HYDROLOGY AND LAND USE IN

VAN BUREN COUNTY, MICHIGAN

By T. R. Cummings, F. R. Twenter, and D. J. Holtschlag

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DEFINITION OF TERMS

Altitude. Vertical distance of a point or line above or below the National Geodetic Vertical Datum of 1929. The National Geodetic Vertical Datum of 1929 (NGVD of 1929) is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. In this report, all altitudes are above NGVD of 1929.

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. It is also called a ground-water reservoir.

Bedrock. Designates consolidated rocks underlying glacial deposits.

Concentration. The weight of dissolved solids or sediment per unit volume of water expressed in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Contour. An imaginary line connecting points of equal altitude, whether the points are on the land surface, on the clay surface, or on a potentiometric or water-table surface.

Discharge. The rate of flow of a stream; reported in cubic feet per second (ft^3/s).

Divide. A line of separation between drainage systems. A topographic divide delineates the land from which a stream gathers its water; a ground-water divide is a line on a potentiometric or water-table surface on each side of which the potentiometric surface slopes downward away from the line.

Equipotential line. A line in an aquifer on which every point has the same potentiometric head. As used in this report, equipotential lines defines the water table. The value identifying a given line is the altitude of all points on that line.

Ground water. Water that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Hydraulic conductivity. The volume of water at the prevailing kinematic viscosity that will move in unit time under a unit hydrualic gradient through a unit area measured at right angles to the direction of flow. In general terms, hydraulic conductivity is the ability of a porous medium to transmit water.

Hydrograph. A graph showing the variations of stage, flow, velocity, discharge, or other aspect of water with respect to time.

NGVD of 1929. See Altitude.

Permeability. A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone, and is independent of the nature of the fluid and of the force field.

Potentiometric surface. In aquifers, the levels to which water will rise in tightly cased wells. More than one potentiometric surface is required to describe the distribution of head. The water table is a particular potentiometric surface.

Recharge. The process by which water is infiltrated and is added to the zone of saturation. It is also the quantity of water added to the zone of saturation.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to which an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

Specific capacity. The rate of discharge of water from a well divided by the drawdown of water level within the well.

Specific conductance. A measure of the ability of water to conduct an electric current, expressed in micromhos (μmhos) per centimeter at 25°C. Because the specific conductance is related to amount and type of dissolved material, it is used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in milligrams per liter) to specific conductance (in micromhos) is in the range 0.5 to 0.8.

Specific Yield. The ratio of the volume of water that the rock, after being saturated, will yield by gravity, to the volume of rock. It is commonly used for unconfined or water-table aquifers as being virtually equal to storage coefficient. Specific yield of most unconfined aquifers ranges from 0.1 to 0.3 and averages about 0.2.

Storage coefficient. The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. Defines conditions in both confined and unconfined aquifers. The storage coefficient of most confined aquifers ranges from 0.00005 to 0.002. For unconfined aquifers, storage coefficient virtually equals specific yield.

Transmissivity. The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells.

CONVERSION FACTORS

Inch-pound units used in this report can be converted to metric (SI) units as follows:

Multiply inch-pound unit	By	To obtain metric unit
acre (ac)	0.004047	square kilometer (km^2)
	0.4047	hectare (ha)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	28.32	liter per second (L/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	10.93	liter per second per square kilometer [(L/s)/km^2]
foot (ft)	0.3048	meter (m)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.207	liter per second per meter [(L/s)/m]
inch (in)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
pound (lb)	0.4536	kilogram (kg)
	453.6	milligram (mg)
pound per acre (lb/ac)	1.121	kilogram per hectare (kg/ha)
square miles (mi^2)	2.590	square kilometer (km^2)
	259.0	hectare (ha)
ton, short	907.2	kilogram (kg)
ton per square mile (ton/mi^2)	3.503	kilogram per hectare (kg/ha)
degrees Fahrenheit (°F)	(1)	degrees Celsius (°C)

[1]Temperature °C = (temperature °F -32)/1.8.

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T. R. Cummings, F. R. Twenter, and D. J. Holtschlag

ABSTRACT

This report gives the results of an investigation to determine the chemical and physical characteristics of ground and surface water in Van Buren County and to relate these characteristics to the agricultural use of land. Chemical inputs to the hydrologic system, including those from precipitation, animal wastes, septic tanks, and fertilizers, are assessed. Land-use, geologic setting, and hydrologic conditions are given as a necessary framework for interpretations.

The land surface in Van Buren county in southwestern Michigan is flat to rolling, and ranges in altitude from 580 to 1,050 feet. About 30,000 acres or 7.4 percent of land is irrigated. Annual precipitation ranges from 34 to 36 inches. Two rivers--the Paw Paw and South Branch Black--drain most of the county. During this study, the maximum discharge of the Paw Paw River was 2,500 cubic feet per second; the minimum discharge was 202 cubic feet per second. The average discharge of the South Branch Black River during a 17-year period of record has been 106 cubic feet per second.

Glacial deposits are the principal source of ground-water supplies. These deposits range in thickness from 100 to 600 feet and consist of till, outwash, and materials of lacustrine and eolian origin. In places the deposits fill buried valleys that are as much as 400 feet deep. The Coldwater Shale of Mississippian age, which underlies the glacial deposits, is mostly shale and usually yields only small amounts of salty water.

Of the glacial deposits, outwash is the most productive aquifer. Most domestic wells obtain water from outwash at depths ranging from 15 to 160 feet. Irrigation wells capable of yielding 1,000 gallons per minute generally are about 200 feet deep. In places in the western part of the county, glacial deposits, which are several hundred feet thick, are mostly clay and yield little or no water.

Areal variations in the chemical and physical characteristics of ground and surface water are related to land use and chemical inputs to the hydrologic system. Information on fertilizer application, septic-tank discharges, animal wastes, and precipitation and dry fallout show that 72.7 percent of nitrogen input is from fertilizer, 21.3 percent from precipitation and dry fallout, 4.5 percent from animal wastes, and 1.5 percent from septic tanks.

Streams and lakes generally contain a calcium bicarbonate type water. The dissolved-solids concentration of streams ranged from 56 to 749 milligrams per liter, and that of lakes, from 28 to 310 milligrams per liter. Water of streams is hard but at most locations is suitable for most uses. Total nitrogen concentrations as high as 15 milligrams per liter were found at two sites. Pesticides (Simazine and Atrazine) were detected at some sites. Relationships between land use and water quality of streams indicate that the nitrate yield of land increases as the percentage of crop land, pasture, and feeding operation increases in a drainage area. Water of lakes also is suitable for most uses, although Alachlor, Atrazine, Silvex, Simazine, Treflan, or 2,4-D were detected in 26 samples.

Ground water is of a calcium bicarbonate type, although sodium, sulfate, and chloride are the predominant ions at some locations. Dissolved-solids concentrations ranged from 112 to 878 milligrams per liter; concentrations of trace metals exceeding those common in water were detected at some locations. Nitrate concentrations in the southern eight townships were generally higher than in the northern ten townships; water from 22 percent of the wells in the southern townships exceeded the 10 milligrams per liter drinking-water standard of the U.S. Environmental Protection Agency. High nitrate concentrations probably are related to fertilizer applications, but equally important seems to be the quantity of irrigation water applied. Oil-field activity in the northern part of the county seems to have increased the chloride concentrations of ground water in some places.

Model simulations of the ground-water flow system matched measured conditions if hydraulic conductivities of 10 to 35 feet per day and a recharge rate of 11.8 inches per year were used. Simulations of 500 gallons per minute pumping from an unconfined aquifer indicated only 2 to 3 feet of drawdown in the vicinity of the pumping well. Similar pumping from a confined aquifer, however, produced about 10 feet of drawdown. Simulations of increased pumping for the irrigated area in the southern part of the county indicated that significant drawdown might be expected in some parts.

INTRODUCTION

Information on the chemical and physical characteristics of water in areas devoted principally to agricultural purposes is generally inadequate to assess the nature and extent of agriculture's impact, or to separate it from other cultural impacts. Although numerous studies of agriculture lands have been made, results are not easily transferable from one region of the country to another because of the wide range of climatic, geologic, and hydrologic conditions. Water-quality data, even when available, frequently have not been evaluated in conjunction with detailed information on land use, on how use varies areally, and on the chemical inputs to the hydrologic system.

In Van Buren County, which is typical of several other counties in southwestern Michigan, the expanding use of ground and surface water for irrigation has been rapid. Of principal concern to many is the extent to which the water resource may be developed and agricultural activity expanded without serious deterioration of water quality. The increased use of water will affect not only the usability of supplies, but the esthetic value of lakes and streams. This report, based on data collected from 1980 through 1982, provides a basis for a continuing assessment and evaluation of changes and their significance.

Purpose and Scope of Study

The purpose of this investigation was to determine the chemical and physical characteristics of ground and surface water in Van Buren County and to relate these characteristics to land use. To do so required an assessment of the chemical inputs to the hydrologic system, including those of precipitation, animal wastes, septic tanks, and fertilizers. Information on geologic and lithologic conditions, which provide the necessary framework for interpretations, was also assembled and evaluated. An inventory of land-use was also required. A ground-water model was developed to aid in understanding hydrologic conditions, and to aid in evaluating the potential impacts of future agricultural development.

Cooperation and Acknowledgments

This investigation was a cooperative effort between the U.S. Geological Survey, the Van Buren County Extension Office, Geological Survey Division of the Michigan Department of Natural Resources, and the Michigan Department of Agriculture. Assistance in phases of the investigation was also provided by the U.S. Soil Conservation Service and the Michigan Department of Public Health. Collection and analysis of geologic, hydrologic, and water-quality data were the responsibility of the U.S. Geological Survey. The collection of land-use data, and surveys of fertilizer use, animal populations, and

septic-tank installations were the responsibility of the Van Buren County Extension Office. The Michigan Department of Agriculture assisted in collecting land-use information, and developed data on land erosion potential. The Michigan Department of Public Health analyzed some samples of water from domestic wells.

Many local and county officials, as well as citizens, provided data and took an active interest in the project. Jerry Smithson, a U.S. Geological Survey hydrologic technician headquartered in Paw Paw, collected most of the hydrologic data and assisted in preliminary analysis of results.

General Description of Area

Van Buren County is in southwestern Michigan (fig. 1) and is partly bounded by Lake Michigan on the west. The county, an area of about 630 square miles (mi^2), is mainly cultivated fields, orchards, vineyards, woodlands, and pasture. The land surface is flat to rolling and ranges in altitude from 580 feet (ft) along Lake Michigan to 1,050 ft in a small area in the southeastern part of the county (fig. 2). The Paw Paw and Black Rivers, both draining westward to Lake Michigan, are the principal streams in the county (pl. 1). More than 100 lakes larger than 10 acres in size are distributed throughout the county.

Population in 1980 was 66,814 (U.S. Bureau of Census, 1982), of which about 22,000 lived in incorporated communities (table 1). The population of

Table 1.--Population and source of water supplies for communities

Community	Population (1980)	Source of water[a]	Depth of wells	Total pumpage in 1981[b] (millions of gallons)
Bangor	2,001	W	60-75	68
Bloomingdale	537	--		
Breedsville	244	--		
Decatur	1,915	W	111-120	107
Gobles	816	W	110-124	20
Hartford	2,493	W	93-107	97
Lawrence	903	W	74-80	37
Lawton	1,558	W	105-125	264
Mattawan	2,143	W	220	45
Paw Paw	3,211	W	62-110	201
South Haven	5,943	L		

[a]Source of water: W: well tapping glacial deposits, L: Lake Michigan.
[b]Approximate, reported by community.

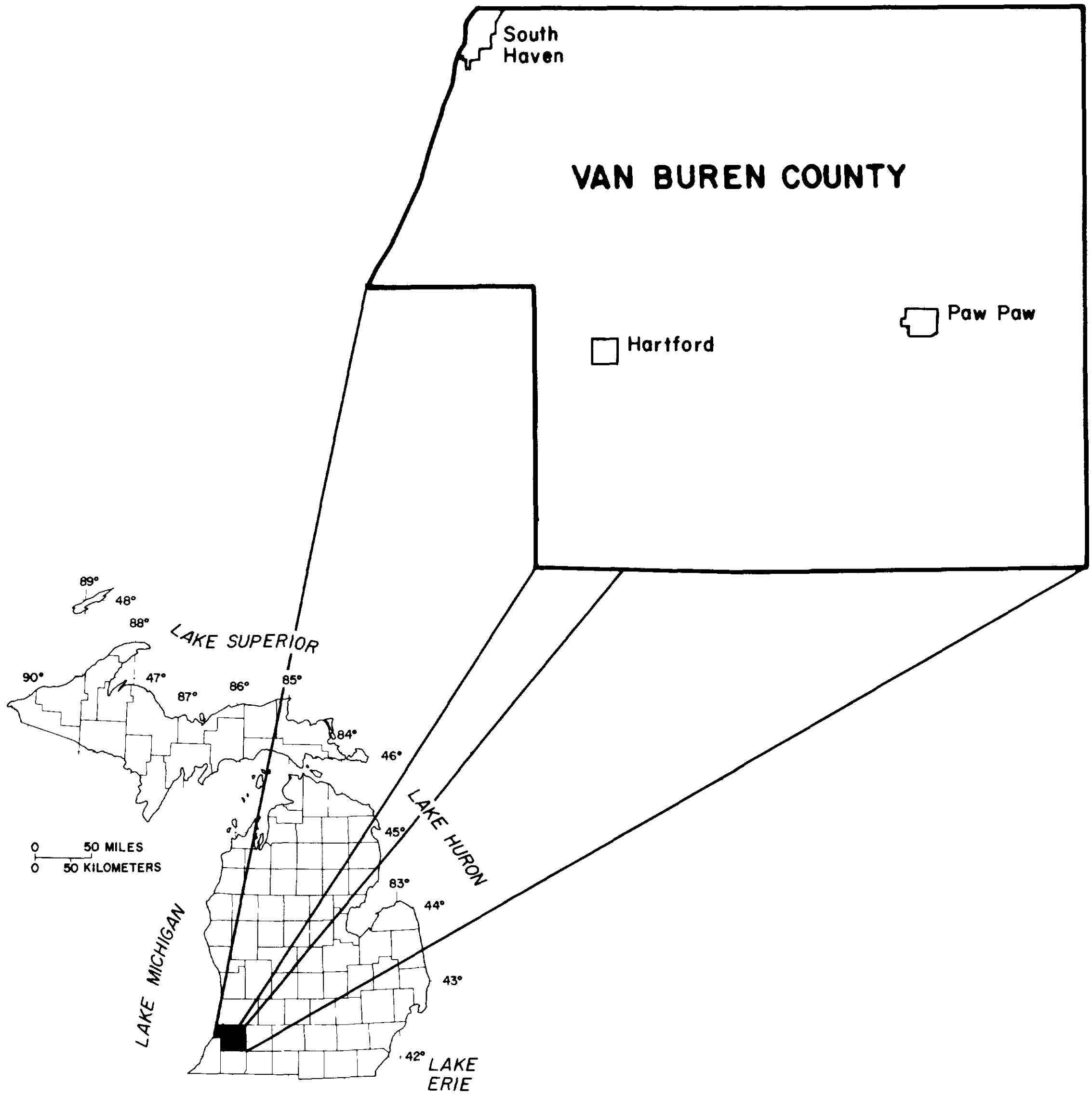


Figure 1.--Location of Van Buren County, Michigan.

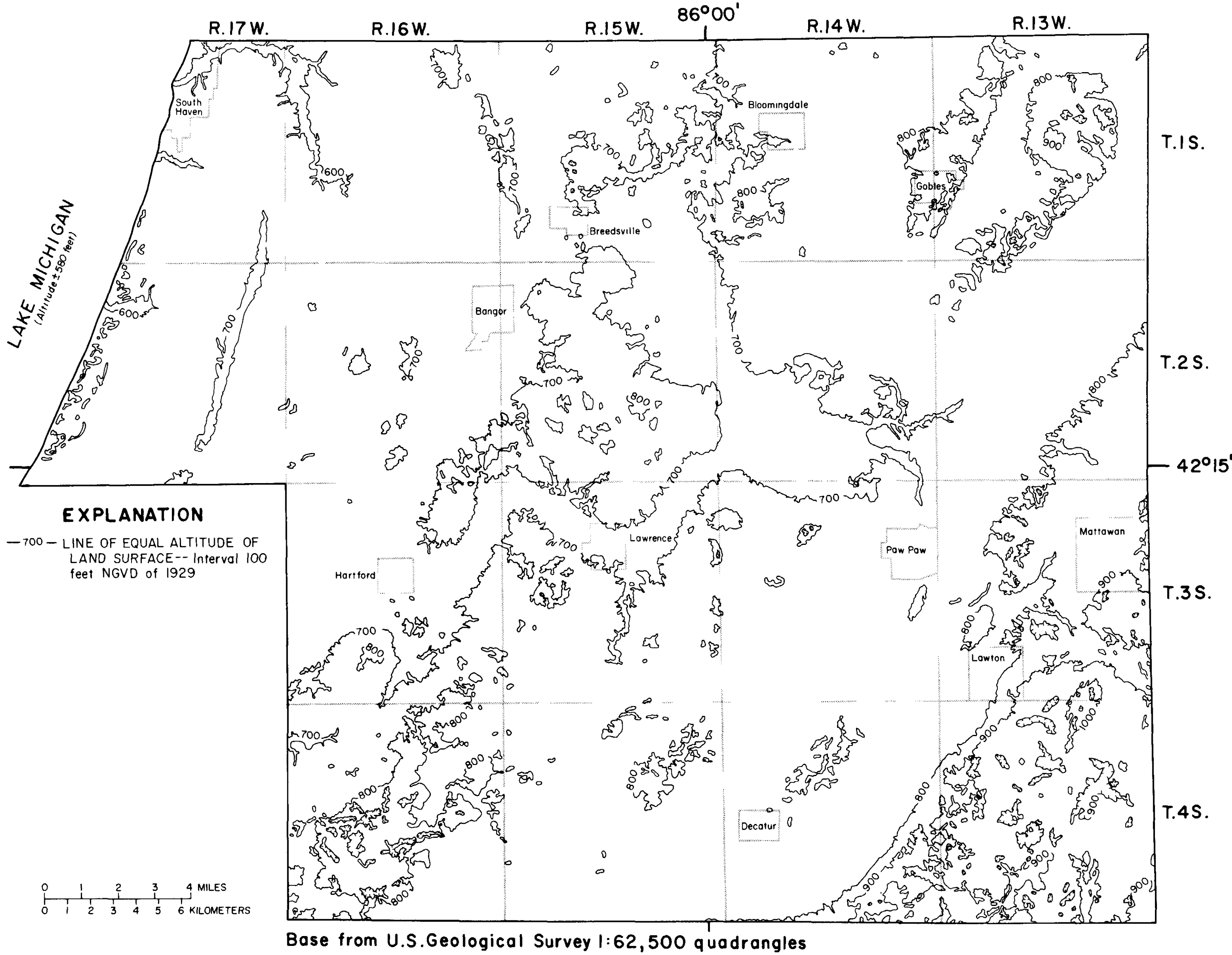


Figure 2.--Altitude of land surface.

the county, by townships, is shown in figure 3. The largest community, South Haven, had a population of 5,943. In addition to permanent residents, large numbers of migrant workers come to the county to help harvest fruit and other crops. The source of public water supply for all communities, except South Haven, which obtains its supply from Lake Michigan, is ground water (table 1).

About 30,000 acres of agricultural land is irrigated. Between 1970 and 1977, the water used for irrigation increased 193 percent (Bedell and Van Til, 1979). The number of county irrigators, 245, is the largest in the state.

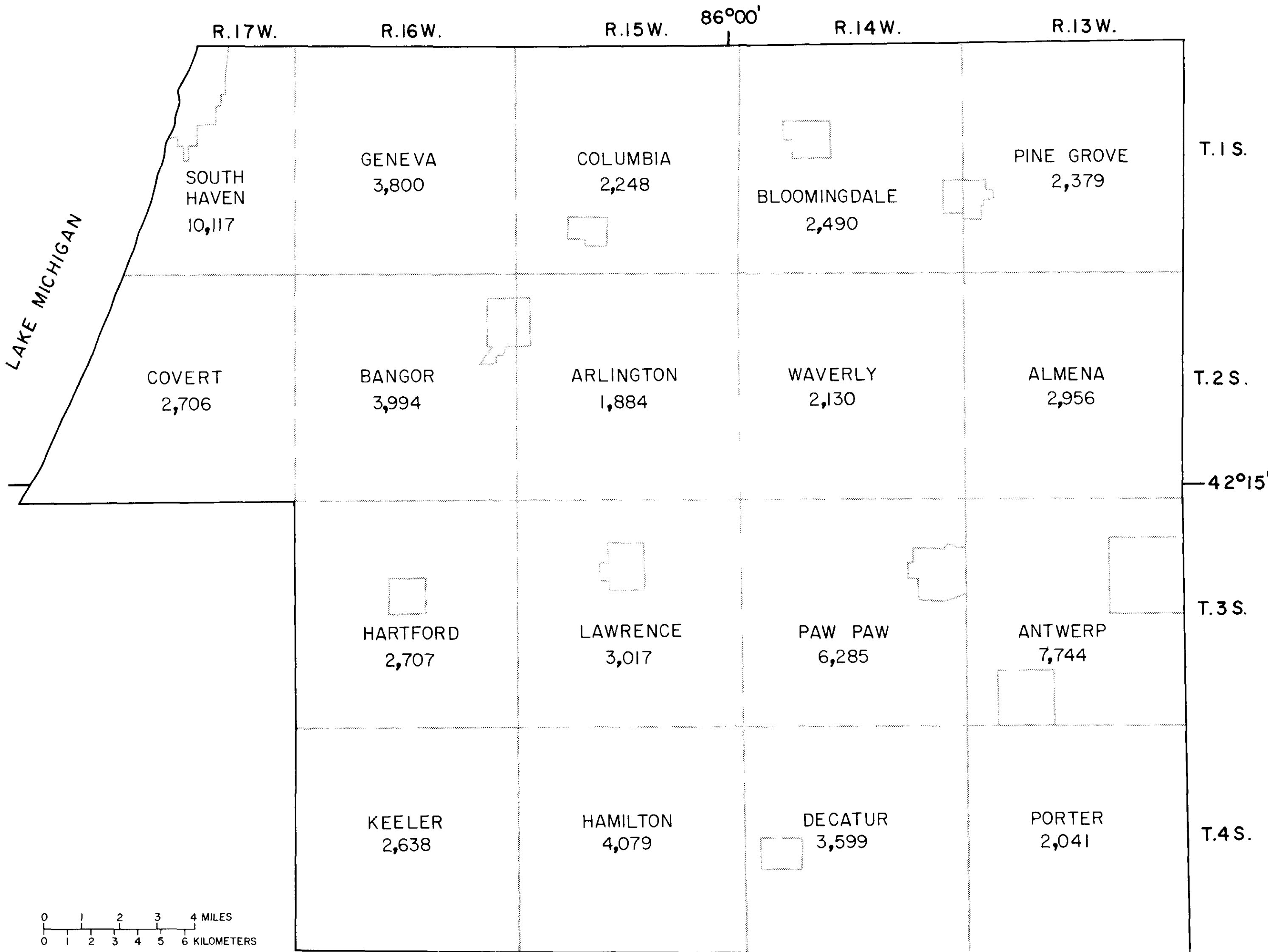
Mean annual precipitation ranges from 34 inches along Lake Michigan to 36 inches inland (National Oceanic and Atmospheric Administration, 1981). Similarily, annual snowfall is about 50 inches near Lake Michigan and 75 inches inland. Mean monthly temperatures range from about 35°F to 60°F.

GEOLOGY

Principal rock units in the county are Quaternary alluvium, eolian deposits, glacial deposits, and the Mississippian Coldwater Shale. Alluvium is the recently deposited sand and gravel in the valleys of present day streams; it is of limited areal extent and, at many places, is hydrologically interconnected with underlying glacial deposits. Because of this, no attempt was made in this study to define the hydrologic characteristics of the alluvium separate from those of the glacial deposits. Eolian deposits form the sand dunes along Lake Michigan and are also of recent origin. Similar to the alluvium, they are hydrologically interconnected with the underlying glacial deposits.

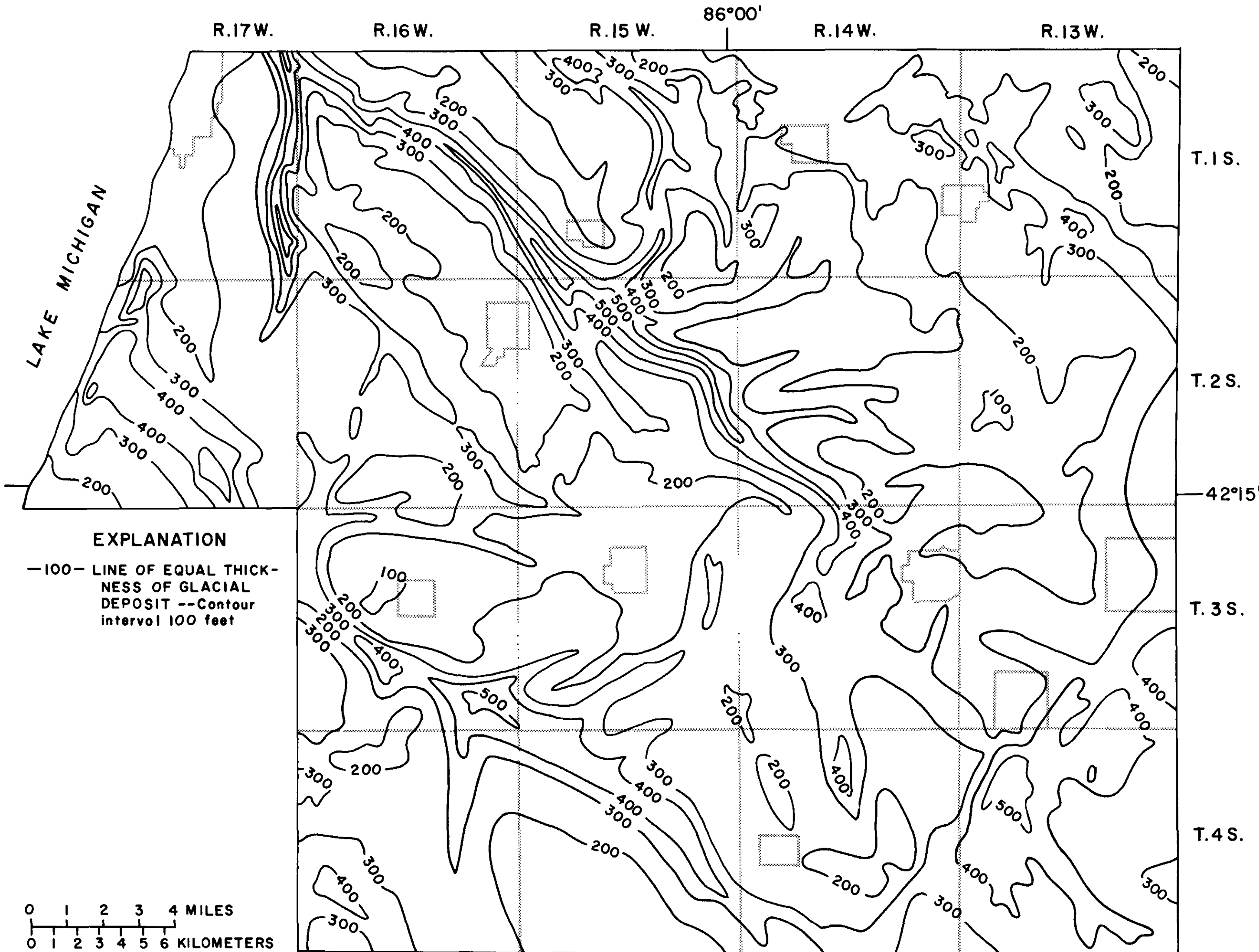
Glacial Deposits

The continental glaciers that moved across Michigan some 10,000 to 15,000 years ago eroded the land mass and left behind extensive deposits of clay, silt, sand, gravel, and large rock fragments. In Van Buren County, these deposits range in thickness from 100 ft in the eastern part of the county to 600 ft near South Haven and Bangor (fig. 4). For this report, the deposits are classified as till, outwash, and lacustrine; their areal extent is shown in figure 5. The lithology of the upper part of these deposits is illustrated by the logs of 30 wells (table 2 and pl. 1) installed by the U.S. Geological Survey.



Base from U.S. Geological Survey 1:62,500 quadrangles

Figure 3.--Population in 1980, by township.



Base from U.S. Geological Survey 1:62,500 quadrangles

Figure 4.--Thickness of glacial deposits.

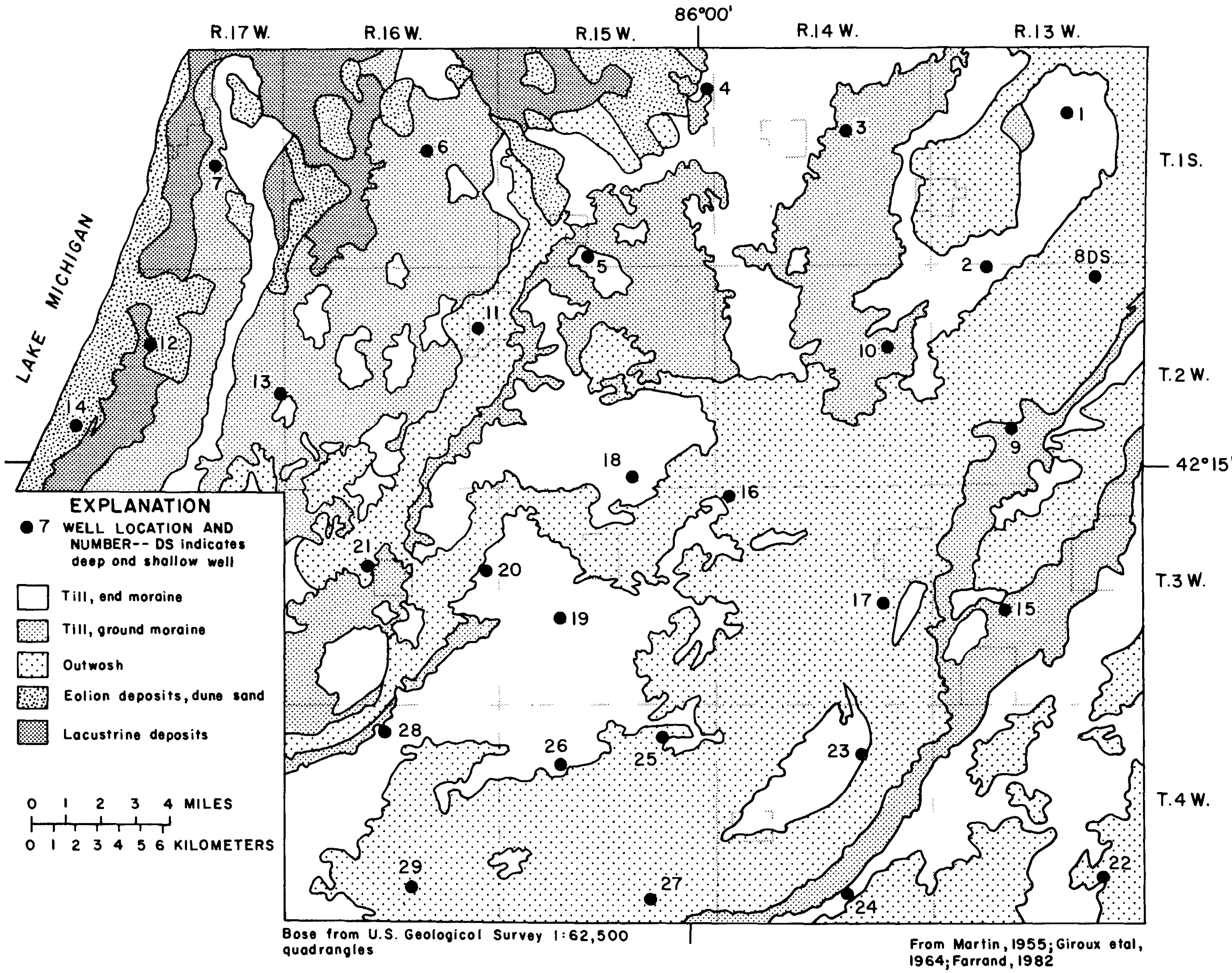


Figure 5.--Areal extent of surficial deposits.

Table 2.--Generalized lithologic data for observation wells installed by U.S. Geological Survey (well locations shown on pl. 1)

Well number	Lithology	Depth to bottom (feet)
1	Clay	6
	Sand and gravel	80
	Clay	90
	Sand, some gravel	115
2	Sand	14
	Sand and gravel, some clay	43
	Clay	64
	Sand, some fine gravel	80
3	Clay, sand, and gravel	30
	Clay	54
	Sand	92
	Clay and gravel	97
4	Clay, some gravel and sand	15
	Sand	42
	Sand and gravel	46
5	Clay	16
	Clay and sand	35
	Sand	65
6	Sand, some clay	8
	Clay, some gravel	20
	Sand	48
	Clay, some gravel	74
	Sand, some gravel	86
7	Sand	10
	Clay, sand, and gravel	54
	Clay and sand	73
	Clay, sand and gravel	80
	Sand	89
[a]8	Sand and gravel, some clay	24
	Sand and gravel	32
	Sand	67
	Sand and gravel, some clay	88
	Gravel	119
	Sandstone (?)	120
9	Sand	10
	Sand and gravel	24
	Clay	36
	Sand	44
	Sand and gravel	56
10	Clay, sandy; some gravel	14
	Clay, sand, and gravel	45
	Sand	93
11	Sand and clay	10
	Clay	22
	Clay and sand	42
	Sand and gravel, some clay	67
12	Sand	19
	Sand and gravel	24
	Sand	30
	Clay, sandy, silty	40
13	Clay, sandy, and sand	8
	Clay, some gravel	24
	Gravel	30
	Sand	45
	Clay, sandy	47
14	Sand, some clay	4
	Sand	84
	Sand, some gravel	93
15	Sand and gravel	46
16	Gravel	17
	Clay	45
	Sand	62
17	Clay	13
	Sand and gravel	34
	Gravel	53
18	Sand and gravel	27
	Sand	53
	Clay, some gravel and sand	113
	Sand and gravel	120
19	Sand, some gravel	46
	Clay	47
20	Clay, sand, and gravel	55
	Gravel, some clay	60
	Sand and gravel	89
	Sandstone (?)	90
21	Sand and clay	6
	Sand and gravel	44
22	Clay, sandy, and gravel	10
	Sand and gravel	79
23	Sand and gravel	18
	Clay, sand, and gravel	38
	Clay	68
	Gravel	81
24	Sand	10
	Sand and gravel	44
25	Gravel	20
	Clay	22
	Sand and gravel	46
26	Clay, sandy	5
	Sand and gravel	58
	Gravel	67
27	Sand and gravel	44
28	Sand and gravel	18
	Sand and gravel, some clay	39
	Clay	56
	Sand and gravel	65
29	Gravel and clay, sandy	7
	Sand and gravel	20
	Sand, some gravel	72
	Sand, some clay	83
	Sand, some gravel	96

[a] Deepest of two wells installed at this site.

Till is a mixture of clay, silt, sand, and larger rock fragments. It was deposited from the melting glacier in two ways. When the rate of melting of the ice front was about equal to the rate of ice advance, materials were dumped at the front producing a series of north-northeast trending ridges called end moraines. When the rate of melting became faster than the rate of glacier advance, the melting ice dropped rock debris over a widespread area forming ground moraines. Kettles, enclosed depressions in morainal areas, were formed by burial, and eventual melting, of large blocks of ice. Some kettles contain lakes, such as Bankson, Huzzy, and Shafer Lakes.

Outwash is the water-sorted sand and gravel deposited by meltwater near the front of the glacier. Silt and clay carried by the meltwater was deposited at a greater distance from the ice front on wide, flooded drainageways and lake plains. Generally, relatively flat plains were formed. Many present streams follow, at least in part, old drainageways.

During final retreat of the glaciers, Lake Michigan inundated areas in the western part of the county. Sands were deposited along the shoreline of these inundated areas.

Deep buried valleys in the surface of the bedrock formation underlying the glacial deposits are the result of the erosive action of preglacial streams and glacial scouring. These valleys are as much as 400 feet deep in places (fig. 6) and contain the thickest glacial deposits. In the southwest corner of Columbia Township and along the east side of South Haven Township, as much as 600 feet of glacial material fill and bury a valley system.

Coldwater Shale

The Coldwater Shale, a bedrock formation of Mississippian age, underlies the glacial deposits throughout the county; it ranges in thickness from 300 to 600 feet. The formation is mostly shale that contains limestone and clayey limestone in some areas. Water can be obtained from the limestone at some places; however, it is generally salty. Because of this, and because the limestone is at great depths--200 to 500 feet--below land surface, the Coldwater Shale is usually not considered to be a source of water.

HYDROLOGY

Of the 34 inches of precipitation that fall each year in Van Buren County, about 18 inches is evaporated and transpired (evapotranspiration) and about 16 inches is discharged by streams. Of the 16 inches in streams, 4 inches is overland surface runoff and 12 inches is recharge to the ground-water reservoirs, which eventually becomes ground-water runoff.

