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Volume 2

EPA

The IJC Menomonee River Watershed Study

Land Use, Population And Physical Characteristics Of The Menomonee River Watershed

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

The Great Lakes National Program Office (GLNPO) of the U.S. EPA, was established in Region V, Chicago to provide a specific focus on the water quality concerns of the Great Lakes. GLNPO also provides funding and personnel support to the International Joint Commission activities under the U.S.- Canada Great Lakes Water Quality Agreement.

Several land use water quality studies have been funded to support the pollution from Land Use Activities Reference Group (PLUARG) under the Agreement to address specific objectives related to land use pollution to the Great Lakes. This report describes some of the work supported by this Office to carry out PLUARG study objectives.

We hope that the information and data contained herein will help planners and managers of pollution control agencies make better decisions for carrying forward their pollution control responsibilities.

Madonna F. McGrath
Director
Great Lakes National Program Office

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LAND USE, POPULATION AND PHYSICAL CHARACTERISTICS OF THE MENOMONEE RIVER WATERSHED
Volume II

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PREFACE

This volume constitutes a detailed description of the Menomonee River Watershed and is designed in such a fashion as to allow, I. a description of the Land Data Management System developed by the Southeastern Wisconsin Regional Planning Commission; II. an evaluation of the ability to use remote sensing for making a sufficiently sensitive land use inventory to be applicable to urban settings; descriptions of land use, soils and landscape features of III, the entire Watershed, and IV, the 48 subwatersheds of area 132 to 11,610 ha.

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PART I

LAND DATA MANAGEMENT SYSTEM

by

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ABSTRACT

The Land Data Management System was developed by the SEWRPC in order to provide an inventory of land use characteristics to be used in investigating the impact of land uses on water quality. The Land DMS is a digital computer-based system designed to store, retrieve, analyze and display, in tabular or graphic form, land data for the Menomonee River Watershed.

The Land DMS is a practical tool that can optimize the use of available data thereby enhancing the quality of the decision-making process in land and water resource planning. Practical applications of the land data management system prepared for or used by the IJC-Menomonee River Pilot Watershed Study participants include both graphic and tabular display of data.

Some of the more important advantages of the Land Data Management System are: a. handling data at the available level of detail; b. minimal manual handling of data; c. ease of update and correction; d. quick response; e. overlay capability; and f. availability of a variety of tabular and graphic outputs.

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ACKNOWLEDGMENT

The study covered in this article was a part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-United States Great Lakes Water Quality Agreement of 1972. Funding was provided by the U.S. Environmental Protection Agency through the Wisconsin Department of Natural Resources.

I-1. INTRODUCTION

The Land Data Management System (Land DMS) is a digital computer-based system designed to store, retrieve, analyze and display in tabular or graphic form land data for the Menomonee River Watershed. The term "land data" as used in the Land DMS is a comprehensive concept that denotes all those types of natural resource and man-made features data that have an areal characteristic. Examples include land use, land cover, soil type, civil division and zoning information. The System was developed by the Southeastern Wisconsin Regional Planning Commission in order to provide an inventory of land use characteristics to be used in investigating the impact of various land uses on water quality.

I-2. SUMMARY AND CONCLUSIONS

The Land Data Management System was developed by the SEWRPC in order to provide an inventory of land use characteristics to be used in investigating the impact of land uses on water quality. The Land DMS is a digital computer-based system designed to store, retrieve, analyze and display, in tabular or graphic form, land data for the Menomonee River Watershed.

The Land DMS is a practical tool that can optimize the use of available data thereby enhancing the quality of the decision-making process in land and water resource planning. Practical applications of the land data management system prepared for or used by the IJC-Menomonee River Pilot Watershed Study participants include both graphic and tabular display of data.

Some of the more important advantages of the Land Data Management System are:

a. Handling data at the available level of detail;

b. Minimal manual handling of data;

c. Ease of update and correction;

d. Quick response;

e. Overlay capability; and

f. Availability of a variety of tabular and graphic outputs.

The principal disadvantage of the system is the initial high cost and cost of maintenance. Thus, such systems are likely to be economically feasible and otherwise practical in the context of a long range, well-established comprehensive regional or metropolitan planning program.

I-3. METHODS AND PROCEDURES

Data Storage Unit

The basic areal unit for storing, retrieving, analyzing and displaying land data is "the cell." At the time the system was designed, in 1974, the "cell mode" approach to data base organization was selected over the "area boundary" approach because the cell mode was judged to be more technically and economically feasible with respect to the effort required to code areal data from primary sources. Also, less computer programming and computer capacity were required to store, retrieve, analyze, and display land data, including the use of overlay techniques.

In applying the Land DMS, the geographic unit of interest, such as the watershed or civil division is subdivided into cells by partitioning United States Public Land Survey quarter sections as shown in Fig. I-1. Specifically, each of the four sides of each quarter section is divided into eight equal segments and the division points on opposite sides of the quarter section are connected, resulting in 64 cells per quarter section, each having a nominal area of 1.0 hectare (2.5 acres).

The use of cells that are partitions of U.S. Public Land Survey quarter sections has one principal advantage. It facilitates geo-referencing of each cell since horizontal survey control, in the form of state plane coordinates, has been established by SEWRPC and by local units of government. Survey control is transferrable directly by computation to the centers and corners of each cell for approximately one-third of the U.S. Public Land Survey quarter section corners in the 6,965 km^2 (2,689 mi^2) planning region using field survey methods. The second reason for forming cells by subdividing each U.S. Public Land Survey section was to permit aggregating the resulting data to the quarter section level so as to be directly comparable to SEWRPC 1963, 1967 and 1970 land use data and other data that were coded and filed on a quarter-section basis.

Each cell is identified by township, range, section, quarter section, and cell number. Cells are numbered 1 through 64 within each quarter section, beginning in the upper right hand corner and proceeding to the left, dropping down one row and proceeding from left to right, dropping one row and proceeding from right to left and continuing in this serpentine fashion to cell number 64. It is important to note that cell-based systems could be developed within the framework of other rectilinear reference systems such as latitude and longitude or the Universal Transverse Mercator System.

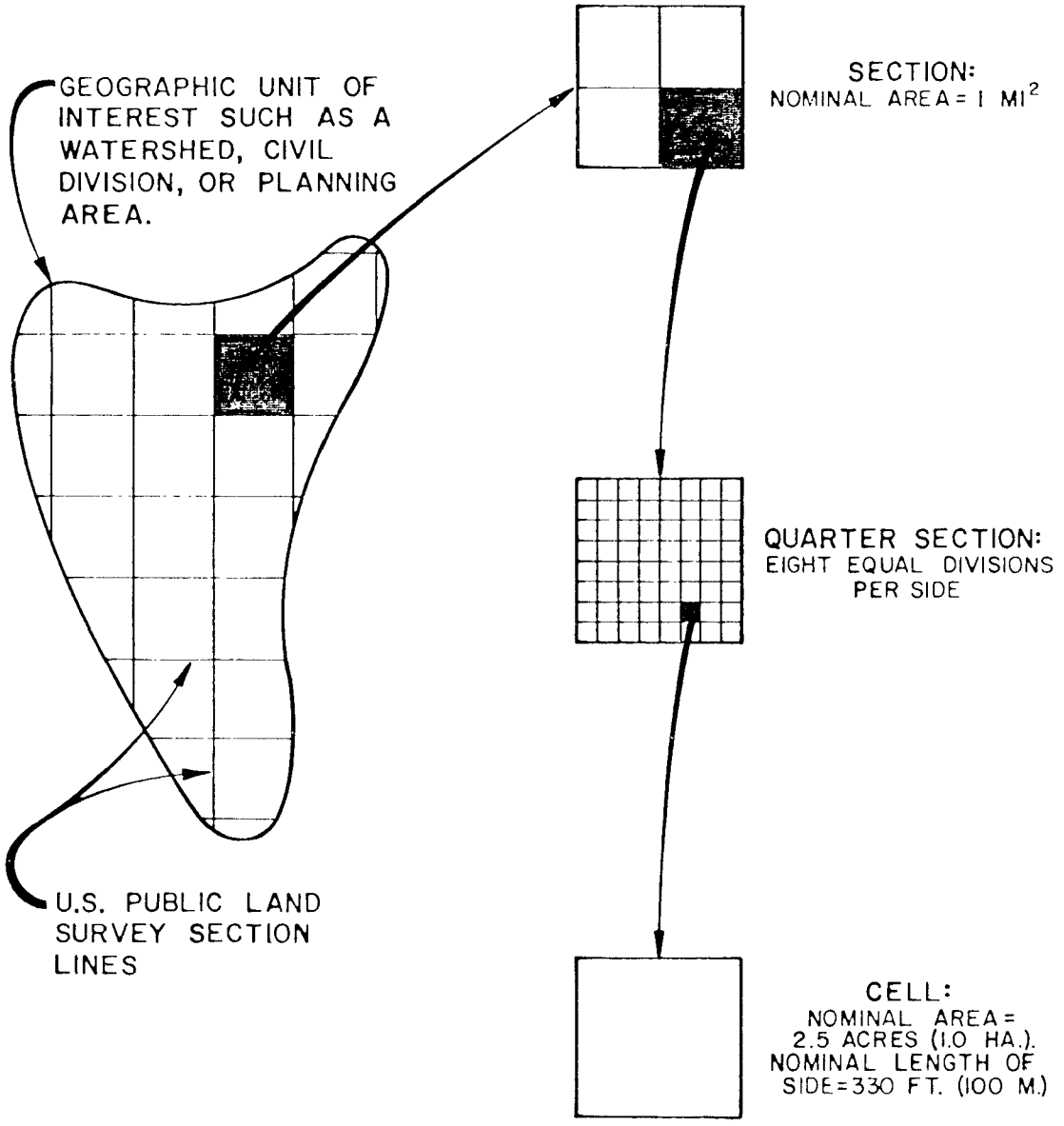


Fig. I-1. "The Cell," the basic areal unit of the Land DMS.

Geo-Referencing

An accurate geo-referencing arrangement is required to permit computation of the area of each cell or of groups of cells and to facilitate display, in computer plotted map form, of selected land data. The best available sources of information are used to first determine the state plane coordinates of the U.S. Public Land Survey corners of each quarter section contained wholly or partly in the geographic unit of interest. Plane geometry is then used via software within the Land DMS to calculate the state plane coordinates of each corner and of the center of each cell. The Land DMS also can readily convert--again using software within the system--the cell corner coordinates to other geo-referencing systems such as latitude and longitude and the Universal Transverse Mercator System.

The Supporting Computer System

The combination of hardware and software needed to support the Land DMS can be broken into four phases as shown in Fig. I-2: a. input; b. data manipulation; c. data base; and d. output. Under the input phase, data are entered into the Land DMS on either magnetic diskettes or punched cards. The second, or data manipulation phase, computer programs that perform contingency checks on the incoming data, provide for maintenance and updating of the data, analyze the data, and prepare it for transfer back to the user. The analysis ability of this phase facilitates the identification of cells having specified combinations of land data types. The data base phase, may be viewed as a large "file cabinet" with many "drawers," as shown in Fig. I-3. Each drawer corresponds to each of the types of areal data on file in the Land DMS. The fourth, or output phase, provides for transfer of land data to the user in a variety of formats. For example, land data can be outputted on a cell basis or aggregated by civil division or some other geographical area of interest. Output can be obtained on several media including magnetic tape, punch cards, line printer and plotter.

Computer system hardware currently used to operate the Land DMS consists of an IBM Model 370/135 computer, IBM Model 3410 tape drives and Model 3340 desk packs, an IBM Model 1403 printer and a Calcomp Model 905 drum plotter.

Land Data Contained in the System

To date the system has been applied to the 352 km^2 (136 mi^2) urbanizing Menomonee River Watershed. Table I-1 sets forth the current status of land data contained in the Land DMS for the Menomonee River Watershed including the medium from which each type of land data was extracted, and the type of cell coding. Table I-1 is intended to show the range of data types that can be accommodated, the variety of data sources and the types of coding that can be used.

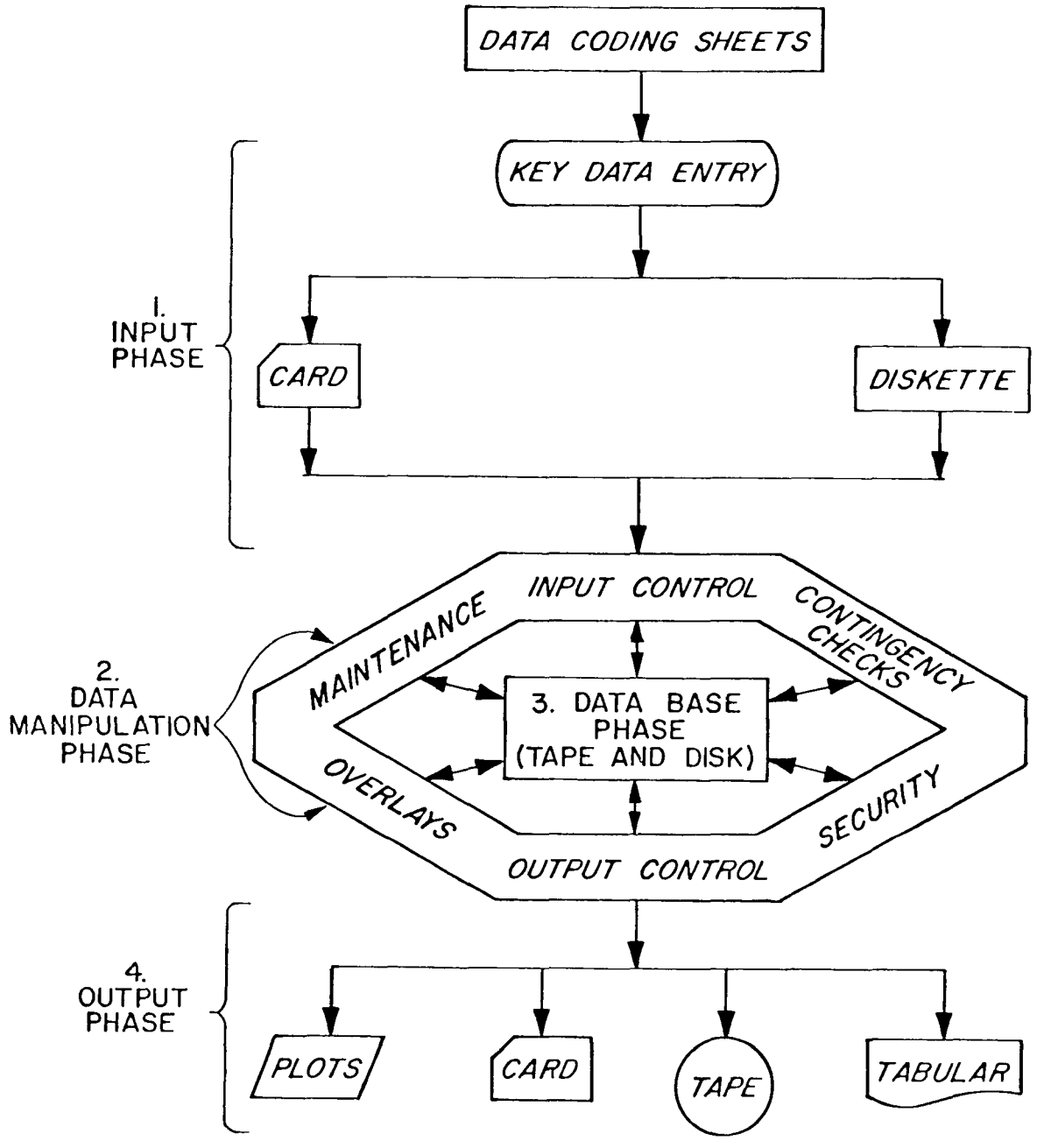
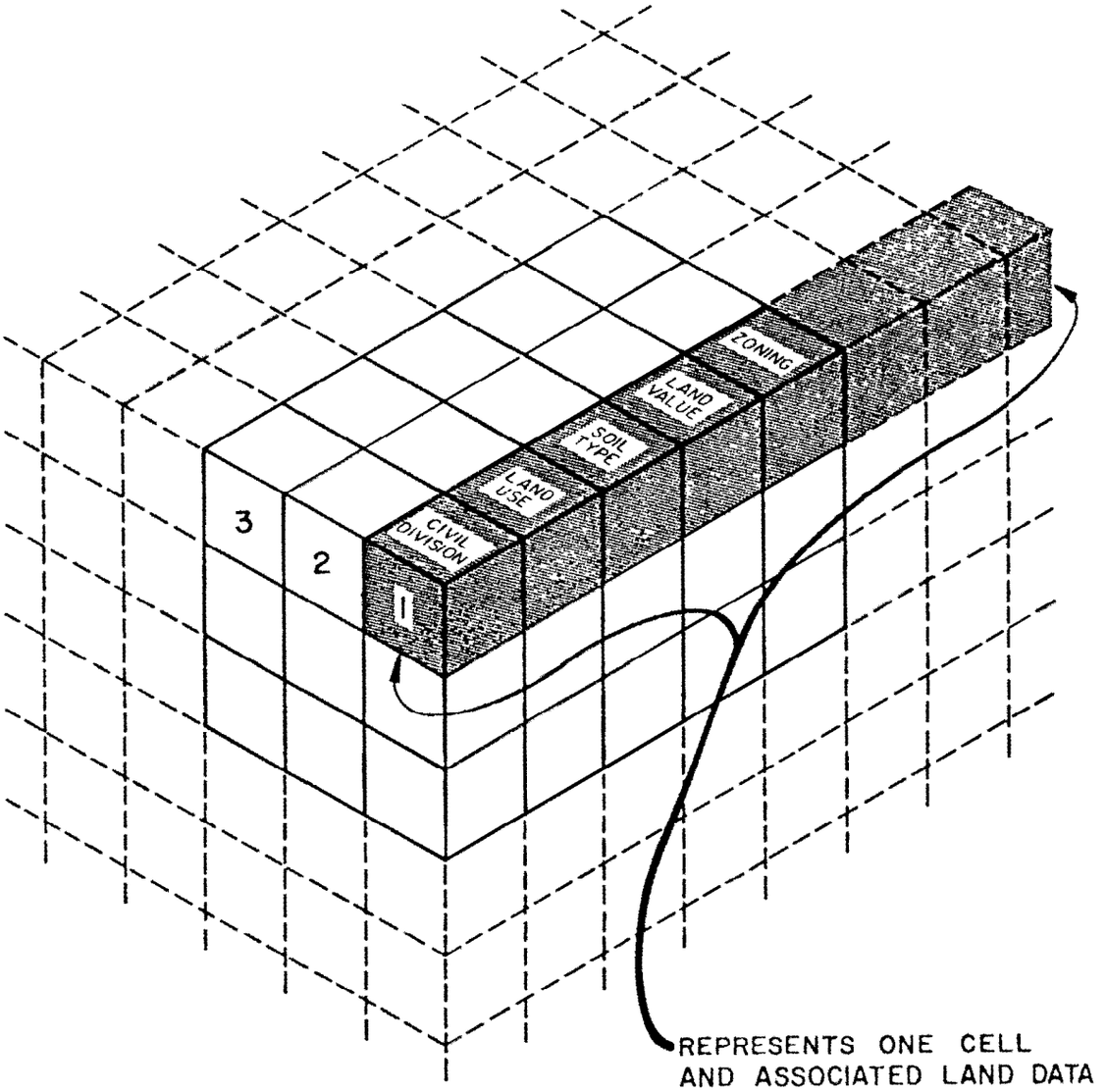


Fig. I-2. Computer hardware and software supporting Land DMS.



NOTE: ACCESS TO DATA BASE IS BY CELL OR BY LAND DATA TYPE.

Fig. I-3. Schematic representation of data base phase of Land DMS.

Table I-1. Status of data in the land DMS for the Menomonee River watershed

Data type	Data source		Type of coding		
	Agency or project	Medium	Dominant characteristic	Percent of cell	Other
Civil division	SEWRPC land use-transportation planning program	1:24,000 map	X		
Sub-basins and subwatersheds	SEWRPC watershed planning program	1:24,000 map	X		
Wildlife habitat (with value ratings)	Wisconsin DNR Field Survey	1:4,800 aerial photographs	X		
Woodland-wetland (with value ratings)	Wisconsin DNR Field Survey	1:4,800 aerial photoraphs	X		
Park and outdoor recreation sites	SEWRPC park, recreation and open space planning program	1:24,000 map	X		
Floodlands	USGS flood hazard delineation	1:24,000 map	X		
Perennial streams	USGS quadrangle maps	1:24,000 map			X*
Conservancy, floodland and related zoning	Community Zoning regulations	Miscellaneous maps	X		
Soils**	SCS Soil Survey	1:24,000 and 1:12,000 maps		X	
Ground elevation	---	Best available topographic maps			X***
Land use-1970	SEWRPC land use inventory	1:4,800 aerial photograph overlays		X	
Riverine area land value	SEWRPC watershed planning program	1:24,000 maps	X		
Land use-1975	SEWRPC land use inventory	1:4,800 aerial photographs		X	
Residential density codes	SEWRPC land use-transportation planning program	SEWRPC Regional Density File	X		
Monitoring stations and area tributary to them (12)	SEWRPC watershed planning program	Sub-basin maps and 1:4,800 aerial photographs	X		
Water Resources Center-special study sites (7)	Water Resources Center delineation	1:4,800 aerial photographs	X		
DNR subwatersheds (48)	DNR delineation	Sub-basin maps and 1:4,800 aerial photographs	X		
Water Resources Center subwatersheds (51)	Water Resources Center delineation	Sub-basin maps and 1:4,800 aerial photographs	X		

*A cell is coded as "perennial stream" if such a stream crosses any part of the cell.
**Soil type, degree of erosion and ground slope.
***The ground elevation of a cell is taken as the elevation at its center.

Land data are extracted from the source material and coded on either a "dominant characteristic" or "percent of cell" basis. Coding on the dominant characteristic basis--which is used when the source data are either unavailable at a high degree of resolution or a high degree of resolution is not needed--consists of determining the dominant characteristic in a given cell for a particular data type. Coding on a percent of cell basis is used when the data are available at high resolution compared to the cell size and when anticipated uses require high resolution. For example, it may be desirable to code land use on a "percent-of-cell" basis with three types of land use present in a particular cell. Land use is coded by indicating the amount of cell area occupied by each of the three land uses with the relative amount being determined by laying a transparent mylar overlay with a uniform dot pattern over the cell and recording the number of dots contained within each of the three land uses. Table I-2 is a typical land use coding sheet used for coding on a percent of cell basis. Software in the Land DMS uses the dot counts to determine the absolute area of each of the three land uses present within the cell, by using as "control totals" the known areas of the cell itself based on second order precision land survey data developed in accordance with the land survey and monumentation methods of the SEWRPC. Coding land use under the dominant characteristics basis would consist of identifying the land use occupying the largest portion of the cell and assigning it to the entire cell.

Application of the Land DMS

On a practical basis, the Land DMS is applied to a geographic area of interest such as a watershed or civil division by partitioning the area of interest into cells, coding the land data types of interest to the cells, inputting them to the system, and retrieving, analyzing and displaying the data as needed. The number of applications of such systems are unlimited because of the wide variety of combinations of data types that can be used and because of the variety of output formats available. Several diverse applications are presented to illustrate the versatility and practicality of the system in land and water resources planning. Each of the applications is drawn from uses in the Menomonee River Pilot Watershed Study.

Graphic or tabular display of data

The simplest use of the Land DMS is to display, in graphic or tabular form, one or more land data types for a given geographic area. Tabular output is shown in Table I-3 in the form of quantified land use and soil data for an in-watershed portion of a given U.S. Public Land Survey section. Graphic output from the Land DMS is shown in Fig. I-4 in the form of mapped land use data by cell for the same section. Maps can be produced by the system at essentially any scale, and maps and tables can be constructed in any desired format. A variety of special graphic displays can be created, for example, isometric representations of surface topographic features.

Table I-2. Typical land use coding sheet

TOWNSHIP	RANGE	SECTION	QUARTER SECTION	CELL IDENTIFICATION NUMBER	LAND USE CODE[a]	NUMBER OF DOTS[b]
7	21	7	1	1	55	8
				1	75	20
				2	75	28
				3	58	6
				3	75	22
				4	54	5
				4	75	23
				5	75	28
				6	90	5
				6	55	2
				6	75	21
				58	51	3
				58	75	25
				59	75	28
				60	75	28
				61	75	28
				62	75	28
				63	75	28
				64	55	8
				64	75	20

[a]SEWRPC LAND USE CODE

[b]USING A TRANSPARENT DOT COUNTER

Table I-3. Example of tabular output from Land DMS for Township 7 North, Range 20 East, Section 28

LAND USE DATA BY LAND USE TYPE

SECTION	LAND USE CODE	AREA IN SECTION (ACRES)	PERCENT OF TOTAL
0720-28	00	65.24	16.46
	05	11.55	2.91
	1[illegible]	13.02	3.28
	20	.28	.07
	54	10.77	2.72
	55	8.61	2.17
	58	8.24	2.08
	59	15.13	3.82
	60	15.17	3.83
	72	.37	.09
	80	83.82	21.14
	82	1.19	.30
	91	12.17	3.07
	92	22.98	5.80
	94	127.92	32.27
TOTAL		396.44	100.01

SOIL DATA BY CELL

SECTION	CELL NO.	SOIL CODE	ACRES
0720-28-1	01	0073	.73
		0357	1.72
	02	0073	.73
		0076	.99
		0357	.48
		0450	.25
	03	0076	.99
		0450	1.47
	60	0212	.25
		0364	2.27
	61	0299	1.52
		0364	1.01
	62	0299	2.27
		0363	.25
	63	0076	.25
		0363	2.25
	64	0076	.25
		0363	2.25
0720-28-2	01	0450	2.55
	02	0450	2.55
	13	0450	2.55
	14	0450	2.55
	15	0450	2.55
	16	0450	2.55
	17	0450	2.55
	18	0450	2.55
	19	0450	2.55
	20	0450	2.55
	21	0450	2.55

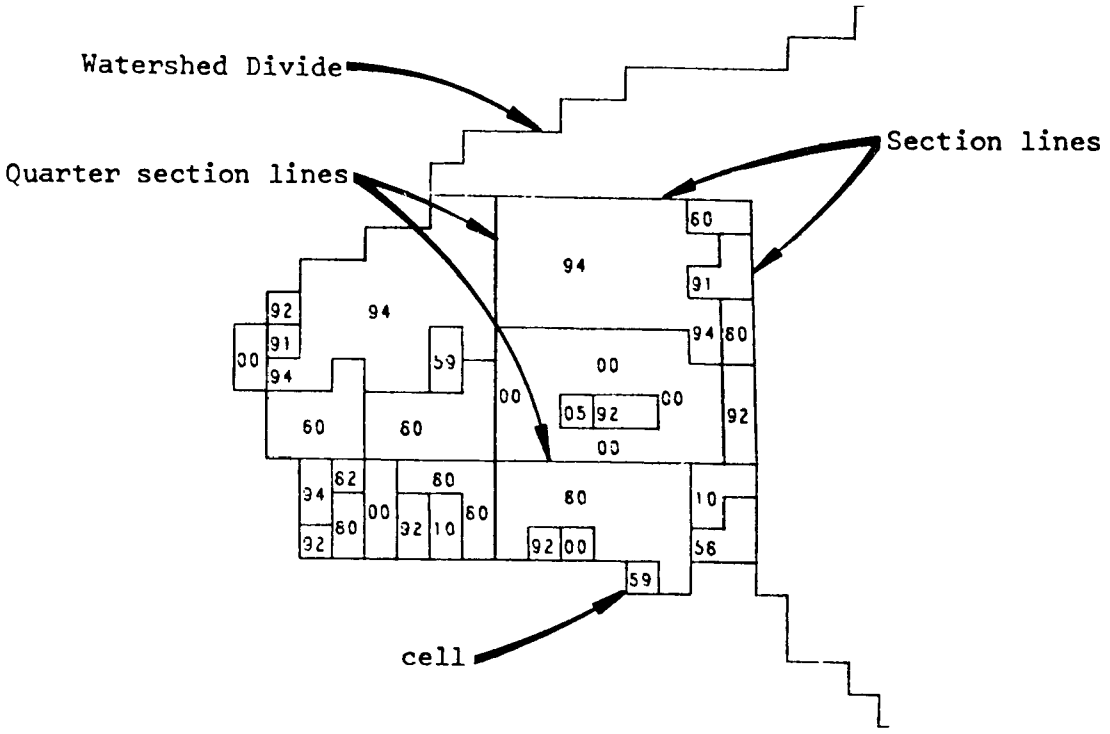


Fig. I-4. Example of graphic output from Land DMS for Township 7 North, Range 20 East, Section 28. The scale is 1:24,000; numbers indicate code of dominant land use.

