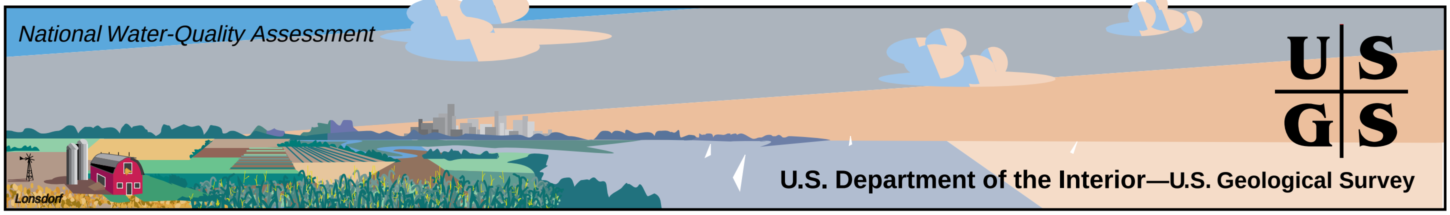
Fact Sheet FS-220-95



Environmental Factors Used to Subdivide the Western Lake Michigan Drainages into Relatively Homogeneous Units for Water-Quality Site Selection

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INTRODUCTION

In 1991, the National Water-Quality Assessment (NAWQA) Program was fully implemented by the U.S. Geological Survey (USGS). The goals of the NAWQA program are to (1) provide a nationally consistent description of water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends (or lack of trends) in water quality; and (3) identify, describe, and explain, as possible, the major factors that affect the observed water-quality conditions and trends (Hirsch and others, 1988).

To fulfill the goals of the NAWQA program, the USGS plans to examine 60 areas (study units) across the United States on a rotational cycle. The first 20 of these study units began intensive investigations in 1991. One of these study units is the Western Lake Michigan Drainages (WMIC)(fig. 1). During the first intensive phase of these investigations (lasting approximately 5 years), study-unit staffs examine available historical data and intensively sample at surface- and ground-water sites to describe water quality throughout the study unit. Historical water quality for streams and ground water for the WMIC study unit are being summarized in retrospective reports. Most historical stream data are from "integrator sites" on relatively large streams that flow through and integrate the effects of varied environmental conditions, not from "indicator sites" on small streams in areas dominated by specific environmental factors (for example, agriculture on clay surficial deposits and carbonate bedrock). Therefore, it is difficult to determine how the differences in surface-water quality throughout the study unit are related to differences in specific environmental factors; namely land use, surficial deposits, and bedrock. In this report, we describe how we subdivided the WMIC study unit into units of relatively homogeneous environmental factors. These relatively homogeneous units are used to select sites for sampling streams and ground water. This subdivision process may be useful for other investigators and water-quality managers to better determine how specific environmental factors affect water quality.