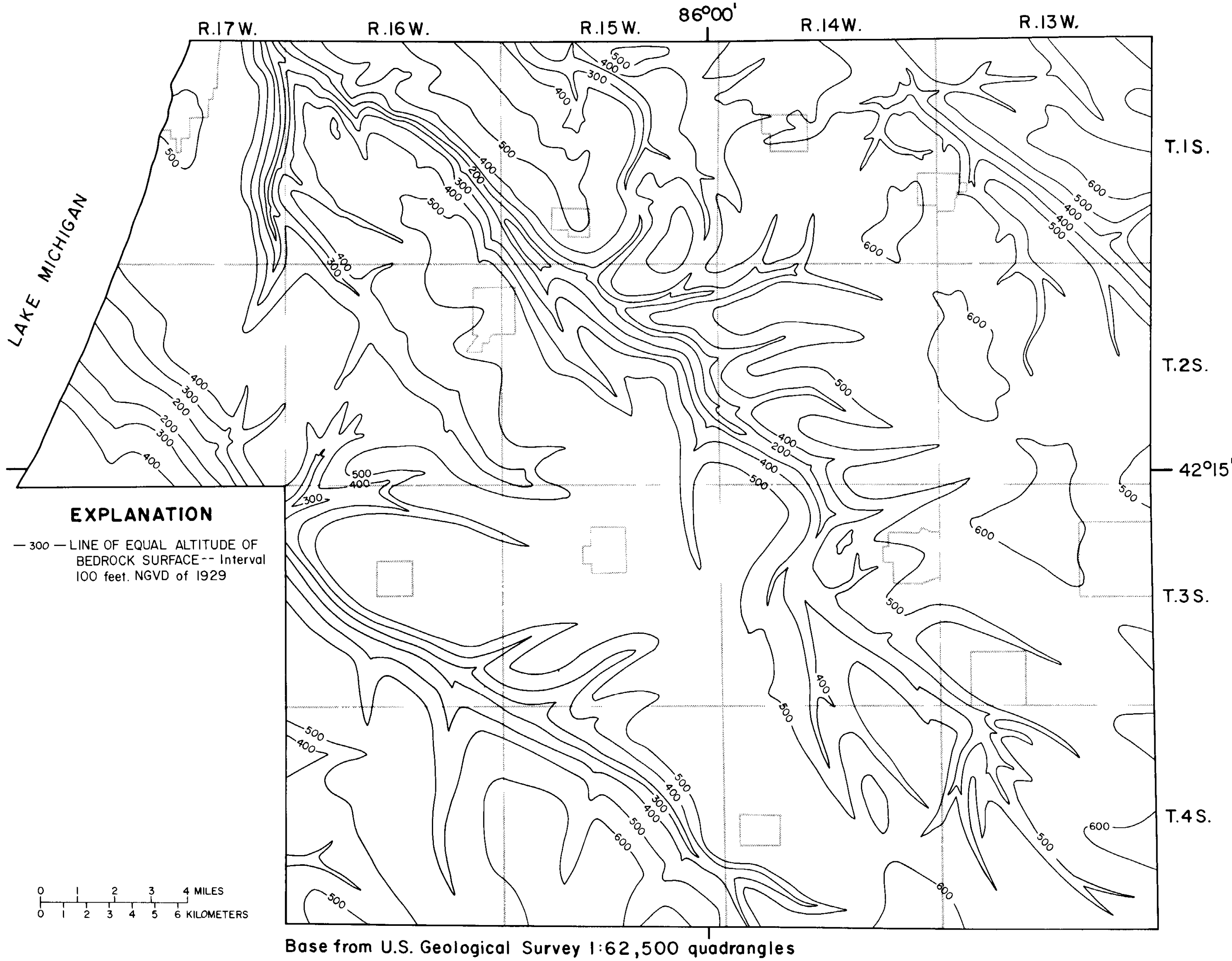


Figure 6.--Configuration of buried valleys in the bedrock surface.

Surface Water

Streams

Van Buren County is drained largely by the Black River in the north and by the Paw Paw River in the south. In the northeastern part of the county, about 30 mi^2 drain to the Kalamazoo River; in the southeastern and southern parts, about 35 mi^2 drain to the St. Joseph River. Daily discharge data have been collected on South Branch Black River near Bangor since 1966 (U.S. Geological Survey station number 04102700). This station, identified as site 33 (pl. 1), has an average discharge of 106 ft^3/s for the period of record. The maximum discharge observed was 1,680 ft^3/s in April 1975; the minimum observed was 20 ft^3/s in September 1966.

For this investigation, two additional gaging stations were installed on the Paw Paw River in July 1980. One, Paw Paw River near Paw Paw (site 18), was located at the 40th Street bridge (U.S. Geological Survey station number 04102320). The second, Paw Paw River near Hartford (site 23), was located at the 56th Avenue bridge (U.S. Geological Survey station number 04102420). During the investigation, the maximum discharge observed near Paw Paw was 1,540 ft^3/s; the minimum observed was 108 ft^3/s. Near Hartford, the maximum discharge observed was 2,500 ft^3/s; the minimum observed, 202 ft^3/s. Figure 7 shows hydrographs for each of the three gaging stations from July 1980 to September 1982.

Measurements of discharge were also made periodically at 36 other sites at the time water-quality samples were collected. The location of the sites is shown on plate 1, and the maximum and minimum discharges are given in table 3. These periodic sites and the gaging stations define 38 drainage areas, lettered A to X in this report (fig. 8). Plate 2a shows estimated runoff, in $(ft^3/s)/mi^2$ (cubic feet per second per square mile), for each drainage area. Values range from about 0.17 to 4.5 $(ft^3/s)/mi^2$. Runoff at the most downstream stations on both the Black and Paw Paw Rivers was 1.3 $(ft^3/s)/mi^2$.

Lakes and Ponds

Van Buren County has 301 lakes and ponds, ranging in size from less than 0.1 acre to 298 acres, comprising a total area of about 9.3 mi^2 (Humphrys and Colby, 1965). The location of the principal lakes is shown on plate 1. Of the 301 lakes and ponds, 35 percent are larger than 10 acres; 7 percent are 100 acres or larger. Fifty-eight percent of all of the lakes have neither inlet or outlet, about 23 percent have inlets and outlets, about 19 percent have outlets only, and less than 1 percent have inlets only. With the exception of the northwestern part of the county, lakes and ponds are well distributed throughout the county.

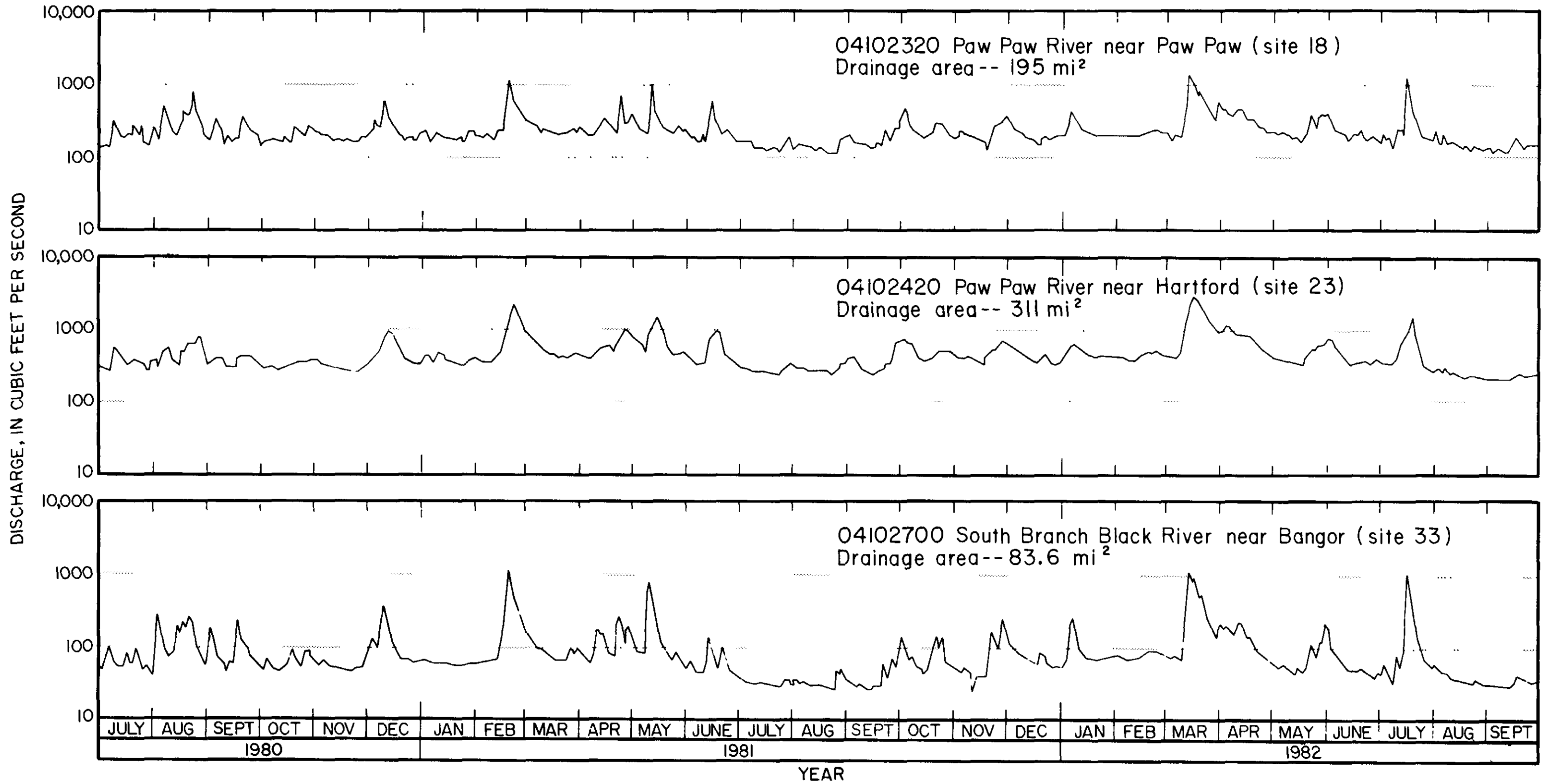


Figure 7.--Hydrograph showing discharge at gaging stations on Paw Paw and Black Rivers, July 1980 through September 1982.

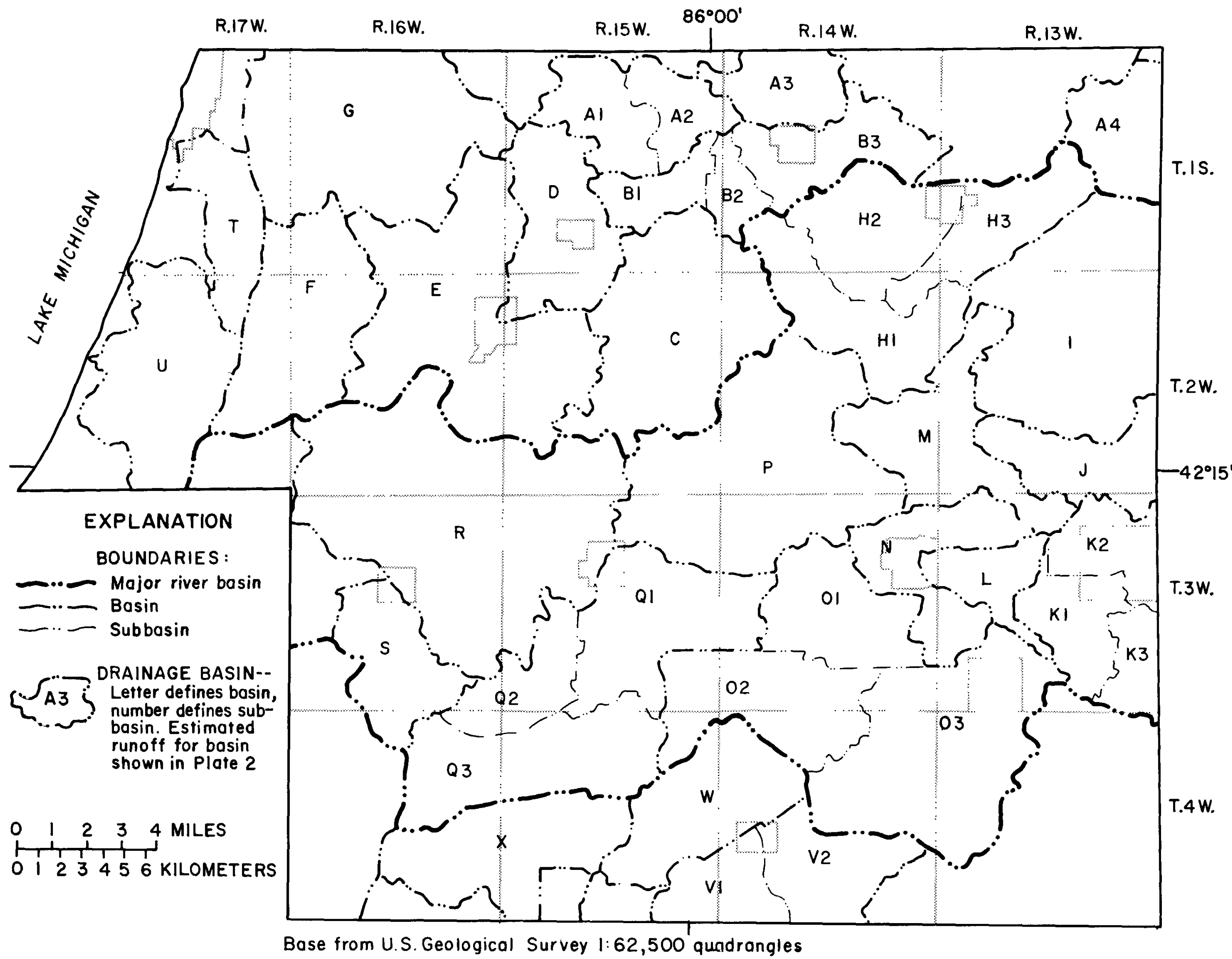


Figure 8.--Map showing drainage areas.

Table 3.--Maximum and minimum discharges at periodically measured sites, 1980-82

Site number	Number of measurements	Maximum (ft^3/s)	Minimum (ft^3/s)
1	13	113	15.3
2	39	196	6.0
3	31	67.5	5.5
4	8	28.6	4.9
5	8	38.8	14.5
6	6	131	42.0
7	34	269	39.8
8	7	35.2	5.5
9	7	31.3	.70
10	30	84.1	18.7
11	35	114	16.1
12	29	208	30.2
13	31	253	36.6
14	30	36.0	9.7
15	7	30.8	1.3
16	7	48.0	.68
17	35	342	2.3
19	8	35.9	9.9
20	7	19.5	1.2
21	32	225	20.7
22	32	2,000	170
24	7	16.9	3.7
26	29	156	2.0
27	28	156	.04
28	35	424	6.3
29	6	80.8	2.7
30	7	147	4.5
31	33	192	.85
32	30	480	23.8
34	35	151	1.1
34A	8	203	49.4
35	23	1,630	31.9
36	7	44.8	2.3
37	7	29.4	2.3
38	7	40.5	5.6
39	8	220	27.1

Ground Water

Source

Glacial deposits are the only source of fresh ground water in most of Van Buren County. The Coldwater Shale underlying the glacial deposits yields little, and commonly, only salty water. Of the glacial deposits, outwash is the most productive aquifer. The largest area of outwash extends as a broad belt northeastward from the southwest part of the county (fig. 5). Some of the best wells in the county are in this belt.

In general, the thicker the deposits the better the chances of obtaining significant amounts of water. A large-diameter well installed in an area of thick deposits of sand and gravel may easily yield 1,000 gal/min. However, if the deposits are mostly clay, such as in Covert and South Haven Townships, only small quantities of water can be obtained. Areas most likely to yield large quantities of water were defined by Giroux and others (1964). Data obtained since that investigation support the boundaries of water availability shown on the township maps in that report.

Domestic wells in most of the county obtain sufficient supplies from wells ranging in depth from 15 to 250 feet (fig. 9); most wells are less than 160 feet deep. Irrigation wells capable of supplying 1,000 gal/min generally are about 200 feet deep.

Levels

Ground-water levels under natural conditions follow an annual cyclic trend. The hydrograph for well 16 (fig. 10) is typical. Water levels are highest in the spring--usually in April or May--and lowest in late fall and early winter. Rising levels reflect recharge from increased precipitation; declining levels result from decreased precipitation, increased evapotranspiration, and pumpage.

Ground-water levels also reflect long-term, climatic conditions. During 1963-64 when precipitation was below normal, water levels were correspondingly low. Following this period of drought, precipitation increased and water levels rose, reaching a high point in 1974. A rise of more than 5 feet was recorded at some sites.

Water levels in some wells are affected by nearby pumping. Abrupt fluctuations are the result of drawdown and recovery when pumps are turned on and off. When two pumping wells are close together, as might occur in irrigation fields or in public supply well fields, there may be interference between wells reducing the quantity of water available to either well.

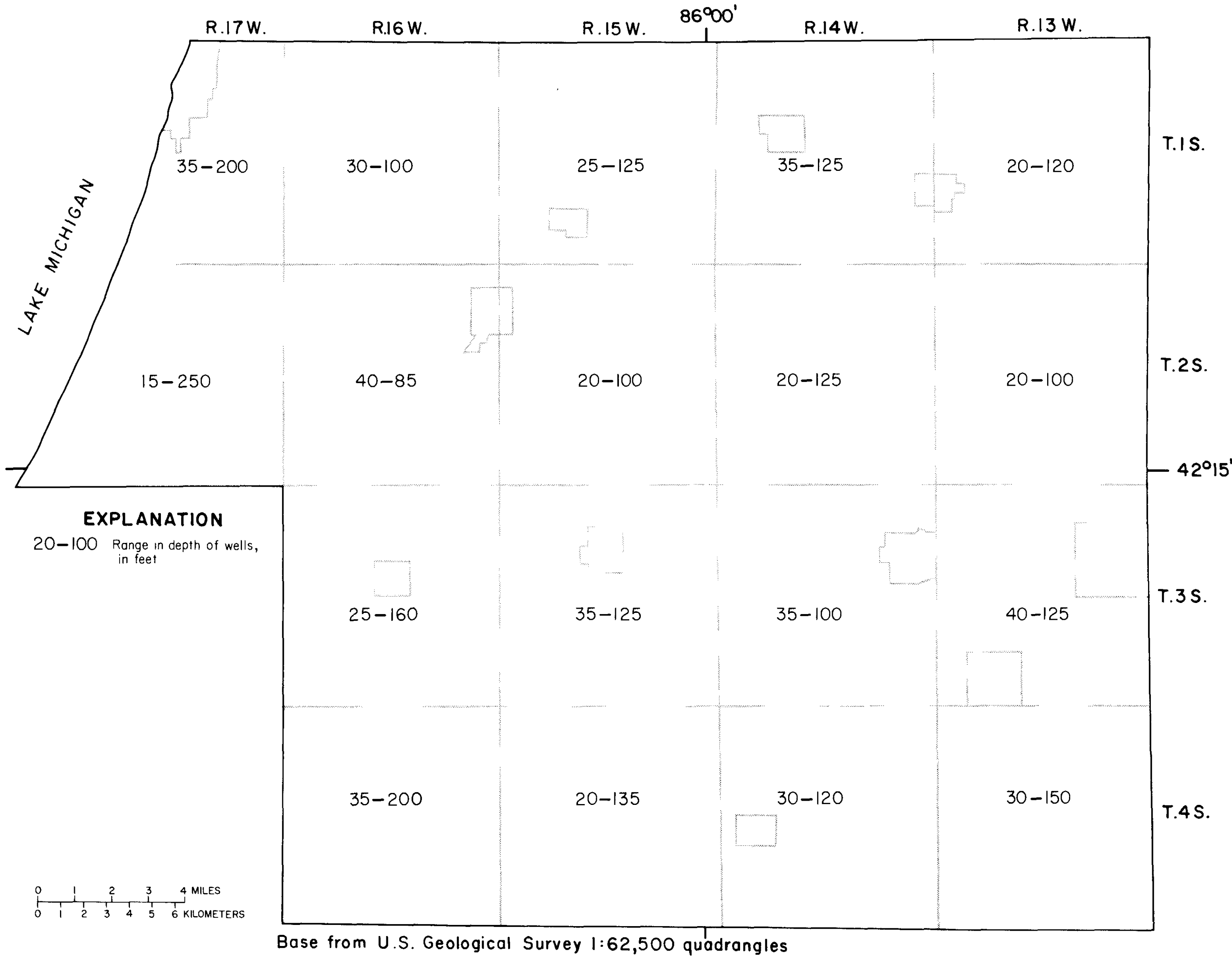


Figure 9.--Range in depth of most wells installed for domestic supplies, by township.

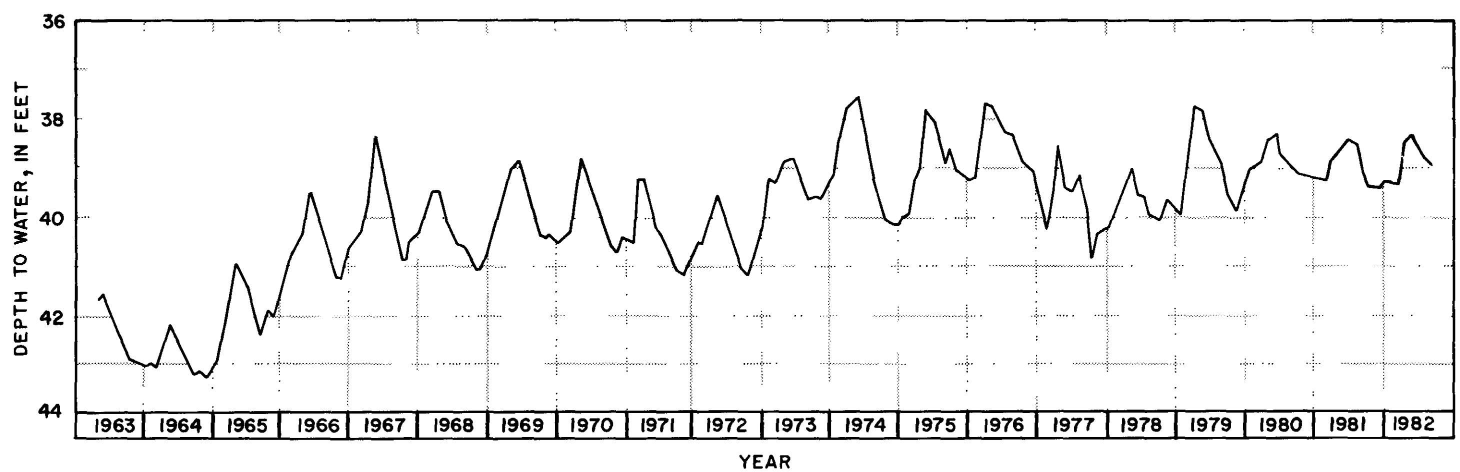


Figure 10.--Hydrograph showing water level in well 16, 1963-82

The depth to water varies in the county. At some sites, water from wells may flow at land surface; at others, water may be at depths of 50 to 200 feet. Shallower depths to water are generally found in low-lying areas along streams, lakes, and swamps; greater depths usually occur under the higher hills. Depths to water in the 30 observation wells installed by the U.S. Geological Survey (fig. 5) ranged from 0.2 to 84 feet. In other wells, depth to water is generally less than 90 feet.

Water-level data were collected from 29 of the U.S. Geological Survey observation wells for a 20-month period. The data seem to indicate that changes in water levels lack significant relation to topographic features or to well depth. Water-level changes in some deeper wells were essentially the same as those in some shallow wells. At some locations the aquifer was thicker than at others, but this also was apparently unrelated to changes in water levels. Data do indicate, however, that the wells can be grouped on the basis of similar changes in water levels[1], as in the following table:

Group	Well number
A	6, 7, 8D, 8S, 12, 13
B	4, 5, 11, 16, 17, 18, 21, 26, 28, 29
C	1, 2, 14, 19, 22

Water levels in groups A and B rose more rapidly and reached their peaks earlier in the spring than did levels in group C (fig. 11). Levels in group A dropped off sharply in summer; whereas, those in groups B and C declined only slightly. These differences in water-level changes are related to differences in the hydrologic characteristics of the surficial glacial deposits as discussed in the section of the report "Simulations of the ground-water system".

[1]Not all wells could be grouped. Although different, water levels in wells 3, 20, and 27 show some similarities to group A, and levels in wells 9 and 10 show some similarities to group C. Water levels in wells 15, 23, and 25 have distinctive characteristics.

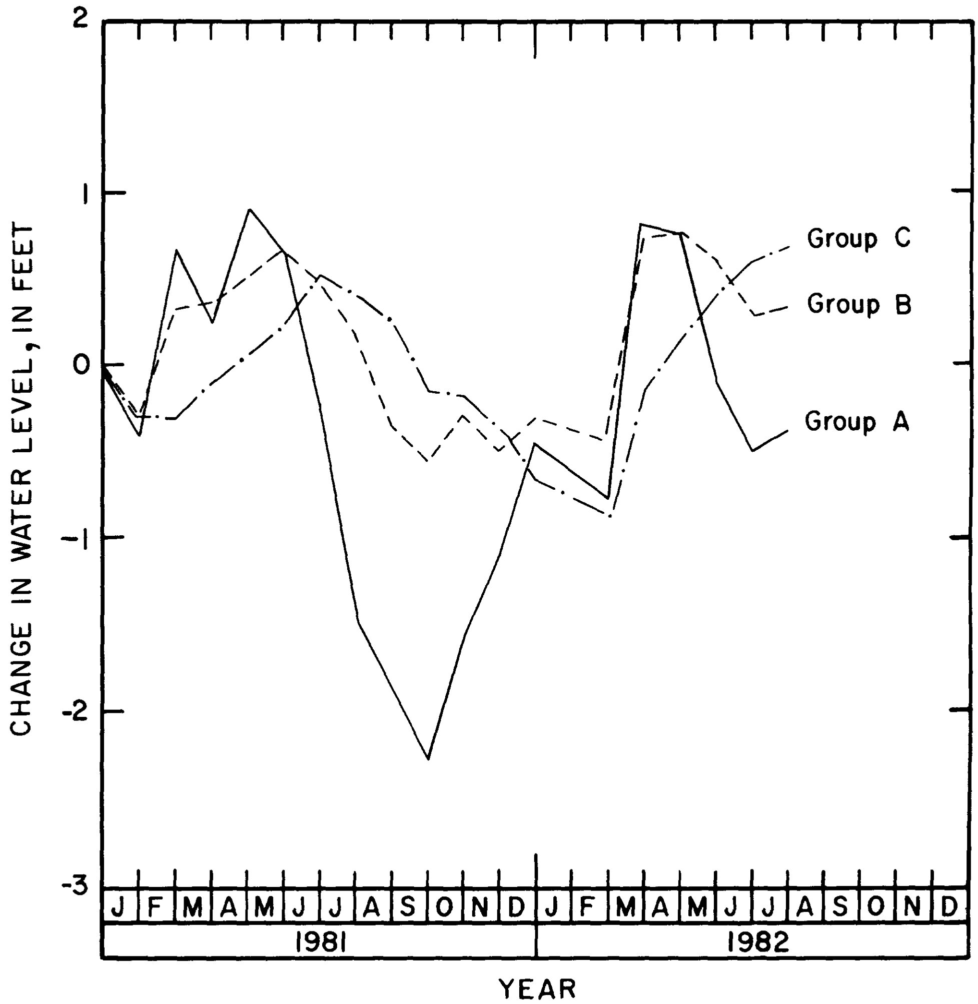


Figure 11.--Hydrograph showing average water levels in selected U.S. Geological Survey observation wells

WATER QUALITY AND LAND USE

Throughout Van Buren County, as in other parts of the country, the relationship between water quality and land use is seldom easily discernable. In this section of the report information on the chemical and physical characteristics of water is discussed. The results of a land-use survey of Van Buren County are described, and chemical inputs to the system, particularly as they relate to nitrogen, are identified. Information on fertilizer applications, animal wastes, septic-tank discharges, and precipitation are assembled as a preliminary step to understanding water quality. Because this report is primarily one of agricultural land use, detailed examination of water quality as it relates to municipal and industrial waste discharges, although commented on at places, is beyond the scope of the report.

Inventory of Land Use

The Van Buren County Extension Service and the U.S. Soil Conservation Service (SCS) conducted a land-use inventory of Van Buren County as part of this investigation. Data from various sources were assembled and analyzed, and use made of aerial photography. A detailed field inventory of 158 randomly selected 160 acre plots, called Primary Sampling Units (PSU), was also made to verify land-use information developed by other techniques. The total acreage represented by the PSU's constitute 6.2 percent of the county.

The major land uses identified for the study and brief definitions are as follows:

(1) Cultivated cropland; hay, rotation, and permanent pasture; confined feeding operations - All land tilled annually, which is or will be planted in crops. Cultivated cropland that is tilled annually; hay, rotation, and permanent pasture that produces grasses for animal consumption; confined feeding operations primarily beef cattle feedlots, and poultry, hog, and fur bearing animal farms. In this report this category is referred to as "cropland, pasture, and feeding operation."

(2) Orchards, bush-fruits, vineyards, and ornamental horticulture - It is referred to as "orchard, fruit, and vineyard."

(3) Brushland; coniferous and deciduous forest land - It is referred to as "brushland and forest."

(4) Mobile home parks; rural residential (1.5 dwellings or less per acre); single/duplex housing (1.5 to 3 dwellings per acre); and migrant quarters; all vacant urban land.

(5) Central business districts, shopping centers, strip developments, neighborhood business districts, institutional land use, industry, utilities, surface and subsurface mining, cemeteries, agricultural business

(6) Rivers, lakes, and ponds

(7) Outdoor recreation

(8) Wooded swamp, shrub swamp, and non-forested wetlands

(9) Apartment developments

(10) Beaches and sand dunes

(11) Interstate highways I-94 and I-96

(12) Airports and associated facilities

Using data obtained by Van Buren County and the SCS, the number of square miles of each type of land use was computed for each of the 38 drainage areas. About 90.6 percent of the county was covered in this manner. The percentage of each area devoted to a particular land use also was computed. No computations were made for categories (9) through (12) above because the amount of land included countywide is minor. Table 4 gives land-use data compiled for the study.

Collection of Water-Quality Data

In the spring of 1980, a reconnaissance of Van Buren County was made to select locations at which water-quality data would be obtained. At each of the three gaging stations--Paw Paw River near Paw Paw, Paw Paw River near Hartford, and South Branch Black River near Bangor--a daily suspended-sediment station was established. Thirty-nine other sites, numbered 1 through 39 for the study (pl. 1 and table 16), were selected for water-quality data collection. Site 25 was established at the Geological Survey gaging station on the Paw Paw River at Riverside, downstream from the Van Buren County line in Berrien County. Only preliminary data were collected at Site 25; routine data collection was not necessary during the course of the study. Another site, site 34A (Black River near Kibbie), was used only when backwater from Lake Michigan made sampling at Site 35 (Black River near South Haven) impossible.

Table 4.--Land-use data for Van Buren County

Area	Size of area (mi^2)	Percent of area in Van Buren County	Cultivated crop land; hay, rotation, and permanent pasture; confined feeding operation		Orchard bush-fruits, vineyards, ornamental horticulture		Brush land, coniferous and deciduous forests		Mobile home parks; rural residential; urban vacant; single/duplex housing; migrant quarters		Business commerce, and industry; institutions; utilities; mining; cemeteries		Rivers, lakes, and ponds		Outdoor recreation		Wooded swamp, shrub swamp, non-wooded wetlands	
			mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent	mi^2	percent
A_1	7.71	100	0.81	10.5	1.09	14.1	4.64	60.1	0.41	5.3	0.02	0.3	0.51	6.6	0.04	0.5	0.20	2.6
A_2	5.01	100	1.26	25.5	.30	6.1	2.80	56.5	.03	.6	--	--	.22	4.4	.04	.8	.30	6.1
A_3	7.10	98	3.92	57.2	.43	6.3	1.84	26.9	.06	.9	.01	.1	.01	.1	--	--	.58	8.5
A_4	9.61	82	4.19	53.2	.15	1.9	2.94	37.3	.13	1.6	.05	.6	.02	.3	.08	1.0	.32	4.1
B	16.8	100	6.32	37.6	1.19	7.1	7.06	42.0	.67	4.0	.22	1.3	.48	2.9	.02	.1	1.23	8.5
B_1	4.50	100	1.51	33.3	.44	9.7	2.44	53.9	.01	.2	--	--	.03	.7	--	--	.10	2.2
B_2	2.96	100	.70	22.9	.71	23.2	1.07	35.0	.11	3.6	.06	2.0	.25	8.1	--	--	.16	5.2
B_3	9.34	100	4.11	42.8	.04	.4	3.55	37.0	.55	5.7	.16	1.7	.20	2.1	.02	.2	.97	10.1
C	23.6	100	11.1	46.6	2.39	10.0	8.78	36.8	.58	2.4	.05	.2	.45	1.9	--	--	.51	2.1
D	12.0	100	4.79	37.8	1.69	13.3	5.50	43.4	.24	1.9	.09	.7	.14	1.1	.02	.2	.20	1.6
E	31.2	100	14.7	46.8	4.50	14.3	10.6	33.7	.89	2.8	.19	.6	.12	.4	.02	.1	.36	1.1
F	17.6	100	7.15	40.3	3.17	17.9	7.16	40.3	.15	.9	.06	.3	--	--	--	--	.06	.3
G	30.8	92	13.7	48.0	1.49	5.2	12.0	42.2	.96	3.4	.09	.3	.02	.1	--	--	.24	.8
H	32.2	100	20.2	62.8	.63	2.0	8.20	25.5	1.37	5.6	.26	1.1	.26	.8	.01	.03	2.84	8.8
H_1	12.4	100	8.76	68.1	.48	3.7	2.58	20.0	.21	1.6	.04	.3	.04	.3	--	-	.77	6.0
H_2	10.7	100	7.01	62.1	.14	1.2	2.82	24.9	.40	3.5	.17	1.5	.06	.5	.01	.1	.70	6.2
H_3	9.05	100	4.42	46.2	.010	.1	2.80	29.3	.76	7.9	.05	.5	.16	1.7	--	--	1.37	14.3
I	37.8	71	11.4	42.6	.46	1.7	8.78	32.9	.98	3.7	.06	.2	.22	.8	--	--	4.85	18.1
J	17.6	51	4.78	53.7	.18	2.0	2.43	27.2	.75	8.4	.02	.2	.11	1.2	--	--	.65	7.3
K	26.9	65	6.86	39.2	1.61	10.8	5.09	29.1	1.79	10.2	.26	1.5	.018	.1	--	--	1.66	11.2
K_1	7.10	100	2.44	33.9	1.05	14.6	2.41	33.4	.71	9.8	.02	.3	.008	.1	--	--	.51	7.1
K_2	10.6	57	2.32	38.0	.34	5.6	1.70	27.9	.80	13.1	.24	3.9	.01	.2	--	--	.51	8.4
K_3	9.20	46	2.10	49.8	.22	5.2	.98	23.2	.28	6.6	--	--	--	--	--	--	.64	15.2
L	4.60	100	2.06	39.7	.28	5.4	1.42	27.3	.56	10.8	.12	2.3	.04	.8	.01	.2	.54	10.4
M	13.1	100	7.50	52.4	.38	2.7	4.08	28.5	.77	5.4	.04	.3	--	--	--	--	1.53	10.7
N	11.6	100	4.59	43.0	.83	7.8	2.31	21.6	1.49	14.0	.64	6.0	.32	3.0	.03	.3	.35	3.3
O	51.2	100	29.9	58.3	3.98	11.7	11.6	22.6	2.03	4.0	.54	1.6	1.02	3.0	.08	.2	2.39	7.0
O_1	10.8	100	5.87	52.8	1.39	12.5	2.07	18.6	.31	2.8	.23	2.1	.28	2.5	--	--	.80	7.2
O_2	14.3	100	9.60	67.5	.23	1.6	2.43	17.1	.34	2.4	.06	.4	.73	5.1	--	--	.84	5.9
O_3	26.1	100	14.4	54.6	2.36	9.0	7.15	27.2	1.38	5.2	.25	.9	.01	.04	.08	.3	.75	2.8
P	30.1	100	15.4	48.2	3.63	11.3	8.78	27.4	.33	1.0	.19	.6	.35	1.1	.18	.6	3.12	9.8
Q	39.9	100	22.5	56.5	2.79	7.0	6.90	17.3	.93	3.3	.31	.8	.86	3.0	--	--	4.27	10.7
Q_1	17.0	100	7.97	51.1	1.35	8.6	2.17	13.9	.76	4.9	.23	1.5	.53	3.4	--	--	2.31	14.8
Q_2	6.89	100	4.91	67.4	.29	4.0	1.50	20.5	.04	.5	.01	.1	.04	.5	--	--	.48	6.6
Q_3	16.0	100	9.66	60.4	1.15	7.2	3.23	20.2	.13	.8	.07	.4	.29	1.8	--	--	1.48	9.2
R	46.0	100	21.6	47.1	4.92	10.7	10.4	22.7	1.96	4.3	.72	1.6	.86	1.9	.04	.1	5.17	11.3
S	9.67	100	4.77	48.3	2.46	24.9	.79	8.0	.51	5.2	.21	2.1	.004	.1	.006	.1	1.02	10.3
T	7.76	100	2.21	29.0	.47	6.2	3.93	51.6	.53	7.0	.22	2.9	.01	.1	--	--	--	--
U	16.7	100	1.96	11.3	.55	3.2	13.3	76.5	.66	3.8	.35	2.0	.01	.06	.08	.5	--	--
V	21.9	69	10.9	72.0	.29	1.9	2.84	18.8	.42	2.8	.17	1.1	.05	.3	--	--	.30	2.0
V_1	7.6	81	4.97	80.4	--	--	.94	15.2	.09	1.5	.05	.8	.03	.5	--	--	.10	1.6
V_2	14.3	63	6.11	68.2	.29	3.2	1.90	21.2	.33	3.7	.12	1.3	.02	.2	--	--	.20	2.2
W	13.1	100	10.1	72.6	.07	.5	1.82	13.1	.87	6.3	.18	1.3	.02	.1	.10	.7	.75	5.4
X	15.5	99	9.03	58.1	1.32	8.5	1.81	11.6	.23	1.5	.03	.20	.60	3.9	.05	.3	2.47	15.9

Beginning in April 1980 monthly samples were collected at 21 of the sites for the analysis of total[1] ammonia, total nitrite, total nitrate, total organic nitrogen, total phosphorous, total orthophosphorous, and suspended sediment. At times during each year of the investigation, dissolved and total nitrogen and phosphorous were simultaneously measured to determine the fraction transported in the dissolved and suspended phases. At an additional 17 sites, samples were collected for the same nutrient analyses about three times each year. At the time of sampling, specific conductance, temperature, pH, and dissolved oxygen were measured at all sites. A discharge measurement, necessary for load computations, was also made at the time of sampling. Comprehensive chemical analyses of water, which included the major dissolved substances, trace metals, and pesticides, were made on samples collected at 38 sites. At 17 of these sites, comprehensive analyses were made on water collected at high and low flow.

Water from 21 wells drilled for this project was analyzed for common dissolved substances, trace metals, and pesticides. Water from an additional 21 domestic wells also was analyzed for many of the same substances. At 261 locations, water from domestic wells was collected and analysed by the Michigan Department of Public Health for iron, sodium, nitrate, hardness, chloride, and fluoride. An additional 232 analyses of nitrate and chloride were available from the files of the Michigan Department of Public Health and the Geological Survey.