Overlay capabilities

The Land DMS is capable of retrieving, analyzing and displaying information for areas having particular combinations of land characteristics. As shown in Table I-4, output using this technique combines land use data and slope data by subbasin. This example quantifies a total of six different land use types together with their associated slopes.

A portion of the watershed having a particular combination of soil data and land use data is shown in Fig. I-5. This map illustrates residential land uses and denotes within each cell a code relating to soil type categorized by soil permeability.

Typical applications using the Land DMS by participants of the Menomonee River Pilot Watershed Study are shown in Table I-5.

Advantages and Disadvantages of the System

The System and other similar systems have positive and negative features that should be considered by potential users. Some of the more important advantages of land data management systems are:

a. The data are stored and analyzed at the level of detail, i.e., the resolution, at which they are available. This contrasts with manual handling of data where a tendency exists to aggregate data to larger areal units in order to minimize the amount of effort involved.

b. Minimal manual handling of basic data is required, i.e., after the data have been entered into the system, analyses are performed by computer in response to programmed instruction, thereby minimizing errors in data handling.

c. The data can be updated and corrected by entering new or refined information into the system.

d. Because of the relatively quick turnaround time quantitative information can be supplied to decision makers in a matter of hours.

e. The System processes analytical capability, primarily in its ability to overlay many land data types.

f. These systems provide tabular and graphic materials for decision making and report preparations.

The primary disadvantage of these systems is the cost of performing the initial data coding, loading into the system and maintaining and updating the data.

In light of these cost considerations, it appears that digital

Table I-4. Example of tabular output using overlay capabilities from Land DMS

LAND USE [a]	SLOPE [b]	ACRES	PERCENT
00	01	1.91	3.35
	02	6.24	10.95
	03	25.11	44.07
	04	7.55	13.25
	05	15.79	27.71
	07	.37	.65
TOTAL		56.97	99.98
05	03	1.65	60.44
	05	1.08	39.56
TOTAL		2.73	100.00
54	01	.64	7.66
	02	1.38	16.51
	03	4.22	50.48
	04	.37	4.43
	05	1.74	20.81
TOTAL		8.35	99.89
55	03	.28	25.45
	04	.55	50.00
	05	.28	25.45
TOTAL		1.11	100.90
80	02	15.20	12.50
	03	68.39	56.24
	04	16.78	13.80
	05	6.40	5.26
	06	7.60	6.25
	07	7.23	5.95
TOTAL		121.60	100.00
94	02	5.05	30.13
	03	11.71	69.87
TOTAL		16.76	100.00
BASIN TOTAL		207.52	

[a] 1970 Land use classification system.

[b] Percent slope or fall/100 ft on which mapped soil occurs.
Land use data and slope data are by sub-basin.

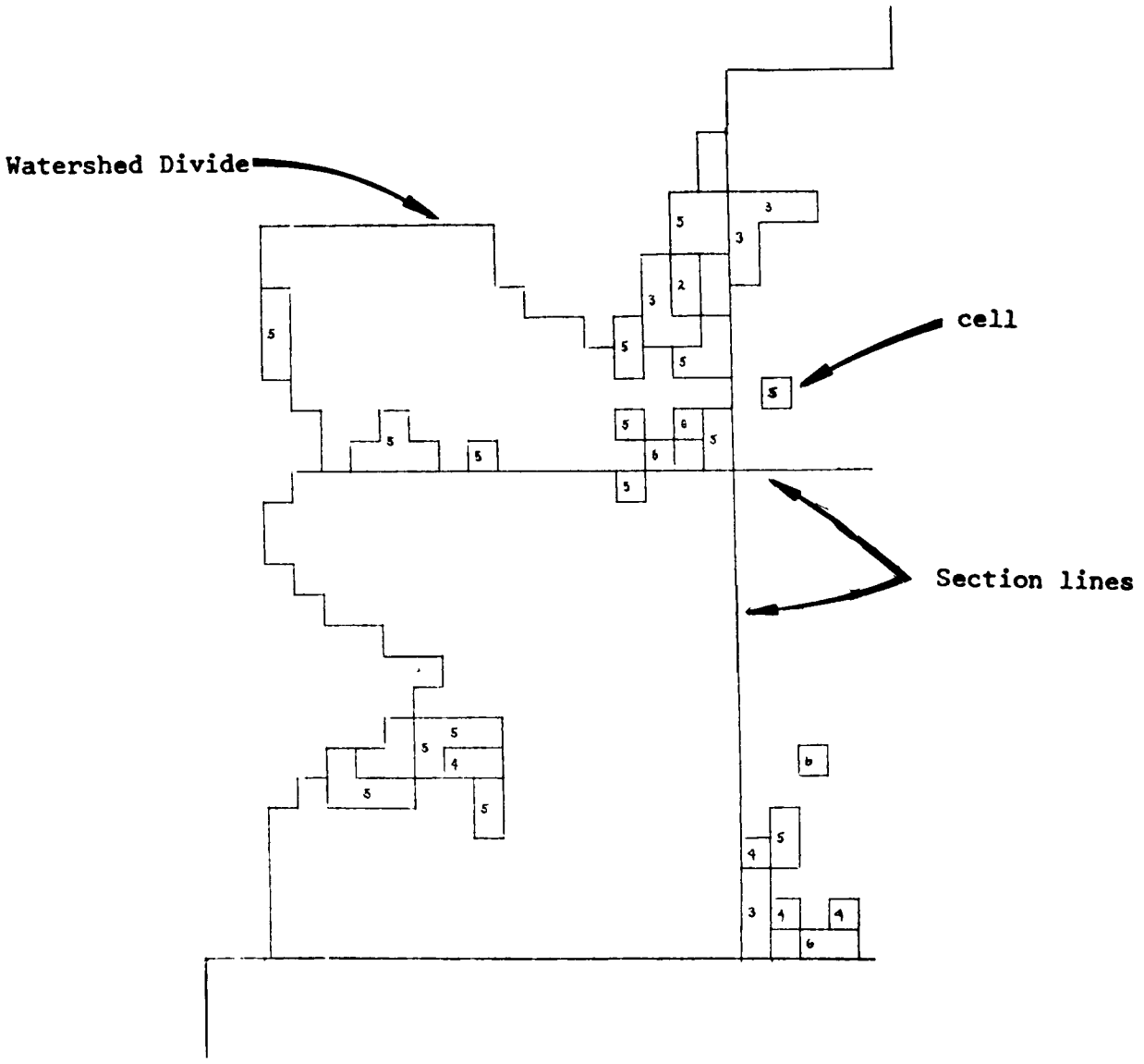


Fig. I-5. Example of graphic output using overlay capabilities from Land DMS for a combination of land use and soil data. The scale is 1:24,000; only cells with a dominant land use of residential type are displayed. Numbers indicate code relating to soil type categorized by soil permeability.

Table I-5. Typical applications of the land data management system developed under the IJC-Menomonee River Pilot Watershed Study: May 1976 to February 1978

	Application	Prepared for or used by
1.	1:4,800 scale computer maps showing boundaries of three monitoring stations to be used for overlaying on aerial photographs.	UW-Madison-Water Resources Center
2.	1:48,000 scale and 1:24,000 scale map of aggregated land uses in the Menomonee River Watershed.	UW-Madison-Geology Department
3.	Tabular summary of 1970 land use for all Menomonee River watershed sub-basins; 1:24,000 scale computer map of dominant 1970 land use per cell.	Marquette University
4.	Tabular summary of each combination of slope and 1970 land use existing in sub-basins of the Watershed.	Marquette University
5.	Tabular summary of percent impervious area by sub-basin.	Marquette University
6.	Tabular summary of land use by section.	UW-Madison-Water Resources Center
7.	1:24,000 scale computer map of dominant land use per cell. Tabular summary of land use by sub-basin, subwatershed and watershed and by area tributary to 12 monitoring stations.	WDNR-Madison
8.	Tabular summary of soil types with a greater than 5% distribution and slopes for each sub-basin.	WDNR-Milwaukee
9.	1:24,000 and 1:48,000 computer maps of dominant soil types.	UW-Madison-Geology Department
10.	Tabular summary of 1975 land uses for the 51 subwatersheds designated for the study.	UW-Madison-Water Resources Center
11.	Computer soils maps based upon permeability and depth to water table.	UW-Madison-Geology Department
12.	A tabular summary of 1975 land use data together with soils, slope and erosion information for the seven predominantly single land use sites monitored in the Watershed.	UW-Madison-Water Resources Center
13.	1:48,000 scale computer maps combining soils with "C" horizon data and 1975 land use data.	UW-Madison-Geology Department
14.	1:4,800 scale maps of soils, slopes, degree of erosion and 1975 land use for each of the seven predominantly single land use sites.	UW-Madison-Water Resource Center
15.	Tabular summary of soils, slope and 1975 land data by monitoring stations.	UW-Madison-Water Resources Center
16.	1:24,000 scale computer maps of soils, slope, erosion data and 1975 generalized land use for each monitoring station.	UW-Madison-Water Resources Center
17.	1:126,720 scale computer map of the 51 subwatersheds designated for the study.	UW-Madison-Water Resources Center
18.	Tabular summary of 1975 land use and degree of imperviousness for each subwatershed.	WDNR-Madison
19.	Tabular summary of 1975 land use and degree of imperviousness for the sub-basins tributary to the mainstem monitoring stations.	WDNR-Madison
20.	Use of cell system to assign density code to residential lands to estimate imperviousness of an area.	SEWRPC
21.	Tabular summary of soils, slope, imperviousness and 1975 land use data for 51 subwatersheds designated for the study.	UW-Madison-Water Resources Center
22.	1:126,720 scale computer map of the 51 subwatersheds designated for the study.	WDNR-Madison
23.	Tabular summary of soil and slope data for each subwatershed.	WDNR-Madison
24.	Tabular summary of combination of land use, soils and slope data for each subwatershed.	WDNR-Madison
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computer-based data handling systems are likely to be economically feasible in land and water resource research and planning projects only where there is extensive use of the system over a long period.

BIBLIOGRAPHY - I

Kiefer, R. W. and M. L. Robbins. 1973. Computer-based Land Use Suitability Maps. J. Surv. and Mapping Div., ASCE, Vol. 99, No. SUI, Proc. Paper 10015, pp. 39-62.

Southeastern Wisconsin Regional Planning Commission. 1976. Alternative Plans and Recommended Plan. In: A Comprehensive Plan for the Menomonee River Watershed, Planning Report No. 26, Vol. 2. Waukesha, Wisconsin.

Southeastern Wisconsin Regional Planning Commission. 1976. Floodland Information Report for the Pewaukee River. Community Assistance Planning Report No. 9, Waukesha, Wisconsin.

Viessman, W., T. E. Harbaugh and J. W. Knapp. 1972. Minor Structure Design. In: Introduction to Hydrology, Intext Educational Publ., New York, pp. 269-315.

Walesh, S. G. 1976. Floodland Management: The Environmental Corridor Concept. SEWRPC Technical Record, Vol. 3, No. 6, Waukesha, Wisconsin.

Williams, D. L., P. G. Rowe and C. P. Sharpe. 1975. Improved Tools for Land Management: Summing it up for the Future. Urban Land 34(9):3-7.

PART II

THE USE OF REMOTE SENSING TO DETERMINE LAND COVER IN THE MENOMONEE RIVER WATERSHED

by

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ABSTRACT

Land cover information for a hydrological model was provided by digital analysis of aerial photography. A fast method for obtaining land cover information in the Menomonee River Watershed was tested and found to be cost effective. Thematic representations as well as tabular information was produced. Accuracy of approximately 90% was determined for the digitally classified imagery when compared to ground truth.

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II-1. INTRODUCTION

Following passage of the Federal Water Pollution Control Act (P.L. 92-500) in 1972, state and federal agencies intensified their interest in point and non-point sources of water pollution. Until recently emphasis has been on point sources because they are easier to detect, monitor and treat. Currently, greater research emphasis is being placed on non-point water pollution; two sources of particular concern are urban uses and construction sites.

Since one of the important input parameters to the overland flow model LANDRUN--which was being tested in the investigation--is land cover, remote sensing was investigated as a possible method of obtaining land cover information. The most widely used remote sensing technique is manual photo interpretation of large scale aerial imagery in conjunction with ground-based field work. Although sufficiently accurate for land cover interpretation in urban areas, this method has proven costly and time-consuming when implemented on areas larger than a few square miles (1).

A second method of obtaining land cover information is by computer analysis of LANDSAT tapes (2,3,4). Although this method is faster and less expensive, it has several drawbacks. One is the 1.1 acre (0.5 ha) resolution cell of the LANDSAT satellite. This requires the amount of impervious surface to be measured indirectly by assigning to each land cover category a predetermined amount of imperviousness. The total amount of impervious surface for each land cover category is calculated by multiplying the number of cells classified for each land cover by the percentage of imperviousness for the land cover category, times 1.1 acres. This technique seems to work well in rural areas, but is less accurate than other techniques in urban areas (5).

A second problem, particularly in Wisconsin, is acquiring cloudless LANDSAT imagery. The ideal season to obtain imagery for mapping land cover, especially impervious land cover, is in the early spring or late fall. Unfortunately this is when the number of cloudless days are at a minimum (6). This time restriction favors analysis of aerial photography instead of LANDSAT imagery for land cover interpretation because the LANDSAT satellites have a fixed schedule while aerial photography can be acquired on any cloud-free day. The goal of this investigation was to develop and test the technique of digital analysis of aerial photography for land cover mapping in urban areas.

II-2. CONCLUSIONS

A cost-effective method of mapping current land cover in an urban area has been demonstrated. The technique involves the use of digitized aerial imagery (either color or color-infrared) that has been properly calibrated. The calibrated digital imagery is classified using a two-stage elliptical table-look-up algorithm which produces a tabular presentation of different land cover classes as well as a thematic representation. The accuracy of the classification was checked by ground calibration and photo interpretation of reconstituted images.

To effectively use hydrologic transport models such as LANDRUN, accurate, current information on land cover is needed. It is believed that remote sensing techniques may be the only practical method of ascertaining such information in a timely fashion. The digital analysis of aerial imagery seems to be superior to the analysis of LANDSAT tapes in an urban area because of the better resolution and versatility in choosing the date of imagery.

II.3 MATERIALS, METHODS AND PROCEDURES

Digitized Photography

Procedures for digitally analyzing aerial photography are essentially the same for color or color-infrared film, the significant difference being in the interpretation of the data derived from the densitometric analysis of the imagery. Since the analysis procedures are similar for all types of multi-emulsion imagery, only a detailed description for color films will be presented. Extensions to the analysis of color-infrared imagery will be indicated in the appropriate sections.

Incident energy from the earth's surface is recorded on a color image in the form of various amounts of colored dyes. The colored dyes used are yellow, magenta, and cyan. At each spatial location on the processed imagery there exists some concentration of yellow, magenta, and cyan dyes. In general, the concentrations of each of these dyes differ from each other as well as differing from the dye concentrations at adjacent parts of the imagery. It is the intent of densitometry on multi-emulsion imagery to infer the amounts of each dye at each spatial location of interest on the imagery. From this data the amount and (to some extent) the spectral distribution of the incident energy on the unexposed film can be inferred.

The structure of a typical color film is shown in Fig. II-1. From the point of view of the user, the three important layers are the ones that are sensitive to the blue, green and red light. Curves representing the sensitivities of these layers can be found in Fig. II-2. After the film has been exposed to visible light and processed, yellow, magenta and cyan dyes are formed in their respective layers. In a color reversal film (such as Kodak Aerochrome MS Film 2448) the amount of dye formed in each layer depends inversely on the amount of light sensitizing each layer. An object that appears blue in nature will, after processing, cause an image to contain a relatively small amount of yellow dye, and proportionately larger amounts of magenta and cyan dyes. Since magenta and cyan dyes absorb the green and red light, the image will appear blue in normal lighting conditions. To infer the amounts of the dyes present in the imagery, some type of measurement must be made on the developed transparency.

These measurements are made by placing the imagery on a scanning microdensitometer which converts the amounts of dye in each of the image layers to a density value.

Densitometry on multi-emulsion imagery has been described adequately elsewhere (7,8,9), thus only a short review of the salient points are presented here. Because of the colored dyes present in the imagery, any density

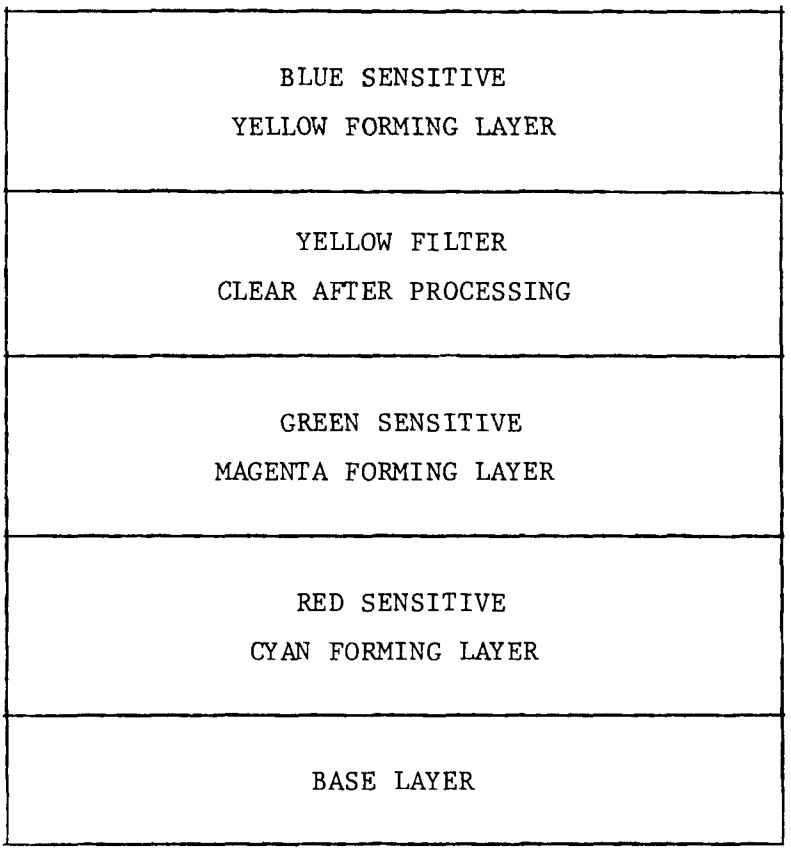

Fig. II-1. Kodak Aerochrome MS Film 2448, Estar Base.

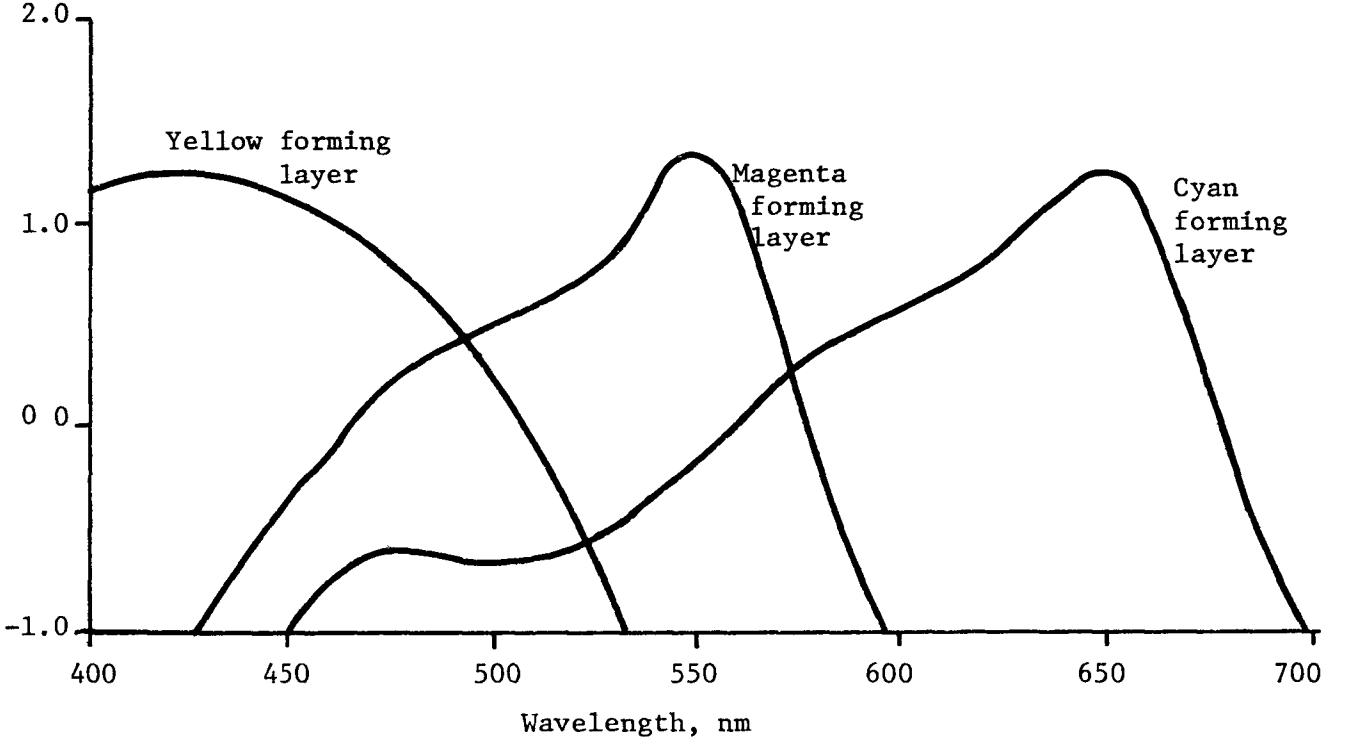

Fig. II-2. Spectral sensitivity curves for Kodak Aerochrome MS Film 2448, Estar Base.

measurement on multi-emulsion imagery is wavelength dependent. Spectral density is a measure of density at a particular wavelength. Any density measurement on multi-emulsion film is an integral density measurement. It is an integral density measurement because the measured density depends on the individual dye densities of each of the film layers. The integral spectral density for a multi-emulsion image can be expressed mathematically as:

$$D(\lambda) = DY(\lambda) + DM(\lambda) + DC(\lambda) + DB(\lambda) \qquad \text{Eq. (1)}$$

where: $D(\lambda)$ is the integral spectral density
$DY(\lambda)$ is the spectral density of the yellow dye layer
$DM(\lambda)$ is the spectral density of the magenta dye layer
$DC(\lambda)$ is the spectral density of the cyan dye layer
$DB(\lambda)$ is the spectral density of the base layer

and λ is the wavelength of the density measurement.

The densities on the right hand side of Eq. (1) are known as spectral analytical densities. The spectral analytical dye densities can be represented as a parameter times a unit spectral density function for each of the dyes. The dye densities can be written:

$$\begin{aligned} DY(\lambda) &= K_y \cdot Y(\lambda) \\ DM(\lambda) &= K_m \cdot M(\lambda) \\ DC(\lambda) &= K_c \cdot C(\lambda) \end{aligned} \qquad \text{Eq. (2)}$$

where: $Y(\lambda)$, $M(\lambda)$ and $C(\lambda)$ are the unit spectral dye densities for the yellow, magenta and cyan dyes, respectively.
K_y, K_m and K_c are the parameters which characterize the amount of dye present in the image. Equation (1) can be rewritten as:

$$D(\lambda) = K_y Y(\lambda) + K_m M(\lambda) + K_c C(\lambda) + DB(\lambda) \qquad \text{Eq. (3)}$$

If the functions $Y(\lambda)$, $M(\lambda)$, $C(\lambda)$ and $DB(\lambda)$ are known, it is possible to determine the parameters K_y, K_m and K_c from measurements of the integral density at three different wavelengths. The base density (DB) can be measured at some overexposed portion (positive transparency) or underexposed portion (negative transparency) of the imagery. If the integral density measurements are taken at λ_1, λ_2 and λ_3 (three different wavelengths), three different equations can be generated from Eq. (3). Letting $\Delta D(\lambda) = D(\lambda) - DB(\lambda)$, then:

$$\Delta D(\lambda_1) = K_y Y(\lambda_1) + K_m M(\lambda_1) + K_c C(\lambda_1)$$

$$\Delta D(\lambda_2) = K_y Y(\lambda_2) + K_m M(\lambda_2) + K_c C(\lambda_2) \qquad \text{Eq. (4)}$$

$$\Delta D(\lambda_3) = K_y Y(\lambda_3) + K_m M(\lambda_3) + K_c C(\lambda_3)$$

This set of equations can be solved and the solution is represented as:

$$K_y = C_{11}\Delta D(\lambda_1) + C_{12}\Delta D(\lambda_2) + C_{13}\Delta D(\lambda_3)$$

$$K_m = C_{21}\Delta D(\lambda_1) + C_{22}\Delta D(\lambda_2) + C_{23}\Delta D(\lambda_3) \qquad \text{Eq. (5)}$$

$$K_c = C_{31}\Delta D(\lambda_1) + C_{32}\Delta D(\lambda_2) + C_{33}\Delta D(\lambda_3)$$

Thus, the parameters K_y, K_m and K_c, can be determined from three integral spectral density measurements if the nine transformation parameters ($C_{jj's}$) are known. The nine transformation parameters are dependent only on the characteristics of the dyes in the film and not on the specific combination of dyes which represent a scene on the imagery. These nine parameters are used in constructing characteristic curves for each dye layer of the film.

Once these parameters of a color or color-infrared film are known, radiometric calibration of the aerial image can take place. The intent of most remote sensing applications of photography is to infer some ground phenomena from a measurement (or interpretation) on the film imagery. It should be noted than film density is not the quantity to be correlated to the reflected energy from the ground. The dye densities formed in films depend--in a non-linear way--not only on the amount of energy and its spectral distribution striking the unexposed film, but also on the processing of the imagery.

The intent of a radiometric calibration is to derive the relationship between film density (or dye constants) and the light impinging on the unexposed film. This relationship is called a characteristic or K/log E curve. It is called a K/log E curve because for a limited range of exposures (incident energy) there is a near linear relationship between density and the logarithm of the incident energy. An example of such a curve can be found in Fig. II-3. Note there is a different characteristic curve for each layer of the film.