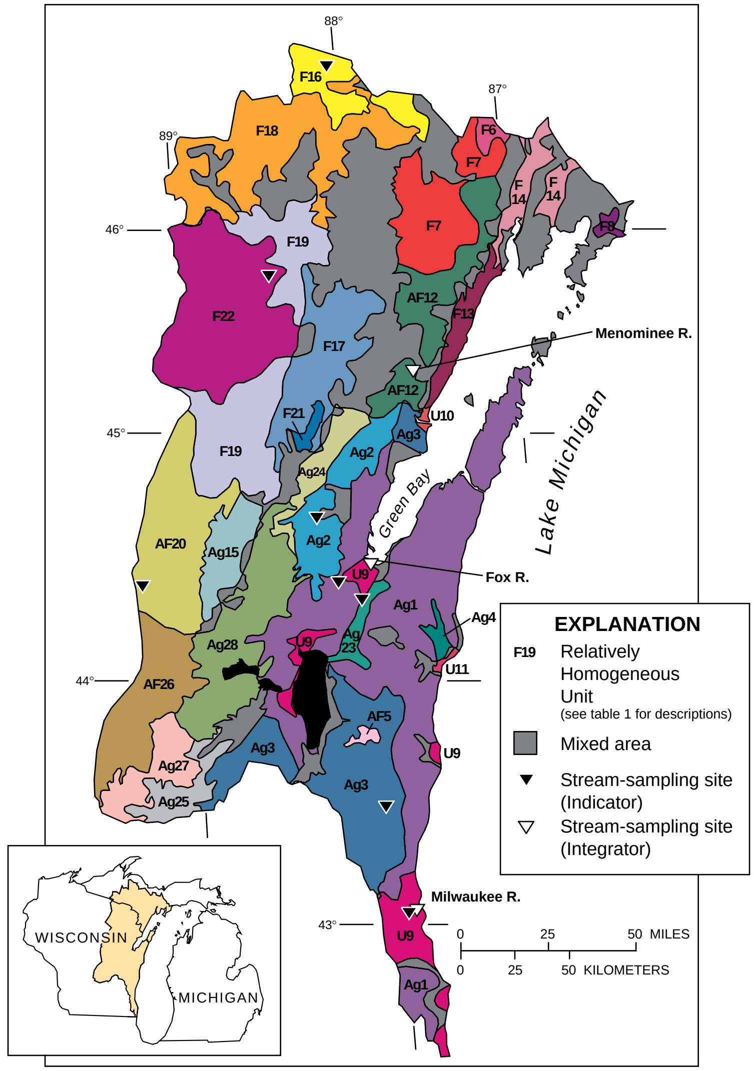

Figure 1. Relatively Homogeneous Units (RHU's) and stream-sampling sites in the Western Lake Michigan Drainages study unit.

ENVIRONMENTAL FACTORS

Various approaches have been used to subdivide landscape features in an attempt to determine how specific environmental factors affect water quality. The most commonly used approach is to compare water quality among different ecoregions (regions based on relative differences in various ecological factors). This approach does not always allow the effects of individual environmental factors to be determined because each factor is not always equally weighted or used independently in defining the ecoregions. To improve the general understanding of how environmental factors affect water quality, the WMIC study unit is divided into areas dominated by one specific type of each of three environmental factors thought to be most important in affecting water quality: land use/land cover, surficial deposits, and bedrock. Therefore, each of the three factors is equally weighted in defining the areas corresponding to specific combinations of these factors. These areas are referred to as "Relatively Homogeneous Units" (RHU's) (fig. 1). The three environmental factors are described in the following sections of this Fact Sheet.

Land Use

Land-use/land-cover (referred to as land use) information for the study unit (fig. 2) was obtained from high-altitude aerial photographs collected by the USGS between 1971 and 1981 (Feagus and others, 1983) and interpreted manually on the basis of the land-use classification system of Anderson and others (1976). Land-use maps were produced from the interpreted data and digitized into a Geographic Information System (GIS).

Forested land covers the largest percentage of the study unit. Forests dominate the northern part of the study unit and grade from deciduous forests in the southwest to evergreen forests in the northeast. Extensive agricultural land, mostly cropland and pasture, in the southern and central part of the study unit, is the second largest land-use category. Wetlands are divided into forested wetlands (wetlands dominated by woody vegetation) and nonforested wetlands (wetlands dominated by herbaceous vegetation or open water). Large contiguous areas of forested wetlands are in the northeastern part of the study unit and along the northwestern shore of Green Bay. Smaller areas of nonforested wetlands are mainly in the central part of the study unit, upstream from Lake Winnebago. Areas of urban or developed land surround the major cities found along Lake Michigan in the southeastern part of the study unit and around and north of Lake Winnebago. Smaller urban areas are also in the northeastern part of the study unit along Green Bay.