Precipitation and dry fallout data were collected at two locations geographically aligned in the direction of prevailing winds, which move from southwest to northeast. Samples were collected on a continuous basis with automatic samplers. Specific conductance and pH of all samples was measured; analyses of nitrogen, phosphorus, and sulfate were made periodically.

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[1]In this report, individual nitrogen compounds are referred to as "total" when laboratory analysis measured both the suspended and dissolved fractions of the compound in an unfiltered sample. "Dissolved" preceeding an individual compound indicates that the sample was filtered through a 0.45 μm filter at streamside, and thus the analytical result indicate that amount of the compound transported in solution. All nitrogen compounds, whether dissolved or total, are reported "as nitrogen" or "as N". "As nitrogen" or "as N" also apply in those discussions where neither the total or dissolved designation is appropriate. "Total nitrogen" or "dissolved nitrogen" indicates the sum of each of the individual compounds reported as N, "total" and "dissolved are applied to phosphorus compounds in the same manner. All measured values are reported "as phosphorus" or "as P".

Results of analyses are reported in μg/L (micrograms per liter) or in mg/L (milligrams per liter), except when other reporting units are appropriate. Analyses made by the Geological Survey for this study have been published in the Survey's annual series of hydrologic data reports (U.S. Geological Survey, 1982, and Miller and others, 1983).

Chemical Inputs to the Hydrologic System

Fertilizer Applications

According to the Van Buren County Extension Service, about 17,500 tons of commercial fertilizers were applied to agricultural land in the county in 1980. Table 5 lists the amounts of nitrogen, phosphorus, and potassium

Table 5.--Fertilizer application in Van Buren County (data from Van Buren County Extension Office)

Crop or fruit	Fertilizer application (pounds per acre)		
	Nitrogen (as N)	Phosphorus (as P)	Potassium (as K)
Row crops			
Corn	150	60	120
Hay	20	60	120
Oats	40	40	40
Soybeans	15	30	90
Wheat	40	40	40
Tree and bush fruits			
Apples	100	20	60
Blueberries	120	20	60
Cherries	120	20	90
Grapes	80	0	120
Peaches	100	20	90
Pears	60	20	60
Plums	60	20	60
Strawberries	80	80	80
Raspberries	80	80	80
Vegetable crops			
Asparagus	80	40	80
Melons	120	120	120
Peppers	120	60	120
Pickles	100	60	120
Snap beans	60	30	90
Tomatoes	120	60	120

applied to row crops, tree and bush fruits, and vegetable crops. These data, and that on the amount of land devoted to agricultural activity by drainage basin (table 4), supplemented by detailed land-use data on PSU's, were used to estimate the application rates of nitrogen in each of the 38 drainage areas (fig. 8). Table 6 shows the results.

Table 6.--Nitrogen application rates, by drainage area

Area[1]	Nitrogen application (as N) (lbs/ac)/yr	(tons/mi^2)/yr	Area	Nitrogen application (as N) (lbs/ac)/yr	(tons/mi^2)/yr
A_1	19.1	6.1	K_3	29.2	9.3
A_2	18.2	5.8	L	28.0	9.0
A_3	33.8	10.8	M	31.0	9.9
A_4	28.0	9.0	N	26.5	8.5
B_1	26.1	8.4	O_1	39.3	12.6
B_2	35.2	11.3	O_2	34.6	11.1
B_3	22.0	7.0	O_3	36.0	11.5
C	33.1	10.6	P	37.0	11.8
D	33.4	10.7	Q_1	30.8	9.9
E	37.3	11.9	Q_2	39.1	12.5
F	37.7	12.1	Q_3	36.7	11.7
G	28.9	9.2	R	33.6	10.8
H_1	38.5	12.3	S	49.2	15.7
H_2	33.5	10.7	T	19.9	6.4
H_3	24.1	7.7	U	9.0	2.9
I	22.5	7.2	V_1	32.1	10.3
J	28.1	9.0	V_2	36.5	11.7
K_1	31.4	10.0	W	38.4	12.3
K_2	24.4	7.8	X	37.4	12.0

[1]Figure 8 shows locations of areas.

Similar computations, given in table 7, show nitrogen applications by township.

Table 7.--Nitrogen application rates, by township

Township	Nitrogen application (as N) (lbs/ac)/yr	Nitrogen application (as N) (tons/mi²)/yr
Almena	24.9	8.0
Antwerp	30.4	9.7
Arlington	36.6	11.7
Bangor	34.5	11.0
Bloomingdale	28.8	9.2
Columbia	26.6	8.5
Covert	17.8	5.7
Decatur	34.5	11.0
Geneva	31.6	10.1
Hamilton	38.6	12.4
Hartford	36.0	11.5
Keeler	37.9	12.1
Lawrence	35.4	11.3
Paw Paw	36.3	11.6
Pine Grove	25.9	8.3
Porter	36.7	11.7
South Haven	19.0	6.1
Waverly	32.7	10.5

Countywide, 10.1 (tons/mi^2)/yr or 31.7 (lbs/ac)/yr nitrogen as N are applied to the land as fertilizer. The eight southern townships receive an average of 11.4 (tons/mi^2)/yr or 35.7 (lbs/ac)/yr; the northern 10 townships 9.06 (tons/mi^2)/yr or 28.3 (lbs/ac)/yr.

Animal Wastes

Estimates of the amount of nitrogen deposited on land in Van Buren County by animals are based on a 1981 survey by the Van Buren County Cooperative Extension Service of the approximate number and type of animals, and on daily nitrogen production data of Miner and Willrich (1970). The survey identified 896 beef cattle, 573 dairy cattle, 436 cows with calfs, 168 horses, 18,066 hogs, 311 sheep, 19 goats, and 129,400 chickens and other poultry. Table 8 shows, by township, estimates of the amount of nitrogen deposited each year.

Table 8.--Nitrogen deposited by animals, by township

Township	Nitrogen deposited (as N)	
	(lbs/ac)/yr	(tons/mi^2)/yr
Almena	0.73	0.23
Antwerp	2.34	.75
Arlington	1.12	.36
Bangor	6.07	1.94
Bloomingdale	3.53	1.13
Columbia	a	a
Covert	a	a
Decatur	a	a
Geneva	1.82	.58
Hamilton	.94	.30
Hartford	.36	.12
Keeler	5.86	1.88
Lawrence	3.63	1.16
Paw Paw	.61	.20
Pine Grove	8.04	2.57
Porter	1.72	.55
South Haven	.81	.26
Waverly	.51	.16

[a]Insignificant number of animals identified during survey.

Countywide average deposition is 0.63 (tons/mi^2)/yr or 1.98 (lbs/ac)/yr. Deposition in the southern eight townships of 0.62 (tons/ mi^2)/yr or 1.93 (lbs/ac)/yr does not differ appreciably from that in the northern ten of 0.65 (tons/mi^2)/yr or 2.02 (lbs/ac)/yr.

Septic-Tank Discharges

To aid in evaluating the contribution of nitrogen from septic tanks to the ground-water system, estimates of the amount of nitrogen discharged by this means were made for each township. The estimates were based on the number of septic-tank installations, on demographic data provided by the Van Buren County Health Department, and on studies of nitrogen discharge from septic tanks by Winneberger (1982). Table 9 shows these estimates.

Table 9.--Nitrogen discharge by septic tanks, by township

Township	Nitrogen discharge (as N) (lbs/ac)/yr	Nitrogen discharge (as N) (tons/mi^2)/yr
Almena	0.78	0.25
Antwerp	1.49	.48
Arlington	.44	.14
Bangor	.52	.16
Bloomingdale	.52	.17
Columbia	.59	.19
Covert	.74	.24
Decatur	.35	.11
Geneva	.78	.25
Hamilton	.42	.13
Hartford	.54	.17
Keeler	.69	.22
Lawrence	.45	.14
Paw Paw	.63	.20
Pine Grove	.73	.23
Porter	.54	.17
South Haven	1.45	.46
Waverly	.56	.18

Countywide, an average of 0.21 (tons/mi^2)/yr [0.66 (lbs/ac)/yr] of nitrogen is discharged from septic tanks. In the southern eight townships, the average is 0.20 (tons/mi^2)/yr [0.64 (lbs/ac)/yr]; in the northern ten townships the average is 0.22 (tons/mi^2)/yr [0.68 (lbs/ac)/yr].

Precipitation and Dry Fallout

Rainfall and snow.--Samples of rainfall and snow were collected at Gobles in the northeastern part of the county and at Keeler in the southwestern part (pl. 1). Table 10 shows the maximum, minimum, and mean

Table 10.--Maximum, mean, and minimum concentrations of nitrogen, phosphorus, and sulfate in rainfall and snow

Substance	Concentration (mg/L)		
	Maximum	Mean	Minimum
Dissolved sulfate	4.0	2.5	1.5
Total ammonia	1.1	.39	.11
Total organic nitrogen	.48	.12	.00
Total nitrite	.08	.01	.00
Total nitrate	1.7	.59	.20
Total nitrogen	2.6	1.0	.38
Total orthophosphorus	.03	.01	.01
Total phosphorus	.04	.02	.01

concentrations of nitrogen, phosphorus, and sulfate in rainfall and snow. A comparison of data collected at each station indicates that the chemical characteristics of precipitation did not differ appreciably, nor were there significant differences among the characteristics of rainfall and snow. Tables 11, 12, 13, and 14 give the results of analyses.

Table 11.--Chemical and physical characteristics of precipitation at Gobles, Michigan
[Analyses by U.S. Geological Survey]

Date	Precipitation (inches)		Specific conductance (μmhos)	pH (units)	Sulfate, dissolved (mg/L as SO_4)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)
	Rain	[a]Snow					
Sept. 25, 1980	0.15	--	--	--	--	0.75	0.11
Oct. 3, 1980	.30	--	--	4.2	--	.41	.04
Oct. 16, 1980	.40	--	--	3.6	--	.79	.00
Oct. 17, 1980	.44	--	--	4.0	--	.27	.02
Jan. 16, 1981	--	[b]0.3	55	4.5	--	.33	--
Feb. 2, 1981	--	.25	20	4.2	--	.34	.05
Mar. 26, 1981	.55	--	31	4.3	--	1.10	.00
Apr. 14, 1981	.50	--	28	4.1	--	.39	.04
July 28, 1981	.78	--	28	4.1	3.3	.20	.00
Oct. 18, 1981	1.00	--	13	4.3	2.2	.25	.00
Mar. 4, 1982	--	.55	25	4.0	--	.13	.12
May 19, 1982	.38	--	27	4.1	2.0	.50	.44
July 17, 1982	4.05	--	33	4.1	4.0	.22	.48

Date	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)
Sept. 25, 1980	0.00	1.7	2.6	0.03	0.03
Oct. 3, 1980	.00	.41	.86	.03	.02
Oct. 16, 1980	.01	1.4	2.2	.02	.03
Oct. 17, 1980	.00	.25	.54	.01	.01
Jan. 16, 1981	<.01	.66	.99	<.01	<.01
Feb. 2, 1981	<.01	.50	.90	<.01	.02
Mar. 26, 1981	<.01	.72	1.6	.01	.02
Apr. 14, 1981	<.01	.48	.92	<.01	.01
July 28, 1981	<.01	.36	.54	<.01	<.01
Oct. 18, 1981	<.01	--	.38	<.01	<.01
Mar. 4, 1982	<.01	.43	.69	.02	.02
May 19, 1982	.04	.64	1.6	.01	.02
July 17, 1982	<.01	.32	1.0	<.01	.01

[a]Water equivalent [b]Estimated

Table 12.--Chemical and physical characteristics of precipitation at Keeler, Michigan
[Analyses by U.S. Geological Survey]

Date	Precipitation (inches)		Specific conductance (μmhos)	pH (units)	Sulfate, dissolved (mg/L as SO_4)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)
	Rain	[a]Snow					
Apr. 14, 1981	0.32	--	21	4.2	--	0.21	0.16
July 28, 1981	1.25	--	16	4.3	1.5	.11	.09
Oct. 18, 1981	1.25	--	15	4.2	1.8	.34	.01
Mar. 4, 1982	--	0.75	23	4.4	2.5	.11	.09
May 19, 1982	1.30	--	23	4.2	2.0	.51	.36
May 22, 1982	2.80	--	35	4.0	3.0	.47	.09

Date	Nitrogen, nitrite total (mg/L as N)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)
Apr. 14, 1981	0.01	0.33	0.71	0.01	0.02
July 28, 1981	<.01	.20	.41	<.01	<.01
Oct. 18, 1981	<.01	--	.57	.03	.04
Mar. 4, 1982	<.01	.41	.62	<.01	.02
May 19, 1982	.08	.68	1.6	.02	.02
May 22, 1982	<.01	.49	1.1	<.01	<.01

[a]Water equivalent

Table 13.--Chemical characteristics of dry fallout at Gobles, Michigan
[Analyses by U.S. Geological Survey]

Period		Nitrogen, total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)
From	To				
Jan. 27, 1981	July 1, 1981	38	19	7.3	0.26
July 1, 1981	Oct. 14, 1981	[a]13	[a]2.7	[a]2.4	[a].03
Mar. 31, 1982	June 7, 1982	9.9	2.7	1.2	.03
June 7, 1982	Sept. 3, 1982	[a]12	[a]6.6	[a]1.2	[a].02

Period		Nitrogen, nitrate total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)
From	To			
Jan 27, 1981	July 1, 1981	12	1.9	2.0
July 1, 1981	Oct. 14, 1981	[a]8.1	[a].94	[a].86
Mar. 31, 1982	June 7, 1982	6.0	.46	.40
June 7, 1982	Sept. 3, 1982	[a]4.4	[a]1.1	[a]1.4

[a]Dissolved

Table 14.--Chemical characteristics of dry fallout at Keeler, Michigan
[Analyses by U.S. Geological Survey]

Period From	Period To	Nitrogen, total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)
Mar. 25, 1981	July 1, 1981	8.7	2.4	1.1	0.04
July 1, 1981	Oct. 15, 1981	[a]2.8	--	[a]2.4	[a].02
Apr. 16, 1982	June 7, 1982	9.2	3.3	1.3	.02
June 7, 1982	Sept. 3, 1982	[a]8.2	[a]4.8	[a].66	[a].01

Period From	Period To	Nitrogen, nitrate total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho total (mg/L as P)
Mar. 25, 1981	July 1, 1981	5.2	0.73	0.56
July 1, 1981	Oct. 15, 1981	[a].34	[a].88	[a].84
Apr. 16, 1982	June 7, 1982	4.6	.52	.48
June 7, 1982	Sept. 3, 1982	[a]2.7	[a].65	[a].60

[a]Dissolved

Only scant data have been published on nitrogen and phosphorus in precipitation at other locations in Michigan. A study conducted by Pecor and others (1973) at Houghton Lake, in the northern part of Michigan's Lower Peninsula, found that mean concentrations of 40 samples collected from February to September 1972 were as follows: Ammonia, 0.29 mg/L; nitrate, 0.44 mg/L; and nitrite, 0.002 mg/L. Mean total phosphorus was 0.04 mg/L, and mean orthophosphorus, 0.03 mg/L. Grannemann (1984) collected data at two locations in Marquette County from 1979 to 1981. He found the following mean concentrations in precipitation: Ammonia, 0.33 mg/L; nitrate, 0.34 mg/L; and sulfate, 2.4 mg/L. In a study of the Upper St. Joseph River basin, Cummings (1978) found the following mean concentrations: Ammonia, 0.48 mg/L; nitrite, 0.01 mg/L; nitrate, 0.58 mg/L; organic nitrogen, 0.41 mg/L; total nitrogen, 1.5 mg/L; orthophosphorus, 0.02 mg/L; and total phosphorus, 0.05 mg/L. The above data, collected at scattered locations in the State, suggest that nitrogen and phosphorus concentrations in precipitation in Van Buren County are similar to those elsewhere.

Analyses of single samples collected at each station indicate that a wide range of substances are present in rainfall. Table 15 shows the results of analyses.

Table 15.--Analyses of rainfall at Gobles and at Keeler, 1982
[Analyses by U.S. Geological Survey]

Substance	Concentration	
	At Gobles[a] (July 17, 1982)	At Keeler[a] (May 22, 1982)
Acidity as $CaCO_3$ (mg/L)	10	2.0
Acidity as H+ (mg/L)	.2	.1
Alkalinity as $CaCO_3$ (mg/L)	1.0	2.0
Aluminum, total (μg/L)	40	10
Arsenic, total (μg/L)	1	1
Barium, total (μg/L)	100	100
Boron, total (μg/L)	10	10
Calcium, dissolved (mg/L)	.7	.2
Carbon, organic, dissolved (mg/L)	3.2	--
Chloride, dissolved (mg/L)	.8	--
Chromium, total (μg/L)	10	10
Cobalt, total (μg/L)	3	3
Copper, total (μg/L)	7	3
Cyanide, total (mg/L)	.01	.01
Fluoride, dissolved (mg/L)	.1	.1
Iron, dissolved (μg/L)	17	10
Iron, total (μg/L)	40	40
Lead, total (μg/L)	9	4
Magnesium, dissolved (mg/L)	.2	.1
Manganese, dissolved (μg/L)	3	3
Manganese, total (μg/L)	10	10
Nickle, total (μg/L)	3	5
Potassium, dissolved (mg/L)	.1	.1
Silica, dissolved (mg/L)	.0	.0
Sodium, dissolved (mg/L)	.2	.6
Solids, residue, dissolved (mg/L)	--	7
Strontium, total (μg/L)	20	10
Zinc, total (μg/L)	30	30

[a]Analyses of periodically measured nitrogen, phosphorus, and sulfate compounds on these dates are given in tables at the back of the report.

Specific conductance and pH of rainfall and snow were measured more frequently than were other characteristics. One hundred and eleven measurements of specific conductance and 123 measurements of pH were made. Figure 12 shows frequency distributions based on all measurements at both stations. Specific conductance ranged from 8 μmhos (snow) to 78 μmhos (rain); the median value was 24 μmhos. The pH ranged from 3.6 (rain) to 5.6 (rain); the mean value was 4.1. About 40 percent of the pH values were 4.0 or less. In general, the lower the pH of precipitation, the higher its specific conductance.

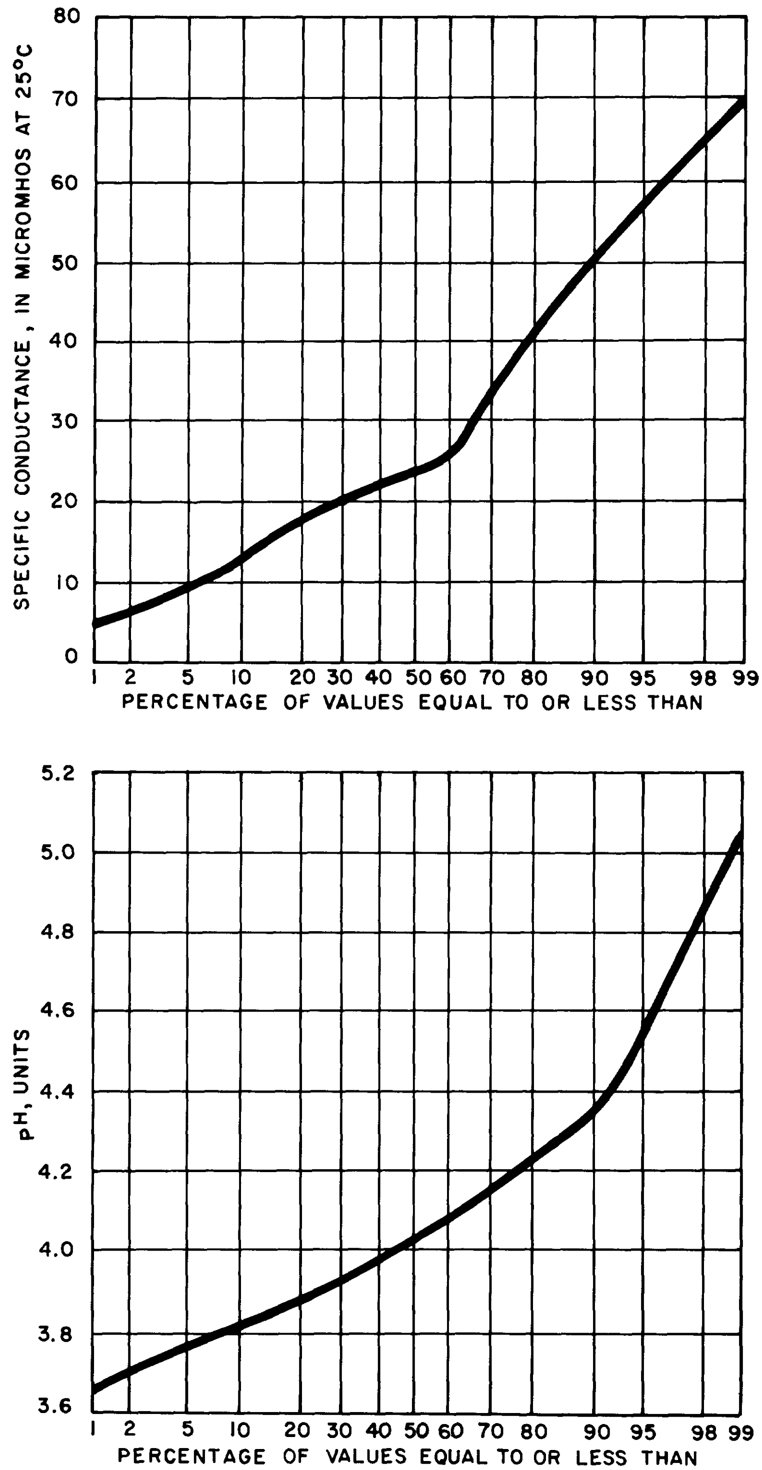

Figure 12.--Frequency distribution of specific conductance and pH of precipitation at Gobles and at Keeler.

Specific conductance and pH data are in close agreement with that found at two stations in Marquette County (Grannemann, 1984). There also the mean specific conductance was 24 μmhos; the mean pH 4.05.

Nitrogen and phosphorous loads in precipitation in Van Buren County have been estimated using long-term precipitation data collected at four stations[1] by the National Oceanic and Atmospheric Administration (1981), and data automatically recorded at the two precipitation stations operated during this study. From September 1980 to July 1982, the period when samples were collected for analysis, mean precipitation at the four long-term stations was 35.1 inches; the mean departure from normal was -0.05 inch. Mean concentrations have been used to estimate the deposition of nitrogen, phosphorus, and sulfate by rainfall and snow in Van Buren County. Table 16 shows deposition rates.

Table 16.--Nitrogen, phosphorus, and sulfate deposition by rainfall and snow

Substance	Nitrogen (as N), phosphorus (as P), and sulfate (as SO_4) deposition	
	(lbs/ac)/yr	(tons/mi^2)/yr
Dissolved sulfate	20	6.4
Total ammonia	3.1	.99
Total organic nitrogen	.95	.30
Total nitrite	.10	.03
Total nitrate	4.7	1.5
Total nitrogen	8.0	2.6
Total orthophosphorus	.08	.03
Total phosphorus	.16	.05

The above values were in reasonable agreement with values found in Michigan by Richardson and Merva (1976) at Pellston and Houghton Lake, by Cummings (1978) in Hillsdale and Calhoun Counties, by Grannemann (1984) in Marquette County, and by Pecor and others (1973) at Houghton Lake.

[1]The stations are at South Haven, at Bloomingdale, and in adjacent Kalamazoo County (at Kalamazoo) and adjacent Berrien County (at Eau Claire).

Dry fallout.--A two-bucket automatic sampler that opened and closed in response to rain and snow was used to collect samples of dry fallout at Gobles and at Keeler. Buckets containing dry material were removed at intervals ranging from about 2 months to about 5 months. Dry fallout was removed by scrubbing a bucket with 200 milliliters of distilled water, allowing the dry fallout to remain in contact with the water for 24 to 48 hours, and then filtering. The material collected on filter paper was dried and weighed; the leachate was analyzed for nitrogen and phosphorus compounds (tables 12 and 13).

The amounts of filterable dry material collected at both precipitation stations was identical--0.024 grams per month, a rate that does not differ greatly from the 0.030 grams per month found by Grannemann (1984) in Marquette County. The nitrogen and phosphorous leached by the above method at Keeler was 60 to 80 percent of that at Gobles. If both stations are considered, the combined amount of leachable nitrogen and phosphorus was equivalent, by weight, to only about 5 percent of the dry weight deposited in buckets. Based on data collected, the dry-fallout deposition in Van Buren County is estimated as follows:

Table 17.--Nitrogen and phosphorus deposition by dry fallout

Substance	Dry fallout	
	(lbs/ac)/yr	(tons/mi^2)/yr
Ammonia	0.20	0.064
Organic nitrogen	.54	.17
Nitrite	.0017	.00054
Nitrate	.56	.18
Nitrogen, total	1.26	.40
Orthophosphorus	.090	.029
Phosphorus	.090	.029
Filterable dry material	28.1	8.99

Combining the dry fallout amounts with those previously cited for rainfall and snow, total deposition of nitrogen from atmospheric sources is 2.96 (tons/mi^2)/yr or 9.26 (lbs/ac)/yr; for nitrate the corresponding value is 1.68 (tons/mi^2)/yr or 5.26 (lbs/ac)/yr.

Chemical and Physical Characteristics of Water

Streams

Specific conductance, dissolved oxygen, pH, and temperature.--Specific conductance is indicative of the amount of dissolved substances in solution. Laboratory measurements of dissolved solids (residue on evaporation) and measurements of specific conductance suggest the following approximate relation for water of streams in Van Buren County.

$$\text{Dissolved solids (mg/L)} = 0.70 \times \text{specific conductance } (\mu\text{mhos})$$

Specific conductance of water ranged from 96 μmhos at Brandywine Creek near South Haven (Site 26) during a period of high flow to 1,020 μmhos at South Branch Paw Paw River near Paw Paw (Site 7) during a period of low flow (table 18, at end of report). This suggests that the dissolved-solids concentration of water of streams in the county ranged from about 56 mg/L to 749 mg/L. No significant areal variation in dissolved-solids concentration in the county was evident from data collected.

Dissolved-oxygen concentrations did not differ appreciably from those found at other locations in Michigan. Mean percent saturation of dissolved oxygen ranged from 74 at Black River at Bangor (Site 32) to 104 at South Branch Paw Paw River (Site 12) (table 18, at end of report). Lowest concentrations were found at Black River at Bangor (3.3 mg/L) and at Black Drain (Site 28) (3.5 mg/L). Because lowest concentrations were present at high flow, it is possible that oxygen-consuming materials are being washed to the stream during rains, or that upstream waste discharges are increased during high flow.

Values of pH ranged from 6.5 at Brandywine Creek near South Haven (Site 26) to 8.9 at Haven and Max Lake Drain near Bloomingdale (Site 30). Mean pH values at all sites ranged from 7.3 to 8.3, which indicates that the pH of streams does not differ greatly from that found at other locations in Michigan (U.S. Geological Survey, 1982).

Common dissolved substances and physical properties.--Surface water of Van Buren County is chiefly of a calcium bicarbonate type, although at two locations on Dowagiac Drain (Site 1 and 2), sulfate is the dominant anion (table 19, at end of report). Highest concentrations of chloride generally are present in the northern part of the county. Based on the U.S. Geological Survey's water-hardness classification scale (Brown and others, 1970), about 40 percent of the sites have water that is very hard.

The following table, based on all analyses of water shown in table 19, shows mean concentrations of some of the dissolved substances and physical properties measured.

Table 20.--Mean concentrations of selected characteristics of streams

Substance or property	Mean value (mg/L)	Substance or property	Mean value (mg/L)
Silica (SiO_2)	6.9	Chloride (Cl)	13
Calcium (Ca)	42	Fluoride (F)	.1
Magnesium (Mg)	14	Hardness (as $CaCO_3$)	164
Sodium (Na)	7.4	Dissolved Solids	
Potassium (K)	1.5	Sum	197
Alkalinity (as $CaCO_3$)	136	Residue	216
Sulfate (SO_4)	25		

Nitrogen and phosphorus.--One of the principal objectives of this study was to determine the loads of nitrogen and phosphorus compounds transported by streams, and to relate if possible, loads to land use. Countywide between 600 and 700 analyses of each of the following were made: Total ammonia, total nitrite, total nitrate, total organic nitrogen, total nitrogen, total orthophosphorus, and total phosphorus. Table 21 (at end of report) gives the maximum, mean, and minimum concentrations of each at each station. The maximum total nitrogen concentration (15 mg/L) was found at South Branch Paw Paw River near Paw Paw (Site 7) and Brandywine Creek near Paw Paw (Site 17). Highest mean concentrations (3.0 and 4.1 mg/L) were found in water of Dowagiac Drain (Sites 1 and 2). Mean total nitrogen concentration, based on all sites in the county, was 1.5 mg/L. This mean concentration does not differ appreciably from that found at 19 National Stream Quality Accounting Network Stations operated by the Geological Survey, which are distributed throughout the State. Areal differences in nitrogen concentrations, however, occur within the county. The mean total nitrogen concentration at sites in the southern eight townships was 1.8 mg/L, whereas the mean was 1.2 mg/L in the northern 10 townships. The difference is due principally to a difference in nitrate--in the southern townships the mean was 1.2 mg/L, whereas the mean was only 0.47 mg/L in the northern townships.

A substantial amount of the nitrogen and phosphorus in streams is sometimes associated with suspended sediments. Burwell and others (1975), in a study in west-central Minnesota, found that 96 percent of the nitrogen and 95 percent of the phosphorus were transported by sediment in runoff. Other studies have shown other amounts. Cummings (1978) found, in the St. Joseph River basin in Michigan, that between 76 and 98 percent of the nitrogen, and between 66 and 84 percent of the phosphorus, were transported in the dissolved phase.

During 1981 and 1982, the fraction of nitrogen and phosphorus transported in each phase was prepared for analysis by using a sample splitter at streamside immediately after sample collection. The half of the sample for dissolved analysis was filtered through a 0.45 μm filter; the unfiltered half was analyzed for the total amounts in the water. The following table, based on from 181 to 188 analyses, shows the maximum, mean, and minimum concentrations of dissolved nitrogen and dissolved phosphorus countywide.

Table 22.--Maximum, mean, and minimum concentrations of dissolved nitrogen and phosphorus of streams

Substance	Concentration (mg/L)		
	Maximum	Mean	Minimum
Dissolved ammonia	2.0	0.084	0.01
Dissolved nitrite	.09	.015	.00
Dissolved nitrate	8.7	.82	.01
Dissolved organic nitrogen	1.6	.39	.04
Dissolved nitrogen	10	1.3	.28
Dissolved orthophosphorus	.16	.016	.00
Dissolved phosphorus	.19	.019	.00

Comparing these results with the results of corresponding analyses of total nitrogen and total phosphorus of split samples, data indicate that most nitrogen and phosphorus is transported in the dissolved phase. Table 23 shows the average percent dissolved and percent suspended.

Table 23.--Average percent dissolved and suspended nitrogen and phosphorus of streams

Substance	Percent	
	Dissolved	Suspended
Ammonia	91.7	8.3
Nitrite	93.2	6.8
Nitrate	98.3	1.7
Organic nitrogen	78.6	21.4
Nitrogen	91.1	8.9
Orthophosphorus	80.8	11.2
Phosphorus	50.1	49.9

Trace metals.--Concentrations of trace metals, except for total recoverable iron, are generally low in water of streams throughout the county. Total recoverable iron ranged from 90 to 3,800 µg/L. Dissolved iron, which is frequently more significant to water users, occurred in much lower concentrations. A comparison of concentrations of trace metals to U.S. Environmental Protection Agency drinking water standards (table 24) indicates that none of

Table 24.--Drinking water standards of the U.S. Environmental Protection Agency (data from U.S. Environmental Protection Agency, 1977a and 1977b)

Contaminant	Maximum contaminant levels for inorganic chemicals	Secondary maximum contaminant levels
Arsenic (as)	50 µg/L	--
Barium (Ba)	1,000 µg/L	--
Cadmium (Cd)	10 µg/L	--
Chloride (Cl)	--	250 mg/L
Chromium (Cr)	50 µg/L	--
Color (Units)	--	15 units
Copper (Co)	--	1 mg/L
Fluoride (F)	1.4 to 2.4 mg/L	--
Iron (Fe)	--	300 µg/L
Lead (Pb)	50 µg/L	--
Manganese (Mn)	--	50 µg/L
Mercury (Hg)	2 µg/L	--
Nitrate (NO_3 as N)	10 mg/L	--
pH (Units)	--	6.5 to 8.5 units
Selenium (Se)	10 µg/L	--
Silver (Ag)	50 µg/L	--
Sulfate (SO_4)	--	250 mg/L
Zinc (Zn)	--	5 mg/L
Total Dissolved Solids	--	500 mg/L

the concentrations exceeded the manditory maximum contaminant levels. Water of Brandywine Creek near South Haven (Site 26) did contain, however, slightly higher iron and manganese concentrations than the established secondary maximum contaminant levels.

Pesticides, polychlorinated biphenyls, and polychlorinated napthalenes.--Samples for analysis of polychlorinated biphenyls (PCB), polychlorinated napthalenes (PCN), and pesticides were collected at all 39 periodic and miscellaneous sampling sites. Initial sampling was conducted in May 1981, a time when it was believed their detection would be most likely. In August 1982, additional samples were collected at a few sites for either a seasonal comparison or to supplement data previously obtained. Analyses were made for the following:

Aldrin, dissolved	Methylparathion, dissolved
Ametryne, total	Methyltrithion, dissolved
Atratone, total	Mirex, dissolved
Atrazine, total	Parathion, dissolved
Chlordane, dissolved	Perthane, dissolved
Cyanazine, total	PCB, dissolved
Cyprazine, total	PCN, dissolved
DDD, dissolved	Prometone, total
DDE, dissolved	Prometryne, total
DDT, dissolved	Propazine, total
Diazinon, dissolved	Propham, total
Dieldrin, dissolved	Sevin, total
Endrin, dissolved	Silvex, total
Endosulfan, dissolved	Simazine, total
Ethion, dissolved	Simetone, total
Heptachlor, dissolved	Simetryne, total
Heptachlorepoxide, dissolved	Toxaphene, dissolved
Lindane, dissolved	Trithion, dissolved
Malathion, dissolved	2,4-D, total
Methomyl, total	2,4,5-T, total
Methoxychlor, dissolved	2,4-DP, total

Only six of the above compounds were detected in water--Atrazine, Diazinon, Dieldrin, Prometryne, Simazine, and 2,4-D. Analyses of triazine herbicides, which include Atrazine, Prometryne, and Simazine, where made on water collected at only 18 sites. Table 25 gives the location of sites and concentrations of those pesticides. The highest concentration found was that of Simazine (3.9 μg/L) in water of Deerlick Creek near South Haven (Site 27). Atrazine (1.0 μg/L) was found in water of Black River at two locations (Sites 33 and 35). Repeat sampling of Black Drain near Bangor (Site 28) and Black River near Bangor (Site 33) in late summer showed that concentrations in spring, as might be expected, are substantially greater.

Suspended sediment.--Compared with streams in many parts of the country, suspended-sediment concentrations of most streams in Van Buren County are low. Table 26 gives the maximum, mean, and minimum concentrations for 39 sites, which include the three daily suspended-sediment stations. The maximum concentration, 552 mg/L, was found at Site 28 on Black River Drain; the mean concentration at this site, however, was 34.3 mg/L. Mean concentrations at sites ranged from 3.3 mg/L at Site 26 on Middle Fork Black River to 42.2 mg/L at Site 27 on Deerlick Creek. The maximum suspended-sediment concentration exceeded 100 mg/L at only nine of the sites. Table 27 shows monthly loads (in tons) for each of the three daily stations--Paw Paw River near Paw Paw (Site 18), Paw Paw River near Hartford (Site 23), and Black River near Bangor (Site 33). Highest concentrations were found at the site on the Black River near Bangor; the lowest was found at Paw Paw River near Paw Paw. Sediment yields, in (tons/mi^2)/yr, were: Site 18, 11.9; Site 23, 24.0; and Site 33, 34.0.

Table 25.--Pesticide concentrations of streams, 1981
[Analyses by U.S. Geological Survey]

Stream	Date of sample	Atrazine, total (µg/L)	Diazinon, dissolved (µg/L)	Dieldrin, dissolved (µg/L)	Prometryne, total (µg/L)	Simazine, total (µg/L)	2,4-D, total (µg/L)
04101698 Dowagiac Drain 1 mile south of Decatur	May 11, 1981	[a]<0.10	<0.01	0.01	[b]0.1	<0.01	<0.01
04101700 Dowagiac Drain 3.7 miles southwest of Decatur	May 11, 1981	<.10	<.01	.01	[b].4	.10	<.01
04101710 Lake of the Woods Drain 3.5 miles southwest of Decatur	May 11, 1981	<.10	<.01	<.01	<.1	.02	.15
04102177 Cook Drain 1 mile west of Mattawan	May 11, 1981	<.10	<.01	<.01	<.1	<.01	.01
04102178 East Branch Paw Paw River 1.5 miles north of Lawton	May 11, 1981	<.10	<.01	<.01	<.1	<.01	.01
04102212 North Branch Paw Paw River 4.3 miles northeast of Paw Paw	May 12, 1981	--	<.01	<.01	--	--	[c].02
04102217 Unnamed Tributary to Paw Paw River 3.5 miles northeast of Paw Paw	May 12, 1981	--	<.01	<.01	--	--	.01
04102240 Brandywine Creek 3.4 miles south of Gobles	May 11, 1981	<.10	.02	<.01	<.1	<.01	<.01
04102246 North Extension Drain 3.7 miles southwest of Gobles	May 12, 1981	--	<.01	<.01	--	--	.01
04102320 Paw Paw River 3 miles northwest of Paw Paw	May 12, 1981	--	<.01	<.01	--	--	.01
04102370 Brush Creek at Lawrence	Aug. 18, 1981	--	--	--	--	--	.01
04102392 Paw Paw River at Lawrence	Aug. 18, 1981	--	--	--	--	--	.01
04102420 Paw Paw River 1.5 miles northwest of Hartford	May 13, 1981	--	<.01	<.01	--	--	.02
04102429 Pine Creek 1 mile west of Hartford	May 13, 1981	--	.01	<.01	--	--	<.01
04102540 Brandywine Creek 2.7 miles northwest of Gobles	May 12, 1981	<.10	<.01	<.01	<.1	.11	.21
04102545 Deerlick Creek 2 miles south of South Haven	May 11, 1981	.20	--	--	<.1	3.9	.01
04102575 Black Drain 3.8 miles northeast of Bangor	May 11, 1981 Aug. 17, 1981	.20 --	.06 --	<.01 --	<.1 --	[d].08 --	.45 [c].01
04102587 Haven and Max Lake Drain 1 mile southwest of Bloomingdale	May 12, 1981	[d].50	.02	<.01	<.1	[d].07	--
04102589 Haven and Max Lake Drain 2 miles southwest of Bloomingdale	May 11, 1981	[d].30	.01	.01	<.1	[d].07	.80
04102590 Haven and Max Lake Drain 4 miles northeast of Bangor	May 13, 1981	--	<.01	<.01	--	--	[e].02
04102618 Black River at Bangor	May 13, 1981	.70	<.01	<.01	<.1	.15	.17
04102700 Black River 4.9 miles northwest of Bangor	May 13, 1981 Aug. 19, 1981	1.0 --	-- --	-- --	.2 --	<.01 --	.15 .01
04102730 South Branch Black River 2 miles northeast of South Haven	Aug. 20, 1981	--	--	--	--	--	.01
04102731 Black River 1 mile east of South Haven	May 12, 1981	1.0	<.01	--	<.1	.42	.01
04102735 Middle Fork Black River 5.5 miles northwest of Bloomingdale	May 12, 1981	<.10	.01	<.01	<.1	<.01	.03
04102750 Melvin Creek 3.2 miles northwest of Bloomingdale	May 13, 1981	--	<.01	<.01	--	--	.47

[a]Less than (<) indicates the detection level; pesticides may or may not be present at a lesser concentration.

