ENVIRONMENTAL SETTING OF BENCHMARK STREAMS IN AGRICULTURAL AREAS OF EASTERN WISCONSIN

By S.J. Rheaume, J.S. Stewart, and Bernard N. Lenz

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

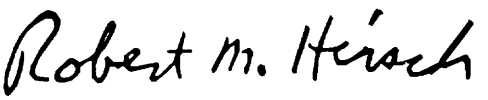
- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
meter (m)	3.281	feet
square kilometer (km^2)	0.3861	square mile
hectare	2.471	acre
meter per second (m/s)	3.281	foot per second
cubic meter per second (m^3/s)	35.31	cubic foot per second

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$°F = 1.8\ (°C) + 32.$

Abbreviated water-quality units: Chemical concentrations are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical values expressed as mg/L and µg/L are approximately the same as for concentrations in parts per million and parts per billion, respectively.

Specific electrical conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

The abbreviation "pH" represents the negative base-10 log of the hydrogen-ion activity in moles per liter.

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Environmental Setting of Benchmark Streams in Agricultural Areas of Eastern Wisconsin

By S.J. Rheaume, J.S. Stewart, *and* B.N. Lenz

Abstract

This report describes the environmental setting of 20 benchmark streams in agricultural areas of eastern Wisconsin that are part of the Western Lake Michigan Drainages, National Water-Quality Assessment Program. Benchmark streams are defined as those that show minimal adverse effects from human activity, and they were selected on the basis of field reconnaissance and the following criteria: (1) available invertebrate or fisheries data that indicated good to excellent water quality, (2) instream habitat restoration for fisheries enhancement, and (3) land management to protect riparian vegetation. Information gathered from these benchmark sites can be used as a standard of reference to compare the health of other streams in agricultural areas on the basis of aquatic-biota communities, habitat, and water-quality characteristics. The information included in this report serves as background information that will be useful for a series of studies at these benchmark-stream sites in the Western Lake Michigan Drainages study unit as part of the National Water-Quality Assessment Program.

Four relatively homogeneous units (RHU's) in agricultural areas that differed in bedrock and surficial geology were selected for study. RHU 1 (clayey surficial deposits over carbonate bedrock) and RHU 3 (sandy-till surficial deposits over carbonate bedrock) are in adjacent agricultural areas in the Southeastern Wisconsin Till Plains ecoregion. RHU 20 (sandy/sand and gravel surficial deposits over igneous and metamorphic bedrock) and RHU 26 (sandy/sand and gravel surficial deposits over sandstone bedrock) are in adjacent areas of agriculture and mixed forests in the North Central Hardwood Forests ecoregion.

Differences in land use/land cover, and riparian vegetation and instream habitat characteristics are presented. Summaries of field measurements of water temperature, pH, specific conductance and concentrations of dissolved oxygen, total organic plus ammonia nitrogen, dissolved ammonium, nitrate plus nitrite as nitrogen, total phosphorus, dissolved orthophosphate, and atrazine are listed. Concentrations of dissolved oxygen for the sampled streams ranged from 6.4 to 14.3 and met the standards set by the Wisconsin Department of Natural Resources (WDNR) for supporting fish and aquatic life. Specific conductance ranged from 98 to 753 µScm with values highest in RHU's 1 and 3, where streams are underlain by carbonate bedrock. Median pH did not vary greatly among the four RHU's and ranged from 6.7 to 8.8 also meeting the WDNR standards. Concentrations of total organic plus ammonia nitrogen, dissolved ammonium, total phosphorus, and dissolved orthophosphate show little variation between streams and are generally low, compared to concentrations measured in agriculturally-affected streams in the same RHU's during the same sampling period. Concentrations of the most commonly used pesticide in the study unit, atrazine, were low in all streams, and most concentrations were below the 0.1 µg/L detection limit. Riparian vegetation for the benchmark streams were characterized by lowland species of the native plant communities described by John T. Curtis in the "Vegetation of Wisconsin." Based on the environmental setting and water-quality information collected to date, these streams appear to show minimal adverse effects from human activity.

INTRODUCTION

In 1991, the U.S. Geological Survey began full-scale implementation of the National Water-Quality Assessment (NAWQA) Program. The objectives of the NAWQA Program are to (1) describe current water-quality conditions for a large part of the Nation's freshwater streams and aquifers, (2) describe trends in water quality over time, and (3) improve understanding of the primary natural and human factors that affect water-quality conditions. This information will be useful for planning future management actions and examining their likely consequences. In all, 60 study units are planned to begin activities on a staggered time scale. The Western Lake

Michigan Drainages was selected as one of 20 study units to begin data collection and analysis in 1991.

The effect of agriculture on stream biota is an important issue in the Western Lake Michigan Drainages. Although numerous studies of the aquatic biota and habitat of agriculturally-affected streams have been done in the areas encompassed by the study unit, very few studies have focused on defining the composition of healthy stream communities that have been largely unaffected by human activity. In order to measure the effects of improvements in agricultural practices on stream communities or the extent of degradation at affected sites, standards are needed from which comparisons can be made. In response to this need for standards of comparison, a set of 20 stream sites were investigated where physical and chemical conditions appear to be less affected by the agricultural activity that generally dominates land use in the drainage basins above the sites. In this report, these relatively unaffected streams are referred to as "benchmark streams." The environmental setting of these benchmark stream sites including ecoregion classification, percent land use/land cover, riparian vegetation classification, and hydrologic and physical characteristics are presented in this report.

Purpose and Scope

This report provides information on the location and environmental setting of 20 benchmark stream reaches in agricultural areas of eastern Wisconsin. The streams were sampled from June 1993 through July 1995. The physical and chemical conditions of these streams and their basins are discussed, including any evidence of adverse effects of human activity on stream biota. Information is provided on other ecoregion and ecosystem classifications to RHU's, geology, riparian and instream-habitat characteristics, land use/land cover, and selected water-quality measurements at these locations. This information will be used to establish the environmental setting of these benchmark stream reaches and help determine if these sites show minimal adverse effects from human activity.

Associations between general stream water-quality conditions and the environmental factors that are used to define RHU's are discussed. This environmental setting report forms the basis for future work that will describe how these factors, bedrock geology, texture of surficial deposits, and land use/land cover, affect habitat and aquatic biota communities, if at all, and whether perceived effects can be quantified.

Western Lake Michigan Drainages Study Unit

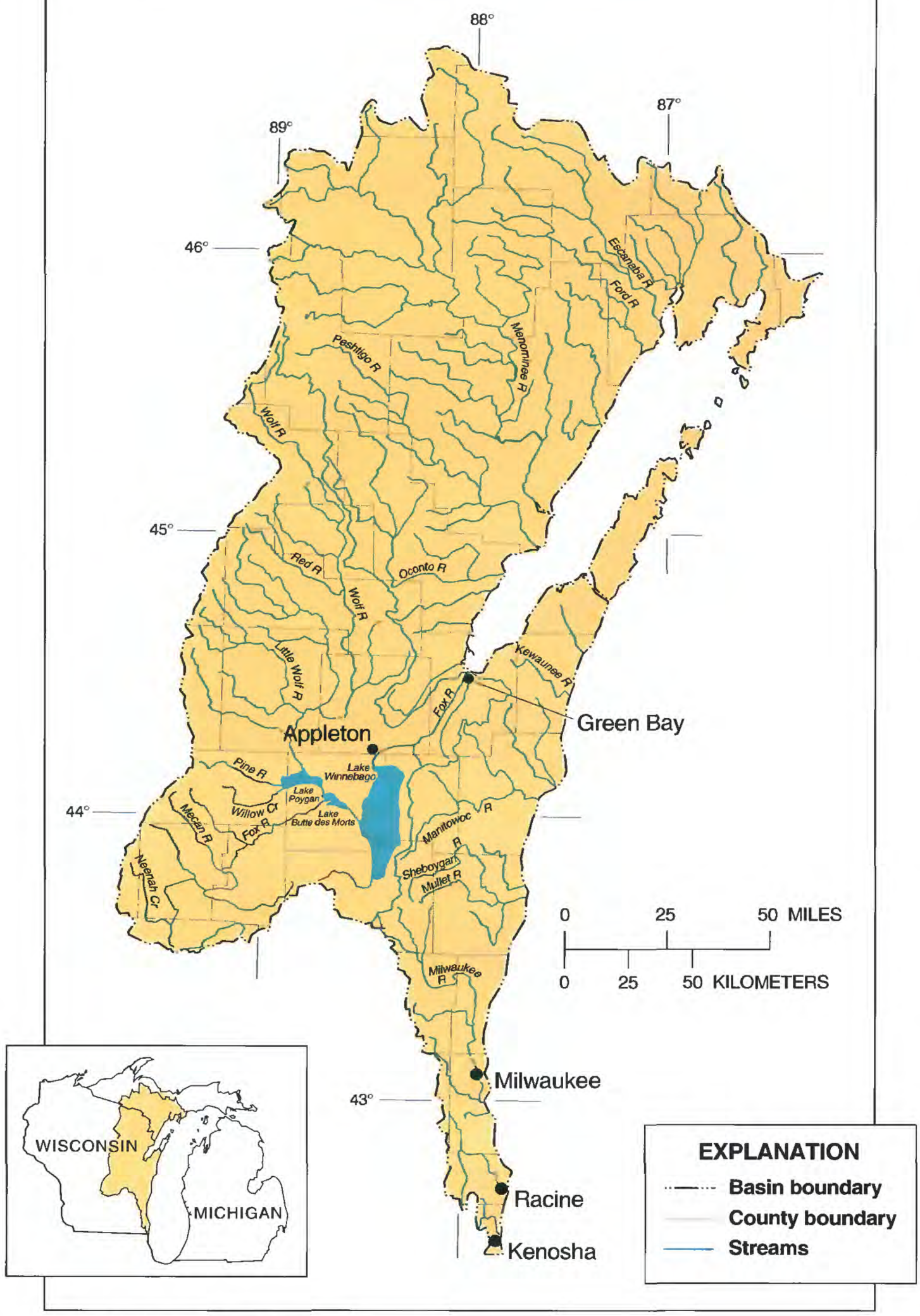
The Western Lake Michigan Drainages study unit encompasses 51,541 km^2 of eastern Wisconsin and the Upper Peninsula of Michigan (fig. 1). Ten major rivers drain the study unit: the Escanaba and Ford Rivers in Michigan; the Menominee River, which partially defines the state boundary between Wisconsin and Michigan; the Peshtigo and Oconto Rivers in northeastern Wisconsin; the Fox/Wolf River complex in east-central Wisconsin, which drains into Green Bay; and the Manitowoc, Sheboygan, and Milwaukee Rivers, which drain the southeastern part of the study unit.

The overall population in the study unit is 2,435,000 (U.S. Bureau of the Census, 1991) with urban land use accounting for less than 4 percent of the area. The major cities and their populations are Milwaukee, 628,000; Green Bay, 96,000; Racine, 84,000; Kenosha, 80,000; and Appleton, 66,000. Agriculture accounts for 37 percent of the land use in the study unit and is devoted almost exclusively to cropland and pasture for dairy production (fig. 2). About 40 percent of the study unit, predominantly in the northwestern part, is forested. Streams and lakes throughout the study unit offer excellent fishing, boating, and other recreational opportunities. Lake Winnebago, a 55,442-hectare lake in the Fox River Basin, is a major surface-water feature of the study unit. About 15 percent of the study unit is classified as wetlands.

To isolate the effects of individual environmental factors on water quality, the Western Lake Michigan Drainages were divided into 28 relatively homogeneous units (RHU) on the basis of bedrock geology, texture of surficial deposits, and land use/land cover (fig. 3). A detailed description of each RHU can be found in Robertson and Saad (1995).

In addition to use of the RHU classification, regional ecological patterns in the study unit can be described in terms of two other ecoregion or landscape classification systems, both of which are recognized regionally or nationally by scientists and environmental-resource managers. Each ecoregion or landscape unit in these two systems is considered to be an area of relative ecological homogeneity.

The ecoregion classification of Omernik and Gallant (1988) divides the study unit into four ecoregions (fig. 4) on the basis of land use, land-surface form, potential natural vegetation, and soils. The thematic maps that were used as components for the ecoregions are available nationally and are small scale (1:7,500,000). This system was developed for the states of Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana, and Ohio and grew out of an effort to improve classification of streams for more effective water-quality management.



Source: Seaber and others, 1986

Figure 1. Western Lake Michigan Drainages study unit of the National Water-Quality Assessment Program.

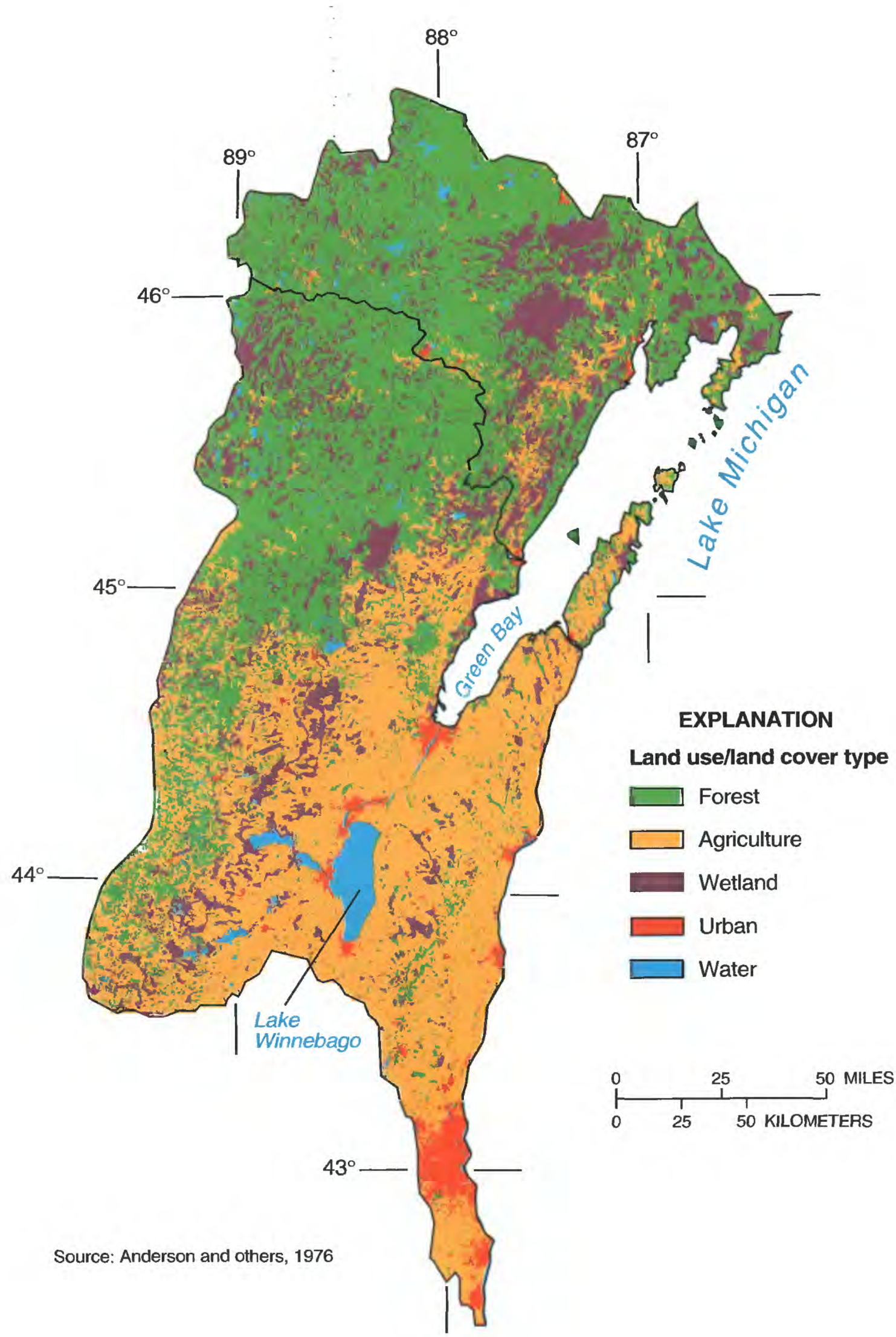
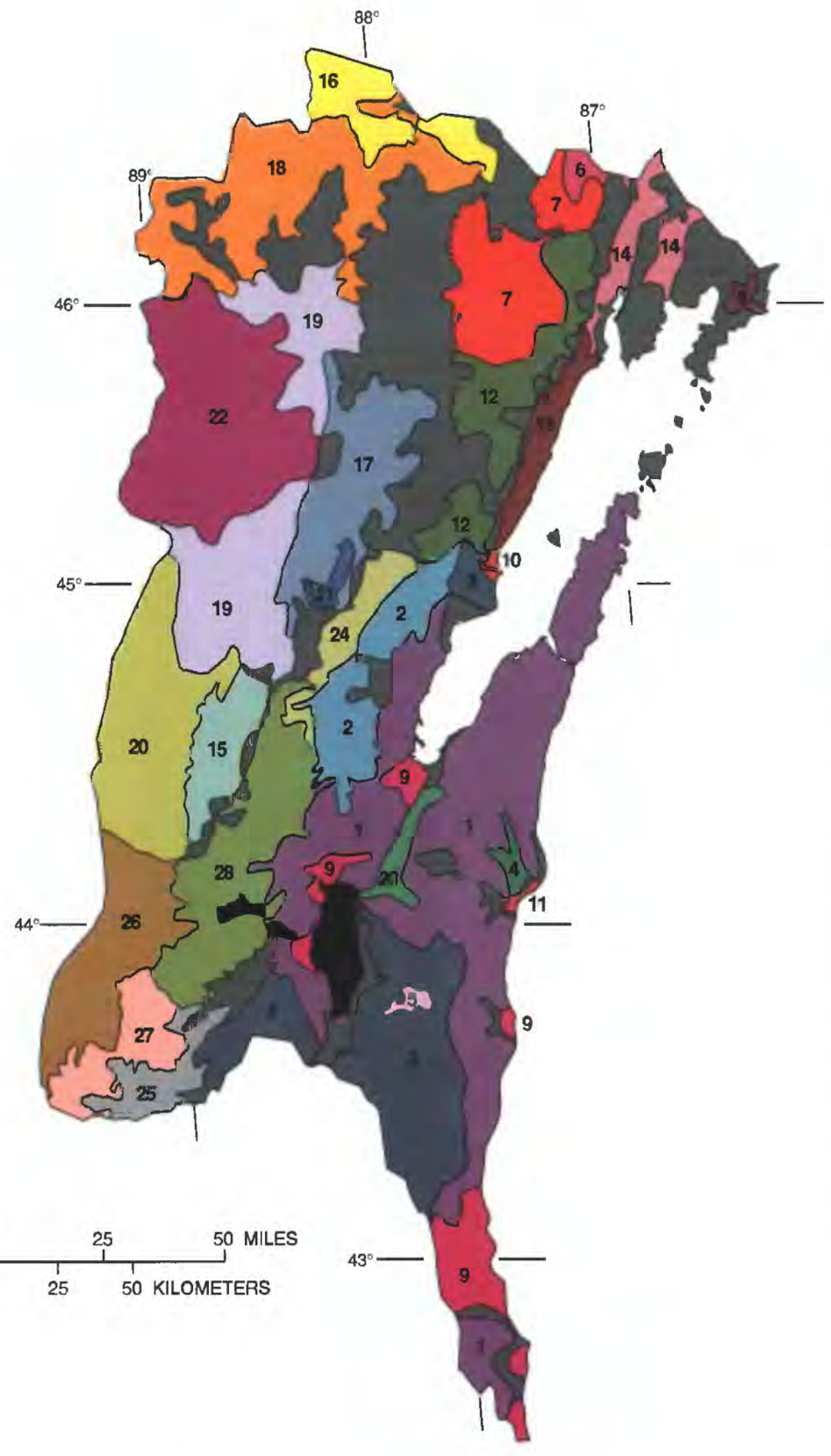


Figure 2. Generalized land use/land cover in the Western Lake Michigan Drainages study unit.