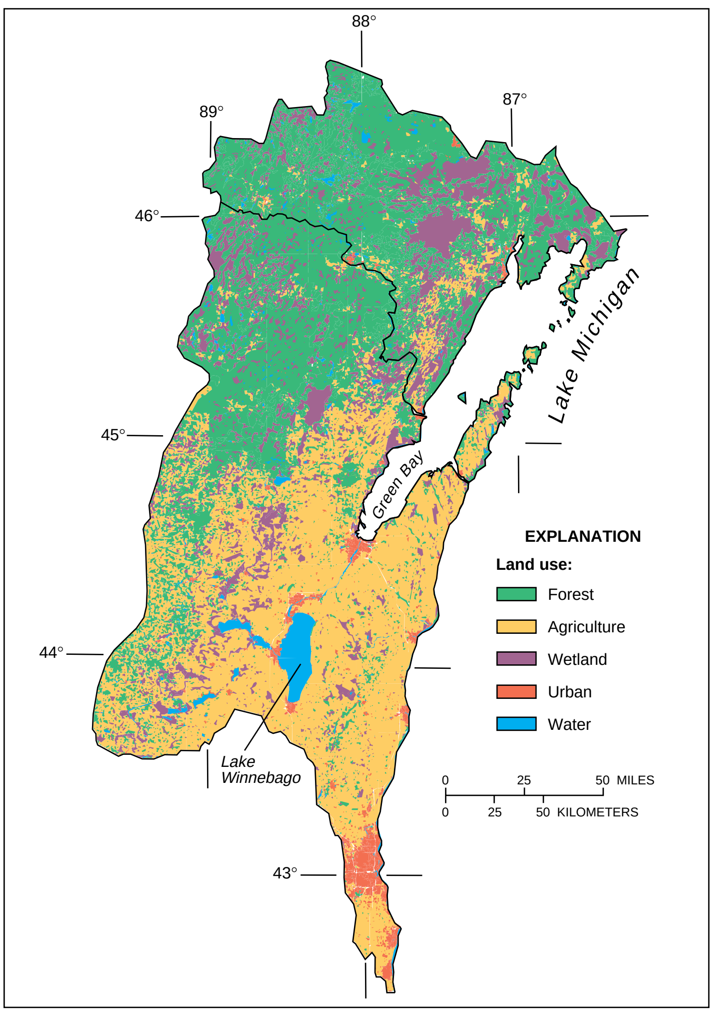

Figure 2. Land use/land cover of the Western Lake Michigan Drainages study unit.

Surficial Deposits

Surficial deposits range in thickness from zero to several hundred feet and consist of glacial and recent-aged deposits. These deposits can be divided into five types based primarily on texture: sand and gravel, sand, loam, clay, and peat. A digital coverage of the texture of surficial deposits for the study unit (fig. 3) was constructed from Quaternary geologic maps published by Richmond and Fullerton (1983) and Farrand and Bell (1982). Sand and gravel deposits are mainly in western and northwestern parts of the study unit, and are remnants of glacial outwash and ice-contact deposits. Sand deposits are also interspersed with the sand and gravel in most of these areas. In the southern part of the study unit, sand deposits predominate and are associated with till. Loamy deposits are in the northeastern part of the study unit and are also associated with till. Clayey deposits predominate in the central and eastern parts of the study unit. In the central part, clay is mainly from glaciolacustrine deposits; in the eastern part, it is associated with till and end moraines. Peat is found in low-lying, poorly drained areas, mainly in the northern part of the study unit.