[b]May 21, 1981

[c]August 17, 1981

[d]May 22, 1981

[e]August 19, 1981

Table 26.--Maximum, mean, and minimum suspended-sediment concentrations of streams, 1980-82 [Results in milligrams per liter. Analyses by U.S. Geological Survey]

Site number	Number of analyses	Maximum	Mean	Minimum
1	13	66	40.0	17
2	35	97	33.2	9
3	31	88	13.4	0
4	7	8	4.6	0
5	7	19	11.0	5
6	7	28	17.3	12
7	33	46	17.3	6
8	7	11	6.4	2
9	7	114	18.1	1
10	31	33	9.1	2
11	31	88	13.2	4
12	30	20	8.0	0
13	31	18	7.7	1
14	31	25	6.6	1
15	7	75	18.6	5
16	7	32	11.3	3
17	30	80	17.8	2
18	752	204	10.0	1
19	7	33	17.6	3
20	7	60	12.3	3
21	33	206	34.6	3
22	33	50	13.8	2
23	756	188	18.8	1
24	7	46	16.7	6
26	29	215	29.0	0
27	28	370	42.2	2
28	31	552	34.3	4
29	7	43	12.6	3
30	7	11	4.9	1
31	30	53	17.0	2
32	29	58	11.9	2
33	756	379	27.6	1
34	32	65	10.6	1
34A	7	18	9.0	2
35	21	159	28.3	2
36	7	7	3.3	1
37	7	21	11.0	3
38	7	15	10.9	3
39	7	34	22.9	10

Table 27.--Measured suspended-sediment loads, in tons, at daily sampling stations[a], July 1980 to August 1982

	Site 18 Paw Paw River near Paw Paw (tons)	Site 23 Paw Paw River near Hartford (tons)	Site 33 Black River near Bangor (tons)
July 1980	[b]92.6	[b]208.0	[b]65.2
August	323.9	843.0	536.1
September	142.2	413.2	369.1
October	50.7	136	44.3
November	56.3	59.4	14.7
December 1980	166.9	352.2	163.5
January 1981	123.0	214.3	44.8
February	257.2	1,465.8	405.5
March	125.6	312.2	107.6
April	226.9	949.5	505.9
May	555.5	2,176	497.5
June	351.6	1,182	273.2
July	234.0	391.1	35.9
August	160.8	258.7	40.4
September	155.9	384.2	65.0
October	91.9	519.3	73.7
November	93.8	211.8	112.0
December 1981	68.5	256.0	32.4
January 1982	146.1	750.6	281.0
February	109.2	410.0	75.7
March	507.5	2,075.4	583.5
April	153.9	612.9	233.7
May	241.6	542.7	249.7
June	315.2	932.6	145.9
July	409.7	947.4	1,413.0
August 1982	[c]77.0	[c]158.0	[c]29.8
Total tons, July 1980 through August 1982	5,238	16,762	6,399

[a]See plate 1 for locations of sites
[b]July 20-31
[c]August 1-15

Figure 13 shows the relation of suspended-sediment concentration to discharge in March 1982--the month when highest flow at the three daily stations occurred. At Sites 18 and 23, peak suspended-sediment concentrations were found near the time of maximum discharge; at Site 33, however, peak sediment concentrations preceeded maximum discharge. At Site 33 on March 31, an increase in sediment concentration was followed by an increase in discharge on April 1, although the increase in flow was much less than that earlier in the month.

Relation of Land Use to Suspended Sediment, Nitrogen, and Phosphorus Yields

Studies of the relation of suspended sediment, nitrogen, and phosphorus transported by streams to land use frequently show inconclusive results. Various conservation practices, and the physical characteristics of land, particularily in areas covering several hundred square miles, may obscure relationships. Transport of dissolved and suspended materials may be modified by ponds, swamps, and associated changes in the velocity of water, or by biologic processes that increase or decrease the concentrations of substances. In Van Buren County, only a few relationships are evident.

Estimated yields, in (tons/mi^2)/yr, were computed for each of the 39 drainage areas identified on plate 2. These estimated yields, table 28, were based on concentration data summarized in tables 21 and 26, on discharge measurements made at the time samples were collected, and on a regression procedure described by Cummings (1984).

Figure 14 is a plot of the suspended-sediment yield of each drainage area for the three major categories of land use--cropland, pasture, and feeding operation; orchard, bush-fruit, and vineyard; and brushland and forest (table 4). A relation between yield and land use is not evident from these plots. Low suspended-sediment concentrations, compared to many other agricultural areas in the country, may be a principal reason. Figure 15 shows similar relationships for total nitrogen, total nitrate, and total phosphorus yields versus the percentage of cropland, pasture, and feeding operation. An increase in yield is suggested as the percentage of cropland, pasture, and feeding operation increases. A regression analysis suggests that an increase nitrate yield can be expected as the percentage of cropland, pasture, and feeding operations increases[1]. For example, the nitrate yield from an area 60 percent in cropland, pasture, and feeding operation will be about twice as great as from an area only 30 percent in the same use.

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[1]To make certain that the higher nitrate yields from areas M, V_1, and V_2 were not the cause of the indicated increase, these data were not included in the regression.

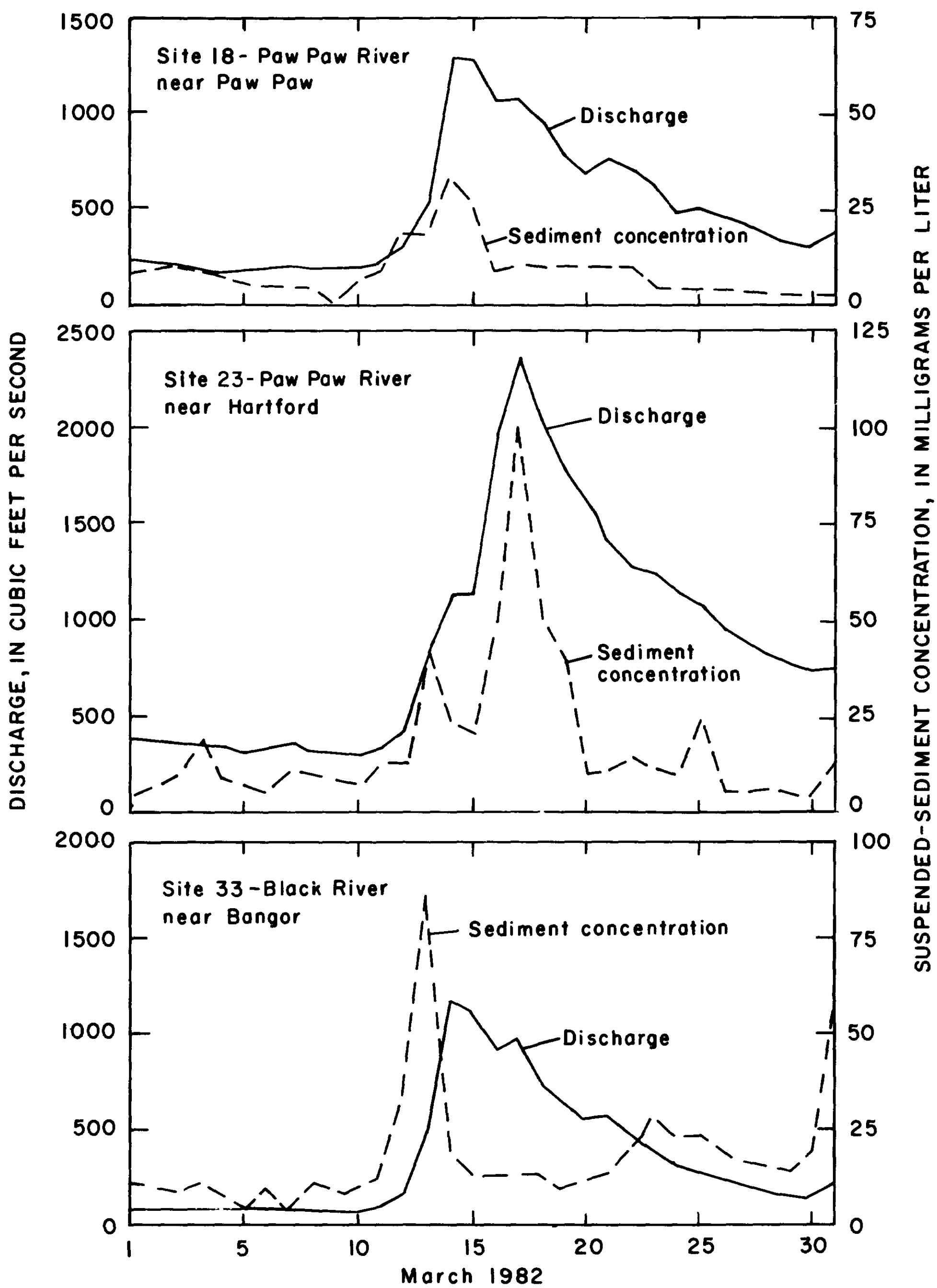

Figure 13.--Relation of suspended-sediment concentration to discharge at daily sampling stations, March 1982.

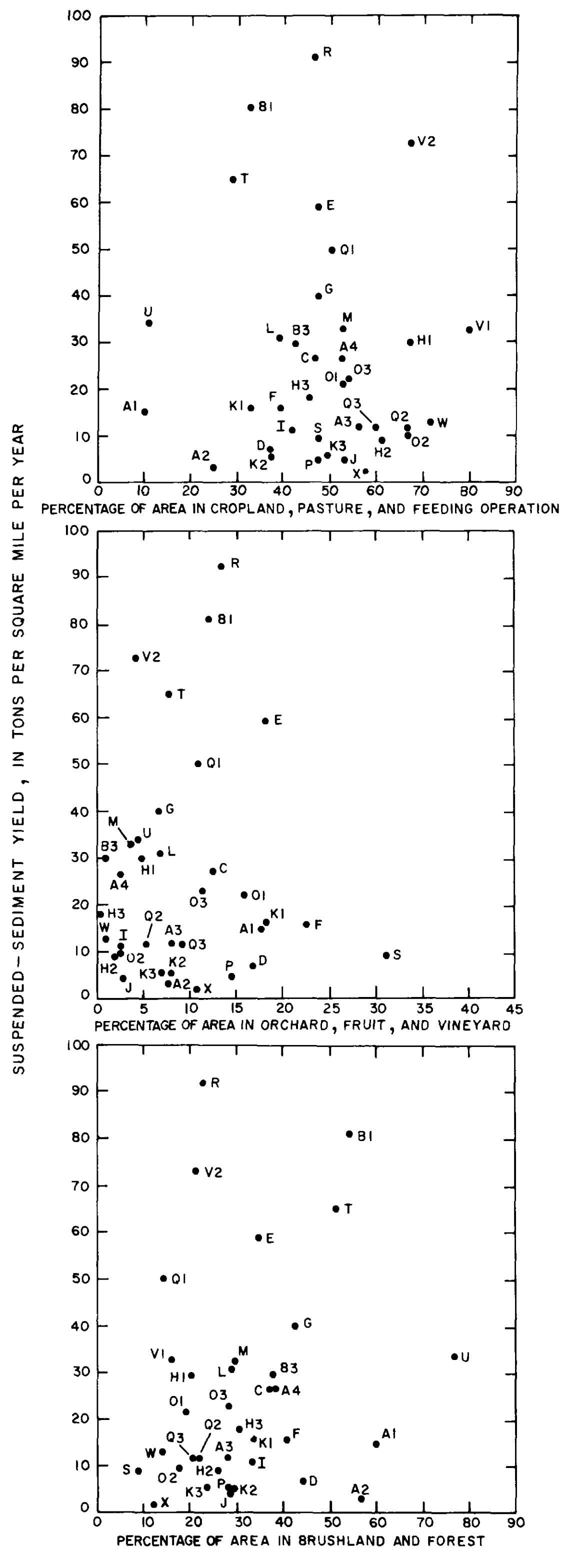

Figure 14.--Relation of suspended-sediment yield to land use. (See figure 8 for letter code and drainage area designation)

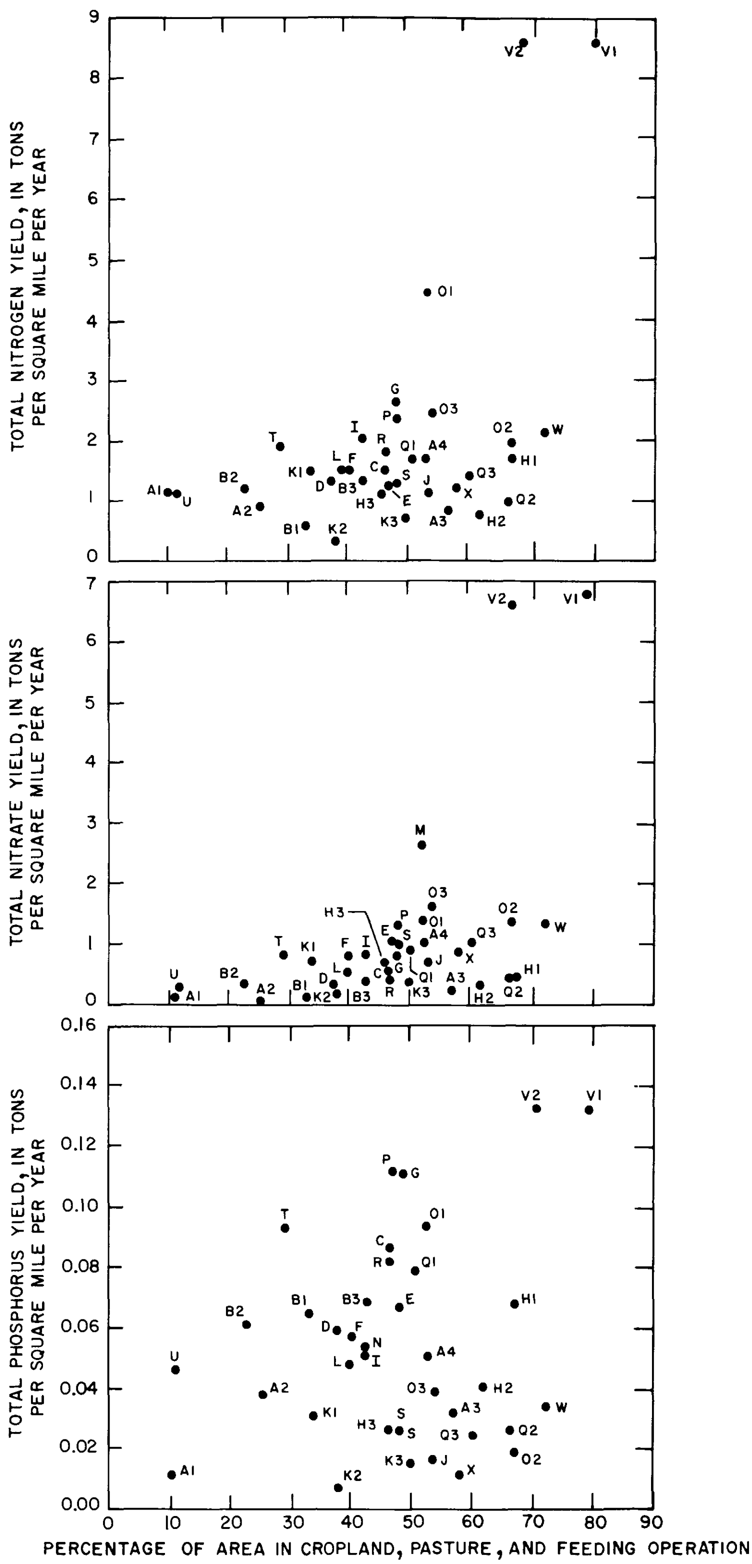

Figure 15.--Relation of nitrogen and phosphorus yields to land use. (See figure 8 for letter code and drainage area designation)

Table 28.--Estimated annual yields of nitrogen, phosphorus, and suspended sediment in Van Buren County (Negative values indicate input is greater than output from area)

Area	Size of area (mi²)	Yield, in tons per square mile per year							
		Nitrogen, ammonia total (as N)	Nitrogen, nitrite total (as N)	Nitrogen, nitrate total (as N)	Nitrogen, organic total (as N)	Nitrogen, total (as N)	Phosphorus, total (as P)	Phosphorus, ortho, total (as P)	Suspended sediment
A_1	7.71	0.14	0.026	0.15	0.73	1.1	0.037	0.012	15
A_2	5.01	.058	.013	.066	.80	.88	.039	.013	3.3
A_3	7.10	.042	.022	.22	.68	.82	.031	.010	12
A_4	9.61	.070	.024	1.0	.49	1.7	.050	.034	27
B	16.8	.097	.013	.29	.72	1.1	.049	.018	31
B_1	4.50	.031	.027	.14	.51	.59	.064	.0032	81
B_2	2.96	.16	-.020	-.46	1.3	1.2	-.061	-.057	-40
B_3	9.34	.068	.024	.36	.88	1.3	.068	.035	30
C	23.6	.10	.024	.55	.81	1.5	.085	.031	27
D	12.0	.10	.023	.32	.93	1.3	.059	.040	6.9
E	31.2	.032	.011	1.0	.16	1.2	.066	.033	59
F	17.6	.087	.023	.75	.66	1.5	.056	.027	16
G	30.8	.030	.025	.80	1.4	2.6	.11	.030	40
H	32.2	.090	.011	.46	.60	1.2	.070	.035	20
H_1	12.4	.14	.017	.42	1.0	1.7	.067	.034	30
H_2	10.7	.10	.014	.31	.28	.72	.040	.022	9.4
H_3	9.05	.026	.010	.71	.40	1.1	.026	.010	18
I	37.8	.061	.014	.79	1.2	2.0	.052	.015	11
J	17.6	.027	.0080	.73	.26	1.1	.016	.0050	4.7
K	26.9	.026	.0070	.35	.29	.76	.016	.0056	8.3
K_1	7.10	.052	.014	.70	.58	1.5	.031	.011	16
K_2	10.6	.010	.0027	.14	.11	.30	.0063	.0021	5.6
K_3	9.20	.024	.0065	.32	.27	.70	.015	.0051	5.6
L	4.60	.042	.014	.51	.76	1.5	.048	.016	31
M	13.1	-.14	-.019	2.6	-2.8	-.52	-.016	.033	33
N	11.6	-.082	.058	-1.2	-.26	-1.6	.053	-.032	-44
O	51.2	.13	.026	1.5	1.1	2.7	.044	.019	22
O_1	10.8	.36	.027	1.3	2.6	4.4	.092	.067	22
O_2	14.3	.057	.028	1.3	.54	1.9	.019	.0098	10
O_3	26.1	.085	.018	1.6	.76	2.4	.039	.011	23
P	30.1	.034	.039	1.2	.77	2.3	.11	.066	4.9
Q	39.9	.059	.011	.84	.45	1.4	.047	.018	28
Q_1	17.0	.10	.013	.85	.52	1.7	.078	.026	50
Q_2	6.89	.021	.0084	.43	.50	.95	.026	.014	12
Q_3	16.0	.031	.011	1.0	.36	1.4	.024	.015	12
R	46.0	.11	.010	.50	1.1	1.8	.081	.032	92
S	9.67	.028	.015	.94	.36	1.3	.026	.022	9.4
T	7.76	.15	.031	.80	.87	1.9	.093	.031	65
U	16.7	.082	.012	.26	.75	1.1	.047	.012	34
V	21.9	.33	.063	6.7	1.4	8.6	.13	.085	59
V_1	7.60	.33	.060	6.8	1.4	8.6	.13	.085	33
V_2	14.3	.33	.066	6.6	1.4	8.6	.13	.085	73
W	13.1	.092	.018	1.3	.59	2.1	.034	.016	13
X	15.5	.014	.017	.82	.33	1.2	.011	.0050	2.2

High yields of total nitrate, total nitrogen, and total phosphorus from areas V_1 and V_2 cannot be adequately explained. The percentages of cropland, pasture, and feeding operation in these areas are, however, among the highest in the county. A more precise breakdown of land uses within the category would probably be necessary; feeding operations cannot be responsible for high nitrate yields because they are absent from the two areas. Plots of nitrogen and phosphorus yields versus other land uses did not suggest relations.

Relation of Erosion Potential to Suspended Sediment, Nitrogen, and Phosphorus Yields

A relation between erodibility of land and the transport of suspended material by stream is well established. Erosion refers to the dislodgement and movement of soil particles within a specific area. Severe erosion, however, does not necessarily indicate that eroded material will reach stream channels. Figure 16, prepared by the Michigan Department of Agriculture for this investigation, shows the erosion potential of land in Van Buren County. Land has been classified as to whether its erosion potential is severe, moderate, or slight. The Michigan Department of Agriculture regards 3 to 5 tons per acre per year of erosion as the maximum acceptable if a productive top soil is to be maintained.

In order to compare erosion potential to the transport of materials by streams, the percentage of land in each erosion potential category was determined for each drainage area (table 29).

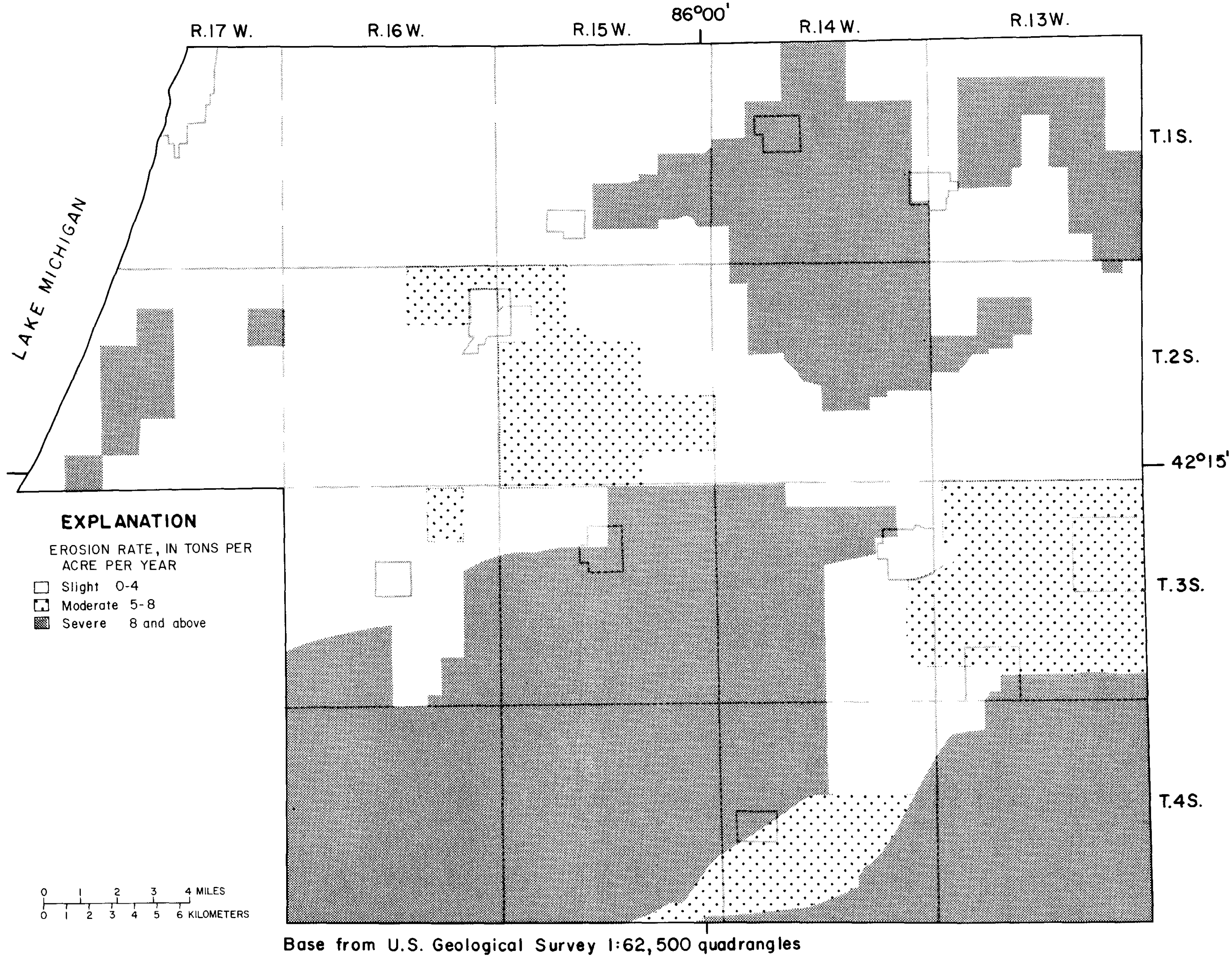

Figure 16.--Erosion potential.

Table 29.--Erosion potential, by drainage area

Area[1]	Erosion potential: Severe (percent of area)	Erosion potential: Moderate (percent of area)	Erosion potential: Slight (percent of area)	Area	Erosion potential: Severe (percent of area)	Erosion potential: Moderate (percent of area)	Erosion potential: Slight (percent of area)
A_1	1	0	99	K_3	41	59	0
A_2	3	0	97	L	0	81	19
A_3	49	0	51	M	13	15	72
A_4	76	0	24	N	13	54	33
B_1	82	0	18	O_1	51	47	2
B_2	83	0	17	O_2	84	0	16
B_3	95	0	5	O_3	37	20	43
C	7	29	64	P	47	7	46
D	0	19	81	Q_1	100	0	0
E	0	34	66	Q_2	100	0	0
F	5	0	95	Q_3	100	0	0
G	0	0	100	R	19	12	69
H_1	92	0	8	S	54	0	46
H_2	94	0	6	T	0	0	100
H_3	22	0	78	U	34	0	66
I	17	0	83	V_1	30	70	0
J	0	24	76	V_2	27	73	0
K_1	8	92	0	W	100	0	0
K_2	0	100	0	X	100	0	0

Figure 17a shows the percent of land in an area classified as having severe erosion potential plotted against the suspended-sediment yield of the area, in (tons/mi^2)/yr. No apparent relation exists, nor does a plot of the mean suspended-sediment concentration at the downstream site of each drainage area indicate a correlation (fig. 17b). Similar plots of nitrogen yield (fig. 17c) and other nutrients also failed to show relations. It is likely, however, that drainage areas of this study are too large, and suspended-sediment concentrations generally too low, for erosion to be demonstrated from measurements at the established sites.

[1]Figure 8 shows location of areas.

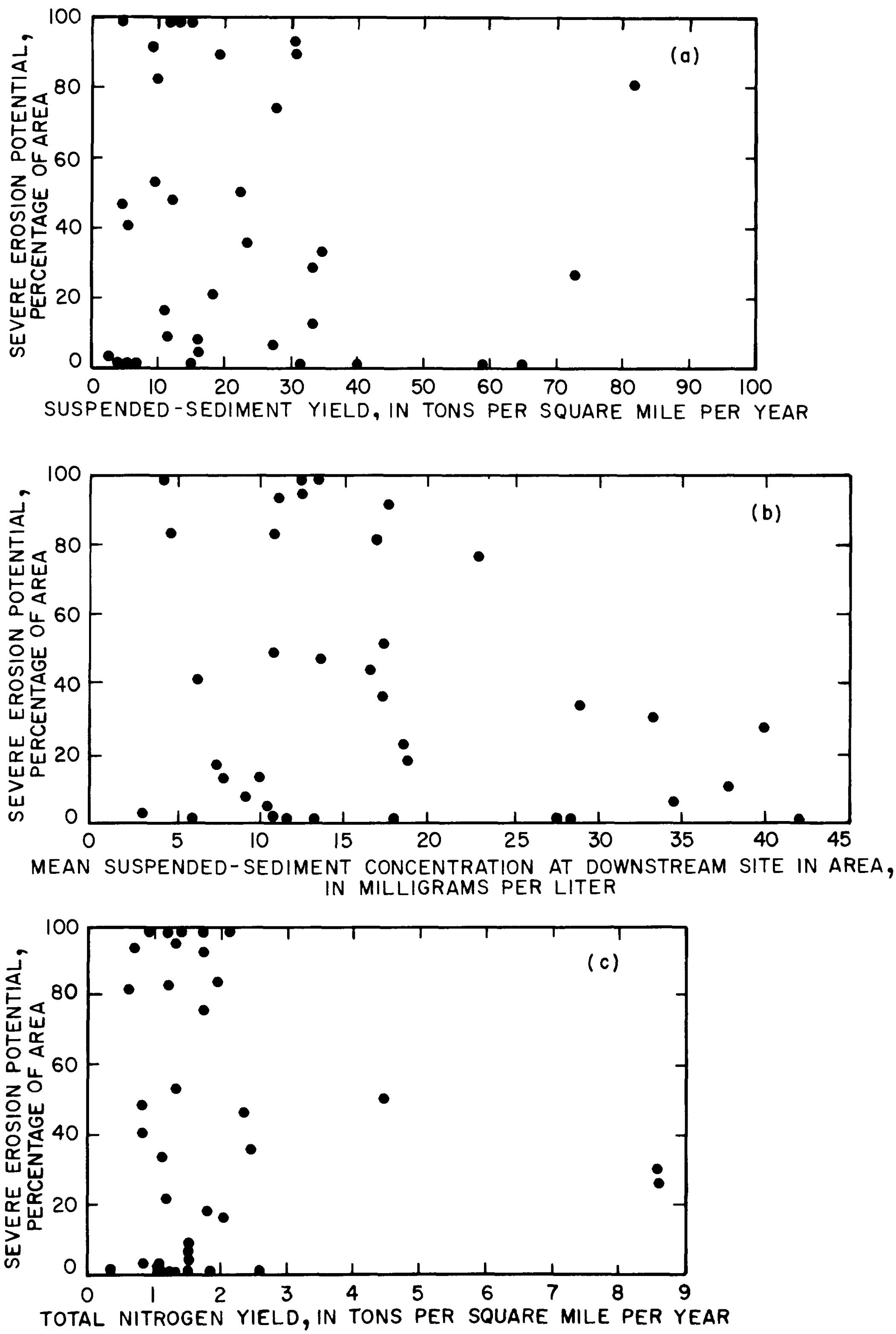

Figure 17.--Relation of erosion potential to suspended sediment and nitrogen yields.

Lakes

Chemical and physical characterisitcs of water from 31 lakes were measured during this study (table 30, at end of report). Water of most lakes is of a calcium bicarbonate type, although, at some locations, sodium and magnesium may constitute more than 50 percent of the sum of cation equivalents. Sulfate and chloride combined also may exceed bicarbonate in water of some lakes. In general, lakes with relatively high sodium concentrations also contain relatively high chloride and sulfate concentrations. Dissolved-solids concentration ranged from 28 mg/L in water of Knickerbocker Lake near Decatur to 310 mg/L in water of Maple Lake. (Samples of Maple Lake were collected at the upstream side of the dam; analyses are identified as Site 12 South Branch Paw Paw River in table 19.) The mean dissolved-solids concentration of all lakes was 143 mg/L.

Concentrations of nitrogen and phosphorus generally were low. Median concentrations of data given in table 24 were: Total ammonia, <0.01 mg/L; total nitrite, <0.01 mg/L; total nitrate, <0.01 mg/L and total organic nitrogen, 0.70 mg/L. Similarly, the median concentration of total orthophosphorus was <0.01 mg/L, and that of total phosphorus, 0.02 mg/L. Data published in U.S. Geological Survey annual reports from 1972 to 1978 indicate that depletion of ammonia, nitrite, and nitrate, and low levels of phosphorus is not uncommon in lakes of Van Buren County. Similar concentrations are indicated by data of the Michigan Department of Natural Resources. Streams, ground-water inflow, and precipitation, which are the sources of water in lakes, normally contain substantially more nitrogen and phosphorus. Utilization by aquatic plant life and denitrification by bacteria are likely responsible for nitrogen and phosphorus loss in lakes.

Trace-metal concentrations were generally low in water of all lakes (table 30, at end of report). None exceeded maximum levels established by the U.S. Environmental Protection Agency (table 24).

Water for analysis of 40 pesticides, polychlorinated biphenyls, and polychlorinated napthalenes was collected from 11 lakes just after pesticide application in May 1982, and from 15 additional lakes in August and September 1982. Agricultural pesticides were detected in each of the 26 lakes (table 31). Alachlor, Atrazine, Silvex, Simazine, Treflan, and 2,4-D were found. Highest concentrations were those of Treflan and 2,4-D. Brownwood and Brandywine Lakes had concentrations of Treflan exceeding 4 μg/L. Crooked, Keeler, and Upper Jephta Lakes had concentrations of 2,4-D exceeding 1 μg/L; Saddle Lake had 2.6 μg/L. These concentrations are higher than commonly found and higher than those found in streams. The fact that they were found in both spring and fall suggests that pesticides may be present in water of lakes during much of the year.

Table 31.--Pesticide concentrations of lakes, 1982
[Analyses by U.S. Geological Survey]

Lake	Date of sample	Alachlor, total (μg/L)	Atrazine, total (μg/L)	Silvex, total (μg/L)	Simazine, total (μg/L)	Treflan (triflu-ralin), total (μg/L)	2,4-D, total (μg/L)
Crooked Lake at Sister Lakes	May 20, 1982	0.04	[a]<0.10	0.20	<0.10	0.06	1.6
Gravel Lake near Marcell	Aug. 25, 1982	--	<.10	<.01	.10	1.18	.08
Round Lake at Sister Lakes	Aug. 31, 1982	--	<.10	<.01	<.10	.24	<.01
Cedar Lake near Marcellus	May 21, 1982	.09	.20	<.01	<.10	.20	.01
Knickerbocker Lake near Decatur	May 21, 1982	.09	<.10	<.01	<.10	.08	<.01
Keeler Lake near Keeler	May 20, 1982	.03	<.10	<.01	<.10	.19	1.1
Bankson Lake near Lawton	Aug. 31, 1982	--	<.10	<.01	<.10	.19	.12
Lake of the Woods near Decatur	May 21, 1982	.05	<.10	<.01	<.10	--	.64
Eagle Lake near Decatur	Aug. 25, 1982	--	<.10	.01	<.10	1.69	.07
Three Mile Lake near Paw Paw	Aug. 31, 1982	--	.10	<.01	<.10	.21	.02
Shafer Lake near Lawrence	Aug. 31, 1982	--	.20	<.01	<.10	.20	.04
Cora Lake near Lawrence	May 20, 1982	--	<.10	<.01	<.10	.12	.04
Maple Lake at Paw Paw	May 21, 1982	.07	<.10	<.01	<.10	--	--
Rush Lake near Toquin	Aug. 12, 1982	--	<.10	<.01	.10	.50	.63
Brownwood Lake near Paw Paw	Aug. 30, 1982	--	<.10	<.01	<.10	4.33	.16
Van Auken Lake near McDonald	May 21, 1982	.05	.20	<.01	.10	--	.06
School Section Lake near Bangor	Sept. 2, 1982	--	.30	<.01	1.0	.28	<.01
School Section Lake near Glendale	Sept. 1, 1982	--	.40	<.01	<.10	.19	.05
North Scott Lake near Bangor	Aug. 12, 1982	--	.10	<.01	3.2	2.1	.19
Upper Jephtha Lake near Breedsville	May 21, 1982	.03	<.10	<.01	<.10	--	1.7
Brandywine Lake near Gobles	Aug. 30, 1982	--	<.10	--	<.10	4.61	--
Great Bear Lake near Bloomingdale	May 21, 1982	.05	.30	<.01	<.10	--	.19
Mill Lake near Gobles	Aug. 24, 1982	--	--	<.01	--	--	.16
Silver Lake near Grand Junction	Sept. 1, 1982	--	<.10	<.01	.60	.23	.15
Saddle Lake near Grand Junction	May 21, 1982	.02	<.10	<.01	<.10	.07	2.6
Clear Lake near Kendall	Sept. 2, 1982	--	.10	<.01	<.10	.05	<.01

[a]Less than (<) indicates the detection level; pesticides may or may not be present at a lesser concentration.

A comparison of data obtained in 1982 with that obtained in 1963 (Giroux and others, 1964) indicates that concentrations of the major dissolved substances in water of lakes have not changed appreciably. The following table shows mean values for 30 lakes.

Table 32.--Mean concentrations of selected substances of lakes, 1963 and 1982

Dissolved substance	Mean concentration (mg/L)	
	1982	1963
Calcium	25.8	25.8
Sulfate	11.1	18.5
Chloride	9.9	11.5
Dissolved solids	143	148

Slight decreases in sulfate and chloride may be due to a reduction in the amount of municipal and industrial wastes discharged to streams.

The quality of water of lakes is also related to inflow-outflow characteristics. Lakes with no outlet or inlet have the lowest dissolved-solids concentration, highest organic nitrogen, and lowest chloride and sulfate concentrations. Those with outlets and inlets, have higher dissolved-solids concentrations and other chemical and physical characteristics that are similar to those of streams. With the exception of Bankson Lake, which has an outlet, lakes with inlets and outlets were the only ones to have nitrate concentrations greater than 0.01 mg/L during this study. Data obtained by the Geological Survey during 1972-1978 in the county indicate a similar situation existed during that period. The following table shows mean concentrations of selected substances for each type of lake.