EXPLANATION

Relatively Homogeneous Unit (RHU) and number —

Characteristics listed for each RHU are bedrock, land use, and surficial deposit, separated by commas. Abbreviations are as follows: Carb, carbonate; IgMet, igneous and/or metamorphic; Shle, shale; Snds, sandstone; Ag, agriculture

- Mixed areas
- (1) Carb, Ag, clayey
- (2) Carb, Ag, loamy
- (3) Carb, Ag, sandy
- (4) Carb, Ag, sand and gravel
- (5) Carb, Ag/wet forest, sandy
- (6) Carb, dry forest, loamy
- (7) Carb, wet forest, loamy
- (8) Carb, wet forest, sandy/sand and gravel
- (9) Carb, urban, clayey
- (10) Carb, urban, sandy
- (11) Carb, urban, sand and gravel
- (12) Carb, Ag/wet forest, loamy
- (13) Carb, wet forest, sandy
- (14) Carb, wet forest, sandy/sand and gravel
- (15) IgMet, Ag, loamy/sand and gravel
- (16) IgMet, dry forest, loamy
- (17) IgMet, dry forest, loamy/sand and gravel
- (18) IgMet, dry forest, sandy
- (19) IgMet, dry forest, sandy/sand and gravel
- (20) IgMet, dry forest/Ag, sandy/sand and gravel
- (21) IgMet, wet forest, clayey
- (22) IgMet, wet forest, sandy/sand and gravel
- (23) Shle, Ag, clayey
- (24) Snds, Ag, loamy
- (25) Snds, Ag, sandy
- (26) Snds, dry forest/Ag, sandy/sand and gravel
- (27) Snds, wet Ag, clayey/sandy
- (28) Snds, wet Ag, clayey
- Open water

Figure 3. Relatively homogeneous units in the Western Lake Michigan Drainages study unit.

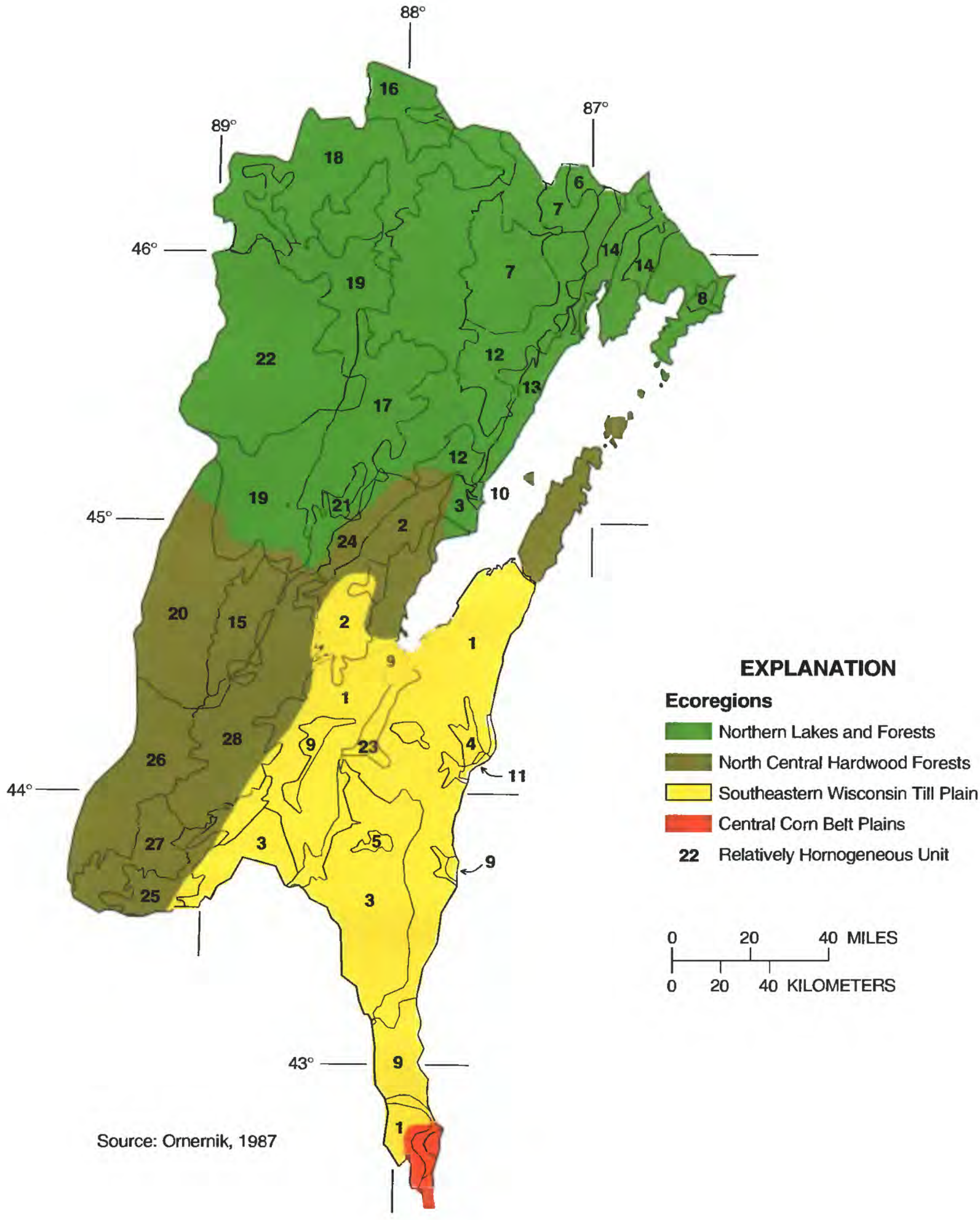


Figure 4. Relatively homogeneous units in the Western Lake Michigan Drainages study unit superimposed on ecoregions of the Upper Midwest states (Omernik and Gallant, 1988).

A more recent and finer scale landscape ecosystem classification developed by Albert (1995) divides the Western Lake Michigan Drainages into 3 sections, at the most general level and into 18 sub-subsections, at the most detailed level (fig. 5). Divisions are made according to a hierarchical classification involving climate, physiography, soils, and vegetation. This system differs from that of Omernik and Gallant in that climate is incorporated and larger scale regional maps (1:100,000 –1:1,000,000) are used to define landscape components. This classification system was developed for the states of Minnesota, Wisconsin, and Michigan, and was a result of an attempt to subdivide the three states into smaller, more uniform areas for the purpose of biological study, inventory, and management.

ENVIRONMENTAL SETTING OF BENCHMARK STREAMS

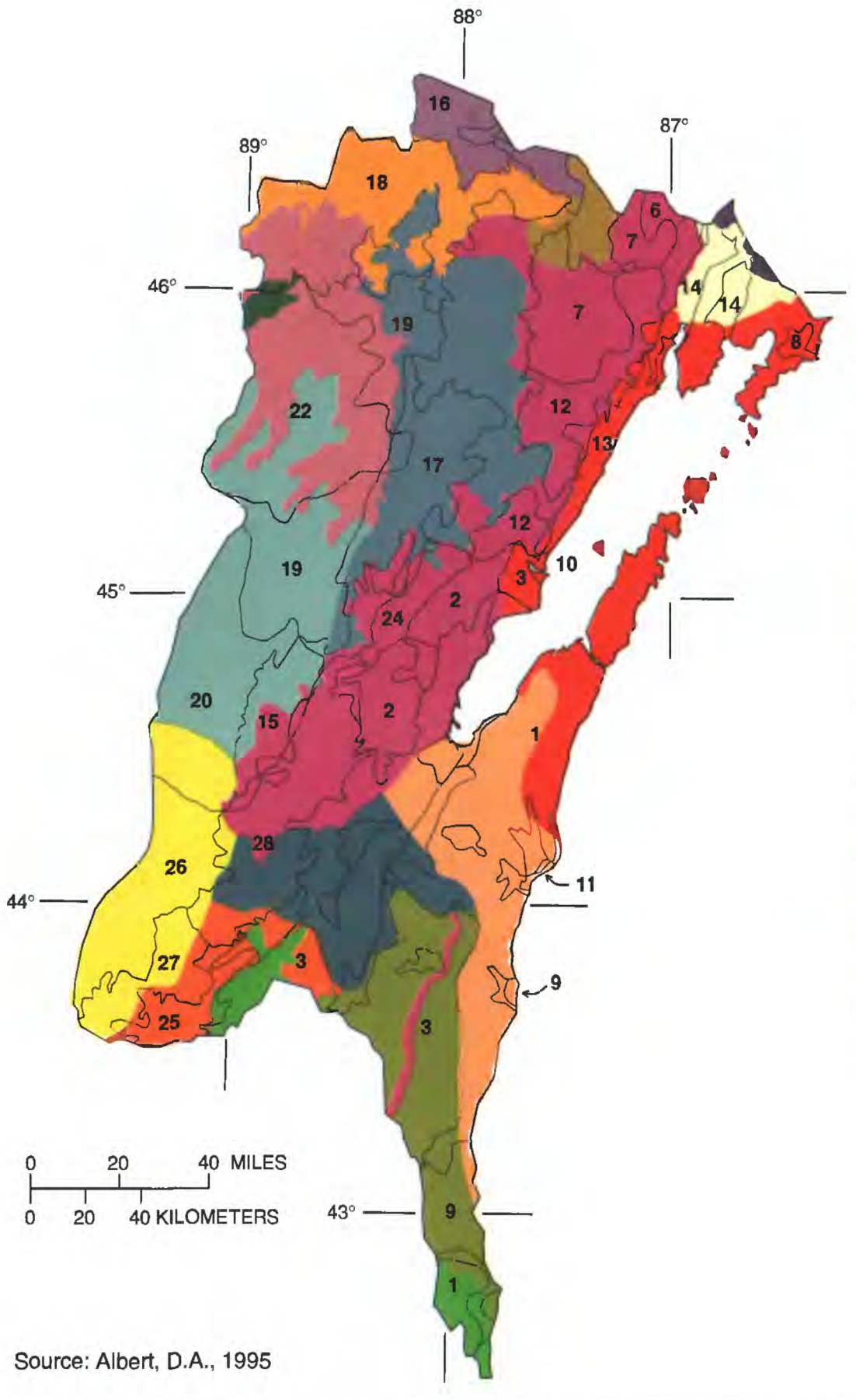
Four of the largest RHU's in the study unit (1, 3, 20, and 26) are in areas of significant agricultural land use and were selected as the focus of this report. The selected RHU's differ geologically by bedrock type and by composition and texture of surficial deposits.

RHU 1 (clayey surficial deposits over carbonate bedrock) and RHU 3 (sandy-till surficial deposits over carbonate bedrock) are in adjacent agricultural areas predominantly in the Southeastern Wisconsin Till Plains ecoregion (Omernik and Gallant, 1988); small parts of RHU 1 are in the North Central Hardwood Forests and the Central Cornbelt Plains ecoregions (fig. 4; table 1 in supplemental data section). The streams selected for sampling in RHU 1 include Casco Creek, Hibbard Creek, Krok Creek, Little Scarboro Creek, and Tisch Mills Creek. The streams selected for sampling in RHU 3 include East Branch Milwaukee River, Mullet River, Nichols Creek, and Watercress Creek. Although both RHU's are predominantly in one ecoregion, they are distinguished from each other by surficial deposits. Dairy and livestock farming is the predominant land use in RHU's 1 and 3, and most cropland is dedicated to the cultivation of forage and feed grains. Cash crops in this area include onions, mint, sweet corn, snapbeans, peas, and other vegetables. In a few locations where soils are somewhat sandy, fruits and other orchard crops are grown (Omernik and Gallant, 1988).

RHU 20 (sandy/sand and gravel surficial deposits over igneous and metamorphic bedrock) and RHU 26 (sandy/sand and gravel surficial deposits over sandstone bedrock) are in adjacent areas of mixed forest and agriculture and in the North Central Hardwood Forests ecoregion (Omernik and Gallant, 1988; table 1 in supplemental data section). The streams selected for sampling in RHU 20 include Camp Creek, Silver Creek, Smith Creek, West Branch Red River, and Whitcomb Creek. The streams selected for sampling in RHU 26 include Chaffee Creek, Lawrence Creek, Mecan River, Neenah Creek, Pine River, and Willow Creek. Although these RHU's are in the same ecoregion, they are distinguished from each other by the underlying bedrock geology. The North Central Hardwood Forests ecoregion is a transitional area between the Northern Lakes and Forests ecoregion and the agricultural ecoregions to the south. Although agriculture is common in this ecoregion, it is less prevalent and takes up proportionally less land than in the Southeastern Wisconsin Till Plains. Agricultural land use in RHU's 20 and 26 is mixed. Most of the agricultural land in RHU 20 and RHU 26 provides feed for dairy cattle or is permanent pasture; however, snapbeans, sweet corn, and other vegetable crops are commonly grown under irrigation. Poultry farms are concentrated in a few areas. The areas that remain forested are used as woodlots or for pulp and timber production (Omernik and Gallant, 1988). The representative plant communities that characterize the benchmark-stream riparian habitat within these RHU's are described by Curtis (1987). Curtis divides Wisconsin into two provinces that are separated by a narrow band, called the tension zone, that extends from the northwest corner to the southeast corner of the state. The tension zone can be defined as the northern limit of certain plant species that are present in southern Wisconsin and the southern limit of certain plant species that are present in northern Wisconsin. Therefore, the tension zone is characterized by plant species from both provinces. Many of the same plant species are distributed throughout the state, in the northern and southern provinces, and in the tension zone.

All benchmark streams in RHU 26 are in the southern province, which can be characterized by plant species from either the Southern Lowland Forest community or the Shrub-Carr community (Curtis, 1987). Species that dominate the Southern Lowland Forest community include silver maple (*Acer saccharinum*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), river birch (*Betula nigr*a), green ash (*Fraxinus pennsylvanica* var. *subintegerrima*), basswood (*Tilia americana*) and black ash (*Fraxinus nigra*). Species that dominate the Shrub-Carr community include red-osier dogwood (*Cornus stolonifera*), pussy willow (*Salix discolor*), meadowsweet (*Spiraea alba*), Bebb willow (*Salix bebbiana*), and slender willow (*Salix petiolaris*).