Once a characteristic curve has been generated for a specific roll of imagery, the use of it in the analysis procedure is relatively straightforward. After the analytical densities have been found for a particular spot on the imagery, the characteristic curve is used to find the three exposures (one for each layer) which represent the incident energy at that spot on the unexposed film. These exposures are the values to be correlated with the ground phenomena via the digital analysis programs. In the Menomonee River Pilot

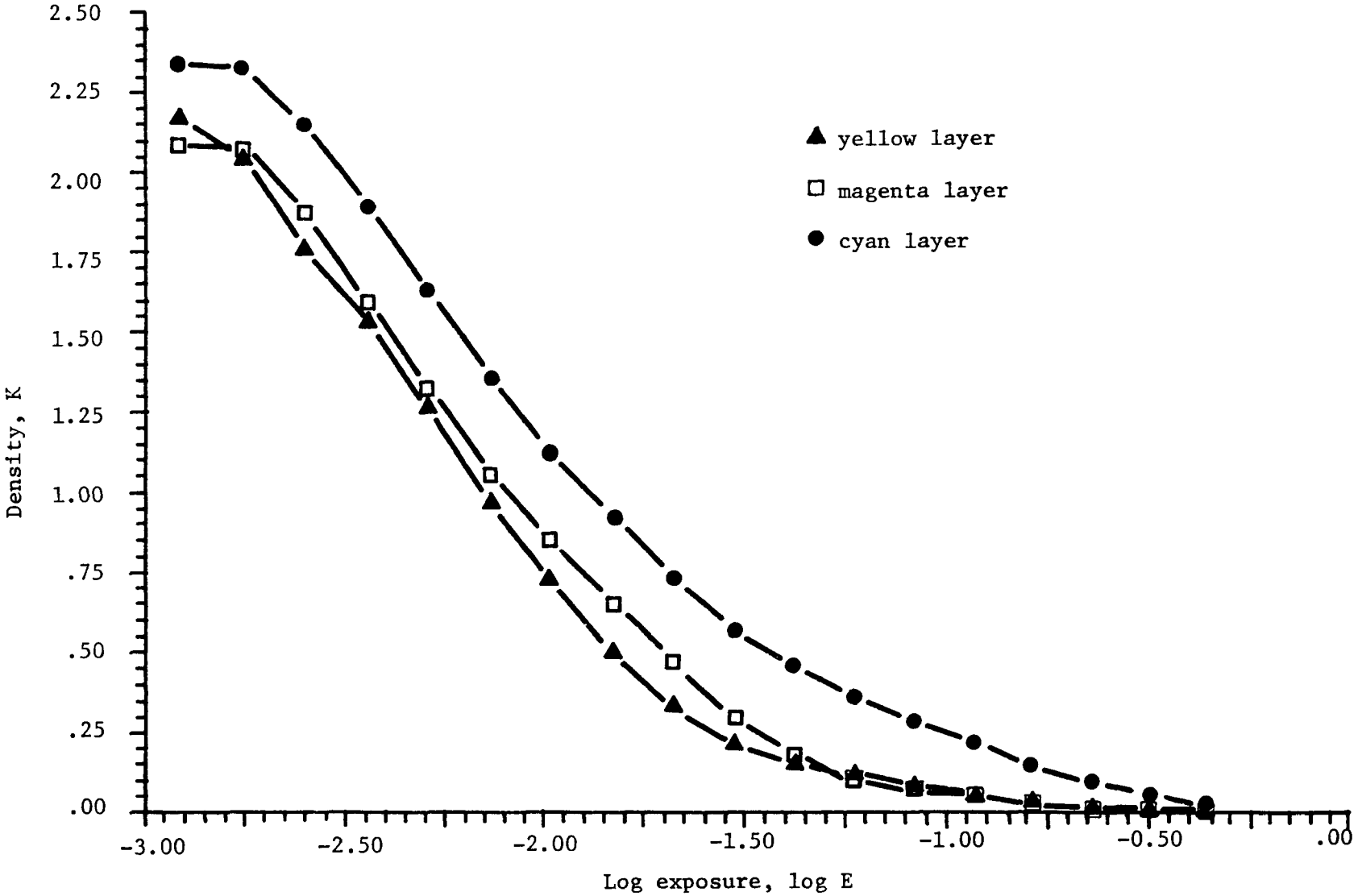

Fig. II-3. Typical K/log E curve for a multi emulsion image.

Watershed Study these values were correlated to land cover.

Application

In order to test this technique two subwatersheds were chosen in the Menomonee River Basin, namely Schoonmaker and Noyes Creeks. Schoonmaker Creek is a completely developed medium density urban area while Noyes Creek is in the early stages of urbanization. NASA color-infrared imagery--at a scale of 1:120,000--of the areas was digitized on an Optronics P-1700 scanning microdensitometer. The ground resolution for both subwatersheds was 6.0 m^2. The computer tapes produced for these areas by the Optronics system were corrected to exposures and placed on disk files. Training areas representing the different land cover categories were chosen in each subwatershed. After the training areas were checked for accuracy, a statistical analysis was performed on them thereby providing the needed statistics for the elliptical classifier.

This type of classifier first creates an ellipsoid in spectral space from the statistics derived for each training area. The classifier then determines if the spectral signature of each pixel falls within the various ellipsoids. If a pixel falls into only one ellipsoid, the pixel is classified as being of that class. If the pixel falls into more than one ellipsoid, the minimum distance to the mean of each ellipsoid is calculated and the pixel is classified to the closest mean. Pixels that do not fit into any of the training area ellipsoids remain unclassified. A schematic of the entire process is shown in Fig. II-4.

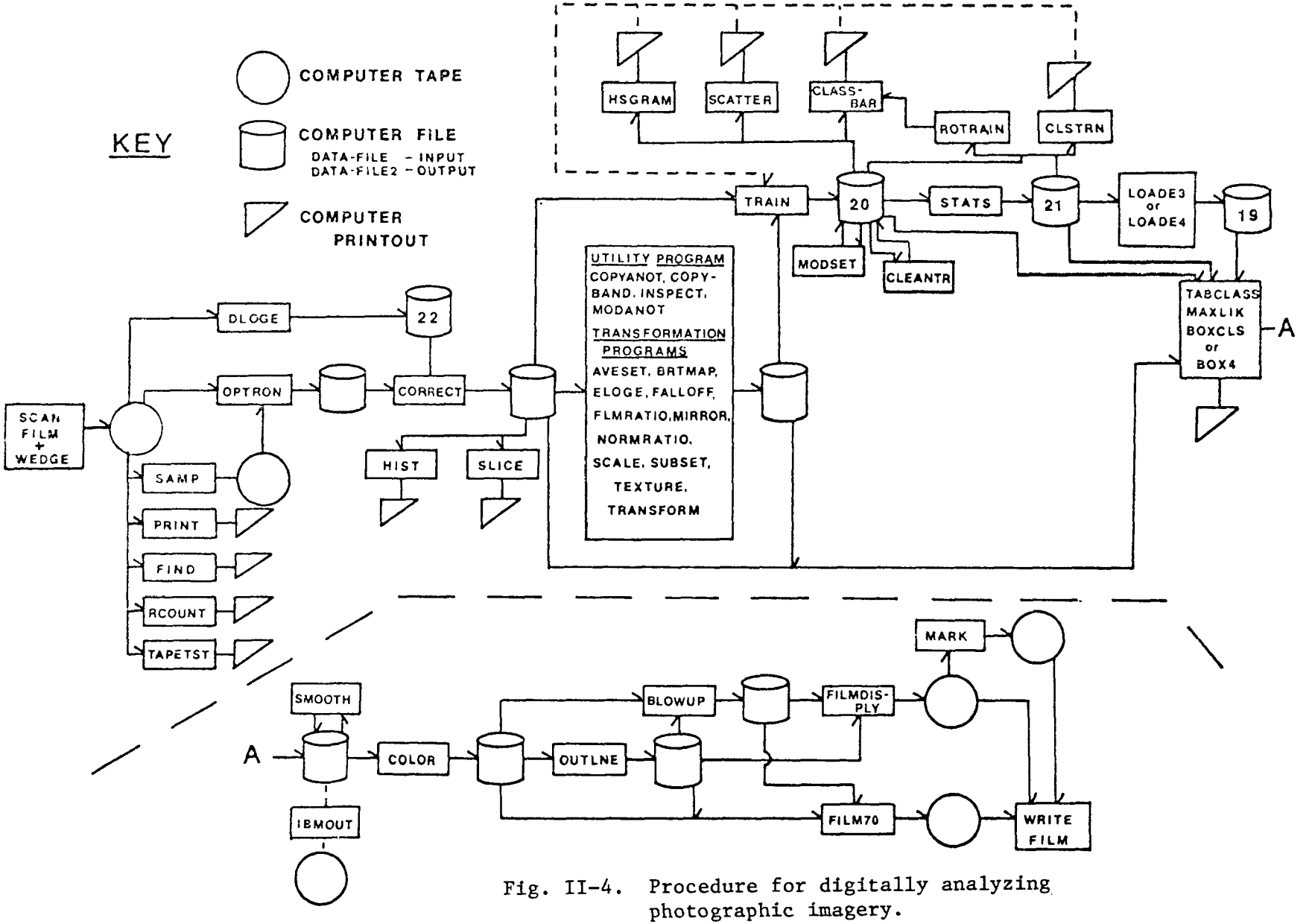

Fig. II-4. Procedure for digitally analyzing photographic imagery.

II-4. RESULTS AND DISCUSSION

The results of the classifications for each subwatershed after several iterations are shown in Table II-1. For the computer classifications five major land cover categories were chosen: impervious surfaces; streets, sidewalks, rooftops, etc.; tree cover; vegetative cover; water; and a transition class. This class usually contains a combination of the impervious and vegetative covers and represents boundary conditions between other land cover categories.

Besides a tabular product both color slides and prints were produced of the two classified subwatersheds. A ground check of the classifications showed them to be approximately 90% accurate.

Three other urban watersheds in the Great Lakes Basin were investigated using this technique. Imagery--of Detroit, Michigan and Windsor, Ontario; Toledo, Ohio; and Rochester, New York--was obtained from the EROS Data Center in Sioux Falls, South Dakota. The scale of the imagery was approximately 1:130,000 and each image was digitized on the Optronics system at 50 micron intervals, making the picture element (pixel) approximate an area on the ground of 6.5 m^2. Several problems hindered the digital analysis process in these areas. First, film wedges were not available from EROS for any of the imagery. This precluded correction of the digitized data resulting in inaccuracies in classifying land cover. Secondly, watershed and subwatershed coordinates and boundaries within these urban areas were not provided. Therefore, no classifications for actual watersheds or subwatersheds were performed; rather, simulated watershed boundaries were contrived so that the process of classification of land cover within an outlined watershed could at least be practiced and tested. The results of the classification on these areas are presented in Table II-2.

A listing of typical costs for classifying various sets of digitized data within these watersheds is presented in Table II-3. This table includes large data sets as well as smaller subsets (subwatersheds) of data and the cost includes both materials and computer costs.

Table II-1. Land cover classifications for Schoonmaker and Noyes Creeks

Landcover	Schoonmaker Creek, %	Noyes Creek, %
Impervious	63.6	38.0
Vegetation	25.4	50.0
Forest	0	3.7
Transition	10.7	3.3
Water	0	0.05
Unclassified	0.3	4.95
	100	100

Table II-2. Land cover classifications for selected urban areas in the Great Lakes Basin expressed as percentages

Cover	Toledo-1	Toledo-2*	Toledo-3**	Toledo-4**	Windsor-1	Windsor-2**	Rochester-1
Impervious	63	33	67	41	28	14	45
Grass	11	0	3	14	28	78	17
Trees	20	0	25	33	28		28
Other/ unclassified	6	67	5	12	16	8	10

*Only impervious surfaces were classified.
**Simulated subwatersheds.

Table II-3. Cost estimates for digital analysis of high altitude aircraft imagery for land cover classification (cost/image)

Process	Cost*, $	Time, hr
Obtain film	$15.00	0
Scan film/store digitized data on tape	12.00	2
Run OPTRON	3.00	0.5
Orient pixels with image from initial level slice	1.00	1
Create subset of data	1.50	0.25
Create ratio of subsetted data	1.50	0.25
Level slice of ratio (all option) Level slice of ratio (overprint option)	4.00	1
Select training sets from overprinted maps	0	1.5
Run TRAIN, CLASSBAR, and ISGRAM	2.00	1
Select standard deviations for training set ellipsoid	0	1.5
Run LOADE3 and TABCLASS	3.00	0.5
Add more training sets; follow previous two steps (in necessary)	5.00	2
Store final classification	2.00	0.5
Run COLOR	2.00	0.5
Run OUTLINE	1.50	0.5
Run FILM70 for 6 files	6.50	0.5
Make film	0	2.5
Take slides from I^2S	3.00	1
Process slides	4.00	0
TOTAL	$62.00	20.0

*Includes materials and computer costs

II. REFERENCES

1. Jackson, T. J., R. M. Ragan and W. N. Fitch. Test of LANDSAT-Based Urban Hydrologic Modeling. J. Water Resource Planning and Management Div., Am. Soc. Civil Engineers, Vol. 103, No. WR1, Proc. Paper 12950, 1977. pp. 141-158

2. Jackson, T. J. and R. M. Ragan. Value of LANDSAT in Urban Water Resources Planning. J. Water Resource Planning and Management Div., Am. Soc. Civil Engineers, Vol. 103, No. WR1, Proc. Paper 12906, 1977. pp. 33-46.

3. McKeon, J. B., L. E. Reed, R. H. Rogers, R. M. Ragan and O. K. Wiegard. LANDSAT Derived Cover and Imperviousness Categories for Metropolitan Washington: An Urban/Nonurban, Computer Approach. In: Proceedings of the 44th Convention Am. Soc. Photogrammetry, Washington, D.C., 1978. pp. 226-239.

4. Dallam, W. C., A. Rango and L. Shima. Hydrologic Land Use Classification of the Patuxent River Watershed Using Remotely Sensed Data. In: Proceedings of the NASA Earth Resources Survey Symposium, Houston, Texas, 1975. pp. 2351-2364.

5. Jackson, T. J. Computer Aided Techniques for Estimating the Percent of Impervious Area from LANDSAT Data. Workshop for Environmental Applications of Multispectral Imagery, Fort Belvoir, Virginia, 1975. pp. 140-155.

6. American Society of Photogrammetry. Manual of Color Aerial Photography. Am. Soc. Photogrammetry, Church Falls, Virginia, 1968.

7. American Society of Photogrammetry. Manual of Remote Sensing. Am. Soc. Photogrammetry, Church Falls, Virginia, 1975.

8. Scarpace, F. L. Densitometry on Color and Color IR Imagery. In: Proceedings of 43rd Convention, Am. Soc. Photogrammetry, Washington, D.C., 1977. pp. 301-318.

9. Evans, R., W. Hanson and W. Brewer. Principles of Color Photography. John Wiley and Sons, Inc., New York, 1953.

PART III

DESCRIPTION OF THE WATERSHED

by

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ABSTRACT

The Menomonee River Watershed is described in order to establish a factual base upon which to draw conclusions concerning the interactions of the ecosystem and the impact on water quality. The description includes natural and cultural features such as population, land use, climate, physiography and geology, soils and water storage areas. Also included in the description are the characteristics and management practices existing in the drainage areas of the mainstem and predominantly single land use monitoring sites.

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III-1. INTRODUCTION

A watershed is a complex of natural and man-made features which interact to comprise a changing environment for all life. The water quality characteristics of the Menomonee River Watershed are primarily a function of the activities of man as he interacts and alters the natural features of the Watershed. A watershed may be viewed as a large ecosystem composed of natural resources, man-made features, and the human and animal populations, all of which interact synergistically to alter the water quality characteristics of the watershed. Of primary concern are the changes in the ecosystem which affect the water quality of the watershed and the final receiving body--Lake Michigan.

Because of the existence of a diversity of land uses in the Menomonee River Watershed, it is well chosen as a study site for determining the impact of man's activities on water quality. Urban land uses range from an intensely-developed commercial-industrial complex in the lower quarter of the Watershed to low to medium-density residential areas in the center half of the Watershed, while the upper quarter is in the process of conversion from rural to urban land use.

The purpose of this Section is to describe the existing ecosystem, thereby establishing a factual base upon which to draw conclusions concerning the interactions of the ecosystem--especially man's activities--and the impact on water quality. Additionally, this information will be used to extrapolate the findings to other urban centers within the Great Lakes Basin.

III-2. WATERSHED CHARACTERISTICS

Location

The Menomonee River Watershed, as shown in Fig. III-1, is a surface water drainage unit, 355 km^2 in areal extent, discharging to the Milwaukee River in the City of Milwaukee $\sim$ 1.4 km upstream of the entrance of the Milwaukee River to Lake Michigan. The relatively narrow Watershed is bounded on the north and east by the Milwaukee River Watershed; on the south by the Kinnickinnic River, Root River and Oak Creek Watersheds; and on the west by the Rock River and Fox River Watersheds. The western boundary of the Watershed marks the subcontinental separation of the Great Lakes-St. Lawrence River and the Illinois-Mississippi drainage basins.

The Menomonee River has its source in a large woodland wetland area located in the northeastern corner of the Village of Germantown in Washington County. From its source, the river flows southeasterly through the Villages of Germantown and Menomonee Falls into Milwaukee County. It is joined by the Little Menomonee River in the City of Milwaukee near state highway 100 and W. Hampton Avenue, the Little Menomonee River having its source in the City of Mequon in Ozaukee County and flowing southerly through the Cities of Mequon and Milwaukee to its junction with the Menomonee River. From its junction with the Little Menomonee, the Menomonee River flows southeasterly through the Cities of Milwaukee and Wauwatosa to be joined by Underwood Creek near W. North Avenue. Underwood Creek drains portions of the Cities of Wauwatosa, Brookfield, West Allis, and New Berlin, as well as the Village of Elm Grove and the Town of Brookfield. Honey Creek, which drains portions of the Cities of Milwaukee, Wauwatosa, West Allis, and Greenfield and the Village of Greendale, joins the Menomonee River from the south near 72nd Street. From its junction with Honey Creek the Menomonee River continues to flow in a generally southeasterly direction through the Cities of Wauwatosa and Milwaukee, entering the Lake Michigan estuary at a low dam located near N. 29th St. in the City of Milwaukee.

Population Size and Distribution

The population of the Watershed was estimated at 336,824 in 1975. As shown in Table III-1, the population increased from 1900 to 1970 at rates generally greater than those of the state and nation. During 1970 to 1975, the population decreased by 2% while the state and nation increased by 4%. This decline is attributed to the migration of people from the larger urban centers to suburban-rural areas within and outside of the Watershed. The outward population movement occurred mainly from the cities and villages

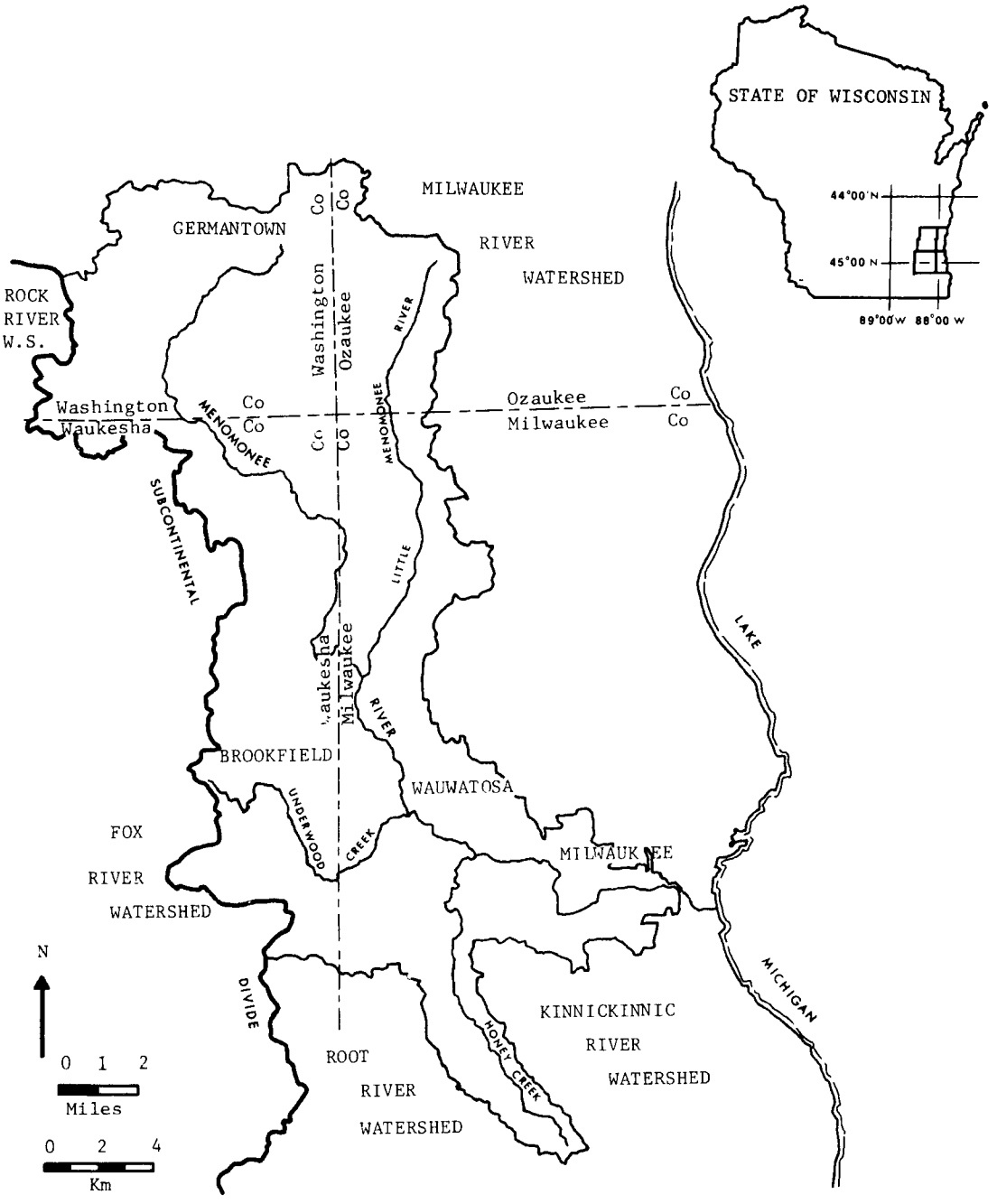

Fig. III-1. The Menomonee River Watershed.

Table III-1. Population in the Menomonee River Watershed, Wisconsin and the United States

Year	Population					
	Menomonee River Watershed		Wisconsin		United States	
	Number	Change during preceding period, %	Number	Change during preceding period, %	Number	Change during preceding period, %
1900	94,917	--	2,069,042	--	75,994,575	--
1910	122,275	29	2,333,860	13	91,972,266	21
1920	151,271	24	2,632,067	13	105,710,620	15
1930	200,403	32	2,939,006	12	122,775,046	16
1940	213,295	6	3,137,587	7	131,669,270	7
1950	240,006	12	3,434,575	9	151,325,798	15
1960	309,121	29	3,952,771	15	179,323,175	18
1970	344,614	12	4,417,933	12	203,184,772	13
1975	336,824	-2	4,581,701	4	212,245,000	4

of Milwaukee County (Table III-2). All other counties and civil divisions, except the Village of Butler, showed a population increase. In 1975, population density of the Watershed was 949 people/km^2, however, some 80% of the population resides in the lower portion of the Watershed in Milwaukee County, and the remaining 20% in the urbanizing areas of Ozaukee, Washington and Waukesha Counties. During the last two decades, the average population density of the Watershed has increased > 40% causing aggrevated water quality problems.

Land Use and Land Cover

General

The Land Data Management System (Land DMS) developed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) provides for 79 land use descriptions (1). Table III-3 lists land use descriptions and associated computer codes and Watershed percentage and area in each land use for 1975. It should be noted that the Land DMS does not contain information on land cover, such as the area covered by impervious surfaces. Land cover information must be obtained from other sources or estimated from the particular land uses in the area under study.

The 79 land use descriptions have been consolidated into 14 land use categories (Table III-4). The consolidation groups similar land uses and land uses that have similar potential for non-point pollution. The 14 land use categories for 1970 and 1975--with Watershed area and percent distribution--are presented in Table III-5. The increase in urban land use during the 5-yr period is a continuing reflection of the historic growth within the Watershed (Fig. III-2). The predominantly urban characteristics of the Watershed are clearly evident as is the pattern of historic growth from the lower to the upper parts of the Watershed. The dominant urban land use in the Watershed is residential and encompasses 9,087 ha, or approximately 26% of the total Watershed area. Most of the larger contiguous non-urbanized lands are located in Washington and Ozaukee Counties with small parcels of rural lands remaining in the northeastern corner of Waukesha County and the northwest corner of Milwaukee County.

Figure III-3 and Table III-6 show the location and associated land uses for the monitoring stations in the Watershed. Table III-6 allows a rapid evaluation of the distribution of the different land uses at each monitoring station. It should be noted that the first three stations are aggregated under one land use breakdown since land uses were not determined for each of the stations. Summation of the individual land use totals for the first 15 stations equal approximately the total area of the Watershed. The remaining stations are contained in the drainage areas of the first group. The drainage areas of the first 15 monitoring stations range in size from a maximum of 6,657 ha to a minimum of 179 ha with an average of 2,713 ha, allowing an initial segmentation of the Watershed into 13 sub-basins.

Table III-2. Population in the Menomonee River Watershed by county and civil division

Civil division*	Population 1950	1960	1970	1975
Milwaukee County				
Cities				
Greenfield	---	4,753	6,892	8,752
Milwaukee	135,808	157,953	168,201	159,819
Wauwatosa	33,324	56,923	58,676	55,712
West Allis	23,572	39,556	40,815	38,753
Villages				
Brown Deer**	---	1,572	---	---
Greendale	90	223	492	495
West Milwaukee	4,072	4,301	3,757	3,230
Towns				
Granville	2,418	---	---	---
Greenfield	7,560	---	---	---
Wauwatosa	19,153	---	---	---
Sub total	225,997	265,281	278,833	266,761
Ozaukee County				
City				
Mequon	---	1,337	1,901	2,026
Town				
Mequon	615	---	---	---
Sub total	615	1,337	1,901	2,026
Washington County				
City				
Milwaukee	---	---	---	2
Village				
Germantown	357	622	6,754	8,317
Town				
Germantown	2,005	3,804	370	375
Richfield	89	152	254	383
Sub total	2,451	4,578	7,378	9,077
Waukesha County				
Cities				
Brookfield	---	13,354	18,387	18,934
New Berlin	---	1,697	2,609	2,657
Villages				
Butler	1,047	2,274	2,261	2,230
Elm Grove	---	4,994	7,201	7,692
Menomonee Falls	2,469	15,469	25,829	27,233
Towns				
Brookfield	4,491	130	174	173
Lisbon	4	7	41	41
Menomonee	2,450	---	---	---
New Berlin	482	---	---	---
Sub total	10,943	37,925	56,502	58,960
Total, Menomonee River Watershed	240,006	309,121	344,614	336,824

*The list of civil divisions in the Watershed and the boundaries of these civil divisions have changed over time because of incorporations and annexations.

**The Village of Brown Deer incorporated from parts of the Town of Granville between 1950-1960; after 1960, the City of Milwaukee attached the Village of Brown Deer.

Table III-3. Land use description and area and percent of each use in the Menomonee River Watershed for 1975

Land use description	3 digit SEWRPC code	Area, ha	% of watershed
Residential			
Single family on lots < 2 ha (non farm)	111	7,958.41	22.56
Single family assoc ated with farm building	113	3.09	0.01
Single family on lots > 2 ha (non farm)	112	74.84	0.21
Two-family residential	120	471.49	1.34
Multi-family high rise (4 or more stories)	142	7.37	0.02
Multi-family low rise (1 to 40 stories)	141	401.18	1.14
Mobile homes	150	19.94	0.06
Residential land under development	199	710.88	2.02
Retail sales and service			
Local retail and service Regional retail and service	210	548.76	1.56
Industrial			
Wholesaling--wholesale structures (food and related, drug and medical, apparel, paper and apparel, paper and paper products, furniture and household wares, not large furniture stores or discount houses); auto salvage yard, junkyards, lumber yards, (not including retail structure on site).	340	82.00	0.23
Storage--motor vehicle storage, fuel products (oil tank farms, large coal storage areas), chemical and allied products (large salt storage areas), stockyards, grain elevators, enclosed storage buildings.	380	371.04	1.05
Manufacturing	310	450.76	1.28
Extractive (quarries and mining)	360	161.15	0.46
Transportation			
Bus terminal	425	1.67	0.00
Rail terminal	445	20.78	0.00
Ship terminal	485	0.00	0.00
Railroad right-of-way	441	320.76	0.91
Railroad yards	443	159.59	0.45
Air terminal and hangers	465	6.75	0.02
Air field	463	143.31	0.41
Land access and collector streets	418	2,333.80	6.62
Standard arterial street and expressway	414	680.93	1.93
Freeway	411	658.60	1.87
Truck terminal	426	82.97	0.24
Off-street parking	430	790.20	2.24
Communication and utilities	510	335.94	0.95
Governmental and institutional			
Local administrative, safety, assembly --city, village, town; post offices (except Milwaukee central), military installations, police stations, union halls, churches, all administrative buildings under city, village, or town authority (i.e. town hall).	611	122.75	0.35
Regional administrative, safety, assembly --county, state, federal, prisons and jails, arenas, exposition and convention centers, auditoriums, all administrative buildings under county, state or federal authority (i.e. social security offices, county courthouse).	612	195.54	0.55
Local educational--all libraries (except Milwaukee, Racine and Kenosha main), day care centers, nurseries, kindergarten, elementary and junior high schools.	641	305.97	0.87
Regional educational--senior high (and junior high combination) schools, colleges (2 and 4 year), technical schools and specialty trade schools, museums, main libraries, (Milwaukee).	642	186.90	0.53
Local health--clinics	661	4.47	0.01
Regional health--hospitals, nursing homes, group quarters	662	318.32	0.90
Local cemetaries--< 2 ha	681	15.01	0.04
Regional cemeteries--> 2 ha	682		

Table III-3 (continued).