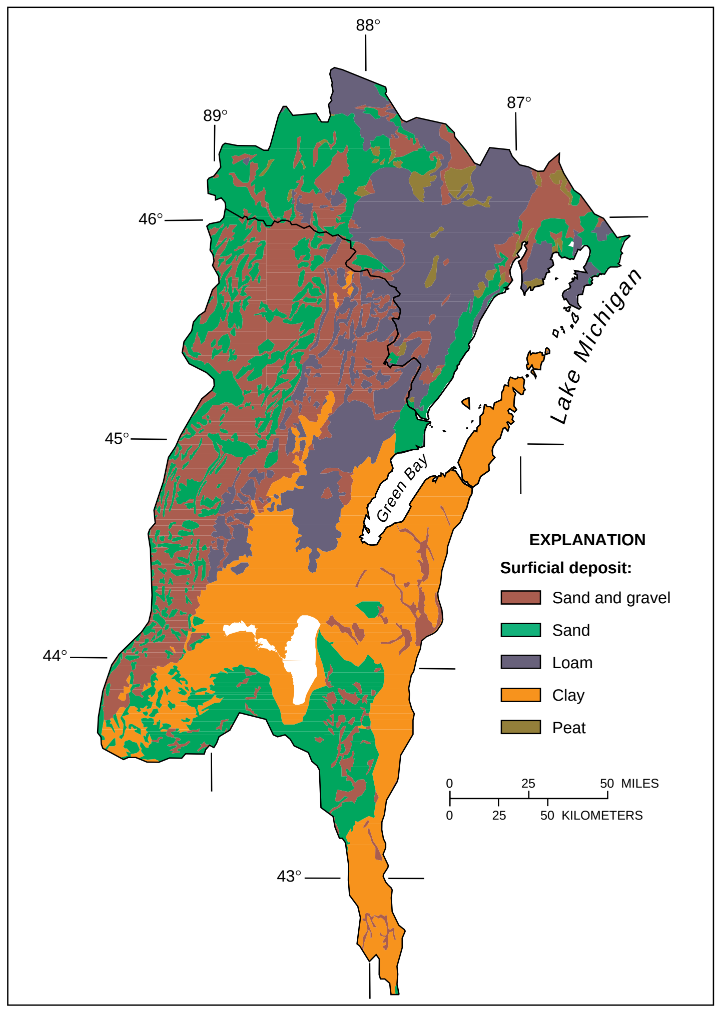

Figure 3. Texture of surficial deposits in the Western Lake Michigan Drainages study unit.

Bedrock

The bedrock underlying the study unit is composed of crystalline and sedimentary rock. Bedrock was divided into four types: igneous/metamorphic, sandstone, carbonate, and shale. A digital coverage for bedrock (fig. 4) was derived from maps published by Mudrey and others (1982) and Reed and Daniels (1987). Bedrock dips southeast toward Lake Michigan. Within the study unit, the oldest rock subcrops in the northwest and the youngest in the southeast.

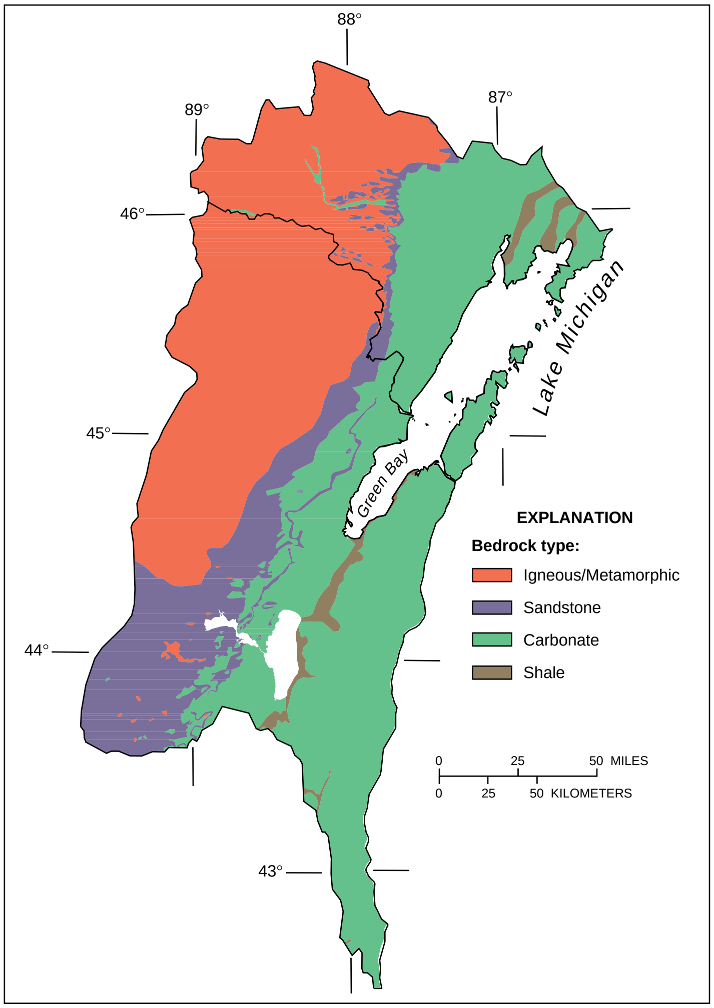

Figure 4. Bedrock in the Western Lake Michigan Drainages study unit.