Table 33.--Mean concentrations of selected substances of lakes, 1972-1978

Outlet/ inlet	Mean concentration (mg/L)						
	Silica	Chloride	Sulfate	Nitrate	Organic nitrogen	Hardness	Dissolved solids
No outlet or inlet	1.2	6.8	9.0	<0.01	2.0	90	113
Outlet only	5.0	12	15	[a]<.01	.84	146	190
Outlet and inlet	5.4	17	24	[b].27	.69	178	242

[a]2.5 mg/L concentration of Bankson Lake omitted from mean computation.
[b]20 mg/L concentration of Brandywine Lake omitted from mean computation.

Ground Water

Chemical and physical characteristics of water from 21 domestic wells and 21 wells drilled for this study were measured. Locations of these wells are shown on plate 1 and analyses are given in tables 34 and 35 (at end of report). Analyses included the major dissolved substances and properties, trace metals, and pesticides. Calcium and bicarbonate were the principal dissolved constituents in 90 percent of the waters. Sodium was the dominant cation in water from three wells; sulfate and chloride were high in water from three wells. Depending upon location, high concentrations of sodium and chloride probably result from surface waste discharges, oil-field activity, and road salting during winter. It is not likely that either constituent is naturally occuring in shallow ground waters at the comparatively high levels detected at some locations. Sulfate, which probably occurs naturally in higher concentrations than chloride, also was higher in water from several wells when chloride was higher.

Dissolved-solids concentration of ground water ranged from 112 to 878 mg/L; the mean concentration was 307 mg/L. The approximate relation between specific conductance and dissolved-solids concentration for ground water in Van Buren County is:

$$\text{Dissolved solids (mg/L)} = 0.62 \times \text{Specific conductance } (\mu\text{mhos})$$

A comparison of data obtained during this study with that obtained during 1963 (Giroux and others, 1964) suggests that the total mineralization of ground water has not changed significantly. The pH ranged from 7.0 to 8.2; the mean was 7.6. In 1963, a mean value of 7.2 was reported.

Median values, based on data in tables 34 and 35 and on analyses made by the Michigan Department of Public Health for this study, have been compared to median values found by Cummings (1980) in a statewide survey of natural ground-water quality. Table 36 shows this comparison for 49 substances and properties. For the major dissolved substances (calcium, magnesium, sodium, and sulfate) differences were not great. The median value of nitrate (0.83 mg/L) in Van Buren County, however, was significantly higher. Most trace-metal concentrations did not differ greatly from state-wide median values, although, at some locations, unusually high values were found. For example, well 7 contained 16,000 μg/L of aluminum, 70 μg/L of lead, 620 μg/L of manganese, 59 μg/L nickel, 2,000 μg/L of zinc, 530 μg/L copper, 25,000 μg/L iron, and 0.02 mg/L cyanide. It is probable that ground water in the vicinity of this well has been contaminated.

Table 36.--Comparison of ground-water quality in Van Buren County with statewide ground-water quality

Substance or property	Median concentration	
	[a]Statewide	[b]Van Buren County
Alkalinity (mg/L as $CaCO_3$)	163	200
Aluminum, Total Recoverable (μg/L as Al)	31	55
Arsenic, Total (μg/L as As)	1	3
Barium, Total Recoverable (μg/L as Ba)	0	100
Beryllium, Total Recoverable (μg/L as Be)	0	<10
Boron, Total Recoverable (μg/L as B)	25	20
Cadmium, Total Recoverable (μg/L as Cd)	1	<1
Calcium, Dissolved (mg/L as Ca)	48	58
Carbon, Organic Dissolved (mg/L as C)	2.9	1.1
Chloride, Dissolved (mg/L as Cl)	2.2	[c]3.8
Chromium, Total Recoverable (μg/L as Cr)	9	10
Cobalt, Total Recoverable (μg/L as Co)	1	1
Color (Platinum Cobalt Units)	4	4
Copper, Total Recoverable (μg/L as Cu)	5	8
Cyanide, Total (mg/L as CN)	.00	<.01
Fluoride, Dissolved (mg/L as F)	.1	.1
Hardness (mg/L as $CaCO_3$)	178	[d]226
Hardness, Noncarbonate (mg/L as $CaCO_3$)	7	33
Iron, Dissolved (μg/L as Fe)	220	[e]160
Iron, Total Recoverable (μg/L as Fe)	740	1,050
Lead, Total Recoverable (μg/L as Pb)	11	5
Lithium, Total Recoverable (μg/L as Li)	0	10
Manganese, Dissolved (μg/L as Mn)	23	29
Manganese, Total Recoverable (μg/L as Mn)	36	50
Magnesium, Dissolved (mg/L as Mg)	15	22
Mercury, Total Recoverable (μg/L as Hg)	.4	<0.1
Molybdenum, Total Recoverable (μg/L as Mo)	1	3
Nickel, Total Recoverable (μg/L as Ni)	5	3
Nitrogen, Total (mg/L as N)	.27	.53
Nitrogen, Ammonia, Total (mg/L as N)	.04	.07
Nitrogen, Nitrate, Total (mg/L as N)	.00	[f].83
Nitrogen, Nitrite, Total (mg/L as N)	.00	<.01
Nitrogen, Organic, Total (mg/L as N)	.10	.27
pH (Units)	7.7	7.5
Phenols (μg/L)	0	<1
Phosphorus, Total (mg/L as P)	.01	.04
Phosphorus, Ortho, Total (mg/L as P)	.00	<.01
Potassium, Dissolved (mg/L as K)	1.0	1.2
Selenium, Total (μg/L as Se)	0	<1
Silica, Dissolved (mg/L as SiO_2)	10	12
Silver, Total Recoverable (μg/L as Ag)	0	<1
Sodium, Dissolved (mg/L as Na)	3.4	4.3
Solids, Residue at 180°C, Dissolved (mg/L)	223	288
Solids, Sum of Constituents, Dissolved (mg/L)	220	262
Specific Conductance (micromhos at 25°C)	370	468
Strontium, Total Recoverable (μg/L as Sr)	120	90
Sulfate, Dissolved (mg/L as SO_4)	12	22
Turbidity (JTU)	2	4.6
Zinc, Total Recoverable (μg/L as Zn)	65	140

[a]Cummings, 1980
[b]This investigation
[c]Based on 283 analyses (MDPH and USGS)
[d]Based on 263 analyses (MDPH and USGS)
[e]Based on 261 analyses (MDPH and USGS)
[f]Based on 493 analyses (MDPH and USGS)

Other high metal concentrations include aluminum in water from well 5 (5,000 μg/L), well 9 (5,000 μg/L), and well 11 (8,000 μg/L). A lead concentration greater than 50 μg/L occurred in water from well 5 (92 μg/L), well 6 (180 μg/L), well 7 (70 μg/L) and well 26 (53 μg/L). Total recoverable iron exceeding 3,000 μg/L was found in water from wells 6, 9, 11, and 19. Dissolved-iron concentrations exceeding 300 μg/L were found in water from 13 wells; dissolved manganese concentrations greater than 50 μg/L were found in water from 12 wells. Cyanide was detected in water from nine wells; the maximum concentration (0.06 mg/L) was found in water from well 5.

Compared to the U.S. Environmental Protection Agency standards (table 24), water from wells 5, 6, 7, and 26 had one or more substances that exceeded maximum contaminant levels for inorganic chemicals.

Water from wells 4, 7, 8S, 8D, 13, 17, 20, 22, 23, and 29 was analyzed in October 1981 for polychlorinated biphenyls (PCB), polychlorinated napthalenes (PCN), and 36 pesticides. Analyses were made for the same compounds determined in previously cited surface-water work, with the exception of Silvex, 2,4-D, 2,4,5-T, and 2,4-DP. None of the compounds were detected in ground water.

Nitrate in ground water.--Table 37 gives maximum, median, and minimum

Table 37.--Maximum, median, and minimum concentrations of nitrate in ground water, by township

Township	Nitrate concentration (mg/L as N)		
	Maximum	Median	Minimum
Almena	4.3	0.015	0.00
Antwerp	18	1.6	.00
Arlington	5.0	.00	.00
Bangor	19	.10	.00
Bloomingdale	11	.050	.00
Columbia	8.1	.010	.00
Covert	4.8	.050	.00
Decatur	16	1.4	.00
Geneva	15	.065	.00
Hamilton	31	5.2	.00
Hartford	22	1.7	.00
Keeler	34	5.8	.00
Lawrence	12	1.5	.00
Paw Paw	24	2.0	.00
Pine Grove	14	1.5	.00
Porter	22	3.0	.00
South Haven	21	.085	.00
Waverly	7.7	.10	.00

concentrations of nitrate in ground water in each township. A total of 493 analyses, made by the U.S. Geological Survey, the Michigan Department of Public Health, and the Van Buren County Health Department, have been used in assessing conditions. Because data indicated that nitrate concentrations in the southern part of the county were higher than in the northern part (see fig. 18),

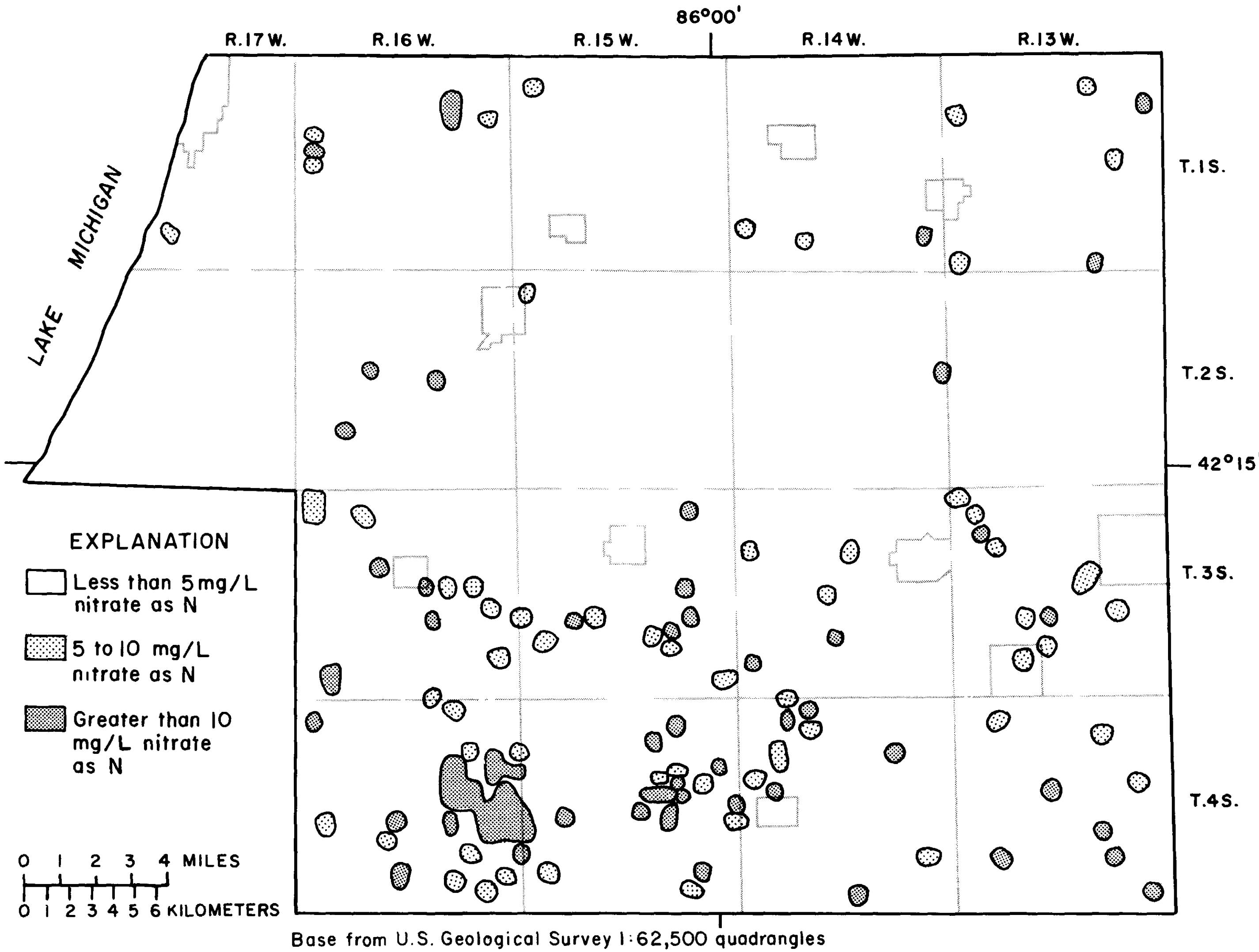

Figure 18.--Generalized areal distribution of nitrate in ground water.

frequency distributions of concentration were made by grouping the 8 southern townships and the 10 northern townships separately. Figure 19 shows these frequency distributions. In the northern townships 50 percent of the nitrate concentrations equal or exceed about 0.05 mg/L, and 5 percent exceed 10 mg/L. In the southern townships 50 percent equal or exceed 2.5 mg/L, and 5 percent equal or exceed 20 mg/L. Judged by the U.S. Environmental Protection Agency's drinking-water standard of 10 mg/L, water from about 22 percent of the wells sampled in the southern part of the county equaled or exceeded permissable limits, whereas in the northern part only about 5 percent did so.

A least-square regression of well depth versus nitrate concentration indicates that shallow ground water tends to have the highest nitrate concentration, which suggests that surface or near-surface sources are the cause. For example, a well yielding water from a depth of 40 feet is likely to have a nitrate concentration about twice as great as one yielding water from a depth of 90 feet.

Surface or near-surface nitrogen inputs in the area are largely fertilizers, animal wastes, septic tanks, and precipitation. Based on the mean values previously cited, total nitrogen input from these sources is about 13.9 (tons/mi^2)/yr in the county. The following table shows the percentage composition of the nitrogen input.

Table 38.--Percentage composition of nitrogen input

Source	Nitrogen input (tons/mi^2)/yr	Nitrogen input Percent
Precipitation and dry fallout	2.96	21.3
Septic tanks	.21	1.5
Animal wastes	.63	4.5
Fertilizers	10.1	72.7

From the above discussion it is reasonable to assume that if nitrogen inputs affect the quality of ground water, fertilizers are the principal source. Septic-tank discharges, although they may contaminate shallow ground-water supplies in some parts of the county, are a contributing, but not a major, factor countywide. No specific instances of contamination by septic tanks were identified in this study, nor does it seem likely that septic-tank discharges could account for the significant difference in mean nitrate concentrations between the northern and southern townships. Nitrogen deposited by a large number of animals in a confined situation probably increased nitrate concentrations of ground water locally, but it is not a major factor in differences observed among townships. A plot of median nitrate concentrations in ground water in each township against total nitrogen deposition by animals showed no discernable relationship.

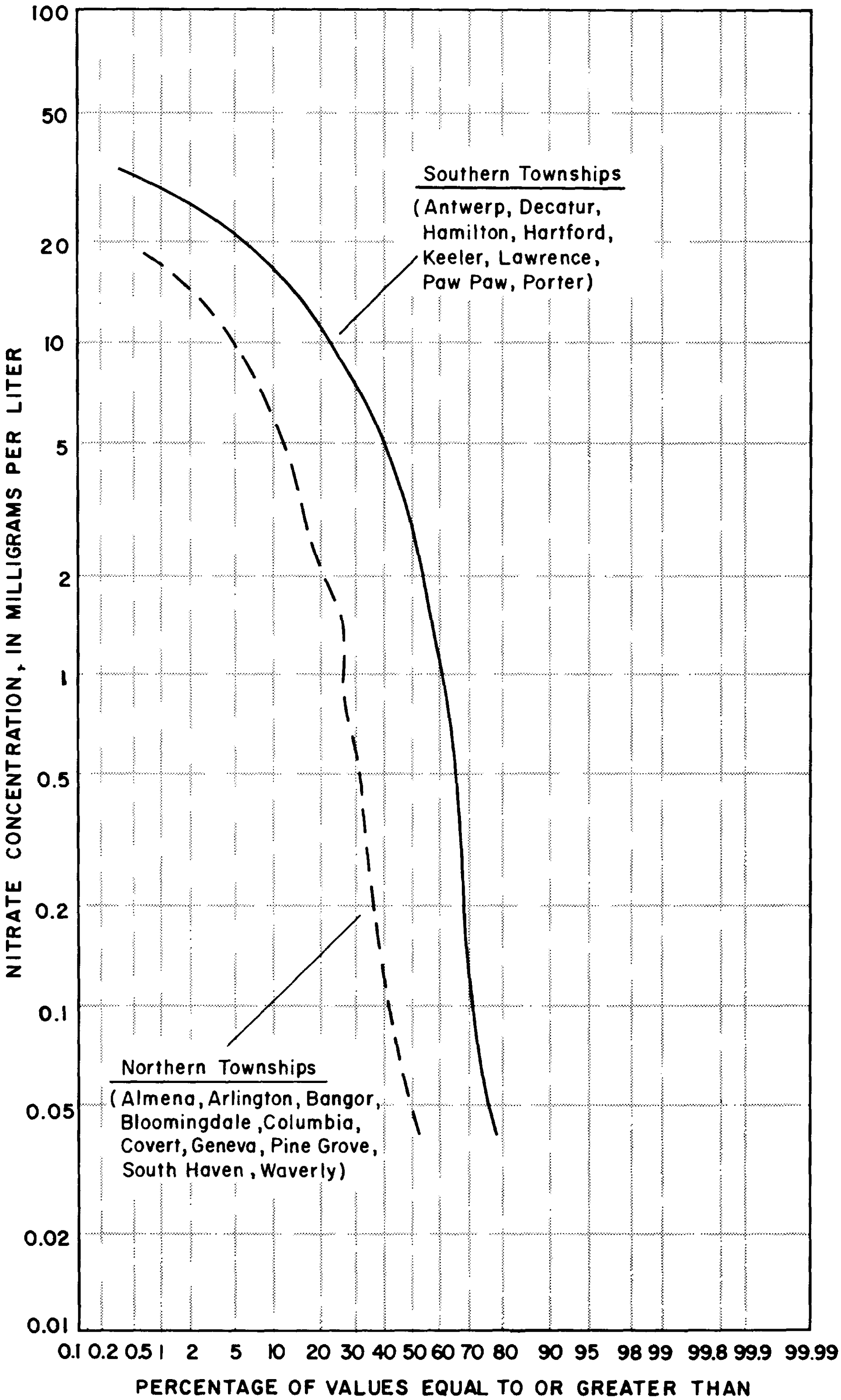

Figure 19.--Frequency distribution of nitrate in ground water.

Figure 20 shows the relation between the median nitrate concentration of ground water and the amount of nitrogen in fertilizer applied in each township (table 39).

Table 39.--Nitrogen input and irrigated acreage

Township	[a]Nitrogen as N [(tons/mi^2)/yr]	[b]Nitrogen as N [(tons/mi^2)/yr]	Number of irrigated acres
Almena	8.0	11.5	1,000
Antwerp	9.7	13.9	749
Arlington	11.7	15.2	784
Bangor	11.1	16.2	785
Bloomingdale	9.2	13.5	300
Columbia	8.5	11.7	160
Covert	5.7	8.9	972
Decatur	11.0	14.1	1,935
Geneva	10.1	13.9	510
Hamilton	12.4	15.8	5,912
Hartford	11.5	14.8	1,928
Keeler	12.1	17.2	8,443
Lawrence	11.3	15.6	1,379
Paw Paw	11.6	15.0	1,587
Pine Grove	8.3	14.1	2,380
Porter	11.8	15.5	368
South Haven	6.1	9.8	345
Waverly	10.5	13.8	0

[a]Fertilizer only
[b]Fertilizer, animal wastes, septic tank discharges, and precipitation and dry fallout

An increase in nitrate concentration is evident, but there seems to be a range of fertilizer application rates that are unrelated to nitrate concentrations. A relation of number of acres irrigated to median nitrate concentrations in ground water is shown in figure 21. At median nitrate concentrations 0.10 mg/L or less, the average irrigated acreage is 509. At median nitrate concentration 1.0 mg/L or greater, the average irrigated acreage is 2,742. Although data suggest that nitrate concentrations are related to fertilizer applications, the number of acres irrigated, and thus the amount of water applied, may be equally important in increasing nitrate in ground water.

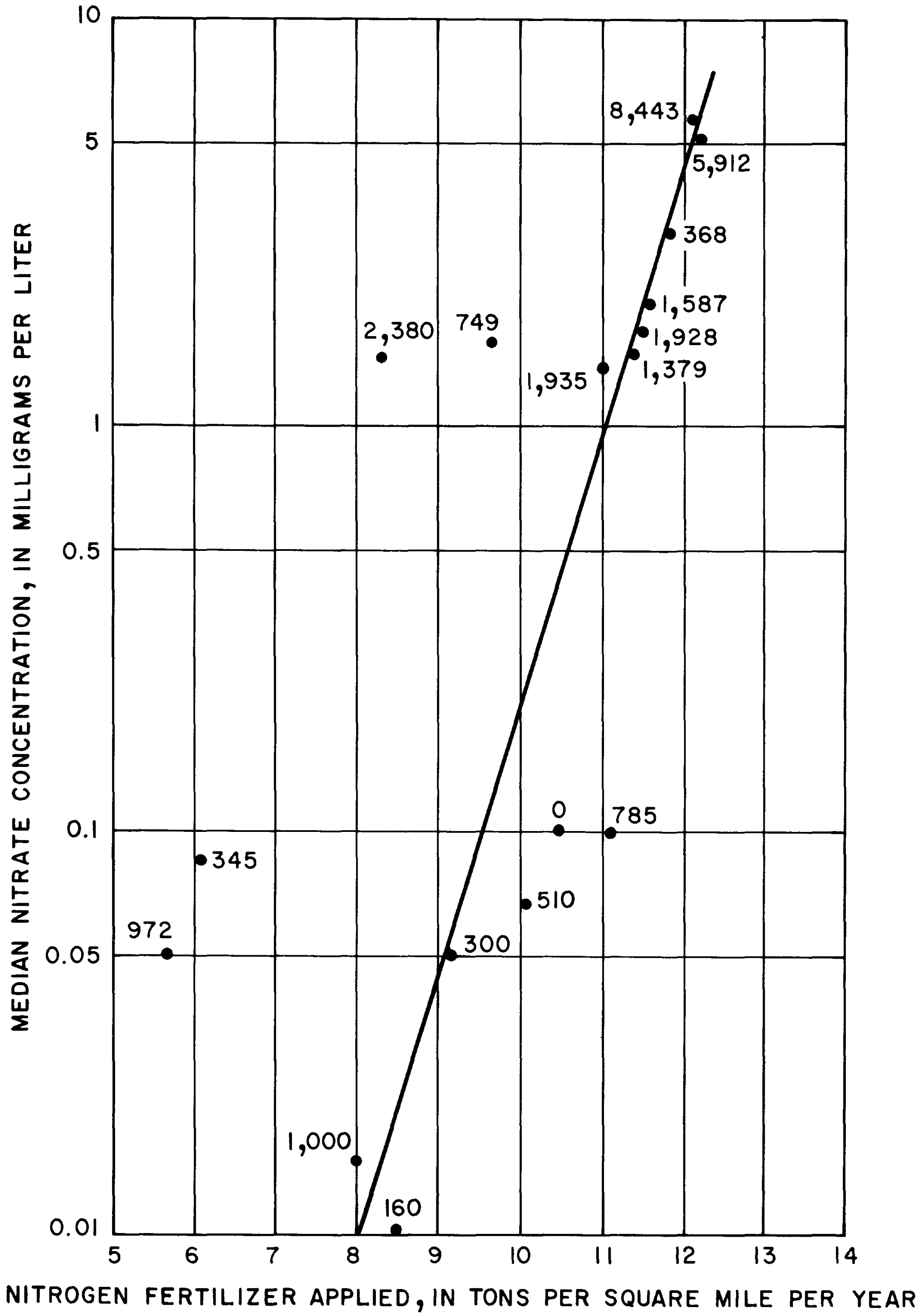

Figure 20.--Relation of nitrate concentration in ground water to amount of fertilizer applied in each township (numbers adjacent to each plotted point represent the number of irrigated acres in a township).

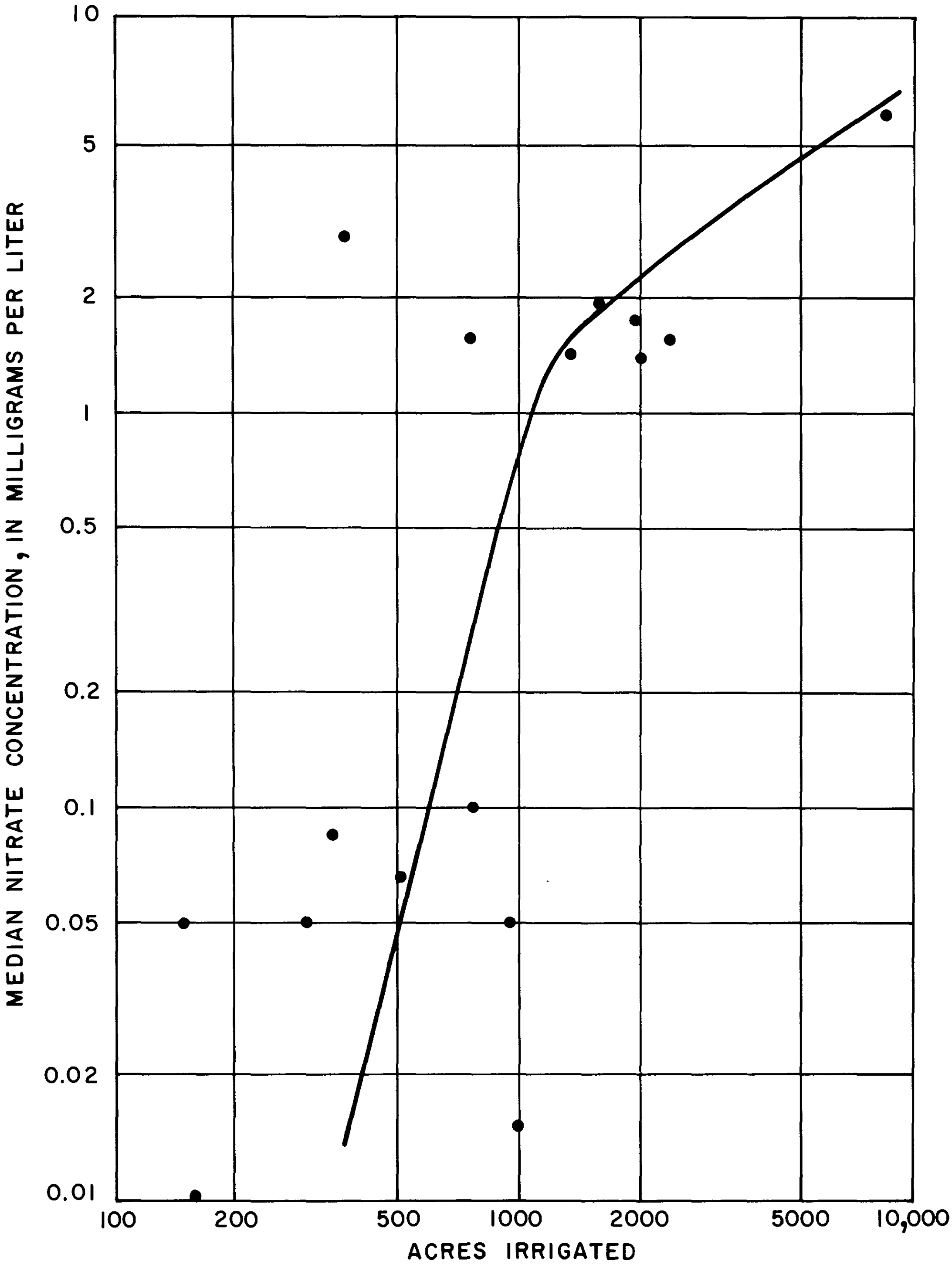

Figure 21.--Relation of nitrate concentration of ground water to number of acres irrigated in each township.

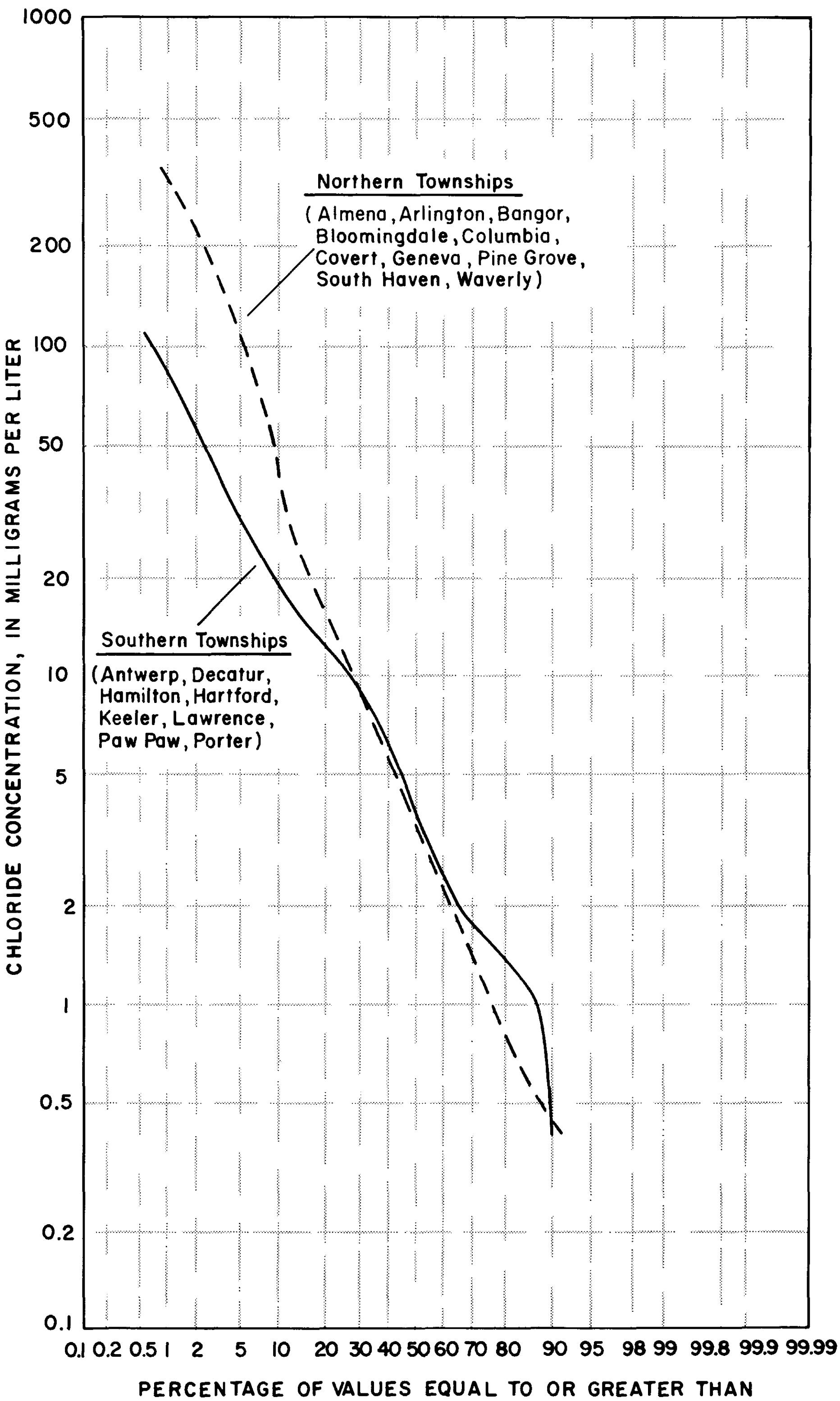

Figure 23.--Frequency distribution of chloride in ground water.

The model included an area of 840 mi^2, 630 mi^2 of which is in Van Buren County and 210 mi^2 of which was in parts of Allegan, Kalamazoo, Cass, and Berrien Counties. The aquifer-stream system was represented in the model by a grid consisting of 85 rows and 104 columns that divided the area into cells 2,000 ft on a side (fig. 24). Boundaries of the model area were described as no-flow cells and constant-head cells. No-flow cells were located at ground-water divides that were assumed to coincide with surface-water divides. Constant-head cells were located on major lakes and rivers where the water-surface elevation could be readily determined and little variation of head was expected, as along the shore of Lake Michigan. Leaky layer cells were used to simulate bed materials that separated water in smaller streams and lakes from the aquifer. No-flow and constant-head cells were located outside the county, where possible, to minimize errors at the Van Buren County boundary.

The model was calibrated by comparing model-simulated data with water-level and streamflow data. Water-level data, measured during the study at the observation wells (fig. 26), were averaged to estimate steady-state heads in the nodes containing the wells. The 55-percent point of flow duration was estimated for sites having four or more base-flow discharge measurements. Hydraulic-conductivity values for glacial deposits and the transmissivity value for the streambed materials were varied so that simulations would match both head and flow data. For the calibrated model, the mean and standard deviations of differences between observed and simulated heads in 29 wells was 2 ft and 17 ft, respectively. The mean and standard deviation of the percent differences between flow estimated on the basis of discharge measurements, and that based on simulations at 18 sites, was 6 and 16 percent, respectively.

Estimation of Recharge

Recharge to the aquifer was determined assuming that no long-term change in ground-water storage occurs. This assumption seemed valid because ground-water levels show no significant long-term or regional trends. Therefore, recharge was considered to equal ground-water discharge to streams. To determine ground-water discharge, base-flow separations of discharge hydrographs were made for the Paw Paw and Black River, and a ratio between ground-water discharge and total discharge was computed (table 40). This ratio was then applied to long-term discharge. For Paw Paw River at site 25, a ratio of 0.81 was applied to the 30-year average discharge of 15.29 in/yr (U.S. Geological Survey, 1982); a ground-water discharge of 12.4 in/yr (357 ft^3/s) was estimated. For Black River at site 33, a ratio of 0.63 was applied to the 15-year average discharge of 17.06 in/yr; a ground-water discharge of 10.7 in/yr (65.7 ft^3/s) was estimated. Past records indicate that a discharge of 357 ft^3/s for Paw Paw River at Site 25 corresponds to an annual flow duration (amount of time that flow in the average year is equaled or exceeded) of 55 percent. A discharge of 65.7 ft^3/s for Black River at site 33 corresponds to an annual flow duration of 54 percent (fig. 25).

Chloride in ground water.--Chloride concentrations in ground water ranged from 0 to 870 mg/L.[1] Higher concentrations are probably related to oil-field activity. Figure 22, adapted from the Michigan Department of Natural Resources (1982), shows the location and extent of oil fields in Van Buren County. Most are located in the northern part of the county. Brines, which contain high chloride concentrations, frequently are brought to the surface and find their way to streams and shallow ground-water systems. Even small amounts may significantly modify the chemical characteristics of water.

Frequency distributions (fig. 23) of chloride concentrations suggest a relation to oil-field activity. For example, 10 percent of the chloride concentrations in ground water in the southern townships are equal to or greater than 19 mg/L; in the northern townships 10 percent are equal to or greater than 40 mg/L. Median chloride concentrations in both the northern and southern townships are about 4 mg/L; in Bloomingdale and Geneva Townships, however, median concentrations are 31 and 29 mg/L, respectively.

SIMULATIONS OF THE GROUND-WATER SYSTEM

Digital-Model Development

A ground-water model was developed to aid in defining the potentiometric surface and hydraulic conductivity of the glacial deposits, and to use for predicting the effect of increased withdrawals on water levels. A finite-difference model was used to solve partial differential equations describing ground-water flow (McDonald and Harbaugh, 1984). Steady-state and transient simulations were made. Assumptions were as follows:

(1) The numerical value of an aquifer property was applicable from the water table to bedrock.

(2) Ground-water flow is horizontal.

(3) Water levels in streams are constant.

(4) Most ground water is discharged from the area by flow to streams and by pumping.

(5) All pumping wells fully penetrate the aquifer and are 100 percent efficient.

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[1]Range is based on 493 analyses made by the U.S. Geological Survey, the Michigan Department of Public Health, and the Van Buren County Health Department. All data have been used in assessing conditions; only analyses by the U.S. Geological Survey have been tabulated in the report.

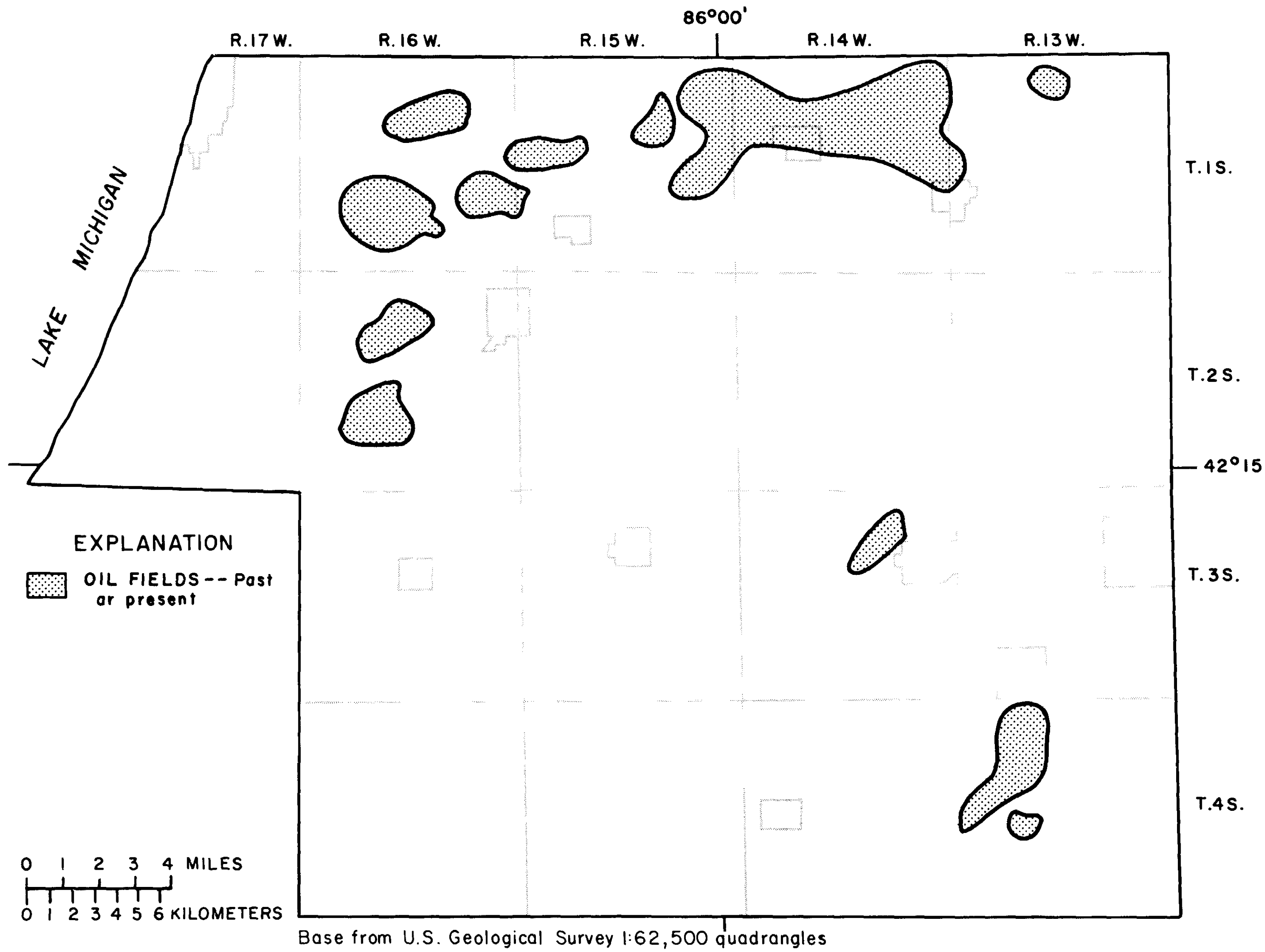

Figure 22.--Generalized distribution of oil fields (Data from Michigan Department of Natural Resources, 1982).