Land use description	3 digit SEWRPC code	Area, ha	% of watershed
Recreation			
Public cultural-special recreation areas--arboretum, zoo, conservatory, planetarium, botanical garden, stadium, Mitchell domes.	711	52.06	0.15
Private cultural special recreation areas (as above)	712	1.52	0.00
Public land related recreation areas (see list)	731	1,227.41	3.48
Private land related recreation areas (as above)	732	285.39	0.81
Public water related recreation areas--beaches, boat launching sites, marinas, fishing piers.	781	0.73	0.00
Private water related recreation areas	782	6.68	0.02
Agricultural			
Row crops	811	3,763.82	10.67
Grain crops	812	988.75	2.80
Vegetable crops	813	1,041.87	2.95
Hay	814	1,824.80	5.17
Pasture	815	2,439.70	6.92
Farm building (no associated animal husbandry)	871	149.59	0.42
Farm building with associated animal husbandry-beef cattle	872	4.17	0.01
Farm building with associated animal husbandry--dairy cattle	873	27.55	0.08
Farm building with associated animal husbandry--horse	874	1.64	0.00
Farm building with associated animal husbandry--fowl (chicken, turkey, duck)	875	1.28	0.00
Farm building with associated animal husbandry--fur (fox, mink)	876	0.00	0.00
Farm building with associated animal husbandry--hogs	877	0.62	0.00
Farm building with associated animal husbandry--sheep	878	0.00	0.00
Farm building with associated animal husbandry--goats	879	0.00	0.00
Orchard and nurseries	820	194.66	0.55
Sod farm	841	34.85	0.10
Berry fields	842	1.02	0.00
Bee hives	849		
Natural areas and other open lands			
Lake, rivers, streams, canals	950	185.20	0.53
General wetlands	910	1,068.21	3.03
Wetland on residential lots with structures (1.2-2.0 ha)	913	0.21	0.00
Wetland on residential lots with structures (> 2 ha)	914	0.00	0.00
Wetland on residential lots committed to residential structures	915	1.03	0.00
Unused urban land	921	1,037.16	2.94
Unused rural land	922	588.17	1.67
Unused land on residential lots with structures (1.2-2.0 ha)	923	64.43	0.18
Unused land on residential lots with structures (> 2 ha)	924	3.08	0.01
Unused land on residential lots committed to res. structures	925	0.00	0.00
Retail sales and services under development	299	6.02	0.02
Industrial land under development	399	194.48	0.55
Transportation land under development	499	0.00	0.00
Communication and utility land under development	599	0.00	0.00
Government and institutional land under development	699	9.96	0.01
Recreational land under development	799	0.00	0.00
Land fill and dumps	930	119.80	0.34
General woodlands	940	1,747.33	4.95
Woodlands on residential lots with structures (1.2-2.0 ha)	943	20.47	0.06
Woodlands on residential lots with structures (> 2 ha)	944	6.42	0.02
Woodlands on residential lots committed to residential structures	945	0.00	0.00

Table III-4. Listing of the land use codes consolidated into 14 land use categories

Land use category	Land use code
1	310, 360
2	210, 340, 380 and 425 to 510
3	411, 414, 418
4	141, 142, 150
5	111, 120
6	112, 113, 871, 874, 875, 876, 878 and 879
7	199, 299, 399, 699 and 799
8	811, 813
9	812, 814, 815, 611 to 682, 711 to 782, 841, 842, 849 and 921 to 925
10	820 and 940 to 945
11	910 to 915
12	872, 873 and 877
13	930
14	950

Table III-5. Urban and rural land uses inventories for the Menomonee River Watershed in 1970 and 1975 as determined by the S.E. Wisconsin Regional Planning Commission

Land use category	Land use description	Area**, ha		% of Watershed	
		1970	1975	1970	1975
	Urban Land Uses				
1. Industrial	Manufacturing and extractive	588	612	1.67	1.75
2. Commercial*	Retail, wholesale, service, communication, utilities, transportation and off street parking excluding roads	2,517	2,864	7.15	8.17
3. Roads	Freeways, standard arterial streets and expressways and local and collector streets	4,095	3,673	11.65	10.48
4. High-density residential	Multi-family and mobile homes	332	428	0.94	1.22
5. Medium-density residential	Single family and two family dwellings	7,486	8,430	21.29	24.06
6. Low-density residential	Single family dwellings on lots > 2 ha and all farm buildings except feed lots	139	230	0.40	0.66
7. Land under development	All types of land	1,023	921	2.91	2.63
Sub total - urban		16,180	17,158	46.01	48.97
	Rural Land Uses				
8. Row crops	Row crops and vegetables	5,491	4,806	15.62	13.71
9. Pastures and small grains*	Grain crops, hay, pasture, park and recreational land, governmental and institutional and unused land	10,533	9,705	29.95	27.69
10. Forested land wood lots	Woodlands, orchards and nurseries	1,677	1,969	4.77	5.62
11. Wetlands	Swamps, marshes and wetlands	997	1,069	2.84	3.05
12. Feedlots	Feedlots	39	32	0.11	0.09
13. Landfill and dumps	Landfills and dumps	101	120	0.29	0.34
14. Water areas	Lakes, rivers, streams and canals	145	185	0.41	0.53
Sub total - rural		18,983	17,886	53.99	51.03
Total - watershed		35,163	35,044	100.00	100.00

*In the Menomonee River Watershed most governmental and institutional buildings are associated with large open parklands and are included in Category 9. In other watersheds, where these buildings are associated with a commercial district, they are better included in Category 2.

**The 1975 data are more accurate because hectare-sized cells were summed; 1970 data were based on 0.65 km^2 cells.

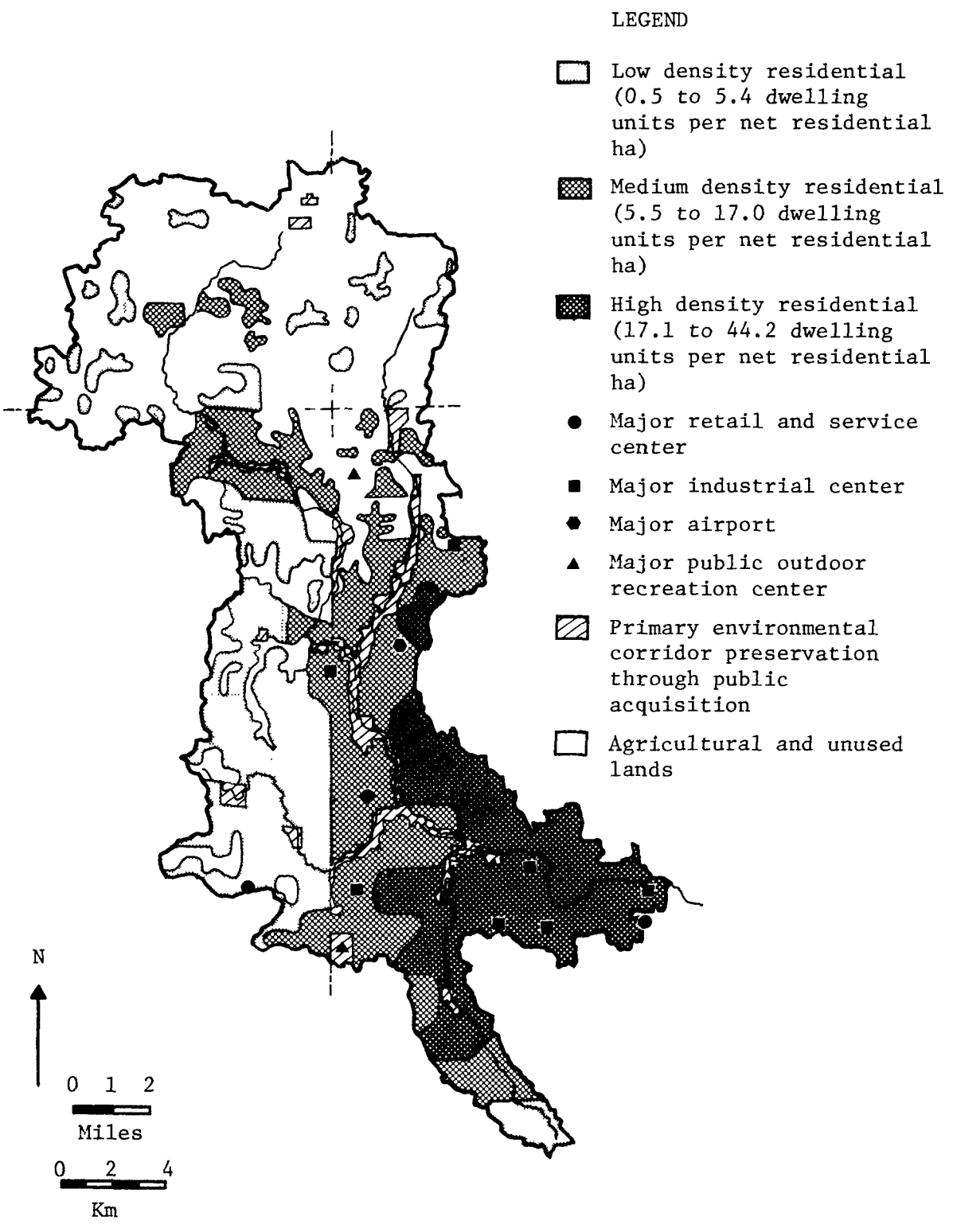

Fig. III-2. Generalized land use in the Menomonee River Watershed, 1975.

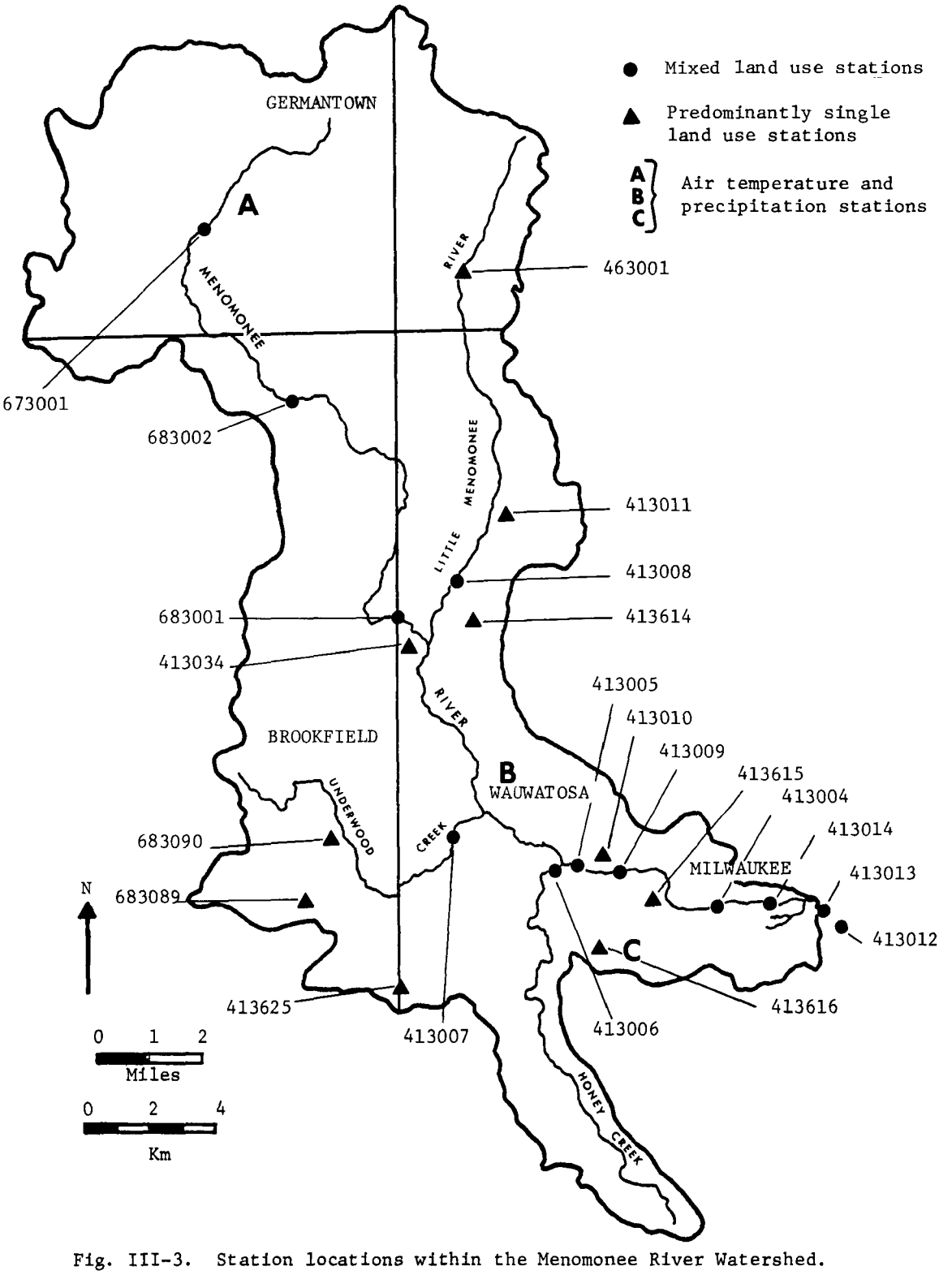

Fig. III-3. Station locations within the Menomonee River Watershed.

Table III-6. Menomonee River Watershed monitoring stations* with area for each land use category: 1975

STORET number	Location of monitoring station	Land use category,** ha														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
413012	Harbor at Hwy. 32 bridge)															
413013	Menomonee River (MR) at 2nd St. bridge)	60	272	227	41	144	0	7	0	95	0	0	0	0	28	874
413014	MR at N. 13th St. bridge)															
413004	MR above 27th St. at Falk Corporation	133	404	397	30	538	1	4	0	293	0	0	0	14	15	1,829
413009	MR at Hawley Road	0.04	11	52	3	94	0	0.2	0	21	0	0	0	0	0	181
413005	MR at 70th St. bridge	105	671	668	94	1,117	0.5	27	11	1,083	24	0	0	2	34	3,836
413006	Honey Creek 140 m above confluence with MR	24	237	541	91	1,262	0 4	49	15	524	14	9	0	13	4	2,783
413007	Underwood Creek above Hwy. 45 off North Ave.	76	446	567	53	1,967	7	145	29	1,297	193	138	0	40	12	4,970
683001	MR at 124th St. (Hwy. M)	106	348	500	11	1,690	54	302	938	2,157	331	164	3	22	31	6,657
413008	Little MR at Appleton Ave. (Hwy. 175)	26	176	160	46	316	19	120	389	891	200	99	0.4	13	7	2,462
683002	MR at Pilgrim Road (Hwy. YY)	27	84	258	12	633	48	130	864	1,250	368	331	3	1	16	4,025
673001	MR at River Lane Road (Hwy. F)	44	101	118	25	233	66	80	1,621	1,542	626	281	14	0	22	4,773
463001	Donges Bay Road, Mequon	0	16	40	1	149	33	34	938	648	210	49	12	0	14	2,144
413010	Schoonmaker Creek at Vliet St.	0	8	40	1	118	0	3	0	9	0	0	0	0	0	179
413011	Noyes Creek at 91st St.	10	83	109	21	167	1	15	1	126	2	0.4	0	15	2	552
413625	City of New Berlin at 124th St. and Greenfield Ave.	0	6	25	2	0	127	6	0	56	2	0	0	0	0	224
683090	Village of Elm Grove, ditch at Underwood Pkwy.	0	3	17	0	0	131	6	0	5	4	0	0	0	0	166
413614	Timmerman Airport, manhole #6	0	134	5	0	0	1	0	0	0	0	0	0	0	0	140
413615	Stadium interchange, I-94, manhole #120	0	9	26	0	11	0	0.1	0	18	0	0	0	0	0	64
683089	Brookfield Square Shopping Center	0	37	3	0	5	0	0	0	16	0	0	0	0	0	61
413034	City of Wauwatosa, off Ferrick St.	25	54	9	0	8	0	0	0	14	0	0	0	0	0	110
413616	Allis-Chalmers Corp., City of West Allis	38	10	0.7	0	0	0	0	0	0	0	0	0	0	0	49

*The harbor stations, numbers 413012, 413013 and 413014 are grab sampling stations. The remaining stations are automatic sampling and continuous flow monitoring except station number 413004 which is automatic sampling only.
**Land use categories are defined in Table III-5.

For purposes of mainstem monitoring, the Watershed was divided into 7 sub-basins for the following reasons:

1. The harbor sites (413012, 413013 and 413014) were only grab sampling stations.

2. The Hawley Road site (413009) received drainage from a combined sewer system.

3. The station at Falk Corporation (413004), although included in the succeeding discussion, was affected by seiche, thus monitored data were inaccurate. For this reason, the 70th Street station (413005) was used to integrate the non-point pollutional land arising from the entire Watershed.

4. Although stations 463001, 413011 and 413010 were on the mainstem or tributary stream, they monitor essentially single land uses, hence they are included with the other predominantly single land use sites--413625, 683090, 413614, 413615, 683089, 413034 and 413616--which are discussed later.

Mainstem and tributary stream monitoring stations

The Menomonee River Watershed was divided into eight tributary areas by utilizing eight automatic monitoring stations on the mainstem of the Menomonee River and major tributary streams (Fig. III-3). Mainstem stations were assigned STORET numbers 673001, 683002, 683001, 413005 and 413004 and tributary streams were 413009, 413007 and 413006. During 1975 the average flow for stations 413008, 413007 and 413006 was 0.48, 0.40 and 0.23 m^3/sec, respectively, while the mainstem station 413005 was 3.03 m^3/sec. As stations 413004 and 413005 were situated in the lower portion of the Watershed the loading values obtained from these monitoring sites represented loadings from the entire Watershed. Tributary areas ranged in size from 2,803 to 34,398 ha and encompassed a variety of land uses, thus providing integrated pollutant loading values. The tributary areas for the eight monitoring stations were selected so that comparisons could be made with small homogeneous tributary areas.

Four sewage treatment plants (STP) with average discharge of ~ 3800 m^3/day are located upstream from station 673001 (1 STP), 683001 (3 STP) and 413005 (4 STP). Results of the 1975 land use inventory are summarized in the form of 14 aggregated land uses for the eight tributary areas (Table III-6). It is important to note that roads were not included in any land use categories except category 3. All roads except category 3 were distributed proportionally among the land use categories. Area directly tributary to a station was defined by the natural watershed boundaries and the highest contour next to the upstream station. For example, station 413005 integrates 29,506 ha of the Watershed but only 3,836 ha lie within the immediate subwatershed of that station.

Examination of land uses for the Watershed show the historical urban development from the harbor section to upstream portions of the Watershed. Most of the commercial and industrial development occurs in the lower one-third of the Watershed and even though medium and high density residential areas are to be found throughout the Watershed, their accumulation is much more pronounced in the lower half (Table III-6). Agricultural land uses are confined almost entirely to the upper portion of the Watershed. It is hoped that variations in pollutant loading at the mainstem stations can be accounted for on the basis of differences in land use distribution.

Based on the 1975 land use inventory SEWRPC was able to determine the extent of imperviousness for each area tributary to a mainstem station (Table III-7). As expected from the land use distribution degree of imperviousness was much more pronounced in the lower half of the Watershed. By a summation from individual land use category data it was possible to determine that portion of the impervious area which was directly connected to a channel (Table III-7). It should be noted that the extent of impervious area directly connected to a channel was closely related to the water load (flow) for each tributary area.

Based on verbal communication with City employees and with staff members of SEWRPC, it was determined that urban areas in the Watershed usually were well maintained. Building exteriors are generally in good condition and laws are well maintained in residential areas. The Watershed does not contain large areas of slums based on buildings being in a rundown condition. Debris tended to be more prevalent around industrial and manufacturing sites than in medium and low density residential areas. Roadways are paved and generally in good repair. Street salting was performed as often as thirty to fifty times during the winter of 1975-1976.

The practice of street sweeping appears to be more prevalent in areas of high population density. Highest sweeping frequency was found in the Cities of Milwaukee, Wauwatosa and West Allis. Rural roadways in municipalities in the upper portion of the Watershed frequently were not included in the sweeping program. By determination of curb km (street km x 2) in each municipality the relative frequency of street sweeping was estimated (Table III-7), e.g., streets were swept 0 to 2 times per year in areas tributary to stations 673001, 683001, 683002 and 413007 while in areas tributary to stations 413006 and 413008 most streets were swept on a weekly basis. The central business districts had relatively high sweeping frequencies. The large municipalities had some method of leaf collection in the fall to supplement their street sweeping activities.

Predominantly single land use monitoring stations

Ten monitoring stations were established in the Watershed to assess storm water pollution from drainage areas which are predominantly in one land use. Table III-8 provides information on the 10 drainage areas and some of this information is not contained in the Land DMS. The area of impervious surfaces and the percent of impervious area connected directly to a channel are

Table III-7. Characteristics and some management practices in the mainstem monitoring drainage areas

Category	STORET number							
	413004	413005	413006	413007	413008	683001	683002	673001
Area adjacent to monitoring station, ha	1,829	3,836	2,783	4,970	2,462	6,657	4,025	4,773
Total imperviousness:								
Area, ha	1,196	1,805	1,257	1,412	378	1,096	485	255
%	65	47	45	28	15	16	12	5
Connected imperviousness:								
Area, ha	833	1,046	778	348	144	222	126	41
%	46	27	28	7	6	3	3	1
Curb length,* km	n.a.	353	322	424	190	289	141	84
Municipalities adjacent to monitoring station	Milwaukee	Butler Milwaukee Brookfield Wauwatosa	West Allis Wauwatosa Milwaukee Greenfield	Brookfield Elm Grove West Allis Wauwatosa New Berlin	Mequon Milwaukee	Menomonee Falls Butler Brookfield Milwaukee	Germantown Menomonee Falls	Germantown

Sweeping operations:	Germantown, Mequon, Elm Grove, New Berlin	No sweeping in central business, residential, commercial or industrial areas; no leaf pickup in fall.
	Greenfield	No sweeping in central business, residential, commercial or industrial areas; leaf pickup in fall.
	Menomonee Falls	Weekly sweeping in central business district; semi-annual sweeping in residential, commercial or industrial areas; leaf pickup in fall.
	Butler	Semi-annual sweeping in central, residential, commercial or industrial areas; leaf pickup in fall.
	Milwaukee, Wauwatosa, West Allis	Weekly sweeping in central business district; biweekly sweeping in residential, commercial or industrial areas; leaf pickup in fall.
	Brookfield	Annual sweeping in central, residential, commercial or industrial areas; no leaf pickup in fall.

*Values for curb length are rough estimates and do not include highways and freeways.
n.a. Not available.

Table III-8. Characteristics of the predominantly single land use drainage areas

Category	STORET number									
	413616	413615	683089	413011	413010	413034	413614	413625	463001	683090
Area, ha	47	59	54	543	202	106	135	223	2,040	161
Imperviousness, %:										
Total	89.8	44.6	50.4	34.9	53.5	73.8	18.0	22.5	4.0	24.3
Connected	89.8	43.2	44.9	28.0	32.7	32.1	6.6	0.3	1.0	0.0
Weighted average slope, %	1.0	5.0	2.8	4.9	3.3	3.5	3.0	3.3	3.3	4.0
Predominant soil textural class	n.a.	n.a.	Silt loam	Silt loam	n.a.	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam
Drainage system	Storm sewered	Storm sewered	Storm sewered	Storm sewered	Storm sewered	Storm sewered	Storm sewered	Natural ditches	Natural ditches	Natural ditches
Roof drain connection	To storm sewer	To storm sewer	To storm sewer	To storm sewer	To lawns	To storm sewer	To storm sewer	To lawns	To lawns	To lawns
Curb length, km*	2.4	21.4(5.8)	2.7(0.6)	104.1	49.7	10.3(2.9)	14.6	39.3	265.4	29.6
Curb	None	Concrete	Concrete	Concrete	Concrete	Concrete	None	None	None	None
Street pavement	Asphalt	Asphalt	Asphalt	Concrete	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt	Asphalt
Pavement condition	Poor	Excellent	Fair	Excellent	Good	Good	Good	Good	Fair	Good
Street sweeping**	Monthly	Monthly	None	Biweekly	Biweekly	Biweekly	Annually	None	None	None
Catch basin cleaning	Semi-annually	No catch basins	No catch basins	No catch basins	Annually	Annually	Annually	No catch basins	No catch basins	No catch basins
Deicing:										
Compound+	NaCl	$CaCl_2$/Nacl	n.a.	n.a.	NaCl	NaCl	None	NaCl	NaCl	NaCl
Amount,+ metric ton	45	31	n.a.	n.a.	3,700	4,500	None	1,180	1,390	18
Snow removal	Plowed to side	Plowed to curb	Plowed to side	Plowed to curb	Plowed to curb	Plowed to curb	Plowed to side	Plowed to side	Plowed to side	Plowed to side
Traffic,++ vehicle/day	200	150,000	11,500	n.a.	1,800	25,000	370	2,500	n.a.	1,000

n.a. Not available.
*The number in parenthesis is the length (total lane km) of non-curbed roadway in the drainage area.
**Street sweeping is performed during the period of April to October.
+Salt application values are estimates from best available data.
++Traffic counts are for workdays.

examples of information not contained in the Land DMS. These values for 1975 were determined using a planimeter on air photographs on which the drainage areas were carefully outlined. The drainage area boundaries were determined from a combination of sources: USGS topographic maps, 0.6 m contour topographic maps and storm sewer plans. The storm sewer plans were required, since in several areas the storm sewers cut across grade. The percent impervious area is determined by hand planimetering all hard surfaces in the drainage area, i.e., roofs, sidewalks, driveways, parking lots and roads. The percent connected impervious area is that portion of the total area that is directly connected to a storm sewer system, i.e., no intervening natural drainage surfaces exist. Table III-A-1 is a complete listing of all land uses in each drainage area for 1975 and Figs. III-A-1 to III-A-10 provide a pictorial description of the 10 drainage areas. The pictorial descriptions and physical data provide a clear description of the characteristics of each monitored drainage area. It should be noted that the drainage areas in Table III-8 and Table III-A-1 are different because the drainage areas in the latter table were determined by computer summation of hectare-sized cells in the Land DMS which only approximate the true configuration of a drainage area.

Climate

General climatic conditions

The mid-continental location* of the Watershed, far removed from the moderating effect of the oceans, gives the Watershed a typical continental-type climate characterized primarily by a continuous progression of markedly different seasons and a wide range of annual temperatures. Low winter temperatures are intensified by prevailing frigid northwesterly winds, while summer high temperatures are reinforced by the warm southwesterly winds common during that season.

The Watershed is positioned astride cyclonic storm tracks along which low pressure centers move from the west and southwest. The Watershed also lies in the path of high pressure centers moving in a generally southeasterly direction. Because the Watershed is located at the confluence of major migratory air masses it is affected by a continuously changing pattern of different air masses. Thus, frequent weather changes--particularly in spring and winter when distinct changes normally occur every three or five days--are superimposed on the wide annual range which is characteristic of the area. These temporal weather changes consist of marked variations in temperatures, type and amount of precipitation, relative humidity, wind speed and direction and cloud cover.