All benchmark streams in RHU 1 and RHU 20 are in the northern province, which can be characterized by plant species from either the Northern Lowland Forest community or the Alder-Thicket community. Species that dominate the Northern Lowland Forest community include white cedar (*Thuja occidentalis*), balsam fir



EXPLANATION

Ecosystem sub-subsections

- V.1.4 Central Wisconsin Sand Plain - Waupaca
- V.2.1 Southeastern Wisconsin Till Plain - Milwaukee
- V.2.2 Southeastern Wisconsin Till Plain - Madison
- V.2.3 Southeastern Wisconsin Till Plain - Galena/Platteville
- V.2.4 Southeastern Wisconsin Till Plain - Kettle Moraine
- V.3 Lake Winnebago Clay Plain
- VIII.1.3 Niagra Escarpment and Lake Plain - Escanaba/Door Peninsula
- VIII.1.4 Niagra Escarprnent and Lake Plain - Green Bay Till and Lake Plain
- VIII.2.1 Northern Lacustrine-Influenced Seney Sand Lake Plain
- VIII.2.2 Northern Lacustrine-Influenced Grand Marais Sandy End Moraine and Outwash
- VIII.3.1 Northern Lacustrine-Influenced Northern Lake Michigan Till Plain
- VIII.3.2 Northern Lacustrine-Influenced Gwinn
- IX.1 Spread-Eagle Dunbar Barrens
- IX.2 Michigarnrne Highland
- IX.3.1 Upper Wisconsin/Michigan Moraines - Brule and Paint Rivers
- IX.3.2 Upper Wisconsin/Michigan Moraines - Vinegar Moraine
- IX.3.4 Upper Wisconsin/Michigan Moraines - Chippewa-Green Bay Lobes
- IX.5 Lac Veaux Desert Outwash Plain
- 22 Relatively Hornogeneous Unit

Figure 5. Relatively homogeneous units in the Western Lake Michigan Drainages study unit superimposed on regional landscape ecosystems of Michigan, Minnesota, and Wisconsin (Albert, 1995).

(*Abies balsamea*), black spruce (*Picea mariana*), tamarack (*Larix laricina*), eastern hemlock (*Tsuga canadensis*), yellow birch (*Betula lutea*), black ash (*Fraxinus nigra*), and American elm (*Ulmus americana*). Species that dominate the Alder-Thicket community include speckled alder (*Alnus rugosa*), meadowsweet (*Spiraea alba*), red-osier dogwood (*Cornus stolonifera*), and American black currant (*Ribes americanum*).

All benchmark streams in RHU 3 are in the tension zone, which is characterized by species from both the northern communities (Northern Lowland Forest and Alder-Thicket) and southern communities (Southern Lowland Forest and Shrub-Carr).

Twenty benchmark streams in these four RHU's were selected for sampling. Some sites were selected on the basis of good to excellent water-quality ratings made previously by use of a stream arthropod family-level biotic index (W.L. Hilsenhoff, Dept. of Entomology, University of Wisconsin–Madison, oral commun., 1992; and S.W. Szczytko, College of Natural Resources, University of Wisconsin–Stevens Point, oral commun., 1993). This arthropod family-level index was developed by Hilsenhoff (Hilsenhoff, 1988) to summarize the various tolerances of the benthic arthropod community to organic and nutrient pollution. Other site selections, as well as study design, were influenced by conversations with Wisconsin Department of Natural Resources (WDNR) personnel and by information provided in habitat-improvement and fishery reports (Wisconsin Department of Natural Resources, 1980; 1990; Hunt, 1988; U.S. Environmental Protection Agency, 1991). Finally, some sites were selected because the surrounding land had received some level of protection from anthropogenic effects or had been managed to protect stream or riparian vegetation. Most of the streams selected are considered to be coldwater streams (Wisconsin Department of Natural Resources, 1980). This means that the streams can support species of fish requiring cold water, such as trout. The coldwater trout streams are further divided into Class I or Class II streams. Class I streams are suitable for natural reproduction of trout at a level that is sufficient to support sport fishing under normal conditions. Class II streams support some natural trout reproduction, but they require supplemental stocking to support sport fishing. The few sites that have fish species characteristic of warm water systems are noted in the descriptions of these benchmark-stream sites.

All 20 benchmark sites are on first-, second-, third-, and fourth-order (Strahler, 1957) wadable streams. Field data for this report were collected in May, June, and August 1993 and in April, June, and July 1995 in wadable stream reaches (less than 1 m in depth). Sampled reaches included repetitive stream-channel geomorphic features (for example, 2 riffles and 2 pools). Reach length was generally determined by multiplying the average channel width by 20 (Meador and others, 1993). Instream, bank, and flood-plain habitat and vegetation characteristics were based on classification methods in Meador and others (1993).

Water-quality data were collected and processed using standard USGS NAWQA techniques (Shelton, 1994). Surface-water samples were collected using the equal-width-increment (EWI) sampling method. The EWI method requires equal spacing of a number of verticals across the cross section and an equal transit rate, both upward and downward, in all verticals. The samples were analyzed for nutrients at the USGS National Water-Quality Laboratory in Lakewood, Co. An immunoassay to screen for triazines was conducted at the Wisconsin State Laboratory of Hygiene, Madison, Wis. Water temperature, pH, specific conductance, and dissolved oxygen concentrations were measured at the time of sample collection with a multiparameter water-quality instrument. Selected location information and physical characteristics of the streams, channels, and substrate types are summarized in table 2. Selected chemical constituents and physical properties and characteristics are listed in table 3. Photographs included in the rest of this report show vegetation in full leaf to characterize the extent and type of riparian vegetation along the reach, and also without leaves, to characterize other habitat and channel features.

Streams Draining Clayey Surficial Deposits Over Carbonate Bedrock

Streams in RHU 1 are characterized by clayey surficial deposits overlying carbonate bedrock in a land-use setting that is 80 percent agricultural (Robertson and Saad, 1995). As previously mentioned, RHU 1 is in three ecoregions, according to Omernik and Gallant (1988). The RHU is similarly divided with respect to the Albert (1995) regional ecosystem classification system (fig. 5). In the Albert system, the northern part of RHU 1 is in the Northern Lacustrine-Influenced Escanaba/Door Peninsula ecosystem and consists of bedrock escarpments, sand and clay lake plains, and lacustrine landforms. To the south is the Northern Lacustrine-Influenced Green Bay Till and Lake Plain ecosystem, consisting of clay loam and silt loam soils on till plains (fig. 5). Clayey deposits are present throughout the RHU and are mainly glaciolacustrine in origin. The textural characteristics of these deposits are believed to affect the quality of stream reaches by affecting overland and streambank erosion rates, particle size of suspended and streambed sediments, vegetation, aquatic biota, and land-use practices. A small portion of RHU 1, near Racine, Wis. is in the Central Cornbelt Plains ecoregion (Omernik and Gallant, 1988) and the Galena-Platteville Southern Wisconsin Till Plain ecosystem (Albert, 1995).

In RHU 1, the clayey surficial deposits are generally thin and poor producers of ground water. The underlying carbonate rocks, mainly consisting of dolomite interspersed with minor layers of limestone and shale, are fairly productive; ground-water discharge from these rocks constitutes about 50 percent of the average annual flow of area streams (Skinner and Borman, 1973) and makes up most streamflow during base flow. This substantial contribution of ground water is reflected in moderately high specific conductances (500-800 µS/cm at 25°C) in local streams (table 3, in supplemental data section).

Five streams—Tisch Mills Creek, Krok Creek, Little Scarboro Creek, Casco Creek, and Hibbard Creek (fig. 6)—were selected for study in RHU 1.

Tisch Mills Creek

Tisch Mills Creek, which averages 6 m in width throughout the sampled reach, is a spring-fed, second-order stream in Kewaunee County, Wis. It is a meandering stream characterized by an equal proportion of riffles, pools, and runs (table 2, in supplemental data section). The water is a clear reddish-brown color. This stream is rated as a Class II trout stream by the WDNR and is stocked with rainbow trout to support sport fishing (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. More than 80 percent of the basin is agricultural (cropland and pasture); the remainder is forested wetland and mixed forest (table 1, in supplemental data section).

The sampled reach begins 3.2 m upstream from the bridge at County Highway BB and extends 152 m upstream. The reach is bordered by the Mark A. Weber Memorial Natural Area. The streambed consists of an even mix of gravel, sand, cobbles, and boulders. Bedrock is exposed in less than 5 percent of the reach length. The wide flood plain and stable banks limit siltation; however, fine materials are present in the deep runs and pools.

The undercut streambanks are low (averaging 0.38 m) and consist of a 1- to 3-cm layer of organic forest-floor debris held in place by the root systems of the mature white cedars (*Thuja occidentalis*) and eastern hemlock (*Tsuga canadensis*), which line the corridor of the creek. This closed canopy significantly reduces sunlight to the stream. Consequently, aquatic macrophytes were found in less than 5 percent of the streambed, whereas aquatic mosses and algae were found throughout the sampled reach. Flood-plain and streambank vegetation consists of species characteristic of the Northern Lowland Forest plant community (Curtis, 1987).

Sampled reach of Tisch Mills Creek, June 4, 1993 showing leaf-on conditions.

Sampled reach of Tisch Mills Creek, April 11, 1995 showing leaf-off conditions.

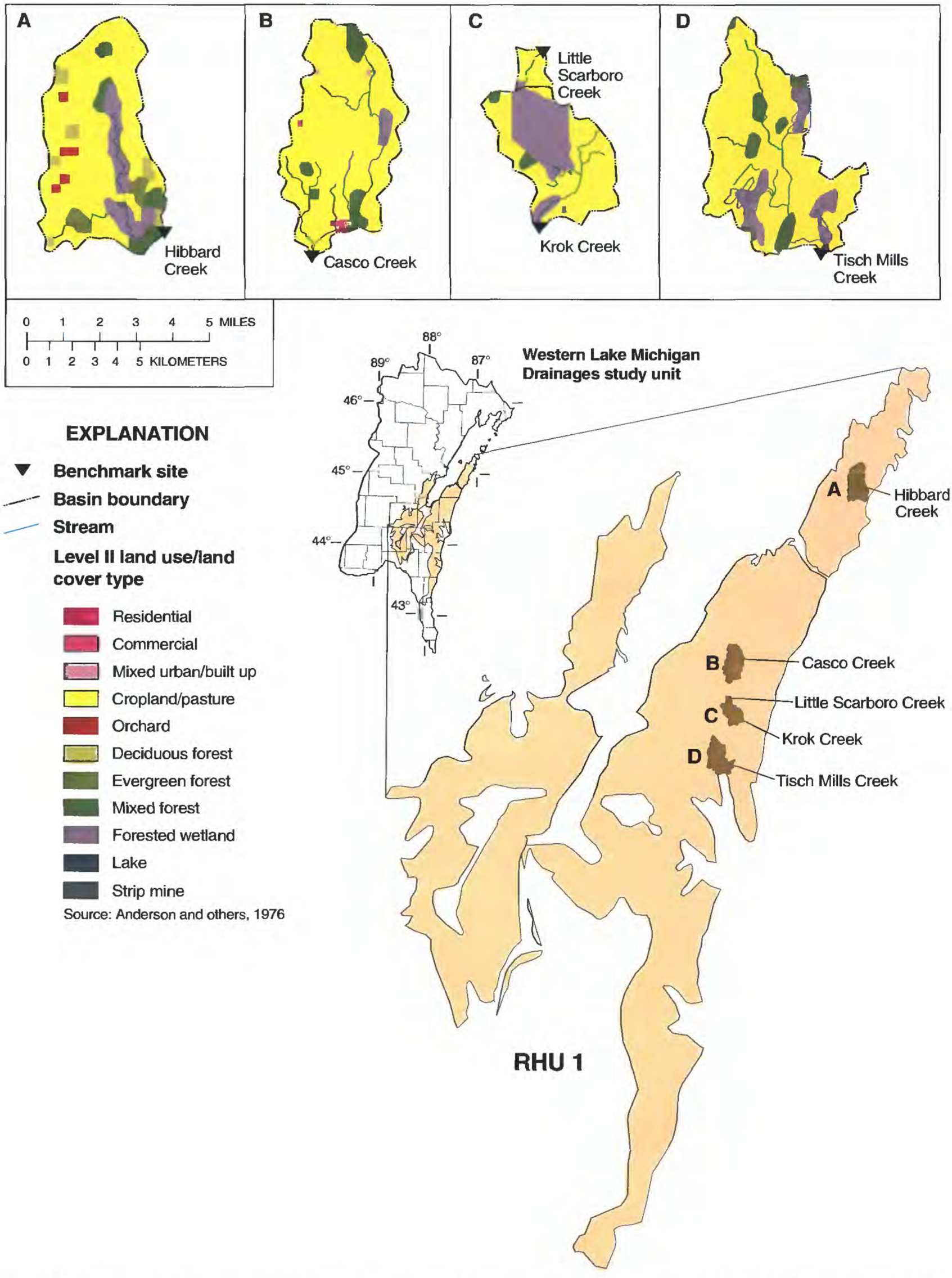


Figure 6. Location and land use/land cover of benchmark-stream basins in the Western Lake Michigan Drainages study unit for relatively homogeneous unit 1.

Krok Creek

Krok Creek, which averages 5 m in width throughout the sampled reach, is a second-order stream in Kewaunee County, Wis. It is characterized by a series of shallow riffles and runs (table 2, in supplemental data section) averaging 0.27 m in depth, separated by small pools. The sampled reach is managed as a Class II trout stream (Wisconsin Department of Natural Resources, 1980) and is stocked with brown and brook trout; the upper reaches of Krok Creek are considered Class I trout waters. In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Slightly more than 60 percent of the basin is agricultural (cropland and pasture); the remainder of the basin is forested wetland and mixed deciduous/coniferous forest (table 1, in supplemental data section).

The sampled reach begins 103 m upstream from the State Highway 29 bridge and extends 58 m upstream. The reach flows through a speckled alder (*Alnus rugosa*) thicket bordered by agricultural crops in the surrounding uplands. The central part of the streambed consists of firm, fine sand and muck (dark, highly organic soil) in the center of the riffles and runs, and muck near the streambanks and in the pools. The cobbles and boulders in the reach were partially embedded in silt (averaging 38 percent), and less than 5 percent of their surfaces were covered with algae. Detritus has built up throughout the reach and consists mainly of twigs and branches. Logs and decaying grasses and leaves also are present and provide a depositional area for silt. Wild celery (*Vallisneria americana*) grows in beds throughout the midstream channel. The aquatic vegetation and woody snags are the most common habitat features of this creek.

The banks are composed of muck and detritus, and slope gently (155°, measured from streambed) up to a swampy flood plain. The flood plain consists of species characteristic of the Alder Thicket community, with remnant species of the Northern Lowland Forest community (Curtis, 1987) including black ash (*Fraxinus nigra*) and white cedar (*Thuja occidentalis*). Sedges (*Carex* sp.) were found along the eroding streambanks and were interspersed with bare soil.

Sampled reach of Krok Creek, June 5, 1993 showing leaf-on conditions.

Sampled reach of Krok Creek, April 11, 1995 showing leaf-off conditions.

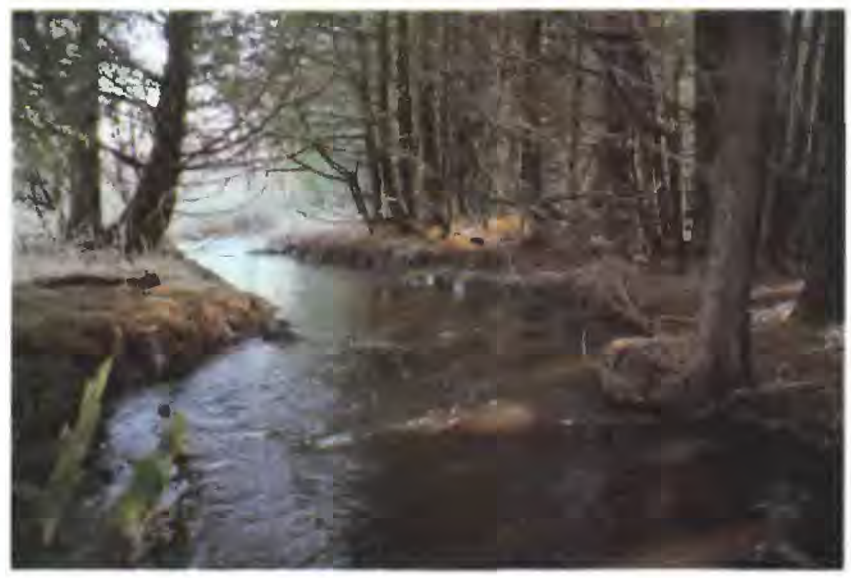
Little Scarboro Creek

Little Scarboro Creek, which averages 2.5 m in width throughout the sampled reach is a spring-fed, first-order stream in Kewaunee County, Wis. It is characterized by a series of short riffles, averaging 3.0 m in length, interspersed between pools and long runs, averaging 8.8 m in length (table 2, in supplemental data section). Runs account for 50 percent of the sampled-reach length in this clear stream. Carbonate deposits are visible on rocks in the channel. This stream is considered a Class I trout stream by the WDNR (1980); however, the WDNR stocks some brown and rainbow trout. In 1993, water quality of the sampled reach was rated "very good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. This basin has the highest percentage of agriculture (93.5 percent cropland and pasture) of any basin described in this report. The other 6.5 percent is forested wetland (table 1, in supplemental data section).

The sampled reach begins 38.7 m upstream from the bridge at County Road A and extends 89 m upstream. The reach is within the C. D. "Buzz" Besadny Fish and Wildlife Area. The streambed substrate consists of sand and gravel, with cobbles and boulders in riffle areas. Stream-habitat improvement structures such as drop riffles, wing dams, and boulder-lined banks have created pools and deep bends in places. Erosion and redeposition of sandbars cause variability in channel width, depth, and bank shape. Few aquatic plants were observed; however, filamentous algae were found throughout the reach on rocks and woody snags.

Little Scarboro Creek meanders across a flood plain consisting of species characteristic of the Northern Lowland Forest plant community (Curtis, 1987). The dense canopy of white cedars (*Thuja occidentalis*) completely shades the reach except for a few wide bends where the tree line is interrupted. Sand and boulders interspersed with muck line the banks. Rootbound banks and toppled white cedars form woody-snag habitat for fish and invertebrates. Fine-grained materials were found only in pooled areas and near woody snags.

