepare an estuary subwatershed planning base map, which can in turn be expanded or reduced in scale for use in various phases of the studies. The map will show, among other information: all major streams and watercourse lines; all railroads, streets, and highways; all township range and section lines; and all civil division lines. Hypsometry can also be added to the base maps using 10 foot interval contour lines. These maps are compiled to the National Map Accuracy Standards utilizing the Wisconsin State Plane Coordinate Grid South Zone as the map projection.

Current aerial photography at appropriate scales will be required to provide detailed historic and existing planimetric information as a basic source for land use data and as a data source for the necessary updating of all base maps. Aerial photography of the entire Region was obtained by the Commission in April of 1963, 1967, 1970, 1975, and 1980. These aerial photographs will be available for the study at scales of 1:48,000 and 1:24,000.

General Natural Resource Base and Environmental Data

A massive amount of basic data about the natural resource base of the Region has already been collected and developed under the work programs of the Commission and of various other public and quasi-public agencies. These data include definitive data on soils, climate, topography, geology, woodlands, wetlands, and wildlife habitat areas. It is envisioned, however, that some additional data collection efforts will be required for specific use in the Milwaukee Harbor estuary subwatershed planning program.

With respect to soils, detailed information will be available to the estuary planning program from the detailed operational soils survey of southeastern Wisconsin completed for the Commission by the U.S. Soil Conservation Service in June 1966, for those areas outside the estuary subwatershed where urban development, with its attendant disturbance of the soil, did not preclude the collection of soils data at that time. Additional data will be available from the subsurface investigations conducted by various governmental agencies operating in the harbor area including, but not necessarily limited to, Milwaukee County, the Milwaukee Metropolitan Sewerage District, the City of Milwaukee, and the Wisconsin Department of Transportation.

Climate is particularly important to water resources management planning, influencing such factors as runoff, treatment facility operation, and estuary currents and water levels as affected by wind setup, seiche, and waves from Lake Michigan. Of particular importance are data on wind speed, wind direction, temperature, precipitation, snowfall accumulation, frost depth, and drought. Much of the climatological information required has been collected and compiled by the U.S. Weather Service, the City of Milwaukee, the Milwaukee Metropolitan Sewerage District, and by the Commission in its ongoing regional planning programs. It is envisioned that this data base will be adequate, providing these efforts are maintained during the study, in order to provide a proper data base for the conduct of the estuary planning program. These meteorologic data are fundamental to hydrologic, hydraulic, and water quality analyses, and to the preparation of design criteria for the proper development and operation of water quality treatment, flood control, and harbor protection facilities.

As each element of the Milwaukee Harbor estuary planning program attains a more precise and definitive stage, maps will be required depicting information on property boundary lines and topography to greater detail and to a greater degree of accuracy and precision than furnished by the general base maps. The degree of accuracy and precision which can be attained in such plan implementation devices as shoreline and floodplain regulation depends in part upon the accuracy and scale of available maps. Such maps will have to be available at a scale of 1:1,200 or 1:2,400, with two-foot contours compiled by stereophotogrammetric methods, and should be compiled to National Map Accuracy Standards. In order to properly correlate topographic and cadastral map data, such maps should be based upon a monumented control survey network which relates the U.S. Public Land Survey System to the State Plane Coordinate System. These maps will be required particularly for those portions of the estuary and direct drainage area subwatersheds that, according to the ultimate plans, may be expected to require floodland and shoreland regulation or require the reservation of land for the ultimate construction of water resource management facilities, including point and nonpoint source pollution control structures, structures or facilities appurtenent to instream pollution abatement measures, shoreline protection structures, and drainage and flood control facilities. These maps should provide a sound basis for the preparation of local plans and plan implementation devices.

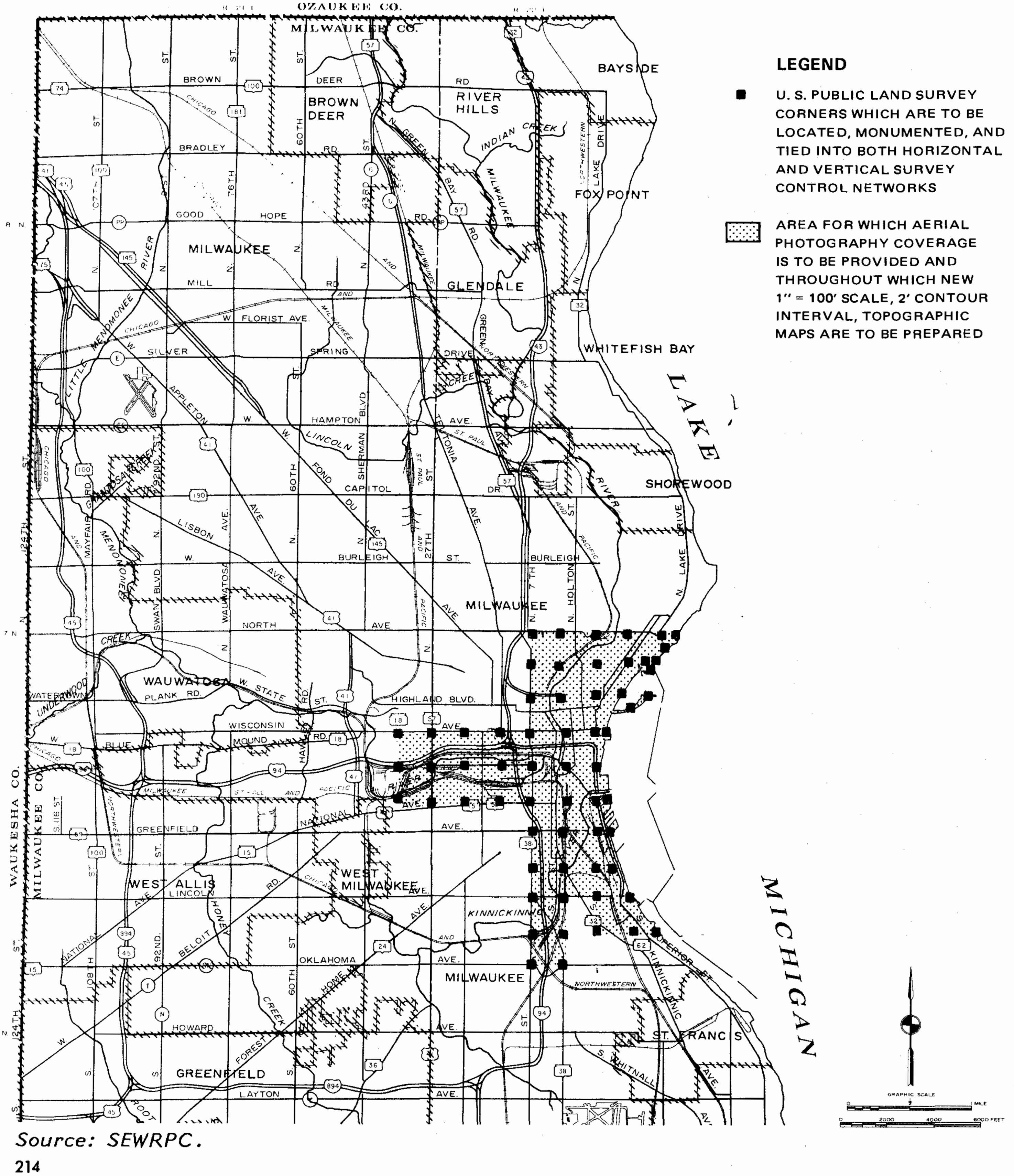
Topography is important to water resources management planning since it is an important determinant of drainage patterns and of the location of watershed, subwatershed, and subbasin boundaries, as well as the location and alignment of wastewater and storm runoff conveyance systems, and the location and configuration of sewage treatment facilities. In the most densely developed areas of the estuary subwatershed, the necessary topographic information will best be obtained in the form of urban street and utility maps and related grades and profiles. Current, accurate data on street elevations and grades, and on existing and proposed sanitary sewer, combined sewer, and storm sewer systems and catchment areas will be particularly important to the study. As described previously, some new topographic map preparation will be required to facilitate the preparation of precise facility plans for water quality, shoreline, and floodland management facilities. The necessary street and utility information already existing can be collected from the local government agencies concerned, primarily the City of Milwaukee. The necessary large-scale topographic mapping would have to be prepared as part of the planning program. The areas proposed for large-scale topographic mapping are shown on Map 29, and total 9.0 square miles in extent.

With respect to geology, it is important to note that two geologic factors --surficial deposits and the nature of and depth to bedrock--in combination with certain hydrologic, surface, and cultural considerations establish the potential for land disposal of dredge spoils and influence the criteria for sanitary sewage and storm water conveyance and treatment facility design. Existing geologic data will be collated and utilized in the conduct of the estuary study. Of special importance will be the extensive data series developed in the subsurface geologic investigations conducted by the Milwaukee Metropolitan Sewerage District, as part of its ongoing water pollution abatement program; the data of the U.S. Geological Survey; the Wisconsin Geological and Natural History Survey; and the Wisconsin and U.S. Departments of Transportation.

Basic inventories of woodlands, wetlands, and wildlife habitat areas have been conducted and are maintained current under other Commission work programs. It is proposed that these available inventories be refined and detailed with the cooperation of the Milwaukee County Department of Parks, Recreation and Culture, the Wisconsin

Map 29

PROPOSED LARGE-SCALE TOPOGRAPHIC MAPPING AREA FOR THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY



Source: SEWRPC.

Department of Natural Resources and the U.S. Fish and Wildlife Service, and be revised as appropriate for the estuary planning program.

Surface Water Inflow

Definitive data on surface water inflow to the estuary from the estuary subwatershed, the tributary rivers, and Lake Michigan are necessary for the preparation of an estuary water budget and determination of chemical and sediment loadings to the estuary and adjacent Milwaukee Bay.

Continued monitoring of streamflow for the Kinnickinnic River at S. 7th St. will provide adequate data for determination of inflow to the Kinnickinnic estuary, because of the close proximity of the gaging station to the upstream limit of the estuary. For the Milwaukee and Menomonee Rivers, however, streamflow gaging stations are sufficiently distant from the estuary limits as to render suspect any extrapolations of these flow data to the upstream limits of these estuaries for non-baseflow periods. Because conventional flow monitoring methods are not applicable at the estuary limits, more sophisticated methods of flow measurement will be necessary for the Menomonee River. For the Menomonee River, it is recommended that the "method of characteristics"[1] or a similarly suitable method be employed using the two existing gaging station structures at the Falk Corporation Dam and at S. 36th Street extended, along with attendant stream channel cross sections to determine inflow to the estuary. For the Milwaukee River, it is recommended that the gaging station at the North Avenue dam be re-activated for the period of field sampling during the study. The operating rules for the gates of the dam would be established during the course of the study, to allow for the most precise possible monitoring of flow during all flow conditions.

It is further proposed that operation of the Milwaukee and Kinnickinnic River flushing tunnels be continuously monitored during the period of study and a continuous record of power consumption at each pumping station be maintained to examine relationships suitable for determination of the specific rates of flow in each flushing tunnel.

Monitoring of flows in separate storm sewers draining selected and representative land use areas for seasonal discrete events will be required to support water quality sampling to determine urban nonpoint source pollutant loadings to the estuary. The Nationwide Urban Runoff Pollution Study and the U.S. Department of Transportation Freeway Runoff Study should provide much of the necessary nonpoint source data, but additional monitoring will be required for industrial, commercial, and recreational land uses, including materials storage areas and staging areas in the Menomonee Industrial Valley, and the harbor facilities of the subwatershed. Estimates of the quantities and quality of the flows contributed from combined sewer overflows (CSO) will be developed on the basis of information and analyses prepared as part of the ongoing Milwaukee Metropolitan Sewerage District (MMSD) facilities planning program. In addition, CSO data will be utilized from the ongoing monitoring

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[1]*The method of characteristics is an iterative technique for solution of non-linear, unsteady state partial differential equations describing unstratified open-channel flow. A computer program employing this technique is described in Computation of Unsteady Flows in Rivers and Estuaries by Chintu Lai and Charles A. Onions, published as U.S. Geological Survey Computer Contribution CC-76/034 in 1976. Input to the program consists of simultaneous water surface elevations at each end of a stream reach along with channel geometry for that reach.*

programs of the MMSD and the City of Milwaukee--described in Chapter II, --to determine CSO quantity and quality during the Milwaukee Harbor estuary study period.

Continued monitoring of wastewater discharge at the Jones Island plant by the MMSD should be maintained and the data made available in a timely way for a coordinated analysis of any associated in-estuary or event-related sample results obtained as part of the planning study. Supplemental measurements at the Jones Island plant should be made as necessary to assure accurate determinations of peak flows, however. Flow monitoring calibration should be maintained to insure accuracy.

Determination of flow through the outer harbor breakwater openings will be necessary and can be carried out using vertically stratified measurements of velocity and water temperature, and using hydraulic simulation modeling, as described in the following three sections of this chapter. Ideally, continuous monitoring of flow between Lake Michigan and the estuary would be conducted to provide real-time data for the conduct of this study. Continuous monitoring by conventional methods is not feasible, however, because frequent ship traffic through the narrow breakwater openings would destroy monitoring equipment. Frequent periodic monitoring using portable equipment is also infeasible because of time consuming logistics and resultant excessive costs. Therefore, it is necessary to conduct an intermittent monitoring program to provide data for calibration of a hydraulic model for simulation of flow to and from the estuary.

Water Level Fluctuations

Water level monitoring in the Milwaukee Harbor estuary is necessary for studies of water circulation patterns and flooding problems, and to estimate the movement of water between the estuary and Lake Michigan proper. The existing water level monitoring programs conducted by the City of Milwaukee, the Port of Milwaukee, the University of Wisconsin-Milwaukee, and the National Ocean Survey in the inner and outer harbors are adequate for the purposes of flooding studies, and it is assumed for the purposes of this study design that these programs will be maintained.

For the water flow and quality investigations, however, a more precise water level monitoring effort will be required in the inner harbor. Precision water level monitoring is required for the determination of flow rate and direction for hydrologic and water quality budget analyses, and--as discussed under "Hydraulic Circulation"--for input to any hydraulic simulation model of the inner or outer harbor flows and stages.

Four existing continuous stage recorders have been operated since 1975 in the inner harbor by the City of Milwaukee at the locations shown on Map 23. The University of Wisconsin-Milwaukee currently operates one precise level monitoring station in the inner harbor. Equipment at the City of Milwaukee monitoring stations should be upgraded to provide a precise water level measurement capability, using low-friction digital stage recorders accurately synchronized and accurately tied to the National Geodetic Vertical Datum. Effects of short-period oscillations in the water level due to waves and ship wakes should be damped by appropriate stilling well intake throttling devices. The data should be recorded in or transferred to digital form for use in hydraulic simulation modeling.

To address effects of long-period oscillations in the inner and outer harbors upon ships moored therein and upon harbor structures, three continuous water level recorders are needed in the outer harbor near the north and south ends and at the main harbor entrance. The National Ocean Survey water level monitoring station located at the southern end of the harbor at the U.S. Coast Guard Station should be supplemented by a new station to be established under this study at the northern end of the harbor near Juneau Park to meet these needs. A new station would also be established by the MMSD at the main harbor entrance. All of the water level recording stations should be operated continuously throughout the period of study.

Water Waves

Water wave data are necessary for addressing problems related to flooding, wave damage, and long period water-level oscillations in the outer and inner harbors. Offshore wave data collected near Milwaukee by the Great Lakes Environmental Research Laboratory (GLERL) are available for a short period of time but are inadequate for definition of deepwater wave characteristics necessary for study of outer harbor surface wave conditions. It will accordingly be necessary to concurrently operate an offshore wave gage along with the outer harbor water level gages--described above--and to monitor wave direction using LANDSAT imagery. It is recommended that the MMSD would collect the data in cooperation with GLERL.

Internal waves caused by surface seiche induced oscillations in the thermocline may cause occasional inflow of hypolimnetic waters from Lake Michigan into the outer and inner harbors. Such inflow may be expected to occur over sufficiently long periods that continuous vertical water temperature monitoring at one location in the outer harbor, in combination with inner and outer harbor bathymetry data, could be utilized to compute Lake Michigan hypolimnetic inflow volumes during periods of thermal stratification. Therefore, it is recommended that such temperature monitoring be conducted at the main breakwater entrance to the outer harbor, with monitoring equipment to be housed at the University of Wisconsin-Milwaukee water level monitoring station put in place in 1980, or at the Milwaukee Metropolitan Sewerage District weather station, to supplement intermittent current velocity measurements referred to earlier in this chapter under the heading "Surface Water Inflow."

Hydraulic Circulation

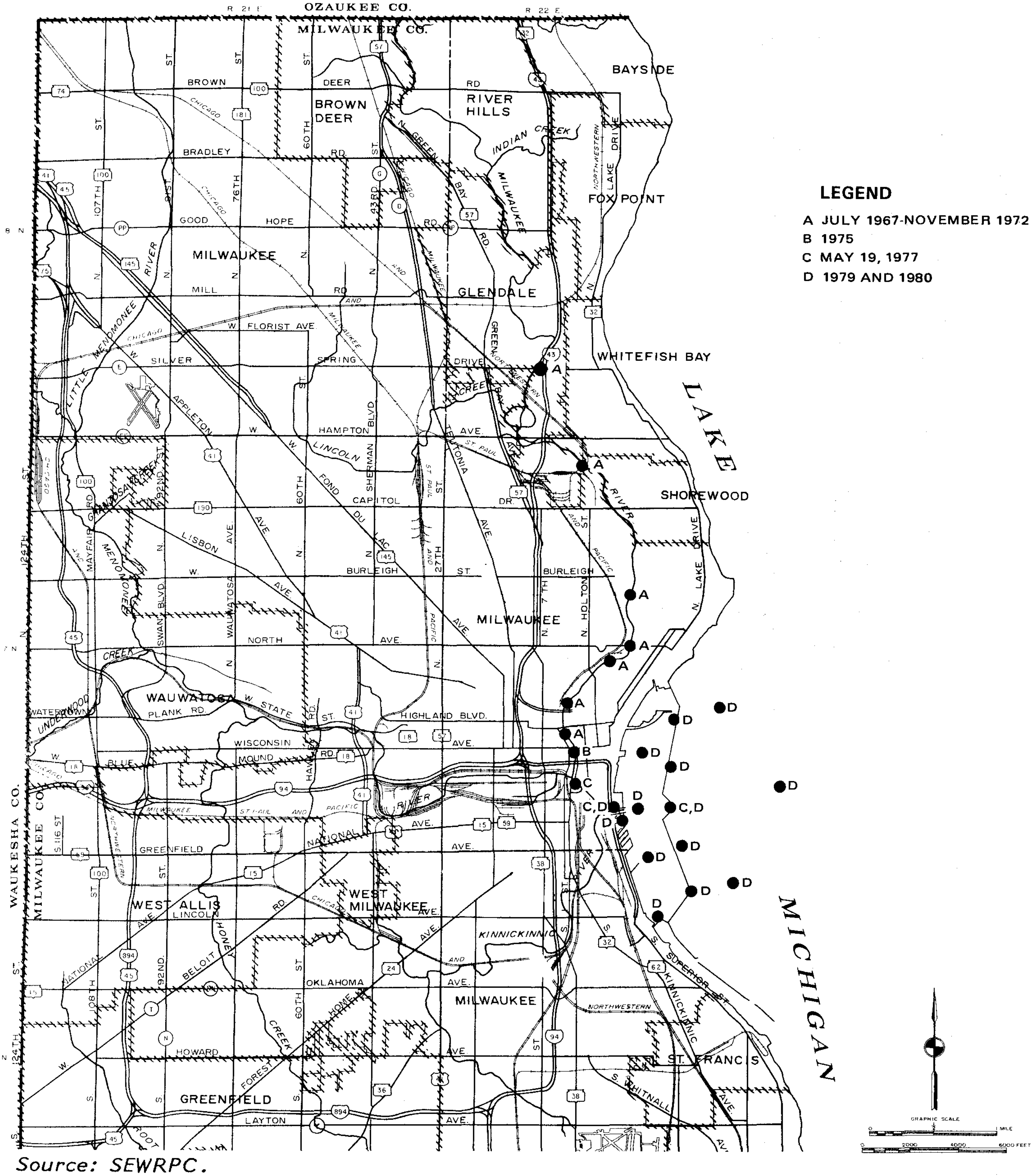
Hydraulic circulation in the Milwaukee Harbor estuary not only affects and is affected by water surface levels, but also affects the chemical and biological characteristics of the estuarine system. Circulation in the inner and outer harbors is complicated because of the interaction of Lake Michigan with the riverine system. To understand sediment and pollutant concentrations in the estuary and the outer harbor, and to develop realistic alternatives for the abatement of pollution and the control of water levels, a time coordinated set of data collected throughout the estuary and outer harbor will be needed.

Some previous studies in the Milwaukee Harbor estuary have involved collection of current speed and direction data to meet the specific needs of individual projects. Locations of sites where known current studies have been made are shown on Map 30. In addition, the University of Wisconsin-Milwaukee presently operates two continuous-record current-velocity meters about one mile east of the main harbor entrance. Unfortunately, as Map 30 indicates, the available data do not permit a time-coordinated study of adequate geographic scope to be made as required for an estuary planning study. Although data collected previously will be useful to the conduct of the proposed study, additional data are necessary.

To calibrate a hydraulic-hydrologic simulation model for determination of continuous water flow in the inner harbor and at the outer harbor breakwater openings, the existing point of continuous-record current-velocity meters in adjacent Milwaukee Bay east of the main harbor entrance should be maintained by MMSD throughout the period of study. Intermittent measurements of current speed and direction throughout

Map 30

LOCATION OF STATIONS FOR MONITORING OF CURRENT VELOCITY IN PREVIOUS STUDIES IN THE MILWAUKEE ESTUARY AND ADJACENT MILWAUKEE BAY



Source: SEWRPC.

the water column will be obtained at all 17 locations in the inner and outer harbors and at the five locations in Milwaukee Bay, shown on Map 31 and described in Table 86. The intermittent current velocity data should be collected during a full range of river flow and limnological conditions so that complete model calibration is possible. Monitoring data, therefore, should be obtained during high, medium, and low river flows, and during periods of both lake-water-intrusion and no-intrusion, throughout the annual static water level cycle of Lake Michigan. During velocity measurements, concurrent vertical water temperature profiles should also be measured to facilitate evaluation of the velocity data. Continuous vertical water temperature measurements at one location in the outer harbor and in each of the three estuaries--as addressed under the section on "Water Quality Baseline and Event Sampling Data"--should provide supplemental data valuable for analysis of the intermittent velocity data. In addition, continuous water level monitoring--described under the section on "Water Level Fluctuations"--is intended to supplement the current velocity data for operation of the continuous simulation hydraulic model.

Geohydrology

A knowledge of geohydrological conditions in the Milwaukee Harbor estuary subwatershed is necessary for evaluation of potential subterranean effects upon surface water flow and quality in the estuary.