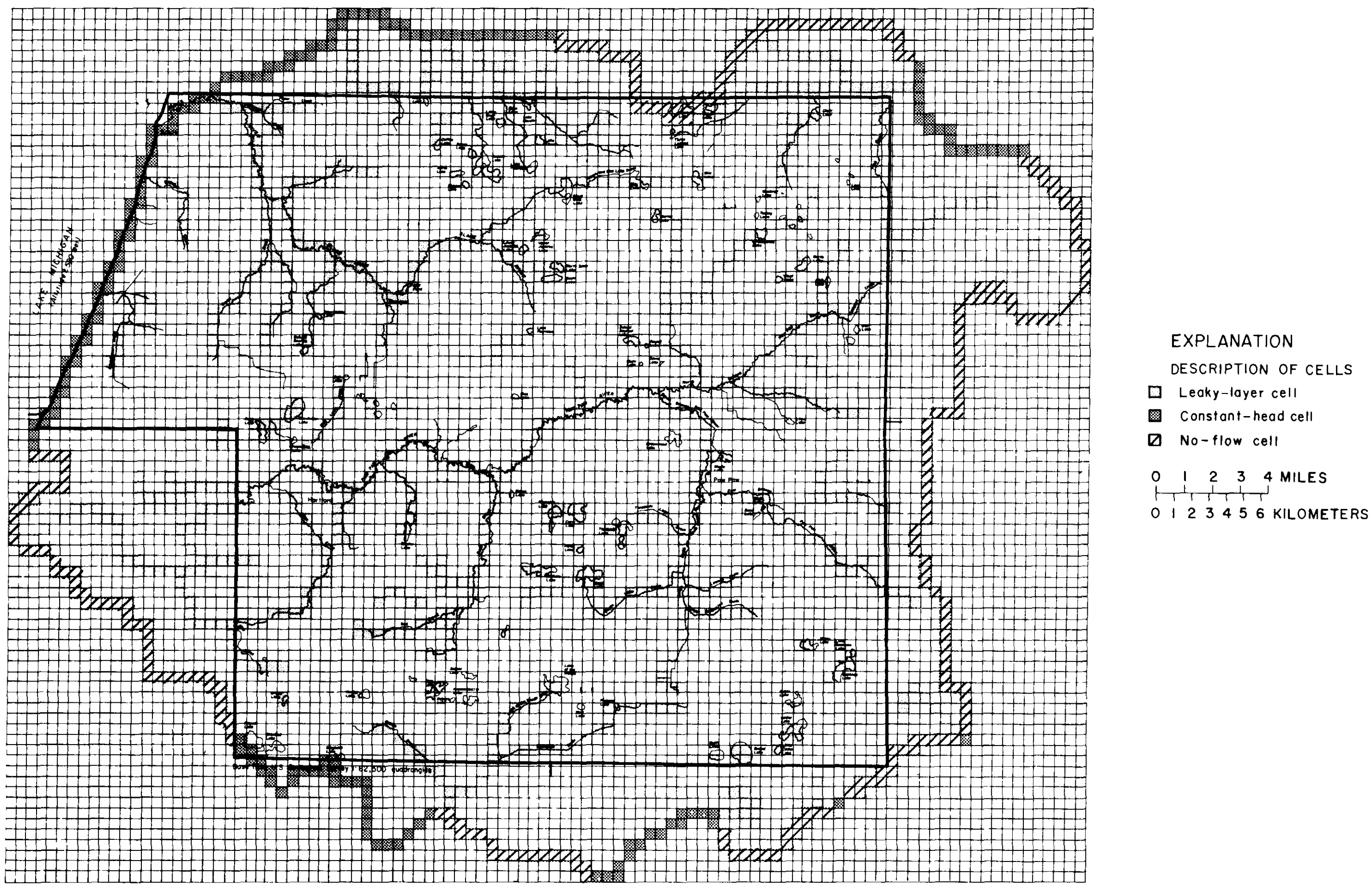

Figure 24.--Grid spacing and characteristics of cells used in ground-water flow model.

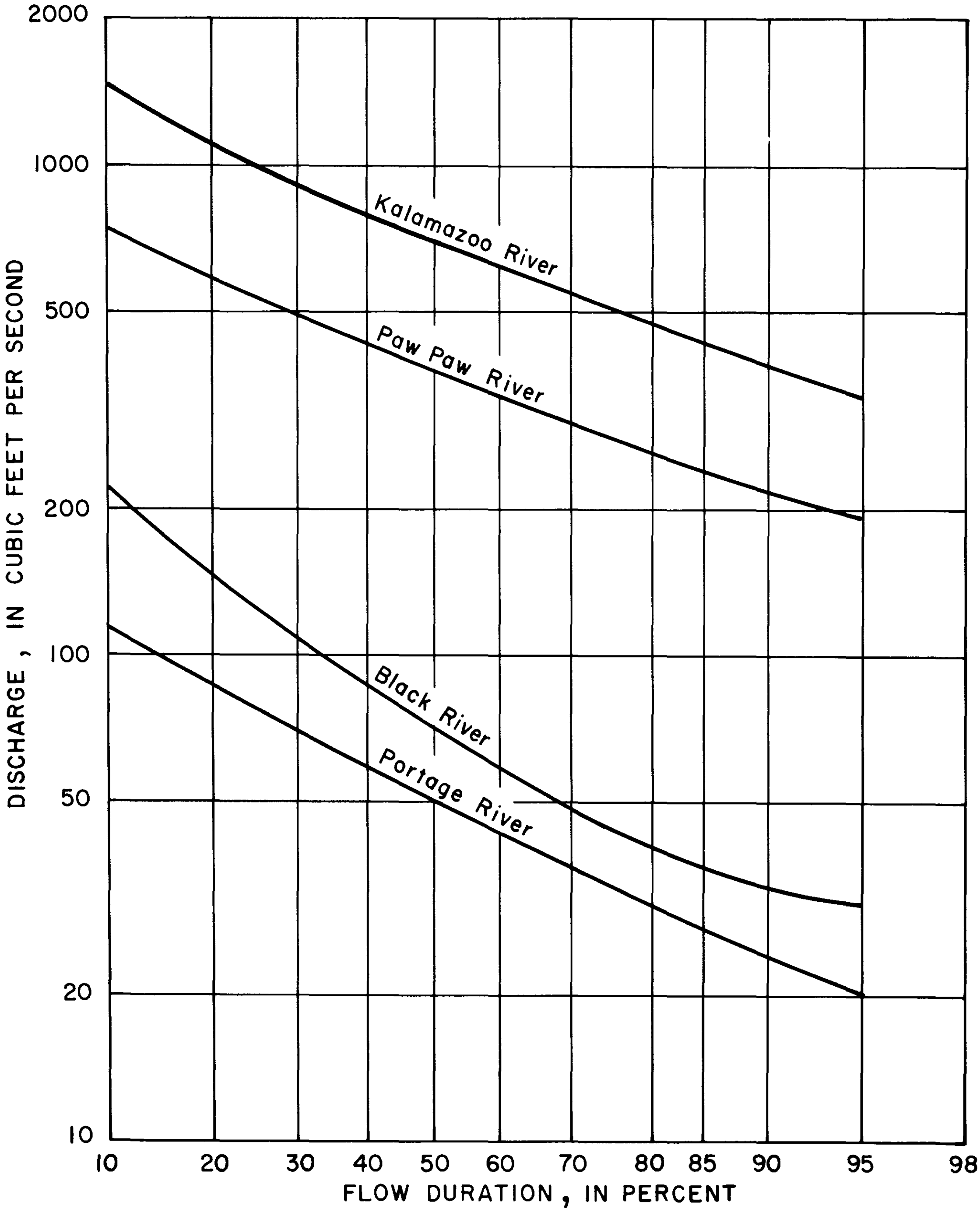

Figure 25.--Annual flow duration for the Paw Paw, Black, Kalamazoo, and Portage Rivers.

Table 40.--Ratio of base-flow discharge to total discharge for the Paw Paw and Black Rivers[1]

Year	Site 23. Paw Paw River near Hartford			Site 33. Black River near Bangor		
	Total discharge (in/yr)	Base-flow discharge (in/yr)	Ratio base flow to total discharge	Total discharge (in/yr)	Base-flow discharge (in/yr)	Ratio base flow to total discharge
1981	17.90	14.37	0.80	16.21	9.81	0.61
1980	19.46	15.93	0.82	19.80	11.38	0.57
1979	19.66	16.46	0.84	19.08	13.44	0.70
1978	15.78	12.19	0.77	20.95	12.13	0.58
1977	13.85	11.27	0.81	11.82	7.73	0.65
1976	19.02	14.84	0.78	18.87	10.81	0.57
1975	19.15	15.86	0.83	20.27	11.73	0.58
1974	19.46	16.00	0.82	18.60	11.87	0.64
1973	19.48	15.63	0.80	18.64	11.52	0.62
1972	15.35	12.94	0.84	14.41	10.04	0.71
1971	14.94	12.50	0.84	12.47	8.33	0.67
Mean	17.64	14.36	0.81	17.37	10.80	0.63
Standard deviation	2.21	1.83	0.02	3.17	1.69	0.05

[1]Site locations are shown on plate 1.

The annual recharge rate in adjacent Kalamazoo County has been estimated to average 9 inches (Allen and others, 1972). This rate corresponds to an annual flow duration of 53 percent of Kalamazoo River near Comstock (USGS station number 04106000 in Kalamazoo County) and 56 percent for Portage River near Vicksburg (USGS station number 04097170 in Kalamazoo County).

On the basis of the above analyses, streamflow at the 55 percent point of annual flow duration was used to estimate ground-water recharge in Van Buren County. Flow-duration estimates for 37 sites were based on correlation of discharge measurements at each site with average daily discharge on Paw Paw River at site 25 and Black River at site 33. Areal distribution of recharge rates was related to the lithologic characteristics of the glacial materials shown in figure 5. Percentages of the area overlain by till, outwash, and lacustrine and eolian deposits were determined for each streamflow drainage site. Multiple-linear regression analysis was used to estimate recharge rates for each type of deposit; the percentages of area covered by each type were used as the independent variables, and the 55-percent flow duration was used as the dependent variable. Results of the analysis are as follows:

Table 41.--Recharge rates of glacial materials

Type of deposit	Recharge rate (in/yr)
Till, ground moraine	6.3
Till, end moraine	10.2
Outwash	14.2
Lacustrine and eolian deposits	17.3

On the basis of this analysis, the weighted average annual recharge rate for glacial deposits in the county is 11.8 in/yr.

Estimation of Hydraulic Conductivity and Transmissivity

In developing the model, the hydraulic conductivity of cells representing glacial deposits and transmissivity of cells representing streambed materials were adjusted until simulated ground-water levels and streamflow matched measured water levels and the 55-percent point of flow duration. Based on the simulations, hydraulic-conductivity values were assigned to areas as shown on figure 26. Streambed materials were assigned a transmissivity of 0.2500 ft^2/s.

Estimation of Storage Coefficients

Values of storage coefficients[1] were determined using transient simulations. The analysis assumed that change in heads in streams during recession periods would not significantly affect flow to streams, and that ground-water recession curves could be estimated from surface-water records.

Storage coefficients were determined from recession curves derived from streamflow records at sites 25 and 33, using a procedure outlined by Riggs (1963). The curves were then compared to those derived from model simulations (fig. 27). Because of differences among the shapes of the recession curves at the two sites, two values for storage coefficient were determined. A value of 0.1 was used for aquifers considered to be unconfined (areas overlain by outwash, and lacustrine and eolian deposits), and a value of 0.002 was used for partially confined aquifers (areas overlain by till).

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[1]Considered equal to specific yield in an unconfined aquifer.

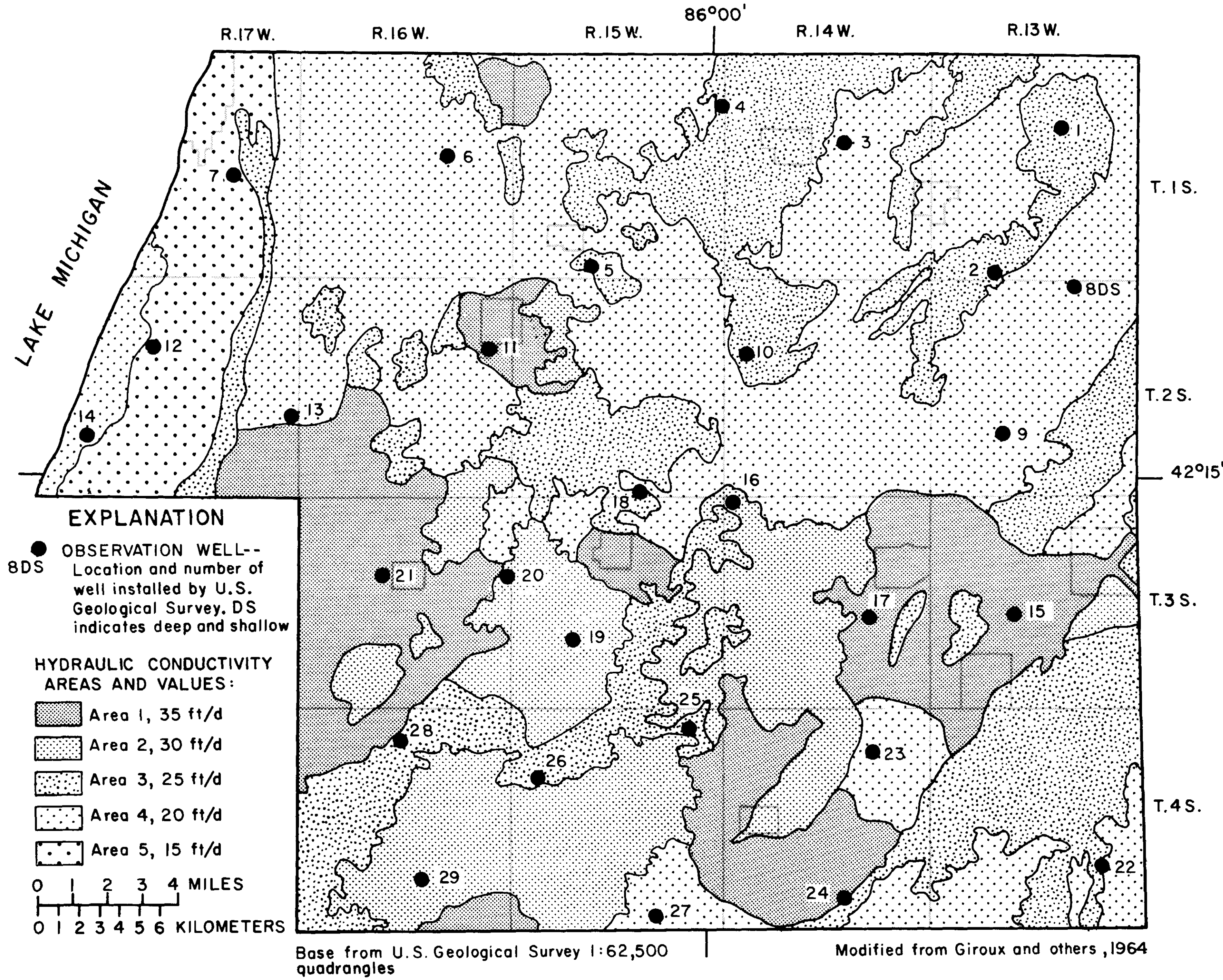

Figure 26.--Hydraulic conductivity of glacial deposits.

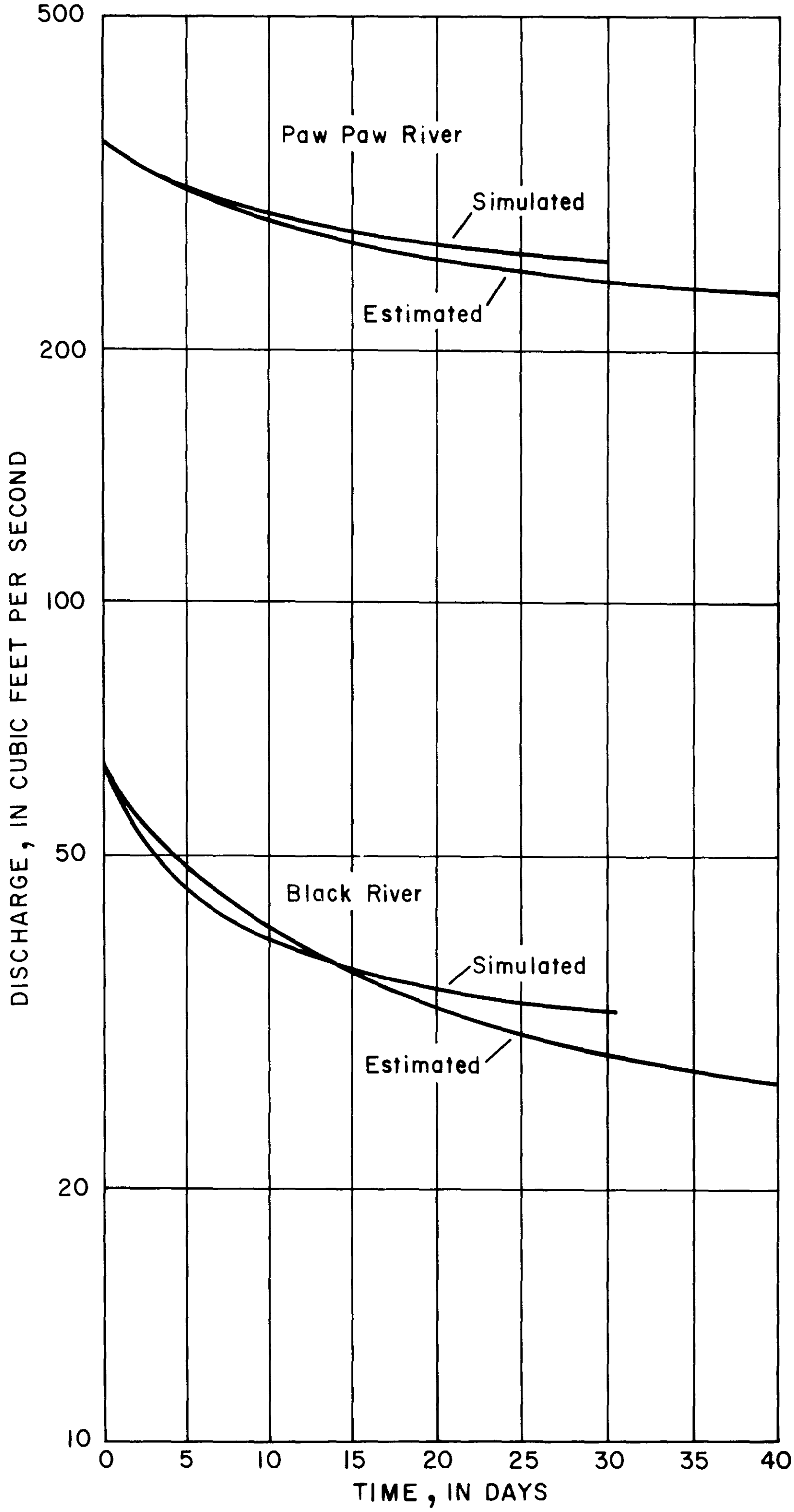

Figure 27.--Comparison of recession curves estimated from streamflow data to simulated curves.

Effects of Pumping

The effect on water levels of withdrawing various amounts of water from the ground-water system was investigated. The impact of withdrawing large amounts from a single well or from closely spaced wells, such as for irrigation, was determined by model simulation.

Domestic Withdrawals

Water use in residential areas averages no more than 90 gallons per day (gal/d) per person. For a household of five, this is 450 gal/d or 0.3 gal/min. In a 1-mi^2 residential area having a population of 10,000, total use would be about 600 gal/min. If this quantity of water were pumped from wells spread among individual households throughout the 1-mi^2 area, there would be a negligible effect on water levels.

Irrigation Withdrawals

Withdrawals of large amounts of water for irrigation were simulated to evaluate the effect on the ground-water system. Five hundred gal/min was assumed to be withdrawn for a 8-week period during which there was no recharge[1] to the aquifer. Simulations of the response of a confined aquifer and unconfined aquifer were made.

In a simulation for an unconfined aquifer, a single well was pumped at a site in the northwest part of Decatur Township. A hydraulic conductivity of 35 ft/d, typical of this area, and a storage coefficient (specific yield) of 0.1, were used. The simulation indicates that the effect of pumping would be to lower water levels less than 0.5 ft at a distance of 1 mi (fig. 28). Within a 1,000-ft radius of the well, however, drawdown would be 2 to 3 ft.

The change in water levels in a partially confined aquifer, such as found in an area of till, were simulated by locating a well pumping 500 gal/min in the southeast part of Geneva Township. A hydraulic conductivity of 20 ft/d, typical of this area, and a storage coefficient of 0.001 were used. In this simulation, the cone of depression was considerably larger than that developed by pumping from the unconfined aquifer. Water levels were lowered about 3 ft at a distance of 1 mi from the pumped well and 10 ft at a distance of 1,000 ft (fig. 29). The difference in cones of depression resulting from pumping from unconfined and confined aquifers is shown in figure 30.

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[1]Lack of recharge causes a lowering of water levels. Results of simulations in this section, however, are corrected to indicate only changes in water levels caused by pumping.

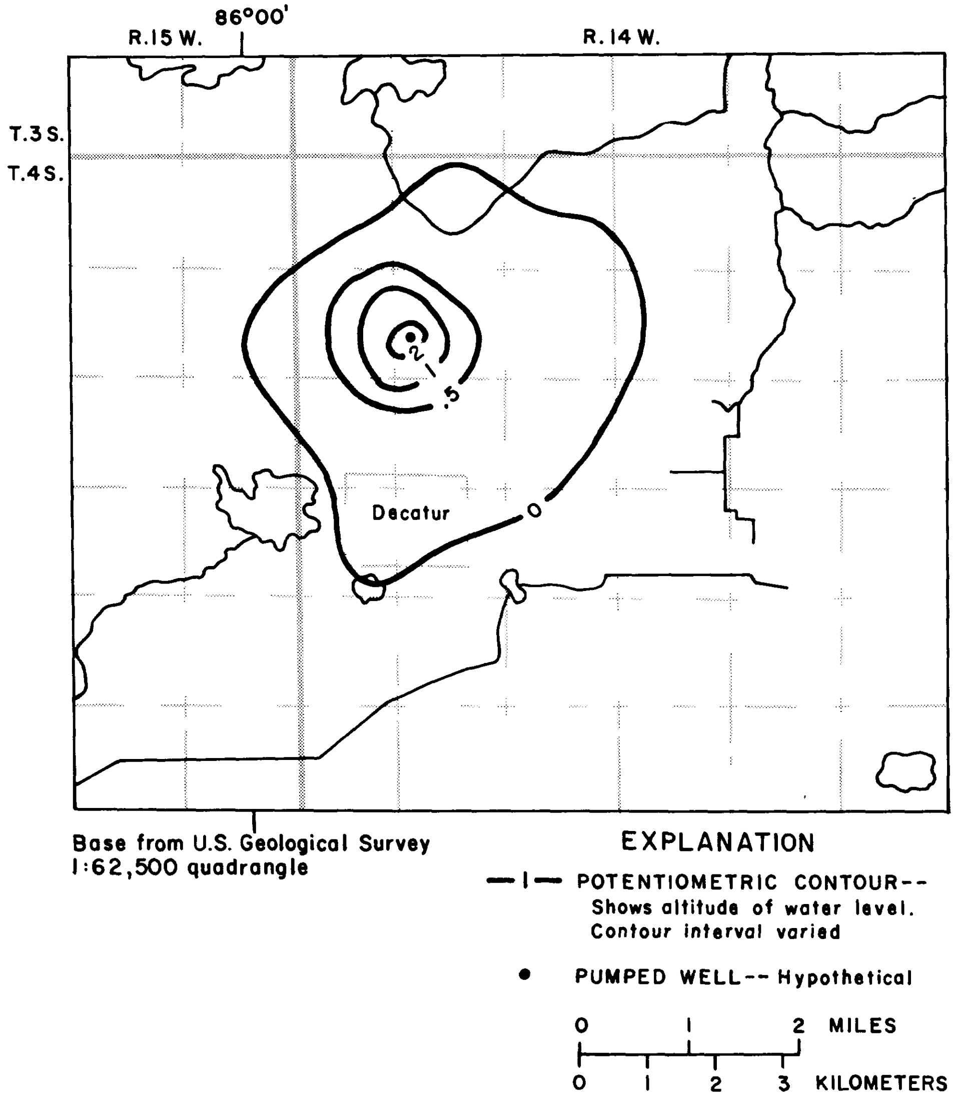

Figure 28.--Areal extent of cone of depression produced by pumping 500 gal/min from unconfined aquifer in Decatur Township.

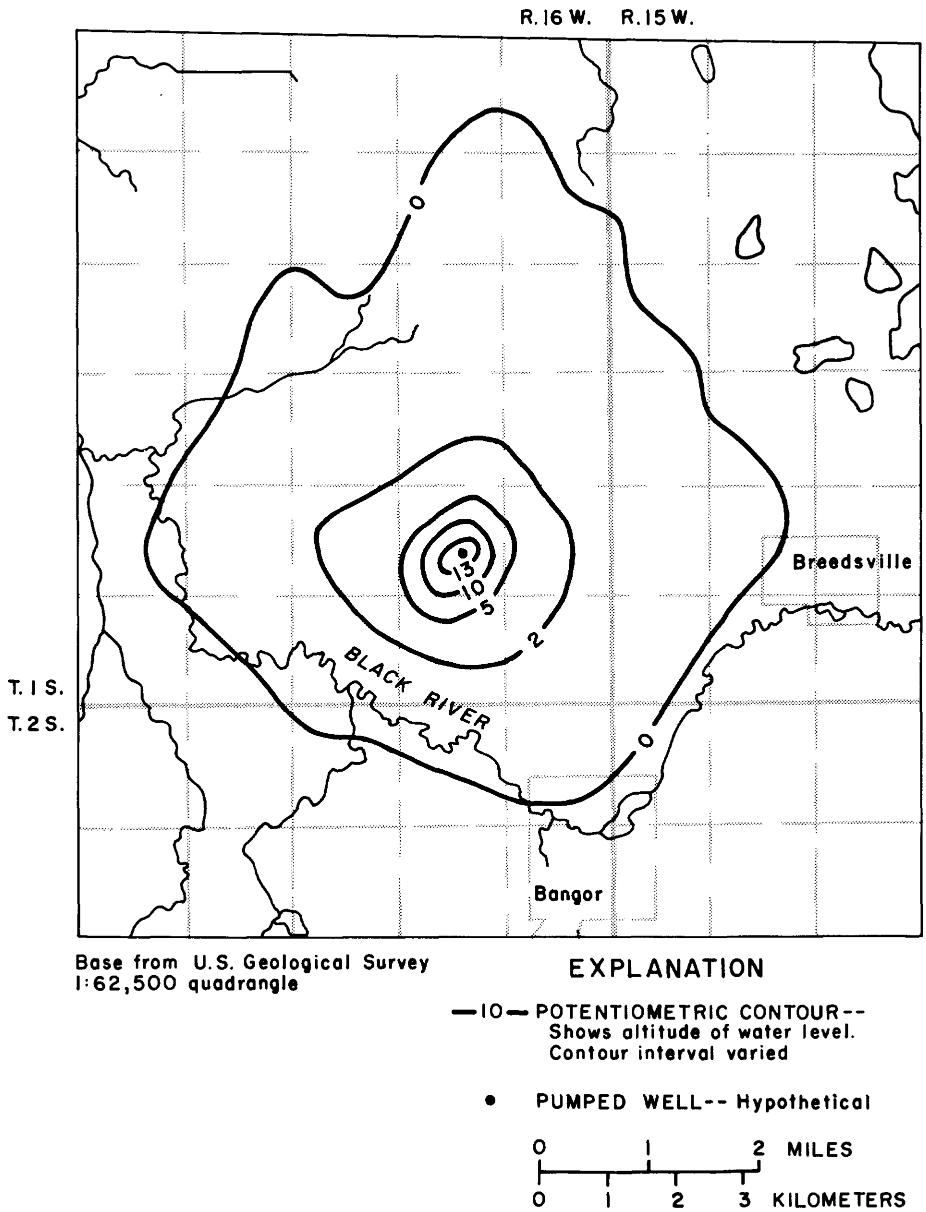

Figure 29.--Areal extent of cone of depression produced by pumping 500 gal/min from confined aquifer in Geneva Township.

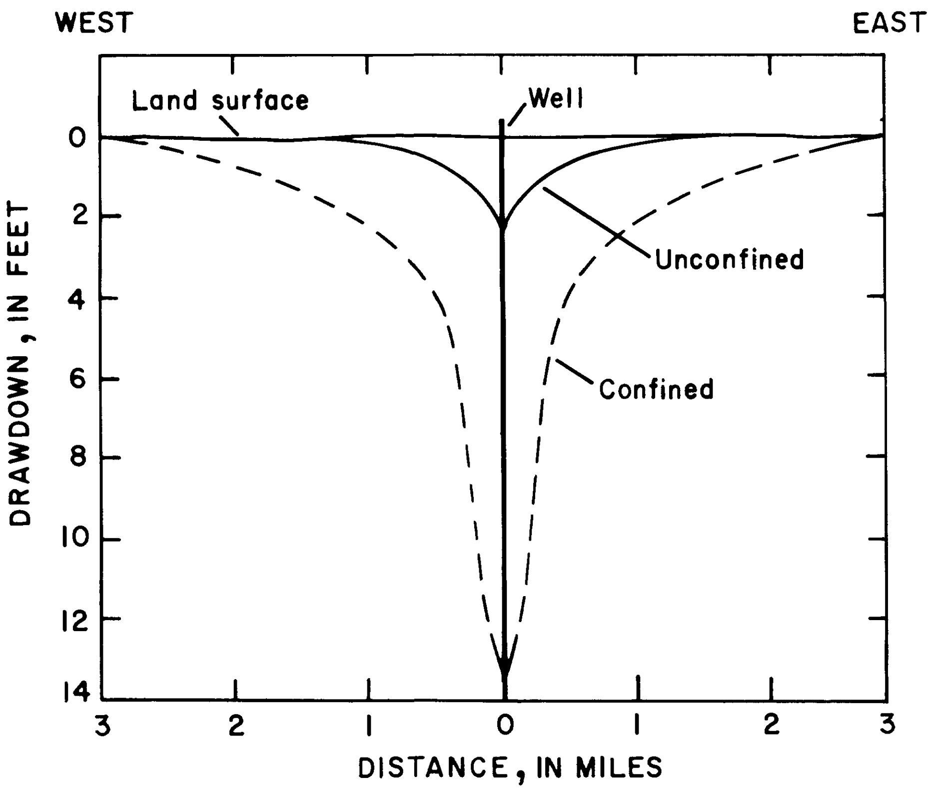

Figure 30.--Cones of depression resulting from pumping 500 gal/min from confined and unconfined aquifers.

The effects of increased ground-water withdrawals on the potentiometric surface were investigated by simulating additional pumping in the irrigated area on figure 31. This area presently has about 17 mi^2 of irrigated land--10 mi^2 in Keeler Township and 7 mi^2 in Hamilton Township. Not all of the area is irrigated by ground water; however, for the purposes of the simulation, it has been assumed that during a period of drought it could be. The simulation was made with the amount of irrigated land being increased by 100 percent to 34 mi^2. Each irrigation well shown on figure 32 was pumped at a simulated rate of 400 gals/min--a quantity based on past irrigation practices. Pumping was simulated as being continuous over a 4-week period. Values used for hydraulic conductivity were as shown on figure 26; values for the storage coefficient were as indicated by geologic units on figure 5. This simulation indicates that water levels would be lowered over most of the irrigated area by about 5 ft, and in the northeastern part of Keeler Township, by 30 ft.

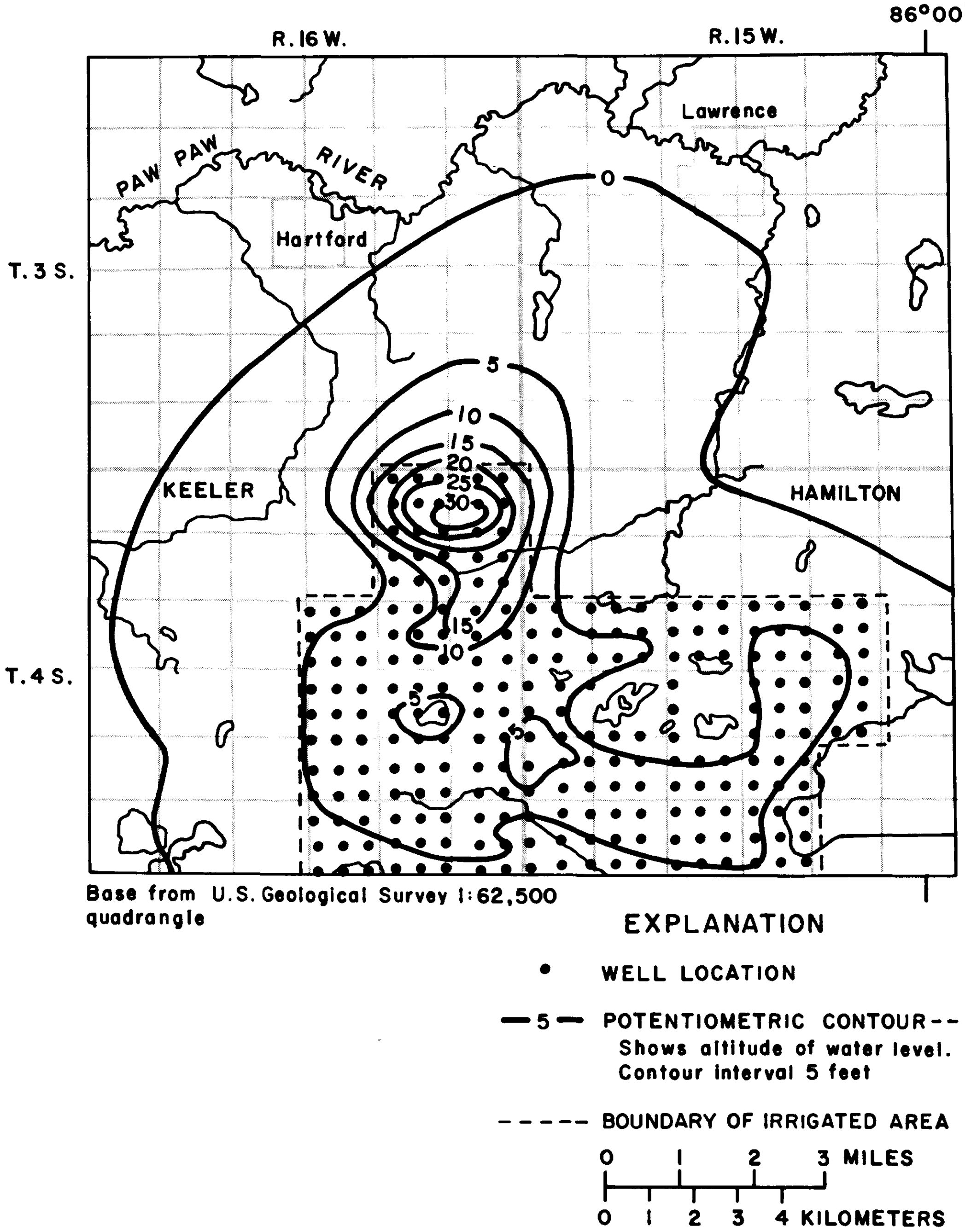

Figure 31.--Effect of increases in ground-water pumping for irrigation on water table in Hamilton and Keeler Townships.

SUMMARY

Nearly 67,000 people lived in Van Buren County in 1980. Of these, about 60,000 used ground water for domestic water supplies. About 30,000 acres of land were irrigated with water from both ground-water and surface-water sources.

The principal surficial rock units in the county are alluvium and glacial deposits; these are underlain by the Coldwater Shale of Mississippian age. Glacial deposits, 100 to 600 ft thick, are the principal source of ground-water supplies. Of the glacial deposits, outwash is the most productive aquifer. Most domestic wells obtain adequate supplies of water from outwash at depths ranging from 15 to 160 ft. Irrigation wells capable of yielding 1,000 gal/min generally are about 200 ft deep. Some glacial deposits in the western part of the county are mostly clay and yield little or no water. The Coldwater Shale is a poor source of ground water, usually yielding only small amounts of water that is commonly salty.

The Paw Paw and South Branch Black Rivers drain most of the county. The maximum discharge of the Paw Paw during this study was 2,500 ft^3/s; the minimum was 202 ft^3/s. The average discharge of the South Branch Black River for the 17-year period of record is 106 ft^3/s.