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*Unless otherwise indicated, climatic, physiographic and geologic descriptions and data presented herein are based on information extracted from SEWRPC (2).

In addition to these distinct temporal variations in weather, the Watershed--in spite of its relatively small size--exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, particularly during the spring, summer, and fall seasons when the temperature differential between the Lake water and the land air masses tends to be the greatest. During these periods, the presence of the Lake tends to moderate the climate of the eastern border of the Watershed. It is common, for example, for midday summer temperatures in shoreline areas to abruptly drop to a temperature level 12°C lower than inland areas because of cooling lake breezes generated by air rising from the warmer land surfaces. This Lake Michigan temperature influence is, however, generally limited to that portion of the Watershed lying within a few kilometers of the shoreline.

Temperature

Data for three air temperature observation stations in the Watershed are presented in Table III-9, and their locations are shown in Fig. III-3. The three stations--Germantown (A), Mount Mary College (B) and West Allis (C)--are located along a generally north-south line traversing the length of the Watershed. Coincident periods of record were not used to prepare Table III-9 because of the widely varying periods of record available, some of which are very short, and because of the absence of readily available data summaries. Although non-coincident periods of records were used, the monthly and annual summary data presented in this Section are judged to be sufficiently accurate to portray the spatial and temporal variations in Watershed temperature. These data indicate the temporal variations and in some instances, the spatial variations in temperature and the temperature ranges which may be expected to occur in the Watershed. The temperature data also illustrate how Watershed air temperatures lag approximately one month behind summer and winter solstices during the annual cycle, with the result that July is the warmest month in the Watershed and January the coldest.

Summer air temperatures throughout the Watershed, as reflected by monthly means at the stations for July and August, are in the 20.8°C to 23.1°C range. Average daily maximum temperatures within the Watershed for these two summer months are in the 27.1°C to 28.8°C range, whereas average daily minimum temperatures vary from 13.2°C to 17.0°C. With respect to minimum daily temperatures, the meteorological station network is not sufficient to reflect all the effects of topography. During nighttime hours, cold air, because of its greater density, flows into low-lying areas. Because of this phenomenon, the average daily minimum temperatures in these topographically low areas, particularly during the summer months, will be less than those recorded by the meterological stations. Winter temperatures for the Watershed as measured by monthly means for January and February are in the range of -7.2°C to -4.1°C. Average daily maximum temperatures within the Watershed for these two winter months vary from -3.3°C to -0.2°C, whereas average daily minimum temperatures are in the -13.3°C to -9.4°C range.

Table III-9. Air temperature (°C) characteristics at selected locations in the Menomonee River Watershed

Month	Location								
	Mount Mary College (1948-1975)			West Allis (1951-1976)			Germantown (1944-1976)		
	Average daily maximum*	Average daily minimum*	Mean**	Average daily maximum*	Average daily minimum*	Mean**	Average daily maximum*	Average daily minimum*	Mean**
January	-2.0	-11.1	-6.4	-2.2	-10.7	-6.4	-2.5	-12.5	-7.5
February	-0.1	-9.1	-4.5	0.1	-8.2	-4.0	-0.4	-10.5	-5.5
March	4.8	-4.4	0.3	4.9	-3.2	0.8	5.0	-5.0	0.0
April	13.6	2.0	7.9	13.1	3.2	8.2	13.2	1.2	7.2
May	20.3	7.3	13.9	19.8	8.5	14.1	19.6	6.2	12.9
June	25.8	13.0	19.5	26.2	14.4	20.3	25.3	11.9	18.6
July	28.6	16.1	22.5	28.6	17.4	23.0	27.9	14.5	21.2
August	27.8	15.5	21.8	27.6	17.2	22.4	27.4	14.1	20.7
September	23.5	11.3	17.5	22.7	12.5	17.6	22.7	9.6	16.2
October	17.6	5.9	11.9	16.6	6.9	11.8	16.9	4.6	10.8
November	8.3	0.8	3.9	7.8	-0.3	3.8	7.6	-2.1	2.7
December	0.8	7.5	-3.2	0.7	-6.8	-3.1	0.1	-9.1	-4.5
Year	14.1	3.2	8.7	13.8	4.3	9.1	13.6	1.9	7.7

*The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compile an average for each month in the indicated period of record; the results are then averaged for all months in the period of record.

**The mean monthly temperature is the average of the average daily maximum temperature and daily minimum temperature for each month.

Air temperature data for the three Watershed stations as prescribed in Table III-9 strongly suggest the existence of an urban heat effect (3,4). Large urban complexes have been observed to exhibit higher air temperatures than surrounding rural areas. This temperature differential is greatest during the evening hours of clear days and is partly attributable to the numerous heat sources in an urban environment. Another factor is the more gradual loss of this heat to the atmosphere due to the dense pattern of the urban structures emitting the heat radiating toward each other rather than into the open atmosphere as in rural areas, and due to the presence of atmospheric contaminants which form a barrier to night time radiation from the earth to the atmosphere.

For all months of the year, average daily minimum temperatures for the West Allis station, which is located in a highly urbanized areas, are -16.5°C to -14.8°C higher than average daily minimum temperatures at Germantown, which is located in a rural area. Average daily minimum temperatures recorded at the Mount Mary College observation station, which is located within an urban area containing considerable open space, lie between those observed at West Allis and Germantown. Although Germantown temperatures would be expected to be slightly lower than West Allis temperatures because of the latitudinal effect--the Germantown station is located about 24 km north of the West Allis station--the temperature differential is most pronounced for average minimum daily temperatures, and is too large to be entirely attributable to differences in latitude or topography.

In summary, then, the air temperature data strongly suggest the existence of an urban heat effect at several locations in the Watershed. One consequence of this effect is an increase in precipitation and cloudiness that is convectively produced as a result of air rising from the warmer urban areas.

Precipitation

Precipitation in the Watershed takes the form of rain, sleet, hail and snow and ranges from gentle showers of trace quantities to destructive thunderstorms, as well as major rainfall-snowmelt events which cause property and crop damage, inundation of poorly-drained areas and stream flooding. Existing sewerage system problems such as overflows from the 27.7 km^2 (area tributary to Watershed) combined sewer service area of the City of Milwaukee are the direct result of even small precipitation events. Heavy rainfall events may also require sewage treatment plants to bypass large volumes of partially treated or untreated sewage--in excess of the hydraulic capacity of the plants--into the storm water sewerage system. Such bypassing is necessary because of the excessive quantities of rain, snowmelt and groundwater flowing into the sanitary sewers via manholes, building sewers, building downspouts and foundation drain connections and by infiltration through faulty sewer pipe joints, manhole structures and cracked pipes.

Monthly average total precipitation and snowfall observations with

totals for three Watershed stations are presented in Table III-10. The average annual total precipitation in the Watershed, based on a numerical average of data for the three stations is 75.77 cm, expressed as water equivalent where 25 cm of measured snowfall is equivalent to 2.5 cm of water, while the average annual snow and sleet measured as snow and sleet is 106.7 cm.

The precipitation data presented in Table III-10 suggests the existence of an urban effect in the precipitation amounts. The average total precipitation for the Mount Mary College and West Allis stations is approximately 6 cm greater than the Germantown station. Since rainfall-snowmelt events are the driving force in diffuse source pollution (non-point pollution), additional precipitation increases the washoff of pollutants from the urban environment.

It should be noted that the precipitation data presented in Table III-10 are again made up of non-coincident periods of record. Although non-coincident periods of record were used, the monthly and annual summary data presented in the section are judged to be sufficiently accurate to portray the spatial and temporal variations in Watershed precipitation.

Physiography and Topography

The 355 km^2 Menomonee River Watershed is a narrow, irregularly shaped drainage basin, with its major axis oriented approximately north and south (Fig. III-1). Its length--measured between the northernmost and southernmost points--is approximately 37 km, and its maximum width, which occurs in the lower third of the Watershed along a line extending from the Milwaukee Harbor directly west to the Watershed divide, is 19 km. The middle portion of the Watershed is about 8 km wide, while the upper headwater area is approximately 14 km in width.

Watershed physiographic features, or surficial land forms, have been determined largely by the underlying bedrock and the overlying glacial deposits of the Watershed. There is evidence of four major stages of glaciation in southeastern Wisconsin. The last and most influential in terms of present physiography and topography was the Wisconsin stage, which is believed to have ended about 11,000 years ago.

The Niagara cuesta on which the Watershed lies is a gently eastward sloping bedrock surface. The topography in this section is asymmetrical with the eastern border of the Watershed being generally lower--about 46 to 92 m--in elevation than the western border. Glacial deposits overlying the bedrock formations form the irregular surface topography of the Watershed, characterized by rounded hills or groups of hills, ridges, broad undulating plains, and poorly drained wetlands.

Interlobate deposits known as the Kettle Moraine, left between the Green Bay and Lake Michigan lobes, or tongues, of the continental glacier which moved in a generally southerly direction from its point of origin

Table III-10. Precipitation (cm) characteristics at selected locations in the Menomonee River Watershed

Month	Location					
	Mount Mary College		West Allis		Germantown	
	Average total precipitation (1946-1976)	Average snow and sleet (1961-1976)	Average total precipitation (1951-1976)	Average snow and sleet (1961-1974)	Average total precipitation (1945-1976)	Average snow and sleet (1961-1976)
January	3.91	23.9	3.51	23.1	2.87	25.9
February	3.23	24.4	2.92	21.8	2.34	23.9
March	5.97	20.8	5.49	20.3	4.55	29.7
April	8.31	5.8	8.33	6.6	7.04	6.6
May	7.37	Trace	7.24	0.0	7.32	0.0
June	9.14	0.0	9.47	0.0	8.76	0.0
July	9.25	0.0	8.56	0.0	8.38	0.0
August	7.67	0.0	7.98	0.0	8.10	0.0
September	7.21	Trace	7.80	0.0	7.98	Trace
October	5.82	Trace	6.40	Trace	5.46	0.3
November	5.08	2.5	5.59	1.8	5.11	5.6
December	4.78	24.4	4.62	22.1	3.81	30.7
Year	77.74	101.8	77.91	95.8	71.72	122.7

in what is now Canada, lie to the west of the Menomonee River Watershed. The northwest portion of the Watershed lies closest to the Kettle Moraine, and contains rolling ground moraine similar to, but more subdued than, the kettle and kame topography of the Kettle Moraine. This area of rolling ground moraine gives the Watershed its highest elevations and areas of greatest local relief.

Surface elevations within the Watershed range from a high of approximately 342 m above sea level in Washington County, to approximately 177 m above sea level in the Menomonee River industrial valley (Milwaukee), a maximum relief of 165 m. The areas of greatest local relief are located in the northwest portion of the Watershed in Washington County.

Most of the Watershed is covered by gently sloping ground moraine--heterogeneous material deposited beneath the ice--and moraines consisting of material deposited at the forward margins of the ice sheet, and outwash plains formed by the action of flowing glacial meltwater. Glacial land forms are of economic significance because some are prime sources of sand and gravel needed for highway and other construction purposes. Because of their beauty and desirability for homesites, glacial land forms also serve as effective indicators of those rural areas of the Watershed likely to experience concentrated residential development. An example of such an area is the attractive rolling ground moraine area in the northwest portion of the Watershed, which provides an excellent view of the Kettle Moraine to the west.

Topography is important to Watershed planning since it is one of the important factors determining the hydrologic response of a Watershed to rainfall and rainfall-snowmelt events, and since topographic considerations enter into the selection of sites and routes for public utilities and facilities such as sewerage and water supply systems and highways. Some type of large scale mapping is available for about 350 km^2, or about 98 percent, of the total Watershed area. Of that total, 145 km^2, representing about 42 percent of the Watershed, is covered by large scale topographic mapping prepared using SEWRPC recommended procedures. For the remaining area, other large scale topographic mapping and sanitary and storm sewer maps either with or without street grade elevations are available. More detailed mapping information is available from SEWRPC (1). The above mapping, together with scale aerial photographs available for the entire Watershed, were used extensively during the Watershed.

As already noted, a major subcontinental divide that separates Mississippi River basin drainage from Great Lakes-St. Lawrence River basin drainage forms much of the western boundary of the Menomonee River Watershed. In addition to the physical significance of the subcontinental divide--it established the overall easterly direction of Menomonee River Watershed surface drainage--the subcontinental divide also carries with it certain legal constraints on the diversion of water across the divide. Also of significance are the water quality requirements imposed on the Watershed as a result of its being tributary to Lake Michigan.

The Fox River and Rock River Watersheds lie west of the Menomonee River

Watershed and of the subcontinental divide. On the north and east, the Menomonee River Watershed adjoins the large Milwaukee River Watershed, while the Kinnickinnic River, Oak Creek, and Root River Watersheds lie to the south of the Menomonee River Watershed. Comprehensive watershed plans have been completed and adopted by the SEWRPC for three of the six watersheds contiguous to the Menomonee River Watershed--the Root River, Fox River, and Milwaukee River Watersheds--while in December 1974 the SEWRPC published a prospectus for one of the remaining three contiguous watersheds--the Kinnickinnic River Watershed.

Surface drainage within the Watershed is very diverse with respect to channel shape and slope, the degree of stream sinuosity, and floodland shape and width. The heterogeneous character of the surface drainage system is partly due to the natural effects of recent glaciation superimposed on the bedrock geology, and partly due to the extensive channel modifications evident in the lower Watershed.

Geology

The geology of the Menomonee River Watershed is a complex system of various layers and ages of rock formations. The type and extent of the various bedrock formations underlying the Watershed were determined primarily by the environments in which the sediments forming the various rock layers were deposited. The surface of this varied system of rock layers was, moreover, deeply eroded prior to being buried by a blanket of glacial deposits consisting of unconsolidated sand, silt, clay, gravel, and boulders. The bedrock formations underlying the Menomonee River Watershed consist of, in ascending order, predominantly crystalline rocks of the Precambrian Era, Cambrian through Devonian Period sedimentary rocks of the Paleozoic Era, and unconsolidated surficial deposits. Only the glacial deposits and the youngest sedimentary rocks are exposed in the Watershed. The subsurface stratigraphy of the Menomonee River Watershed is summarized in Table III-11.

Precambrian crystalline rocks thousands of meters thick formed the basement on which younger rocks were deposited. Little is known of their origin, but in wells within or near the Watershed that reach the Precambrian basement, the rock types include quartzite and granite. The Precambrian rocks were extensively eroded to an uneven surface before the overlying sedimentary formations were deposited. Layered sedimentary rocks overlying the Precambrian rocks consist primarily of sandstone, shale, and dolomite. These rocks were deposited during the Cambrian, Ordovician, Silurian, and Devonian geologic time periods, in seas that covered much of the present North American continent.

The Cambrian rocks in the Watershed are primarily sandstone, but contain some siltstone, dolomite, and shale. The most dominant Cambrian rock units are the two lowermost units, the Mount Simon sandstone which was deposited on the Precambrian surface, and the Eau Claire sandstone. The two units are present throughout the Watershed. The other three Cambrian rock units

Table III-11. Stratigraphy of the Menomonee River Watershed

Geologic Age	Stratigraphic unit	Thickness range, m	Lithology	Areal extent
Holocene	Alluvium and marsh deposits		Peat, clay, silt, sand and gravel.	Occurs only locally in stream, valleys and marshes.
Pleistocene	Glacial deposits	0-8(?)	Clay, silt, sand and gravel.	Underlies entire watershed except on rock outcrops.
Devonian	Dolomite, undifferentiated	0-11	Dolomite, thick-bedded, gray.	Recognized only in three wells in the southeastern part of the watershed.
Silurian	Dolomite, undifferentiated	14-136	Dolomite, dense, thick-bedded, light gray; some beds cherty; some coral reefs.	Underlies entire watershed.
Ordovician	Maquoketa Shale, undifferentiated	31-63	Shale, dolomitic, gray, with interbedded dolomite.	Underlies entire watershed.
	Galena Dolomite, Decorah Formation and Platteville Formation, undifferentiated	66-101	Dolomite, light gray to tan. Sandy dolomite or dolomitic sandstone at base.	Underlies entire watershed.
	St. Peter Sandstone	24-78	Sandstone, medium to fine grained, dolomitic, white to light gray.	Underlies entire watershed.
Cambrian	Trempealeau Formation	0-5	Sandstone, very fine to medium grained. Dolomite light gray, interbedded with siltstone in lower part.	These units are recognized only in one well in the southwest part of the watershed.
	Franconia Sandstone	0-3(+)	Sandstone, very fine to medium grained, glauconitic.	
	Galesville Sandstone	0-41	Sandstone, fine to medium grained, light gray.	Recognized only in two wells, in southern part of watershed.
	Eau Claire Sandstone	35-104	Sandstone, very fine to medium grained. Dolomite and shale.	These units underlie entire watershed.
	Mount Simon Sandstone	78-519+(?)	Sandstone, fine to coarse grained, white or light gray. Some interbedded thin shale.	
Precambrian	Undifferentiated	(Thousands of meters)	Crystalline rocks including granite and quartzite.	Underlies entire watershed.

in the Watershed--the Galesville sandstone, Franconia sandstone, and Trempealeau formation--are younger than the Mount Simon and Eau Claire sandstones, and have been found only locally in the southern portion of the Basin. Most of the Galesville and Franconia sandstones and the Trempealeau formation were probably eroded and thereby removed from the Watershed before deposition of the Ordovician rock units. Cambrian rocks are thickest in the Milwaukee County area, where the combined thickness of the Mount Simon and Eau Claire sandstones is probably in excess of 366 m. Northward into the headwater areas of the Watershed, the thickness of the Cambrian rocks is significantly reduced to about 183 m.

The Ordovician rocks in the Watershed consist of sandstone, dolomite, and shale. The St. Peter sandstone, which was deposited on an erosion surface cut into the underlying Cambrian formations, has a relatively uniform thickness of about 61 m over much of the Watershed except for the northern portions, where it appears to thin to less than 46 m. The Platteville formation, Decorah formation, and Galena dolomite were deposited in succession on top of the St. Peter sandstone, but are not differentiated in the Watershed. The combined thickness of these dolomitic units is generally between 61 and 92 m. Above these is the Maquoketa shale, which has a thickness of about 61 m throughout the Watershed.

The Silurian rocks consisting of undifferentiated dolomite strata overlie the Maquoketa shale. They form the bedrock beneath the glacial deposits in essentially all of the Watershed. The outcrops of Silurian dolomite appeared and were quarried at several localities within the Watershed. Relative to most of the other rock units found in the Watershed, the thickness of the Silurian dolomite exhibits marked spatial variations. Thickness ranges from a minimum of about 31 to 46 m in the southeastern portion of the Watershed and in the Village of Menomonee Falls to a maximum of over 137 m in the City of Mequon. Large local differences in the thickness of the Silurian dolomite are probably due to pre-glacial and glacial erosion. Dolomitic rocks of Devonian age are known to overlie the Silurian dolomite at only three well locations in the southeastern part of the Watershed.

The unconsolidated deposits of boulders, gravel, sand, silt and clay overlie the sedimentary rocks. These were deposited during the Pleistocene age by continental glaciers that covered the Region intermittently between one million and possibly as recently as 5,000 years ago. The deposits can be classified according to their origin into till and stratified drift. Till, a heterogeneous mixture of clay, silt, sand, gravel, and boulders, was deposited from ice without the sorting action of water. Most of the Watershed is overlain by till in the form of either ground moraine or end moraine. Stratified drift consists primarily of sand and gravel that was sorted and deposited as outwash by glacial meltwater. Part of the Village of Germantown in the extreme northwestern portion of the Menomonee River Watershed is overlain with stratified drift. Although end moraine deposits are composed mainly of till, they may locally contain stratified drift in the form of outwash sand and gravel.

Holocene materials consist of alluvium and marsh deposits. They

occur only along streams and in marshy areas, and constitute a very small fraction of the unconsolidated deposits covering the Watershed land surface.

Table III-12 summarizes the lithology and water-yielding characteristics of the unconsolidated, deposits of the Pleistocene and Holocene Ages in the Menomonee River Watershed. As indicated in the table, the unconsolidated deposits are lithologically varied and generally yield only small quantities of water to wells.

Soils

Soil associations

The nature of the soils in the Menomonee River Watershed is the result of the interaction of parent materials, topography, climate, vegetation and animals, and time. Within each soil, the effects of these soil-forming factors are reflected in the transformation of soil material in place, chemical removal of soil components by leaching or physical removal by wind or water erosion, additions by chemical precipitation or physical deposition and transfer of some soil components from one part of the soil profile to another.

Diversity of soils exist in the Menomonee River Watershed due to spatial variations of soil-forming factors particularly topography and composition of parent materials.

Soil associations indicate the general idea of the soils in a watershed. A soil association is a landscape that has a distinctive proportional pattern of soils. It consists of one or more major soils and at least one minor soil, and is named after the major soils. The soils in one association may occur in another, but in a different pattern.

The five soil associations identified in the Menomonee River Watershed were compiled from the soil survey reports of the four counties comprising the Watershed (5,6,7). The distribution of these soil associations are depicted in Fig. III-4. It is noted from Fig. III-4 that soils appear to be more varied in the northwestern section of the Watershed.

Ozaukee-Mequon

Well-drained to somewhat poorly-drained soils that have a subsoil of silty clay loam and silty clay; formed in thin loess and silty clay loam glacial till; on moraines.

The soils in this association are in the uplands on silty clay loam glacial till. They are mostly gently sloping and sloping. Somewhat

Table III-12. Lithology and water-yielding characteristics of the unconsolidated deposits of Pleistocene and Holocene Ages in the Menomonee River Watershed

Unit	General description	Water-yielding characteristics
Organic deposits	Peat and muck	Generally saturated; not used as a source of water for wells
Stream alluvium	Clay, silt, and sand; sorted and stratified	Generally saturated but too thin to be a source of water for wells
Buried outwash	Mostly sand and gravel, sorted and stratified, lying within or beneath glacial till	Yield small to moderate quantities of water
Ice-contact deposits	Clay, silt, sand, gravel, and boulders; unstratified to stratified and unsorted to sorted	Yield small quantities of water; upper part commonly unsaturated
Glacial till	Clay, silt, sand, gravel, and boulders; unsorted and unstratified	Permeability low to very low; not used as a source of water for wells

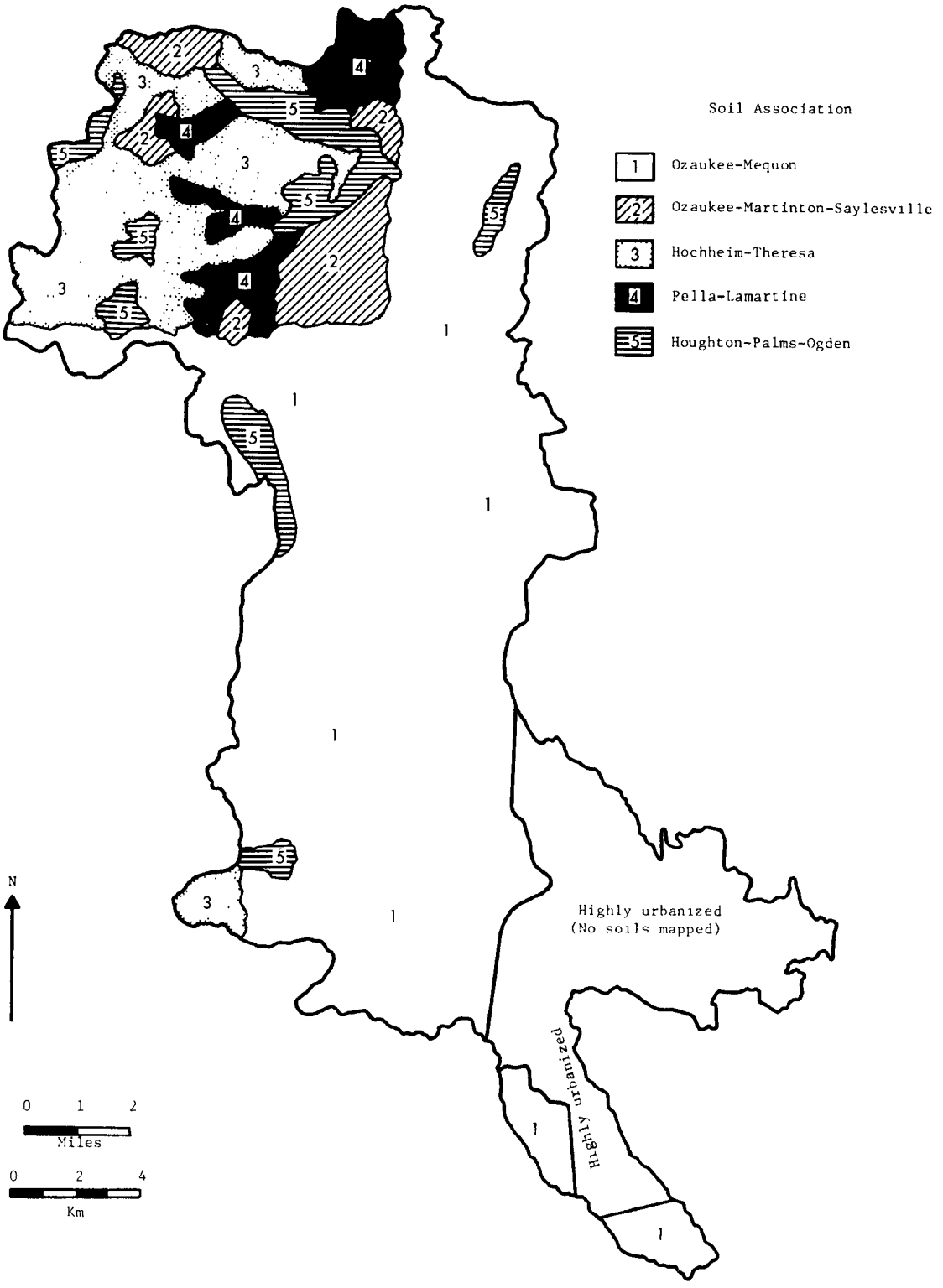

Fig. III-4. Generalized soil map of the Menomonee River Watershed.

poorly-drained soils are along waterways and in scattered broad drainageways.

The major soils are the Ozaukee and Mequon series. The Ozaukee soils make up about 9,126 ha and Mequon about 4,360 ha. Among the minor soils are Ashkum and Sebewa.

The Ozaukee soils are nearly level to sloping and they occupy ridges and convex side slopes of glacial moraines. They are well-drained to moderately well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is silty clay loam.

The Mequon soils which are generally gently sloping occur in drainageways and depressions. They have restricted drainage and temporary high water table. Their surface layer is very dark grayish-brown silt loam, their subsoil is silty clay loam to silty clay and mottled.

The minor soils in this association are in depressions and on low flats along major drainageways. They are generally poorly drained.

Ozaukee-Martinton-Saylesville

Well-drained and somewhat poorly-drained soils that have a subsoil of silty clay loam to clay; over silty clay loam glacial till or lake-laid silt and clay; on ground moraines and lacustrine basins.

This association consists of nearly level to steep soils that are underlain by calcareous silty clay loam glacial till and lacustrine silt and clay. The landscape consists of soils that form broad, smooth hills and valleys. The drainage patterns in the association is irregular.

The Ozaukee soils occupy about 1,654 ha in the Watershed; Martinton soils (formerly named Tichigan), 430 ha; and Saylesville soils, 206 ha.

The Ozaukee soils are nearly level to sloping and they occupy ridges and convex side slopes of glacial moraines. They are well-drained to moderately well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is silty clay loam.

The Saylesville soils are nearly level to gently sloping formed in lacustrine silt and clay. These well-drained soils have a silt loam surface layer and a silt clay loam to clay subsoil.

The Martinton soils, formed in lacustrine silt and clay, are in depressional areas and somewhat poorly-drained. Their surface layer is grayish-brown silt loam and their subsoil is mottled silty clay.