Previous geological, geohydrological, and subsurface engineering investigations completed by the U.S. Geological Survey and the Milwaukee Metropolitan Sewerage District should provide useful data for assessment of these effects for the purposes of the estuary planning study. These data will be collated and utilized in the determination of estuary water and chemical budgets, and for use in the preparation of alternative plans involving subsurface engineering structures. In addition, special groundwater quality and quantity studies will be conducted as described below under the section entitled "Groundwater." The results of these special studies will be integrated with the other data available, and documentation will be prepared to describe the salient findings of the inventory.

Sediment Processes

The effect of sediments--and related processes such as scour and resuspension--on water quality conditions in the Milwaukee Harbor estuary must be investigated in order to provide a basis for the development of a sound water resources management plan for the Milwaukee Harbor estuary. There are five issues which must be addressed in the study.

1. The study must identify the existing quantity and the physical and chemical characteristics of the sediments throughout the Milwaukee Harbor estuary.

2. The study must identify the sources and the contribution of those sources to the sediments of the estuary under existing and future conditions.

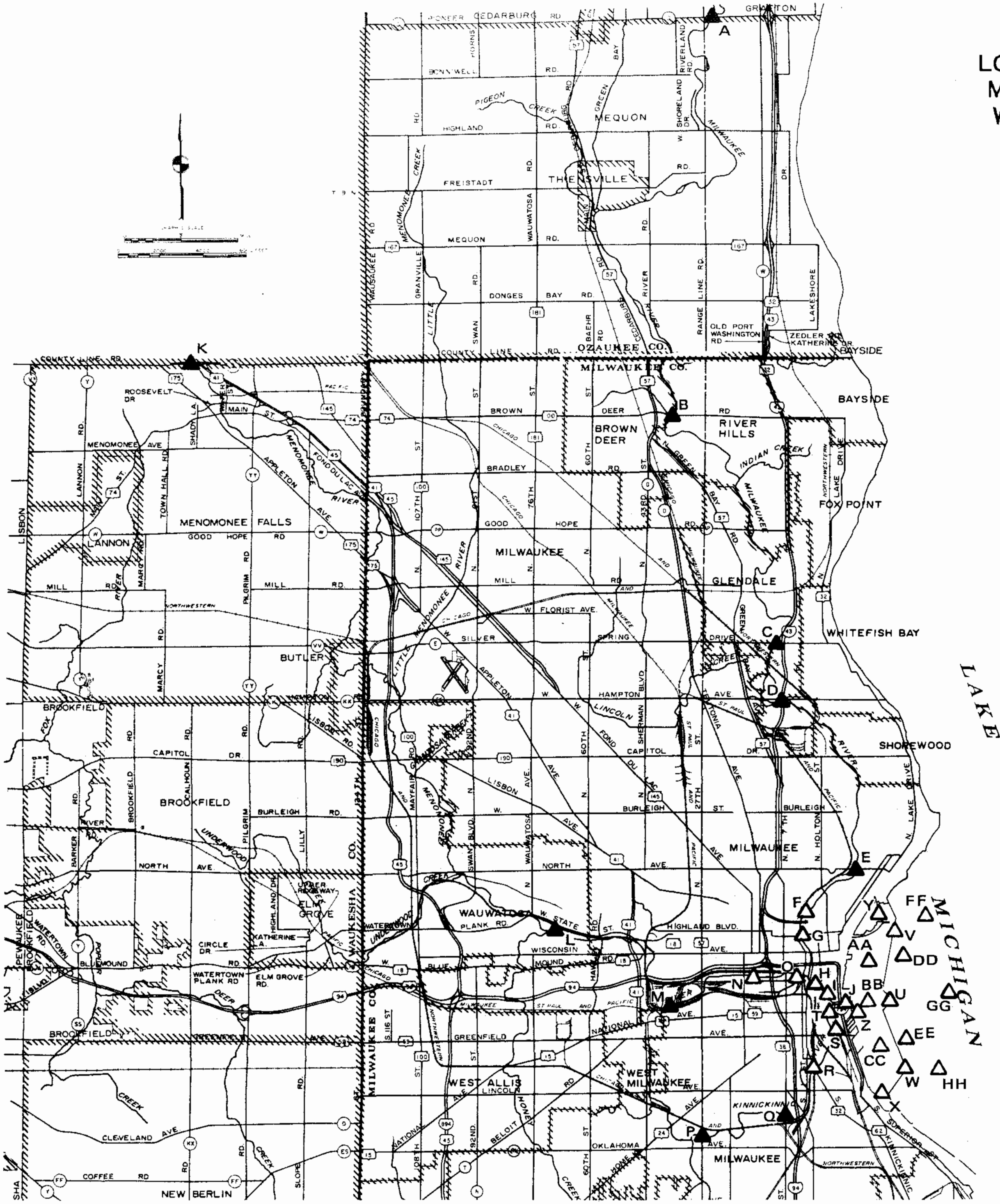
3. The study must identify the mechanisms by which and the rates at which physical scour, resuspension, and other related physical and diurnal processes and in-situ chemical and biological processes affect water quality.

4. The study must provide information on the combined effects of the individually identified mechanisms on water quality in the estuary.

5. The study must relate the sediment characteristics and related mechanisms to potential instream water quality management measures.

Map 31

LOCATION OF PROPOSED STATIONS FOR MONITORING CURRENT VELOCITY AND WATER QUALITY FOR THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY



LEGEND

▲ WATER QUALITY MONITORING STATION

△ WATER QUALITY AND CURRENT VELOCITY MONITORING STATION

F REFERENCE LABEL FOR SAMPLING STATIONS LOCATED IN TABLE 86

Source: SEWRPC.

Table 86

SAMPLING STATION DESCRIPTIONS FOR THE
MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

Location	Reference Number On Map 31	Site	Sampling Platform	Anticipated Number of Vertical Sampling Points[a]	Purpose
Milwaukee River	A	Pioneer Road (River Mile 26.25)	Bridge	1	To reflect impacts of rural areas on river water quality upstream from the limits of Milwaukee Metropolitan Sewerage District service area.
	B	Brown Deer Road[b] (River Mile 14.99)	Bridge	1	To reflect impacts of separate sewer service areas, upstream from combined sewer service area.
	C	Silver Spring Drive[b] (River Mile 8.49)	Bridge	1	To reflect impacts of separate sewer service area, upstream from combined sewer service area.
	D	Port Washington Road (River Mile 6.91)	Bridge	1	To reflect impacts of combined sewer service area (CSSA) contributions from Lincoln Creek, upstream of estuary.
	E	North Avenue dam (River Mile 3.10)	Bridge	1	To quantify pollutant loadings at upstream limit of estuary, and to provide a continuous dissolved oxygen (DO) monitoring site in the CSSA.
	F	Walnut Street (River Mile 2.25)	Bridge	3	To reflect conditions in the Milwaukee River portion of the estuary and to provide a continuous DO monitoring site in the CSSA.
	G	Wells Street (River Mile 1.41)	Bridge	3	To reflect conditions in the Milwaukee River estuary above the confluence with Menomonee River.
	H	Water Street (River Mile 0.78)	Bridge	3	To reflect conditions in the Milwaukee River estuary below the confluence with Menomonee River.
	I	C&NW Railway (River Mile 0.44)	Boat	3	To reflect conditions in the estuary above the confluence of the Milwaukee River with the Kinnickinnic River estuary, and in the central turning basin.
	J	Hoan Bridge-River Mouth (River Mile 0.00)	Boat	3	To reflect conditions in the estuary below the confluence with the Kinnickinnic River and to quantify pollutant loadings to the outer harbor.
Menomonee River	K	County Line Road[b] (River Mile 23.47)	Bridge	1	To reflect impacts of rural areas upon river quality upstream from the limits of the Milwaukee Metropolitan Sewerage District service area.
	L	N. 70th Street (River Mile 6.10)	Bridge	1	To reflect conditions in the separate sewer service area upstream from the combined sewer service area.
	M	Falk Corporation Dam (River Mile 2.22)	?	1	To quantify pollutant loadings into the upstream limit of the estuary and to reflect water quality conditions within the combined sewer service area.

Table 86 (continued)

Location	Reference Number On Map 31	Site	Sampling Platform	Anticipated Number of Vertical Sampling Points[a]	Purpose
Menomonee River (continued)	N	Muskego Avenue (River Mile 0.92)	Bridge	3	To reflect conditions in the Menomonee River estuary and to provide a continuous DO monitoring site.
	O	S. 2nd Street (River Mile 0.06)	Bridge	3	To reflect conditions at the downstream end of the Menomonee River estuary.
Kinnickinnic River	P	S. 27th Street[b] (River Mile 4.91)	Bridge	1	To reflect conditons in the separate sewer service area upstream from the combined sewer service area.
	Q	S. 7th Street (River Mile 2.88)	Bridge	1	To quantify pollutant loadings into the upstream end of the estuary and to reflect conditions in the combined sewer service area.
	R	S. 1st Street (River Mile 1.43)	Bridge	3	To reflect conditions in the estuary and to provide limited continuous water quality monitoring.
	S	Greenfield Avenue extended (River Mile 0.57)	Boat	3	To reflect conditons in the Kinnickinnic turning basin in the estuary.
	T	Jones Island Ferry (River Mile 0.15)	Boat	3	To reflect conditions near the mouth of the Kinnickinnic estuary.
Outer Harbor	U	Main Harbor Entrance at the Breakwater	Boat	3	To measure the amount and quality of discharge to/from Lake Michigan.
	V	North fairweather gap	Boat	3	To measure the amount and quality of discharge to/from Lake Michigan.
	W	South fairweather gap	Boat	3	To measure the amount and quality of discharge to/from Lake Michigan.
	X	Russell Avenue gap	Boat	3	To measure the amount and quality of discharge to/from Lake Michigan.
	Y	McKinley Marina	Boat	3	To determine water quality conditions in the marina area.
	Z	Jones Island STP Plume	Boat	3	To determine sewage treatment plant effluent impacts on water quality.
	AA BB CC	Outer Harbor--north, central, and south	Boat	3	To characterize dilution effects upon harbor water quality.
	DD-HH	Lake Michigan waters in Milwaukee Bay (5 sites)	Boat	3	To characterize dilution effects upon Lake Michigan water quality.

NOTE: See Map 31 for sampling site locations.

[a]Discrete samples will be taken at mid-depth unless 3 sampling points are indicated. In this case discrete samples would also be taken 1 meter below the water surface and 1 meter above the bottom.

[b]Streamflow to be determined for each water sample using stage-discharge relationships developed by current meter measurement.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC

By the conduct of appropriate sediment-related inventories, it is proposed that the first three objectives would be directly met. In addition, when the inventory findings are applied in conjunction with the other data collection efforts proposed as part of the Milwaukee Harbor estuary study, these inventory activities would provide a basis for the attainment of the other study objectives described herein.

The existing quantities and physical and chemical characteristics of the estuary sediments will require careful study. It is proposed that the type, depth, and extent of the existing sediments be mapped at the start of the field inventory period. Areas of sedimentation and areas of scour would be identified on the basis of the mapping. The characteristics of the different types of sediments, and of the interstitial waters, would then be determined on the basis of samples, the sampling sites being judiciously located on the basis of an analysis of the mapped areas and depths. This information developed in the initial stages of the study will be used as a basis for the development of the specific details of any further sediment studies required to adequately understand the dymanic processes affecting the relatioship between sediment quality and quantity and water quality. The more detailed process studies may require sampling on an event-by-event basis at carefully selected locations.

The proposed mapping and sampling would determine the location, depth, and characteristics of the sediments in the inner harbor. Combined with data on the geometry of the channel bottom, the maps would provide a basis for estimating the volume of the sediments resident within the inner harbor at the onset of the 28-month sampling program. The resulting unconsolidated sediment thickness map, used in conjunction with the sediment quality studies further described below, will be fundamental to the determination of the masses of pollutants in the unconsolidated deposits, and to the horizontal and vertical distributions of the pollutants within the deposits. Such information will be important to any evaluation of the effects of various mitigative measures, and to any assignment of the methods and costs of dredging and of dredged materials disposal.

The costs of the sampling of the physical and chemical qualities of the bottom sediments and associated interstitital waters have been estimated in this study design on the basis of the assumption that sampling would be conducted at the 15 locations set forth in Table 87, and depicted on Map 32. The cost estimates assumed that these sediments would be tested for the chemical and physical indicators set forth in Table 88. For purposes of cost estimation, it has been further assumed that such sampling would be conducted four times per year for each of the two years of the field study, following an initial four-month period of testing the sediment sampling methods. Although this sampling design is subject to revision or refinement as the earliest sample results become available, the Ad Hoc Technical Task Force concluded that the costs of this sampling design provide a reasonable basis for budget preparation.

For the sources of sediment and the associated rates of contribution, a special sediment-related element of the water column sampling programs will be undertaken to evaluate suspended sediment transport rates and deposition rates through the use of sediment traps under various conditions in the inner harbor and the free flowing rivers above and below the combined sewer service area. The suspended sediment monitoring as described in the water quality section below will be conducted during the study period at 32 locations shown on Map 31. In addition, bed load sampling using the Helley-Smith sampler will be used along with the Einstein-Colby equation to determine bed load transport as part of the sediment transport studies. Continuous monitoring of suspended sediments will be conducted during runoff events at the

Table 87

INITIALLY PROPOSED SAMPLING STATIONS FOR BOTTOM SEDIMENT PROCESS STUDIES IN THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

River	Location	Data Type				
		Sediment Chemistry	Inter-stitial Water Chemistry	Sediment (Traps) Deposition Rates	Gas Produc-tion	Benthic Oxygen Production/ Consumption
Milwaukee	Pioneer Road	--	--	--	--	X
	Hampton Avenue	X	X	X		
	Locust Street	X	X	X	X	--
	Walnut Street					X
	Wells Street	X	X	X	X	
	St. Paul Avenue	X	X	X	X	X
	Broadway	X	X	X	X	--
	Kinnickinnic River	X	X	X	X	--
Menomonee	Hampton Avenue	X	X	X	--	--
	Hawley Road	X	X	X	--	--
	Falk Dam	X	X	X	X	X
	Muskego Avenue	X	X	X	X	X
	Burnham Canal	X	X	X	X	--
Kinnickinnic	S. 35th Street	--	--	--	--	X
	Wilson Park Creek	X	X	X	--	--
	Chase Avenue	X	X	X	X	--
	S. First Street	X	X	X	X	X
	Greenfield Avenue (extended)	X	X	X	X	X

NOTE: The sampling sites are identified for purposes of cost-estimation, but are subject to review and confirmation or to refinement and revision on the basis of early sediment survey findings.

Source: SEWRPC

Map 32

INITIALLY PROPOSED LOCATION OF SAMPLING STATIONS FOR BOTTOM SEDIMENT PROCESS STUDIES IN THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

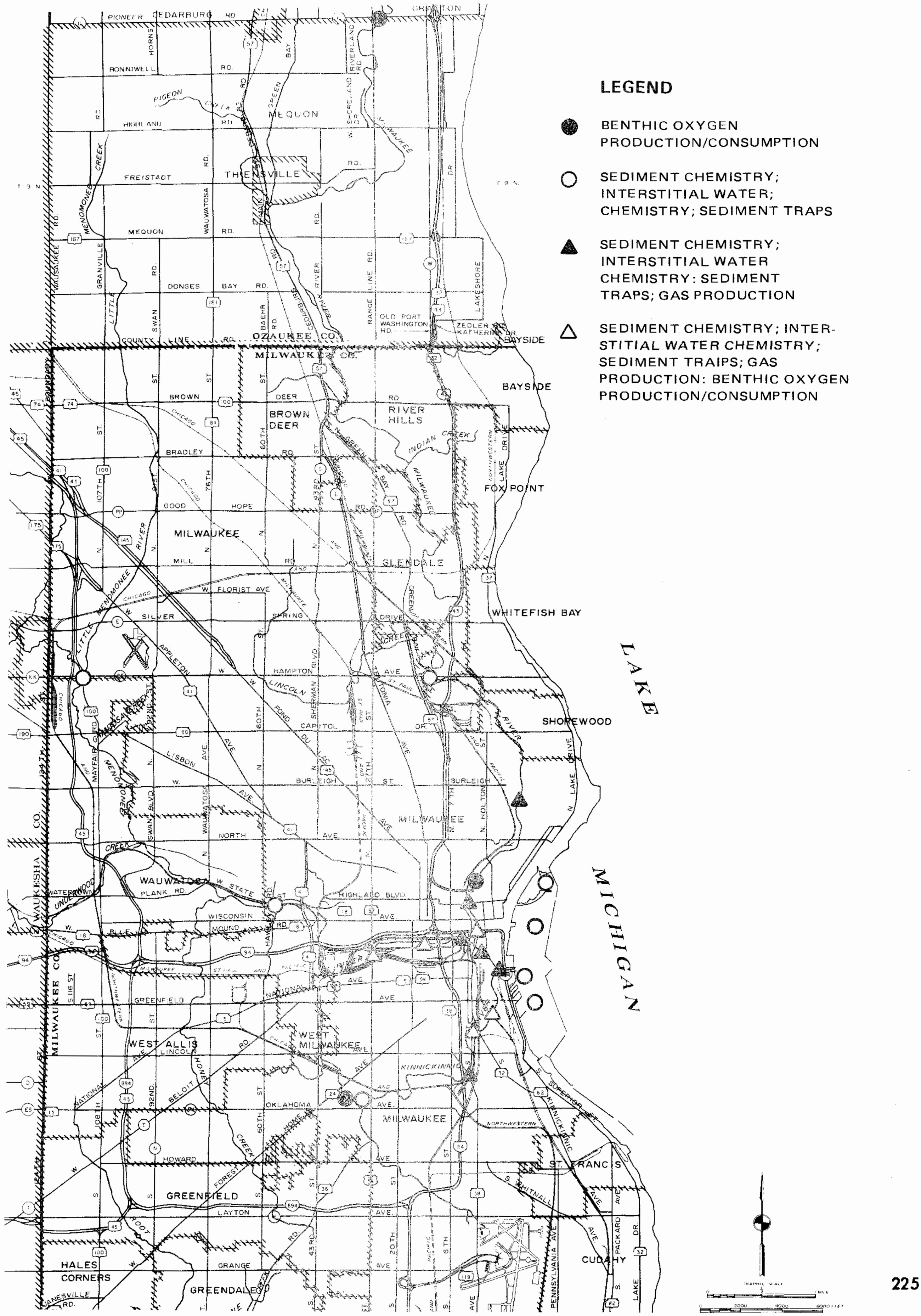


Table 88

SEDIMENT CHEMISTRY AND RELATED INDICATORS TO BE ANALYZED
FOR THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

Type of Data	Sampling Frequency	Indicators[a]	
Sediment Traps	Bi-Weekly	Total organic carbon Total inorganic carbon Chlorophyll-a	Chemical oxygen demand BOD_{20}
	Monthly	Particle size distribution	
Gas Generation	Seasonally	Methane Hydrogen sulfide	Carbon dioxide Air
Sediment Cores	Variable by site--weekly to monthly March through June of each year.	Total solids Total volatile solids Density Particle size distribution Chemical oxygen demand Immediate oxygen demand Total Kjeldahl nitrogen Total phosphorus Multi-metal scan	Total hydrogen sulfide PCB's Methyl mercury Methyl lead Alpha and gamma spectra 2,4-D Polychlorinated napthalenes (PCN's) Strontium-90[b] Plutonium-239[b] Cesium-137[b]
	Quarterly	Total solids Total sulfide Immediate oxygen demand	
Interstitial Water	Variable by site--weekly to monthly March through June of each year.	Total solids Chemical oxygen demand Immediate oxygen demand Ammonia nitrogen	Total Kjeldahl nitrogen Total phosphorus Multi-metal scan Sulfate Total organic carbon Total inorganic carbon Sulfide
Sediment oxygen demand (in situ)	Seasonally	Dissolved oxygen Turbidity Secchi depth	Water Temperature Chlorophyll-a

[a]The sampling effort will generally test unfiltered samples, for "total" concentrations, in light of previous samples which have indicated the solids to be the principle vehicle of solids retention and transport. Testing of filtered samples to check for dissolved pollutants will be conducted to the degree necessary to confirm the continued validity of this assumption.

[b]To be analyzed once annually at one site each in the Milwaukee, Menomonee, and Kinnickinnic River estuaries.

Source: SEWRPC

seven U.S. Geological Survey (USGS) river gaging stations using pump samplers with daily sampling during normal flow periods. During runoff events, this frequency will be increased as appropriate for the determination of event loads. The remaining 3 river and 10 inner harbor sites will be sampled on a weekly basis, except during the four runoff events to be sampled annually, at which time samples will be obtained approximately every four hours. Using observed and simulated streamflow data in the free-flowing rivers and the inner harbor, observed suspended and bed load sediment data will be utilized to compute event, monthly, and annual sediment loads at the sites listed in Table 86. Suspended sediment sampling at the breakwater openings will be conducted by the MMSD during the routine weekly water quality surveys by that agency. In addition, the MMSD will conduct sampling at these sites on a daily basis during a major spring rainstorm event each year. Results of these sampling activities will be utilized in the forecast and analyses described later in this chapter. For selected suspended sediment samples a particle size distribution will be obtained. For the rates of deposition, it is proposed that sediment traps be utilized at the 15 locations described in Table 87. The MMSD will provide the divers needed to provide for the collection and analysis of sediment deposition rate data.

With respect to the mechanisms and rates at which physical scour, resuspension, and other related physical and chemical processes and in-situ chemical and biochemical processes affect water quality, it is proposed that field and laboratory studies be conducted of scouring phenomena, in-situ gas generation rates, benthic algae productivity, and sediment oxygen demand. The proposed scouring studies would include detailed mapping of the unconsolidated sediments at a characteristic combined sewer outfall in order to evaluate the impacts of specific storm events and associated combined sewer overflow rates upon the mass of sediments at that site. Laboratory studies of scouring rates will be conducted through the use of the MMSD pilot plant facilities, with the sediments subjected to various physical perturbations and with the hydraulic and chemical response of the sediments measured and evaluated. It is anticipated that gas generation studies would be conducted through the use of in-situ techniques, utilizing gas collection devices to obtain stratified samples of the rates of gas production in the sediments and to identify the specific gases associated with the sediment decomposition processes. These evaluations will account for the role of temperature and pressure in the changes in rates of gas production. Benthic algae and sediment oxygen demand studies and other aquatic biology studies would provide information on the existing and anticipated future oxygen production and consumption in the benthic zone through the use of light and dark chambers placed on the bottom sediments. As shown in Table 87, such studies would be conducted at a minimum of eight locations in the three rivers and inner harbor. Replicate measurements will also be made under different meteorological, hydraulic, and seasonal conditions to fully characterize the benthic oxygen production and demand in the estuarine system. Simultaneous turbidity measurements by secchi disk and photometer readings will also be taken, as will chlorophyll-a and periphyton samples as indicators of the primary productivity levels in the aquatic system. These data will provide the basis for relating sediment behavior to the frequency and magnitude of sediment disturbance associated with various levels of combined sewer overflow protection, and to potential disturbances by naturally and humanly induced hydraulic phenomena. Thus, the results of these evaluations of the amounts and character of sediment, the sources and rates of contribution of sediment, and the rates of sediment exertion will be fundamental to the conduct of the forecast and analysis as described below. In addition, the sediment inventory studies described above, taken in conjunction with water column studies described elsewhere, will provide a basis for the evaluation of sediment-water interaction analyses, and for the evaluation of potential instream measures and their impacts on the water quality and associated aquatic biota.