Areal differences in the chemical and physical characteristics of ground and surface water were determined and related to land use. Information on fertilizer applications, animal wastes, septic-tank discharges and precipitation were assembled and analyzed. Data indicate that application of nitrogen in fertilizer in 38 drainage areas ranged from 2.9 to 15.7 $(tons/mi^2)/yr$; the range was 5.7 to 12.4 $(tons/mi^2)/yr$ for the various townships. Eight southern townships receive an average of about 25 percent more fertilizer than do the northern ten townships. Nitrogen deposited in animal wastes in each township ranges from insignificant amounts in three townships to as much as 2.57 $(tons/mi^2)/yr$ in one township. Mean deposition of nitrogen by animals, countywide, is 0.63 $(tons/mi^2)/yr$. Nitrogen discharged to the subsurface environment by septic tanks in each township ranges from 0.11 to 0.48 $(tons/mi^2)/yr$; the mean value for the county is 0.21 $(tons/mi^2)/yr$. Precipitation and dry fallout contribute 2.96 $(tons/mi^2)/yr$ of nitrogen. Based on mean values, the percentage of total nitrogen input from these four major sources is 21.3 percent from precipitation and dry fallout, 1.5 percent from septic tanks, 4.5 percent from animal wastes, and 72.7 percent from fertilizers.

Specific-conductance measurements indicate that the dissolved-solids concentration of water of streams ranged from 56 to 749 mg/L. Mean percent saturation of dissolved oxygen at each site ranged from 74 at Black River near Bangor to 104 at South Branch Paw Paw River near Paw Paw. Lowest values of dissolved oxygen generally were found at Black River sites. Values of pH ranged from 6.5 at Brandywine Creek near South Haven to 8.9 at Haven and Max Lake Drain near Bloomingdale. Water at most sites is of a calcium bicarbonate type, although sulfate was the dominant anion at two sites. At about 40 percent of the sites water may be classed as very hard. Total nitrogen concentration ranged from 0.44 mg/L to 15 mg/L.

Trace metal concentrations were low in water of streams; pesticides were detected at some locations. Mean suspended-sediment concentrations ranged from 3.3 to 42.2 mg/L. The maximum, 552 mg/L, were found at Black River Drain northeast of Bangor.

Few relationships between water quality of streams and the yield of dissolved and suspended substances are evident. Plots of total nitrogen, total phosphorus, and total nitrate suggest that yields increase as the percentage of land in crop land, pasture, and feeding operation increases. The most obvious increase was in nitrate. No relationships between the erosion potential of land and water quality could be demonstrated.

Water of most lakes is of a calcium bicarbonate type, although sodium and magnesium may constitute more than 50 percent of the cations at some locations. Sulfate and chloride also may exceed bicarbonate in water of some lakes. The dissolved-solids concentration ranged from 28 mg/L (Knickerbocker Lake) to 310 mg/L (Maple Lake). The mean dissolved-solids concentration of lakes in the county was 143 mg/L. Concentrations of nitrogen and phosphorus were generally low; the median concentration of nitrate of all lakes was less than 0.01 mg/L. Either Alachlor, Atrazine, Silvex, Simazine, Treflan, or 2,4-D was detected in 26 lakes. Highest concentrations were those of Treflan and 2,4-D. A comparison of data collected during this investigation with that collected in 1963 suggest that concentrations of the major dissolved substances have not changed appreciably. Lakes with no outlet or inlet have the lowest dissolved-solids concentration. The chemical characteristics of lakes with inlets and outlets are similar to those of streams in the county.

Calcium and bicarbonate were the principal dissolved substances in 90 percent of the ground waters, although sodium, sulfate, and chloride predominate at some locations. Dissolved-solids concentrations ranged from 112 to 878 mg/L; the mean concentration was 307 mg/L. A comparison of data collected during this investigation with that collected in 1963 suggest that the total mineralization of ground water has not changed significantly. High concentrations of aluminum, lead, manganese, nickel, zinc, copper, and cyanide suggest ground-water contamination at a few sites. Pesticides were not detected in ground water.

A comparison of nitrate concentrations in ground water in Van Buren County with those of uncontaminated waters statewide indicates that nitrate in the county is significantly higher; nitrate concentrations in the southern eight townships are higher than in the northern ten townships. In the northern townships, 50 percent of the nitrate concentrations equal or exceed 0.05 mg/L; in the southern townships, 50 percent equal or exceed 2.5 mg/L. About 22 percent of the wells sampled in the southern townships contain water whose nitrate exceeded the U.S. Environmental Protection Agency standard of 10 mg/L for drinking water. In general nitrate concentrations decrease as the depth of wells increase. Data indicate that nitrate in ground water is related to fertilizer applications, but equally as important may be the number of acres irrigated, and by implication, the amount of water applied.

Chloride concentrations in ground water ranged from 0 to 870 mg/L. Higher concentrations are probably related to oil-field activity, which occurs principally in the northern part of the county. Frequency distributions of chloride concentrations indicate that, in the northern townships, 90 percent of the chloride concentrations are equal to or less than 40 mg/L; in the southern townships, 90 percent are equal to or less than 14 mg/L.

Model simulations of the ground-water flow system in the surficial deposits matched measured conditions if hydraulic conductivities of 10 to 35 ft/d and an estimated recharge rate of 11.8 in/yr were used. Simulations of 500 gal/min pumping from an unconfined aquifer indicated only 2 to 3 ft of drawdown in the vicinity of the pumping well. Similar pumping from a partially confined aquifer, however, produce 13 ft of drawdown. Simulations in which pumpage for irrigation was double that of 1983 indicated that as much as 30 ft of drawdown might be expected in some areas in the southern part of the county.

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TABLES OF DATA

Table 18.--Maximum, mean, and minimum values of specific conductance, dissolved oxygen, and pH of streams, 1980-82

Site	Number of analyses		Specific conductance (µmhos)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	pH (units)
		Maximum	650	13.0	133	8.4
1	13	Mean	560	9.5	88	7.9
		Minimum	430	6.8	71	7.3
		Maximum	800	12.1	112	8.5
2	33	Mean	602	8.7	76	7.6
		Minimum	480	6.2	60	6.6
		Maximum	460	12.4	108	8.3
3	31	Mean	414	8.9	82	7.8
		Minimum	345	6.0	62	6.8
		Maximum	385	9.2	84	8.4
4	8	Mean	339	7.9	78	7.6
		Minimum	210	6.8	72	6.8
		Maximum	512	11.5	117	7.8
5	8	Mean	458	9.3	87	7.7
		Minimum	320	7.8	73	7.5
		Maximum	684	9.6	102	8.0
6	7	Mean	586	9.2	89	7.7
		Minimum	460	8.6	79	7.3
		Maximum	1,020	12.2	103	8.3
7	33	Mean	561	9.2	81	7.6
		Minimum	460	6.9	69	6.9
		Maximum	466	10.1	96	8.7
8	8	Mean	416	8.6	84	8.0
		Minimum	320	6.3	66	7.7
		Maximum	431	10.3	99	9.1
9	7	Mean	360	9.1	90	8.1
		Minimum	180	8.1	85	7.3
		Maximum	457	12.5	104	8.4
10	30	Mean	395	10.0	89	7.9
		Minimum	260	7.7	78	7.1
		Maximum	438	13.8	109	8.7
11	32	Mean	371	10.7	95	8.0
		Minimum	260	8.6	81	6.8
		Maximum	542	16.0	182	8.8
12	29	Mean	462	10.8	104	8.1
		Minimum	375	7.3	84	7.2
		Maximum	446	12.6	93	8.2
13	31	Mean	384	9.1	81	7.8
		Minimum	255	5.6	57	6.8

Table 18.--Maximum, mean, and minimum values of specific conductance, dissolved oxygen, and pH of streams, 1980-82--Continued

Site	Number of analyses		Specific conductance (μmhos)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	pH (units)
14	30	Maximum	404	12.6	116	8.4
		Mean	345	10.2	94	7.9
		Minimum	255	7.3	78	7.2
15	7	Maximum	300	9.4	96	8.1
		Mean	215	8.6	90	7.7
		Minimum	134	7.6	85	6.9
16	7	Maximum	365	11.8	126	8.5
		Mean	307	8.6	93	7.9
		Minimum	211	6.6	73	7.3
17	31	Maximum	420	12.1	95	8.2
		Mean	316	9.2	80	7.6
		Minimum	120	5.8	57	7.1
18	44	Maximum	492	13.0	114	8.3
		Mean	401	9.9	84	7.8
		Minimum	225	5.3	60	7.3
19	8	Maximum	379	11.2	92	8.6
		Mean	341	9.6	90	7.9
		Minimum	243	8.4	88	7.6
20	7	Maximum	460	10.6	104	8.0
		Mean	385	9.4	90	7.8
		Minimum	182	8.3	78	7.2
21	32	Maximum	495	13.7	97	8.2
		Mean	369	10.1	87	7.8
		Minimum	170	7.4	78	6.8
22	32	Maximum	496	12.6	97	8.3
		Mean	399	9.5	83	7.8
		Minimum	200	5.6	64	7.2
23	45	Maximum	490	13.0	102	8.8
		Mean	381	10.1	85	7.8
		Minimum	220	5.7	59	6.8
24	6	Maximum	562	12.6	119	8.7
		Mean	521	10.2	99	8.1
		Minimum	440	7.3	80	7.6
26	29	Maximum	357	13.6	102	8.2
		Mean	214	9.8	85	7.3
		Minimum	96	7.2	72	6.5
27	28	Maximum	1,000	13.2	105	8.2
		Mean	381	9.9	85	7.5
		Minimum	131	5.6	62	6.7

Table 18.--Maximum, mean, and minimum values of specific conductance, dissolved oxygen, and pH of streams, 1980-82--Continued

Site	Number of analyses		Specific conductance (μmhos)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	pH (units)
		Maximum	543	14.2	109	8.5
28	30	Mean	411	9.3	81	7.7
		Minimum	250	3.5	39	6.8
		Maximum	858	10.6	119	8.4
29	7	Mean	494	9.4	97	8.0
		Minimum	292	8.0	85	7.4
		Maximum	926	10.7	124	8.9
30	7	Mean	453	9.0	102	8.3
		Minimum	332	7.9	71	7.5
		Maximum	573	14.2	146	8.6
31	28	Mean	464	10.5	97	7.8
		Minimum	338	6.4	70	7.1
		Maximum	473	13.2	100	8.2
32	29	Mean	403	8.7	74	7.6
		Minimum	222	3.3	38	6.7
		Maximum	480	13.6	106	8.3
33	36	Mean	379	10.4	90	7.8
		Minimum	160	5.5	67	6.9
		Maximum	470	14.9	114	8.3
34	30	Mean	301	9.8	85	7.7
		Minimum	100	5.6	61	6.8
		Maximum	470	12.6	92	8.2
34A	9	Mean	415	9.8	84	7.7
		Minimum	360	7.6	74	6.8
		Maximum	470	13.5	107	8.2
35	23	Mean	346	9.5	82	7.6
		Minimum	130	5.1	62	6.9
		Maximum	370	9.1	97	8.0
36	7	Mean	292	8.3	86	7.7
		Minimum	191	7.0	77	7.2
		Maximum	760	10.2	107	8.2
37	7	Mean	661	9.4	92	8.0
		Minimum	345	8.2	83	7.3
		Maximum	294	8.6	94	8.0
38	7	Mean	257	8.0	82	7.6
		Minimum	167	7.7	75	7.1
		Maximum	552	9.5	94	8.8
39	8	Mean	512	8.7	85	8.1
		Minimum	395	8.1	80	7.5

Table 19.--Chemical and physical characteristics of streams, 1981-82

Site number	Station number and name	Date of sample	Time	Stream-flow, instan-taneous (ft^3/s)	Temper-ature (deg C)	Turbid-ity (FTU)	Color (plat-inum-cobalt units)	Specific conduct-ance (μmhos)	Oxygen, dis-solved (mg/L)	Oxygen, dis-solved (percent satur-ation)	pH (units)
1	04101698 Dowagiac Drain 1 mile south of Decatur	May 11, 1981	1457	113	8.0	5.8	80	608	9.6	77	7.3
2	04101700 Dowagiac Drain 3.7 miles southwest of Decatur	May 11, 1981	1635	153	8.0	4.2	75	608	7.7	67	7.0
		Sept. 14, 1981	1030	24	17.5	--	--	585	6.5	68	7.7
		Aug. 16, 1982	1200	22	18.0	6.8	25	480	7.2	74	8.0
3	04101710 Lake of the Woods Drain 3.5 miles southwest of Decatur	May 11, 1981	1750	51	9.5	3.0	45	377	8.6	107	7.0
		Aug. 16, 1982	1400	5.5	20.0	1.2	18	375	9.8	105	8.2
4	04101715 Osborne Drain 5 miles southwest of Keeler	May 12, 1981	0835	29	6.5	.80	65	210	9.2	78	6.8
5	04102140 Eagle Lake Drain 3.5 miles west of Lawton	May 12, 1981	1025	39	9.0	1.8	40	390	9.0	76	7.5
6	04102143 Gates Drain 3 miles west of Lawton	May 12, 1981	1135	131	8.5	2.5	33	574	9.6	81	7.3
7	04102148 South Branch Paw Paw River 1.4 miles south of Paw Paw	May 12, 1981	1305	188	8.0	3.0	42	540	9.0	78	7.2
		Aug. 17, 1982	0830	41	15.0	3.0	17	480	7.6	73	8.0
8	04102165 East Branch Paw Paw River 3 miles east of Lawton	May 11, 1981	1530	35	9.0	1.0	38	325	9.2	79	7.7
9	04102177 Cook Drain 1 mile west of Mattawan	May 11, 1981	1800	31	8.0	1.5	60	180	10.3	87	7.3
10	04102178 East Branch Paw Paw River 1.5 miles north of Lawton	May 11, 1981	2000	84	8.5	1.7	28	280	10.4	87	7.6
11	04102180 East Branch Paw Paw River at Paw Paw	May 12, 1981	0830	114	7.0	1.5	30	290	11.6	94	7.7
		Sept. 14, 1981	1600	27	18.5	--	--	400	8.8	94	8.2
		Aug. 17, 1982	1045	28	16.0	1.4	16	340	8.8	87	8.2
12	04102192 South Branch Paw Paw River 1 mile north of Paw Paw	May 13, 1981	1945	182	11.5	3.7	31	400	9.8	88	7.9
		Aug. 17, 1982	1300	64	23.0	3.7	16	395	16.0	182	8.5
13	04102212 North Branch Paw Paw River 4.3 miles northeast of Paw Paw	May 12, 1981	1300	224	9.5	1.9	55	285	10.4	89	7.6
		July 7, 1981	1100	45	21.0	--	--	400	7.3	79	7.9
		Aug. 17, 1982	1500	40	21.0	1.6	16	360	8.5	93	8.2
14	04102217 Unnamed Tributary to Paw Paw River 3.5 miles northeast of Paw Paw	May 12, 1981	1100	33	10.5	.90	22	290	11.0	96	7.8
		Aug. 23, 1982	1700	--	22.0	<1.0	16	310	8.2	93	8.3
15	04102240 Brandywine Creek 3.4 miles south of Gobels	May 11, 1981	1530	31	8.0	5.0	120	134	--	--	7.6
		July 6, 1981	1200	1.7	19.0	--	--	300	7.6	92	7.9
16	04102246 North Extension Drain 3.7 miles southwest of Gobels	May 12, 1981	1445	48	13.0	5.9	48	211	--	--	7.3
17	04102260 Brandywine Creek 4.4 miles north of Paw Paw	May 12, 1981	1500	167	10.5	11	70	180	9.6	83	7.5
		July 7, 1981	1345	6.9	19.5	--	--	380	6.9	73	7.8
		Aug. 18, 1982	1000	4.8	16.0	3.0	19	360	8.0	79	8.1
18	04102320 Paw Paw River 3 miles northwest of Paw Paw	May 12, 1981	1900	951	10.5	4.0	43	285	10.5	92	7.6
		Aug. 18, 1982	1200	140	20.0	2.7	19	365	8.3	89	8.1
19	04102350 Brush Creek 4.5 miles south of Lawrence	May 12, 1981	1530	36	12.0	4.8	45	243	11.2	--	7.6
20	04102362 Red Creek 3.5 miles south of Lawrence	May 13, 1981	0830	20	8.0	9.5	100	182	10.6	93	7.2
21	04102370 Brush Creek at Lawrence	May 13, 1981	1005	122	10.0	8.0	65	272	9.0	--	7.5
		Aug. 18, 1982	1430	21	17.5	2.2	19	340	8.9	91	8.2
22	04102392 Paw Paw River at Lawrence	May 12, 1981	2130	1,420	10.5	4.9	38	260	10.1	88	7.6
		Aug. 18, 1982	1630	175	21.0	3.9	15	370	8.1	88	8.1
23	04102420 Paw Paw River 1.5 miles northwest of Hartford	May 13, 1981	1630	1,200	11.5	4.4	40	275	9.5	85	7.5
		Aug. 19, 1982	1100	227	20.5	4.2	17	390	8.4	--	8.2

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Silica, dis-solved (mg/L as SiO_2)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, ammonia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, nitrate total (mg/L as N)	Nitro-gen, organic total (mg/L as N)
1	9.7	92	25	4.3	4.6	100	15	.2	0.23	0.05	7.3	2.2
2	9.5	96	24	4.9	4.6	100	14	.2	.14	.05	7.2	1.8
	--	--	--	--	--	35	--	--	.09	.03	1.6	.62
	9.7	67	25	5.7	1.1	57	8.0	.2	--	--	--	--
3	4.9	48	17	4.6	2.0	36	12	.1	.06	.02	1.9	1.1
	9.1	50	18	6.5	1.1	40	9.1	.1	--	--	--	--
4	4.4	38	9.7	2.6	.7	11	5.1	<.1	.06	<.01	.56	.78
5	8.3	57	17	5.4	1.3	36	5.5	.1	.14	.02	1.6	.72
6	10	73	22	7.7	1.7	69	14	.1	.13	.02	1.6	1.1
7	11	74	23	9.1	1.7	66	16	.2	.12	.02	1.4	.98
	10	66	22	17	1.9	42	24	.2	--	--	--	--
8	8.0	45	17	2.5	.7	9.8	4.1	.1	--	--	--	--
9	6.5	22	8.0	4.4	.7	8.5	6.4	<.1	.01	<.01	.06	.74
10	8.1	37	14	3.5	.8	13	5.9	.1	.03	<.01	.16	.50
11	8.3	36	13	4.3	.7	13	6.4	.1	.03	<.01	.16	.77
	--	--	--	--	--	10	--	--	.04	.01	.40	.22
	10	48	19	6.8	.5	22	9.9	.1	--	--	--	--
12	7.8	53	17	7.4	1.4	42	13	.1	.06	.02	.88	.67
	6.0	50	21	12	1.1	39	18	.2	--	--	--	--
13	7.3	39	12	3.9	1.1	21	5.9	.1	.03	.01	.47	.70
	--	--	--	--	--	--	--	--	.02	<.01	.28	.48
	9.7	53	18	5.4	.4	23	8.1	.2	--	--	--	--
14	6.8	37	12	3.9	.7	17	6.4	.1	.04	.01	.49	.71
	9.9	46	16	5.6	.4	19	8.9	.1	--	--	--	--
15	3.1	15	5.2	2.1	1.5	8.0	5.5	<.1	.11	.02	.94	1.5
	--	--	--	--	--	--	--	--	<.01	.01	1.3	.57
16	3.7	25	8.5	2.4	1.7	9.1	5.0	<.1	.07	.01	.42	.76
17	4.1	22	8.0	2.8	1.9	9.5	6.2	.1	.07	.02	.53	1.0
	--	--	--	--	--	--	--	--	.05	<.01	.38	.51
	9.6	54	19	4.7	.4	27	8.7	.2	--	--	--	--
18	6.3	36	12	4.7	1.5	25	8.7	.1	.02	.01	.54	.72
	8.5	52	19	9.6	.5	32	11	.2	--	--	--	--
19	7.2	32	12	3.0	1.2	18	5.3	<.1	.05	.02	.98	.69
20	4.7	25	8.5	1.9	1.9	9.0	4.6	<.1	.04	.01	.47	1.3
21	7.0	35	13	3.7	2.5	16	7.4	.1	.23	.03	.97	.87
	11	53	20	6.4	.5	24	9.6	.2	--	--	--	--
22	6.4	37	13	5.3	1.6	22	8.6	.1	.04	.02	.40	.84
	9.1	53	20	8.1	.8	28	11	.2	--	--	--	--
23	6.1	36	13	5.0	1.6	19	8.2	.1	.03	.01	.38	.75
	9.2	55	21	8.8	.9	29	12	.2	--	--	--	--

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)	Cyanide, total (mg/L as CN)	Phenols (µg/L	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Aluminum, total recoverable (µg/L as Al)	Arsenic, total (µg/L as As)
1	9.7	0.06	0.11	--	--	190	330	140	384	481	--	2
2	9.1	.06	.11	--	--	180	340	160	381	--	--	2
	2.3	.03	.05	--	--	--	--	--	--	--	--	--
	--	--	--	<.01	<1	233	270	37	314	369	80	3
3	3.1	.03	.08	--	--	--	190	22	226	270	--	2
	--	--	--	<.01	<1	169	200	30	236	295	30	3
4	1.4	.01	.01	--	--	100	110	10	122	145	--	0
5	2.5	<.01	.02	--	--	180	210	25	240	285	--	1
6	2.8	<.01	.05	--	--	200	270	73	318	387	--	2
7	2.5	<.01	.05	--	--	200	280	80	321	355	--	2
	--	--	--	<.01	<1	221	260	34	316	377	90	3
8	--	--	--	--	--	180	180	2.0	200	210	--	0
9	.81	<.01	.02	--	--	86	88	2.0	108	124	--	0
10	.69	<.01	.02	--	--	140	150	8.0	168	178	--	1
11	.96	<.01	.02	--	--	140	140	3.0	167	175	--	1
	.67	.02	.02	--	--	--	--	--	--	--	--	--
	--	--	--	<.01	<1	178	200	20	223	257	50	3
12	1.6	<.01	.04	--	--	170	200	32	244	310	--	1
	--	--	--	<.01	<1	176	210	35	253	292	50	3
13	1.2	<.01	.04	--	--	140	150	7.0	175	186	--	1
	.78	<.01	.04	--	--	--	--	--	--	--	--	1
	--	--	--	<.01	<1	191	210	15	233	246	80	3
14	1.3	<.01	.03	--	--	140	140	2.0	168	182	--	0
	--	--	--	<.01	<1	161	180	20	203	199	40	2
15	2.6	.04	.08	--	--	56	59	16	65	87	--	0
	1.9	<.01	.05	--	--	--	--	--	--	--	--	--
16	1.3	.03	.11	--	--	93	97	1.0	111	126	--	0
17	1.7	.02	.11	--	--	81	88	7.0	103	127	--	0
	.94	.03	.06	--	--	--	--	--	--	--	--	1
	--	--	--	<.01	<1	189	210	24	237	277	120	3
18	1.3	.03	.05	--	--	130	140	9.0	173	201	--	0
	--	--	--	<.01	<1	184	210	24	243	258	100	3
19	1.7	<.01	.06	--	--	110	130	19	145	163	--	1
20	1.8	.03	.06	--	--	89	97	6.0	110	148	--	0
21	2.1	.05	.11	--	--	130	140	11	163	184	--	1
	--	--	--	<.01	<1	195	210	20	242	281	60	3
22	1.3	.01	.06	--	--	130	140	9.0	170	183	--	0
	--	--	--	<.01	<1	188	210	27	243	250	80	3
23	1.2	<.01	.08	--	--	130	140	7.0	165	187	--	1
	--	--	--	<.01	<1	194	220	30	253	264	100	3

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Barium, total recov-erable (µg/L as Ba)	Boron, total recov-erable (µg/L as B)	Cadmium, total recov-erable (µg/L as Cd)	Chro-mium, total recov-erable (µg/L as Cr)	Cobalt, total recov-erable (µg/L as Co)	Copper, total recov-erable (µg/L as Cu)	Iron, total recov-erable (µg/L as Fe)	Iron, dis-solved (µg/L as Fe)	Lead, total recov-erable (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)
1	--	--	3	10	3	3	1,600	--	1	10	130	--
2	--	--	2	20	2	2	1,100	--	1	8	110	--
	--	--	--	--	--	--	--	--	--	--	--	--
	100	90	--	10	3	6	810	35	2	--	80	48
3	--	--	2	10	2	2	600	--	1	6	60	--
	100	100	--	10	3	5	340	31	3	--	40	27
4	--	--	1	10	1	5	320	--	4	<4	40	--
5	--	--	1	<10	1	5	500	--	4	4	60	--
6	--	--	1	<10	1	5	900	--	5	4	80	--
7	--	--	1	10	1	6	1,000	--	4	5	70	--
	200	50	--	20	2	110	770	6	6	--	70	40
8	--	--	1	10	1	1	120	--	1	9	10	--
9	--	--	1	20	1	7	600	--	6	<4	20	--
10	--	--	1	<10	1	5	440	--	4	<4	20	--
11	--	--	1	10	2	7	300	--	4	<4	20	--
	--	--	--	--	--	--	--	--	--	--	--	--
	100	20	--	20	2	5	190	11	2	--	20	13
12	--	--	1	<10	1	9	500	--	8	<4	50	--
	<100	40	--	20	1	5	180	9	2	--	40	2
13	--	--	1	<10	1	6	900	--	4	4	20	--
	--	--	--	--	--	--	--	--	--	--	--	--
	200	20	--	20	1	5	270	8	4	--	40	15
14	--	--	1	<10	1	6	320	--	1	<4	20	--
	200	50	--	10	<1	4	90	10	2	--	20	9
15	--	--	2	<10	1	3	700	--	1	<4	40	--
	--	--	--	--	--	--	--	--	--	--	--	--
16	--	--	1	<10	1	7	700	--	4	4	60	--
17	--	--	1	<10	1	10	1,000	--	26	<4	40	--
	--	--	--	--	--	--	--	--	--	--	--	--
	<100	10	--	10	2	5	400	42	4	--	70	45
18	--	--	1	20	1	9	600	--	22	<4	20	--
	100	30	--	<10	1	5	280	15	4	--	50	13
19	--	--	1	<10	1	10	1,100	--	12	5	80	--
20	--	--	2	10	2	2	1,300	--	1	5	90	--
21	--	--	1	<10	1	6	1,500	--	1	<4	70	--
	<100	20	--	10	2	4	330	20	2	--	60	41
22	--	--	5	10	1	7	700	--	2	<4	40	--
	100	90	--	10	1	4	330	17	2	--	50	19
23	--	--	1	<10	1	17	600	--	40	<4	30	--
	100	90	--	10	2	6	350	<3	1	--	50	18

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Mercury, total recoverable (μg/L as Hg)	Nickel, total recoverable (μg/L as Ni)	Selenium, total (μg/L as Se)	Strontium, total recoverable (μg/L as Sr)	Strontium, dissolved (μg/L as Sr)	Zinc, total recoverable (μg/L as Zn)	Potassium 40 dissolved (pCi/L as K40)
1	<.1	10	0	150	150	30	3.4
2	<.1	9	0	160	180	30	3.4
	--	--	--	--	--	--	--
	--	1	--	180	--	10	--
3	<.1	8	0	90	80	20	1.5
	--	1	--	140	--	10	--
4	<.1	9	0	40	30	30	.50
5	<.1	2	0	90	80	40	1.0
6	<.1	4	0	120	110	60	1.3
7	<.1	9	0	110	110	30	1.3
	--	3	--	120	--	<10	--
8	<.1	3	0	50	50	20	.50
9	<.1	6	0	30	30	40	.50
10	<.1	1	0	50	40	30	.60
11	<.1	9	0	50	50	20	.50
	--	--	--	--	--	--	--
	--	3	--	80	--	20	--
12	<.1	7	0	90	80	40	1.0
	--	3	--	100	--	70	--
13	<.1	3	0	80	70	50	.80
	--	--	--	--	--	--	--
	--	1	--	90	--	10	--
14	<.1	5	0	60	60	30	.50
	--	4	--	80	--	10	--
15	.1	8	0	20	20	40	1.1
	--	--	--	--	--	--	--
16	<.1	4	0	50	50	30	1.3
17	<.1	4	0	50	40	40	1.4
	--	--	--	--	--	--	--
	--	4	--	90	--	<10	--
18	<.1	3	0	70	60	30	1.1
	--	5	--	100	--	<10	--
19	<.1	8	0	60	50	20	.90
20	<.1	6	0	40	30	30	1.4
21	.3	7	0	60	50	30	1.9
	--	3	--	100	--	10	--
22	<.1	7	0	70	60	30	1.2
	--	2	--	130	--	40	--
23	<.1	8	0	70	60	30	1.2
	--	2	--	130	--	50	--

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Station number and name	Date of sample	Time	Streamflow, instantaneous (ft^3/s)	Temperature (deg C)	Turbidity (FTU)	Color (platinum-cobalt units)	Specific conductance (μmhos)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	pH (units)
24	04102429 Pine Creek 1 mile west of Hartford	May 13, 1981	1330	17	11.0	10	25	440	9.8	87	7.6
26	04102540 Brandywine Creek 2.7 miles south of South Haven	May 12, 1981	1030	156	7.0	7.0	60	96	9.5	79	6.8
		Aug. 23, 1982	1200	2.1	17.0	3.0	65	220	7.6	79	8.2
27	04102545 Deerlick Creek 2 miles south of South Haven	May 11, 1981	1745	156	8.0	84	60	121	10.7	90	7.8
28	04102575 Black Drain 3.8 miles northeast of Bangor	May 12, 1981	0900	381	9.0	7.6	60	250	--	--	7.4
		Aug. 19, 1982	1315	9.9	16.0	17	16	440	8.3	82	8.2
29	04102587 Haven and Max Lake Drain 1 miles southwest of Bloomingdale	May 12, 1981	1330	81	16.0	6.0	55	292	--	--	7.4
30	04102589 Haven and Max Lake Drain 2 miles southwest of Bloomingdale	May 11, 1981	2100	147	11.0	2.6	18	403	--	--	7.5
31	04102590 Haven and Max Lake Drain 4 miles northwest of Bangor	May 13, 1981	1205	192	12.0	1.7	32	338	7.9	74	7.4
		Sept. 17, 1981	1030	4.5	14.0	--	--	480	8.0	76	8.0
		Aug. 19, 1982	1500	--	24.0	3.2	25	460	12.3	146	8.6
32	04102618 Black River at Bangor	May 13, 1981	1430	370	13.0	10	60	273	--	--	7.6
33	04102700 Black River 4.9 miles northwest of Bangor	May 13, 1981	1130	572	11.0	10	50	247	--	--	7.8
		Aug. 19, 1982	1700	36	21.0	2.4	23	430	--	--	8.2
34	04102720 Cedar Creek 4.6 miles southeast of South Haven	May 13, 1981	1100	98	10.5	3.5	60	160	9.4	83	7.3
		Aug. 20, 1982	0945	2.8	19.0	31	20	320	5.6	61	8.0
34A	04102730 South Branch Black River 2 miles northeast of South Haven	Aug. 20, 1982	1130	53	21.0	2.2	17	405	7.6	83	8.2
35	04102731 Black River 1 mile east of South Haven	May 12, 1981	1720	1,480	10.0	29	70	165	9.4	85	7.4
36	04102735 Middle Fork Black River 5.5 miles northwest of Bloomingdale	May 12, 1981	1200	45	9.0	.60	45	191	--	--	7.2
		July 7, 1981	1115	2.3	21.0	--	--	308	7.0	84	7.6
37	04102750 Melvin Creek 3.2 miles northwest of Bloomingdale	May 13, 1981	1340	29	10.0	3.5	.40	345	10.0	88	7.3
		July 7, 1981	1220	2.8	17.0	--	--	750	8.2	99	8.0
38	04102770 Barber Creek 1.1 miles east of Grand Junction	May 12, 1981	1100	41	8.0	1.1	80	167	--	--	7.1
		July 7, 1981	1000	5.6	16.5	--	--	283	7.8	94	7.3
39	04107740 Pine Creek 6.5 miles northeast of Gobles	May 11, 1981	1830	222	8.0	3.5	60	395	--	--	7.5

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Silica, dis-solved (mg/L as SiO_2)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Nitro-gen, ammonia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, nitrate total (mg/L as N)	Nitro-gen, organic total (mg/L as N)
24	6.2	48	16	14	1.8	41	20	.2	.08	.02	2.2	.80
26	4.7	12	3.5	3.6	1.2	8.4	5.1	<.1	.05	<.01	.15	.73
	9.0	26	7.3	12	1.0	11	21	<.1	--	--	--	--
27	3.4	14	4.4	4.1	1.7	9.8	6.3	<.1	.13	.01	.35	.97
28	4.2	31	10	6.6	2.0	10	13	.1	.07	.02	.45	.88
	13	59	24	15	1.1	17	17	.3	--	--	--	--
29	3.3	17	11	9.7	2.3	14	17	.1	.06	.03	.41	.90
30	3.0	38	14	12	2.0	13	25	.1	.06	.01	.33	.66
31	4.1	42	14	13	1.9	9.5	24	.1	.03	.01	.16	.64
	--	--	--	--	--	3.5	--	--	.05	<.01	.04	.50
	4.4	46	19	33	1.9	17	72	.2	--	--	--	--
32	4.5	33	11	7.6	2.1	11	14	.1	.08	.02	.37	.89
33	4.7	31	9.8	6.0	2.0	12	11	.1	.09	.02	.47	1.0
	10	49	21	17	1.2	23	25	.2	--	--	--	--
34	5.6	21	6.8	3.3	1.9	16	5.6	.1	.07	.02	.47	.77
	7.8	43	16	8.8	1.4	27	12	.2	--	--	--	--
34A	9.0	47	19	15	1.2	23	22	.2	--	--	--	--
35	4.3	19	6.2	3.6	2.3	11	6.5	<.1	.20	.02	.63	.80
36	2.9	21	6.9	7.7	.8	4.2	13	<.1	.03	.01	.01	.53
	--	--	--	--	--	--	--	--	<.01	<.01	.16	.49
37	4.6	37	13	21	2.2	11	40	.1	.06	<.01	.17	.73
	--	--	--	--	--	--	--	--	.01	.02	.34	.33
38	3.2	17	5.0	5.7	1.2	12	11	<.1	.32	<.01	.11	.50
	--	--	--	--	--	--	--	--	.03	<.01	.20	.58
39	5.8	47	12	2.5	1.8	46	6.4	.1	.14	.02	2.1	.96

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)	Cyanide, total (mg/L as CN)	Phenols (μg/L)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Aluminum, total recoverable (μg/L as Al)	Arsenic, total (μg/L as As)
24	3.1	0.02	0.07	--	--	180	190	6.0	256	302	--	0
26	.93	.02	.04	--	--	31	44	13	57	75	--	0
	--	--	--	<.01	<1	80	95	15	136	139	90	2
27	1.5	.04	.10	--	--	43	53	10	70	85	--	0
28	1.4	.02	.07	--	--	110	120	9.0	143	168	--	1
	--	--	--	<.01	<1	242	250	4.0	292	317	240	9
29	1.4	.02	.08	--	--	120	88	5.0	162	192	--	0
30	1.1	<.01	.03	--	--	170	150	3.0	200	248	--	0
31	.84	<.01	.04	--	--	150	160	8.0	199	220	--	0
	.59	.02	.03	--	--	--	--	--	--	--	--	--
	--	--	--	<.01	<1	158	190	35	289	339	110	3
32	1.4	.03	.05	--	--	110	130	18	150	170	--	0
33	1.6	.05	.06	--	--	94	120	24	133	161	--	0
	--	--	--	<.01	<1	214	210	.00	275	314	50	4
34	1.3	.02	.07	--	--	68	81	13	101	117	--	0
	--	--	--	<.01	<1	146	170	27	204	249	110	2
34A	--	--	--	<.01	<1	198	200	.00	256	292	60	3
35	1.7	.04	.08	--	--	59	73	14	88	108	--	0
36	.58	<.01	.03	--	--	77	81	1.0	103	120	--	0
	.65	.02	.04	--	--	--	--	--	--	--	--	--
37	.96	.02	.04	--	--	130	150	14	208	232	--	0
	.70	.02	.04	--	--	--	--	--	--	--	--	--
38	.93	<.01	.03	--	--	56	63	7.0	90	117	--	0
	.81	.02	.04	--	--	--	--	--	--	--	--	--
39	3.2	.04	.05	--	--	160	170	17	209	289	--	1

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Barium, total recov-erable (µg/L as Ba)	Boron, total recov-erable (µg/L as B)	Cadmium, total recov-erable (µg/L as Cd)	Chro-mium, total recov-erable (µg/L as Cr)	Cobalt, total recov-erable (µg/L as Co)	Copper, total recov-erable (µg/L as Cu)	Iron, total recov-erable (µg/L as Fe)	Iron, dis-solved (µg/L as Fe)	Lead, total recov-erable (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)
24	--	--	1	<10	1	7	700	--	1	<4	60	--
26	--	--	1	20	1	2	730	--	1	<4	20	--
	100	90	--	<10	1	7	1,100	480	3	--	80	68
27	--	--	1	10	1	7	3,800	--	4	<4	140	--
28	--	--	1	10	2	7	700	--	5	<4	20	--
	200	120	--	10	3	7	730	15	1	--	40	34
29	--	--	1	<10	1	6	900	--	1	<4	50	--
30	--	--	2	20	2	1	310	--	1	9	50	--
31	--	--	1	20	1	6	700	--	7	<4	30	--
	--	--	--	--	--	--	--	--	--	--	--	--
	100	110	--	10	3	8	280	26	2	--	20	13
32	--	--	1	10	1	4	470	--	1	<4	40	--
33	--	--	1	10	1	22	580	--	12	<4	50	--
	100	100	--	10	5	7	290	17	7	--	40	18
34	--	--	1	<10	1	9	600	--	13	<4	30	--
	100	100	--	10	2	5	340	74	3	--	70	47
34A	100	100	--	10	4	5	290	29	3	--	60	28
35	--	--	1	20	1	30	890	--	16	<4	60	--
36	--	--	1	20	2	5	210	--	6	<4	10	--
	--	--	--	--	--	--	--	--	--	--	--	--
37	--	--	1	20	1	8	800	--	4	4	60	--
	--	--	--	--	--	--	--	--	--	--	--	--
38	--	--	1	<10	1	6	500	--	3	<4	40	--
	--	--	--	--	--	--	--	--	--	--	--	--
39	--	--	3	10	1	2	600	--	1	6	60	--