Some of the minor soils in this association are the Mequon and Montgomery (formerly Bono) series. These nearly level and gently sloping soils are in depressions or in drainageways between the gently sloping soils of the broad

uplands. The Mequon soils are somewhat poorly drained and the Montgomery soils are poorly drained.

Hochheim-Theresa

Well-drained soils that have a subsoil of clay loam and silty clay loam; formed in loess and loam glacial till; on ground moraines.

This association consists of nearly level to steep soils, mostly on drumlins, that are underlain by calcareous sandy loam to loam glacial till. The major soils of this association are well-drained.

The major soils of this association occupy about 1,989 ha of the Watershed. Hochheim soils make up about 1,055 ha and Theresa about 934 ha.

The Hochheim soils are generally sloping or moderately steep and occur mainly on ground moraines and convex side slopes of drumlins above the Theresa soils. These well-drained soils formed in calcareous loamy glacial till. They have a loam and silt loam surface layer and a clay loam to loam subsoil.

The Theresa soils, which are nearly level to sloping, occur in convex side slopes of uplands, generally below the Hochheim soils. They are underlain by loess or calcareous loamy glacial till and are well-drained. The surface layer of these soils is dark grayish-brown silt loam and the subsoil is mainly clay loam to loam.

The minor soils in the association include the Mayville, Lamartine, Brookston, Pella and Miami series. These soils except the Miami series occur along foot slopes or between sloping to steep soils on hills and ridges and they are somewhat poor to poorly drained.

Pella-Lamartine

Somewhat poorly drained and poorly drained soils that have a subsoil of clay loam or silty clay loam; formed in loess and underlying loam to sandy loam glacial till.

The soils in this association are nearly level to gently sloping underlain by calcareous loam to sandy loam glacial till. They occur on ground moraines. The topography consists mainly of low drainageways and some broad, irregular areas between uplands.

The major soils occupy about 1,202 ha of the Watershed with Pella (formerly Ehler) comprising 929 ha and Lamartine, 273 ha.

The nearly level Pella soils formed in calcareous loamy till occur in low lands. These soils are poorly drained. The surface layer of these soils

is black silt loam and the subsoil is gray silty clay loam and silt loam.

The Lamartine soils are nearly level to gently sloping formed in loess over calcareous loamy till. These soils along footslopes of uplands are somewhat poorly drained. They have a surface layer of very dark gray silt loam. Their subsoil is mottled silt loam and silty clay loam.

Among the minor soils of this association are Brookston, Kendall (formerly Clyman) and Palm series. These somewhat poorly drained soils are underlain by loamy glacial till.

Houghton-Palms-Ogden

Very poorly drained organic soils along drainageways, in depressions and in old lakebeds.

This association consists of nearly level, very poorly drained organic soils formed from dead and decaying remains of plants. They occur on lowlands that in most places are along drainageways, in marshy depressions, and in old lakebeds.

The major soils in the association occupy about 1,555 ha of the Watershed. The Houghton soils make up about 782 ha of the Watershed and Palm soils about 497 ha and Ogden soils about 276 ha.

The Houghton soils, which occur in larger organic areas, contain more than 42 inches of muck or mucky peat deposits over sandy to loamy materials. The Palms soils are shallower than the Houghton and are generally in narrow drainageways and depressions or along outer margins of Houghton soils. They are are formed in less than 42 inches of organic deposits over loamy materials. The Ogden soils, found in depressions and in old lakebeds, have black mucky peat underlain by clayey material at a depth of less than 60 inches.

The minor soils in this association are poorly drained and include the Pella, Brookston, Mussey, Sebewa, Muskego, Rollin, and Adrian series.

Soil texture, slope, permeability and hydrologic group

In the Menomonee River Watershed about 70 soil series and 100 soil types have been identified. The area covered and some properties of the various soil types are listed in Table III-13.

Detailed soils data are available for 29,290 ha, or 83% of the Menomonee River Watershed. The excluded area consists of the heavily urbanized eastern-most portion of the Watershed. Detailed descriptions of the soils as well as interpretations of soil characteristics and properties for engineering, agricultural, resource conservation, and urban and rural planning purposes are

Table III-13. Areal extent and some water management characteristics of the various soil types in the Menomonee River Watershed

Soil type	Areal extent* Area, ha	Areal extent* %**	Hydrologic soil group	Depth of A horizon, cm	Permeability of A horizon cm/hr	Available H_2O capacity, cm/cm	Depth to H_2O table, cm	Drainage class
Silt loams	23,322	88.0						
Ozaukee	10,780	40.7	C	0-20	2.0-6 4	0 51	90-150	Well to moderately well
Mequon	4,360	16.4	C	0-20	2.0-6.4	0.51	30-90	Somewhat poor
Hochheim	1,055	3.98	B	0-23	2.0-6.4	0.46	>150	Well
Theresa	934	3.52	B	0-23	2.0-6.4	0.51	>150	Well
Ehler***	929	3.51	D	0-25	6.4-12.7	0.61	0-30	Poor
Sebewa	527	1.99	D	0-36	2.0-6.4	0.61	0-30	Poor to very poor
Knowles	493	1.86	B	0-18	2.0-6-4	0 51	>150	Well
Matherton	455	1.72	C	0-28	2.0-6.4	0.51	30-90	Somewhat poor
Tichigan***	430	1.62	C	0-28	2.0-6.4	0.51	90-150	Somewhat poor
Mayville	378	1.43	B	0-28	2.0-6.4	0.51	90-150	Moderately well
Casco	281	1.06	B	0-23	2 0-6.4	0.51	>150	Well
Lamartine	273	1.03	C	0-30	2.0-6.4	0.51	30-90	Somewhat poor
Colwood	256	0.97	D	0-30	2.0-6.4	0.64	0-30	Poor to very poor
Fox	228	0.86	B	0-25	2.0-6.4	0.51	>150	Well
Saylesville	206	0.78	C	0-23	2.0-6.4	0.46	30-90	Well to moderately well
Pistakee	188	0.71	C	0-64	2 0-6.4	0 56	30-90	Somewhat poor
Kibbie	179	0 68	C	0-38	2.0-6.4	0.46	30-90	Somewhat poor
Clyman	167	0.63	C	0-30	2.0-6.4	0.51	30-90	Somewhat poor
Westland	160	0.60	D	0-30	2.0-6 4	0.61	0-30	Poor
Calamus	148	0 56	B	0-25	2.0-6.4	0.51	90-150	Moderately well
Sisson	147	0 55	B	0-20	2.0-6.4	0.56	>150	Well
Sleeth	92	0.35	C	0-30	2.0-6.4	0.51	30-90	Somewhat poor
Brookston	85	0.32	D	0-30	2.0-6 4	0.61	0-30	Poor
Ionia	72	0 27	B	0-25	2.0-6 4	0.51	90-150	Moderately well
Dodge	60	0.23	B	0-30	2.0-6.4	0.51	>150	Well
Fabius	57	0.22	C	0-23	2.0-6.4	0.51	30-90	Somewhat poor
Lorenzo	35	0.13	B	0-20	2.0-6.4	0.51	>150	Well
Juneau	31	0.12	C	0-66	2.0-6.4	0.51	90-150	Well to moderately well
Nenno	31	0.12	C	0-33	2.0-6.4	0.51	30-90	Somewhat poor
Thackery	30	0.11	B	0-30	2 0-6.4	0.51	90-150	Moderately well
Ockley	30	0.11	B	0-33	2.0-6.4	0.51	>150	Well
Mosel	28	0.10	C	0-33	6.4-12.7	0.51	30-90	Somewhat poor
Lawson	25	0.09	D	0-64	2.0-6.4	0.61	30-90	Somewhat poor
Abington	21	0.08	D	0-46	2.0-6.4	0.61	0-30	Very poor
Blount	20	0.08	C	0-28	2.0-6.4	0.51	30-90	Somewhat poor
Ashford	20	0.08	B	0-28	2.0-6.4	0.46	90-150	Moderately well
Mussey	18	0.07	D	0-46	2 0-6.4	0.61	0-30	Poor to very poor
Hebron	17	0.06	B	0-23	2 0-6.4	0.56	90-150	Well to moderately well
Morley	12	0.04	C	0-20	2.0-6.4	0.51	90-150	Well to moderately well
Aztalan	12	0.04	C	0-23	2.0-6.4	0.56	30-90	Somewhat poor
Yahara	11	0.04	C	0-25	2.0-6 4	0.56	30-90	Somewhat poor
Navan	9.4	0 04	D	0-30	2.0-6.4	0.56	0-30	Poor to very poor
Wallkill	6.5	0.02	D	0-81	2.0-6.4	0 51	0-30	Poor
Crosby	5.6	0.02	C	0-30	2.0-6.4	0.46	30-90	Somewhat poor
Kane	4.9	0.02	C	0-33	2.0-6.4	0.51	30-90	Somewhat poor
Wauconda	3.8	0.01	C	0-25	2.0-6 4	0 56	30-90	Somewhat poor
Miami	3.2	0.01	B	0-28	2.0-6.4	0.41	>150	Well
Warsaw	3.1	0.01	B	0-30	2.0-6 4	0.51	>150	Well
Keowns	2.2	<0 01	D	0-30	2 0-6.4	0.61	0-30	Poor
Ashkum-Beecher	1.1	<0.01	C-D	0-33	2.0-6.4	0.51	0-90	Somewhat poor to poor
Dorchester	0.9	<0.01	B	0-51	2.0-6.4	0.51	90-150	Well to moderately well
Varna	0.5	<0.01	B	0-33	2.0-6.4	0.56	90-150	Well to moderately well
Tippecanoe	0.2	<0 01	B	0-30	2.0-6.4	0.61	90-150	Moderately well
Loams	409	1 54						
Matherton	103	0 39	C	0-33	2.0-6.4	0 41	30-90	Somewhat poor
Fox	59	0.22	B	0-25	2.0-6.4	0.41	>150	Well
Casco	52	0.20	B	0-23	2.0-6 4	0.41	>150	Well
Hochheim	46	0.17	B	0-23	2 0-6.4	0.41	>150	Well
Fabius	45	0.17	C	0-23	2.0-6.4	0.41	30-90	Somewhat poor
Casco-Rodman	23	0.09	A-B	0-23	2.0->25.4	0.05-0 41	>150	Well to excessive
Hochheim-Sisson-Casco	22	0.08	B	0-23	2.0-6.4	0.41-0.51	>150	Well
Aztalan	15	0.06	C	0-23	2.0-6.4	0.51	30-90	Somewhat poor
Sebewa	10	0 04	D	0-36	2.0-6.4	0.51	0-30	Poor to very poor
Knowles	5.3	0.02	B	0-23	2.0-6.4	0.41	>150	Well
Ockley	5.1	0.02	B	0-33	2.0-6 4	0.51	>150	Well
Hochheim-Hennepin	5.1	0.02	B	0-23	2.0-6 4	0.41	>150	Well to excessive
Hochheim-Theresa	4.9	0.02	B	0-23	2.0-6 4	0 41-0 51	>150	Well
Hebron	3.9	0.01	B	0-23	2 0-6.4	0.41	90-150	Well to moderately well
Mussey	3 1	0 01	D	0-46	2.0-6.4	0 51	0-30	Poor to very poor
Rodman	2.3	<0.01	A	0-20	>25.4	0 05	>150	Excessive
Ionia	1.8	<0.01	B	0-25	2.0-6.4	0 41	90-150	Moderately well
Dousman	1.6	<0.01	C	0-33	2.0-6.4	0.41	30-90	Somewhat poor
Sisson	0.7	<0.01	B	0-20	2.0-6.4	0.51	>150	Well
Yahara	0.5	<0.01	C	0-25	2.0-6.4	0.56	30-90	Somewhat poor
Muck or mucky peat	1,587	5.99						
Houghton	782	2 95	D	0->152	6 4-12.7	0.51	0-30	Very poor
Palms	497	1 88	D	0-76	6.4-12.7	>0.51	0-30	Very poor
Ogden	276	1.04	D	0-64	6.4-12.7	>0.51	0-30	Very poor
Rollin	19	0.07	D	0-96	6.4-12.7	>0.51	0-30	Poor
Adrian	6.6	0.02	D	0-66	6 4-12 7	>0.51	0-30	Poor
Muckego	6.0	0.02	D	0-64	6.4-12 7	>0 51	0-30	Poor
Sandy loams	13	0.05						
Fox	6 0	0.02	B	0-25	6 4-12.7	0 30	>150	Well
Wea	4.3	0.02	B	0-33	6.4-12.7	0 41	>150	Well
Lapeer	1 1	<0 01	B	0-30	6.4-12.7	0.30	>150	Well
Parr	0 6	<0.01	B	0-28	6.4-12 7	0.41	>150	Well
Yahara	0 4	<0.01	C	0-25	2 0-6.4	0.56	30-90	Somewhat poor
Colwood	0.3	<0 01	D	0-30	2.0-6.4	0.51	0-30	Poor to very poor
Wauconda	0.3	<0 01	C	0-25	2.0-6.4	0.51	30-90	Somewhat poor
Loamy sands	7.2	0.03						
Hackett	3 6	0 01	A	0-36	12.7-25.4	0.18	>150	Somewhat excessive
Tustin	3 1	0.01	B	0-25	12.7-25 4	0.20	>150	Excessive
Granby	0.4	<0 01	D	0-30	12.7-25.4	0.20	0-30	Poor
Tedrow	0 1	<0.01	A	0-23	12.7-25.4	0.20	30-90	Somewhat poor
Silty clay loams	1,155	4.36						
Ashkum	684	2.58	D	0-33	2.0-6.4	0.51	0-30	Poor
Bono***	471	1.78	D	0-46	0.5-2 0	0.51	0-30	Very poor

*Total area of the watershed is 35,271 ha of which 26,493 ha (75%) were mapped by soil types. The difference constitutes of the following: alluvial lands = 205 ha; marsh = 3 9 ha, filled areas = 2,342 ha, quarry and gravel pit = 140 ha; dump = 68 ha; water, pond and lake = 38 ha; and highly urbanized area = 5,981 ha.

**Based on 26,493 ha mapped as soil types.

***Present names of the following soils are. Ehler = Pella, Tichigan = Martinton; Bono = Montgomery.

found in the planning report prepared by SEWRPC (8). Updated and correlated information is given in the soil survey reports for the counties of Ozaukee (5), Washington (6) and Milwaukee and Waukesha (7).

Soils data in the Watershed such as soil types, area, slope, permeability, hydrologic soil groups and other properties have been incorporated in the Land DMS. Utilizing this system soils information can be retrieved and displayed in tabular or graphical form.

Groupings were made according to textural class, slope, permeability of the A-horizon, and hydrologic soil groups. Table III-14 summarizes the areas under each category of textural class, slope, permeability and hydrologic soil group for the entire Watershed. These properties are deemed the most important ones influencing the potential movement of soils in the Watershed. Distributions of these properties in smaller areas, i.e., in 48 subwatersheds of the Watershed, are discussed in Volume 2, Part IV.

The textural class that predominates in the Watershed is silt loam (Tables III-13 and III-14). Silt loams are well-distributed throughout the Watershed with Ozaukee silt loam being the major soil type. This textural class occupies 23,322 ha or 88% of the 26,493 ha mapped as soil types. The organic soils--mucks or mucky peats (6.0%), and the fine-textured soils--silty clay loams (4.4%) occupy moderate areas. Only small scattered areas of coarse textured soils, sandy loams and loamy sands, are found in the Watershed.

Slope is one soil characteristic that has a strong influence on the erosion of soil particles on the land surface. Soil slope varies from a low of 0 to 2% to a high of 30 to 45%. It can be seen from Table III-14 that most of the soils in the Watershed are nearly level to gently sloping, i.e., in the 0 to 2% and 2 to 6% slope ranges corresponding to 34 and 55%, respectively, of the area that was mapped as soil types. Sloping areas (6 to 12% slope range) represent about 10% of the mapped area while steep areas (> 12% slopes) comprise only a small percentage. Although high slope areas represent only a small portion of the Watershed they may present a serious erosion hazard.

Permeability reflects the rate of water movement through a saturated soil. Generally, fine textured soils are less permeable than coarse textured soils. Permeability of the A-horizon varies from a low of 0.5 to 2.0 cm/hr to a high of > 25.4 cm/hr (Table III-14). Soils with low permeability, i.e., 2.0 to 6.4 cm/hr are dominant, occupying about 88% of the total area mapped. Soils with a very low permeability (0.5 to 2.0 cm/hr) exist in about 2% of the area and those with moderate to high permeability (> 6.4 cm/hr), about 10%.

The soils of the Menomonee River Watershed have been classified into four hydrologic soil groups designated as A, B, C, and D, based upon those soil properties affecting runoff. Hydrologic soil groups reflect the ability of soils to restrain runoff from a heavy storm after they have been thoroughly wetted.

Group A soils are mainly sandy or gravelly. They exhibit very low

Table III-14. Summary of the areal (ha) extent of soil textural class, slope, permeability of A horizon and hydrologic group in the Menomonee River Watershed

Soil property	Textural class						
	Silt loam	Loam	Sandy loam	Loamy sand	Silty clay loam	Muck/mucky peat	Total*
Slope, %							
0-2	6,004	383	0.8	3.1	1,119	1,535	9,045
2-6	14,393	136	8.5	4.0	27	56	14,625
6-12	2,561	33	3.4	0.1	8.6	0	2,606
12-20	335	45	0	0	0	0	380
20-30	26	17	0	0	0	0	43
30-45	3.4	0	0	0	0	0	3
Total	23,322	614	13	7.2	1,155	1,591	26,702
Permeability, cm/hr							
0.5- 2.0	0	0	0	0	471	0	471
2.0- 6.4	22,365	384	1.0	0	684	0	23,434
6.4-12.7	957	205**	12	0	0	1,591+	2,765
12.7-25.4	0	0	0	7.2	0	0	7
>25.4	0	25	0	0	0	0	25
Total	23,322	614	13	7.2	1,155	1,591	26,702
Hydrologic group							
A	0	2	0	3.7	0	0	6
B	3,936	229	12	3.1	0	0	4,180
C	17,346	165	0.7	0	0	0	17,512
D	2,040	218**	0.3	0.4	1,155	1,591+	5,004
Total	23,322	614	13	7.2	1,155	1,591	26,702

*Excludes areas of filled or made land (sand - 15 ha, loam - 824 ha, clay - 1,503 hr), pond and lake (38 ha), quarry and gravel pit (140 ha) and dump (68 ha).
**Includes alluvial lands (205 ha).
+Includes marsh (3.9 ha).

runoff potential because of high infiltration capacity, high permeability, and good internal drainage.

Group B soils have moderately fine to moderately coarse textures which permit moderate amounts of runoff due to moderate infiltration rate, moderate permeability, and moderately good internal drainage.

Group C soils are medium to fine textured soils. Potential for runoff from these soils is large because of slow infiltration capacity, low permeability and poor internal drainage.

Group D soils consist mainly of 1. clay soils with high shrink-swell potential, 2. soils with high permanent water table, 3. soils with claypan or clay layer at or near the surface, and 4. shallow soils with nearly impervious substrata. These soils have high runoff potential because of very slow infiltration rate, low permeability and very poor internal drainage.

Hydrologic soil Group C is dominant in the Watershed (Table III-14). This hydrologic soil group covers about 66% of the portion of the Watershed from which detailed soils data are available. Only a negligible portion of the Watershed is occuped by Group A soils while Groups B and D soils exist in 16 and 19%, respectively, of the total area mapped. Based on this classification the majority of soils in the Watershed have high runoff potential.

Surface Water Storage Area

Natural surface water storage areas in a watershed serve to modify runoff or rainfall-snowmelt events primarily by decreasing peak discharges and by diminishing the volume of direct runoff as a result of increased infiltration. Natural surface storage areas are generally divided into lakes, wetlands and floodland areas.

No major lake, i.e., 20 ha or more, lies in the Menomonee River Watershed. Water areas, including 14 minor lakes and ponds, comprise only 38 ha. Wetlands consisting of swamps and marshes are located mainly in the headwater portions of the Watershed or along the central western edge. These comprise 1,070 ha or 3% of the Watershed area.

The third type of surface water storage area consists of the floodlands generally associated with streams and water courses. Because of the absence of major lakes and the small areas of remaining wetlands, floodlands constitute the main natural surface water storage areas with the potential for reducing peak discharges of runoff (1). Floodlands are an integral part of the stream system of a watershed and, as such, are regularly inundated by waters. During inundation the floodlands, in effect, store and retard direct runoff, thereby decreasing downstream flood discharges.

REFERENCES - III

1. Walesh, S. G. Land Use, Population and Physical Characteristics of the Menomonee River Watershed. Part I: Land Data Management System. Final Report of the Menomonee River Pilot Watershed Study, Vol. 2, U.S. Environmental Protection Agency, 1979.

2. Southeastern Wisconsin Regional Planning Commission. A Comprehensive Plan for the Menomonee River Watershed. Vol. 1. Inventory, Findings, and Forecasts. SEWRPC Planning Report No. 26, 1976.

3. Lowry, W. P. The Climate of the City. *In*: Weather and Life: An Introduction to Biometeorology. Academic Press, 1969.

4. Watt, K. E. F. Urban, Regional and National Planning in Light of Ecological Principles. *In*: Principles of Environmental Science McGraw-Hill Book Co., New York, 1973.

5. Parker, D. E., D. C. Kurer and J. A. Steingraeber. Soil Survey of Ozaukee County, Wisconsin. U.S. Dept. of Agriculture, Soil Conservation Service, 1970.

6. Schmude, K. O. Soil Survey of Washington County, Wisconsin. U.S. Dept. of Agriculture, Soil Conservation Service, 1971.

7. Steingraeber, J. A. and C. E. Reynolds. Soil Survey of Milwaukee and Waukesha Counties, Wisconsin. U.S. Dept. of Agriculture, Soil Conservation Service, 1971.

8. Southeastern Wisconsin Regional Planning Commission. Soils of Southeastern Wisconsin, SEWRPC Planning Report No. 8, 1966.

APPENDIX A. LAND USE AND LANDSCAPE CHARACTERISTICS AT THE PREDOMINANTLY SINGLE LAND USE MONITORING SITES

Table III-A-1. Land use type and area and percent of each use in the predominantly single land use monitoring sites for 1975

3 digit SEWRPC code	Land use type	Area, ha	%
	STORET no. 413616 Allis Chalmers		
111	Residential single family nonfarm lot under 2 ha	.15	.31
210	Retail sales and service	.11	.23
310	Industrial manufacturing	38.04	77.66
380	Industrial storage	6.82	13.92
418	Land access and collector streets	.74	1.52
430	Off street parking	1.57	3.21
441	Railroad right of way	1.55	3.16
	Total	48.98	100.01
	STORET no. 413615 Stadium Interchange		
111	Residential single family nonfarm lot under 2 ha	10.47	16.26
120	Residential two family	.41	.63
141	Residential multi-family low rise	.37	.58
199	Residential land under development	.11	.18
210	Retail sales and service	.45	.69
411	Freeway	16.86	26.19
414	Standard arterial street and expressway	1.30	2.02
418	Land access and collector streets	7.43	11.55
430	Off street parking	7.84	12.18
441	Railroad right of way	.36	.57
510	Communication and utilities	.44	.68
612	Region administrative, safety, assembly	.22	.35
682	Regional cemetaries	15.77	24.50
731	Rec. public land related rec. area	2.17	3.36
921	Unused urban land	.19	.29
		64.39	100.03
	STORET no. 683089 Brookfield Square		
111	Residential single family nonfarm lot under 2 ha	5.00	8.25
210	Retail sales and service	19.66	32.47
414	Standard arterial street and expressway	1.63	2.70
418	Land access and collector streets	1.33	2.19
430	Off street parking	17.07	28.18
815	Ag. pasture	3.81	6.29
921	Unused urban land	8.85	14.62
922	Unused rural land	3.21	5.29
		60.56	99.99
	STORET no. 413614 Timmerman Airport		
111	Residential single family nonfarm lot under 2 ha	1.21	.85
141	Residential multi-family low rise	.30	.21
210	Retail sales and service	.48	.34
310	Industrial manufacturing	.11	.08
380	Industrial storage	.25	.18
414	Standard arterial street and expressway	4.44	3.13
418	Land access and collector streets	.67	.47
430	Off street parking	.59	.42
463	Air field	126.82	89.27
465	Air terminal and hangers	6.75	4.75
921	Unused urban land	.44	.31
		142.06	100.01
	STORET no. 413011 Noyes Creek		
111	Residential single family nonfarm lot under 2 ha	159.02	28.74
113	Residential single family assoc. with farm bldg.	.19	.03
120	Residential two family	7.70	1.39
141	Residential multi-family low rise	18.16	3.28
142	Residential multi-family high rise	2.55	.46
199	Residential land under development	15.20	2.75
210	Retail sales and service	13.07	2.36
310	Industrial manufacturing	10.23	1.85
340	Industrial wholesale	2.65	.48
380	Industrial storage	5.79	1.05
411	Freeway	8.89	1.61
414	Standard arterial street and expressway	30.97	5.60
418	Land access and collector streets	69.38	12.54
430	Off street parking	20.54	3.71
441	Railroad right of way	3.59	.65
510	Communication and utilities	37.94	6.86
611	Local administrative, safety, assembly	3.56	.64
641	Local educational	16.38	2.96
661	Local health-clinics	.15	.03
662	Regional health	3.24	.59
731	Rec. public land related rec. area	28.04	5.07
732	Rec. private land related rec. area	18.66	3.37
813	Ag. vegetable crops	1.39	.25
815	Ag. pasture	5.56	1.01
820	Ag. orchard and nurseries	2.42	.44
871	Ag. farm bldg. no assoc. animal husb.	.81	.15
910	General wetlands	.41	.07
921	Unused urban land	50.05	9.05
922	Unused rural land	.19	.03
930	Land fill and dumps	14.56	2.63
950	Lake, rivers, streams, canals	2.04	.37
		553.33	100.02

Table III-A-1 (continued)

3 digit SEWRPC code	Land use type	Area, ha	%
	STORET no. 413010 Schoonmaker Creek		
111	Residential single family nonfarm lot under 2 ha	96.84	54.31
120	Residential two family	21.36	11.98
141	Residential multi-family low rise	.45	.25
199	Residential land under development	2.54	1.42
210	Retail sales and service	5.59	3.14
418	Land access and collector streets	40.28	22.59
430	Off street parking	2 31	1.30
611	Local administrative, safety, assembly	.54	.30
612	Regional administrative, safety, assembly	.22	.12
641	Local educational	1.71	.96
662	Regional health	2.91	1 63
681	Local cemetaries	1.97	1.11
731	Rec. public land related rec. area	1.61	.90
		178.33	100.01
	STORET no. 413034 Wauwatosa		
111	Residential single family nonfarm lot under 2 ha	7.72	7.03
199	Residential land under development	.36	.33
210	Retail sales and service	10.05	9.15
310	Industrial manufacturing	24.51	22.30
340	Industrial wholesale	1.87	1.70
380	Industrial storage	2.43	2.21
414	Standard arterial street and expressway	4.06	3.69
418	Land access and collector streets	4.46	4.06
426	Truck terminal	7.76	7.06
430	Off street parking	30.32	27.60
441	Railroad right of way	1.06	.96
510	Communication and utilities	1.16	1.06
921	Unused urban land	14.12	12.85
		109.88	100.00
	STORET no. 413625 New Berlin		
111	Residential single family nonfarm lot under 2 ha	126.53	56.77
141	Residential multi-family low rise	1.50	.67
199	Residential land under development	5.69	2.55
210	Retail sales and service	3.45	1.55
340	Industrial wholesale	.07	.03
380	Industrial storage	.06	.03
414	Standard arterial street and expressway	3.01	1.35
418	Land access and collector streets	21.80	9.78
430	Off street parking	2.84	1.27
611	Local administrative, safety, assembly	.66	.30
682	Regional cemetaries	24.29	10.90
732	Rec. private land related rec. area	1.38	.62
815	Ag. pasture	24.49	10.99
820	Ag. orchard and nurseries	1.47	.66
921	Unused urban land	4.53	2.03
922	Unused rural land	1.10	.50
		222.87	100.00

3 digit SEWRPC code	Land use type	Area, ha	%
	STORET no. 683090 Elm Grove		
111	Residential single family nonfarm lot under 2 ha	130.66	78.99
112	Residential single family nonfarm lot over 2 ha	.04	.02
199	Residential land under development	5.71	3.45
210	Retail sales and service	.41	.25
414	Standard arterial street and expressway	.59	.35
418	Land access and collector streets	16.26	9.83
430	Off street parking	2.27	1.37
611	Local administrative, safety, assembly	.59	.35
641	Local educational	1.10	.66
661	Local health-clinics	.47	.29
820	Ag. orchard and nurseries	1.21	.73
921	Unused urban land	3.00	1.82
943	Woodlands on res. lots w/struct. 1.2-2.0 ha	.55	.33
944	Woodland on res. lot w/ struct. over 2 ha	2.59	1.57
		165.45	100.01
	STORET no. 463001 Donges Bay		
111	Residential single family nonfarm lot under 2 ha	146.13	6.81
112	Residential single family nonfarm lot over 2 ha	.27	.01
113	Residential singl family assoc. with farm bldg.	12.71	.59
120	Residential two family	3.08	.14
141	Residential multi-family low rise	.84	.04
199	Residential land under development	34.42	1.60
210	Retail sales and service	1.18	.06
380	Industrial storage	.39	.02
414	Standard arterial street and expressway	20.34	.95
418	Land access and collector streets	17.56	.82
426	Truck terminal	.51	.02
430	Off street parking	1.05	.05
510	Communication and utilities	15.14	.71
611	Local administrative, safety, assembly	.51	.02
641	Local educational	2.42	.11
681	Local cemetaries	1.01	.05
682	Regional cemetaries	24.01	1.12
781	Rec. public water related rec. area	.34	.02
811	Ag. row crops	720.30	33.58
812	Ag. grain crops	170.48	7.95
813	Ag. vegetable crops	218.12	10.17
814	Ag. hay	308.35	14.38
815	Ag. pasture	105.79	4.93
820	Ag. orchard and nurseries	28.19	1.31
871	Ag. farm bldg. no assoc. animal husb.	20.46	.95
873	Ag. farm bldg. assoc. with dairy cattle	11.87	.55
877	Ag. farm bldg. assoc. with hogs	.39	.02
910	General wetlands	48.61	2.27
921	Unused urban land	1.32	.06
922	Unused rural land	33.31	1.55
940	General woodlands	181.92	8.48
950	Lake, rivers, streams, canals	13.98	.65
		2,145.00	99.99

Fig. III-A-1. Allis Chalmers Corporation. STORET number 413616

Stormwater from this drainage area is conveyed via an underground stormwater sewerage system to the plant's clarifier pond. The main storm sewer, leading to the clarifier pond, contains an overflow weir which directs a portion of the stormwater flow to the outlet system where the monitoring station is located. Stormwater flow from the clarifier pond will depend on the volume of the flow into the pond and the level of the pond. Almost all storms result in flow to the outlet storm sewerage system since the pond is maintained at its maximum level. Stormwater enters the stormwater sewerage system of the City of West Allis which drains into the Menomonee River. Heavy industrial activity predominates in this drainage area. The plant buildings were constructed in the early 1900's.