Of particular importance to obtaining sound, useful sediment data is the provision of a preliminary period of sampling in order to verify the sampling procedures which are currently proposed to be used. The practical implementation of the sediment sampling procedures described here will require sufficient lead time in order to assure that data will be obtained in coordination with the proposed 24-month water column sampling program. Thus, a total of 28 months of sediment sampling will be necessary. The MMSD will develop the sediment sampling techniques and will collect the subsequent field data for the remaining 2-year monitoring period. These data will be provided to SEWRPC and a consultant for interpretation and development of algorithms describing bottom sediment processes for utilization in water quality simulation modeling.

Bathymetry

Bathymetric data are necessary for hydraulic, hydrologic, water quality and biological analyses in the Milwaukee Harbor estuary, as input for hydraulic-hydrologic modeling, for preparation of chemical and sediment budgets, and for analysis of aquatic habitats. Bathymetric maps are also useful for studies of wave diffraction, refraction, reflection, and breaker height; harbor oscillation currents; and dredging requirements for maintenance of navigation and water quality. Bathymetric data collected in the recent past throughout the estuary and in adjacent Milwaukee Bay by the University of Wisconsin-Milwaukee, the U.S. Army Corps of Engineers, and the National Ocean Survey will be collated and should provide an adequate data base for the purposes of the estuary planning study. Supplemental soundings should be made, however, during sampling periods at all physical, chemical, and biological sampling sites.

Harbor Operation Problems

Problems in the operation of the Milwaukee Harbor facilities are primarily related to dredging for navigational maintenance and to storm damages, in addition to water quality and related aesthetics problems. No significant problems attributable to floating ice are reported to exist in the estuary. As discussed in Chapter II, the U. S. Army Corps of Engineers conducts dredging operations for the maintenance of navigation in congressionally authorized federal channels in the inner and outer harbors. These channels are shown on Map 2 in Chapter II. Dredging projects have been discontinued upstream from Buffalo Street on the Milwaukee River, however, because of the discontinuation of deep-draft ship traffic beyond that location. Dredging within 75 feet of dockwalls in the harbor is the responsibility of adjacent property owners. The Port of Milwaukee conducts maintenance dredging in slips in the outer harbor, in the Burnham Canal west of S. 11th Street, and in the Kinnickinnic Estuary between S. First Street and W. Becher Street.

All dredging operations in Milwaukee Harbor require state and federal permits for disposal of dredge spoils. As a matter of policy, open-lake disposal of harbor dredge spoils is prohibited by the Wisconsin Department of Natural Resources. In addition, disposal in the U. S. Army Corps of Engineers "contained spoils disposal facility" located in the south end of the outer harbor is prohibited for spoils classified as "hazardous" by the U.S. Environmental Protection Agency (USEPA). Because of relatively high lake levels in recent years, extensive dredging has not been required, and attendant spoils disposal has not, therefore, been a major problem. With the inevitable decline in lake levels, however, disposal of spoils from the needed dredging projects will become a critical problem which could seriously hinder commercial navigation activity in the Milwaukee Harbor, and the related transportation activities in the Region. Consequently, the Milwaukee Harbor estuary planning study will address the need for additional dredge spoils disposal facilities by conducting an inventory of potential contained sites for spoils disposal in both the Milwaukee Harbor area and inland for hazardous spoils. This effort will use, as a point of departure, the results of the Regional Planning Commission preliminary analysis of potential areas for upland disposal of dredge spoils, an analysis conducted in the summer of 1981 under contract to the Milwaukee Harbor Commission through a grant provided by the Coastal Management Program of the U.S. Department of Commerce. In addition, potential means of lake-related disposal, such as injection below the thermocline, beach augmentation, or off-shore island construction, will be investigated to identify methods that may be environmentally appropriate for disposal of harbor sediments. If lake-related disposal methods were implementable for Milwaukee Harbor sediments, the life of the existing contained spoils disposal facility would be increased, and the need for additional in-lake and inland contained disposal areas would be diminished. Bottom sediments in the harbor will be inventoried--as described earlier in this chapter under "Sediment Processes"--and classified according to appropriate disposal methods based upon sediment quality characteristics and sediment volume.

Storm damages in Milwaukee Harbor have been caused in part by incoming waves, reflected waves, and wind blown spray--all of which are magnified by the effects of wind set-up--and strong oscillating currents associated with harbor surge. As part of the Milwaukee Harbor estuary planning study, an inventory of historic storm-related damages will be conducted to qualify and quantify damages and specific causes of such damages. This information will be considered in conjunction with historic and forecast water level and wave monitoring data--discussed previously in this chapter, and in Chapter II--to identify the steps necessary to address storm-related damages in the harbor. This effort would entail identification and general evaluation of alternative means of attenuating the most severe wave and current conditions in the outer harbor; consideration of the economic, social, and environmental effects of alternative measures; documentation of the evaluations; identification of any facilities design or refinement studies which are necessary, and recommendation of the steps to implement the findings and recommendations.

Water quality and aesthetic conditions affect harbor operations, particularly in the inner harbor. Tour boats and pleasure craft utilizing the Milwaukee and Kinnickinnic River estuary waterways have frequently encountered obnoxious conditions. Under some seasonal conditions, large quantities of aquatic vegetation, such as algae and duck weed, pass over the North Avenue dam, creating unsightly, and sometimes obnoxious, conditions in the Milwaukee estuary with the decaying vegetation creating odors and excessive oxygen demand in the water column. The Port of Milwaukee is charged with the responsibility of removing obnoxious aquatic vegetation, as well as floating debris, which is unsightly or causes obstruction to navigation. Degraded water quality in the McKinley Marina, at the north end of the outer harbor, and near the South Shore Yacht Club, at E. Iron Street and Shore Drive, may be attributed primarily to combined sewer overflows, and to a lesser extent perhaps to marina operations, recreational boating activity, and local runoff. To alleviate water quality problems in these two recreation areas and to improve the quality of flushing tunnel withdrawals near these two areas, pollution sources should be identified and quantified for the development of remedial plans to address these particular problems. Inventories to be made for assessment of water quality-related problems relevant to harbor operations are included with water quality data inventories which are described below in this chapter.

Land Use Inventory

Since land use is an important determinant of water use and of the quantity and rate of runoff, a land use inventory will be required as an integral part of the estuary subwatershed study. The inventory must reveal the existing and proposed amount, type, intensity, and spatial distribution of land uses, at a level of detail sufficient to provide an understanding of historic patterns and trends and to serve as a basis for the preparation of a basinwide land use plan. This inventory effort will also identify the transportation-related land uses which are pertinent to the harbor operations and commercial navigation activities. The land use data in turn will serve as a framework for the collection of more detailed nonpoint source inventory data about the type and extent of nonpoint sources of water pollution, including storage piles of coal, salt, scrap metal, and other materials discussed below. Essentially, much of the land use data for the needed studies is available--at the cost of collation--as data from local agencies of government--including the Milwaukee Harbor Commission and the City of Milwaukee Department of City Development--and from the Regional Planning Commission as a part of its continuing regional land use-transportation study.

Public Utility Facilities

Mapping of the existing and proposed public utility systems within the estuary subwatershed, and particularly of the sanitary sewer systems, public water supply systems, and storm water drainage systems will be required to determine urban land use capabilities and possible future relationships to development in the Milwaukee Harbor estuary basin. Special attention should be given to the identification and characterization of points of combined and separate sanitary sewer flow relief devices discharging to the tributaries of the estuary and directly to the estuary, and to existing or proposed storm sewer outlets, as well as to the delineation of the tributary areas served by these devices and outlets.

Extensive data on the sanitary and combined sewer systems in the study area are available from previous studies. For the purposes of the Milwaukee Harbor estuary planning study, available information on the sanitary and combined sewerage system in the files of the Milwaukee Metropolitan Sewerage District and the Regional Planning Commission will be adequate, and can be assembled for use in the study at the cost of collation.

Data on existing industrial and commercial water withdrawals, and on the existing and planned public water supply intakes will be assembled and collated for the Milwaukee Harbor estuary study area.

Of particular importance to water resources management planning in the Milwaukee Harbor estuary is an inventory of all existing urban storm water drainage systems, including piped storm sewers and identified open channels which provide for urban storm water drainage. Under the Section 208 planning program, a significant inventory effort was mounted with respect to urban storm sewers and identified drainage channels. Other data are available from the studies conducted by the MMSD and local units of government. For the purposes of the estuary planning study, information collected during the Section 208 program and the Milwaukee Metropolitan Sewerage District facilities planning study will be collected and checked. After confirmation of the continued validity of the data, the information will be used with limited further inventory efforts only where necessary to refine or extend the available data.

Water Use Inventory

An investigation will be required of the various kinds and intensities of water use, and of the relationship of use to water quality and to land use. The existing water demand must be identified with regard to the quantity, quality, location, and timing of use. In the Milwaukee Harbor estuary subwatershed, the potential use categories include industrial, cooling, waste assimilation, flow augmentation, fish and wildlife, recreation, navigation, and aesthetic uses. The extent to which these are presently served will have to be determined. This evaluation will include appropriate assessments of the relationship of the land-based features of the study area to the related water uses.

Existing and Anticipated Future Nonpoint Source Pollution Control Practices

Because nonpoint sources of water pollution are generalized discharges of waste and because they cannot, by definition, be traced to a specific discrete source, they are more difficult to inventory than are point sources of pollution. Nonpoint source pollutants are contained in storm water runoff and snowmelt. Figure 8 illustrates the various sources and types of pollutants and their routes of movement to receiving waters. The pollutants contained in runoff include:

1. Pollutants contained in grit; cinders; oil; gas; rubber, asbestos and metal particles; garbage; animal wastes; and deicing salts and sands from streets, highways, and parking areas.

2. Eroded soil particles from cropland areas which are not protected by soil and water conservation practices or from urban areas in which construction erosion controls are not adequately applied.

3. Air pollutants from atmospheric washout and fallout.

4. Nutrients and hazardous chemicals from lawn and garden fertilizers and pesticides.

5. Nutrients and hazardous chemicals from agricultural and silvicultural fertilizers and pesticides.

6. Biochemical oxygen demand, nutrients, chemicals, and pathogenic organisms from liquid waste and solid waste storage, loading and disposal areas, and from landfills.

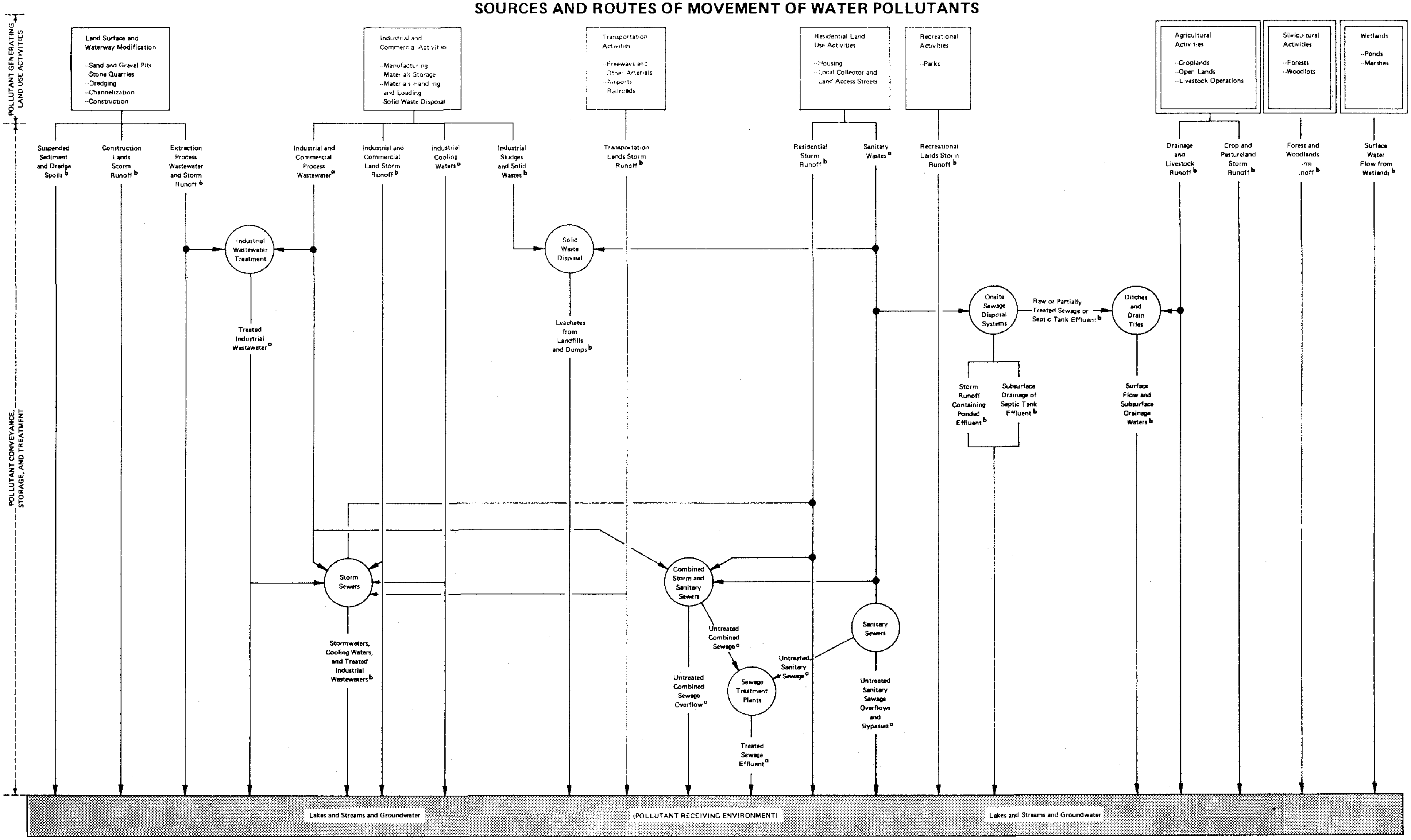
7. Biochemical oxygen demand, nutrients, and pathogenic organisms from animal feed lots and manure storage areas, and from livestock transport and processing.

8. Heavy metals, grease and oil, a wide range of process chemicals, and particulate matter from industrial sources discharging into storm and combined sewers, and in runoff from outdoor storage and work yards.

For the purposes of the estuary planning study, an inventory will be conducted of existing and anticipated future nonpoint sources of pollution and related control practices. Particular emphasis will be placed upon inventorying such sources and practices in the estuary subwatershed, an area which is highly developed and contains major concentrations of intensive commercial and industrial land uses. The inventory effort will rely upon the land use inventory data as a point of departure, and will include the use of detailed inventory questionnaires, field surveys, and property manager interviews, as appropriate. The available data developed by the City of Milwaukee Department of City Development, as part of the Menomonee River Industrial Valley Development Project, will be utilized to the greatest degree possible. Methods of storage of deleterious substances in industrial and commercial areas, along with the methods of urban land management, will be inventoried and supplemented by miscellaneous runoff quality sampling as described in this chapter in the section concerning water quality data.

Figure 8

SOURCES AND ROUTES OF MOVEMENT OF WATER POLLUTANTS



LEGEND

PREDOMINANTLY URBAN LAND USE ACTIVITIES

PREDOMINANTLY RURAL LAND USE ACTIVITIES

MAN-MADE STRUCTURAL CONTROLS

ROUTES OF POLLUTANTS

[a] *Routes of pollutant-bearing substances predominantly point in nature.*

[b] *Routes of pollutant-bearing substances predominantly nonpoint or diffuse in nature.*

Source: SEWRPC.

Hazardous Material Spills: Hazardous material spills within the urbanized portion of the lower Milwaukee Harbor watershed may contribute to the loading of toxic and hazardous materials to the Milwaukee Harbor estuary. During the period 1975-1977, 160 spills were reported to the Wisconsin Department of Natural Resources in Milwaukee County in the Milwaukee, Kinnickinnic, and Oak Creek watersheds. No such similar data were collated by the DNR in the Menomonee River watershed but it is likely that numerous spills occurred in that watershed also. The DNR estimates, in its unpublished report "Milwaukee County River Basins Study," that perhaps 90 percent of such spills are unreported. For the purposes of the estuary planning study, spill reports from the DNR; the U.S. Coast Guard; and the USEPA Spill Prevention, Control, and Countermeasure Program will be collated for use in classifying types of materials spilled, spill-prone areas, causes of spills, and spill sources. Measures used for spill control by the DNR, USEPA, and others will also be inventoried and evaluated. The proposed river and estuary water and sediment quality monitoring--described elsewhere in this chapter--should provide data helpful in evaluating the significance of toxic and hazardous substance spills upon estuary water quality. In particular, the proposed MMSD continuous monitoring of dissolved oxygen, pH, and specific conductance and temperature at the three stations to be established under the study, may provide information useful in evaluating the frequency and severity of some types of spills noticeably affecting receiving water quality during low flow periods. It is anticipated that spills during high flow periods may go undetected because of dilution effects and high concentrations of pollutants originating from sewerage system flow relief devices and from urban nonpoint sources of water pollutants.

Hazardous materials utilized in industrial processes and petroleum products are stored at numerous locations in the lower Milwaukee Harbor watershed in Milwaukee County. In addition, there are many materials storage areas for hazardous substances which may not be protected from the action of wind and rain, and therefore are potential sources of pollution to the Milwaukee Harbor estuary. Locations of storage areas of hazardous materials will be inventoried through review of the files of state and federal regulatory agencies, and through the use of inventory questionnaires and interviews. The USEPA Spill Prevention, Control, and Countermeasure Program requires spill prevention, control, and cleanup plans for facilities storing petroleum or chemicals in amounts exceeding 1,320 gallons above ground and 42,000 gallons below the ground surface. Such plans are not usually filed, however, until after a spill occurs. These plans will be examined along with DNR spill reports to assist in identification of hazardous materials storage areas. As a result of this work task, a detailed map will be prepared to indicate the land cover and specific materials exposed to precipitation in the estuary subwatershed. This mapping will provide a detailed basis for the interpretation of storm water and snowmelt runoff samples obtained for water quality evaluation of nonpoint sources of water pollution.

Existing and Proposed Dredging Programs

Dredging in the Milwaukee Harbor estuary is currently conducted by the U.S. Army Corps of Engineers in the designated "Federal Channels" (Map 2, Chapter II); by the Port of Milwaukee in the municipal mooring basin, the Burnham Canal west of 11th Street, and in the Kinnickinnic estuary between First and Becher Streets, and in the outer harbor slips; and by private owners from dockwalls out 75 feet to the federal channel. Dredging is performed as the need arises. For the purposes of the estuary planning study, an inventory will be conducted to document the frequency and extent of dredging in the inner and outer harbors, the quantities of materials dredged, and the means used for disposal of dredged materials for use in analyzing dredging programs and problems. Historic dredging information will be obtained from the Army Corps of Engineers, the Port of Milwaukee, the Wisconsin Department of Natural Resources, and other entities involved in dredging since 1950. Data will be obtained, inter-related, and summarized concerning the timing, locations, and amounts of dredging activities, and the characteristics and disposal locations of the dredged spoils, along with the costs of the dredging projects and the transport and disposal elements thereof, and the historic extent of the interference of such activities with the conduct of recreational and commercial navigation, water intake, related transportation, and other activities.

Mathematical Simulation Models and Analytic Techniques

Mathematical simulation model techniques are desirable for the proper conduct of the Milwaukee Harbor estuary study because of the need to quantitatively assess anticipated future as well as existing water quality conditions, and the impacts of such conditions on committed or proposed water quality management actions. Existing sampling data alone cannot provide an adequate basis for such assessment.

The application of simulation model techniques to the study of the Milwaukee Harbor estuary is problematic for several reasons. First, the hydraulics of the Milwaukee Harbor estuary are very complex. As documented elsewhere in this study design, the estuary is susceptible to numerous physical forces and is sufficiently small to respond significantly, and within a relatively brief time, to these forces. As noted earlier, the harbor can respond significantly to such actions as storm events in the upper watersheds, storm events in the immediate area, and storm events on Lake Michigan; the intrusion of lake waters, wind and wave action, and the movement of ships during non-storm conditions; the discharge of industrial effluents including thermal wastewaters; the use of the dilutional flushing tunnels in the Milwaukee and Kinnickinnic Rivers; and dredging and other instream activities. In addition to the hydraulic complexity, the interactions between the sediment and the overlying water column effecting water quality conditions are a major complicating factor for which the existing technical research base is still evolving.

It would be highly desirable to have available or to be able to develop a mathematical simulation model which would permit accurate quantitative assessment of water flow and water quality conditions in both the inner and outer harbors including the interfaces with the near-shore zone, and the interfaces with the upper watersheds beyond the area directly tributary to the estuary. In order for such a model to be useful in the proposed study, it should be able to simulate hydrologic, hydraulic, and water quality conditions including the sediment-water column interactions and the effects of thermal discharges. The Commission staff reviewed the available simulation models and other analytic tools which would be applicable to an estuary study. The existing potentially applicable models are described in Table 89. Based upon careful review of the currently available models, it was concluded that none of the models currently available provide the full capability required at this time. The Commission staff and Task Force concluded, therefore, that the development of the required three-dimensional hydrodynamic and water quality simulation model capability for the inner and outer harbors should be undertaken. It was further concluded that there is an inherent uncertainty in any simulation modeling if a calibrated and verified model is to be achieved--especially in a case involving such a complex hydraulic simulation. Therefore, and in light of the especially stringent time constraints involved in the planning study and in the related aspects of the Water Pollution Abatement Program of MMSD, it was concluded that a parallel effort utilizing available statistical and correlational techniques should also be undertaken.