Sampled reach of Little Scarboro Creek, June 5, 1993 showing leaf-on conditions.



Sampled reach of Little Scarboro Creek, April 2, 1995 showing leaf-off conditions.

Casco Creek

Casco Creek, which averages 10 m in width throughout the sampled reach, is a third-order stream in Kewaunee County, Wis. It is characterized by alternating riffles and runs (table 2, in supplemental data section). Most of the year, the water has a brownish tint. The sampled reach is considered a Class I brook trout stream; however, brown and rainbow trout are stocked (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. Approximately 90 percent of the land use in the basin is agricultural (cropland and pasture). The remainder of the area is composed of mixed forest, forested wetlands, and residential, commercial and urban uses (table 1, in supplemental data section).

The sampled reach begins 29 m upstream from the bridge at Rockledge Road and extends 162 m upstream. The streambed consists of boulders, cobbles, gravel, and sand. All substrates were covered with a fine layer of silt, the thickest deposits of sediments being found in pools. Aquatic macrophytes, such as pondweed (*Potamogeton* sp.) and broad-leaved arrowhead (*Sagittaria latifolia*), are present but scarce.

This meandering creek has low (averaging 0.30 m) sandy banks lined with species characteristic of the Northern Lowland Forest plant community (Curtis, 1987). The canopy allows sunlight to penetrate the stream surface, and algal coverage of rocks exceeds 50 percent. In a few unvegetated pockets, the streambank has eroded by debris avalanche or undercutting. Fallen logs and scattered boulders were the most common habitat features for fish and invertebrates.

Sampled reach of Casco Creek, June 6, 1993 showing leaf-on conditions.

Sampled reach of Casco Creek, April 12, 1995 showing leaf-off conditions.

Hibbard Creek

Hibbard Creek, which averages 7 m in width throughout the sampled reach, is a second-order creek located in Door County, Wis. Ninety percent of the sampled reach is characterized by runs and pools averaging 0.42 m in depth; the remainder of the reach is riffles averaging less than 0.20 m in depth (table 2, in supplemental data section). The water is tinted brown. The WDNR (1980) manages Hibbard Creek as a Class II trout stream and stocks brook, brown, and rainbow trout. Because this creek drains directly into Lake Michigan, it is inhabited by a wide variety of fish, warmwater as well as coldwater species (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "very good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. Slightly more than 70 percent of the land use in the basin is cropland and pasture. Two percent of the land is used for orchards, and the remainder of the area is covered by forested wetlands and mixed deciduous/coniferous forest (table 1, in supplemental data section).

Data were collected from a 155-m-long reach beginning at the State Highway 57 bridge and extending upstream. The reach begins several hundred yards upstream from where the creek flows into Lake Michigan. Sand and cobbles cover the streambed, whereas sand mixed with muck and detritus cover the streambanks. The creek meanders, creating undercut banks on the outside of bends and sloping point bars along the inside. Silt and organic matter collect in the eddies and pools.

The flood-plain and streambank vegetation consists of species characteristic of the Northern Lowland Forest plant community (Curtis, 1987). There is evidence of recent selective logging of hardwoods. Large logs and woody snags create the major instream habitat features. Overhanging vegetation limits the sunlight reaching the creek surface. Arrowhead (*Sagittaria* sp.) and iris (*Iris* sp.) were the only aquatic macrophytes observed.

Sampled reach of Hibbard Creek, May 6, 1993 showing leaf-on conditions.

Sampled reach of Hibbard Creek, April 12, 1995 showing leaf-off conditions.

Streams Draining Sandy-Till Surficial Deposits Over Carbonate Bedrock

RHU 3 is characterized by sandy-till surficial deposits overlying carbonate bedrock in an 78-percent (Anderson Level I) agricultural land-use setting (Robertson and Saad, 1995). As previously mentioned, this RHU is in the Southeastern Wisconsin Till Plain ecoregion of Omernik and Gallant (1988). Albert's regional ecosystem classification (1995) matches that of Omernik and Gallant, and places this RHU in a unit of the same name; however, Albert's region is only a small subset of Omernik and Gallant's and is restricted to silty-loam-capped loess and rolling ground moraines. A band of steep ice-disintegration topography marked by kettle lakes and kames runs through the center of the RHU (fig. 5). Sand and gravel deposits are generally thin and are found mainly in outwash plains and in glaciofluvial meltwater in the eastern part of the RHU. Sandy materials (loess clay) are commonly found in the southeast part of RHU 3. The underlying carbonate rocks mainly consist of Silurian and Devonian dolomite interspersed with minor layers of limestone and shale. Where the sand and gravel thicken, the surficial deposits and underlying bedrock both are capable of producing ground-water supplies; however, base flow in streams is primarily discharge from the carbonate rocks (Skinner and Borman, 1973).

Four streams—East Branch Milwaukee River, Nichols Creek, Mullet River, and Watercress Creek (fig. 7)—were selected for study in RHU 3.

East Branch Milwaukee River

The East Branch Milwaukee River, which averages 16 m in width throughout the sampled reach, is a second-order stream in Fond du Lac County, Wis. It is characterized by sandy runs, cobble and gravel riffles, and fine-grained substrates of organic-rich deposits in pools (table 2, in supplemental data section). This river is designated as a warmwater sport fishery; white sucker (*Catastomus commersoni*), rock bass (*Ambloplites rupestris*), and a variety of minnows are present. WDNR personnel rated this as one of the highest-quality streams in the area (M. Miller, Wisconsin Department of Natural Resources, oral commun., 1993). In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Land use in the basin is 56 percent agricultural cropland and pasture. The remainder of the land cover is a combination of mixed deciduous/coniferous forest and forested wetlands that form a riparian zone (table 1, in supplemental data section).

The sampled reach begins 117 m upstream from the bridge at Youth Camp Road and extends for 202 m upstream. The channel in the upper reach averages almost 1 m in depth with a dominant sand and silt substrate. The flood plain and banks are characterized by species from two plant communities, the Alder-Thicket and the Shrub-Carr (Curtis, 1987). These communities, which represent a northern and a southern plant community, are both found here because this basin is in the tension zone (Curtis, 1987). The streambanks are composed largely of muck and are stabilized by vegetation. Very little erosion is evident. The banks are undercut, with speckled alder (*Alnus rugosa*) and willow (*Salix* sp.) overhanging the water. The center of the channel remains open to sunlight. Mussels (*Unionidae*) were abundant and dominated by the species *Elliptio dilatata*. Macrophytes present included patches of wild celery (*Vallisneria americana*), pondweed (*Potamogeton* sp.), bulrush (*Scirpus* sp.), and sedges (*Carex* sp.). Scattered debris, including logs and woody snags, are common instream habitat.

The lower part of the sampled reach is channelized, and streambanks are lined with boulders. Here, the substrate is gravel and cobble, and rows of boulders placed across the stream create small pockets and drop riffles. This part of the reach is bordered by upland where white spruce (*Picea abies*) and red pine (*Pinus resinosa*) plantations are interspersed with white oak (*Quercus alba*).

Sampled reach of East Branch Milwaukee River, May 20, 1993 showing leaf-on conditions.

Sampled reach of East Branch Milwaukee River, April 10, 1995 showing leaf-off conditions.

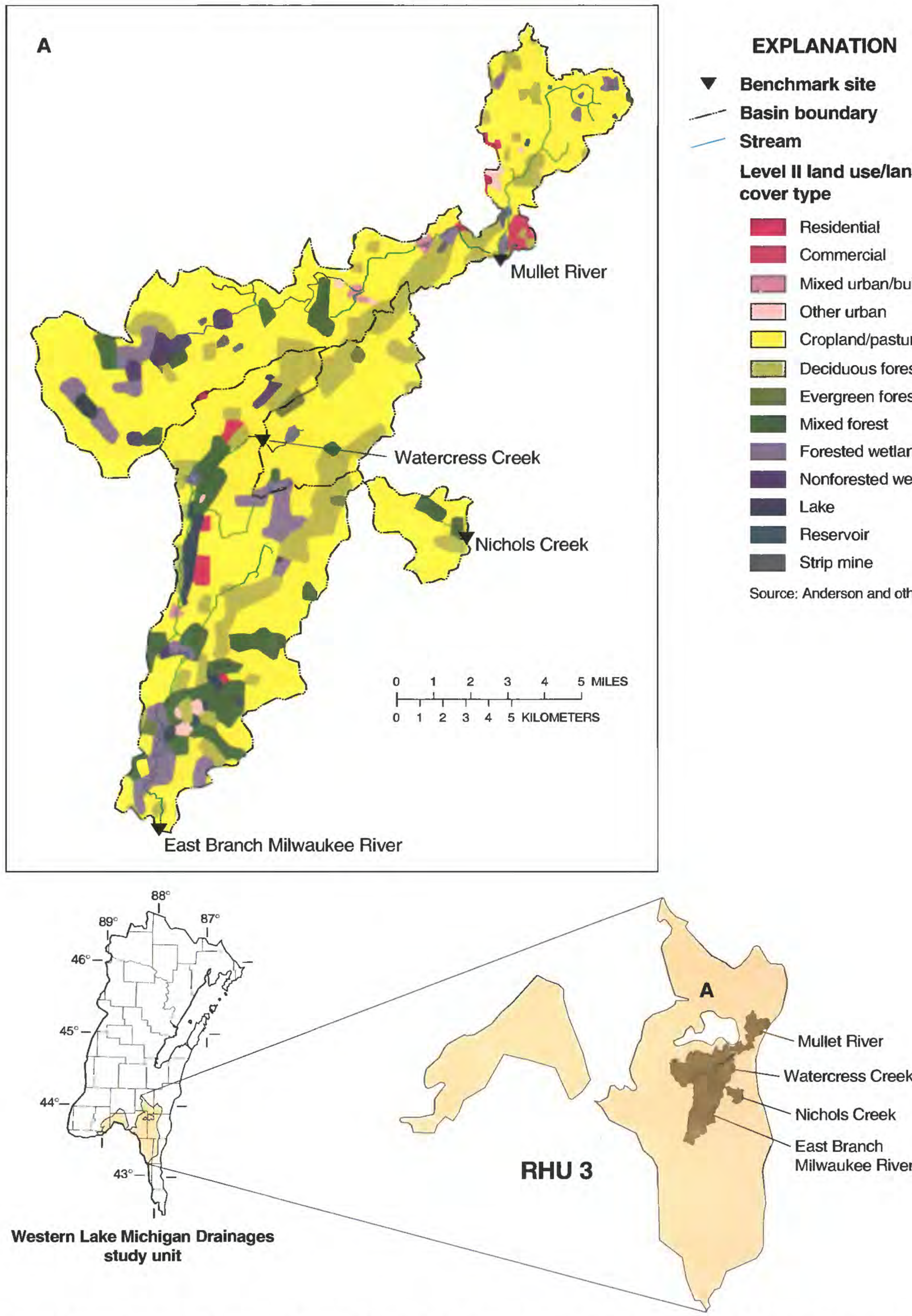


Figure 7. Location and land use/land cover of benchmark-stream basins in the Western Lake Michigan Drainages study unit for relatively homogeneous unit 3.

Nichols Creek

Nichols Creek, which averages 4.5 m in width throughout the sampled reach, is a spring-fed, first-order stream in Sheboygan County, Wis. This spring-fed creek is characterized by a series of riffles and runs (table 2, in supplemental data section). It is a Class I trout stream containing brown and brook trout (Wisconsin Department of Natural Resources, 1980). During 1980–81, a habitat development project was completed on the creek. It included habitat improvements such as debrushing, brush bundles, half logs, bank covers, rock riffles, and current deflectors, all of which increased the trout population (Hunt, 1988). Remnants of these structures remain. In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. The basin is within the Kettle Moraine State Forest. Land use in the basin is 80 percent agriculture (cropland and pasture) with some deciduous and mixed deciduous/coniferous forest in the rolling upland moraines (table 1, in supplemental data section).

The sampled reach begins 59 m upstream from the Cedar Lane Road bridge and extends 74 m upstream. The streambed substrate is composed of sand, gravel, cobbles, and boulders. Algae-covered cobbles and boulders are present in the riffles, whereas fine sand predominates in areas of slow-moving water. Aquatic-macrophyte beds consisting of watercress (*Nasturtium officinale*) are present throughout the reach.

The streambanks consist of muck and are held firmly in place by speckled alder (*Alnus rugosa*) roots and grasses. Erosion is evident where root systems are lacking, creating vertical or undercut banks. The creek contains small islands comprised of muck and fine sand, covered by speckled alder (*Alnus rugosa*) and sedges (*Carex* sp.). Boulders and woody snags create natural habitat for the fish and invertebrates. Speckled alders (*Alnus rugosa*) overhang the channel; however, owing to the absence of mature trees in most of the flood plain, the canopy over the stream is more than two-thirds open. The flood plain and banks are covered by species characteristic of the Northern Lowland Forest (Curtis, 1987) such as white cedar (*Thuja occidentalis*) and speckled alder (*Alnus rugosa*). Because this RHU is in the tension zone, one would expect to see species from either northern or southern plant communities (Curtis, 1987).

Sampled reach of Nichols Creek, May 21, 1993 showing leaf-on conditions.

Sampled reach of Nichols Creek, April 11, 1995 showing leaf-off conditions.

Mullet River

The Mullet River, which averages 28 m in width throughout the sampled reach, is a fourth-order stream in Sheboygan County, Wis. Riffles and runs are interspersed throughout the reach (table 2, in supplemental data section). The river is considered a warmwater sport fishery, and it supports a diverse minnow population (Wisconsin Department of Natural Resources, 1980). It is listed as a Class II trout stream and is stocked with brown trout. In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. The basin is 75 percent cropland and pasture, the remaining major land cover being deciduous forest and forested wetlands. Much of the land surrounding the reach is owned by the State of Wisconsin (table 1, in supplemental data section).

The sampled reach begins 100 m downstream from the culvert at County Highway J and extends 182 m downstream. Streambed substrate throughout the reach is sand, gravel, and cobbles with scattered boulders. Over the years, attempts have been made to keep the flow channelized by using wing dams and lining the banks with boulders. These channel modifications have worked in places, but they are failing in about 75 percent of the areas. Scour was observed behind obstructions. The river has many small islands of boulders and muck, which are elongated in the direction of flow. About half of these islands are vegetated with sedges (*Carex* sp.) and speckled alder (*Alnus rugosa*). Backwater areas contain fine sediments and aquatic macrophytes such as watercress (*Nasturtium officinale*), cattail (*Typha* sp.), and iris (*Iris* sp.).

Unaltered streambanks are composed of muck and sand and are covered with organic debris. Filamentous algae is present on rocks throughout the reach. Common instream habitat features include woody snags, boulders, and undercut banks. An open canopy allows sunlight to reach the stream surface. Bank and flood-plain vegetation is characteristic of the Northern Lowland Forest and Alder Thicket communities (Curtis, 1987), such as speckled alder (*Alnus rugosa*) and white cedar (*Thuja occidentalis*).

Sampled reach of Mullet River, May 21, 1993 showing leaf-on conditions.

Sampled reach of Mullet River, April 11, 1995 showing leaf-off conditions.

Watercress Creek

Watercress Creek, which averages 2.5 m in width throughout the sampled reach, is a second-order stream in Sheboygan County, Wis. It originates from springs in the kettle moraine area and is part of the headwaters for the East Branch of the Milwaukee River. The creek receives sedimentation from upland erosion, which causes very turbid water during high flows. Concentration of bed and suspended sediments and summer low flows (less than 1 ft^3/s) are the limiting factors affecting biota in the stream (Wisconsin Department of Natural Resources, 1990). This creek is classified as a Class II trout stream, and brook and brown trout are occasionally stocked (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. More than 65 percent of the basin consists of agricultural land, the remainder being mainly deciduous forest (table 1, in supplemental data section).

The sampled reach begins 95 m downstream from the bridge on Watercress Creek Road, approximately one-half mile west of State Highway 67 and extends 58 m downstream. The streambed is composed of muck and detritus with sand and gravel in places. Woody snags are abundant throughout the reach. Erosion by slumping and undercutting was evident along the streambank. The banks are lined with speckled alder (*Alnus rugosa*) and willow (*Salix* sp.), which overhang and shade the stream. The flood plain is an open, low-lying area vegetated with sedges (*Carex* sp.), grasses, stinging nettle (*Urtica* sp.), and jewelweed (*Impatiens capensis*). Cropland can be seen within 70 m of the reach. Curtis (1987) characterizes many species that occur at this site as species of weed communities where some form of disturbance may have occurred. Because this site is in the tension zone, it could potentially support plant species from either northern or southern plant communities, barring any disturbance (Curtis, 1987).

Sampled reach of Watercress Creek, May 22, 1993 showing leaf-on conditions.

Sampled reach of Watercress Creek, April 11, 1995 showing leaf-off conditions.

Streams Draining Sandy/Sand and Gravel Surficial Deposits Over Igneous and Metamorphic Bedrock

RHU 20 is characterized by sandy/sand and gravel surficial deposits over igneous and metamorphic bedrock in a 44-percent (Anderson Level I) agricultural land-use setting (Robertson and Saad, 1995). In Albert's classification (1995), the basins of interest in this RHU are in the Upper Wisconsin/Michigan Moraines, Chippewa-Green Bay Lobes ecosystem and consists of sandy loam northern end moraines, kettle lakes, and northern hardwood forests. This ecosystem is in the ecoregion that Omernik and Gallant (1988) call the North Central Hardwood Forest ecoregion. Although RHU 20 and RHU 26 are both included in the North Central Hardwood forest, Albert places these RHU's in two separate ecosystems. The boundary defined by Albert (1995) is similar to the RHU boundary (fig. 3 and 5).