Fig. III-A-2. Stadium Interchange, I-94. STORET number 413615

Stormwater from this drainage area is conveyed via an extensive underground stormwater sewerage system directly to the Menomonee River which can be seen in the upper left portion of the photograph. The drainage area includes the interchange and approach roads, and in addition, a parking lot and a portion of a single family residential area and cemetery in the lower right portion of the photograph. The monitoring station is located in the outlet stormwater sewer 61 m above the sewer's outfall to the Menomonee River.

Fig. III-A-3. Brookfield Square Shopping Center. STORET number 683089

Stormwater from the shopping mall, an office building and their parking lots drains directly to an underground stormwater sewerage system. In addition, a small residential area, an outdoor theater and unused land drains via natural drainage ditches to the shopping mall's stormwater sewerage system. Most structures in the drainage area were constructed in the last 15 years. The only exception being a 7800 m^2 expansion of the mall and parking area during mid-April to July of 1977. The monitoring station is located in the outlet stormwater sewer which drains to Underwood Creek, a major tributary to the Menomonee River.

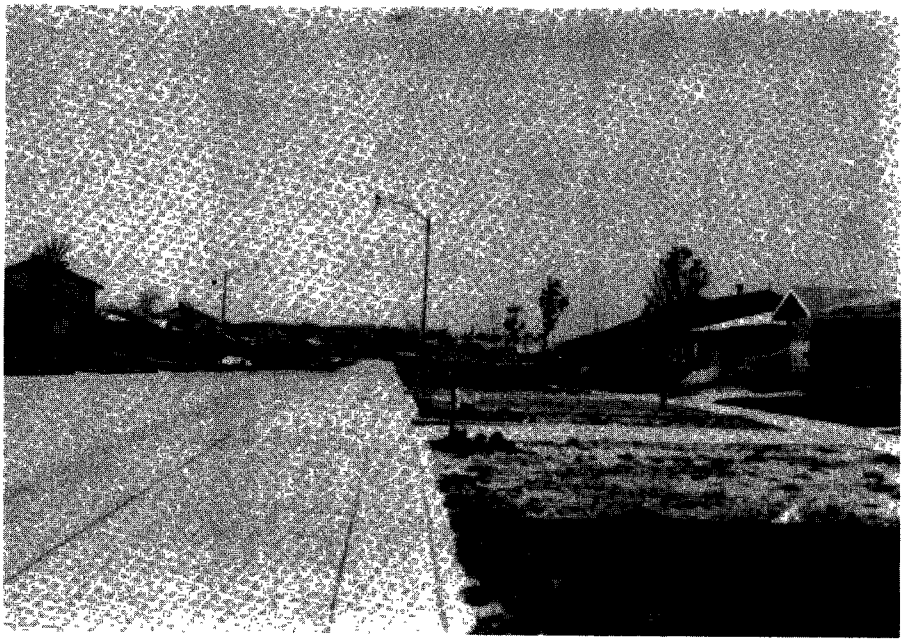

Fig. III-A-4. Noyes Creek. STORET number 413011

Stormwater from this drainage area is conveyed via an underground storm sewerage system to Noyes Creek which is an open grassed channel. The area is predominantly medium density residential with two large commercial complexes and a major expressway traversing the area. Development started in the area during mid-1960's. Prior to and throughout the study period, residential construction continued on approximately 8 ha of land adjoining the Creek. In addition, approximately 1.2 km of roadway were constructed in the summer of 1977, and in the late summer construction began on a 2 ha site for an electrical power transfer station. Construction activity was always preceded by the construction of the stormwater sewerage network. No sediment control procedures were employed at any of the construction sites. The monitoring station is located on Noyes Creek approximately 400 m above the Creek's confluence with the Little Menomonee River.

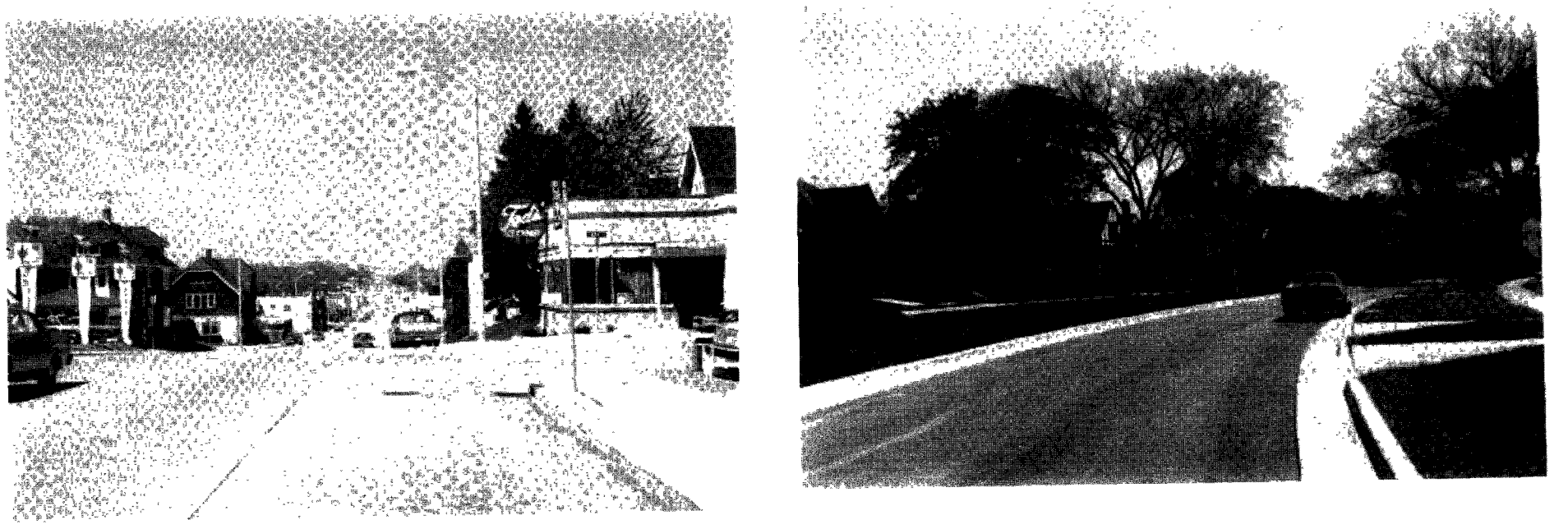

Fig. III-A-5. Schoonmaker Creek. STORET number 413010

Stormwater from this drainage area is conveyed via an underground storm sewerage system to Schoonmaker Creek which is an open channel with stone walls for banks. The upper 75% of the drainage area is medium density residential with a small commercial district along North Avenue (left photograph). It is sharply delineated from the lower portion of the drainage area which is low to medium density residential (right photograph). Both areas were established in early 1940 and are well treed with Dutch Elms even though Dutch Elm disease is present in the area. Autumn leaf pickup is offered weekly. During May to July of 1977 approximately 2 km of streets were removed and rebuilt from the base up. The monitoring station is located on Schoonmaker Creek approximately 975 m above the Creek's confluence with the Menomonee River.

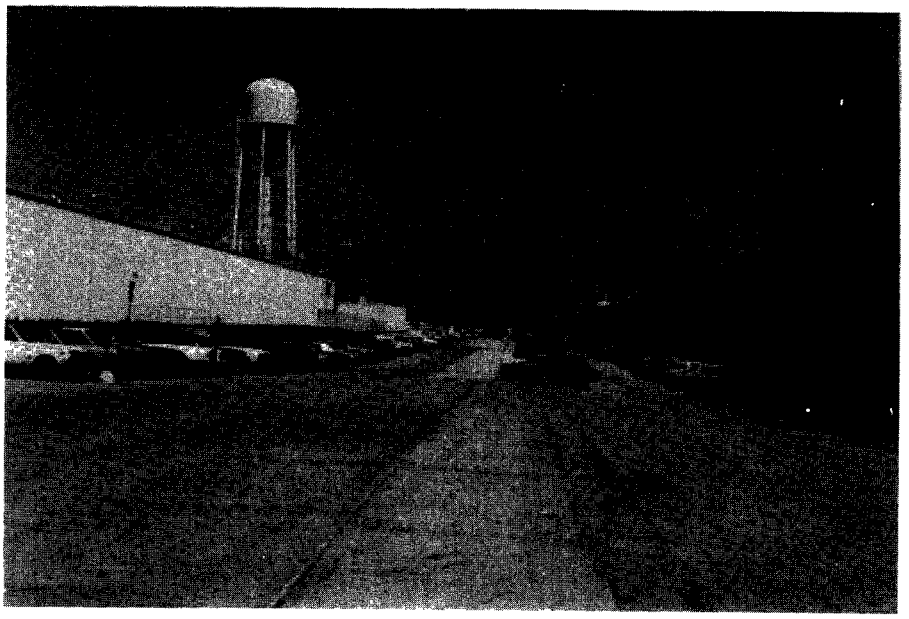

Fig. III-A-6. City of Wauwatosa. STORET number 413034

The drainage area is divided approximately in half by 124th Street. The area west of 124th Street is drained by a series of natural drainage ditches which empty into the fully storm-sewered eastern half of the area. Light industry, wholesale and retail establishments predominate in the drainage area. The Briggs and Stratton Corporation plant and parking lot has its own drainage system (23% of the area) which empties into an open cooling reservoir. Any excess stormwater is passed into the regular storm sewerage system from the reservoir, otherwise the water is circulated through the plant and reservoir as a closed system. The monitoring station is located in the outlet storm-water sewer that services the drainage area approximately 850 m above the point where the sewer drains into the Menomonee River.

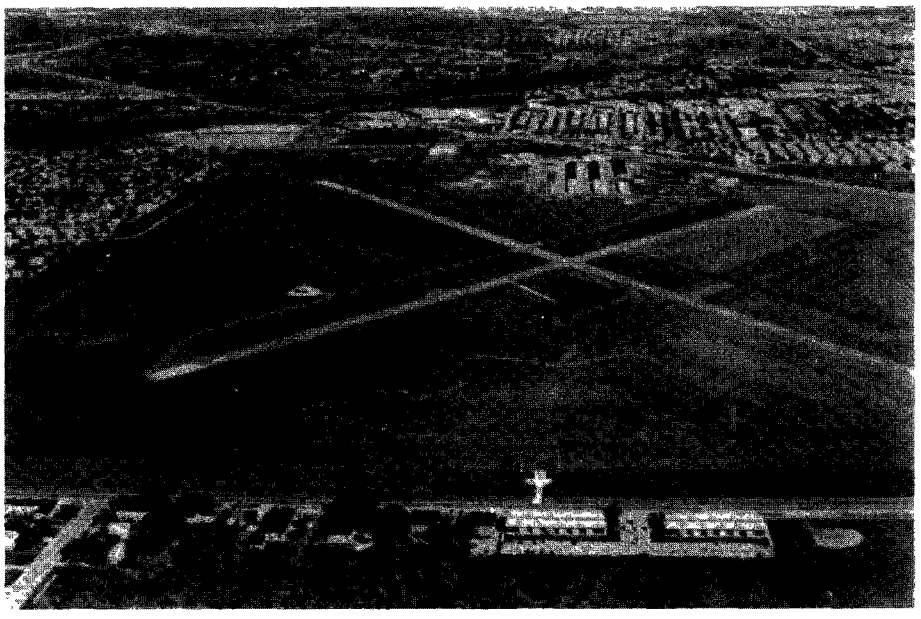

Fig. III-A-7. Timmerman Airport. STORET number 413614

Stormwater from this drainage area is conveyed via an extensive underground stormwater sewerage system. The hangar areas, roof drains, parking lots and turnabout areas are directly connected to storm sewers. The runways are not storm sewered, but there are stormwater inlets located nearby in the grassed areas, as well as intermittently throughout the grassed field. The airport services approximately 135,000 small propeller and turbo-propeller planes each year. The main airport structures were built 20 to 50 years ago. The monitoring station is located in the outlet stormwater sewer and ultimately drains to the Little Menomonee River.

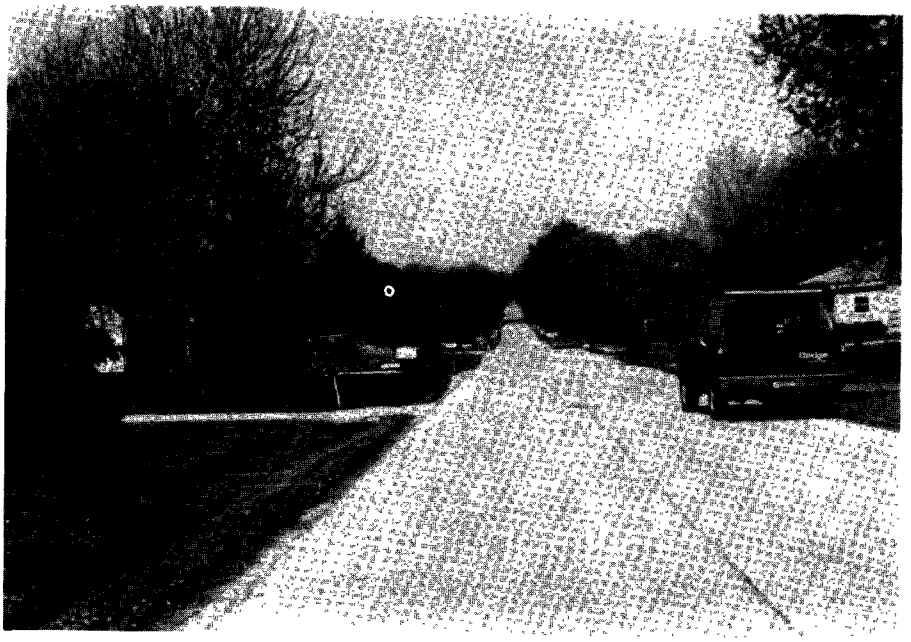

Fig. III-A-8. City of New Berlin. STORET number 413625

Stormwater, from this drainage area, is mostly conveyed via natural drainage ways to a central drainage ditch, which in some sections is undergoing bank erosion. Two small portions of the area incorporate road side culverts and open asphalt-lined drainage ways just above the monitoring station. Approximately 75% of the area is comprised of low to medium density residential housing established about 25 years ago with the upper 25% in agricultural and open lands which is slowly yielding to development. Throughout the study period construction continued on a small number of lots, however, due to the low relief in the area and the natural drainage characteristics it is believed that the construction impact on water quality was minor. Portions of the area are heavily treed, however no leaf pickup program is provided nor is leaf burning prohibited. The monitoring station is located on a drainage ditch which is tributary to the south branch of Underwood Creek, a tributary to the Menomonee River.

Fig. III-A-9. Donges Bay Road. STORET number 463001

Stormwater from this rural drainage area is conveyed via natural drainage channels to the Little Menomonee River. The land use is predominantly agricultural. The population of the City of Mequon contained in the Watershed is 780. The monitoring station is located on the Little Menomonee River approximately 5 km downstream from the headwaters.

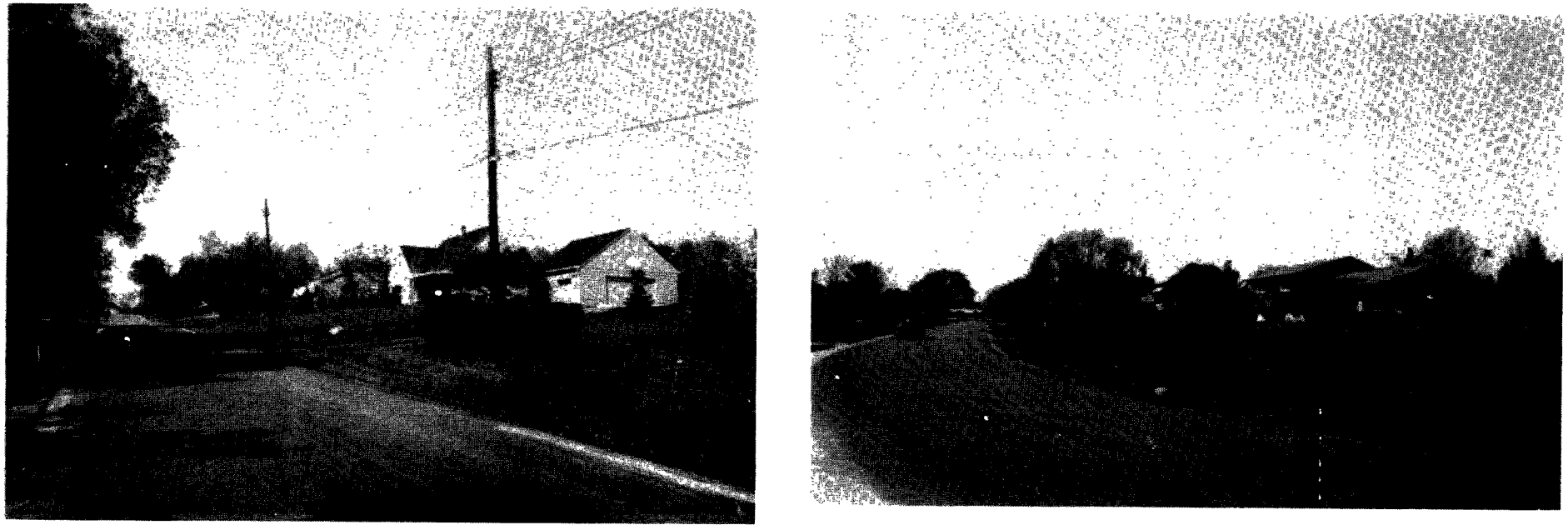

Fig. III-A-10. Village of Elm Grove. STORET number 683090

Stormwater from this drainage area is conveyed via a system of well maintained natural (grass) drainage ways to Underwood Creek. Two distinct neighborhoods exist in the drainage area separated by North Avenue. The upper half of the drainage area is an older (1950) medium density residential area which is well treed and is shown in the left photograph. The lower half of the drainage area is a newer (1965) low density residential area with large (minimum 0.2 ha) well maintained lots (right photograph). Only the largest storms ($\geq$ 1.3 cm, total rainfall) generate runoff from this drainage area. The station is located on a drainage ditch approximately 180 m above the ditch's confluence with Underwood Creek, a major tributary of the Menomonee River.

PART IV

PHYSICAL CHARACTERISTICS OF THE SUBWATERSHEDS

by

G. V. SIMSIMAN
S. G. WALESH

ABSTRACT

Important natural and cultural features of 48 subwatersheds comprising the Menomonee River Watershed are described in more detail so that variations in pollutant loadings through land surface drainage can be evaluated. Soil characteristics, land use distribution, degree of imperviousness and erosion potential in the subwatersheds are presented. Variation in erosion potential is closely associated with land use.

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IV-1. INTRODUCTION

In analyzing land-related pollution in a watershed system it is essential to identify those land areas in the basin that are likely to serve as sources of pollutants. Source identification is particularly important in a heterogeneous basin like the Menomonee River Watershed--a basin that is diverse with respect to natural features such as soil type, land slope and vegetation and cultural features such as land use and land management practices. Watersheds that are spatially diverse with respect to the natural and man-made features are more likely to exhibit wide spatial variation with respect to potential for pollution than are more spatially homogeneous basins.

Attempts to describe in more detail the natural and man-made features of smaller units of land surface are presented herein. Some 48 subwatersheds in the Menomonee River Watershed are described so that variations in pollutant loadings through land surface drainage can be evaluated. Included in the description are soil characteristics such as textural class, slope, permeability and hydrologic group, land use and degree of imperviousness. An analysis of the spatial variation of erosion potential in the 48 subwatersheds also is presented.

IV-2. THE SUBWATERSHEDS

The 48 subwatersheds delineated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) are depicted in Fig. IV-1. One, or an aggregate, of subwatersheds constitutes the drainage area adjacent to a mainstem or predominantly single land use monitoring station (1).

Subwatershed Nos.	Adjacent monitoring station nos.
12A,B,C,D and E	673001
10A,B,C,D and E	683002
7A,B,C,D,E,F,G and H	683001
11A,B and C	463001
9	413011
8A,B and C	413008
6A,B,C,D,E and F	413007
4A,B,C and D	413006
3A,B,C,D,E,F,G, and H	413005
5	413010
2	413009
1A,1B and 19	413004

Soil Characteristics

Utilizing the Land DMS, groupings were made according to soil textural class, slope, permeability and hydrologic soil class for each subwatershed. The areal distributions of the various groupings for the 48 subwatersheds are given in Tables IV-1 and IV-2.

Silt loam is the textural class that predominates in the subwatersheds (Table IV-1). Loam, silty clay loam and muck soils occupy considerably fewer areas in many of the subwatersheds and only small areas of sandy soils are found in a few of the subwatersheds. Filled areas, consisting essentially of loamy and clayey materials are found in most of the subwatersheds occupying the lower 75% of the Menomonee Watershed.

Slope is the principal natural land feature affecting soil erosion. Table IV-2 indicates that the majority of soils in the subwatersheds have slopes of 0 to 2 and 2 to 6% (nearly level to gently sloping) although substantial areas have slopes of > 6%. Erosion hazard is high in the steep areas (> 6%) but may also be high in gently sloping areas where soils are under intensive cultivation.

Permeability, defined as the rate of water movement through a saturated

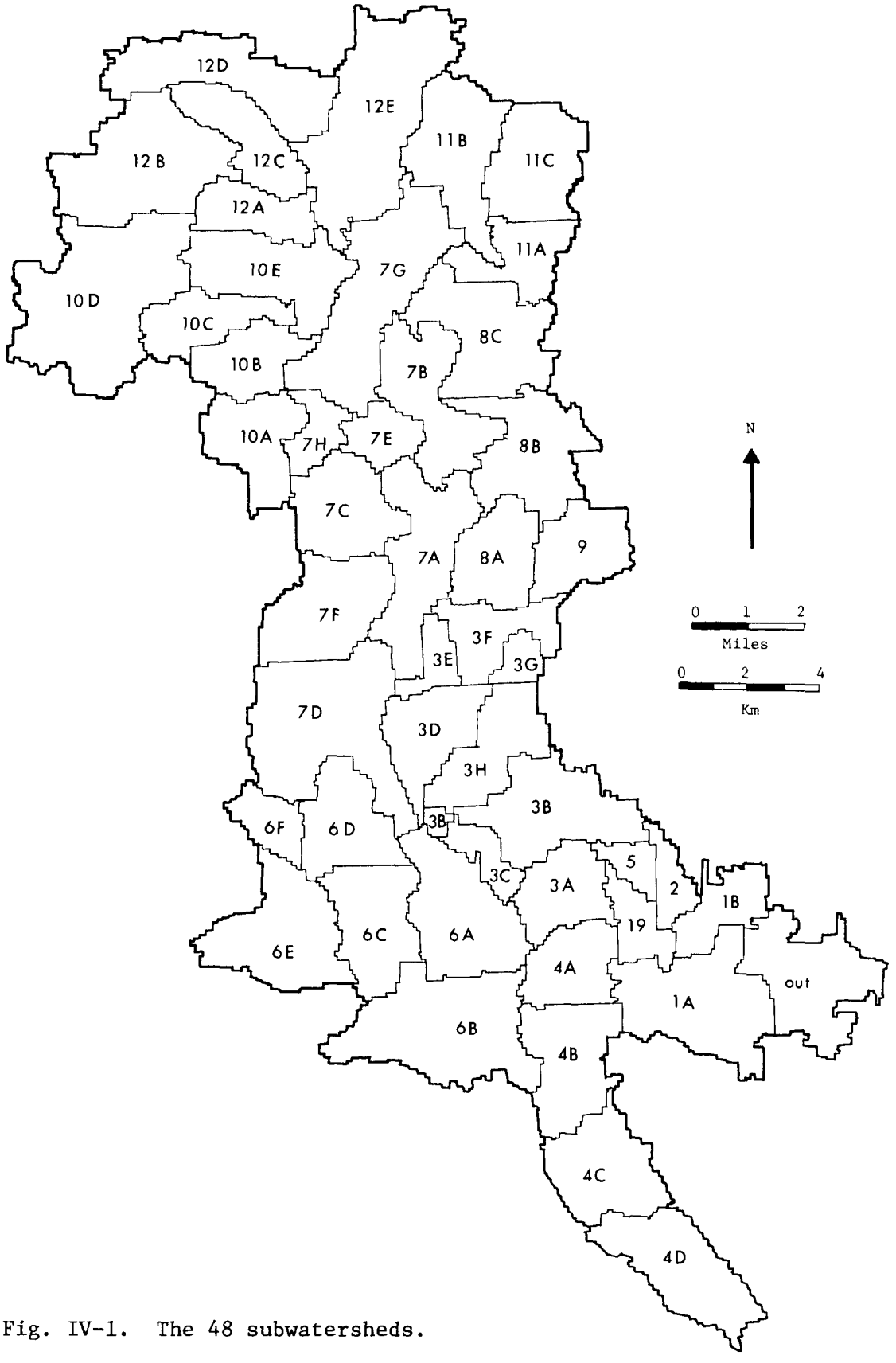

Fig. IV-1. The 48 subwatersheds.