Table 89

WATER RESOURCES SIMULATION MODELS POTENTIALLY SUITABLE FOR APPLICATION IN THE MILWAUKEE HARBOR ESTUARY PLANNING STUDY

Model Name	Type		Capability					Application	Availability	
	Continuous Simulation	Discrete Event	Hydraulic Simulation	Hydraulic Transport of Conservative Materials	Dynamic Water Quality Simulation & Transport	Hydrologic Simulation	Thermal Simulation		Public	Proprietary
Hydrocomp Simulation Program (SEWRPC)	X	X	X	X	X	X	--	Free-flowing river reaches in the Milwaukee Harbor watershed. Model set up and calibrated in previous SEWRPC studies.	--	X
Stormwater Management Model--SWMM (Milwaukee Metropolitan Sewerage District)	--	X	X	X	--	X	--	Separate storm sewers and combined sewers in Milwaukee Harbor estuary subwatershed. Model set up and operated by MMSD for entire estuary subwatershed.	X	--
Storage Treatment Overflow Runoff Model--STORM (Milwaukee Metropolitan Sewerage District	X	X	X	X	--	X	--	Separate storm sewer and combined sewer service areas in the Milwaukee Harbor estuary subwatershed. Model set up and operated by MMSD for entire subwatershed.	X	--
Branching Network Model (U.S. Geological Survey)	X	X	X	--	--	--	X	Riverine reaches of Milwaukee Harbor estuary.	X	--
Two-dimensional Unsteady State Flow and Water Quality Model (UW-Milwaukee)	X	X	X	X	X	X	X	Outer harbor and adjacent Milwaukee Bay	X	--
One-dimensional Unsteady/Steady State Water Quality Model (U.S. Geological Survey)	X	X	--	X	X	--	--	Riverine reaches of Milwaukee Harbor estuary.	X	--
One-dimensional Steady State Dissolved Oxygen Model (U.S. Geological Survey)	--	X	--	X	X	--	--	Riverine reaches of Milwaukee Harbor estuary.	X	--
Harper's One-dimensional Water Quality Model (Milwaukee Metropolitan Sewerage District)	X	X	--	X	X	--	--	Riverine reaches of Milwaukee Harbor estuary. Model operational in Milwaukee River branch of estuary	--	X

NOTE: See Table 90 for summary input/output information for each model.

Source: SEWRPC

As a practical objective, the Commission staff and Task Force concluded that in addition to the proposed model development, it would be possible and useful to quantify the flux of pollutants into and out of the Milwaukee Harbor estuary; to estimate the mass of pollutants which are currently inplace within the system; and to utilize information to be collected in this study and from previous studies to estimate the flushing rates for the sediments and other inplace pollutants, and to forecast the long-term water quality conditions in the estuary and describe the seasonal variations in this condition. Such evaluations would also be prepared for individual storm, snowmelt, dry weather, or lake events which are observed during the proposed sampling effort. The capability exists to quantify in this manner the amounts of water and rates of flow and the associated movement of sediment and other pollutants into and out of the estuary to a sufficient degree of accuracy and precision.

The deterministic hydrodynamic and water quality simulation model to be developed would be applied to the estuary--both inner and outer harbors--and adjacent Milwaukee Bay. A three-dimensional model would be utilized and would incorporate algorithms to be developed in this study for sediment oxygen demand as affected by scouring at CSO outfalls. In addition, the model would utilize previously developed algorithms for analysis of the remaining sources and sinks of dissolved oxygen, as well as for fecal coliforms and transport of some conservative and nonconservative constituents. The three-dimensional model would be applied for selected discrete periods, rather than being operated as a long-term continuous simulation model, in order to limit the amounts of computer time required for simulation. Further discussion of this modeling effort is provided in subsequent paragraphs and also later in this chapter under "Hydraulic Studies" and "Water Quality Studies." The following sections describe analytic procedures proposed to be utilized in the Milwaukee Harbor estuary study. For each procedure there is an identification of the technique, and a brief description of the inputs and outputs for the models or techniques to be applied. A summary of the inputs and outputs is set forth in Table 90.

For the amount and quality of storm water runoff from the Milwaukee Harbor estuary subwatershed, it is proposed that the STORM and SWMM models which were applied by the Milwaukee Metropolitan Sewerage District in its facilities planning studies be further applied to the proposed estuary study. Under this approach, observed meteorologic conditions would be utilized as input to estimate the direct combined sewer overflow and separate sewer overflow discharge quantity and quality during periods of hydrologic and water quality monitoring conducted as part of the study.

For the contributions from the upper reaches of the inflowing rivers, it is proposed that the Hydrologic-Hydraulic-Water Quality Simulation Model developed by SEWRPC from the Hydrocomp Simulation Program be used to provide a characterization of the volumes, rates, and quality of flow from the three rivers tributary to the estuary for both normal and extreme hydrologic conditions. The model would be recalibrated, if necessary, but would be used to estimate annual, seasonal, and event loadings to the estuary, and to develop frequency distributions of the pertinent flow and water quality measures. The observed meteorologic conditions and reported point source pollution loads--including those from flow relief devices--and the upstream flow and water quality conditions would be used as input to estimate the quantity and quality of streamflow at the upstream limits of the combined sewer service area.

Streamflow within the three main channel branches in the inner harbor will be continuously simulated for a two-year period using the Branching Network Model developed by the U.S. Geological Survey. Input to the model would consist of monitored flows at the upstream end of each estuary branch, flushing tunnel flows, simulated

Table 90

SUMMARY INPUT/OUTPUT INFORMATION FOR WATER RESOURCES SIMULATION MODELS POTENTIALLY SUITABLE FOR APPLICATION IN THE MILWAUKEE HARBOR ESTUARY PLANNING STUDY

Model Name	Fixed Input[a]	Variable Input[b]	Output
Hydrocomp Simulation Program--HSP (SEWRPC)	Land cover, drainage network geometry	Meteorological data; chemical, biochemical, and biological rate coefficients for water column and sediments; impervious and pervious area washoff coefficients; algal growth rates and sinking rates; pollutant accumulation rates on pervious and impervious areas; point source loading rates	Dissolved oxygen, phosphate phosphorus, fecal coliform, CBOD, ammonia nitrogen, nitrate nitrogen, organic nitrogen, water temperature, total dissolved solids, algae, zooplankton, chlorides and other conservative substances, and streamflow
Storm Water Management Model--SWMM (MMSD)	Land use, population, drainage network geometry	Rainfall and snow; antecedent conditions; impervious area; infiltration capacity; dust and dirt chemistry and accumulation rates; Universal Soil Loss Equation factors; area subject to erosion; street cleaning frequency, sweeper efficiency, and number of passes; catchbasin BOD; groundwater infiltration; wastewater flow and chemistry; storage/treatment facilities and unit costs; interest rate and amortization period	Discrete event runoff hydrographs; BOD, total suspended solids, total coliforms, dissolved oxygen, COD, settleable solids, total nitrogen, phosphate and grease; dry weather sanitary flow; infiltration/inflow; storm conduit depostion; storage/treatment costs for short and long term
Storage Treatment Overflow Runoff Model --STORM (MMSD)	Land use, drainage network geometry	Hourly precipitation, temperature, impervious and pervious area and associated runoff coefficients, pollutant accumulation rates, pollutant washoff factors, street sweeping frequency and efficiency, evaporation, depression storage; Universal Soil Loss Equation factors	Hourly runoff volume; washoff of suspended solids; settleable solids; BOD, total nitrogen, and orthophosphate; annual statistics on rainfall-snowmelt; runoff; pollutant washoff; quantity, quality, and frequency of overflows; and sediment production and delivery
Branching Network Model (USGS)	Channel network and geometry	Water levels; channel roughness; momentum, drag and flow resistence coefficients; velocity distribution; water and air temperatures, wind speed and direction; external inflow and outflows	Streamflow at designated time intervals; minimum, mean, and maximum daily streamflow; water level; average cross-sectional velocity; and cross-sectional area
Two- and Three-Dimensional Unsteady State Flow Models (UW-Milwaukee and USGS)	Lake and harbor geometry, coriolis parameter	Wind speed and direction; depth; water temperature; turbulent diffusion, Chezy friction, and wind stress coefficients; vertical velocity profile coefficient; point source concentration and flow rate	Time average flow velocity at nodes in grid network, concentration of conservative substances from point sources

Table 90 (continued)

SUMMARY INPUT/OUTPUT INFORMATION FOR WATER RESOURCES SIMULATION MODELS
POTENTIALLY SUITABLE FOR APPLICATION IN THE MILWAUKEE HARBOR ESTUARY PLANNING STUDY

Model Name	Fixed Input[a]	Variable Input[b]	Output
One-Dimensional Unsteady/Steady State Water Quality Model (USGS)	Channel network and geometry, barometric pressure	Time-varying point and diffuse source loading rates of CBOD and NBOD; sedimentation rates for CBOD; atmospheric reaeration coefficients; algal photosynthesis and respiration; sediment oxygen demand; time of travel; water temperature; time-varying streamflow	Dissolved oxygen, CBOD, NBOD, and streamflow by computation interval; minimum, mean, and maximum DO, CBOD, and NBOD for each reach
One-Dimensional Steady-State Segmented Dissolved Oxygen Model (USGS)	Channel network and geometry	Same as above but for steady-state loading rates and streamflow conditions	Dissolved oxygen, CBOD, NBOD, and streamflow by computation interval; dissolved oxygen deficits attributable to CBOD, NBOD, SOD, and algae; atmospheric aeration
Harper's One-Dimensional Water Quality Model (MMSD)	Channel network and geometry (utilized in separate hydraulic model)	Point and nonpoint source pollutant loading rates; phytoplankton concentration, growth rate, respiration rate, and settling rate; incident solar radiation and extinction coefficient; benthic algae concentration, growth rate, and respiration rate; atmospheric aeration coefficient, algal DO production, and sediment oxygen demand; water temperature, net heat transfer, specific heat of water, wind speed, vapor pressure, barometric pressure, and air temperature; BOD concentration and decay rate coefficients; bacteria growth rate and die-off rate coefficients; bacteria counts	Dissolved oxygen, fecal coliforms

NOTE: See Table 89 for summary descriptions of models.

[a]Fixed inputs are those normally held constant such as drainage network pattern, channel and conduit geometry, and land use/management data.

[b]Variable inputs include meteorological, hydrologic-hydraulic, chemical, and biological parameters.

Source: SEWRPC.

storm runoff from the estuary subwatershed as described above, and precise water level monitoring and channel geometry data collected within the inner harbor. Numerous streamflow measurements in the inner harbor and continuous water temperature records will provide the basis for model calibration. Model output would consist of mean daily flows and discharge at 15-minute intervals during runoff events. The method will provide data for the entire inner harbor network.

A three-dimensional simulation model will be developed, if possible, and utilized to simulate flow and water quality in the inner and outer harbors. Input to the model will consist of water level records in the inner and outer harbors and current velocity data for Milwaukee Bay, wind speed and wind direction, water and temperature data, and point and nonpoint source pollutant loadings. Frequent (weekly or more often) current data to be used for calibration purposes would also be obtained during water quality surveys and would consist of current velocity measurements within the estuary and necessary drogue studies by the USGS to evaluate the consistency and accuracy of simulated flows and circulation patterns. In addition, outer harbor circulation patterns will be modeled and graphical output prepared to reflect a variety of hydrologic-hydraulic-meteorologic conditions to assist in identification of periods during which critical water quality conditions could occur. Model outputs provided would include daily flows through the breakwater openings and within the inner harbor for selected discrete periods, as well as hourly flows during meteorological-hydraulic events, maps of outer harbor circulation patterns for selected periods, and vertical current velocity profiles for the inner and outer harbors. Water quality simulations including sediment resuspension would also be conducted for the same periods for model calibration/verification, and also for alternative levels of CSO abatement and point and nonpoint source pollution control. The study of sediment processes will provide information which will be utilized to assist in the development and interpretation of the three-dimensional water quality model.

Water quality data to be collected in the inner and outer harbors during both low- and high-flow conditions will be utilized along with the simulated daily flows and event flows from the Branching Network Model to compute pollutant loadings at points within the estuary to determine pollutant budgets using mass balance computations. Loadings will be calculated for each of the three inner harbor branches, and for the Milwaukee River at the mouth. Pollutant loadings to Lake Michigan through the outer harbor breakwater openings will be simulated for selected runoff events using the three-dimensional water quality model described previously.

For the inner harbor, simulated daily flow and event hydrographs will be plotted graphically along with observed water quality data to assist in development of pollutographs at each monitoring site. The resultant pollutographs will be combined mathematically with the hydrographs using computerized procedures to determine individual pollutant loads. The computed estuary loads will be utilized along with loads in the rivers upstream and nonpoint loads in a mass balance analysis to estimate the sources, sinks, and transport rates for representative substances.

Concentrations of individual pollutants in the inner and outer harbors will be evaluated to determine the frequency, extent, and location of water quality standard violations and to relate such violations to the hydrologic-hydraulic-meteorologic conditions. Pollutant concentrations will be correlated with measured loads to the estuary for each pollutant and consideration given to the mass of the pollutant already in place, in an attempt to develop an empirical understanding adequate for evaluating the relative merits of alternative water quality control measures. This will provide a fall-back procedure in the event water quality simulation modeling proves unsuccessful. The analyses will provide estimates of harbor water quality resulting from a set of riverine and nonpoint source pollutant loadings to the estuary including effects of CSO abatement for alternative levels of protection, and will relate the pollutant loads and behavior to the potential instream management measures.

Sediment loading rates and budgets will be prepared by the USGS in a similar manner as that described above for water quality data utilizing both observed and simulated flows along with observed sediment concentrations during both low- and high-flow periods. Loadings of chemical constituents attached to suspended sediments will also be estimated for use in the sediment and sediment quality budget analyses to determine the source and fate of these materials. Included in the empirical analysis will be an evaluation of sediment deposition and scour based upon changes in instream loads and concentrations. Also considered will be the scouring potential, based upon channel geometry and river and CSO flow rates as well as bottom sediment characteristics. Measured and simulated channel and CSO velocities will serve as the basis for developing the necessary flow rate data. The analyses will provide estimates of sediment transport and deposition within the estuary along with the transport, deposition, and resuspension of pollutants attached to suspended sediments.

Water Quality Baseline and Event Sampling Data

As described in Chapter II, voluminous water quality data have been collected since 1950 and continue to be collected in the Milwaukee Harbor area rivers and estuaries, and in Milwaukee Bay. The data were collected in more than 60 special purpose investigations. Yet these investigations have not provided a data base adequate for the conduct of the proposed Milwaukee Harbor estuary planning study. This is because--as described previously--the geographic scope, timing, parameters studied, and methods employed in these previous investigations were limited and uncoordinated so that the results do not address all of the data needs of the proposed estuary planning study. The previous studies do, however, provide a useful point of departure for the conduct of the proposed Milwaukee Harbor estuary study. Especially for the dissolved oxygen dynamics of the inner harbor, and for the general current patterns within the outer harbor, the previous studies do provide some insight into the behavior of this complex surface water system. Thus, water quality data needs for the proposed study have been significantly reduced by the previous study efforts. Accordingly, the proposed study will include the collation of all detailed water quality data from the previous studies.

Since one of the primary purposes of the Milwaukee Harbor Estuary Comprehensive Water Resources Planning Study is to quantify pollutant loadings to the estuarine system and the behavior of these pollutants within the estuary and the pollutant loadings from the estuary to Lake Michigan, and to identify the sources and respective amounts of these pollutants, the proposed study must include a water quality monitoring program conducted in full coordination with the sediment monitoring program described earlier in this chapter under "Sediment Processes." The instream water quality monitoring effort must also be carefully coordinated with the pollutant source monitoring effort described below.

The proposed lake and stream water quality monitoring program will be conducted for a two-year period to obtain both high- and low-flow event data, and also to ensure the collection of representative data reflecting the variable effects of Lake Michigan. As discussed below, sampling will be required in the rivers at the upstream end of each estuary, within the inner and outer harbors, and in adjacent Milwaukee Bay. In addition, it will be necessary to monitor water quality upstream from the estuary subwatershed to provide a complete set of concurrent data to estimate the pollutant loadings to the estuary and Lake Michigan from the upper watersheds of the Menomonee and Milwaukee Rivers, together with the estimated loads from the separate sewer service areas in the Milwaukee area and from the combined sewer service area within the urbanized portions of the Milwaukee Harbor estuary subwatershed. Sampling sites are listed in Table 86, and set forth on Map 33. Ongoing urban nonpoint source pollution studies monitoring programs of the Nationwide Urban Runoff Pollution Study, City of Milwaukee and Milwaukee Metropolitan Sewerage District for combined and separate sanitary sewer overflows will be supplemented as necessary and used in conjunction with existing data in order to estimate the pollutant loadings.

The proposed surface water quality sampling effort is comprised of a "baseline" component, and an "event-related" component. Table 91 sets forth the water quality indicators to be analyzed in both the baseline and event-related monitoring. As indicated in the table, unfiltered samples would be analyzed to obtain "total" concentrations of all pollutants except dissolved phosphorus and dissolved organic carbon, with filtered (water only) sampling tests conducted only in the event that the initial test results indicated a need to do so. The baseline monitoring will afford thirty sampling surveys per year at a total of 34 locations, including seven locations which will also be monitored for continuous streamflow. Additional intermittent streamflow data will be obtained at four other locations in the free-flowing rivers. The associated water quality survey sampling frequency will vary from weekly in the summers to less frequent, (e.g., monthly) in the winters. In addition, it is assumed that existing and planned continuous dissolved oxygen monitoring by the MMSD will continue throughout the estuary study period at the three Milwaukee River sites described in Chapter II of this report and at the sites in the Kinnickinnic and Menomonee River estuaries, with the addition of water temperature monitoring, along with weekly sampling cruises in Milwaukee Bay.

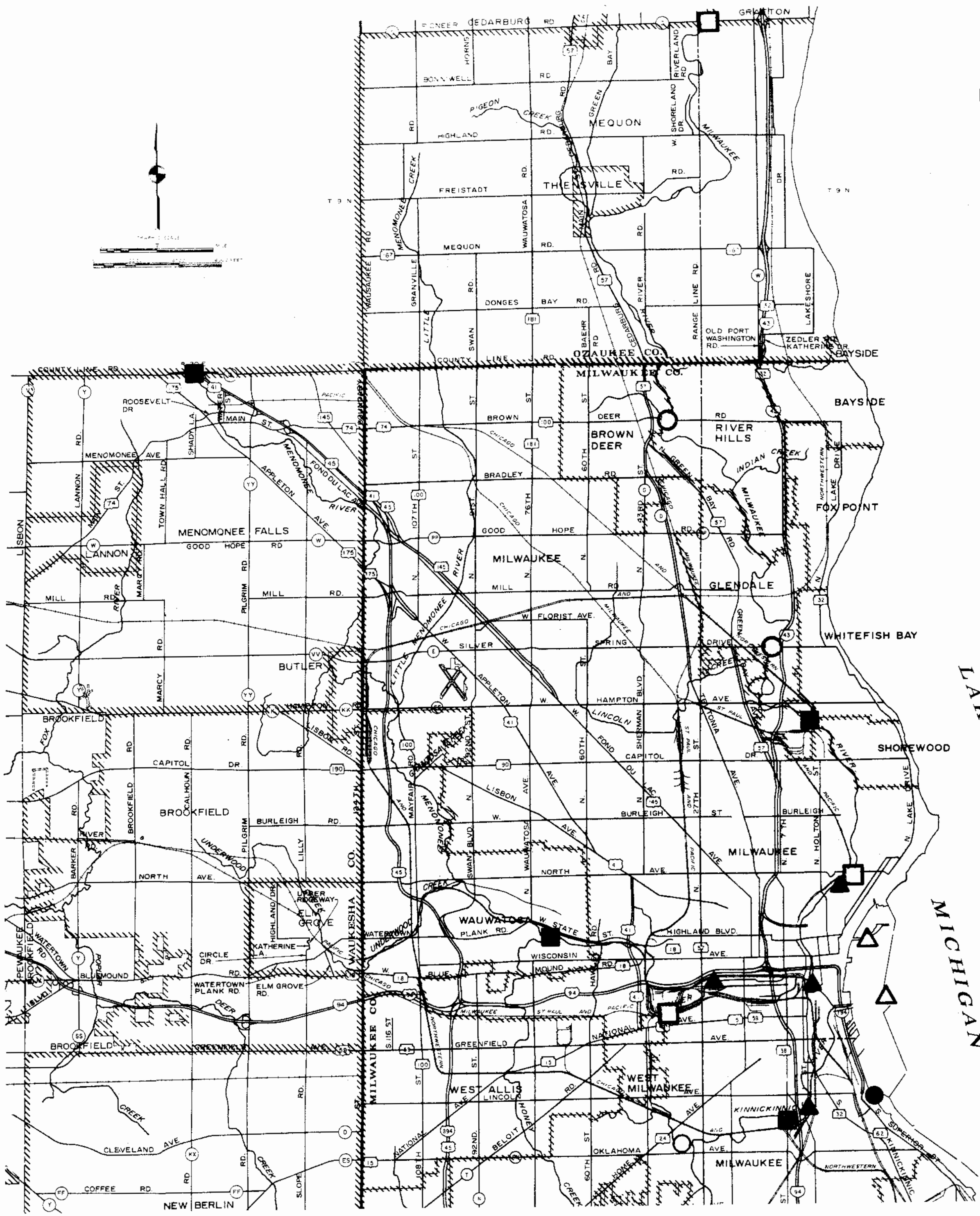
The proposed water quality surveys will require substantial effort in data collection and laboratory analysis. It is envisioned that during the two-year water quality sampling period, the collection of 5,544 samples at 18 locations in the inner and outer harbor will be conducted by boat by the MMSD staff. It is also envisioned that during the same period, about 7,056 samples will be obtained at 16 locations in the inner harbor and along the tributary rivers by the USGS staff, working from bridges. Vertical profiles of velocity (i.e., speed and associated direction), dissolved oxygen (DO), and temperature will be obtained as part of all multiple depth samples taken in the estuary.

As shown in Table 92, the event-related data are envisioned as providing one complete low-flow survey--presumably conducted during the "weekly" baseline sampling described above--and eight wet-weather surveys (four per year). Of the wet-weather surveys, six (three per year) would be storm-related, and two (one per year) would be associated with spring thaw/snowmelt events. It is assumed that, with only modest schedule adjustments, the baseline monitoring effort will serve to capture data pertaining to wind or seiche set-up conditions. Monitoring will be conducted in a manner that will provide for estimates of annual, seasonal, and runoff event pollutant loads from upstream, to be compared to estimated loadings based upon data monitored at other locations in the urbanized estuarine portions of the watersheds.

Laboratory analyses for the water quality indicators will be conducted by both the USGS and the MMSD. The MMSD will analyze indicators contained in the "cardinal" list as defined in Table 91, and the USGS will analyze the indicators contained in the "supplemental" list also defined in Table 91.

Map 33

LOCATION OF EXISTING AND PROPOSED U.S. GEOLOGICAL SURVEY STREAMFLOW AND WATER LEVEL MONITORING SITES IN THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY



LEGEND

- ■ EXISTING CONTINUOUS RECORD STREAMFLOW GAGING STATION
- □ PROPOSED CONTINUOUS RECORD STREAMFLOW GAGING STATION
- ▲ EXISTING CONTINUOUS RECORD WATER LEVEL MONITORING STATION TO BE OPERATED BY THE USGS
- △ PROPOSED CONTINUOUS RECORD WATER LEVEL MONITORING STATION TO BE OPERATED BY THE USGS
- ● EXISTING CONTINUOUS RECORD WATER LEVEL MONITORING STATION OPERATED BY THE NATIONAL OCEAN SURVEY
- ○ INTERMITTENT STREAMFLOW MONITORING STATION TO BE CALIBRATED BY THE USGS

Source: SEWRPC.