Sand and gravel deposits are present throughout the RHU in outwash plains and in glaciofluvial meltwater channels, but they are most extensive in the western part of the unit. In RHU 20, these sand and gravel deposits are the only dependable ground-water source and are the primary contributor to base flow of streams (Olcott, 1968). The Basement Complex underlying the sandy surficial deposits in RHU 20 is composed of Precambrian igneous and metamorphic rocks (Kammerer, 1984). In general, wells drilled into the Basement Complex yield water only if they are completed in fractured or weathered zones (Batten, 1987, 1989).

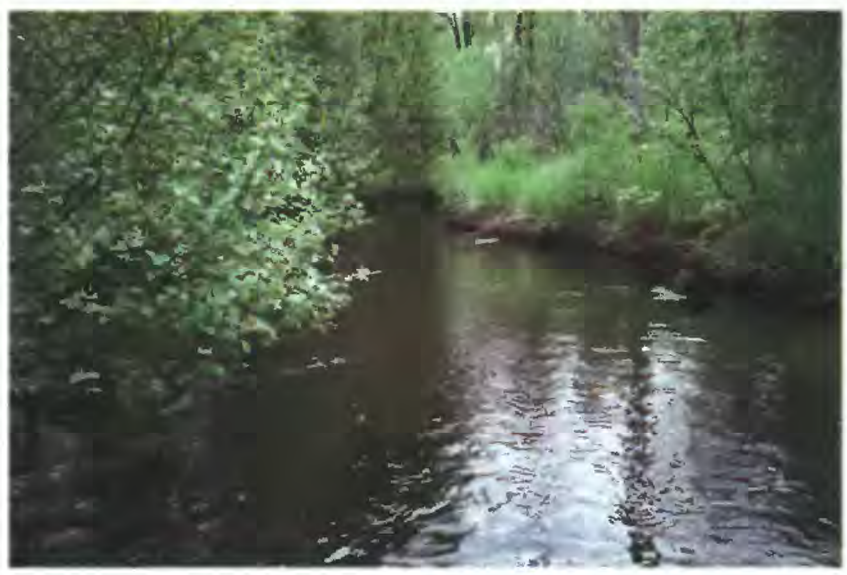
Five streams—Whitcomb Creek, West Branch Red River, Silver Creek, Smith Creek, and Camp Creek (fig. 8)—were selected for study in RHU 20.

Whitcomb Creek

Whitcomb Creek, which averages 5 m in width throughout the sampled reach, is a second-order stream in Waupaca County, Wis. About 90 percent of the reach consists of runs, the remainder being evenly divided between riffles and pools (table 2, in supplemental data section). The stream is designated as a Class I brook trout stream (Wisconsin Department of Natural Resources, 1980) and is noted locally as being a "good trout producer". In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Only 30 percent of this basin is used for agriculture (cropland and pasture). Most of the basin is mixed deciduous/coniferous forest and forested wetlands (table 1, in supplemental data section).

The sampled reach begins approximately 107 m downstream from the County Highway G bridge and extends 199 m downstream. In this reach, the creek flows through a wetland whose vegetation consists of speckled alder (*Alnus rugosa*), willow (*Salix* sp.), and red-osier dogwood (*Cornus stolonifera*); many of these trees overhang the channel. The stream has a sand and silt substrate with muck banks stabilized by grasses and ferns. Beaver had created a series of dams and pools in this reach in 1994. The ponded areas behind these dams are silt filled.

Aquatic macrophytes such as wild celery (*Vallisneria americana*) and sedges (*Carex* sp.) are present throughout the reach. Bank and flood plain vegetation are characteristic of species in the Northern Lowland Forest community (Curtis, 1987).



Sampled reach of Whitcomb Creek, June 1, 1993 showing leaf-on conditions.

Sampled reach of Whitcomb Creek, April 13, 1995 showing leaf-off conditions.

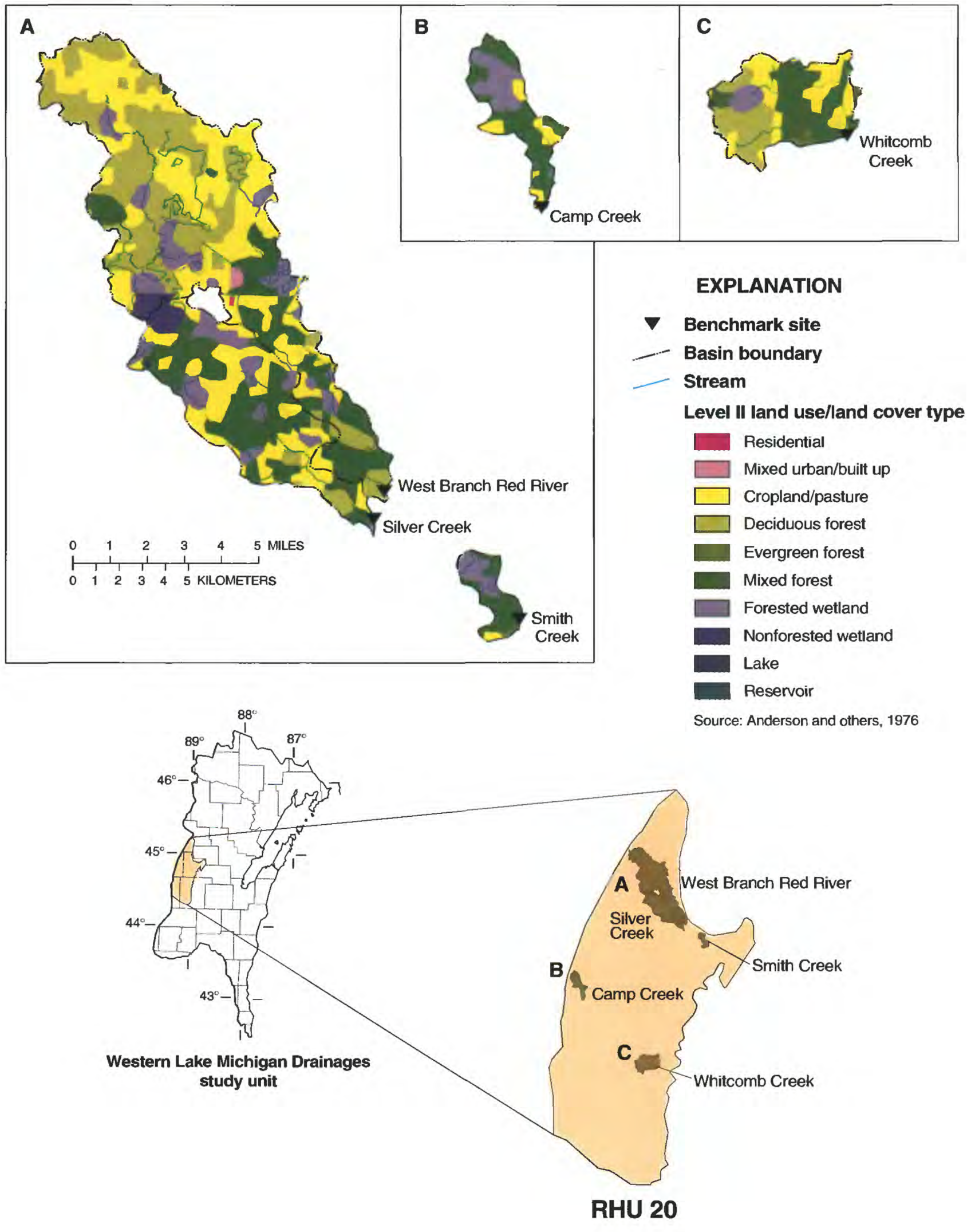


Figure 8. Location and land use/land cover of benchmark-stream basins in the Western Lake Michigan Drainages study unit for relatively homogeneous unit 20.

West Branch Red River

The West Branch Red River, which averages 10 m in width throughout the sampled reach, is a second-order stream on the Stockbridge-Munsee Indian Reservation, in Shawano County, Wis. Nearly three-quarters of the reach consists of runs (table 2, in supplemental data section). The river is managed as a Class II brook and brown trout stream (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "very good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. Slightly less than 40 percent of the basin is in agricultural land use (mostly cropland and pasture). Most of the basin is mature deciduous and mixed deciduous/coniferous forest, with some forested and nonforested wetlands (table 1, in supplemental data section).

Data were collected from a reach that begins 40 m downstream from the bridge at Stub Road and extends 193 m downstream. The streambed consists of sand and gravel in the riffles, sand in the runs, and silt in the pools. Algae-covered boulders are scattered throughout the reach. Depths in the channel vary greatly, owing to scour around obstructions in sections of rapid flow. Woody snags and logs provide instream habitat for aquatic macroinvertebrates. The reach contains one large island comprised of muck and sand, vegetated by sedges (*Carex* sp.) and speckled alder (*Alnus rugosa*).

This stream has muck and sand banks that are vegetated with sedges (*Carex* sp.) and speckled alder (*Alnus rugosa*). Erosion, where it occurs, is by way of debris avalanche where vegetation is absent or by undercutting of root systems. This stream is shaded by overhanging bank vegetation; however, enough sunlight reaches the center of the channel to support aquatic plants, such as wild celery (*Vallisneria americana*). Flood-plain vegetation is characteristic of species in the Northern Lowland Forest community (Curtis, 1987).

Sampled reach of West Branch Red River, June 8, 1993 showing leaf-on conditions.

Sampled reach of West Branch Red River, April 13, 1995 showing leaf-off conditions.

Silver Creek

Silver Creek, which averages 10 m in width throughout the sampled reach, is a second-order stream on the Stockbridge-Munsee Indian Reservation, in Shawano County, Wis. Two-thirds of the reach consists of runs; riffles and pools make up the rest (table 2, in supplemental data section). The water has a slight reddish-brown tint. This creek is considered a Class I trout stream with a naturally reproducing brook trout population (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. Only 35 percent of the basin is in agricultural land use (mostly cropland and pasture). Most of the basin is mature mixed deciduous/coniferous forest and forested wetlands (table 1, in supplemental data section).

The sampled reach begins 125 m downstream from the culvert under Silver Creek Road and extends 200 m downstream. The reach consists of two distinctly different subreaches. The upper subreach consists of runs through mature white cedars (*Thuja occidentalis*), eastern hemlock (*Tsuga canadensis*), and balsam fir (*Abies balsamea*). The dense canopy in this reach prevents light from reaching the sparse understory. Moss-covered boulders are present throughout this section. The substrate is cobbles and gravel with some sand.

The lower subreach meanders across a wetland covered with speckled alder (*Alnus rugosa*), nannyberry viburnum (*Viburnum lentago*), black ash (*Fraxinus nigra*), and black cherry (*Prunus serotina*). The sand and muck banks are covered with grasses, ferns, and sedges (*Carex* sp.), which overhang and shade the creek. Throughout the sampled reach, root systems are undercut and topple into the stream, forming woody snags. The bank and flood-plain vegetation is characteristic of species in the Northern Lowland Forest community (Curtis, 1987).

Sampled reach of Silver Creek, June 6, 1993 showing leaf-on conditions.

Sampled reach of Silver Creek, April 13, 1995 showing leaf-off conditions.

Smith Creek

Smith Creek, which averages 5 m in width throughout the sampled reach, is a spring-fed, second-order stream on the Stockbridge-Munsee Indian Reservation, in Shawano County, Wis. It is characterized mainly by runs with a few pools (table 2, in supplemental data section). The water has a reddish-brown tint. This creek is considered a Class II brook trout stream, with some natural brook trout reproduction (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. This basin has very little agricultural land (5 percent), 90 percent of the basin being mixed deciduous/coniferous forest and forested wetlands (table 1, in supplemental data section).

The sampled reach begins 5 m upstream from the Camp 14 Road bridge and extends 108 m upstream. The streambed consists of fine sands underlain by muck. Organic debris accumulates on the streambed in areas of slow flow. Woody snags and logs are the most common instream habitat. The creek has sloping banks of muck and sand that show signs of erosion.

The reach meanders through an organic-rich flood plain vegetated with white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), and black ash (*Fraxinus nigra*). Mosses, ferns, and sedges (*Carex* sp.) dominate the understory. The flood-plain vegetation overhangs the creek, preventing direct sunlight from reaching the stream throughout most of the reach. Wild celery (*Vallisneria americana*) was the only aquatic macrophyte found. Flood-plain vegetation is characteristic of species in the Northern Lowland Forest community (Curtis, 1987).

Sampled reach of Smith Creek, June 6, 1993 showing leaf-on conditions.

Sampled reach of Smith Creek, April 12, 1995 showing leaf-off conditions.

Camp Creek

Camp Creek, which averages 5 m in width throughout the sampled reach, is a first-order stream in Marathon County, Wis. Eighty-four percent of the reach consists of runs, and the remainder is evenly divided between pools and riffles (table 2, in supplemental data section). The streamwater is brown and turbid. Despite the visible silt and organic-matter deposits, Camp Creek is considered a Class I brook trout stream (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. The basin is largely mixed forest or forested wetlands (82 percent). Only 18 percent of the basin is devoted to agricultural land use (cropland and pasture) (table 1, in supplemental data section).

The sampled reach begins 17.8 m downstream from the River Road culvert and extends 96 m downstream. The streambed substrate through this reach is predominantly sand and muck with patches of gravel in a few riffle areas. No cobbles, boulders, or aquatic plants were seen in the reach. The streambanks are composed of muck with fine sand and debris. Woody vegetation tends to overhang and shade the stream, yet scattered breaks in the canopy allow small amounts of light to reach the creek. Vegetation lines the banks, yet erosion commonly occurs by undercutting. The vegetation collapses, falls into the stream, and collects on the numerous logs and woody snags throughout the reach. The flood plain is vegetated with species characteristic of the Northern Lowland Forest community (Curtis, 1987).

Sampled reach of Camp Creek, June 10, 1993 showing leaf-on conditions.

Sampled reach of Camp Creek, April 13, 1995 showing leaf-off conditions.

Streams Draining Sandy/Sand and Gravel Surficial Deposits Over Sandstone Bedrock

RHU 26 is characterized by sandy/sand and gravel surficial deposits over sandstone bedrock in a 52-percent (Anderson Level I) agricultural land use setting (Robertson and Saad, 1995). According to Albert (1995) RHU 26 falls in the Waupaca sub-subsection of the Central Wisconsin Sand Plain ecosystem, and consists of sandy end moraines, ground moraines, pitted outwash, and oak forests (fig. 5). Although Omernik and Gallant (1988) place this ecosystem in the same unit as RHU 20, Albert's system (1995) uses the characteristics of vegetation and bedrock geology to distinguish these RHU's from each other.

This RHU is characterized by permeable sand and gravel aquifers over sandstone aquifers composed of Cambrian and Ordovician rocks. Highest ground-water yields are in areas where sandstone aquifers are overlain by sand and gravel aquifers; however, both aquifers are considered to contribute to base flow in streams (Young and Batten, 1980). A combination of overland runoff, streambank erosion, and the weathering of sandstone outcrops have resulted in sand being the predominant substrate type in local streams.

Six streams—Lawrence Creek, Neenah Creek, Chaffee Creek, Mecan River, Willow Creek, and Pine River (fig. 9)—were selected for study in RHU 26.

Lawrence Creek

Lawrence Creek, which averages 3 m in width throughout the sampled reach, is a first-order stream in Adams County, Wis. Installation of bank covers and current deflectors in 1964 (Hunt, 1988) has created a creek characterized by 75 percent runs and 25 percent riffles with sweeping bends (table 2, in supplemental data section). This stream has been designated as a Class I brook trout stream. In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies, stoneflies, and caddisflies were present. Approximately 50 percent of the basin is agricultural (cropland and pasture); the other half is mostly mixed deciduous/coniferous forest (table 1, in supplemental data section).

The sampled reach begins approximately 400 m upstream from the bridge at 1st Avenue and extends 156 m upstream. The entire reach is in the Lawrence Creek Habitat Management Project area. The flood plain is a swampy, open area with an artificial boulder-lined channel cut through it. The streambed substrate is predominantly sand with gravel and cobbles in the riffles (average embeddedness is 70 percent). Overhanging grasses and cattails (*Typha* sp.) provide shade and habitat throughout the reach. Waterweed (*Elodea* sp.), pondweed (*Potamogeton* sp.), and duckweed (*Lemna* sp.) were seen in the reach. Artificial undercut banks line the stream in many places.

Streambanks are stabilized by boulders, so little alteration of the channel has occurred as a result of erosion. Bank and flood-plain vegetation is characteristic of the Southern Lowland Forest and Shrub-Carr communities (Curtis, 1987), with the exception of speckled alder (*Alnus rugosa*).

Sampled reach of Lawrence Creek, May 24, 1993 showing leaf-on conditions.

Sampled reach of Lawrence Creek, April 14, 1995 showing leaf-off conditions.