Table IV-1. Areal distribution (ha) of soil textural class and other land type in the Menomonee River Watershed

	Textural class						Filled areas						
Subwatershed*	Silt loam	Loam**	Sandy loam	Loamy pond sand	Silty clay loam	Muck/mucky peat+	Sand	Loam	Clay	Dump	Quarry and gravel pit	Pond and lake	Total
12A	342	5	0	0	7	75	0	0	0	0	0	0	429
12B	1,069	36	1	0	21	53	1	1	0	0	17	0	1,199
12C	447	4	0	1	23	88	0	1	0	0	7	0	571
12D	870	0	0	0	10	101	0	0	0	0	0	0	981
12E	1,164	6	0	0	179	243(0.4)	0	0	0	0	0	0	1,592
Subtotal	3,892	51	1	1	240	560	1	2	0	0	24	0	4,772
10A	368	0	0	0	50	132	0	36	14	0	0	0	600
10B	380	12(7)	0	0	7	0	0	57	3	0	0	0	459
10C	411	1	0	0	61	28	0	0	0	0	0	0	501
10D	1,315	100(3)	5	0	47	113	0	2	8	0	19	2	1,611
10E	701	6	0	0	64	79	3	0	0	0	0	0	853
Subtotal	3,175	119(10)	5	0	229	352	3	95	25	0	19	2	4,024
7A	787	27(13)	0	0	8	0	0	4	154	0	2	0	982
7B	636	7	0	0	31	27	0	41	34	16	26	0	818
7C	672	0	3	4	30	0	10	0	0	0	0	0	719
7D	1,270	6(2)	0	0	65	16	0	4	32	0	7	5	1,405
7E	254	43(21)	0	0	1	0	0	4	0	0	0	0	302
7F	724	2	0	0	42	5(3.1)	0	16	43	0	0	0	832
7G	1,190	6	0	0	6	12	0	1	125	0	0	1	1,341
7H	206	6(6)	0	0	1	0	0	26	12	0	0	0	251
Subtotal	5,739	97(42)	3	4	184	60	10	96	400	16	35	6	6,650
11A	438	2	0	0	17	58	0	12	0	0	0	0	527
11B	753	26(12)	0	0	25	44	0	0	0	0	5	1	854
11C	630	20(4)	0	0	10	105	0	0	0	0	0	0	765
Subtotal	1,821	48(16)	0	0	52	207	0	12	0	0	5	1	2,146
9	331	2	4	0	39	0	0	22	144	11	0	0	553
8A	486	17(17)	0	0	13	0	0	0	83	0	0	0	599
8B	666	5	0	0	88	0 4(0.4)	0	26	66	0	1	0	852
8C	833	1	0	0	35	27	0	61	38	12	4	0	1,011
Subtotal	1,985	23(17)	0	0	136	27	0	87	187	12	5	0	2,462
6A	723	43(24)	0	0	4	7	0	137	56	0	0	0	970
6B	735	120	0	3	48	6	2	150	102	29	12	28	1,235
6C	662	5(4)	0	0	18	4	0	36	16	0	2	0	743
6D	543	11(8)	0	0	24	24	0	28	10	0	29	0	669
6E	662	3	0	0	52	233	0	22	3	0	0	0	975
6F	186	2	0	0	11	90	0	5	0	0	0	0	294
Subtotal	3,511	184(36)	0	3	157	364	2	378	187	29	43	28	4,886
4A	28	0	0	0	0	0	0	0	28	0	0	0	56
4B	53	0	0	0	1	0	0	0	0	0	0	0	54
4C	282	0	0	0	8	0	0	24	0	0	0	0	314
4D	357	0	0	0	55	17	0	9	20	0	0	0	458
Subtotal	720	0	0	0	64	17	0	33	48	0	0	0	882
3A	164	3(2)	0	0	0	0	0	6	0	0	0	0	173
3B	346	8(8)	0	0	0	0	0	37	40	0	1	0	432
3C	161	0	0	0	2	0	0	53	8	0	0	0	224
3D	375	25(25)	0	0	40	0	0	2	162	0	0	0	604
3E	106	31(31)	0	0	0	0	0	1	91	0	0	0	229
3F	447	1(1)	0	0	0	1	0	0	46	0	0	0	495
3G	64	0	0	0	1	0	0	0	85	0	0	0	150
3H	479	23(17)	0	0	11	0	0	0	82	0	8	0	603
Subtotal	2,142	91(84)	0	0	54	1	0	99	514	0	9	0	2,910
Total	23,316	615(205)	13	8	1,155	1,588(3.9)	16	824	1,505	68	140	37	29,285

*Subwatersheds 1A, 1B, 2, 5, 19 and portions of 3A, 3B, 3H, 4A, 4B, 4C, 4D and 6B with an aggregate area of 5,983 ha are highly urbanized; no soils data available.
**Alluvial soils are included in this textural class; areas are in parenthesis.
+Marshes are included in the textural class; areas are in parenthesis.

Table IV-2. Areal extent of soils grouped according to slope categories, permeability of surface soil (A horizon) and hydrologic soil group for the 48 subwatersheds in the Menomonee River Watershed

Subwatershed*	Area, ha	Area** (ha) of soils with slope (%) of					Area (ha) of soils with permeability (cm/hr) of.				Area (ha) of soils under hydrologic soil group		
		0-2	2-6	6-12	12-20	20-30	0 5-2 0***	2.0-6 4+	6.4-12 7	12 7-25 4++	B+	C	D++
12A	429	270	127	27	4	1	7	347	75	0	188	125	116
12B	1,199	676	343	123	35	2	21	994	183	1	824	120	255
12C	571	316	198	47	2	0	19	418	134	0	333	80	158
12D	981	631	278	71	1	0	10	702	269	0	504	172	305
12E	1,592	853	604	115	18	2	140	1,190	262	0	166	985	441
Sub total	4,772	2,746	1,550	383	60	5	197	3,651	923	1	2,015	1,482	1,275
10A	600	183	318	48	0	1	12	453	135	0	2	445	153
10B	459	71	289	33	5	0	6	449	4	0	50	392	17
10C	501	279	194	23	5	0	53	395	53	0	95	234	172
10D	1,611	668	572	191	119	31	41	1,369	200	1	892	380	339
10E	854	455	340	51	5	0	52	717	82	3	180	503	171
Sub total	4,025	1,656	1,713	346	134	32	164	3,383	474	4	1,219	1,954	852
7A	981	167	524	120	9	0	150	831	0	0	86	678	217
7B	821	294	337	66	3	0	56	719	42	4	135	530	156
7C	718	85	587	46	0	0	0	714	0	4	24	630	64
7D	1,406	204	1,012	129	13	0	43	1,264	99	0	56	1,166	184
7E	301	130	143	18	5	0	0	298	3	0	47	244	9
7F	832	204	494	63	12	0	47	725	59	0	31	595	206
7G	1,343	348	633	200	33	1	126	1,185	30	2	199	938	206
7H	251	25	179	9	0	0	13	238	0	0	7	232	12
Sub total	6,652	1,457	3,909	651	75	1	435	5,974	233	10	585	5,013	1,054
11A	527	241	242	29	5	0	0	456	71	0	29	376	122
11B	852	364	372	97	13	0	0	815	37	0	173	576	103
11C	765	353	292	109	11	0	0	567	198	0	99	440	226
Sub total	2,144	958	906	235	29	0	0	1,838	306	0	301	1,392	451
9	554	82	277	16	1	0	177	371	6	0	15	350	189
8A	599	101	389	26	1	0	50	549	0	0	36	423	140
8B	852	295	352	106	5	0	77	775	0	0	80	672	100
8C	1,011	436	396	59	6	0	38	933	40	0	136	741	134
Sub total	2,462	832	1,137	191	12	0	165	2,257	40	0	251	1,836	374
6A	970	61	571	139	6	0	56	906	8	0	47	852	71
6B	1,235	238	568	104	1	0	102	1,034	94	.5	166	798	270
6C	743	107	383	190	10	0	15	724	4	0	74	569	100
6D	669	148	331	110	13	0	10	605	54	0	71	469	129
6E	975	358	506	65	15	5	5	699	269	1	111	543	321
6F	293	118	137	30	4	0	0	197	97	0	43	138	113
Sub total	4,885	1,030	2,496	638	49	5	188	4,165	526	6	512	3,369	1,004
4A	56	0	27	1	0	0	28	28	0	0	0	29	28
4B	54	1	53	0	0	0	0	54	0	0	0	54	0
4C	314	8	282	0	0	0	0	314	0	0	0	314	0
4D	458	70	344	14	1	0	20	418	20	0	0	396	61
Sub total	882	79	706	15	1	0	48	814	20	0	0	793	89
3A	173	22	93	47	5	0	0	173	0	0	34	139	0
3B	432	11	335	6	2	0	40	392	0	0	24	366	42
3C	224	13	126	23	0	0	8	216	0	0	38	176	10
3D	604	67	365	4	5	0	140	464	0	0	12	412	160
3E	229	32	87	18	0	0	78	151	0	0	33	104	92
3F	495	36	384	22	7	0	46	448	1	0	4	410	80
3G	151	1	65	0	0	0	85	66	0	0	0	68	83
3H	602	26	476	10	0	0	82	520	0	0	27	488	88
Sub total	2,910	208	1,931	130	19	0	479	2,430	1	0	192	2,163	555
Total	29,286	9,048	14,625	2,605	380	43	1,853	24,883	2,529	21	5,090	18,352	5,843

*Subwatersheds 1A, 1B, 2, 5, 19 and portions of 3A, 3B, 4B, 4C, 4D and 6B with an aggregate area of 5,983 ha are highly urbanized, no soils data available

**Does not include areas of filled lands, dump, gravel pit lakes, etc where no slope was assigned, aggregate area of these land categories is 2,585 ha

***Includes areas of made land filled with clay materials

+Includes areas of made land filled with loamy materials

++Includes areas of made land filled with sand and gravel

+++Hydrologic soil group A is present but area is negligible

-Includes areas of made land tilled with sand and loamy materials

--Includes areas of made land tilled with clay materials

soil, determines to a large extent the amount of water available for overland flow during storm events. Generally, fine-textured soils exhibit lower permeability than coarse-textured soils. Most of the soils in the subwatersheds have low permeability (2.0 to 6.4 cm/hr) in their A horizons. Soils with very low permeability (0.5 to 2.0 cm/hr) and moderate to high permeability (> 6.4 cm/hr) are not widespread.

Soils in the subwatersheds were classified into hydrologic groups as defined earlier (Part III). Group C soils are dominant in most of the subwatersheds followed in order of importance by Group D soils (Table IV-2). Soils in these groups have high runoff potential because of low infiltration rate, low permeability and poor internal drainage.

Land Use

The Menomonee River Watershed features a variety of land uses. Aggregation into 14 land use categories by subwatersheds were made for the 1975 SEWRPC land use inventory (Table IV-3). Land development occurs in almost all of the subwatersheds although the degree of development is more pronounced in several upper subwatersheds. Row croplands are found mostly in the upper subwatersheds. Generally, the lower subwatersheds are highly urbanized while the upper ones are essentially rural. Greater changes in land use would be expected in the upper subwatersheds due to urbanization brought about by increasing population pressure.

The kinds and amounts of land-derived pollutants depend on the land use as affected by man's activities, degree of imperviousness, soil texture, degree of erodibility and slope. While slope and soil texture are the predominant factors in rural subwatersheds, the main factor governing inputs from urban and urbanizing subwatersheds is likely to be degree of imperviousness of the land surface. The degree of imperviousness associated with the subwatersheds ranges from 2 to 70% (Table IV-3). More impervious areas are located in the lower subwatersheds which is indicative of the variation in extent of urban development in the Watershed as a whole.

Soil Erosion Potential

An analysis was made by SEWRPC (2) to identify the spatial variation of erosion potential in the Menomonee River Watershed using the Universal Soil Loss Equation (USLE) as the basic analytical tool. The USLE (3) predicts primarily long-term average annual soil erosion potential from a parcel of land having a given combination of the various natural and man-made features and is limited to the erosion caused by rainfall in rill and inter-rill areas. It does not necessarily predict the amount of soil and other particulate matter moving from the land surface to the receiving waters. The USLE was applied within the context of the Land DMS.

The USLE and definition of the various terms within the equation are

Table IV-3. Land use categories (1975) in the 48 subwatersheds of the Menomonee River Watershed

No.	Area, ha	Land use* distribution, %													Imperviousness, %	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	Connected
12A	429	0 4	3.3	0	6.7	8.7	0.7	7 8	17	48	2.6	0.4	0	0	4 0	17	6
12B	1,200	4.3	3.2	1 9	0.3	6.2	1.6	3.6	36	29	6 0	7.0	0.5	0	0 2	7	1
12C	571	0.6	1.8	0	0	9 6	1.9	1 4	31	38	9 4	4.8	0.5	0	0 4	8	1
12D	981	0	2 4	0	0	3.5	1 5	0.3	45	32	12	3 2	0.3	0	0	2	1
12E	1,592	0	0.7	0	0	4.3	1.4	0 4	31	30	24	8 6	0.2	0	0	2	1
10A	599	0 2	4.0	0	2.0	37	0 2	4.4	1.3	25	1 3	24	0	0 2	0.6	23	12
10B	459	1.1	4.6	5 9	1.8	36	2.5	1 9	15	25	4.5	0.3	0	0	1 0	28	2
10C	502	0.1	3.1	2.7	0	9.6	1.4	1 8	31	32	13	5.3	0	0	0	7	1
10D	1,610	1.8	1.1	2.2	0.1	12	1.4	5 9	19	38	13	4.4	0.2	0	0.5	8	2
10E	853	0	0.2	0.8	0	14	1.2	1.7	37	26	8.5	11	0	0	0 1	6	2
7A	981	3.1	5.7	8.0	0	18	0.6	5.0	8.9	40	7.0	2 2	0	0	1 7	23	11
7B	820	5.9	5.9	2.7	0.4	6.8	1.3	1.5	18	51	2.8	0.8	0	2 6	0.6	11	1
7C	718	0	3.1	0	0.2	48	0.7	6.7	9.0	28	2.6	0.7	0	0	0	17	1
7D	1,406	1.1	3 2	0	0.1	56	0.4	6.5	5.1	19	3.6	5.0	0	0	0 3	18	1
7E	301	2.7	8.2	3.5	0	28	1.0	3.0	5.5	41	5.9	0	0	0	0.8	24	7
7F	832	1.1	6.6	0	0	24	0.9	4 9	21	37	3.9	0.4	0	0	0.2	12	1
7G	1,343	2.7	4.9	2 4	0.2	8.3	1.5	6 5	28	32	8.9	4.1	0.2	0	0 1	11	1
7H	251	0.2	8.3	0	4 5	65	0	4 6	0 1	16	0.4	1.3	0 1	0	0	34	17
11A	527	0	1.2	0	0	2.4	2 5	0.2	68	18	6.2	1.5	0	0	0.2	5	1
11B	852	0	0.2	0	0.2	7.6	1 4	2.7	33	38	10	4.0	0 8	0	1 5	5	2
11C	765	0	1.3	0	0	12	1.5	2.1	39	31	12	0.8	0.7	0	0	3	1
9	555	3.4	15	1.6	6.8	41	0.2	3.9	0.2	24	0.4	0.1	0	2.6	0.4	42	27
8A	599	0.1	2.0	7.7	2.9	36	0.4	4.5	2 6	40	3 1	0.6	0	0	0.5	26	10
8B	853	1.3	7.8	0	2.9	13	0.9	5 8	14	45	5.5	2.9	0	1 6	0	13	8
8C	1,011	2.2	9.8	0	1.9	4.3	1.0	6 2	26	28	13	6.9	0	0	0 4	12	1
6A	970	2.0	8.9	4.1	2.9	47	0	1.0	0	30	0.4	0	0	3.8	0 1	41	17
6B	1,323	4.5	15	5.7	2.6	41	0	2 8	0	26	0.8	1.0	0	0.3	0 6	39	12
6C	744	0.5	6.9	0	1.8	58	0.1	4 7	0	20	6.3	1.0	0	0	0 1	23	1
6D	669	5.1	1.0	0	1.3	53	0.4	4.9	0	24	4.4	6.3	0	0	0 1	14	-
6E	974	0	8.3	0	0	45	0.3	5.8	3 0	26	7.4	4.5	0	0	0.2	21	1
6F	294	0.3	4.3	0	0	25	0.3	0.1	0	50	10	10	0	0	0	10	1
4A	545	4.0	11	7.0	5.4	47	0	0.2	0	26	0	0	0	0	0	51	33
4B	752	2.5	9.1	0.4	2.3	69	0	0.4	0	16	0	0	0	0	0 3	48	30
4C	707	0.1	5.5	0	11	67	0	2 5	0	13	0	0	0	0	0.1	52	32
4D	799	0	6.4	2 7	5.1	49	0.1	5 2	1 9	25	1.7	1.1	0	1 6	0 1	32	20
3A	527	0.2	5.8	0	4.1	42	0	0.1	1.5	43	2.1	0	0	0	1 7	46	32
3B	940	1 3	4.5	0.2	5.0	69	0	0 3	0	19	0	0	0	0	0.7	51	30
3C	225	0	20	4.7	8.4	23	0	0.8	0	39	2.5	0	0	0	1 8	47	33
3D	605	15	24	2.1	0.5	26	0	1.4	0	30	1 1	0	0	0.1	0 6	51	18
3E	230	7 9	34	7.9	3 7	11	0	0.4	0	33	0 3	0	0	0.6	1 3	46	36
3F	496	3.0	17	1.9	9.1	32	0 1	2.4	0.6	33	0	0	0	0	0.6	46	30
3G	151	0 2	85	0	4.4	8 6	0	0	0	1.5	0	0	0	0	0	21	11
3H	642	8.1	15	1 2	4.4	32	0	1 8	0	37	0	0	0	0	0 7	47	30
5	175	0	5.6	0	0.4	87	0	2 0	0	5.3	0	0	0	0	0	55	33
2	182	0	7.2	0	3 3	77	0	0 2	0	13	0	0	0	0	0	56	34
1A	1,143	17	25	3.8	2.3	33	0.1	0	0	18	0	0	0	0	0.8	70	50
1B	389	8 3	18	5.9	5.5	40	0	0.2	0	18	0	0	0	3.2	0.8	59	41
1J	305	5.0	12	0	2.5	65	0	1.1	0	13	0	0	0	0.4	0.8	56	36
Total	34,397	2.6	7 3	1.8	1.9	29	0.7	3.1	14	29	5.7	3 1	0 1	0 3	0 4	24	11

*Land use categories are: 1-industrial, 2-commercial, 3-freeway (other roads are proportionately distributed among the other land uses), 4-high density residential, 5-medium density residential, 6-low density residential, 7-land under development, 8-row crops, 9-pasture and small grains, 10-forested land and woodlots, 11-wetlands, 12-feedlots, 13-landfill and dumps, 14-water areas (land use categories are described in Table III-5 found in (1)

as follows:

$$E = A \times R \times K \times LS \times C \times P$$

where:

E = soil loss by water erosion in rill and inter-rill areas (Tonnes/ha/yr).

A = area (ha).

R = a rainfall factor that accounts for the erosive forces of rainfall and runoff [EI (erodibility index) units/yr].

K = soil erodibility factor that reflects the physical and chemical properties of a particular soil (Tonnes/ha/EI unit).

LS = slope-length factor that reflects the effects of length and steepness of the land surface (dimensionless).

C = a cropping-management factor that reflects the influence of vegetation, mulch and the soil surface (dimensionless).

P = erosion control practice factor that is similar to the cropping-management factor but accounts for practices superimposed on the land surface such as contouring, terracing, compacting, sediment basins, and control structures (dimensionless).

Analysis of erosion potential by subwatersheds indicates high variability of erosion rate in the Watershed as a whole (Table IV-4). Based on area, most of the soils in the subwatersheds have low erosion potential (< 4.5 Tonnes/ha/yr). However, considerable soil areas have high erosion potential (> 4.5 Tonnes/ha/yr) particularly in the upper subwatersheds. The unit erosion potential ranges from 0.41 to 9.13 Tonnes/ha/yr; a variation of over 20 times for the 48 subwatersheds.

An examination of the terms of the USLE reveals that the unit erosion potential is determined largely by the soil erodibility factor (K), the slope-length factor (LS) and the cropping-management factor (C). The area-weighted values of these parameters are given in Table IV-4. Area weighted values for the K factor for the 48 subwatersheds range from 0.19 to 0.48 (maximum to minimum ratio is 2.5), the LS factor values range from 0.326 to 0.885 (ratio 2.7) and C factor from 0.011 to 0.145 (ratio 13). Considering the range in values of these factors it is likely that the cropping-management factor is the primary determinant of variations in unit potential erosion, followed in order of importance by the erodibility and slope-length factors.

The cropping-management factor is closely related to land uses (2). The highest cropping-management factors are associated with land uses such as agriculture (0.08), land fills and dumps (1.00), extractive areas (1.00), and land under development (1.00). All other land uses have cropping

Table IV-4. Areal extent of soils grouped according to erosion potential predicted by the Universal Soil Loss Equation and annual unit erosion potential for the 48 subwatersheds in the Menomonee River Watershed

Subwatershed*	Area, ha	Area (ha) of soils with erosion potential (Tonnes/ha/yr) of:						Erosion potential		Area-weighted parameters**		
		0-4.5	4.5-9	9-13.5	13.5-18	18-25	>25	Tonnes/yr	Tonnes/ha/yr	K	LS	C
12A	429	325	76	21	2	2	3	1,334	3.10	0.33	0.508	0.063
12B	1,199	793	272	68	35	8	23	6,148	5.12	0.37	0.599	0.095
12C	571	441	95	15	11	4	5	1,906	3.34	0.30	0.539	0.069
12D	981	722	194	43	14	4	4	3,396	3.46	0.34	0 505	0.069
12E	1,592	918	457	149	35	16	17	7,861	4.94	0.39	0.560	0.064
Sub total or mean	4,772	3,199	1,094	296	97	34	52	20,645	4.32	0.36	0.551	0.073
10A	600	463	60	25	10	10	32	3,359	5.60	0.35	0.569	0.068
10B	459	301	92	35	7	16	8	2,047	4.47	0.39	0.619	0.052
10C	501	322	118	38	12	1	10	2,384	4.75	0.42	0.517	0.072
10D	1,611	1,012	317	95	54	30	103	13,659	8.48	0.34	0.696	0.120
10E	854	498	225	71	19	16	25	5,038	5.90	0.40	0.527	0.077
Sub total or mean	4,025	2,596	812	264	102	73	178	26,487	6.58	0.37	0.610	0.089
7A	981	631	156	100	36	12	46	6,946	7.08	0.44	0.673	0.073
7B	820	524	172	59	20	20	25	4,323	5.27	0.36	0.554	0.145
7C	718	373	190	72	23	11	49	5,187	7.22	0.48	0.692	0.083
7D	1,406	940	201	80	30	26	129	11,246	8.00	0.47	0.720	0.091
7E	301	221	43	20	9	4	4	1,188	3.94	0.44	0.608	0.049
7F	832	438	234	94	29	13	24	5,098	6.13	0.42	0.612	0.075
7G	1,343	664	407	134	51	55	32	8,683	6.47	0.40	0.694	0.069
7H	251	208	6	3	5	5	24	1,636	6.52	0.40	0.641	0.065
Sub total or mean	6,652	3,999	1,409	562	203	146	333	44,307	6.66	0.43	0.663	0.085
11A	527	298	173	36	15	4	1	2,418	4.60	0.44	0.522	0.068
11B	852	489	212	61	31	17	42	7,775	9.12	0.42	0.608	0.110
11C	765	451	151	79	33	19	32	5,223	6.83	0.43	0.616	0.077
Sub total or mean	2,144	1,238	536	176	79	40	75	15,416	7.19	0.43	0.589	0.088
9	554	515	11	5	2	5	15	1,355	2.45	0.31	0.459	0.066
8A	599	421	65	19	9	16	69	5,371	8.98	0.39	0.572	0.118
8B	852	453	248	68	35	16	32	6,516	7.65	0.42	0.621	0.092
8C	1,011	642	268	46	21	19	15	4,794	4.75	0.40	0.480	0.077
Sub total or mean	2,462	1,516	581	133	65	51	116	16,681	6.78	0.40	0.551	0.092
6A	970	882	30	9	12	14	23	2,533	2.60	0.37	0.692	0.072
6B	1,235	1,112	32	15	14	13	49	4,844	3.92	0.32	0.531	0.049
6C	743	625	18	23	15	18	44	4,467	6.01	0.43	0.885	0.062
6D	669	512	39	24	17	13	63	5,689	8.50	0.40	0.713	0.129
6E	975	796	75	25	16	16	50	4,516	4.64	0.35	0.586	0.072
6F	293	266	8	9	3	1	6	770	2.62	0.27	0.621	0.033
Sub total or mean	4,885	4,193	202	103	77	75	235	22,809	4 67	0.36	0.658	0.056
4A	56	56	0	0	0	0	0	23	0.40	0.24	0.389	0.011
4B	54	52	0	0	1	0	1	96	1 78	0.49	0.766	0.015
4C	314	277	6	3	3	7	18	1,304	4.14	0.46	0.688	0.061
4D	458	328	29	17	20	27	37	3,074	6.71	0.45	0.642	0.107
Sub total or mean	882	713	35	20	24	34	56	4,497	5.09	0.44	0.650	0 079
3A	173	169	2	1	1	0	0	257	1.48	0.43	0.872	0.018
3B	432	417	7	4	2	0	2	498	1.15	0.38	0.616	0.013
3C	224	210	8	1	1	1	3	386	1.72	0.33	0.584	0 023
3D	604	597	1	1	1	1	3	437	0.72	0.34	0.491	0.014
3E	229	223	2	1	1	1	1	210	0.91	0.26	0.459	0.021
3F	495	464	7	8	3	4	9	1,104	2.23	0 43	0.626	0.024
3G	151	150	0	0	0	0	1	79	0.52	0.19	0.326	0 012
3H	602	600	0	0	0	2	0	473	0.78	0.41	0.574	0.011
Sub total or mean	2,910	2,830	27	16	9	9	19	3,444	1.18	0.37	0.568	0.016
Total or mean	29,286	20,799	4,707	1,575	658	467	1,079	155,641	5.31	0.39	0.608	0.072

*Subwatersheds 1A, 1B, 2, 5, 19 and portions of 3A, 3B, 3H, 4A, 4B, 4C, 4D and 6B with an aggregate area of 5,983 ha are highly urbanized; no soils data available.

**K is erodibility factor; LS is slope-length factor; C is cropping factor.

management factors of 0.01 or less. It is apparent that land uses associated with high C values have high erosion potential.

Subwatersheds 11B, 8A, 6D, 10D, 7D and 8B have the highest unit erosion potential. The high erosion rates in these subwatersheds are generally associated with agriculture and/or land under development (Table IV-3).

REFERENCES - IV

1. Simsiman, G. V., J. Goodrich-Mahoney, G. Chesters and R. Bannerman. Land Use, Population and Physical Characteristics of the Menomonee River Watershed. Part III: Description of the Watershed. Final Report of the Menomonee River Pilot Watershed Study, Vol. 2, U.S. Environmental Protection Agency, 1979.

2. Southeastern Wisconsin Regional Planning Commission. Spatial Variations of Erosion Potential in the Menomonee River Watershed as Determined by the Universal Soil Loss Equation. SEWRPC Staff Memorandum, 1977.

3. Wischmeier, W. H. Use and Misuse of the Universal Soil Loss Equation. J. Soil Water Conserv. 31 (1):5-9, 1976.

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University of Wisconsin System Water Resources Center and the Southeastern Wisconsin Regional Planning Commission

16. ABSTRACT

The Menomonee River Watershed is described in order to establish a factual base upon which to draw conclusions concerning the interactions of the ecosystem and the impact of water quality. The description includes natural and cultural features such as population, land use, climate, physiography and geology, soils and water storage areas. Also included in the description are the characteristics and management practices existing in the drainage areas of the mainstream and predominantly single land use monitoring sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

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