Table 91

WATER QUALITY INDICATORS TO BE ANALYZED FOR THE
MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

Frequency	Indicators[a,b,c]			
(CARDINAL LIST[f])				
Monthly Sampling[d]	Alkalinity Iron	Chromium Lead	Mercury Zinc	Cadmium
Routine Weekly Sampling and Runoff Event Sampling[e]	Total phosphorus Dissolved phosphorus Ammonia N	Nitrate N Nitrite N TKN	Chlorides COD BOD_5	Fecal coliforms[g] Chlorophyll-a
	Total organic carbon Dissolved organic carbon		Total solids Suspended solids Volatile suspended solids	
(SUPPLEMENTAL LIST[f])				
Annual Sampling and Major Spring Runoff Event Sampling[e]	Gross radioactivity 2,4-D Toxaphene Methoxychlor	Lindane Heptachlorepoxide Heptachlor Chloradane		PCB's Phenols Grease and oil

NOTE: Sampling site information is presented in Table 86 and on Map 32.

[a]Total concentrations--of unfiltered water samples which would include suspended sediments--will be determined except for the evaluations of dissolved phosphorus and dissolved organic carbon. In addition, filtered samples will be analyzed monthly for dissolved metals by the MMSD at no extra cost to the estuary study.

[b]All water column quality sampling sites where loadings are to be determined will be monitored at a frequency suitable for determination of annual, seasonal, and event chemical loads. Frequency of sampling for various parameters may be altered during the course of the study if data collected indicate that more or less frequent sampling is required for some parameters than others. A sampling schedule has been prepared for each monitoring site along with a specific laboratory analysis schedule upon which the budget in Chapter V is based.

[c]The parameters listed were selected in part on the basis of a SEWRPC staff analysis of the historic water quality data available and the resulting indications of which parameters may, from time to time, exceed the recommended levels.

[d]Supplemental sampling indicators, to be tested in conjunction with one of the weekly sample sets each month.

[e]Runoff event sampling information is presented in Table 92.

[f]The indicators associated with monthly and weekly sampling taken together are referred to in the text as the "Cardinal" list. The "Cardinal" and the "Supplemental" lists together constitute the "Maximal" list of indicators to be examined. The USGS will provide laboratory services for analysis of all water quality indicators on the supplemental list. The MMSD laboratory will analyze all indicators on the cardinal list.

[g]Surface sample only. Although fecal coliform may be considered a biological parameter, it is included in this list because of its importance to any meaningful surface water quality study.

Source: SEWRPC

Table 92

FREQUENCY AND NUMBER OF WATER QUALITY SAMPLING SITES, SURVEYS, AND SAMPLES FOR THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

Sampling Period	Annual Frequency	Water Quality Parameter List[a,f]	Number of Sampling Sites		Number of Samples Per Survey		Total Number of Samples in Two Years	
			Bridge	Boat	Bridge	Boat	Bridge	Boat
Weekly[a]	30	Cardinal	16	18	28	54	1,680	3,240
Snowmelt Event[b]	1	Cardinal	16	4	672	288	1,344	576
Heavy Spring Rain[c]	1	Maximal	16	4	672	288	1,344	576
Summer Storm[d]	1	Cardinal	16	4	672	288	1,344	576
Fall Storm[d]	1	Cardinal	16	4	672	288	1,344	576
Annually[e]	e	Maximal	16[g]	18[g]	28[g]	54[g]	56[g]	108[g]
Totals	34						7,056	5,544

[a]Baseline water quality sampling at approximate one-week intervals except during winter periods when the sampling interval can be extended depending upon hydrologic and water quality conditions. Thirty surveys will be conducted each year for two years.

[b]The first late winter thaw each year for two years whether runoff be caused by warming or by a combination of warming and rainfall. Event sampling 6 times per day for 4 days.

[c]The first large rainstorm event each year for 2 years causing major flushing of pollutants into receiving streams. Maximal list for first day only, "Cardinal" list remainder of event.

[d]Large, intense rainstorm following a relatively dry period of at least 5-days duration.

[e]Late winter baseflow period prior to snowmelt. Consider as one of the weekly surveys.

[f]See Table 91 for water quality parameters to be analyzed. The complete table represents the "Maximal" list of parameters, whereas the "Cardinal" list is a subset of the "Maximal" list as designated in the table.

[g]Sampling for the annual "Maximal" list is already included in the totals as a part of the "weekly" sampling.

Source: SEWRPC

The U.S. Environmental Protection Agency (USEPA) will provide technical assistance to the estuary planning study by providing laboratory quality assurance. The USEPA will provide a continuing quality assurance function through use of split-samples and of standard reference samples prepared by that agency. The Great Lakes National Program Office laboratory will analyze selected samples and sample results from the laboratories utilized during the study to ensure quality control.

Streamflow monitoring at existing gaging stations on the Menomonee River at Menomonee Falls, the Menomonee River at Wauwatosa, and the Kinnickinnic River at S. 7th Street will be continued at the expense of current funding sources. In addition, the MMSD, in cooperation with the USGS, will fund separately a proposed gaging station on the Milwaukee River at Pioneer Road and the existing gaging station on the Milwaukee River at Estabrook Park. Two gaging stations to be reactivated and funded by the Milwaukee Harbor estuary planning study are on the Menomonee River at the Falk Corporation Dam near S. 27th Street and on the Milwaukee River at the North Avenue dam. The proposed streamflow monitoring gage site network for the estuary study is depicted on Map 33 along with proposed water level monitoring stations in the inner and outer harbors. The four inner harbor stations, currently operated by the City of Milwaukee, will be upgraded by the USGS to provide precise water level monitoring capability and will utilize 15-minute interval digital recording devices. The stations will be serviced by the USGS, with copies of the data provided to the City of Milwaukee and to the MMSD. The proposed outer harbor station will be located at Juneau Park in the north end of the harbor, and will supplement water level data to be collected by the MMSD at a proposed station on the breakwater at the main harbor entrance, and the water level data collected by the National Ocean Survey at the U.S. Coast Guard station located at the south end of the harbor.

Continuous monitoring of dissolved oxygen (DO), specific conductance, pH, and water temperature will be conducted by the MMSD at the streamflow gaging stations on the Kinnickinnic River at S. 7th Street, the Milwaukee River at Estabrook Park, and the Menomonee River at S. 70th Street, to assist in studies of toxic and hazardous substance spills as described in this chapter under "Hazardous Materials Spills", and to provide continuous data to supplement the baseline and event sampling data. For intervening or upstream reaches of the three rivers in the inner harbor estuary, this sampling scheme will be further supplemented by the existing continuous DO monitoring program by MMSD at North Avenue, Cherry Street, and St. Paul Avenue on the Milwaukee River; and planned DO monitoring by MMSD at Muskego Avenue on the Menomonee River, and at S. First Street on the Kinnickinnic River

The water quality monitoring described above will entail primarily manual collection techniques with the water samples collected at discrete depths as indicated in Table 86, rather than depending upon automatic sampling and monitoring. Manual sampling will be supplemented by automatic samplers and water quality monitors to ensure complete monitoring of runoff events and base flow. Results at automatic and manual fixed point sampling locations will be compared with composite samples for determination of mean concentrations. Periodic reviews of the water quality data collected will be conducted to determine if sampling schedule revisions, water quality parameter changes, or laboratory analysis schedule revisions are called for to ensure that adequate data are collected for the lowest possible cost. Therefore, it will be essential that laboratory results be provided and interpreted with a minimum of delay.

Continuous vertical water temperature monitoring will be conducted in the inner harbor at four locations: the Kinnickinnic River at S. First Street, the Menomonee River at Muskego Avenue, the Milwaukee River at St. Paul Avenue, and the Milwaukee River at Cherry Street. At the St. Paul Avenue site, the Milwaukee Metropolitan Sewerage District (MMSD) currently monitors dissolved oxygen, temperature, and conductance continuously. It is also anticipated that current speed and direction and water level monitoring will be added at this site during the study. Also MMSD plans to establish continuous dissolved oxygen (DO) monitoring stations at the Kinnickinnic (S. 1st Street) and Menomonee River (Muskego Avenue) sites. Water temperature monitoring at these sites is not included in these plans, however. Therefore, the Milwaukee Harbor estuary planning study will provide MMSD with the additional funding necessary to add multi-depth water temperature monitoring at these two locations and also at the MMSD DO monitoring station on the Milwaukee River at Cherry Street. In addition, it is assumed that continued operation of the St. Paul Avenue station and the Cherry Street, Muskego Avenue, and S. First Street DO monitoring stations will be sustained and funded by MMSD throughout the planning study two-year monitoring period.

Continuous vertical water temperature monitoring will be conducted in the main harbor entrance at the Milwaukee Metropolitan Sewerage District meteorology station to quantify Lake Michigan water intrusion to assist in computation of outer harbor pollutant budgets and for use in hydraulic model calibration and verification.

The Milwaukee Metropolitan Sewerage District currently monitors near-shore zone water quality to provide background water quality data for existing conditions (see Chapter II, "Outer Harbor and Near-shore Sampling Program"). It is assumed that this program will be continued during the two-year sampling period for the Milwaukee Harbor estuary planning study. At this time, sampling in the near-shore zone is conducted approximately every two weeks at five sites just outside the breakwater in Milwaukee Bay and at 15 sites further offshore between Fox Point and Wind Point. Water quality parameters analyzed are listed in Table 57 in Chapter II of this report. Sampling locations are shown on Map 22. The MMSD near-shore zone sampling program is adequate for the purposes of the estuary planning study. However, coordination of sampling efforts by MMSD with the estuary study will be necessary so that near-shore zone data will be collected concurrently with runoff event sampling to be conducted by the estuary planning study in the inner and outer harbors, and also concurrent with the low-flow intensive water quality survey described previously in this chapter.

Taken together with the sediment sampling projects described above, the proposed water quality sampling effort will be a complicated one involving several agencies. To assure the careful and efficient conduct of these sampling activities, the Regional Planning Commission will serve as a coordinating agency. The required coordination will be achieved, in part, through the preparation and execution of appropriate interagency memoranda of understanding and contracts.

Groundwater

Groundwater volumes and groundwater pollutant loadings as determined in the International Joint Commission (IJC) Menomonee River Pilot Watershed Study for the upper portions of the Menomonee River watershed are low in comparison with runoff event volumes and associated pollutant loads. Zinc concentrations, however, in the shallow glacial aquifer were found by the IJC study to be more than an order of magnitude higher than the U.S. Environmental Protection Agency toxic and hazardous criterion for fish and other aquatic life. Because groundwater from the shallow glacial aquifer is estimated to contribute about 50 percent of the non-event flow in the Menomonee River, groundwater may contribute a significant nonpoint source loading of pollution to the Milwaukee Harbor estuary, particularly in the Menomonee Valley. Accordingly, the USGS will conduct a groundwater study to address pollution of the shallow aquifer of the Milwaukee Harbor estuary subwatershed in the Menomonee River Industrial Valley. The study will use existing IJC study wells and 3 to 5 additional new wells along the Menomonee River estuary in order to address the existing quantity and quality of groundwater which discharges to, or recharges from, the estuary. Annual and seasonal pollutant loads will be estimated for use in the pollutant mass balance analyses for the estuary.

Pollution Sources

The collection of all the data necessary to describe the water quality characteristics of all pollution sources would be prohibitively expensive. Accordingly, it will be necessary to use the field data collected in careful combination with all other data available. The other data to be used include the inventory data described elsewhere in this study design, and the historic data available to describe the pollutant concentrations and loads from industrial wastewater outfalls, municipal sewage treatment plants, combined and separate sewer flow relief devices, and storm sewer outfalls.

The following sections describe the field sampling activities proposed to be conducted to quantify the pollutant loadings from the Jones Island sewage treatment plant; selected combined sewer overflows, separate sanitary sewer flow relief devices, storm sewer outfalls and related channels of surface water runoff, and industrial wastewater outfalls.

Jones Island Sewage Treatment Plant and Other Point Sources: Wastewater discharge quantity and quality monitoring is required by the Wisconsin Pollutant Discharge Elimination System (WPDES) for both public and private dischargers within the State of Wisconsin. Data submitted by these dischargers within the Milwaukee, Menomonee, and Kinnickinnic River watersheds will be obtained from the Wisconsin Department of Natural Resources as part of the wastewater discharge inventory of the estuary planning study. These data will be utilized to identify and quantify all municipal sewage treatment plants as sources of pollution within the estuary subwatershed and upstream from the subwatershed, and to assist in pollutant loading budget calculations.

Effluent from the Jones Island wastewater treatment plant is routinely monitored by the MMSD for the 20 parameters and at the frequencies listed in Table 58 in Chapter II. This parameter list will be supplemented by the MMSD in cooperation with the estuary planning study to provide dissolved oxygen monitoring, alkalinity, phenols and gross PCB's and PCN's. It should be noted that monitoring of dissolved oxygen in the effluent is not currently being conducted.

Combined and Sanitary Sewer Overflow: Combined sewer overflow (CSO) monitoring is currently being conducted by the Milwaukee Metropolitan Sewerage District at eight sites in the City of Milwaukee as required by the Wisconsin Pollutant Discharge Elimination System (WPDES), and described in Chapter II. The City of Milwaukee Bureau of Engineers monitors ten sites within the City for sanitary sewer overflows (SSO) to storm sewer crossovers for quantity and quality to meet WPDES requirements. Continued monitoring of overflow quantity and quality at these sites will be maintained throughout the proposed estuary study two-year monitoring period. Flow rate, 5-day BOD, suspended solids, pH, and fecal coliform are currently analyzed at the CSO and SSO monitoring sites. The resulting data will be utilized with the STORM

Model, as developed for the Milwaukee Metropolitan Sewerage District, to estimate the annual, seasonal, and event loads for the overflows under existing and forecast future conditions.

Storm Sewer Outfalls: Storm water quality from separate storm sewers and from direct shoreland runoff is of particular importance in the Milwaukee Harbor estuary, and especially within the harbor-related industrial areas like the Menomonee River Industrial Valley, because of the high degree of dense commercial and industrial development and the intensity of these land uses in the estuary subwatershed. For the residential and commercial lands served by separate storm and sanitary sewers beyond the outer fringes of the combined sewer service area, it was concluded that information already available or being developed as part of the Nationwide Urban Runoff Pollutant (NURP) Study --by the Department of Natural Resources and the U.S. Geological Survey in cooperation with the Commission--would provide a sufficient basis for the estimation of nonpoint source pollution loads. Storm sewer water quality is currently being monitored by the NURP Study at eight locations in Milwaukee County ultimately tributary to the Milwaukee Harbor. Six of the stations monitor runoff from residential land use, with two sites monitoring commercial land use runoff quality and quantity. Monitoring commenced in 1980 and is scheduled for completion in 1982.

Also contributed via separate storm sewers from within the estuary subwatershed is freeway runoff which is believed to have been sufficiently studied to assure reliable estimates of the resulting nonpoint pollution loads. There remain, however, the commercial and industrial lands in the inner city areas which are served by--or proposed by the Milwaukee Water Pollution Abatement Program to be served in the future by--separate storm sewers. A 1976 study conducted by the Milwaukee Department of City Development estimated that an average of more than 2 million tons of bulk material alone was stored in the Menomonee River Industrial Valley area of the estuary subwatershed. For such areas it will be necessary to conduct specialized storm water runoff sampling surveys. Ideally, these surveys would be conducted concurrently and in full coordination with the lake and river sampling during storm events. It is envisioned that the runoff from the following types of activities will be addressed:

1. tannery operations, including loading and storage;

2. metals processing, including loading and storage;

3. bulk storage of lumber, salt, coal, coke, sand, gravel, limestone, gypsum, and other uncovered materials;

4. chemical processing, including loading and storage;

5. motor vehicle storage and maintenance;

6. railroad yards and equipment repair;

7. petroleum loading, storage, and distribution;

8. general cargo loading (slips and piers).

Runoff quality will be monitored in storm sewer outfalls or open channels draining shoreland areas during a summer rainfall event and a snowmelt period, to determine what types and concentrations of pollutants are being washed directly into the inner and outer harbors. The specific monitoring sites will be selected after a field inspection of potential sites. Potential sites will be selected, with about ten sites anticipated for grab sampling. Selected water quality parameters listed in Table 91 are to be analyzed.

Additional nonpoint source information will be required for the conduct of the estuary planning study to evaluate the relative effects of atmospheric wet- and dry-fallout upon estuary water quality. To this end, ambient air quality monitoring data currently being collected throughout the City of Milwaukee and elsewhere in Milwaukee County by the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency will be utilized, along with air and rain quality monitoring data collected during the IJC Menomonee River Pilot Watershed Study, to estimate the proportion of estuarine pollutant loadings attributable to atmospheric fallout. Parameters studied in the past by these work efforts included PCB's, lead, calcium, cadmium, magnesium, nitrogen, phosphorus, and sodium. These data can also be interpreted in conjunction with the air quality sampling conducted routinely for areas of the subwatershed.

Industrial Wastewater Outfalls: Industrial wastewaters discharged directly to surface waters, or discharged via storm sewers, are regulated under the Wisconsin Pollutant Discharge Elimination System (WPDES). The discharge permit conditions require submittal of reports on the amounts and strengths of wastewater discharge. Data submitted by the dischargers within the estuary will be obtained from the DNR for the period of field study. The data to be obtained will also include the information on the "priority pollutants" being sampled in 24-hour composite samples of industrial wastewater effluents to be tested through the WPDES requirements.

It is of special note, however, that the WPDES permits require intake and outfall water temperature monitoring at the Valley and Commerce Street power plants operated by Wisconsin Electric Power Company in the estuary subwatershed as discussed in Chapter II. It is assumed that such monitoring will continue throughout the estuary planning study monitoring period, and that this data will be made available for the study. The 7-day, 2-year low-flows of the Milwaukee River and the Menomonee River could be drawn entirely through the boilers of the Commerce Street and Valley power plants, respectively, during a normal day's operation. Therefore, it is anticipated that both positive and negative effects occur upon the aquatic environment and water use potential in the Milwaukee and Menomonee estuaries, and perhaps in the Kinnickinnic estuary and the outer harbor as well. To ascertain the effects of Wisconsin Electric Power Company thermal discharges upon receiving water temperatures, continuous water temperature data collected at the sites described above in the inner harbor will be utilized, as well as numerous water temperature data to be collected during the baseline water quality surveys.

Biological Resources

The biological community of the estuary can serve as an indicator of the integrity of the aquatic environment, and represents one of the important water quality goals to be achieved--namely,the support of various levels of fish and other aquatic life. Accordingly, it is fundamental to the conduct of the proposed study that a characterization of the biological resources of the aquatic environment be developed. The biological resources include the bacteria, phytoplankton, zooplankton, periphyton, benthos, forage fishes, game fishes, and waterfowl and terrestrial wildlife. The inventory effort will entail the collection and summary of available information, the appropriate collection of necessary minnows and forage fishes, and the collection of algal productivity data to evaluate the potential future response of the primary producers to improved water quality conditions.

Collection and Summary of Available Data: Zooplankton, phytoplankton, periphyton, benthic macroinvertebrate, bacteriological, and fish data previously collected from the Milwaukee Harbor estuary will be assembled for summary presentation as part of the study. Information concerning game fishes, waterfowl, and terrestrial wildlife in and near the Milwaukee Harbor estuary were collated by the Milwaukee Metropolitan Sewerage District for the Jones Island facility planning study environmental assessment. These data will be reviewed and field checked as necessary by the DNR and SEWRPC staffs. Major species of game fishes were identified. Types of terrestrial wildlife in the urban area were identified as were the Great Lakes shoreline-area terrestrial fauna and waterfowl. Wildlife habitat areas in the estuary, taken from a coastal zone management study, are mapped, identifying the habitat areas rated as "most desirable", "desirable", and "supplemental" or class 1, 2, and 3, respectively. Data are also available on the fish spawning zones and will be obtained from the U.S. Fish and Wildlife Service. The available information and references should be adequate for the purposes of the estuary planning study. Therefore, it is anticipated that no additional field data observations or field studies for primary data collection will be necessary to address game fishes, waterfowl, or terrestrial wildlife in the Milwaukee Harbor estuary subwatershed. The major data sources to be reviewed will be the files and reports of the University of Wisconsin-Milwaukee, the Wisconsin Department of Natural Resources, the U.S. Fish and Wildlife Service, and the Wisconsin Electric Power Company.

Collection of Minnows and Forage Fishes: Data qualifying the minnow and forage fish populations will be collected for the estuary planning study during a summer low-flow period. Sampling will be conducted in the Milwaukee, Menomonee, and Kinnickinnic River estuaries as well as in the outer harbor. Fish will be collected using net trawling or electro-shocking methods, as appropriate. Counts and species and their age classification will be summarized for segments of the above-noted four sampling areas. The survey will be conducted under conditions when intrusion effects of Lake Michigan waters into the harbors are minimal.

Algal Productivity Studies: Algal data in the estuary have been collected by the Wisconsin Department of Natural Resources, Wisconsin Electric Power Company, UW-Milwaukee, and by the Milwaukee Metropolitan Sewerage District for the major facilities planning study conducted as part of the Water Pollution Abatement Program. Data collected by these agencies will be collated as part of the estuary planning study, as noted above. Although the types of phytoplankton and periphyton present in parts of the estuary are known, knowledge of algal growth potential in the waters of the inner and outer harbors is lacking. Because algae are a potential source of residual water quality problems after abatement of grosser forms of pollution, an analysis of algal growth potential will be conducted. This analysis will evaluate the effects upon algal populations of the improved water quality which might be expected to occur in the estuary if water quality objectives are achieved by various managment alternatives. The growth response of existing algal communities, including both phytoplankton and periphyton, will be studied in order to determine the types and quantities of algae that could be expected, and the potential for future algae blooms within the Milwaukee Harbor estuary. Algal productivity data to be collected during the Milwaukee Harbor estuary study in conjunction with the bottom sediment process studies will be supplemented by the data collected previously for use in this analysis.

Water Resources Management Institutions

Under the previously conducted regional water quality management planning program, an inventory was conducted of the wastewater management institutional structure in the Region. This inventory included the identification of all wastewater management agencies, their areas of jurisdiction and their relationship to the local governmental structure; and intergovernmental agreements relating to wastewater management, administrative data, and financial data. This inventory served to provide the basis for an analysis of the existing wastewater management institutional structure, which in turn provided the basis for management recommendations, including agency designations, in the areawide water quality management plan. For the estuary planning study, the inventory of the wastewater management institutional structure will be updated to the base year 1980 and extended as necessary to address the authorities and jurisdictions of the agencies and units of government involved in the management of the Milwaukee Harbor estuary and tributary area.

Inventory of Previous Water Quality-Related Plans and Their Implementation Status

There exists in the Milwaukee Harbor watershed a series of related water quality management plans prepared in previous years. These include the comprehensive plans for the Milwaukee, Menomonee, and Kinnickinnic River watersheds, prepared and adopted by the Commission. This category of plan elements also includes the regional sanitary sewerage system plan, the regional land use plan and the regional park and open space plan. In addition, plans have been prepared by the Milwaukee Metropolitan Sewerage District, the Milwaukee Department of City Development, and the Milwaukee City Harbor Commission. An inventory of these and of their status of implementation and of other identified plans will be conducted, with particular emphasis on those elements dealing with land use, natural resource base protection, water control facility, storm water drainage, and water pollution. This inventory will include an identification of specific implementation recommendations; the various steps taken toward implementation by the units and agencies of government involved; and any problems encountered during plan implementation. The inventory will provide current information for use in the development of alternative plans for the management of the Milwaukee Harbor estuary.