RELATIVELY HOMOGENEOUS UNITS

Areas with similar land use, surficial-deposit texture, and bedrock were created by overlaying digital coverages of the three environmental factors by use of a GIS. The result was a single coverage that defined many small, discontiguous areas for any specific combination of the environmental factors. Almost every stream intersected several different types of areas; therefore, to categorize stream reaches on the basis of these environmental factors, it was necessary to generalize and simplify these features. **Land use** was generalized into large areas dominated by a single land-use type. For example, an area that was predominantly agriculture, but that also included small areas of forest and wetlands, was classified as agriculture. Areas of nearly equal parts forest and agriculture were classified as agriculture/forest; to be classified into this category, there needed to be over 30 percent agriculture and over 30 percent forest. In addition, areas that were classified as forest were subdivided into wet or dry forest on the basis of whether more or less than 20 percent of the area contained forested wetlands. The texture of **surficial deposits** was generalized into large areas dominated by one or two types of deposits. For example, areas predominantly clay were classified as clay and areas of sand and gravel interfingered with areas of sand were combined into one classification called sand/sand and gravel. Areas that were not extensive enough to be generalized into one of seven categories (table 1) were classified as mixed. **Bedrock** was generalized into large areas dominated by a single bedrock type. A few geologically complex areas were classified as mixed.

Digital coverages of the generalized features were made from hand-drawn maps and were again overlayed by use of a GIS. The resulting coverage contained larger more contiguous areas of relatively homogeneous land use, surficial deposits, and bedrock: the Relatively Homogeneous Units or RHU's mentioned earlier in this Fact Sheet (fig. 1). Areas classified as mixed in any of the three generalized coverages and small discontiguous areas resulting from the final overlay were classified as mixed areas. There are 28 RHU's in the study unit in addition to the mixed areas; a description of each is in table 1. Ten of the RHU's represent agriculture on different combinations of bedrock and surficial deposits; 11 represent forest on different combinations of bedrock and surficial deposits (6 wet forest and 5 dry forest); 4 represent an agriculture/forest mixture; and 3 represent urban areas.

SELECTION OF WATER-QUALITY SITES

The RHU's were used to design the stream and ground-water sampling networks of the WMIC study unit. For the stream sampling network, 11 sites were established to describe flow characteristics; concentrations and loads of nutrients, major ions, and suspended sediment; and biological communities. Eight of these sites have drainage basins entirely in one RHU (indicator sites) (fig. 1 and table 1). Of the 8 indicator sites, 4 sites were chosen to represent agricultural areas (Ag1, Ag2, Ag3, and Ag23), 2 sites to represent forested areas (F22, wet forest and F16, dry forest), 1 site to represent mixed agriculture/forest areas (AF20), and 1 site to represent an urban area (U9). Three integrator sites on the Menominee, Fox, and Milwaukee Rivers were chosen to represent most of the water leaving the WMIC study unit. Two indicator sites (in RHU's Ag1 and Ag3) and one integrator site (Milwaukee River) were chosen to collect water samples for pesticide analysis. The characteristics of the basins of these sites are given in table 1. For practical application, not all of the RHU's could be sampled as part of the basic stream-sampling network. Selection of RHU's to be sampled depended partially on its size; the amount of available data; its importance to local, State, and Federal agencies; the extent of ongoing and past studies in these areas; and its importance at a national level. To determine how well the chosen fixed sites represent other streams in the study unit, USGS investigators will analyze data from other sites sampled in the 8 RHU's with indicator sites and from sites in other RHU's as part of a regional synoptic study.