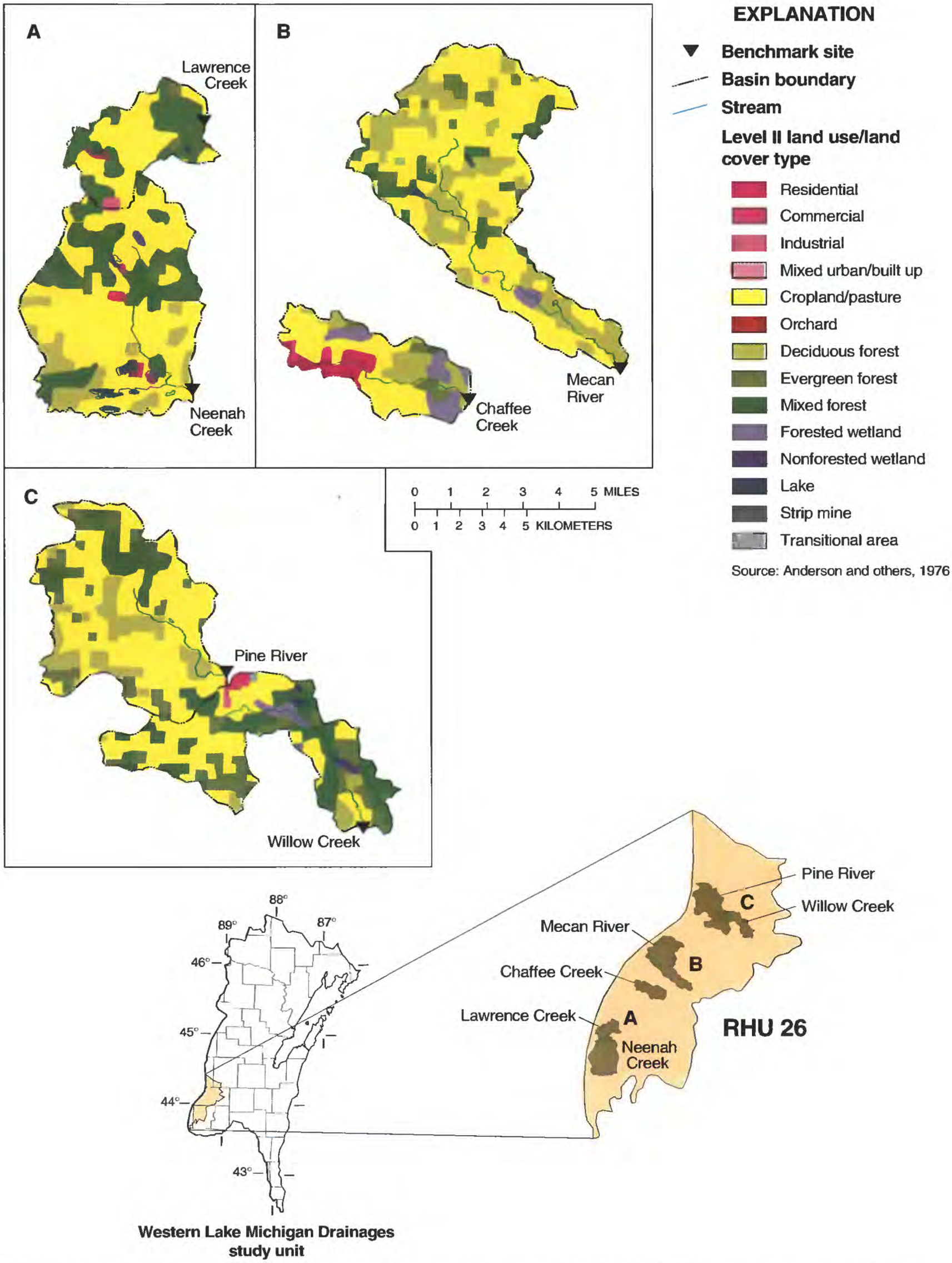


Figure 9. Location and land use/land cover of benchmark-stream basins in the Western Lake Michigan Drainages study unit for relatively homogeneous unit 26.

Neenah Creek

Neenah Creek, which averages 5 m in width throughout the sampled reach, is a second-order stream in Adams County, Wis. It is characterized by alternating riffles and runs (table 2, in supplemental data section). A habitat improvement project in 1982 included debrushing, brush bundles, sandbag bank covers, and current deflectors (Hunt, 1988). The creek is considered a Class I brown trout stream with size limits to encourage trophy class fish (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Land use in the basin is nearly 60 percent agricultural (cropland and pasture); land cover in the rest of the basin is mainly deciduous and mixed deciduous/coniferous forests, with some wetlands and lakes (table 1, in supplemental data section).

The sampled reach begins approximately 800 m upstream from the bridge at 1st Avenue, in a State fisheries area, and extends 117 m upstream. The reach meanders across an open wetland, where the stream is exposed to sunlight. The streambed substrate is sand, with gravel, cobbles, and boulders in the riffle areas. Sandbars have formed throughout the reach around rocks, logs, and woody snags. Various aquatic macrophytes were found, including waterweed (*Elodea* sp.), pondweed (*Potamogeton* sp.), and duckweed (*Lemna* sp.)

The streambanks are composed of sand and muck and are stabilized by reed canary grass (*Phalaris arundinacea*), sedges (*Carex* sp.), and speckled alder (*Alnus rugosa*). Erosion is by undercutting and debris avalanche. Boulder walls have been placed on the outside bends of the stream to limit meandering. The footings that support the artificial banks are eroding in places, causing the structures to fail. Flood-plain vegetation characteristic of the Southern Lowland Forest and Shrub-Carr communities (Curtis, 1987) was found in addition to speckled alder (*Alnus rugosa*).

Sampled reach of Neenah Creek, May 25, 1993 showing leaf-on conditions.

Sampled reach of Neenah Creek, April 14, 1995 showing leaf-off conditions.

Chaffee Creek

Chaffee Creek, which averages 4 m in width throughout the sampled reach, is a second-order, spring-fed stream in Marquette County, Wis. Riffles comprise 50 percent of the reach whereas runs and pools each comprise 25 percent of the reach (table 2, in supplemental data section). In this reach, the creek is considered a Class II trout stream containing brown and rainbow trout (Wisconsin Department of Natural Resources, 1980). It is a Class I trout stream in its upper reaches. In 1993, water quality of the sampled reach was rated "good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Major land-use/land-cover categories in the basin are agricultural (cropland and pasture), at 44 percent; deciduous forest, at 19 percent; forested wetlands, at 17 percent; and residential, at 13 percent. This basin has the highest residential use of any basin in this study (table 1, in supplemental data section).

The sampled reach begins approximately 193 m upstream from the County Highway B bridge and extends 85 m upstream. The reach is in the Chaffee Creek State Fishery Area. The channel is sinuous and narrow, and some pools are more than 2 m deep. The streambed substrate is sand; few rocks or aquatic plants were seen in the reach.

The streambanks are composed of sand covered with organic debris and vegetation, including grasses, speckled alder (*Alnus rugosa*), and ninebark (*Physocarpus opulifolius*). This vegetation, which stabilizes the banks, becomes undercut as the sand below the root systems is eroded away. Woody snags and undercut banks are the major habitat feature of this stream. The reach is shaded by overhanging vegetation, which reduces the amount of sunlight reaching the stream. Bank and floodplain vegetation are characteristic of the Northern Lowland Forest community (Curtis, 1987), even though this RHU is south of the tension zone.

Sampled reach of Chaffee Creek, May 25, 1993 showing leaf-on conditions.

Sampled reach of Chaffee Creek, April 14, 1995 showing leaf-off conditions.

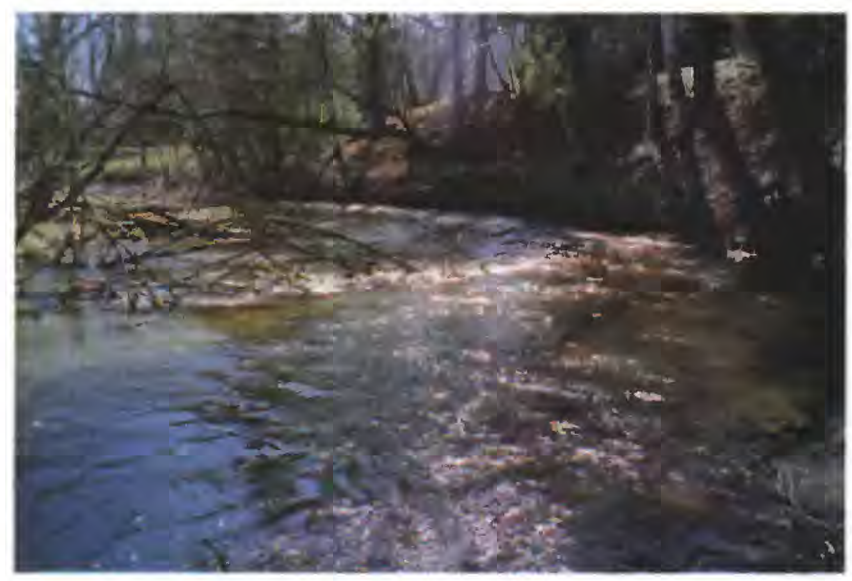
Mecan River

The Mecan River, which averages 10 m in width throughout the sampled reach, is a second-order stream in Waushara County, Wis. Runs comprise 63 percent of the reach, whereas riffles and pools account for 33 and 4 percent, respectively (table 2, in supplemental data section). The Mecan River is designated as a Class II coldwater sport fishery by the WDNR and contains brown, brook, and rainbow trout (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "very good" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Major land use categories in the basin are agriculture (cropland and pasture), at 59 percent; mixed upland forests, at 39 percent; and wetlands, at 2 percent (table 1, in supplemental data section).

The sampled reach begins 8.7 m upstream from the County Highway JJ bridge, in the Mecan River State Fishery Area, and extends 190 m upstream. The streambed consists of sand with pockets of gravel, cobbles, and boulders in riffle areas. This river has a continually shifting bed of very fine sand, which collects behind obstructions. Old, failing habitat improvements include sky booms and wing dams. Fallen trees and woody snags create the most common instream habitat.

This reach meanders through an open flood plain bordered by sandy bluffs. Streambanks are composed of muck and fine sand and are vegetated with grasses, sedges (*Carex* sp.), speckled alder (*Alnus rugosa*), and choke cherry (*Prunus virginiana*). Bank and flood-plain vegetation is characteristic of the Northern and Southern Lowland Forest communities (Curtis, 1987), even though this RHU is south of the tension zone.

Sampled reach of Mecan River, May 26, 1993 showing leaf-on conditions.



Sampled reach of Mecan River, April 14, 1995 showing leaf-off conditions.

Willow Creek

Willow Creek, which averages 6 m in width throughout the sampled reach, is a second-order stream in Waushara County, Wis. It is characterized by meanders and a diverse mix of runs, riffles, pools, and islands (table 2, in supplemental data section). This reach of Willow Creek had the greatest observed average velocity (0.79 m/s) of the streams described in this report, during the sampling period. The study reach, listed as a Class II trout stream, is stocked with brown trout and sustains naturally reproducing brown and brook trout populations (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Slightly more than 40 percent of the basin is used for agriculture (cropland and pasture). The rest of the basin is mainly forest with some wetlands (table 1, in supplemental data section).

The sampled reach begins in the Willow Creek State Fishery Area and Public Hunting Grounds, approximately 250 m upstream from the County Highway W bridge and extends 188 m upstream. Streambed substrate is characterized by sand with patches of gravel and scattered boulders. Woody snags and undercut banks are the dominant habitat features in this reach.

The streambanks consist of muck and sand and are vegetated with grasses and speckled alder (*Alnus rugosa*). In places, streambanks have been lined with boulders to reduce erosion. The creek cuts across a flood plain bordered by hills and upland grassy fields. Bank and floodplain vegetation is characteristic of the Alder-Thicket community (Curtis, 1987), even though this RHU is south of the tension zone.

Sampled reach of Willow Creek, May 26, 1993 showing leaf-on conditions.

Sampled reach of Willow Creek, April 13, 1995 showing leaf-off conditions.

Pine River

The Pine River, which averages 4 m in width throughout the sampled reach, is a spring-fed, second-order stream in Waushara County, Wis. It is characterized by alternating sand and gravel runs and riffles (table 2, in supplemental data section). The State of Wisconsin has designated the Pine as a wild and scenic river. The study reach is listed as a Class I trout stream and is populated by naturally reproducing brown and brook trout (Wisconsin Department of Natural Resources, 1980). In 1993, water quality of the sampled reach was rated "excellent" by use of a stream arthropod family-level biotic index (Hilsenhoff, 1988). Mayflies and caddisflies were present. Almost 60 percent of the basin is used for agriculture (cropland and pasture); land cover of the rest is a combination of deciduous, evergreen, and mixed deciduous/coniferous forests (table 1, in supplemental data section).

Data were collected from a reach that begins approximately 1,400 m upstream from the County Highway AA bridge, in the Pine River State Fishery Area, and extends 127 m upstream. Most of the streambed consists of a firm sand with some gravel and cobbles; however, fine sand and muck collects in beds of watercress (*Nasturtium officinale*) and water milfoil (*Myriophyllum* sp.) and behind debris. Habitat-restoration features include boulder riffles, bank structures, and failing wing dams. Woody snags and scattered boulders are common.

The reach meanders through a hummocky wetland of alternating grasses and overhanging speckled alders (*Alnus rugosa*) and ninebark (*Physocarpus opulifolius*). The streambanks consist of muck, sand, and boulders, covered with organic matter. Where vegetated, the streambanks are stable; however, some evidence of debris avalanche and undercut banks can be seen. Flood-plain vegetation is characteristic of the Northern Lowland Forest community (Curtis, 1987), even though this RHU is south of the tension zone.

Sampled reach of Pine River, May 27, 1993 showing leaf-on conditions.

Sampled reach of Pine River, April 13, 1995 showing leaf-off conditions.

IMPLICATIONS OF ENVIRONMENTAL SETTING ON WATER QUALITY

General streamwater-quality conditions in each of the RHU's can, in part, be attributed to bedrock geology, texture and type of surficial deposits, and land use. Water quality can be related to these natural and anthropogenic factors on the basis of field measurements of pH, specific conductance, water temperature, dissolved oxygen concentration, and laboratory concentrations of total organic plus ammonia nitrogen, dissolved ammonium as nitrogen, dissolved nitrate plus nitrite as nitrogen, total phosphorus, dissolved orthophosphate, and atrazine assay results.

Median pH did not vary greatly (fig. 10) among the four RHU's. All measured pH values were between 6.0 and 9.0, a range that meets the Water Quality Standards for Wisconsin Surface Waters (Wisconsin Department of Natural Resources, 1989) needed for the protection and propagation of an aquatic-life community. Median specific conductance (fig. 11) values were highest in streams in RHU's 1 and 3, which are underlain by carbonate bedrock. They were lowest in RHU 26, which is underlain by sandstone bedrock and RHU 20, which is underlain by igneous-metamorphic bedrock.

Dissolved oxygen (DO) concentrations ranged from 6.4 to 14.3 mg/L on the dates measured and were most variable in streams in RHU 3. These concentrations also meet the Wisconsin Department of Natural Resources (1989) water-quality standards. According to the Water-Quality Standards, the DO concentration should not be artificially lowered to less than 6.0 mg/L at any time, nor should the DO be lowered to less than 7.0 mg/L during the spawning season.

Concentrations of total organic plus ammonia nitrogen, dissolved ammonium, total phosphorus, and dissolved orthophosphate show little variation between streams and are generally low, compared to concentrations measured in agriculturally-affected streams in the same RHU's during the same sampling period (D.M. Robertson, U.S. Geological Survey, written commun., 1996). Concentrations of dissolved nitrate plus nitrite were less than 3.0 mg/L in most streams, with 3 streams, located in RHU's 1 and 3, showing concentrations between 3.0 and 6.0 mg/L. These higher concentrations may result in increased algal densities and associated photosynthesis/respiration functions (Mace and others, 1984). The lowest concentrations of dissolved nitrate plus nitrite were measured in RHU 20, where the percentage of agricultural land use was lowest. The single highest concentration of dissolved nitrate plus nitrite recorded was from Little Scarboro Creek in RHU 1, where the clay surficial deposits may contribute to increased surface runoff. The highest percentage of agricultural land use also occurred in this basin and RHU.

Concentrations of the most commonly used pesticide in the study unit, atrazine, were low in all streams, and most concentrations were below the 0.1µg/L detection limit. The immunoassay used for these samples is designed to be most sensitive to atrazine but may detect other triazines. All samples for atrazine were collected during the March 1995 sampling, a time when surface runoff was generally moderate. The only atrazine concentration recorded was 0.1 µg/L at eleven sites. Concentrations at the remaining sites were below the 0.1µg/L detection limit. The State of Wisconsin's safe drinking water limit is 3 µg/L, and the preventive action level (the concentration at which the state becomes concerned about drinking water) is 0.3 µg/L. The lowest percentage of detections of atrazine in streams was in RHU 20, which is also the RHU with the lowest percentage of agricultural land use. In RHU 26, atrazine was detected in all streams. The sandy surficial deposits underlain by sandstone in this RHU may allow for rapid recharge of surface runoff by infiltration into the sandstone aquifer.

Water-temperature measurements varied greatly, from 3 to 23 degrees Celsius, and is related to the season and time of sample collection. The water-temperature measurements did not seem to be related to RHU and were probably influenced by the fact that most streams selected were considered coldwater streams (Wisconsin Department of Natural Resources, 1980). Canopy cover and ground-water contributions may also contribute to the water-temperature variations at each of the measured reaches.