Identification and Review of Concurrent Water Quality-Related Planning and Management Efforts

A particularly important coordinative work element of any major estuary planning program is the identification and review of all concurrent water quality planning efforts and water quality-related management efforts. The work programs and results of these efforts will be directly incorporated into the Milwaukee Harbor estuary planning program wherever possible. Every attempt has been made under the Milwaukee Harbor estuary study design to avoid any unnecessary duplication of effort with respect to collection of water quality data for planning and management purposes. When the Milwaukee Harbor estuary planning study commences, a review will again be made of any relevant work efforts undertaken subsequent to the completion of this study design. Appropriate elements of the planning study will then be amended, as necessary, based upon that review.

ANALYSES AND FORECASTS

Inventories provide the factual information about historic and present situations, but analyses and forecasts are necessary to provide estimates of future needs for water management-related facilities and measures. These future needs must in part be determined from a sequence of interlocking forecasts. Economic activity and population forecasts enable determination of future growth within an area and its subareas, which in turn can be translated into future demands for such items as land use, water use, and water management facilities. These future demands can then be scaled against the existing resource availability and plans formulated to meet deficiencies. Where appropriate, the alternative forecasts developed in the SEWRPC Analysis of Alternative Futures will be utilized to assure that the findings and recommendations of the estuary planning program will be valid and applicable to the full range of demographic and economic scenarios which are possible for southeastern Wisconsin during the planning period.

Land Use Base

Any analyses and forecasts to be made for planning purposes are restricted by existing and projected land use in the planning area. Land use data for the Milwaukee Harbor estuary planning study for current conditions will be derived from the Commission digitized 1980 land use base. Plan year 2000 land use will be the land use base utilized for forecasting purposes and for the development of alternative water resources management plans for the estuary, with explicit consideration of the potential alternative future land-use scenarios.

Forecast Growth and Change

As noted earlier, the Milwaukee Harbor estuary planning program will be prepared within an overall regional planning framework that includes alternative futures for a regional land use plan based upon a range of revised regional economic and demographic forecasts, and within a subregional planning framework to be developed for the estuary subwatershed. It will be necessary under the estuary planning program to relate such forecasts and the regional land use plan elements to the specific water resource-related problems of the estuary. In this respect, it will be necessary to determine accurately the urban nonpoint source pollutant loadings in relation to rural loadings, and to forecast future changes in urban land use activities, along with the attendant effects upon estuary water uses, water quality, and upon maintenance of navigation in the inner and outer harbors. In addition, it will be necessary to forecast the effects of the implementation of the recommended regional air quality attainment and maintenance plan upon estuary water quality, to confirm that attainment of the applicable air quality standards in conjunction with nonpoint source water pollution controls will suffice in the achievement of applicable water quality standards or alternatives thereto.

Water Resources Investigations

Although numerous water resources investigations have been conducted since 1950 in the Milwaukee Harbor estuary subwatershed and environs, these studies were for the most part special purpose in nature, or limited in geographic scope and, therefore, do not provide a time coordinated set of work efforts completely addressing the problems requiring study in the estuary. Consequently, a coordinated work effort is planned for the Milwaukee Harbor estuary which will involve hydrologic, hydraulic, water quality, sedimentation, and aquatic biology studies. These studies will be carried out to provide an increased understanding of the estuarine system as a basis for forecasting the effects alternative water resources management measures would have upon estuary water quality, recreation, and navigation. Water quality forecasts will be made for a number of alternative pollution management plans with cost estimates to be made for each respective plan. The inventories and analyses are so oriented that forecasts can be made for not only Q7,10 low-flow conditions, but also to allow for evaluation of the percent of time water quality standards would be met.

For estuary problems related to storm damage, the planning study will collect necessary data and pertinent information to characterize storm conditions--including post-storm lake level oscillations and harbor surging--in an attempt to better define problems extant in Milwaukee Harbor. Because of the complex hydraulic interactions not only between Lake Michigan and the harbor, but also within the harbor itself due to its complex geometry, it is necessary to collect certain basic data and conduct the fundamental or basic analyses necessary to assure an understanding of the physical system before a more sophisticated study, if necessary, can be designed and conducted. Thus, the work efforts described herein may relate more to the definition of the problem than to the identification of solutions. Accordingly, the recommendations may include a designation of the further studies needed by specific agencies for resolution of the potentially complex problems that may exist in Milwaukee Harbor.

Hydrologic Studies: Hydrologic studies will be conducted to determine the water budgets for various segments of the Milwaukee Harbor estuary and for urban and rural segments of the Milwaukee Harbor watershed upstream from the estuary subwatershed. The primary purpose of the hydrologic budgets will be to develop water quality budgets as described subsequently in this chapter. In addition, hydrologic studies will address long-term lake level fluctuations and offshore wave climatology. Hydrologic studies will also be used to support the conduct of necessary hydraulic studies of flood stages in the inner harbor.

To prepare water budgets for the Milwaukee Harbor estuary subwatershed, streamflow records collected at U.S. Geological Survey (USGS) gaging stations to be operated during the planning study will be combined with simulated flow records in the estuary proper, along with monitored and simulated sanitary and combined sewer overflows, and flushing tunnel flows so that runoff volumes and rates can be determined for the two-year monitoring period and itemized for the major subareas of the watershed: rural; urban separate sewer service areas; urban combined sewer service areas; the inner harbor subwatershed including the Menomonee Valley industrial area, the downtown Milwaukee commercial area, harbor facility areas, and residential areas; and the outer harbor subwatershed including harbor facilities areas, the Jones Island wastewater treatment plant, combined and separate sewer service areas and areas contributing direct runoff.

In addition, water budgets will be itemized for each of the riverine branches of the estuary including not only the Milwaukee, Menomonee, and Kinnickinnic estuaries, but also the Burnham Canal and thermal discharges from the two major electric power generation plants. Water budgets to be developed will include mean daily flows for the two-year study period, runoff event volumes, and peak discharges. Flows for the riverine branches of the estuary will be developed, if feasible, through the use of hydraulic simulation modeling of the discharges from the storm, sanitary, and combined sewers discharging to the estuary. Direct storm water runoff from the estuary subwatershed will be estimated using computer simulation modeling, calibrated using monitored combined sewer overflow and precipitation data. Such modeling capability was developed by the Milwaukee Metropolitan Sewerage District for the combined sewer overflow abatement project described in Chapter II, and will be adapted for use in the estuary planning study. Rain gages operated by the City of Milwaukee, the Milwaukee Metropolitan Sewerage District, and the National Weather Service should provide adequate precipitation data for urban storm water runoff modeling.

The groundwater contribution to the hydrologic budget within the estuary proper will also be estimated utilizing available data and data to be collected during the two-year monitoring period by the USGS. The USGS will determine seasonal and annual groundwater flow to and from the estuary within the shallow aquifer as part of a groundwater pollutant transport analysis.

Historic lake stage data for Lake Michigan will also be analyzed to provide information useful in forecasting long-term, annual, and short-term lake level fluctuations. Studies of wave climatology will provide data useful for the determination of design wave heights, and will provide information on the frequency of storms. Such information will also be utilized in addressing both harbor operation and water quality problems.

Hydraulic Studies: Hydraulic studies of the Milwaukee Harbor estuary will be conducted to confirm or refine the results of previous studies of the flood stages in the inner harbor and to provide information necessary for determination of hydrologic, water quality, and sediment budgets for the Milwaukee River, the Menomonee River, and the Kinnickinnic River portions of the inner harbor and also the outer harbor. Such information will also be utilized in studies of harbor and lake level oscillations, harbor current variations, wave damage, and flooding.

The general inventory data, the hydraulic structures data, and the hydrologic data will be used to check the 10-year, 50-year, and 100-year recurrence interval flood stages previously established for the inner harbor. The analyses will include a full reevaluation of the hydraulic backwater effects of hydraulic structures which have been replaced or modified since the conduct of the analyses of the comprehensive watershed studies of the Milwaukee, Menomonee, and Kinnickinnic Rivers. The relationship of the historic, currently proposed, and alternative future channel dredging plans--for water quality or navigational purposes--to the hydraulic capacity of the channels will be explored. Hydraulic grade lines for existing and future conditions will be determined, and the results presented in detailed flood profile drawings, and in flood stage tables. Recommendations will be developed for regulatory flood stages in the inner harbor.

One-dimensional and three-dimensional hydrodynamic models will be employed in the inner harbor with the one-dimensional model providing continuous flow simulation throughout the two-year monitoring period and also serving as a back-up to, and independent check on, the three-dimensional model. The three-dimensional model would be applied only for discrete periods rather than as a continuous simulation tool. The periods to be modeled would include the runoff events to be sampled during the two-year monitoring period for calibration/verification purposes, as well as selected normal or low-flow periods sampled during the study. Following verification of the hydrodynamics, this model would then be applied--for forecasting purposes--to a set of characteristic hydraulic and associated water quality conditions to be selected representing the range of such conditions that can be expected to occur. Coupled with water quality modeling, the expected range in water quality conditions for these characteristic hydrodynamic periods should then include critical conditions necessary for evaluation of alternative levels of protection for combined sewer overflow abatement and other nonpoint source pollution control, as well as for point source wasteload allocation purposes and for consideration of instream measures. The three-dimensional model would be particularly useful in the evaluation of sediment scour and transport at CSO outfalls, and for the evaluation of lake water intrusion into the harbor.

Current speed and direction data described earlier in the inventory section of this chapter will be reduced to a format suitable for use in the calibration and verification of hydrologic-hydraulic models of the inner and outer harbors. Precise water level monitoring data will be assembled in a format suitable as input to the simulation model, and vertical water temperature profile data will be prepared in a format suitable for the documentation of thermally stratified conditions to aid in the hydraulic simulation analysis. Frequency and duration of current reversals and lake water intrusions and the environmental factors affecting these phenomena will be identified to aid in the interpretation of physical, chemical, biological, and sediment data in the inner harbor.

Current speed and direction data collected in the outer harbor at the four breakwater openings will be utilized to estimate the rates of water and pollutant exchange between the outer harbor and Lake Michigan. Such studies will utilize either a two- or three-dimensional hydrodynamic simulation model, as appropriate. The two-dimensional model which would be constructed as part of the three-dimensional model development process would also serve as a back-up if three-dimensional modeling proves to be infeasible.

If deterministic modeling proves feasible, flow through the breakwater openings will be simulated for use in developing average daily flow values. Other evaluations will address the expected frequency and duration of current reversals, lake water intrusions, and water level oscillations in the outer harbor, described using model input and output information to aid in interpretation of physical, chemical, biological, and sediment data in the outer harbor.

Bathymetric data and water level records collected near the north and south ends of the outer harbor will be analyzed during periods of surging to determine modes of oscillation and to identify and quantify associated currents. The effects of deepening the outer harbor to 37 feet, a proposal under consideration by the Army Corps of Engineers, upon surge characteristics will also be addressed. The frequency of surge events and the cause of surges will be determined so that appropriate remedial measures can be identified for resolution of surge-related problems in the outer harbor. The effects of surge-induced currents upon bottom sediment resuspension will also be addressed.

The occurrence of internal waves from Lake Michigan within the outer and inner harbors will be evaluated utilizing continuous vertical water temperature records so that the frequency, duration, and timing of these events can be documented, and so the causes and characteristics of these waves may be determined.

Offshore wave data will be utilized to evaluate the effects of the outer harbor breakwater upon incoming wave heights. Critical wave train direction in relation to the breakwater orientation will be determined, along with attendant fetch, storm duration, and resultant wave height, to develop design wave heights at various locations in the outer harbor. Means of reducing wave heights in the outer harbor will also be addressed. Past wave studies in the vicinity of Milwaukee Harbor will be drawn upon for use in this analysis.

Water Quality Studies: The primary purposes of water quality studies in the Milwaukee Harbor estuary planning study are to prepare pollutant mass and loading budgets for various subelements of the Milwaukee Harbor watershed, to identify sources and quantify the amounts of pollutants from these sources; to identify, qualify, and quantify the locations and qualities of deposits of polluted sediments; to document extant water quality conditions; to address the effects of bottom sediments upon water column quality; to refine and extend previous estimates of pollutant loadings to Lake Michigan; and to explore and identify the circumstances--and their frequency of occurrence--which may be expected to result in the most severe water quality conditions in the Milwaukee Harbor estuary. Pollutant loadings will be calculated using flow and water quality data collected over the two-year estuary study monitoring period at the seven continuous record U.S. Geological Survey gaging stations shown on Map 31, as well as at 13 baseline and event water quality sampling stations in the free-flowing rivers and the inner harbor. Event, seasonal, and annual loadings will be determined for each of the pollutants listed in Table 91. Hydrologic and water quality budgets will also be calculated for the Milwaukee and Kinnickinnic River flushing tunnels utilizing pumping rate data to be supplied by MMSD and water quality data collected in McKinley Marina and at the Russell Avenue breakwater gap near the Kinnickinnic River flushing tunnel intake.

Using simulated flow data and sampled water quality data collected in the inner harbor, pollutant loadings will also be calculated for the Milwaukee River at St. Paul Avenue and at the mouth, for the Menomonee River at S. Second Street, and for the Kinnickinnic River at Greenfield Avenue, as well as for the flushing tunnels as described above. Loadings will be calculated for event, seasonal, and annual periods of the two-year monitoring period for the parameters listed in Table 91.

Pollutant loadings to Lake Michigan from the outer harbor will be estimated utilizing the best available information. If deterministic flow simulation through the breakwater openings proves to be feasible, simulated daily flows and real water quality data will be utilized to compute pollutant loadings to the lake for selected major runoff events.

If continuous, deterministic flow simulation for individual events in the outer harbor is not found to be feasible, pollutant loadings to the lake will be estimated using average river inflow, Jones Island discharge, and direct runoff and associated water quality data along with water quality data collected at the breakwater openings. Annual loadings will be estimated for the parameters in Table 91. To the extent possible, seasonal loadings will also be estimated, as well as loadings for selected runoff events.

Urban nonpoint source pollutant loading rates will be estimated by upstream-downstream comparison of riverine loads monitored during the study period; by analysis of computed loading rates at the NURPS storm sewer stations, the City of Milwaukee WPDES sanitary sewer overflow monitoring stations, and the Milwaukee Metropolitan Sewerage District WPDES combined sewer overflow monitoring stations; by analysis of estimated loading rates from large industrial and commercial areas; and by analysis of estimated loading rates for runoff from harbor facilities areas. Combined sewer overflow loading rates will also be estimated utilizing the SWMM and STORM models previously developed for the estuary subwatershed by the MMSD. Loadings for all monitored events will be calculated and tabulated for use in identification of source areas for each of the constituents monitored and for estimation of quantities of pollutants from these sources. Included in the urban nonpoint source pollution analysis will also be wet- and dry-fallout pollutant loading estimates to ascertain the relative importance of atmospheric loadings upon estuary water quality.

Upon completion of the chemical water quality budgets, and sediment quantity and quality budgets described later in this chapter, unit pollution loading rates will be developed for the various land uses within the Milwaukee Harbor watershed for use in the development of alternative plans for control of nonpoint source pollution within the estuary subwatershed. The nonpoint source water pollution control recommendations of the areawide water quality management plan, for the tributary areas of the watersheds upstream from the estuary, when considered in concert with the measures recommended for the estuary subwatershed, will be reviewed to confirm or to revise the measures recommended to support attainment of water quality objectives for the estuary.

The effects of polluted bottom sediments upon water column quality are not well understood currently, with additional basic scientific research required at this time. For the Milwaukee Harbor estuary planning study, a study will be conducted to estimate when, where, and to what degree the bottom sediments are significantly degrading water quality. Runoff event pollutant loading comparisons provide one means of identifying the relative importance of disturbances of bottom sediments. In addition, the sediment process studies described earlier in this chapter will attempt to qualify and quantify the effects of both disturbed and undisturbed bottom sediments upon overlying water quality, especially with respect to dissolved oxygen. High- and low-flow condition data will then be used to identify the areas in the estuary where bottom sediments most significantly degrade water quality. Such areas may then become potential candidates for dredging for water quality purposes.

Data from the water quality and sedimentation studies in particular, along with pertinent hydraulic, hydrologic, and biological data, will be utilized to determine the "level of protection" (LOP) required to meet water quality objectives in the estuary. LOP is herein defined as the expected recurrence interval for combined sewer overflows into the estuary or the streams tributary to the estuary. A range of LOP's will be evaluated--from the one-half year to 5-year LOP's--with consideration given to the associated costs, expected water quality conditions, and how these respective conditions compare to the water use objectives and supporting standards for the estuary. Forecast conditions will be estimated employing statistical and correlational techniques and water-quality simulation-modeling methods, such methods to be founded upon the data base to be collected during the 2-year field survey, as well as upon relevant data collected in the past to be used, in part, for verification purposes.

The results of the empirical and simulation modeling studies will be combined for analysis of dissolved oxygen, fecal coliforms, hazardous substances, and sediment transport for determination of not only the LOP required for control of combined sewer overflows, but for determination of necessary control measures in the separate sewer service areas and tributary rural areas of the Milwaukee Harbor watershed, and for the consideration of instream measures. The effects of control measures upon water quality in each of the three estuary branches will be addressed separately to evaluate the effects of control measures specific to each estuary branch. These measures would then be evaluated to determine if water quality objectives would also be met near the mouth of the Milwaukee River in the inner harbor and in the outer harbor.

Sedimentation: Because bottom sediments in the Milwaukee Harbor estuary will have an adverse effect upon both water quality and navigational use as well as related transportation activities, a need exists for quantification of suspended and deposited sediments, identification of deposition areas and rates of deposition, identification of areas subject to scour, and qualification and quantification of sediment pollutants. In addition, estimates of the effects of inplace pollutants upon water quality after CSO abatement are necessary to determine if natural processes will significantly or completely diminish the deleterious effects, and to determine the associated time period required for stabilization to occur. Such studies are necessary for determination of areas where dredging may be required not only for navigation, but also for water quality purposes. In addition, such studies will be necessary for determination of the means of dredge spoil disposal.

Fundamental to the sedimentation studies will be the determination of sediment loading rates at the sites shown on Map 31. Using both observed and simulated flows, sediment data will be utilized to compute transport rates of suspended load and bed load for event, seasonal, and annual intervals during the two-year estuary study monitoring period. The sediment transport budgets will then be evaluated to quantify unit-area sediment yields. Selected bed load samples will be collected during runoff events for separate chemical analysis to determine the quality characteristics of bed load sediment. The data from this analysis will be used along with data from the sediment process studies to identify source areas, deposition areas and rates of deposition, and also to assist in identification of areas subject to scour.

Unconsolidated sediment thickness maps--discussed earlier in the inventory section of this chapter--will be utilized to assist in the identification of deposition areas, scour areas, areas to be dredged for water quality purposes, and areas to be dredged for navigational purposes. Quantities of unconsolidated materials will be computed utilizing the sediment thickness map for analysis of dredging alternatives. The chemistry of these deposits, taken from core sample data, will be combined with the thickness data to 1) describe the horizontal and vertical loading of the various pollutants within these sediments, 2) to compute the total quantities of each pollutant in the sediments, 3) to identify specific areas where sediments can be classified as either nonpolluted, polluted, or hazardous on both horizontal and vertical bases, and 4) to quantify separately the nonpolluted, polluted, and hazardous sediments in various subareas of the harbor to assist in the analysis of alternatives for dredge spoil disposal.

Based upon the inventory studies of the amounts, sources, and behavior of suspended and bottom sediments, the related interstitial waters, and the associated pollutants, the major processes by which sediments affect the observed water quality and related biological conditions of the estuary will be identified. Of special importance will be the analysis and discussion of the observed high levels of sediment oxygen demand in the Milwaukee Harbor estuary. Also addressed will be the role and relationship of the processes--such as sediment deposit, sediment scour and resuspension, aerobic and anaerobic sediment decomposition, and other chemical and biological transformation--to: a) the hydrology and hydraulics of the estuary, b) the various methods and related levels of protection of CSO abatement, c) the existing and potential future nonpoint source pollution control measures, and d) the potential instream measures for water pollution abatement. Forecasts will be prepared of the impacts on water quality of the potential CSO abatement measures, nonpoint source controls, and instream measures. The expected periods of sediment stabilization will be identified, and specific conclusions drawn with respect to the long-term CSO-sediment effects on the water quality of the entire estuary, and the extent--or lack--of the need for these measures.

Any areas potentially requiring dredging for water quality purposes will be identified based upon sediment chemistry, scour potential during highwater periods, and near-sediment water chemistry gradients and sediment oxygen demand during high- and low-flow periods. Associated quantities of dredge materials will also be specified. Potential disposal sites for the dredge spoils will be identified.

Aquatic Biology: Aquatic biology studies will describe extant flora and fauna utilizing the inner and outer Milwaukee harbors, the frequency and duration of their habitation, the water quality and sediment conditions preferred by these aquatic species, and the potential aquatic life--algae in particular--for the enhanced water and sediment quality conditions anticipated under alternative future conditions. Information upon which these studies will be based are previous biological studies described in Chapter II of this report, as well as the fishery surveys and the algal productivity studies proposed earlier in this chapter. Thus, the inventory findings would be further analyzed in light of the inventory and analysis of the hydrology, hydraulics, water quality, and sediments of the estuary.

DESIGN, TESTING, AND EVALUATION OF ALTERNATIVE WATER RESOURCES MANAGEMENT PLANS

The ultimate purpose of the proposed Milwaukee Harbor estuary subwatershed planning program will be the preparation and presentation of a number of feasible alternative plans for public evaluation, and the selection of a final plan for adoption and implementation. Alternative plans may include proposals for point source wasteload allocations, including CSO loadings, nonpoint source pollution management plans, plans for instream water quality management measures, navigation maintenance-related plans, and harbor operation and storm protection plans. Each alternative plan must be quantitatively tested to establish the ability of the proposed measures to meet the water resources management objectives of the estuary planning study.

Any single plan for specific water management facilities and engineering structures may carry with it far-reaching effects on general land and water use patterns, the allocation of resources, public investment policies, and broad community "benefits" and "costs". Decisions regarding such broad matters should not be made by technicians alone. Such decisions properly belong in the realm of public policymaking and should actively involve elected officials and interested citizens. If adopted, the estuary subwatershed plan should represent more than technical decisions; therefore, the related physical, economic, social, and legal effects of alternative plans must be analyzed and presented in understandable form to elected public officials and interested citizens for study and evaluation. This effort should be accomplished through planning reports describing the corollary effects and broad benefits of alternative plans.

Planning reports adequate for plan selection and public policymaking purposes should include, in addition to a description of the feasible alternative plans, clear statements providing information on the following important points:

1. The purpose of the estuary subwatershed planning program and the resultant planning report as an instrument for public decision-making.