Ground-water activities focus on the effects of agricultural practices on water quality. Two areas (Ag3 and AF20/AF26 combined) were chosen to examine how agricultural practices affect shallow ground-water quality in areas with different surficial deposits. To ensure that land use is consistent among RHU's, all wells sampled were installed downgradient from fields that rotated through corn and alfalfa crops.

Table 1. Description of Relatively Homogeneous Units (RHU's) and stream-sampling sites for the Western Lake Michigan Drainages study unit shown in figure 1. Land use and surficial deposit are followed by the percentage of the dominant type or deposit. Abbreviations: km^2; square kilometers; Ag, agriculture; For, forest; Df, dry forest; Wf, wet forest; S&G, sand and gravel; Carb, carbonate; SS, sandstone; I/M, igneous/metamorphic]

RHU or sampling site	Area (km^2)	Land use (percent)	Surficial deposit (percent)	Bedrock
Ag1	7,531	Ag (80)	Clay (95)	Carb
Duck Cr. (Ag 1)	247	Ag (89)	Clay (76)	Carb
Ag2	1,356	Ag (79)	Loam (95)	Carb
Pensaukee R. (Ag2)	93	Ag (86)	Loam (99)	Carb
Ag3	3,548	Ag (78)	Sand (85)	Carb
N. Br. Milwaukee R. (Ag3)	133	Ag (88)	Sand (89)	Carb
Ag4	142	Ag (67)	S&G (80)	Carb
Ag15	835	Ag (84)	Loam (65)/S&G (32)	I/M
Ag23	304	Ag (84)	Clay (86)	Shale
East R. (Ag23)	122	Ag (92)	Clay (95)	Shale
Ag24	650	Ag (67)	Loam (95)	SS
Ag25	667	Ag (72)	Sand (78)	SS
Ag27	956	Ag (52)	Clay (77)/Sand (23)	SS
Ag28	2,480	Ag (58)	Clay (97)	SS
AF5	81	Ag (31)/For(58)	Sand (34)/S&G (66)	Carb
AF12	1,642	Ag (31)/For(64)	Loam (95)	Carb
AF20	2,519	Ag (44)/For(53)	Sand (32)/S&G (68)	I/M
Tomorrow R. (AF20)	114	Ag (58)/For(39)	Sand (39)/S&G (61)	I/M
AF26	1,854	Ag (52)/For(43)	Sand (31)/S&G (63)	SS
F6	155	Df (97)	Loam (100)	Carb
F7	1,832	Wf (95)	Loam (93)	Carb
F8	103	Wf (97)	Sand (100)	Carb
F13	543	Wf (90)	Sand (85)	Carb
F14	719	Wf (90)	Sand (35)/S&G (55)	Carb
F16	995	Df (90)	Loam (92)	I/M
Peshekee R. (F16)	127	Df (98)	Loam (100)	I/M
F17	1,900	Df (91)	Loam (40)/S&G (59)	I/M
F18	3,098	Df (93)	Sand (86)	I/M
F19	3,160	Df (91)	Sand (36)/S&G (61)	I/M
F21	140	Wf (83)	Clay (91)	I/M
F22	3,701	Wf (92)	Sand (39)/S&G (61)	I/M
Popple R. (F22)	360	Wf (90)	Sand (24)/S&G (76)	I/M
U9	1,227	Urban (69)	Clay (97)	Carb
Lincoln Cr. (U9)	25	Urban (100)	Clay (100)	Carb
U10	40	Urban (50)	Sand (94)	Carb
U11	35	Urban (63)	S&G (71)	Carb
MIxed	8,808	Mixed	Mixed	Mixed
Menominee R.	10,103	Integrator	Integrator	Integrator
Fox R.	15,630	Integrator	Integrator	Integrator
Milwaukee R.	1,782	Integrator	Integrator	Integrator

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Information on technical reports and hydrologic data related to NAWQA can be obtained from:

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