Interpretation of these data based on ecosystems delineated by Albert (1995) rather than RHU's results in similar findings largely because the RHU and regional ecosystem boundaries are comparable. Even if the data were interpreted on the basis of the coarser-scaled ecoregions of Omernik and Gallant (1988), the interpretations would be similar. In the Omernik and Gallant system, RHU's 1 and 3 are both in the Southeastern Wisconsin Till Plains ecoregion, whereas RHU's 20 and 26 are both in the North Central Hardwood Forest ecoregion. In comparing water quality among these latter ecoregions, similarities were often found between RHU's 1 and 3, and between RHU's 20 and 26. Although results do not appear different when using the RHU (Robertson and Saad, 1995), ecosystem (Albert, 1995) or ecoregion (Omernik and Gallant, 1988) maps, the RHU map isolates and specifies the environmental factors such as bedrock geology, texture of surficial deposits and land use/land cover that may influence water quality in these units. The ecoregion (Omernik and Gallant, 1988) and ecosystem (Albert, 1995) approach base their boundaries on relative differences in various environmental factors, that may or may not be equally-weighted or used independently.

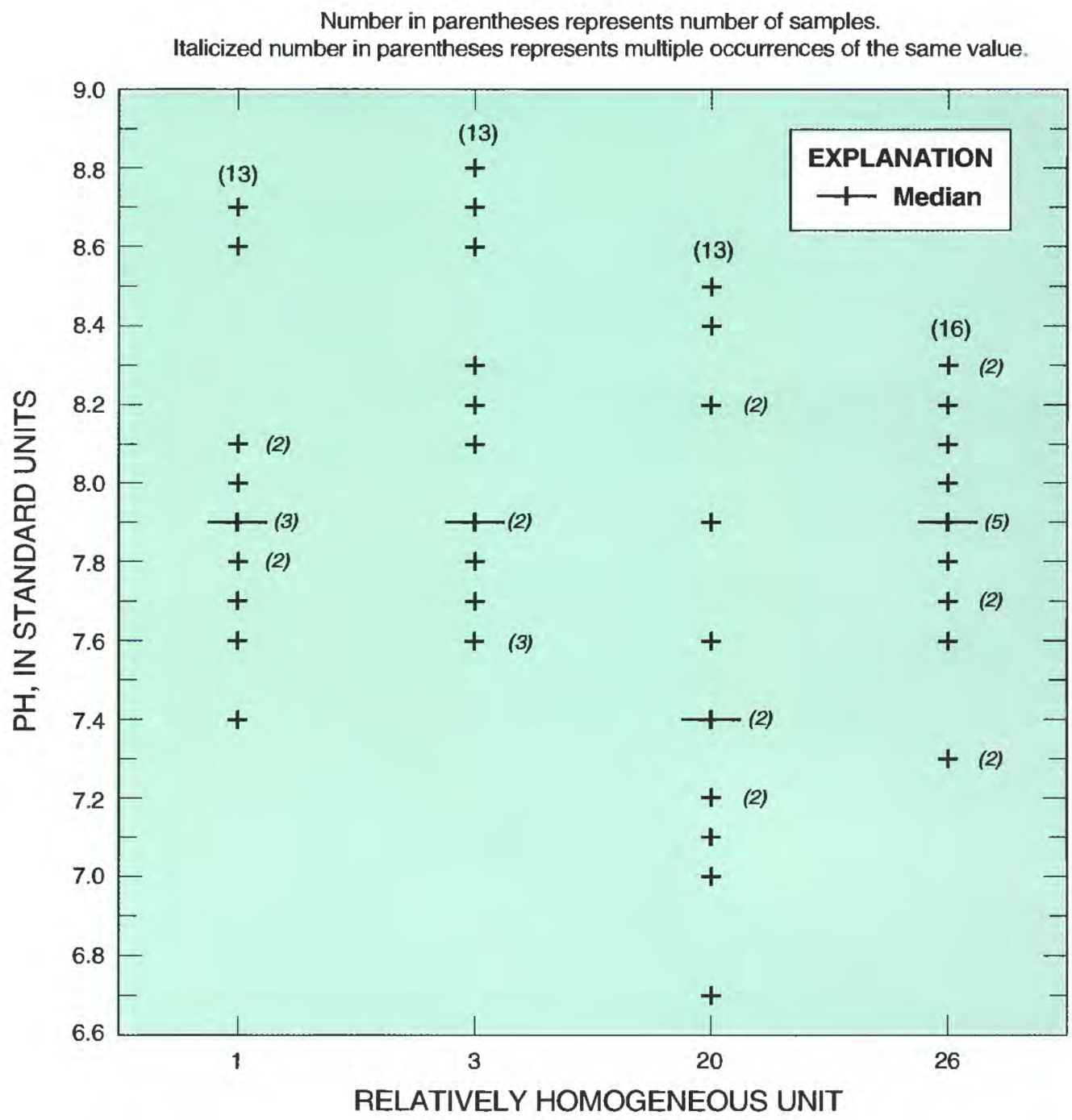


Figure 10. Plot of pH measurements by relatively homogeneous unit, Western Lake Michigan Drainages study unit.

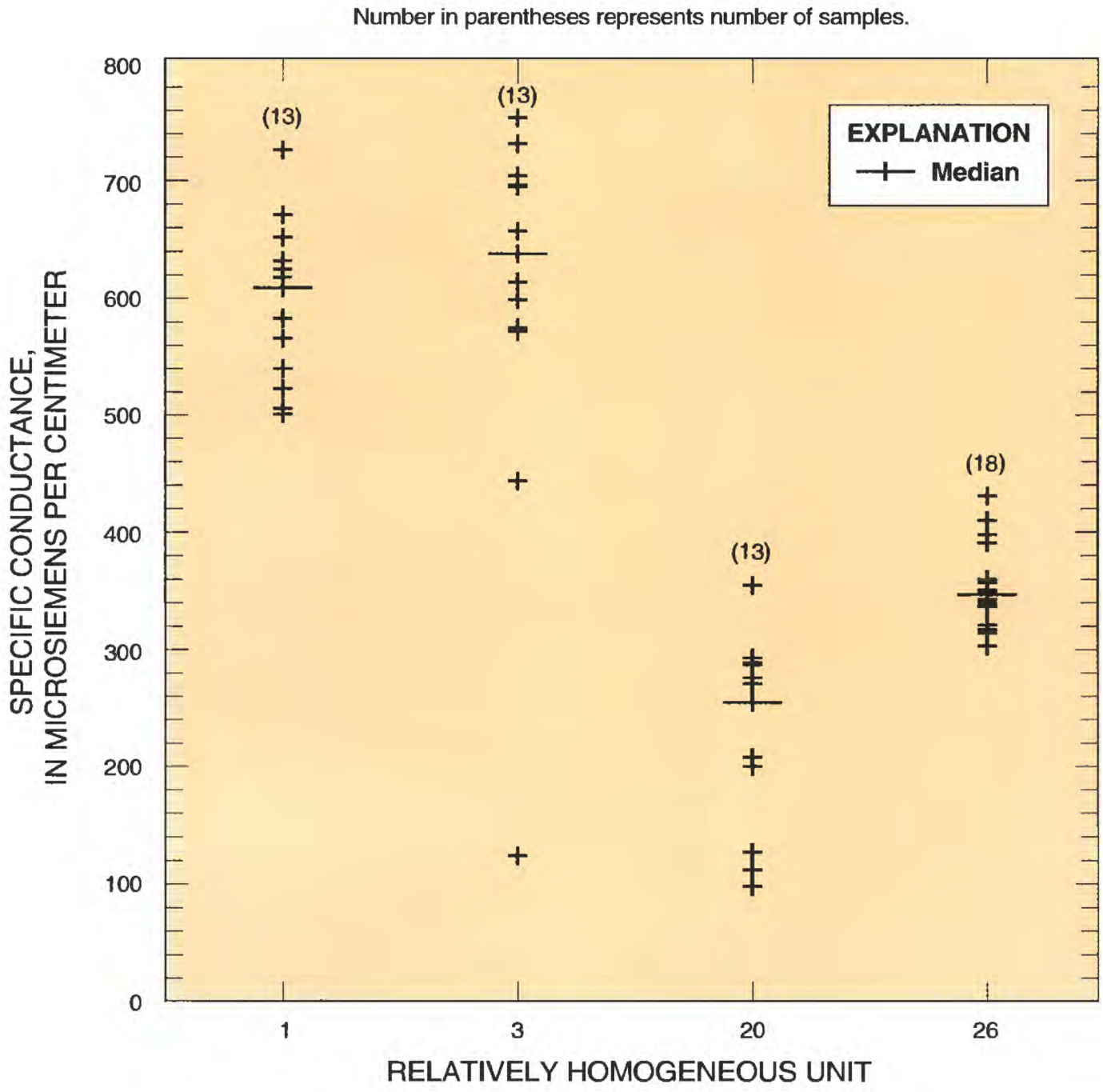


Figure 11. Plot of specific conductance measurements by relatively homogeneous unit, Western Lake Michigan Drainages study unit.

During the site-selection process, an attempt was made to select benchmark streams that represent healthy aquatic communities in agricultural areas. Based on the water-quality information collected to date, these streams appear to be largely unimpacted by human activity. This absence of adverse affects in part may be due to the fact that many of the reaches are surrounded by natural areas or are buffered from agricultural activities by riparian zones. Subsequent studies at these streams are planned to define and investigate further the aquatic ecosystem health of benchmark streams in agricultural areas by use of data on algae, invertebrates, fish and additional habitat characteristics. Information gathered from these benchmark sites can be used as a standard of reference to compare the health of other streams in agricultural areas on the basis of aquatic biota communities, habitat, and water-quality measurements.

SUMMARY

The mission of the U.S. Geological Survey is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at federal, state, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission. This report is an element of the comprehensive body of information developed as part of the NAWQA Program.

The Western Lake Michigan Drainages study unit comprises 51,541 km^2 of eastern Wisconsin and the Upper Peninsula of Michigan. Ten major rivers drain the study unit: the Escanaba and Ford Rivers in Michigan; the Menominee River, which partially defines the state boundary between Wisconsin and Michigan; the Peshtigo and Oconto Rivers in northeastern Wisconsin; the Fox/Wolf River complex, which drains into Green Bay, and the Manitowoc, Sheboygan, and Milwaukee Rivers, which drain the southeastern part of the study area.

This report describes the environmental setting of 20 benchmark streams in agricultural areas of eastern Wisconsin. Benchmark streams are defined as streams that have been largely unaffected by human activity. Four relatively homogeneous units (RHU's) in agricultural areas of differing bedrock and surficial geology were selected for study. RHU 1 (clayey surficial deposits over carbonate bedrock) and RHU 3 (sandy-till surficial deposits over carbonate bedrock) are in adjacent agricultural areas in the southeastern Wisconsin Till Plains ecoregion. RHU 20 (sandy/sand and gravel surficial deposits over igneous and metamorphic bedrock) and RHU 26 (sandy/sand and gravel surficial deposits over sandstone bedrock) are in adjacent areas of mixed forests and agriculture in the North Central Hardwood Forests ecoregion.

Twenty benchmark streams in these four RHU's were selected for sampling. All 20 agricultural benchmark sites were located at first-, second-, third-, or fourth-order wadable streams. Field data for this report were collected during May–June 1993 and April, June, and July 1995 in wadable stream reaches (less than 1 m in depth). Sampled reaches included repetitive geomorphic features (for example, two riffles and two pools). Reach length was generally determined by multiplying the average channel width by 20.

Characterizations of the physical and hydrologic features of each of these streams, such as stream order, drainage area, streamflow discharge, geomorphic units, and dominant substrate types, are described in this report. In addition, differences in land use/land cover based on the Anderson classification system (Anderson and others, 1976) are noted, and information on riparian and instream habitat characteristics is presented.

Summaries of field measurements of water temperature, pH, specific conductance, dissolved oxygen, nutrients, and atrazine assay levels are listed. Dissolved-oxygen for the sampled streams ranged from 6.4 to 14.3 mg/L and met the water-quality standards set by the WDNR for coldwater communities (Wisconsin Department of Natural Resources, 1989). Specific conductance ranged from 98 to 753, and pH ranged from 6.7 to 8.8, also meeting the WDNR standards. Effects of environmental setting on water quality by relatively homogeneous units are discussed.

General stream water-quality conditions in each of the RHU's can be attributed to bedrock geology, surficial deposits, and land use. This environmental setting report forms the basis for future work that will describe how these factors affect biotic communities and water chemistry, if at all, and whether any perceived effects can be quantified. This document is intended to serve as a reference for forthcoming reports on the results of sampling habitat and algal, benthic invertebrate, and fish communities at benchmark streams in agricultural areas of the Western Lake Michigan Drainages study unit.

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SUPPLEMENTAL DATA SECTION

Table 1. Selected information for benchmark-stream basins in agricultural areas of the Western Lake Michigan Drainages study unit
[RHU, relatively homogeneous unit]

Stream name	Ecoregion[1]		Ecosystem[2]		Land use/land cover[3]			
					Level I		Level II[4]	
	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of level I
RHU 1								
Tisch Mills Creek	North Central Hardwood Forests	100	VIII.1.3	96.0	Agriculture	80.9	21	100
			VIII.1.4	4.0				
					Forest	7.8	43	100
					Wetland	11.1	61	100
					Barren	.2	75	100
Krok Creek	Southeastern Wisconsin Till Plains	100	VIII.1.3	100	Agriculture	60.6	21	100
					Forest	2.7	43	100
					Wetland	36.5	61	100
					Barren	.2	75	100
Little Scarboro Creek	Southeastern Wisconsin Till Plains	100	VIII.1.3	100	Agriculture	93.5	21	100
					Wetland	6.5	61	100
Casco Creek	Southeastern Wisconsin Till Plains	100	VIII.1.3	25.5	Urban	1.5	11	30.1
			VIII.1.4	74.5			12	42.5
							16	27.4
					Agriculture	89.4	21	100
					Forest	7.0	43	100
					Wetland	2.1	61	100
Hibbard Creek	North Central Hardwood Forests	100	VIII.1.3	100	Agriculture	73.3	21	97.4
							22	2.6
					Forest	14.4	41	29.9
							42	26.6
							43	43.5
					Water	.4	52	100
					Wetland	11.7	61	100
					Barren	.2	75	100
RHU 3								
East Branch Milwaukee River	Southeastern Wisconsin Till Plains	100	V.2.1	57.1	Urban	2.2	11	61.5
			V.2.4	42.9			16	9.2
							17	29.3
					Agriculture	55.6	21	100

Table 1. Selected information for benchmark-stream basins in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Stream name	Ecoregion[1]		Ecosystem[2]		Land use/land cover[3]			
					Level I		Level II[4]	
	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of level I
				RHU 3—Continued				
East Branch Milwaukee River—Continued					Forest	32.0	41	61.4
							42	4.0
							43	34.6
					Water	2.4	52	100
					Wetland	7.8	61	92.3
							62	7.7
Nichols Creek	Southeastern Wisconsin Till Plains	100	V.2.1	100	Agriculture	80.9	21	100
					Forest	19.1	41	39.7
							43	60.3
Mullet River	Southeastern Wisconsin Till Plains	100	V.2.1	77.4	Urban	2.9	11	13.6
			V.2.4	22.6			12	34.5
							16	27.0
							17	24.9
					Agriculture	72.3	21	100
					Forest	15.4	41	74.0
							43	26.0
					Water	.8	52	93.5
							53	6.5
					Wetland	7.6	61	64.2
							62	35.8
					Barren	1.0	75	100
Watercress Creek	Southeastern Wisconsin Till Plains	100	V.2.1	87.2	Agriculture	65.7	21	100
			V.2.2	12.8				
					Forest	31.1	41	85.7
							42	8.6
							43	5.6
					Wetland	3.2	61	100
				RHU 20				
Whitcomb Creek	Southeastern Wisconsin Till Plains	100	IX.3.4	100	Agriculture	30.4	21	100
					Forest	63.0	41	38.5
							42	3.8
							43	57.7
					Water	.4	52	100
					Wetland	6.2	61	100

Table 1. Selected information for benchmark-stream basins in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Stream name	Ecoregion[1]		Ecosystem[2]		Land use/land cover[3]			
					Level I		Level II[4]	
	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of level I
				RHU 20—Continued				
West Branch Red River	North Central Hardwood Forests	100	IX.3.4	100	Urban	0.6	11	14.3
							16	85.7
					Agriculture	37.9	21	100
					Forest	51.2	41	68.5
							42	.2
							43	31.3
					Water	.2	52	52.4
							53	47.6
					Wetland	10.1	61	86.3
							62	13.7
Silver Creek	North Central Hardwood Forests	100	IX.3.4	100	Agriculture	35.4	21	100
					Forest	44.9	41	11.7
							42	.1
							43	88.2
					Water	.4	52	58.5
							53	41.5
					Wetland	19.3	61	79.3
							62	20.7
Smith Creek	North Central Hardwood Forests	100	IX.3.4	100	Agriculture	5.2	21	100
					Forest	59.5	42	5.8
							43	94.2
					Wetland	35.3	61	100
Camp Creek	North Central Hardwood Forests	100	IX.3.4	100	Agriculture	18.0	21	100
					Forest	53.6	43	100
					Wetland	28.4	61	100
				RHU 26				
Lawrence Creek	North Central Hardwood Forests	100	V.1.4	100	Urban	2.9	11	37.7
							13	62.3
					Agriculture	49.7	21	100
					Forest	46.1	42	6.9
							43	93.1
					Water	1.2	52	100
					Barren	.1	75	100

Table 1. Selected information for benchmark-stream basins in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Stream name	Ecoregion[1]		Ecosystem[2]		Lend use/land cover[3]			
					Level I		Level II[4]	
	Classification	Percentege of total	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of level I
				RHU 26—Continued				
Neenah Creek	North Central Hardwood Forests	100	V.1.4	100	Urban	1.4	11	88.1
							13	11.9
					Agriculture	58.2	21	100
					Forest	37.7	41	31.1
							42	3.7
							43	65.2
					Water	2.2	52	100
					Wetland	.4	62	100
					Barren	.1	75	100
Chaffee Creek	North Central Hardwood Forests	100	V.1.4	100	Urban	13.6	11	93.8
							12	6.2
					Agriculture	43.6	21	99.8
							22	.2
					Forest	25.6	41	74.8
							42	22.1
							43	3.1
					Water	.1	52	100
					Wetland	17.1	61	100
Mecan River	Southeastern Wisconsin Till Plains	100	V.1.4	100	Urban	.2	16	100
					Agriculture	58.7	21	100
					Forest	39.5	41	70.6
							42	10.2
							43	19.2
					Water	.2	52	100
					Wetland	1.4	61	80.7
							62	19.3
Willow Creek	Southeastern Wisconsin Till Plains	100	V.1.4	100	Urban	2.0	11	39.6
							12	42.1
							13	18.3
					Agriculture	41.0	21	100
					Forest	51.8	41	9.1
							42	36.3
							43	54.6
					Water	.8	52	100

Table 1. Selected information for benchmark-stream basins in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Stream name	Ecoregion[1]		Ecosystem[2]		Land use/land cover[3]			
					Level I		Level II[4]	
	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of total	Classification	Percentage of level I
				RHU 26—Continued				
Willow Creek—Continued					Wetland	4.1	61	73.2
							62	26.8
					Barren	.3	76	100
Pine River	North Central Hardwood Forests	100	V.1.4	100	Urban	.2	12	53.3
							13	46.7
					Agriculture	57.6	21	100
					Forest	42.2	41	42.4
							42	26.0
							43	31.6

[1]Based on Omernik and Gallant (1988) ecoregion classification system.