2. The existing and potential natural resource problems of the estuary subwatershed as revealed by the surveys and studies.

3. The existing and potential water and water-related resource problems of the estuary as revealed by the surveys and studies.

4. The alternative means for abating estuary water resource problems.

5. The evaluation of the benefits and costs, broadly defined, of the short- and long-term economic, environmental, and social impacts of the alternative means for abating estuary problems.

6. The critical decisions that need to be made in the Milwaukee Harbor watershed in light of the total problem.

Flood Control Plans

Structure modification and replacements, and channel maintenance projects have been conducted for the inner harbor, and shore protection measures undertaken for the outer harbor. The regulatory flood profiles--which support the engineering design assumptions behind these projects--will be confirmed or new flood profile data will be developed for consideration in the final plan, in coordination with the pollution control, instream rehabilitation, and dredging elements of the estuary plan, on the basis of the evaluation and testing of alternative plan elements.

Point Source Wasteload Allocations

Alternative point source wasteload allocation schedules will be developed for both public and private wastewater treatment facilities in the Milwaukee Harbor watershed in Milwaukee County. Wastewater discharges to receiving waters upstream from Milwaukee County are either so small in magnitude or so distant from the estuary that the effects of these discharges upon estuary water quality are minor compared to effects from point source discharges within Milwaukee County and from nonpoint source loadings from the entire Milwaukee Harbor watershed. The only possible exception relates to the nutrient pollution associated with upstream pollution sources. Therefore, the estimated total point source loadings at the Milwaukee County line will be utilized as a boundary condition for determination of public and private wasteload allocations within the Milwaukee County portion of the Milwaukee Harbor watershed. Wasteload allocations so developed will be based upon potentially achievable nonpoint source pollutant loading alternatives, upon the results of the Jones Island facilities planning study, upon the combined sewer overflow abatement alternative to be implemented, and upon the results of water quality analyses conducted as part of the proposed study.

Nonpoint Source Pollution Management Plans

Nonpoint, or diffuse, sources of water pollution include urban sources--such as runoff from residential, commercial, industrial, transportation, and recreational land uses; construction activities; and onsite sewage disposal systems--and rural sources--such as runoff from cropland, pasture, and woodland, atmospheric contributions, and livestock wastes. These sources of pollutants discharge to surface waters by direct overland drainage, by drainage through natural channels, by drainage through engineered storm water drainage systems, and by deep percolation into the ground and subsequent return flow to the surface waters.

The water quality analyses presented in the areawide water quality management plan indicated that a reduction in the transport of pollutants from nonpoint sources was necessary in combination with the point source pollution abatement measures if water use objectives were to be met. The analyses indicated that many streams in the Region, including some in the Milwaukee Harbor estuary subwatershed, would not meet the water use objectives and supporting water quality standards if adequate nonpoint source controls were not implemented, regardless of the level of point source controls applied. The nonpoint source pollution control measures recommended by the areawide water quality management plan will be reevaluated to assure that these measures are adequate to meet the water quality objectives for the Milwaukee Harbor estuary. For those areas directly tributary to the Milwaukee Harbor estuary, which contribute nonpoint pollution via separate storm sewer outfalls, the Commission will identify land management practices and other mechanisms of nonpoint pollution control necessary and sufficient to achieve the selected water use objectives and supporting standards.

Instream Water Quality Management Measures

The Milwaukee Metropolitan Sewerage District facilities planning study concluded that instream water quality management measures such as mechanical surface aeration, flow augmentation, and dredging of polluted sediments are potential alternative measures which should be considered for implementation as necessary to meet water use objectives. Plan evaluation will include assessment of the potential impacts upon navigation and related transportation facilities. The estuary planning study will evaluate these potential instream water quality enhancement measures in greater detail and prepare alternative plans describing the types and locations of instream measures to be used, along with an economic analysis and an institutional analysis for designation of appropriate agencies to implement instream water quality management measures. Such plans for instream measures will be coordinated with control of point and nonpoint source pollution so that a cost-effective solution to the water quality management problems of the estuary can be obtained. The potential benefits of repeated dredging in lieu of higher levels of combined sewer overflow abatement will also be considered. These analyses will also consider, among other things, the effects of alternative plans on commercial navigation and related transportation uses.

Navigation Maintenance Dredging and Spoils Disposal Plans

Alternative dredging plans will be developed under the estuary planning study for both water quality and navigation purposes. In addition, analysis of dredge spoil disposal alternatives will also be carried out to determine the optimum means of disposal within the bounds of legal, economical, social and land use constraints. Such dredging plans will be coordinated with the point source and nonpoint source pollution control analyses, and the instream aeration and flow augmentation studies to determine the cost-effective combination of measures for each branch of the estuary that will meet water quality objectives. In addition, analyses of dredging for navigational purposes will be coordinated with analyses of dredging conducted for water quality enhancement, to develop dredging plans compatible with both water quality and navigation needs.

Harbor Storm Protection Plans

The Milwaukee Harbor estuary planning study will analyze harbor storm damage problems, addressing the problems of maintaining safe anchorage and navigation, as well as shoreline protection in the outer harbor. Storms over Lake Michigan have caused overtopping of the breakwater, damage to recreational and commercial water craft and attendant facilities, and damage to shoreline areas in the outer harbor. Analysis of these storm damage problems will be carried out in the estuary planning study for the development of technically and economically feasible plans which address these problems to the greatest degree possible. Additional necessary facilities design or refinement studies will be identified, if it is found that such efforts are required for further development of feasible plans.

PLAN SELECTION AND ADOPTION

One plan should be chosen, after public hearings, as the final plan to be used to guide the long-range physical development of the estuary subwatershed and--through cooperative adoption by all levels and agencies of government involved--to be used as the basic reference for future investment in public works and port development and for future urban and rural development patterns, soil and water management programs and detailed drainage and sewerage designs within the Milwaukee Harbor watershed. The final published planning reports should include a clear graphic and written description of the general plans and the reasons for their selection.

An administrative and financial study will be required to suggest practical organizational and financial arrangements under which the selected estuary subwatershed plan can be implemented. These studies will address the capabilities of local units of government to implement the various plan recommendations, will identify the federal and state financial and technical assistance available for such implementation, and will identify an appropriate agency for implementation of each specific element of the overall estuary subwatershed plan.

PLAN IMPLEMENTATION AND PREPARATION OF PRECISE PLANS

Two vital portions of the process of selection of the final plan are an administrative and financial analysis, and the establishment of a continuing water resources management program.

Administrative and Financial Analysis

An administrative and financial study will be required to suggest the practical organization and financial arrangements under which the selected Milwaukee Harbor estuary plan and its related water resources management structures and practices can be constructed, installed and operated. The study will analyze the capabilities of local units of government to implement the plan recommendations, as well as those capabilities of state and federal institutions. The study will further identify federal and state financial and technical assistance for the implementation of the selected plan and will recommend an organizational structure for the implementation of the plan.

Continuing Water Resources Management

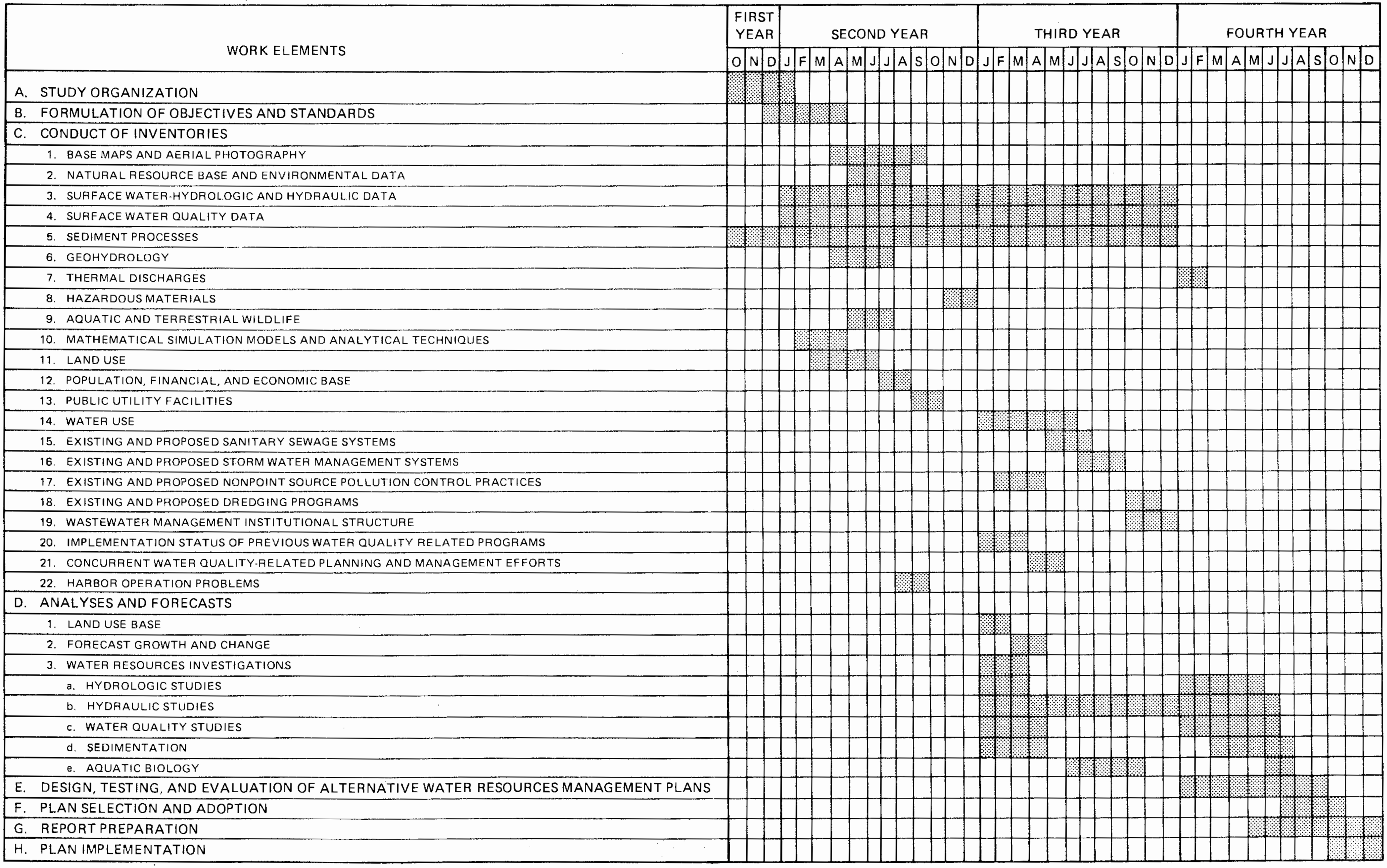
After preparation of the physical elements of the final selected Milwaukee Harbor estuary water resources management plan, recommendations shall be made relating to the establishment of a continuing water resources management program for the estuary subwatershed. Such recommendations shall specifically include the organizational and staffing elements of the program, and shall suggest a recommended budget for the program, including a recommended source of funding.

TIME SCHEDULE

An estimated time schedule for the accomplishment of the major elements of the studies is shown in Figure 9. As shown in the figure, it is estimated that completion of the study will require a period of forty months. The schedule presented is subject to revision upon preparation of detailed study design subelements. Study organization and cost estimates are based upon the recommended time schedule, which identifies all the major work elements.

Figure 9

TIMING OF MAJOR WORK ELEMENTS OF THE MILWAUKEE HARBOR COMPREHENSIVE WATER RESOURCES PLANNING STUDY



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Chapter V

ORGANIZATION FOR THE MILWAUKEE HARBOR ESTUARY COMPREHENSIVE WATER RESOURCES PLANNING STUDY

INTRODUCTION

The proposed Milwaukee Harbor estuary planning study outlined in the preceding chapter of this document necessarily concerns a number of levels, units, and agencies of government. Accordingly, the organizational structure for the proposed program must provide for the active participation of these levels, units, and agencies of government and thereby provide a cooperative, intergovernmental approach to the problems to be addressed. The following discussion considers various aspects of the proposed organizational structure, including staff and consultant requirements, committee structure, and public participation.

STAFF AND CONSULTANT REQUIREMENTS

The proper execution of the Milwaukee Harbor estuary planning study will require a staff trained and experienced in many different skills, professions, and disciplines. These include, among others, economics, land use planning, resource conservation, biology, hydrology, hydraulics, civil engineering, analytical chemistry, and geo-chemistry. The complexity of the water resources problems existing in the estuary, coupled with conflicting interests and demands on this water resource make an interdisciplinary approach to the planning work particularly important. The proposed organizational structure for the Milwaukee Harbor estuary planning study is set forth in Figure 10.

The Southeastern Wisconsin Regional Planning Commission, as the formally designated areawide water quality management planning agency for southeastern Wisconsin, is charged with the responsibility to prepare, adopt, maintain, extend and refine a Section 208 water quality management plan for the Region. The Commission is, therefore, proposed to be the primary agency responsible for the organization of the work, mounting the necessary work effort, securing the necessary intergovernmental coordination and citizen participation, and selecting and adopting a Milwaukee Harbor estuary water resources management plan.

Because of the importance of conducting the estuary study within the comprehensive regional planning framework already established by the Commission and because of the important substantial technical relationships which must exist between the sources of technical expertise about the estuary, it is recommended that the proposed studies be carried out by the staff of the Southeastern Wisconsin Regional Planning Commission, assisted as appropriate by the staffs of other governmental agencies and units of government and by University or private consultants. The Commission would assume direct responsibility for all work elements which might logically be considered of a regional planning nature. These work elements might include staff work necessary for the collation or collection of population, economic activity, and land use data; for the collation of available data concerning hydrology, hydraulics, water quality, biology, public utilities, water use, nonpoint pollution sources and control techniques, dredging programs, and financial resources; for the conduct of

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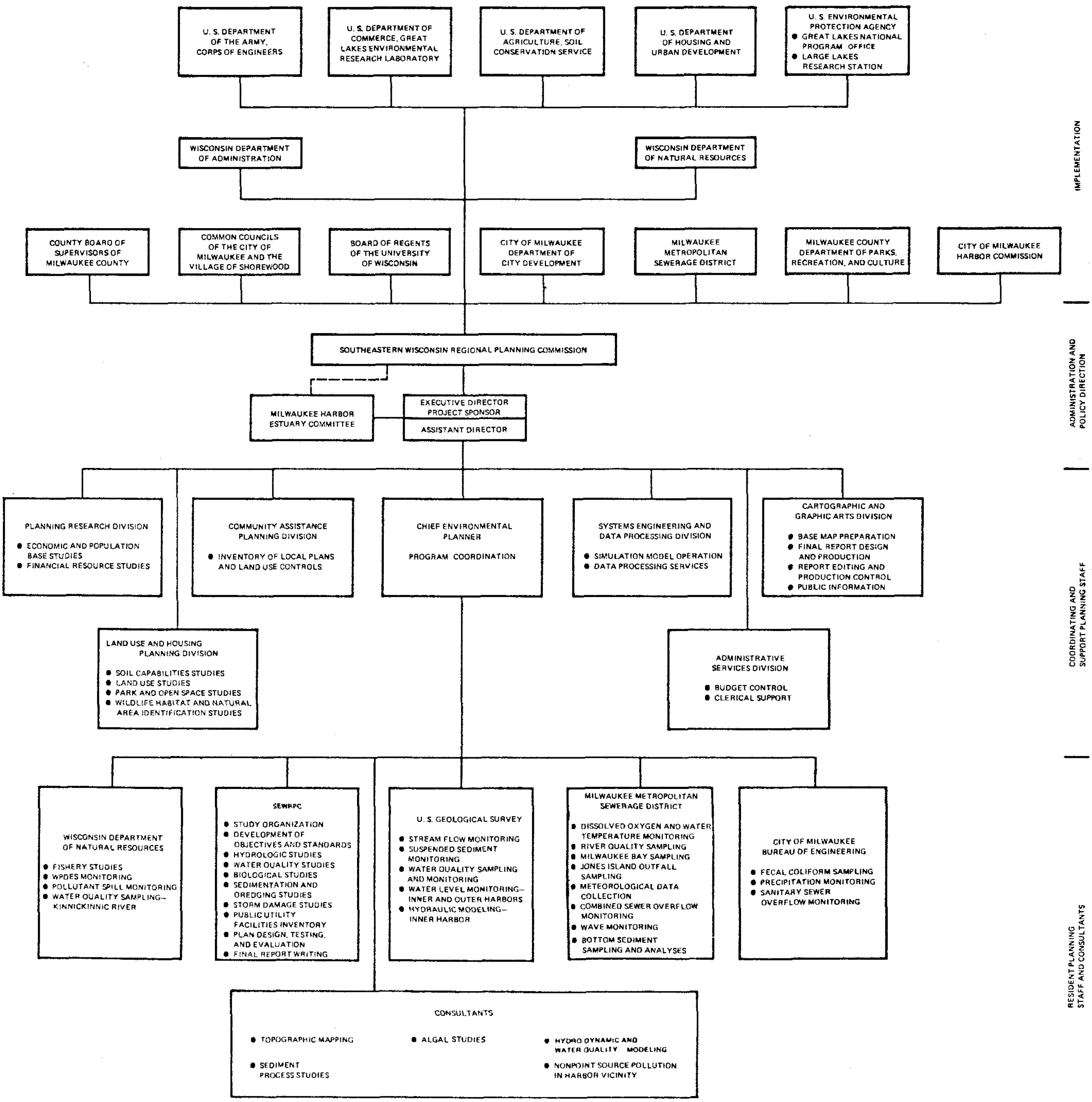
ORGANIZATIONAL STRUCTURE FOR THE MILWAUKEE HARBOR ESTUARY COMPREHENSIVE WATER RESOURCES PLANNING STUDY



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hydrologic, hydraulic, and water quality analyses; for the evaluation of field data collected by contractors; for the preparation and recommended adoption of development objectives and standards pertaining to the estuary; for the formulation and evaluation of alternative plans; and for the selection of a final plan for the resolution or abatement of the water resources problems of the Milwaukee Harbor estuary.

It is estimated that this portion of the work would require the equivalent services of one full-time planner and two full-time engineers over the period of the study, together with supporting administrative, clerical, and drafting services. The Commission would also be responsible for interpreting the results of this study for the local units of government concerned and for the involved governmental agencies, and for assisting these units and agencies of government in plan implementation. Thus, continuity would be assured for the planning program following completion of the studies themselves and for the promotion of plan implementation.

It is further recommended that this nucleus planning staff be supplemented by the use of contractual services to provide other professional skills required to successfully complete the study. In particular, the skills required to complete the hydrologic and hydraulic data collection and analyses; the surface water and groundwater quality data collection and analyses; the control survey and photogrammetric engineering; the sediment sampling and evaluation; water chemistry and sediment chemistry laboratory tests; algal conductivity studies; and the collection of minnows and forage fishes would be needed. In addition, contractual service agreements might be arranged with those governmental agencies exhibiting special skills, such as particular aspects of natural resource conservation management, including fish and wildlife and surface water and groundwater investigations. It is extremely important, however, that the proposed study, including the contractual services, be carried out under the administrative direction of the Commission staff. The size and complexity of the task to be accomplished require that all participants in the study function as a cohesive and organized single staff unit with full coordination and high levels of ongoing communication among the project participants.

It must be recognized that actual service agreements negotiated during the detailed study will be necessary to precisely specify the personnel requirements, the lines of authority and responsibility, and particularly the functional designation of tasks. Figure 10, however, does indicate generally and at a preliminary level, the relationships which are envisioned.

The proposed contractors to the estuary planning study and the associated work tasks include: 1) the U.S. Geological Survey for streamflow, water level, groundwater, and water quality data collection and one-dimensional hydraulic modeling of the inner harbor; 2) an as yet undesignated contractor for three-dimensional hydraulic and water quality modeling of the outer harbor; 3) an as yet undesignated contractor for bottom sediment process studies; and 4) an as yet undesignated contractor for studies of nonpoint sources of pollution from industrial and commercial areas draining directly to the estuary via separate storm sewers and overland runoff. Private consultants, universities, and government agencies may be utilized as contractors for specific subelements of the proposed study.

Private consultants will be selected through the activities of an appropriate interview board created by the Commission, comprised of the most knowledgeable people in the field to be addressed, and including in all cases at least one representative each from the MMSD and DNR. Candidate firms will be invited to submit their qualifications as a basis for screening these firms to a subset of firms (e.g., about 3 to

8) to be invited for personal interviews. Based upon the interview results, the interview-board will rank the candidate firms with respect to their qualifications to conduct the specific studies at hand. Negotiations will then be undertaken with the first-ranked firm to arrange a contract within the time and budgetary limits of the project. In the event that terms cannot be agreed upon, the firm would be dismissed, and negotiations begun with the next-ranked firm. This process would be followed until a satisfactory contract is arranged.

Technical Coordination

To assure coordination of efforts by study participants, Commission staff will convene regular work sessions at monthly intervals or--more often as may be needed--to assist in planning and organizing the various work tasks. Reports will be made by Commission staff and other participants on work progress, trends, and preliminary findings of various study subelements. Such sessions will aid in providing a sound technical base and in keeping all participants informed on study progress.

TECHNICAL ADVISORY COMMITTEE STRUCTURE AND FUNCTION

Committee Structure

As shown in Figure 10, it is recommended that one advisory committee be made an integral part of the organization of the proposed study, namely, the Milwaukee Harbor Estuary Committee. This committee would be advisory to the Commission and would be created by action of the Regional Planning Commission. Composition of the committee would include representatives from the following interest groups:

1. Local governmental groups (City of Milwaukee and Milwaukee County)

2. State government (Department of Natural Resources and Wisconsin Geological and Natural History Survey)

3. Federal government (U. S. Geological Survey, U. S. Environmental Protection Agency, U.S. Fish and Wildlife Service)

4. Recreational interest groups involved in fishing, sailing, and aesthetic uses in the estuary and coastal area (yacht clubs, Lake Michigan fishing sportman's associations, charter fishing representatives, Milwaukee County Parks and appropriate downtown redevelopment groups)

5. Groups involved in land use and land management decisions in the estuary area (Department of City Development, various industrial activities in the Menomonee Valley)

6. Industrial wastewater dischargers (Wisconsin Electric Power Company)

7. Commercial navigational interests (City Harbor Commission)

8. Storm water and sanitary sewerage management agencies (City of Milwaukee, Bureau of Engineers, and Milwaukee Metropolitan Sewerage District)

9. Lake Michigan research expertise (Center for Great Lakes Studies of the University of Wisconsin-Milwaukee, Great Lakes Environmental Research Lab of NOAA, Great Lakes Basin Commission)

10. University of Wisconsin-Madison and Marquette University.

The individual members of the Technical Advisory Committee would be identified by the Regional Planning Commission--acting in accordance with the provisions of Chapter 66.945 of the Wisconsin Statutes--in cooperation with the MMSD and DNR, in order that a mutually agreeable committee would be established.

Committee Function

The basic purpose of the Milwaukee Harbor estuary committee would be to actively involve the various governmental bodies, technical agencies, and private interest groups concerned with the Milwaukee Harbor estuary and its direct drainage area, and to assist the Commission in determining and coordinating the necessary basic studies and the basic policies involved in the conduct of the program. The Committee will have a particularly important role in the selection of the final plan and in assuring the financial and administrative feasibility of the plan; and the Committee will assist in familiarizing the political, business, and industrial leadership within the estuary area with the studies and the findings, and in fostering an understanding of the basic objectives of the plan, and the implementation procedures necessary.

PUBLIC PARTICIPATION

Public participation will be essential to the conduct of the Milwaukee Harbor estuary study. It is envisioned that such participation be provided for in the following ways:

1. An initial public hearing on the proposed work effort would be held at the outset of the study.

2. Periodic articles would be presented in the SEWRPC Newsletter which is widely distributed.

3. A series of special public informational documents would be prepared in cooperation with the University of Wisconsin Extension Service to inform and advise all interested publics.

4. The Milwaukee Harbor Estuary Committee would meet in open public meetings and that due public notice would be provided to assure that there was general awareness of the meetings and their content.

5. The meetings of the Committee would be held at a location which is publicly accessible and located in the immediate area of the estuary itself.

6. Conferences or workshops would be held as necessary.

7. Public informational meetings and hearings would be held on the recommended Milwaukee Harbor estuary plan and the alternatives thereto considered in the plan preparation.

In addition to the foregoing, consideration will be given to the appropriate use of educational television, newspaper supplements, attitudinal surveys, self-guiding field trips and primary and secondary school educational materials to ensure that all citizens in or near the estuary area have an opportunity to be informed about the work program, as well as an opportunity to offer comments to the advisory committee and Commissioners as decision-makers in the project.

SPACE AND EQUIPMENT REQUIREMENTS

It is proposed that the Commission planning staff be housed in the Commission offices at the Old Courthouse in Waukesha, Wisconsin, with a working station to be located in the immediate area of the harbor. The field office would enhance intergovernmental communications for those agencies and units of government involved in the conduct of field studies in the estuary. The cost estimates for the program set forth in the next chapter include allocations for proportionate shares of the overhead costs at both facilities. All of the necessary data processing work will be accommodated within the Commission's established data processing center. The Commission currently possesses an IBM System 370, Model 3031 Computer with appropriate storage and printing capabilities and online terminal service. It will be established in the various contracts and interagency agreements that the water and sediment sampling and testing contractors or agencies will obtain and be responsible for the necessary sampling and laboratory equipment, with maximum use to be made of any currently-available equipment acquired under previous water resources-related studies in the Milwaukee area.

Chapter VI

ESTIMATED COSTS OF THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY

Estimated study costs for the Milwaukee Harbor estuary study are shown in Table 93, and are based upon the scope of work, time schedule, and study organization set forth in this study design. Cost estimates were prepared by the Commission staff on a work element by work element basis and are based upon estimates of both the staff and consultant direct labor and associated overhead costs, as well as separate estimates of cost for such items as travel, data processing and printing. Where applicable, these cost estimates were developed in cooperation with the government agencies and units of government which are most likely to assist in the conduct of the individual work programs.

Clearly, the Milwaukee Harbor estuary study would affect and therefore be of concern to several levels of government. However, the proposed study would be of primary concern to the MMSD in its water pollution abatement program and, therefore, the study costs are proposed to be borne primarily by this agency with federal financial assistance in light of the important role of the MMSD in the protection of the water quality of the estuary. More specifically, it is recommended that the costs be allocated as shown in Table 94. The U.S. Geological Survey, a principal water resources investigation agency of the federal government, will be requested to provide matching money to the Milwaukee Harbor estuary water resources planning study as part of the ongoing nationwide river quality assessment program by that agency. Also, the USGS will participate in the Milwaukee Harbor study in basic data collection and interpretive studies.

It is anticipated that funding for the estuary planning study would be secured by the Milwaukee Metropolitan Sewerage District through a U.S. Environmental Protection Agency Section 201 grant. The MMSD would supply the necessary local matching funds and the MMSD would contract with the SEWRPC for the conduct of the planning study. SEWRPC would let subcontracts for designated elements of the study--e.g., topographic mapping, simulation modeling, and water quality sampling--and would carry out the remainder of the study, including preparation of the final report.

Table 93

COST ESTIMATES FOR THE MILWAUKEE HARBOR ESTUARY COMPREHENSIVE WATER RESOURCES PLANNING STUDY[a]

Work Element	Cost	
	SEWRPC/ MMSD	USGS
A. Study Organization	$4,644	
B. Formulation of Objectives and Standards	9,288	
Subtotal	$13,932	--
C. Conduct of Inventories		
1. Base maps, aerial photography, and topographic mapping	150,431	
2. Natural Resource base and environmental data	10,245	
3. Surface water-hydrologic and hydraulic data	--	$ 13,800[b]
4. Surface water quality data	498,417[c]	407,900
5. Sedimentation	587,976	109,250
6. Geohydrology	10,245	35,000
7. Thermal discharges	5,601	
8. Aquatic and terrestrial wildlife	14,802	
9. Mathematical simulation models and analytical techniques	9,402	
10. Land use	10,245	
11. Public utility facilities	16,803	
12. Water use	19,533	
13. Existing and proposed nonpoint source pollution control practices	21,447	
14. Existing and proposed dredging programs	5,601	
15. Water quality management institutional and legal structure	10,245	
16. Implementation status of previous water quality related programs	10,245	
17. Concurrent water quality-related planning and management efforts	5,601	
18. Harbor operation problems	10,245	18,216[d]
Subtotal	$1,397,084	$584,166

Table 93 (continued)

Work Element	Cost	
	SEWRPC/ MMSD	USGS
D. Analyses and Forecasts		
1. Land use base	$ 5,601	
2. Forecast growth and change	10,245	
3. Water resources investigations		
a. Hydrologic studies	117,014	
b. Hydraulic studies	224,471	$100,000
c. Harbor storm studies	39,818	
d. Water quality studies	40,988	9,000
e. Sedimentation	29,833	9,000
f. Aquatic biology	7,923	--
Subtotal	$ 475,893	$118,000
E. Design, Testing, and Evaluation of Alternative Water Resources Management Plans	242,864	
F. Plan Selection and Adoption	10,245	
G. Report Preparation	57,864	
H. Plan Implementation	10,245	
Subtotal	$ 321,218	--
Total	$2,208,127	$702,166

[a]Costs listed in this table would be borne by the U.S. Environmental Protection Agency and the Milwaukee Metropolitan Sewerage District and the U.S. Geological Survey which could provide $702,166 in matching money (in addition to the EPA and MMSD monies listed above) as part of a nationwide river quality assessment program currently being conducted by that agency.

[b]Hydraulic data to be collected for model calibration and verification are included with the costs for Hydraulic Studies (Analyses and Forecasts). Continuous streamflow monitoring costs are included under "Surface Water Quality Data".

[c]Weekly water sampling by MMSD in the outer harbor and adjacent Milwaukee Bay will continue uninterrupted throughout the 2-year sampling period with the estuary planning study bearing the costs only of laboratory analyses to be performed by the MMSD and the USGS.

[d]Outer harbor water level monitoring at Juneau Park and wave monitoring in Milwaukee Bay are included in this cost.

Source: SEWRPC.

Table 94

PROPOSED FUNDING SOURCES AND COST ALLOCATIONS FOR THE MILWAUKEE HARBOR ESTUARY WATER RESOURCES PLANNING STUDY[a]

Agency	Cost Allocation					
	First Year[b]	Second Year	Third Year	Fourth Year	Total	Percent
U.S. Environmental Protection Agency......	$150,252	$616,829	$501,205	$387,809	$1,656,095	75
Milwaukee Metropolitan Sewerage District..	50,084	205,610	167,068	129,270	552,032	25
Total	$200,336	$822,439	$668,273	$517,079	$2,208,127	100

[a]In addition to the funding to be provided by the EPA and MMSD, the U.S. Geological Survey will provide $702,166 in matching services as part of a nationwide river quality assessment program currently being conducted by that agency.

[b]It is estimated that only four months of the first year would be involved.

Source: SEWRPC.

Chapter VII

SUMMARY

The preparation of a study design for a Milwaukee Harbor Estuary Comprehensive Water Resources Planning Study was initially requested by the Common Council of the City of Milwaukee on July 24, 1973, prior to the completion of the comprehensive studies of the three tributary watersheds. The request was reaffirmed by the City of Milwaukee on March 20, 1979. The development of a design for such a study was again requested June 12, 1980, by the U.S. Environmental Protection Agency. In response to these requests from governmental entities, and working jointly with the ad hoc review task force identified in Appendix B, the Commission prepared the study design described herein.

The Milwaukee Metropolitan Sewerage District (MMSD), Wisconsin Department of Natural Resources (DNR), and the U.S. Environmental Protection Agency (USEPA) staff members involved with the Milwaukee Water Pollution Abatement program agreed that the study was needed to develop the most cost-effective combination of actions which would achieve the applicable water use objectives and supporting water quality standards. The actions to be considered include--but are not limited to--the construction and operation of properly-sized facilities for conveyance, storage, and treatment of combined sewer overflows; the application of appropriate point source and nonpoint source water pollution controls in the Milwaukee, Menomonee, and Kinnickinnic River upstream watershed areas tributary to the Milwaukee Harbor estuary; and the design and implementation of suitable instream measures for water quality management of the estuary. Only by the selection and implementation of the most cost-effective combination of these measures can the water pollution, public health, water supply, water-based recreation, and general aesthetic problems of the inner and outer harbors be properly addressed within the necessary framework relating these problems to the flood control, navigation, and wave damage problems of the harbor.

The proposed planning program is designed to serve a number of objectives, including the assessment of water quality conditions and problems; assessment of flooding conditions and problems; identification of all sources of pollution, and their associated effects upon the water quality of the Milwaukee Harbor estuary; the evaluation of the role of in-place pollutant sources; the formulation of appropriate water use objectives and supporting water quality standards; formulation, evaluation of, and recommendations for the best means of abating the water pollution problems of the estuary in a cost-effective manner; extension of the regional water quality management plan to include the Milwaukee Harbor estuary; identification of implementing agencies and actions; identification of and recommendations for any necessary revisions or modifications to water quality standards of the state and federal government; and most importantly, the abatement of the water pollution, flooding, and wave damage problems of the harbor estuary.

The major work elements of the proposed planning program include the review and formulation of objectives, principles, and standards for the estuary; conduct of relevant inventories of information on the man-made and natural features of the Milwaukee Harbor estuary system with special emphasis on the sources of water pollution to that system; analyses and forecasts of the conditions in the estuary; design, testing, and evaluation of alternative water resources management plans; plan selection and adoption; and identification of the necessary implementation steps and responsible agencies.

Objectives and standards for the Milwaukee Harbor estuary will be formulated after review of the previously formulated pertinent resource conservation and development objectives under prior Commission work programs. The formulation of new water resource management objectives relating to the harbor estuary will provide a basis for the evaluation of existing conditions, and will provide a set of planning standards as measures for the relative merits of alternative plans.

The inventory program for the proposed study will, as necessary, collate the existing historic water quality and sediment study data described in Chapter II of this report; collect and collate available aerial photography and 1" = 2000' base maps from the Commission's continuing land use-transportation planning studies; collect and collate the topographic survey data necessary for preparation of large scale base maps; collect and collate hydrologic data for the rivers tributary to the Milwaukee Harbor estuary, and water level and wave data for the estuary and Lake Michigan, to characterize hydrologic conditions in the riverine and estuarine systems and to aid in water quality and storm damage studies; collect and collate hydraulic data for the estuary and Lake Michigan to characterize circulation and to aid in hydrodynamic modeling of the estuary; collect and collate suspended and bottom sediment data for the estuary to identify sediment sources, to characterize sediment transport, to quantify effects of sediments upon water quality, and to evaluate the feasibility of dredging, flow augmentation or aeration for water quality improvement; collect and collate geohydrologic data to ascertain the effects of the groundwater system upon flow and water quality in the Menomonee River estuary; collect and collate water quality data for the estuary and Lake Michigan which will fully characterize water quality conditions and serve as calibration and verification data for water quality modeling in the estuary; and collect and collate supplemental data for point and nonpoint source pollution, water use, and water management studies. In addition, information will be collected on harbor operation problems, land use, public utility facilities, existing and anticipated nonpoint source water pollution control practices, historic and proposed dredging programs, aquatic life in the estuary, the institutional structure for water resources management, previous water quality-related plans and their implementation status, and concurrent water quality-related planning and management efforts.

The data developed by the inventories listed above will be utilized to prepare the appropriate technical analyses of existing conditions and the necessary forecasts of future conditions and to prepare for the evaluation of the impacts of alternative water resources management measures upon those future conditions. As a basis for the evaluation of existing conditions and for purposes of forecasting future quantity and quality of urban and rural storm water runoff and pollution contributions from public and private sewage treatment plants, the land use base for future conditions will be developed on the basis of the adopted regional land use plan. The underlying forecasts of growth and change in the population and economics of the Region will be utilized, as appropriate, in this effort. Important water resources investigations will include the conduct of hydrologic studies and hydraulic studies to evaluate both the amounts and peak rates of flow in the three riverine reaches of the inner harbor and in the outer harbor as well. Also considered will be the hydraulic current patterns within the Milwaukee Harbor estuary. Such studies will address not only the observed conditions during the field sampling activities, but also the evaluation of typical conditions in the Milwaukee Harbor estuary system and the capability to forecast such conditions under alternative water resources management measures. Water resources studies of the water quality conditions of the inner and outer harbor will be conducted in order to relate the observed water quality conditions in the Milwaukee Harbor estuary to the meteorologic conditions and water pollution sources which are identified during the study. These investigations will be used to analyze the influence of these factors upon observed conditions and to relate the observed conditions to more typical, long-term conditions. These studies will be of particular importance in identifying the relationship of existing water quality to the various levels of combined sewer overflow abatement, nonpoint source water pollution control, and instream measures for water quality management. Related analyses of the sedimentation rate and the aquatic biology are also of importance in understanding the water quality dynamics of the estuary, and will therefore be the subject of additional water resources-related analyses.

Alternative water resources management plans will then be designed, tested, and evaluated, including elements for flood damage abatement, point and nonpoint source water pollution abatement, instream water quality management, and harbor storm protection. A recommended plan will then be selected and recommended for adoption and implementation. Means for plan implementation will be identified, and following appropriate public information meetings and hearings, a final plan will be prepared for adoption, for certification to implementing units and agencies of government, and for implementation.

In order to mount the proposed study, it is envisioned that the MMSD would be the applicant for federal financial assistance through the Section 201 facilities planning program of the USEPA, with the District in turn contracting with the Regional Planning Commission to undertake the study. The Commission would conduct and coordinate the work to prepare an integrated analysis of findings and to prepare a documented set of recommendations, and in this process, would prepare and execute subcontracts with the USGS, a private mapping firm, and other subcontractors as appropriate.

The proposed planning program will be conducted under the supervision of the Milwaukee Harbor Estuary Committee, which will be composed of representatives of appropriate units and agencies of government and selected interest groups. The forty-month study will be conducted by the Southeastern Wisconsin Regional Planning Commission with assistance from the Milwaukee Metropolitan Sewerage District, U.S. Geological Survey (USGS), and from other subcontractors. The Commission's role will be both administrative and technical in that the Commission will prepare and administer contracts necessary for the conduct of the study and oversee the work to be performed by contractors, and will perform some of the basic technical work in the form of engineering analyses for various elements of the study. Private contractors will prepare the base mapping. The U.S. Geological Survey and the District will collect most of the water resources and sediment data for the program, with private contractors or universities collecting some additional data for specific subelements of the study. The U.S. Geological Survey will conduct the inner harbor one-dimensional modeling study subelement of the program and a study of groundwater pollution transport in the shallow aquifer in the estuary subwatershed. Subcontractors yet to be selected will conduct the three-dimensional water quality modeling study of the inner and outer harbors, bottom sediment process studies, and field studies of the pollutant loadings of nonpoint sources of water pollution conveyed to the estuary via storm sewers or direct overland flow. The Milwaukee Metropolitan Sewerage District will continue operation of existing and planned water quality monitoring programs, with costs for laboratory analysis of samples to be borne by the estuary study exclusive of such costs for samples collected offshore in Lake Michigan.

The cost of the proposed study is estimated to total about $2,910,293, of which about $2,208,127 would be provided jointly by the USEPA and MMSD. In addition to these monies, the USGS will provide $702,166 in matching services as part of the nationwide river quality assessment program. Of the project costs, the Regional

Planning Commission will utilize $787,703 for conduct of its program subelements, the MMSD will utilize $814,023 in support of "force account" work activities--primarily for water quality and laboratory services--with the balance of the funding ($606,401) to be utilized by contractors for the remaining subelements of the study.

APPENDICES

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Appendix A

DEFINITIONS OF SELECTED TERMS

BASIC DEFINITIONS

A definition of certain terms is in order prior to any further consideration of the Milwaukee Harbor Estuary Comprehensive Water Resources Management Planning Program. Accordingly, the following definitions of key terms used throughout the study design are provided.

COMBINED SEWER OVERFLOW--Discharge of combined storm water and sanitary wastewater from the flow relief (diversion) structure of a common sewer which, by design, conveys at all times storm water runoff and untreated wastewater, and which overflows during periods of snowmelt or rainfall events when the dry-weather hydraulic design capacity of the combined sewer is exceeded.

ESTUARY--Estuaries have been defined as surface water systems where freshwaters from rivers and streams mix with and measurably dilute sea waters. For the purposes of this study design, the definition has been modified to describe estuaries as surface water areas in which drainage waters from the Region's rivers and streams meet and mix with Lake Michigan's waters to produce an environment which exhibits characteristics of both water systems. Factors considered in defining the upper limits of an estuary include upstream limits of channel maintenance for navigation purposes; discontinuities in channel bottom slope, width, and cross section; presence of dams and other hydraulic structures forming physical boundaries or controls; and dominance of the influence of lake levels and phenomena. The lakeward limits of an estuary complex are defined by the breakwaters and jetties protecting the harbor areas. The Milwaukee Harbor estuary is located entirely within the City of Milwaukee and includes the three-mile reach of the Milwaukee River downstream from the North Avenue dam, the 2.2-mile reach of the Menomonee River downstream from the Falk Corporation Dam, and the 1.7-mile reach of the Kinnickinnic River downstream from the Chase Avenue bridge. The lakeward limits of the estuary are bounded by the outer harbor breakwater.

ESTUARY SUBWATERSHED--The geographic area directly contributing runoff to the estuary proper by overland flow or through ditched or piped stormwater drainage facilities. The Milwaukee Harbor estuary subwatershed includes two separate areas served by combined sewers which are not located adjacent to the estuary, yet result in discharges into the Milwaukee River estuary just downstream from the North Avenue dam.

INNER HARBOR--That portion of the estuary west of the mouth of the Milwaukee River at the outer harbor at a line connecting the east ends of the two jetties east of the 25th Street bridge over the Menomonee River and north of the Becher Street bridge on the Kinnickinnic River which mark the upstream limits of commercial navigation.

MILWAUKEE HARBOR WATERSHED--The land surface area of the entire Milwaukee River watershed, including the Kinnickinnic and Menomonee River basins, and the land surface area draining directly to Milwaukee Bay, otherwise known as the outer harbor, comprising a total area of about 860 square miles.

NEAR-SHORE ZONE--The western portion of Lake Michigan bounded on the west by the lake shore as defined by the farthest landward extent of the beach, the breakwaters, and the piers in Milwaukee County; and on the east at the boundary between the near-shore and offshore currents at a location which varies during the year from about 2 to 10 miles offshore.

OUTER HARBOR--That portion of the Milwaukee Harbor estuary, otherwise known as Milwaukee Bay, formed by the Lake Michigan breakwater near the mouth of the Milwaukee River, but not including the area protected by the offshore breakwater south of Lincoln Avenue extended; and eastward of the jetties at the mouth of the Milwaukee River.

REGIONAL PLANNING--Comprehensive planning for a geographic area larger than a county, but smaller than a state, united by economic interests, common geographic features, or common areawide development problems.

WATER POLLUTION--A condition in which the quality of water in a lake, a stream, or a natural or artificial embayment is impaired by human activities which produce point or nonpoint loadings of undesirable substances in sufficient quantities and during critical time periods, so as to cause deleterious effects upon aesthetics; upon the use of the receiving waters for the propagation of fish and other wildlife, for recreation, or for navigation; or upon the use of the receiving water as a source of industrial or domestic water supply.

Appendix B

MEMBERSHIP

AD HOC TECHNICAL TASK FORCE FOR THE MILWAUKEE HARBOR ESTUARY STUDY DESIGN

Norman P. Lasca, Chairman	Professor, UW-Milwaukee; Chairman, Department of Geological Sciences; Representative of SEWRPC Technical Coordinating and Advisory Committee on Coastal Management in Southeastern Wisconsin
Thomas G. Ross, Vice Chairman	Chief, U.S. Geological Survey, Southeast Subdistrict
Kurt W. Bauer, Secretary	Executive Director, Southeastern Wisconsin Regional Planning Commission
Earl K. Anderson	Harbor Engineer, City of Milwaukee Harbor Commission
Eugene J. Aubert	Director, Great Lakes Environmental Research Laboratory, Ann Arbor, Michigan
David N. Edgington	Director, Center for Great Lakes Studies, University of Wisconsin-Milwaukee
Kent B. Fuller	Chief, Environmental Planning Staff, Great Lakes National Program Office, U. S. Environmental Protection Agency
Ronald G. Hennings	Water Resources Specialist, Wisconsin Geological and Natural History Survey, UW-Extension
John G. Konrad	Chief of Non-Point Source Section, Bureau of Water Quality, Wisconsin Department of Natural Resources
Timothy J. Kubiak	Fish and Wildlife Biologist, Fish and Wildlife Service, U.S. Department of the Interior
George A. Kupfer	Superintendent, Bureau of Consumer Protection and Environmental Health, City of Milwaukee

Orville L. Kurth	District Conservationist, U. S. Soil Conservation Service
Edwin J. Laszewski	City Engineer, City of Milwaukee
Patrick Marchese	Acting Director of Technical Services, Milwaukee Metropolitan Sewerage District
Robert J. Mikula	Director, Department of Parks, Recreation, and Culture, Milwaukee County
Rudolpho N. Salcedo	Environmental Scientist, Department of City Development, City of Milwaukee

The following individuals also participated actively in the work of the Task Force during preparation of the study design: Roger T. Bannerman, Environmental Specialist, Bureau of Water Quality, Wisconsin Department of Natural Resources; Ronald L. Burk, Research Engineer, Bureau of Engineers, City of Milwaukee; David A. Gruber, Water Quality Specialist, Milwaukee Metropolitan Sewerage District; Leo B. House, Hydrologist, U.S. Geological Survey; Kwang K. Lee, Professor, University of Wisconsin-Milwaukee; John H. Moser, General Supervisor Research, Milwaukee Metropolitan Sewerage District; and Vladimir Novotny, Professor, Marquette University.

Appendix C

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