[2]Based on Albert regional landscape ecosystems (1995); V.1.4, Central Wisconsin sand plain–Waupaca; V.2.1, Southeastern Wisconsin till plain–Milwaukee; V.2.2, Southeastern Wisconsin till plain–Madison; V.2.4, Southeastern Wisconsin till plain–Kettle Moraine; VIII.1.3, Niagra Escarpment and lake plain–Escanaba/Door Peninsula; VIII.1.4, Niagra Escarpment and lake plain–Green Bay till plain and lake plain; IX.3.4, Upper Wisconsin/Michigan moraines–Chippewa-Green Bay lobes.

[3]Based on Anderson and others (1976) classification system; percentages estimated from digital line graph land use/land cover from high-altitude photography taken from 1972–81 and interpreted according to methods in Fegeas and others (1983).

[4]Level II classification: 11, residential; 12, commercial and services; 13, industrial; 16, mixed urban or built-up land; 17, other urban; 21 cropland and pasture; 22, orchards, groves, vineyards, nurseries, and ornamental horticultural areas; 41, deciduous forest land; 42, evergreen forest land; 43, mixed forest land; 52, lakes; 53, reservoirs; 61, forested wetland; 62, nonforested wetland; 75, strip mines, quarries, and gravel pits; 76, transitional areas.

Table 2. Location, name, hydrologic, and physical characteristics of benchmark streams in agricultural areas in the Western Lake Michigan Drainages study unit

[USGS, U.S. Geological Survey; km^2, square kilometers; mi^2, square miles; RHU, relatively homogeneous unit; --, missing data]

Site name	USGS station number	Latitude-longitude	Stream order	Drainage area (km^2 [mi^2])	Percent of each in reach			Predominant substrate type
					Riffle	Run	Pool	
RHU 1								
Tisch Mills Creek at Tisch Mills, Wis.	040852508	44°19'40" 87°38'10"	2	42.2 [16.3]	36	31	33	Gravel, sand, cobbles
Krok Creek near Ellisville, Wis.	04085233	44°26'34" 87°37'46"	2	200.6 [8.8]	49	37	14	Sand and muck with detritus
Little Scarboro Creek near Luxemburg, Wis.	040851987	44°30'49" 87°37'41"	1	2.3 [.9]	14	49	37	Sand and gravel with boulders and cobbles
Casco Creek near Casco, Wis.	040851970	44°32'43" 87°38'05"	3	38.9 [15.0]	57	41	2	Boulders, cobbles, and gravel
Hibbard Creek at Jacksonport, Wis.	04085170	44°59'16" 87°10'31"	2	42.5 [16.4]	10	49	41	Cobbles, gravel, and sand with boulders
RHU 3								
East Branch Milwaukee River near New Fane, Wis.	04086198	43°33'54" 88°11'04"	2	138.0 [53.3]	38	36	25	Sand and gravel with muck and cobbles
Nichols Creek near Cascade, Wis.	04086277	43°40'50" 88°01'12"	1	11.9 [4.6]	52	48	0	Gravel, sand, and cobbles
Mullet River near Plymouth, Wis.	04085760	43°47'21" 88°00'15"	4	117.6 [45.4]	74	26	0	Sand and gravel with cobbles
Watercress Creek near Dundee, Wis.	04086156	43°43'03" 88°07'54"	2	31.1 [12.0]	16	79	5	Muck with detritus
RHU 20								
Whitcomb Creek near Big Falls, Wis.	04079790	44°35'10" 89°02'15"	2	22.0 [8.5]	7	86	7	Sand
West Branch Red River near Bowler, Wis.	04077605	44°55'29" 88°57'21"	2	95.8 [37.0]	9	73	18	Sand with gravel
Silver Creek at Silver Rd. near Bowler, Wis.	04077614	44°54'48" 88°57'40"	2	40.9 [15.8]	28	67	5	Mixed boulders, cobbles, gravel, and sand
Smith Creek near Bowler, Wis.	04077653	44°52'35" 88°52'4"	2	5.7 [2.2]	--	--	--	Sand and muck
Camp Creek near Galloway, Wis.	04079589	44°44'21" 89°17'17"	1	12.4 [4.8]	7	85	8	Sand and gravel
RHU 26								
Lawrence Creek near Lawrence, Wis.	04072749	43°53'53" 89°36'04"	1	21.5 [8.3]	25	75	0	Sand
Neenah Creek near Oxford, Wis.	04072657	43°47'25" 89°35'56"	2	63.7 [24.6]	41	59	0	Sand and gravel

Table 2. Location, name, hydrologic, and physical characteristics of benchmark streams in agricultural areas in the Western Lake Michigan Drainages study unit—Continued

Site name	USGS station number	Latitude-longitude	Stream order	Drainage area (km^2 [mi^2])	Percent of each in reach			Predominant substrate type
					Riffle	Run	Pool	
RHU 26—Continued								
Chaffee Creek near Neshkoro, Wis.	04073248	43°58'28" 89°26'34"	2	23.8 [9.2]	24	25	51	Sand
Mecan River near Richford, Wis.	04073200	43°59'27" 89°21'29"	2	73.8 [28.5]	33	63	4	Sand
Willow Creek near Mount Morris, Wis.	04081437	44°07'11" 89°10'21"	2	41.7 [16.1]	21	65	14	Sand with boulders and gravel
Pine River at Wild Rose, Wis.	04081407	44°10'49" 89°15'04"	2	55.2 [21.3]	35	65	0	Sand with gravel and cobbles

Table 3. Chemical and physical characteristics of benchmark streams in agricultural areas of the Western Lake Michigan Drainages study unit

[µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; RHU, relatively homogeneous unit; <, less than; --, no data]

Site name	Date sampled	Instantaneous discharge[1] (m^3/s [ft^3/s])	pH	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Nitrogen			Phosphorus		Atrazine (µg/L by triazine screen)[2]
							Totai organic plus ammonia nitrogen (mg/L as N)	Nitrate plus nitrite, dissoived (mg/L as N)	Ammonium, dissolved (mg/L as N)	Total phosphorus (mg/L es P)	Dissolved orthophosphate (mg/L as P)	
RHU 1												
Tisch Mills Creek at Tisch Mills, Wis.	06/04/93	0.31 [11]	7.8	583	13.0	9.3	--	--	--	--	--	--
	04/11/95	.29 [10]	8.6	609	6.0	13.2	0.5	1.2	<0.02	<0.01	<0.01	<0.1
	07/11/95	.010 [0.37]	8.1	625	18.5	8.2	--	--	--	--	--	--
Krok Creek near Ellisville, Wis.	06/05/93	.16 [5.6]	7.6	506	14.0	9.3	--	--	--	--	--	--
	04/11/95	.20 [7.2]	8.7	501	7.0	11.9	.7	1.3	.02	.02	.01	.1
	06/27/95	.014 [.51]	7.7	652	18.0	7.9	.5	3.6	.04	.05	.04	<.1
Little Scarboro Creek near Luxemburg, Wis.	06/05/93	.11 [3.9]	7.9	632	12.0	10.3	--	--	--	--	--	--
	04/11/95	.17 [5.9]	7.8	618	5.0	12.3	.6	6.0	<.02	.02	<.01	<.1
	06/27/95	.045 [1.6]	8.0	671	13.5	10.6	.3	6.3	.02	.01	<.01	<.1
Casco Creek near Casco, Wis.	06/06/93	.31 [11]	7.9	726	15.5	9.5	--	--	--	--	--	--
	04/12/95	.74 [26]	--	--	--	--	--	--	--	--	--	.1
Hibbard Creek at Jacksonport, Wis.	05/06/93	.27 [9.6]	7.9	540	14.5	9.3	--	--	--	--	--	--
	04/12/95	.90 [32]	7.4	523	5.5	11.8	.4	1.7	.02	<.01	<.01	<.1
	06/27/95	.093 [3.3]	8.1	566	23.0	9.2	.7	1.6	.03	.01	<.01	<.1
RHU 3												
East Branch Milwaukee River near New Fane, Wis.	05/20/93	.91 [32]	7.9	124	14.0	8.7	--	--	--	--	--	--
	04/10/95	1.8 [65]	8.3	443	3.5	14.3	0.8	0.09	0.02	0.03	<0.01	<0.1

Table 3. Chemical and physical characteristics of benchmark streams in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Site name	Date sampled	Instantaneous discharge[1] (m^3/s [ft^3/s])	pH	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Nitrogen			Phosphorus		Atrazine (µg/L by triazine screen)[2]
							Total organic plus ammonia nitrogen (mg/L as N)	Nitrate plus nitrite, dissolved (mg/L as N)	Ammonium, dissolved (mg/L as N)	Total phosphorus (mg/L as P)	Dissolved orthophosphate (mg/L as P)	
RHU 3—Continued												
Nichols Creek near Cascade, Wis.	05/21/93	0.20 [6.9]	7.6	696	14.5	8.2	--	--	--	--	--	--
	08/24/93	.19 [6.9]	7.8	731	14.0	8.7	<0.2	3.70	<0.01	0.01	<0.01	--
	06/06/94	.22 [7.8]	7.6	657	14.0	9.8	.4	3.50	.02	.02	<.01	--
	04/11/95	.34 [12]	8.6	695	4.5	11.7	.4	3.90	.02	.02	<.01	<0.1
	06/26/95	.16 [5.8]	7.9	753	15.5	9.7	.4	4.60	.02	.02	<.01	<.1
Mullet River near Plymouth, Wis.	05/21/93	.75 [26]	8.1	599	17.0	8.5	--	--	--	--	--	--
	04/11/95	1.1 [40]	8.7	575	4.5	13.9	.5	.68	<.015	.01	<.01	0.1
	07/11/95	.27 [9.6]	8.8	614	21.5	11.7	--	--	--	--	--	--
Watercress Creek near Dundee, Wis.	05/22/93	.0071 [.25]	7.6	638	13.0	6.4	--	--	--	--	--	--
	04/11/95	.059 [2.1]	8.2	572	4.0	12.4	.6	.69	.06	.02	.01	.1
	06/26/95	.019 [.66]	7.7	704	16.5	8.0	.6	1.60	.04	.18	.04	.1
RHU 20												
Whitcomb Creek near Big Falls, Wis.	06/01/93	.49 [17]	7.4	287	10.5	10.2	--	--	--	--	--	--
	04/13/95	.36 [13]	8.5	288	7.0	11.7	0.7	0.53	<0.015	0.02	<0.01	<0.1
	06/29/95	.23 [8.0]	7.9	355	16.5	8.2	.7	.73	.03	.05	<.01	.1
West Branch Red River near Bowler, Wis.	06/08/93	2.0 [70]	7.6	289	14.0	9.8	--	--	--	--	--	--
	04/13/95	2.1 [73]	8.2	293	4.5	12.4	.5	1.1	.02	.02	<.01	<.1
Silver Creek at Silver Rd. near Bowler, Wis.	06/09/93	1.6 [56]	7.2	208	14.0	9.0	--	--	--	--	--	--
	04/13/95	1.2 [44]	8.2	276	3.5	12.4	.6	.92	.02	.02	<.01	<.1

Table 3. Chemical and physical characteristics of benchmark streams in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Site name	Date sampled	Instantaneous discharge[1] (m^3/s [ft^3/s])	pH	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Nitrogen			Phosphorus		Atrazine (µg/L by triazine screen)[2]
							Totai organic pius ammonia nitrogen (mg/L as N)	Nitrate plus nitrite, dissoived (mg/L aa N)	Ammonium, diasoived (mg/L as N)	Total phosphorus (mg/L as P)	Diasolved orthophosphate (mg/L as P)	
RHU 20—Continued												
Smith Creek near Bowler, Wis.	06/09/93	0.25 [9.0]	7.0	98	14.0	7.6	--	--	--	--	--	--
	04/12/95	.081 [2.9]	7.2	112	3.0	12.0	0.6	0.16	0.02	0.01	<0.01	<0.1
	06/28/95	.077 [2.7]	7.1	200	16.0	7.1	.8	.31	.05	.04	<.01	<.1
Camp Creek near Galloway, Wis.	06/10/93	.70 [25]	6.7	127	16.5	7.2	--	--	--	--	--	--
	04/13/95	.13 [4.7]	8.4	271	6.5	11.9	.5	1.10	.02	<.01	<.01	<.1
	06/28/95	.12 [4.4]	7.4	255	17.0	8.3	.6	.79	.06	.01	.02	<.1
RHU 26												
Lawrence Creek near Lawrence, Wis.	05/24/93	.46 [16]	7.3	339	11.5	7.8	--	--	--	--	--	--
	04/14/95	.54 [19]]	7.9	351	14.0	10.9	0.2	2.1	0.015	0.02	0.02	0.1
	06/30/95	.28 [10]	8.0	360	12.5	8.9	.2	1.8	.03	.02	.02	<.1
Neenah Creek near Oxford, Wis.	05/25/93	.77 [27]	7.7	337	14.5	8.6	--	--	--	--	--	--
	04/14/95	.93 [33]	8.3	349	12.0	11.8	<.2	1.5	<.015	.01	<.01	.1
Chaffee Creek near Neshkoro, Wis.[3]	05/25/93	.67 [24]	7.9	303	14.5	7.9	--	--	--	--	--	--
	04/13/95	.71 [25]	7.8	314	6.5	11.1	<.2	1.9	<.015	.01	<.01	.1
	07/11/95	1.0 [37]	7.9	321	17.0	8.7	.2	1.8	.03	.02	.02	--
Mecan River near Richford, Wis.[4]	05/26/93	1.7 [59]	7.9	357	15.5	8.6	--	--	--	--	--	--
	04/14/95	2.1 [75]	7.8	343	6.5	11.3	.3	2.2	<.015	<.01	<.01	.1
	07/11/95	1.5 [54]	8.1	347	19.0	9.0	.2	1.7	--	.03	--	--

Table 3. Chemical and physical characteristics of benchmark streams in agricultural areas of the Western Lake Michigan Drainages study unit—Continued

Site name	Date sampled	Instantaneous discharge[1] (m^3/s [ft^3/s])	pH	Specific conductance (µS/cm)	Water temperature (°C)	Dissolved oxygen (mg/L)	Nitrogen			Phosphorus		Atrazine (µg/L by triazine screen)[2]
							Total organic plus ammonia nitrogen (mg/L as N)	Nitrate plus nitrite, dissolved (mg/L as N)	Ammonium, dissolved (mg/L as N)	Total phosphorus (mg/L as P)	Dissolved orthophosphate (mg/L as P)	
RHU 26—Continued												
Willow Creek near Mount Morris, Wis.	05/26/93	0.65 [23]	7.6	317	12.0	8.0	--	--	--	--	--	--
	04/14/95	.91 [32]	7.9	340	5.5	11.6	0.7	1.5	0.02	0.02	<0.01	0.1
	06/29/95	.42 [15]	--	348	19.5	9.0	.5	1.2	.03	.02	<.01	<.1
Pine River at Wild Rose, Wis.[5]	05/27/93	.21 [7.6]	7.6	398	11.5	7.2	--	--	--	--	--	--
	04/13/95	.28 [10]	8.3	410	10.5	10.4	.2	2.5	.015	<.01	<.01	.1
	06/29/95	.23 [8.1]	--	431	16.5	9.0	.6	2.1	.02	.04	.02	<.1
	07/11/95	.27 [9.6]	8.2	391	18.5	10.0	.2	1.3	--	.02	--	--

[1]Instantaneous discharge for April 1995 sample dates are estimated.
[2]Screen is designed to be most sensitive to Atrazine but may detect other triazines.
[3]Water-quality site (near Budsin, Wis., station identification number 04073302) downstream from site sampled for biota on 7/11/95.
[4]Water-quality site (at 14th Street near Richford, Wis., station identification number 04073230) downstream from site sampled for biota on 7/11/95.
[5]Water-quality site (near Saxeville, Wis., station identification number 04081412) downstream from site sampled for biota on 7/11/95.