Table 19.--Chemical and physical characteristics of streams, 1981-82--Continued

Site number	Mercury, total recoverable (μg/L as Hg)	Nickel, total recoverable (μg/L as Ni)	Selenium, total (μg/L as Se)	Strontium, total recoverable (μg/L as Sr)	Strontium, dissolved (μg/L as Sr)	Zinc, total recoverable (μg/L as Zn)	Potassium 40 dissolved (pCi/L as K40)
24	<.1	6	0	80	80	20	1.3
26	<.1	6	0	40	40	20	.90
	--	8	--	100	--	10	--
27	<.1	9	0	50	40	50	1.3
28	<.1	25	0	100	80	40	1.5
	--	4	--	360	--	30	--
29	<.1	3	0	70	70	30	1.7
30	.1	9	0	120	100	10	1.5
31	<.1	12	0	120	110	40	1.4
	--	--	--	--	--	--	--
	--	3	--	250	--	30	--
32	<.1	4	0	80	90	30	1.6
33	.1	6	0	90	80	30	1.5
	--	5	--	260	--	10	--
34	<.1	3	0	60	60	20	1.4
	--	3	--	200	--	20	--
34A	--	<1	--	240	--	10	--
35	<.1	6	0	50	50	30	1.7
36	.1	16	0	70	70	30	.60
	--	--	--	--	--	--	--
37	<.1	31	0	170	150	70	1.6
	--	--	--	--	--	--	--
38	<.1	4	0	80	60	20	.90
	--	--	--	--	--	--	--
39	<.1	8	0	80	70	30	1.3

Table 21.--Maximum, mean, and minimum concentrations of total nitrogen and total phosphorus at stream sites, 1980-81 [Results in milligrams per liter. Analyses by U.S. Geological Survey]

Site number	Number of analyses		Nitrogen, ammonia total (as N)	Nitrogen, nitrate total (as N)	Nitrogen, nitrite total (as N)	Nitrogen, organic total (as N)	Nitrogen, total (as N)	Phosphorus, total (as P)	Phosphorus, ortho total (as P)
		Maximum	0.23	7.3	0.05	2.2	9.7	0.11	0.06
1	11	Mean	.11	2.2	.03	.75	3.0	.06	.03
		Minimum	.04	1.2	.01	.32	1.9	.03	.01
		Maximum	1.5	12.0	.08	1.8	14.0	.18	1.0
2	29	Mean	.19	3.2	.03	.70	4.1	.07	.06
		Minimum	.04	.55	.00	.24	.84	.01	.00
		Maximum	.65	4.6	.04	2.4	5.6	.10	.07
3	26	Mean	.11	1.2	.02	.67	2.0	.03	.02
		Minimum	.01	.54	.01	.23	.80	.01	.00
		Maximum	.07	2.4	.03	1.1	3.1	.03	.01
4	5	Mean	.03	1.8	.02	.70	2.5	.02	.01
		Minimum	.01	.56	.01	.31	1.4	.01	.00
		Maximum	.14	1.6	.03	1.2	2.5	.02	.01
5	5	Mean	.06	1.4	.03	.57	2.0	.02	.01
		Minimum	.01	1.3	.02	.26	1.6	.01	.00
		Maximum	.13	1.6	.03	1.1	2.8	.05	.02
6	5	Mean	.07	1.4	.02	.64	2.1	.03	.01
		Minimum	.02	1.2	.02	.37	1.6	.01	.00
		Maximum	.38	3.0	.06	14.0	15.0	.12	.09
7	28	Mean	.12	1.3	.02	.97	2.4	.04	.02
		Minimum	.00	.91	.01	.18	1.2	.01	.00
		Maximum	.04	3.1	.02	.6	3.7	.04	.08
8	5	Mean	.03	1.0	.01	.41	1.3	.02	.02
		Minimum	.02	.25	.00	.24	.61	.01	.00
		Maximum	.05	.20	.01	.84	.81	.03	.01
9	5	Mean	.02	.18	.01	.51	.60	.02	.01
		Minimum	.01	.06	.00	.29	.44	.01	.00
		Maximum	.19	2.0	.03	.68	2.7	.06	.02
10	26	Mean	.04	.48	.01	.32	.84	.02	.01
		Minimum	.00	.16	.00	.09	.48	.01	.00
		Maximum	.09	.55	.02	.77	1.0	.05	.03
11	27	Mean	.03	.38	.01	.33	.76	.02	.01
		Minimum	.00	.01	.00	.11	.49	.01	.00
		Maximum	.15	.98	.03	4.4	4.9	.08	.03
12	25	Mean	.06	.67	.02	.59	1.3	.03	.01
		Minimum	.00	.27	.01	.10	.61	.01	.00
		Maximum	.26	1.7	.05	9.1	10.0	.07	.08
13	26	Mean	.05	.54	.01	1.0	1.6	.03	.01
		Minimum	.00	.22	.01	.06	.45	.01	.00
		Maximum	.08	1.4	.02	1.1	2.1	.05	.03
14	25	Mean	.04	.92	.01	.36	1.3	.02	.01
		Minimum	.00	.49	.01	.13	.87	.01	.00
		Maximum	.11	1.3	.02	1.5	2.6	.08	.04
15	5	Mean	.05	1.1	.01	.94	2.1	.05	.02
		Minimum	.01	.91	.01	.56	1.7	.03	.00

Table 21.--Maximum, mean, and minimum concentrations of total nitrogen and total phosphorus at stream sites, 1980-81--Continued

Site number	Number of analyses		Nitrogen, ammonia total (as N)	Nitrogen, nitrate total (as N)	Nitrogen, nitrite total (as N)	Nitrogen, organic total (as N)	Nitrogen, total (as N)	Phosphorus, total (as P)	Phosphorus, ortho total (as P)
		Maximum	0.88	1.0	0.06	1.1	2.9	0.11	0.08
16	5	Mean	.23	.55	.03	.77	1.6	.09	.05
		Minimum	.03	.33	.01	.45	.92	.06	.03
		Maximum	2.2	1.7	.09	14.0	15.0	.22	.16
17	27	Mean	.16	.62	.02	1.2	2.0	.08	.04
		Minimum	.01	.23	.01	.03	.67	.03	.01
		Maximum	0.15	1.5	.05	.85	2.2	.28	.05
18	35	Mean	.06	.79	.02	.46	1.3	.05	.02
		Minimum	.00	.17	.01	.13	.65	.01	.00
		Maximum	.07	1.3	.02	.69	1.9	.06	.02
19	5	Mean	.04	1.2	.01	.46	1.7	.03	.01
		Minimum	.01	.98	.01	.23	1.5	.01	.01
		Maximum	.06	1.7	.04	1.3	2.3	.06	.03
20	5	Mean	.03	1.0	.02	.74	1.8	.04	.02
		Minimum	.01	.47	.01	.36	1.5	.01	.01
		Maximum	.23	1.4	.05	9.1	10.0	.21	.07
21	27	Mean	.07	.95	.02	.78	1.8	.06	.02
		Minimum	.01	.24	.01	.15	.87	.01	.01
		Maximum	.11	1.2	.04	.84	1.8	.08	.09
22	28	Mean	.05	.73	.02	.43	1.2	.04	.02
		Minimum	.00	.39	.01	.15	.68	.01	.01
		Maximum	.15	1.3	.16	1.5	2.1	.14	.06
23	37	Mean	.06	.73	.02	.53	1.3	.05	.02
		Minimum	.00	.01	.00	.20	.49	.01	.00
		Maximum	.08	2.2	.05	.80	3.1	.07	.02
24	5	Mean	.04	1.3	.03	.53	1.9	.03	.01
		Minimum	.01	.87	.01	.28	1.6	.01	.00
		Maximum	.16	.44	.02	2.3	2.6	.13	.04
26	25	Mean	.07	.22	.01	.64	.93	.04	.01
		Minimum	.00	.13	.00	.19	.53	.00	.00
		Maximum	.92	1.2	.05	.97	2.2	.28	.07
27	25	Mean	.10	.52	.02	.56	1.2	.06	.02
		Minimum	.00	.13	.00	.22	.70	.01	.00
		Maximum	.24	.74	.07	2.0	2.5	.45	.05
28	26	Mean	.08	.29	.02	.58	.96	.06	.02
		Minimum	.00	.09	.00	.16	.44	.02	.01
		Maximum	.13	.54	.03	1.1	1.4	.08	.03
29	5	Mean	.06	.30	.02	.74	1.1	.06	.03
		Minimum	.01	.13	.01	.53	.74	.05	.02
		Maximum	.22	.33	.02	1.3	1.1	.04	.02
30	5	Mean	.07	.12	.01	.74	.81	.03	.01
		Minimum	.01	.01	.00	.52	.56	.02	.00
		Maximum	.15	.49	.04	1.5	2.1	.06	.05
31	24	Mean	.06	.17	.01	.65	.85	.04	.02
		Minimum	.01	.02	.00	.33	.48	.03	.00

Table 21.--Maximum, mean, and minimum concentrations of total nitrogen and total phosphorus at stream sites, 1980-81--Continued

Site number	Number of analyses		Nitrogen, ammonia total (as N)	Nitrogen, nitrate total (as N)	Nitrogen, nitrite total (as N)	Nitrogen, organic total (as N)	Nitrogen, total (as N)	Phosphorus, total (as P)	Phosphorus, ortho total (as P)
		Maximum	0.13	0.74	0.08	2.6	2.9	0.11	0.06
32	25	Mean	.07	.25	.02	.59	.93	.05	.03
		Minimum	.02	.08	.01	.27	.44	.00	.01
		Maximum	.20	1.2	.04	1.0	2.0	.13	.06
33	32	Mean	.07	.49	.02	.46	1.0	.06	.03
		Minimum	.00	.14	.01	.17	.54	.02	.00
		Maximum	.13	1.2	.05	4.3	5.0	.09	.06
34	26	Mean	.06	.76	.02	.63	1.5	.04	.02
		Minimum	.00	.29	.01	.26	.80	.00	.00
		Maximum	.13	.68	.03	2.0	2.7	.10	.03
34A	7	Mean	.06	.46	.01	.70	1.2	.05	.02
		Minimum	.02	.19	.01	.22	.53	.03	.01
		Maximum	.20	.97	.04	4.5	5.1	.12	.07
35	21	Mean	.06	.52	.02	.73	1.3	.06	.03
		Minimum	.00	.31	.00	.22	.66	.00	.01
		Maximum	.08	.16	.01	.73	.92	.05	.02
36	5	Mean	.04	.09	.01	.58	.72	.03	.01
		Minimum	.01	.01	.01	.49	.58	.02	.00
		Maximum	.06	.34	.04	1.1	.96	.04	.02
37	5	Mean	.03	.19	.02	.61	.76	.03	.01
		Minimum	.01	.05	.00	.33	.65	.02	.00
		Maximum	.32	.20	.04	1.1	1.4	.04	.02
38	5	Mean	.11	.15	.02	.59	.86	.03	.01
		Minimum	.03	.11	.01	.32	.51	.02	.00
		Maximum	.14	2.1	.02	.96	3.2	.05	.04
39	5	Mean	.07	.89	.02	.45	1.4	.03	.02
		Minimum	.03	.47	.01	.15	.69	.01	.01

Table 30.--Chemical and physical characteristics of lakes, 1982
[Analyses by U.S. Geological Survey]

Lake	Location[a/]	Date of sample	Temperature (deg C)	Turbidity (FTU)	Color (platinum-cobalt units)	Specific conductance (μmhos)	Oxygen, dissolved (mg/L)
Crooked Lake at Sister Lakes	T.4S., R.16W., sec. 32	May 20, 1982	25.5	--	--	270	--
		Aug. 31, 1982	23.5	--	--	220	9.2
Gravel Lake near Marcell	T.4S., R.14W., sec. 31	Aug. 25, 1982	22.5	1.4	10	220	8.1
Round Lake at Sister Lakes	T.4S., R.16W., sec. 31	Aug. 31, 1982	22.0	1.3	14	65	8.8
Cedar Lake near Marcellus	T.4S., R.13W., sec. 28	May 21, 1982	20.0	--	--	250	--
		Aug. 25, 1982	21.5	--	--	200	7.2
Knickerbocker Lake near Decatur	T.4S., R.15W., sec. 21	May 21, 1982	21.0	--	--	--	--
		Aug. 25, 1982	24.5	--	--	--	6.5
Keeler Lake near Keeler	T.4S., R.16W., sec. 23	May 20, 1982	25.5	--	--	--	--
		Aug. 26, 1982	24.0	--	--	50	6.6
Bankson Lake near Lawton	T.4S., R.13W., sec. 14	Aug. 31, 1982	21.5	1.5	11	145	7.0
Lake of the Woods near Decatur	T.4S., R.15W., sec. 24	May 21, 1982	20.0	--	--	370	--
		Aug. 25, 1982	21.5	--	--	300	5.6
Huzzys Lake near Lawton	T.4S., R.13W., sec. 10	Aug. 26, 1982	23.0	--	--	155	6.2
Eagle Lake near Decatur	T.3S., R.14W., sec. 32	Aug. 25, 1982	27.0	1.4	10	165	9.2
Christie Lake near Lawrence	T.3S., R.15W., sec 25	Aug. 26, 1982	25.0	--	--	185	6.5
Three Mile Lake near Paw Paw	T.3S., R.14W., sec. 21	Aug. 31, 1982	22.0	--	20	78	6.2
Shafer Lake near Lawrence	T.3S., R.15W., sec. 19	Aug. 31, 1982	22.5	1.0	7	230	8.0
Cora Lake near Lawrence	T.3S., R.14W., sec. 18	May 20, 1982	18.5	--	--	240	--
		Aug. 26, 1982	24.0	--	--	185	6.4
Maple Lake at Paw Paw	T.3S., R.14W., sec. 1	May 21, 1982	19.5	--	--	470	--
Rush Lake near Toquin	T.3S., R.16W., sec. 5	Aug. 12, 1982	25.0	1.0	8	255	10.4
Brownwood Lake near Paw Paw	T.3S., R.14W., sec. 2	Aug. 30, 1982	22.0	<1.0	13	200	5.8
Van Auken Lake near McDonald	T.2S., R.16W., sec. 32	May 21, 1982	20.0	--	--	330	--
		Sept. 1, 1982	22.5	--	--	280	8.2
School Section Lake near Bangor	T.2S., R.16W., sec. 16	Sept. 2, 1982	23.0	4.1	69	245	9.8
School Section Lake near Glendale	T.2S., R.14W., sec. 16	Sept. 1, 1982	22.0	1.9	18	215	6.6
Merriman Lake near Bangor	T.2S., R.16W., sec. 9	Sept. 1, 1982	23.5	--	--	300	6.2
Fish Lake near Gobles	T.2S., R.13W., sec. 3	Aug. 24, 1982	24.0	--	--	305	6.9
North Scott Lake near Bangor	T.2S., R.15W., sec. 1	Aug. 12, 1982	22.0	1.5	15	265	5.0
Upper Jephtha Lake near Breedsville	T.1S., R.15W., sec. 35	May 21, 1982	22.0	--	--	330	--
		Sept. 2, 1982	22.5	--	--	295	9.0
Brandywine Lake near Gobles	T.1S., R.13W., sec. 29	Aug. 30, 1982	21.5	6.5	150	52	6.6
Great Bear Lake near Bloomingdale	T.1S., R.15W., sec. 24	May 21, 1982	22.0	--	--	375	--
		Aug. 12, 1982	23.0	--	--	350	7.2
Mill Lake near Gobles	T.1S., R.14W., sec. 14	Aug. 24, 1982	22.0	<1.0	15	145	4.8
Silver Lake near Grand Junction	T.1S., R.15W., sec. 16	Sept. 1, 1982	22.0	1.0	33	135	6.1
Saddle Lake near Grand Junction	T.1S., R.15W., sec. 10	May 21, 1982	19.0	--	--	260	--
		Aug. 12, 1982	23.0	--	--	240	5.3
Muskrat Lake near Gobles	T.1S., R.14W., sec. 2	Aug. 30, 1982	22.5	--	--	200	8.9
Clear Lake near Kendall	T.1S., R.13W., sec. 3	Sept. 2, 1982	20.0	1.2	39	265	5.8

a/ Locations are given for lake outlet if one exists; otherwise location is arbitrarily chosen as central part of lake.

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Oxygen, dissolved (percent saturation)	pH (units)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Crooked Lake at Sister Lakes	--	8.8	--	--	--	--
	106	8.5	0.4	27	13	7.3
Gravel Lake near Marcell	92	8.4	5.8	30	14	3.4
Round Lake at Sister Lakes	99	8.3	.3	10	3.2	2.2
Cedar Lake near Marcellus	--	8.3	--	--	--	--
	80	8.5	2.0	27	13	2.2
Knickerbocker Lake near Decatur	--	7.6	--	--	--	--
	76	6.4	.2	1.8	.4	.3
Keeler Lake near Keeler	--	8.2	--	--	--	--
	78	8.1	.3	6.1	1.9	.4
Bankson Lake near Lawton	78	8.3	.5	22	8.7	2.0
Lake of the Woods near Decatur	--	8.4	--	--	--	--
	62	8.3	7.1	41	18	5.3
Huzzys Lake near Lawton	71	8.9	.9	21	9.6	1.5
Eagle Lake near Decatur	114	9.0	.6	22	11	2.3
Christie Lake near Lawrence	77	8.6	.8	24	14	1.6
Three Mile Lake near Paw Paw	70	7.9	.3	12	4.2	1.5
Shafer Lake near Lawrence	91	8.7	1.1	29	14	6.5
Cora Lake near Lawrence	--	8.4	--	--	--	--
	74	8.9	.7	21	11	6.0
Maple Lake at Paw Paw	--	8.2	--	--	--	--
Rush Lake near Toquin	120	8.8	5.0	25	18	3.9
Brownwood Lake near Paw Paw	65	8.5	2.6	30	11	4.3
Van Auken Lake near McDonald	--	8.1	--	--	--	--
	93	8.6	1.6	31	15	13
School Section Lake near Bangor	113	8.9	6.6	32	11	11
School Section Lake near Glendale	75	8.1	2.7	31	11	4.2
Merriman Lake near Bangor	71	8.6	5.3	43	15	8.0
Fish Lake near Gobles	81	8.1	9.8	42	17	5.4
North Scott Lake near Bangor	46	8.0	2.2	32	14	4.5
Upper Jephtha Lake near Breedsville	--	8.3	--	--	--	--
	102	8.5	5.0	41	16	5.2
Brandywine Lake near Gobles	73	7.8	1.3	8.8	3.0	2.6
Great Bear Lake near Bloomingdale	--	8.5	--	--	--	--
	82	8.3	4.1	37	16	14
Mill Lake near Gobles	55	7.6	.3	18	6.5	6.8
Silver Lake near Grand Junction	88	7.8	.7	17	5.3	7.0
Saddle Lake near Grand Junction	--	8.0	--	--	--	--
	60	7.6	2.1	28	10	8.1
Muskrat Lake near Gobles	101	8.8	1.1	24	13	5.3
Clear Lake near Kendall	63	7.8	2.4	40	30	2.5

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	0.6	16	10	<0.1	<0.01	<0.01
Gravel Lake near Marcell	.6	5.1	10	.1	<.01	<.01
Round Lake at Sister Lakes	<.1	3.5	5.0	.1	<.01	<.01
Cedar Lake near Marcellus	--	--	--	--	--	--
	.6	3.5	9.0	.2	<.01	<.01
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	<.1	.4	3.0	<.1	<.01	<.01
Keeler Lake near Keeler	--	--	--	--	--	--
	<.1	.9	3.0	.1	<.01	<.01
Bankson Lake near Lawton	<.1	4.8	5.0	<.1	.01	<.01
Lake of the Woods near Decatur	--	--	--	--	--	--
	1.1	9.0	27	.1	<.01	<.01
Huzzys Lake near Lawton	.3	3.2	6.0	.1	<.01	.02
Eagle Lake near Decatur	.7	5.3	11	.2	<.01	<.01
Christie Lake near Lawrence	.6	3.2	13	.1	<.01	<.01
Three Mile Lake near Paw Paw	.4	4.4	7.0	<.1	.01	<.01
Shafer Lake near Lawrence	1.3	9.8	16	.1	<.01	<.01
Cora Lake near Lawrence	--	--	--	--	--	--
	.3	13	8.0	.1	<.01	<.01
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	.8	4.4	21	.1	.02	<.01
Brownwood Lake near Paw Paw	.5	7.6	12	<.1	<.01	<.01
Van Auken Lake near McDonald	--	--	--	--	--	--
	1.7	25	17	.1	.02	<.01
School Section Lake near Bangor	.6	20	10	.1	<.01	<.01
School Section Lake near Glendale	1.8	7.0	9.0	.1	<.01	<.01
Merriman Lake near Bangor	1.1	12	18	.1	.02	<.01
Fish Lake near Gobles	.3	8.8	9.0	.1	<.01	<.01
North Scott Lake near Bangor	1.4	6.3	14	.1	.02	<.01
Upper Jephtha Lake near Breedsville	--	--	--	--	--	--
	1.0	8.9	19	.1	<.01	<.01
Brandywine Lake near Gobles	.4	5.6	4.0	<.1	.02	.01
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	1.7	23	13	.1	.01	<.01
Mill Lake near Gobles	.7	16	8.0	.1	.02	<.01
Silver Lake near Grand Junction	1.1	11	15	.1	<.01	<.01
Saddle Lake near Grand Junction	--	--	--	--	--	--
	.1	12	9.0	.1	.04	<.01
Muskrat Lake near Gobles	1.4	10	8.0	.1	.02	<.01
Clear Lake near Kendall	.4	6.4	14	.1	<.01	<.01

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Nitrogen, nitrate total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)	Cyanide, total (mg/L as CN)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	<0.01	0.50	0.50	0.01	0.02	--
Gravel Lake near Marcell	<.01	--	--	< .01	.05	--
Round Lake at Sister Lakes	<.01	2.8	2.8	< .01	.02	<0.01
Cedar Lake near Marcellus	--	--	--	--	--	--
	<.01	.90	.90	.02	.02	--
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	<.01	.40	.40	< .01	.04	--
Keeler Lake near Keeler	--	--	--	--	--	--
	<.01	.20	.20	< .01	< .01	--
Bankson Lake near Lawton	2.3	.59	2.9	< .01	.02	<.01
Lake of the Woods near Decatur	--	--	--	--	--	--
	<.01	1.0	1.0	< .01	.04	--
Huzzys Lake near Lawton	<.01	.30	.30	< .01	.01	--
Eagle Lake near Decatur	<.01	.30	.30	< .01	< .01	<.01
Christie Lake near Lawrence	<.01	.50	.50	< .01	.01	--
Three Mile Lake near Paw Paw	<.01	.89	.89	< .01	.01	<.01
Shafer Lake near Lawrence	<.01	.50	.50	< .01	.02	<.01
Cora Lake near Lawrence	--	--	--	--	--	--
	<.01	.50	.50	< .01	.01	--
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	<.01	1.5	1.5	.02	.02	<.01
Brownwood Lake near Paw Paw	<.01	3.9	3.9	< .01	.02	<.01
Van Auken Lake near McDonald	--	--	--	--	--	--
	<.01	.78	.80	< .01	.03	--
School Section Lake near Bangor	<.01	1.4	1.4	< .01	.05	<.01
School Section Lake near Glendale	<.01	.70	.70	< .01	.03	<.01
Merriman Lake near Bangor	<.01	.88	.90	< .01	.02	--
Fish Lake near Gobles	<.01	.30	.30	< .01	.02	--
North Scott Lake near Bangor	<.01	.88	.90	.02	.02	<.01
Upper Jeptha Lake near Breedsville	--	--	--	--	--	--
	<.01	.50	.50	< .01	.03	--
Brandywine Lake near Gobles	<.01	20	20	< .01	.03	<.01
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	<.01	.59	.60	.03	.03	--
Mill Lake near Gobles	<.01	.98	1.0	.01	.02	<.01
Silver Lake near Grand Junction	<.01	.60	.60	< .01	.02	<.01
Saddle Lake near Grand Junction	--	--	--	--	--	--
	<.01	.56	.60	.02	.06	--
Muskrat Lake near Gobles	<.01	5.6	5.6	< .01	.02	--
Clear Lake near Kendall	<.01	.70	.70	< .01	.02	<.01

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Phenols (µg/L)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Carbon, organic dissolved (mg/L as C)	Solids, sum of constituents, dissolved (mg/L)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	--	98	120	23	4.7	133
Gravel Lake near Marcell	<1	122	130	11	3.7	142
Round Lake at Sister Lakes	<1	33	38	5.0	4.7	44
Cedar Lake near Marcellus	--	--	--	--	--	--
	--	113	120	8.0	4.8	125
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	--	8.0	6	.0	7.2	11
Keeler Lake near Keeler	--	--	--	--	--	--
	--	22	23	1.0	5.0	26
Bankson Lake near Lawton	1	81	91	10	6.1	92
Lake of the Woods near Decatur	--	--	--	--	--	--
	--	146	180	31	6.5	196
Huzzys Lake near Lawton	--	86	92	6.0	4.4	94
Eagle Lake near Decatur	<1	89	100	11	5.1	107
Christie Lake near Lawrence	--	98	120	20	4.6	116
Three Mile Lake near Paw Paw	<1	35	47	12	9.1	51
Shafer Lake near Lawrence	<1	113	130	17	5.2	146
Cora Lake near Lawrence	--	--	--	--	--	--
	--	86	98	12	5.3	112
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	<1	115	140	22	6.9	147
Brownwood Lake near Paw Paw	<1	102	120	18	6.0	129
Van Auken Lake near McDonald	--	--	--	--	--	--
	--	116	140	23	7.6	174
School Section Lake near Bangor	2	108	130	17	18	156
School Section Lake near Glendale	<1	112	120	11	8.2	134
Merriman Lake near Bangor	--	149	170	20	11	192
Fish Lake near Gobles	--	171	180	4.0	3.6	195
North Scott Lake near Bangor	<1	126	140	12	8.6	150
Upper Jephtha Lake near Breedsville	--	--	--	--	--	--
	--	149	170	19	6.3	186
Brandywine Lake near Gobles	5	23	34	11	20	40
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	--	134	160	24	7.7	190
Mill Lake near Gobles	<1	57	72	15	6.1	91
Silver Lake near Grand Junction	5	45	64	19	9.6	84
Saddle Lake near Grand Junction	--	--	--	--	--	--
	--	99	110	12	7.8	129
Muskrat Lake near Gobles	--	99	110	15	5.7	122
Clear Lake near Kendall	3	145	150	8.0	12	166

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Solids, residue at 180 deg. C, dissolved (mg/L)	Aluminum, total recoverable (µg/L as Al)	Arsenic, total (µg/L as As)	Barium, total recoverable (µg/L as Ba)	Boron, total recoverable (µg/L as B)	Chromium, total recoverable (µg/L as Cr)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	175	--	--	--	--	--
Gravel Lake near Marcell	147	30	3	<100	50	20
Round Lake at Sister Lakes	66	60	1	<100	50	10
Cedar Lake near Marcellus	--	--	--	--	--	--
	143	--	--	--	--	--
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	28	--	--	--	--	--
Keeler Lake near Keeler	--	--	--	--	--	--
	40	--	--	--	--	--
Bankson Lake near Lawton	102	50	2	<100	40	10
Lake of the Woods near Decatur	--	--	--	--	--	--
	227	--	--	--	--	--
Huzzys Lake near Lawton	117	--	--	--	--	--
Eagle Lake near Decatur	139	40	1	100	50	10
Christie Lake near Lawrence	141	--	--	--	--	--
Three Mile Lake near Paw Paw	60	50	1	<100	50	10
Shafer Lake near Lawrence	127	40	1	100	40	20
Cora Lake near Lawrence	--	--	--	--	--	--
	147	--	--	--	--	--
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	167	30	1	100	40	10
Brownwood Lake near Paw Paw	143	40	1	100	60	10
Van Auken Lake near McDonald	--	--	--	--	--	--
	204	--	--	--	--	--
School Section Lake near Bangor	217	40	3	<100	110	20
School Section Lake near Glendale	123	30	1	<100	50	20
Merriman Lake near Bangor	208	--	--	--	--	--
Fish Lake near Gobles	206	--	--	--	--	--
North Scott Lake near Bangor	162	10	1	100	40	10
Upper Jephtha Lake near Breedsville	--	--	--	--	--	--
	214	--	--	--	--	--
Brandywine Lake near Gobles	86	110	2	100	130	10
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	216	--	--	--	--	--
Mill Lake near Gobles	103	30	1	<100	60	<10
Silver Lake near Grand Junction	100	30	1	<100	70	20
Saddle Lake near Grand Junction	--	--	--	--	--	--
	162	--	--	--	--	--
Muskrat Lake near Gobles	133	--	--	--	--	--
Clear Lake near Kendall	190	80	1	<100	70	10

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Cobalt, total recoverable (µg/L as Co)	Copper, total recoverable (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lithium, dissolved (µg/L as Li)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	--	--	--	--	--	<4
Gravel Lake near Marcell	2	6	100	10	4	--
Round Lake at Sister Lakes	2	13	130	11	5	--
Cedar Lake near Marcellus	--	--	--	--	--	--
	--	--	--	--	--	<4
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	--	--	--	--	--	<4
Keeler Lake near Keeler	--	--	--	--	--	--
	--	--	--	--	--	<4
Bankson Lake near Lawton	2	7	100	4	1	--
Lake of the Woods near Decatur	--	--	--	--	--	--
	--	--	--	--	--	4
Huzzys Lake near Lawton	--	--	--	--	--	<4
Eagle Lake near Decatur	5	6	50	17	3	--
Christie Lake near Lawrence	--	--	--	--	--	<4
Three Mile Lake near Paw Paw	2	7	90	13	2	--
Shafer Lake near Lawrence	1	3	120	<3	3	--
Cora Lake near Lawrence	--	--	--	--	--	--
	--	--	--	--	--	<4
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	<1	5	80	<3	4	--
Brownwood Lake near Paw Paw	1	4	40	<3	3	--
Van Auken Lake near McDonald	--	--	--	--	--	--
	--	--	--	--	--	5
School Section Lake near Bangor	1	2	100	28	5	--
School Section Lake near Glendale	1	3	110	14	2	--
Merriman Lake near Bangor	--	--	--	--	--	5
Fish Lake near Gobles	--	--	--	--	--	4
North Scott Lake near Bangor	<1	7	80	<3	3	--
Upper Jephtha Lake near Breedsville	--	--	--	--	--	--
	--	--	--	--	--	4
Brandywine Lake near Gobles	2	4	670	300	3	--
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	--	--	--	--	--	<4
Mill Lake near Gobles	2	6	40	13	4	--
Silver Lake near Grand Junction	2	3	60	22	3	--
Saddle Lake near Grand Junction	--	--	--	--	--	--
	--	--	--	--	--	<4
Muskrat Lake near Gobles	--	--	--	--	--	<4
Clear Lake near Kendall	1	2	100	42	3	--

Table 30.--Chemical and physical characteristics of lakes, 1982--Continued

Lake	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Nickel, total recoverable (µg/L as Ni)	Strontium, total recoverable (µg/L as Sr)	Strontium, dissolved (µg/L as Sr)	Zinc, total recoverable (µg/L as Zn)
Crooked Lake at Sister Lakes	--	--	--	--	--	--
	--	--	--	--	41	--
Gravel Lake near Marcell	30	1	5	40	--	50
Round Lake at Sister Lakes	20	1	3	20	--	20
Cedar Lake near Marcellus	--	--	--	--	--	--
	--	--	--	--	33	--
Knickerbocker Lake near Decatur	--	--	--	--	--	--
	--	--	--	--	2	--
Keeler Lake near Keeler	--	--	--	--	--	--
	--	--	--	--	13	--
Bankson Lake near Lawton	30	1	3	30	--	30
Lake of the Woods near Decatur	--	--	--	--	--	--
	--	--	--	--	83	--
Huzzys Lake near Lawton	--	--	--	--	25	--
Eagle Lake near Decatur	10	5	2	30	--	20
Christie Lake near Lawrence	--	--	--	--	28	--
Three Mile Lake near Paw Paw	10	1	1	20	--	30
Shafer Lake near Lawrence	10	<1	2	50	--	10
Cora Lake near Lawrence	--	--	--	--	--	--
	--	--	--	--	28	--
Maple Lake at Paw Paw	--	--	--	--	--	--
Rush Lake near Toquin	40	2	6	70	--	30
Brownwood Lake near Paw Paw	40	<1	1	60	--	20
Van Auken Lake near McDonald	--	--	--	--	--	--
	--	--	--	--	150	--
School Section Lake near Bangor	70	6	3	140	--	10
School Section Lake near Glendale	30	14	2	70	--	10
Merriman Lake near Bangor	--	--	--	--	110	--
Fish Lake near Gobles	--	--	--	--	76	--
North Scott Lake near Bangor	40	11	6	90	--	10
Upper Jephtha Lake near Breedsville	--	--	--	--	--	--
	--	--	--	--	73	--
Brandywine Lake near Gobles	230	40	1	30	--	10
Great Bear Lake near Bloomingdale	--	--	--	--	--	--
	--	--	--	--	110	--
Mill Lake near Gobles	20	11	8	40	--	10
Silver Lake near Grand Junction	10	3	1	40	--	10
Saddle Lake near Grand Junction	--	--	--	--	--	--
	--	--	--	--	130	--
Muskrat Lake near Gobles	--	--	--	--	60	--
Clear Lake near Kendall	30	7	4	--	70	10

Table 34.--Chemical and physical characteristics of water from U.S. Geological Survey observation wells, 1981-82 [Analyses by U.S. Geological Survey]

Well number	Date of sample	Temperature (deg C)	Turbidity (FTU)	Color (platinum-cobalt units)	Specific Conductance (μmhos)	pH (units)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
4	Oct. 20, 1981	11.5	4.5	<1	525	7.6	10	56
5	Oct. 20, 1981	12.5	25	3	710	7.6	13	80
6	Oct. 21, 1981	11.5	70	2	370	7.4	16	46
7	Oct. 21, 1981	12.0	280	5	325	7.5	11	24
8D	Oct. 19, 1981	12.5	2.1	1	320	7.3	16	44
8S	Oct. 19, 1981	11.5	1.3	2	770	7.2	14	97
9	Oct. 20, 1981	11.5	60	5	240	7.0	8.1	33
11	Oct. 20, 1981	12.5	90	8	1,400	7.2	13	84
12	Oct. 21, 1981	12.0	5.4	16	240	7.4	11	29
13	Oct. 21, 1981	11.5	.50	1	380	7.4	9.7	40
15	Apr. 29, 1982	14.0	1.6	3	200	8.0	7.4	27
17	Oct. 23, 1981	11.5	4.6	4	475	7.3	15	60
19	Nov. 3, 1981	12.5	110	2	455	8.2	11	61
20	Oct. 22, 1981	11.5	8.1	2	520	7.2	14	68
21	Oct. 22, 1981	11.5	9.3	2	995	7.7	11	85
22	Oct. 23, 1981	11.0	<1.0	1	745	7.2	15	92
23	Oct. 23, 1981	11.5	17	4	605	7.3	17	67
26	Oct. 22, 1981	10.5	15	2	470	7.5	13	59
27	Nov. 4, 1981	11.5	20	2	520	7.6	13	70
28	Nov. 4, 1981	11.5	18	2	380	8.1	14	55
29	Oct. 22, 1981	11.5	1.0	2	380	7.5	12	46

Well number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)
4	25	12	1.5	9.4	4.4	0.4	0.18	<0.01
5	44	7.0	1.6	23	42	.1	.02	<.01
6	19	8.3	1.0	7.6	15	.2	.12	.01
7	9.9	31	2.4	6.8	5.9	.7	.61	.10
8D	13	11	1.1	3.2	1.5	.1	.09	.01
8S	33	40	1.5	120	24	<.1	.07	<.01
9	7.8	2.9	.5	5.3	37	<.1	.02	<.01
11	24	180	9.6	320	.9	.1	7.3	.01
12	9.1	1.6	1.9	5.1	17	<.1	.13	<.01
13	15	2.8	5.3	27	21	<.1	.05	<.01
15	8.0	2.1	.3	2.2	23	<.1	<.01	<.01
17	21	3.8	.7	5.0	21	.1	.16	<.01
19	27	2.2	.8	22	31	<.1	.03	.02
20	27	4.1	.8	3.8	34	.2	.05	<.01
21	37	11	20	110	69	<.1	4.9	<.01
22	39	3.8	1.0	16	19	.1	<.01	<.01
23	26	17	1.1	12	<.1	.2	.26	.01
26	26	3.6	.7	3.4	37	.1	.04	<.01
27	19	4.6	3.2	15	41	.2	.26	<.01
28	18	1.8	.7	2.9	18	.1	.05	<.01
29	18	3.7	.8	1.4	25	<.1	.02	.01

Table 34.--Chemical and physical characteristics of water from U.S. Geological Survey observation wells, 1981-82--Continued

Well number	Nitrogen, nitrate total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as P)	Cyanide, total (mg/L as Cn)	Phenols (μg/L)	Alkalinity, (mg/L as $CaCO_3$)
4	0.02	0.04	0.24	<0.01	0.02	<0.01	--	290
5	2.8	.39	3.2	.01	.05	.06	<1	320
6	.03	.17	.33	.02	.07	<.01	<1	190
7	.17	.05	.93	.19	.39	.02	--	160
8D	<.01	.14	.23	<.01	.02	<.01	--	190
8S	.04	.24	.35	<.01	<.01	.01	--	250
9	.01	<.01	.03	.02	.08	<.01	<1	81
11	.02	2.2	9.5	.02	.11	<.01	<1	200
12	.11	.14	.38	.01	.03	<.01	<1	91
13	1.7	.31	2.1	<.01	.02	.02	--	110
15	<.01	<.01	<.10	<.01	.02	<.01	<1	78
17	.02	.41	.59	<.01	.03	.01	--	210
19	11	.34	11	.02	.17	.00	2	190
20	.03	.27	.35	<.01	.01	.01	--	260
21	22	3.4	30	<.01	.03	<.01	<1	150
22	10	.39	10	<.01	.01	.01	--	320
23	.12	.28	.67	.02	.05	.01	--	270
26	.05	.18	.27	<.01	.03	<.01	<1	210
27	.03	.27	.56	.02	.06	.00	1	210
28	.03	.29	.37	<.01	.03	.00	3	200
29	.04	.22	.29	<.01	.02	<.01	--	170

Well number	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Carbon, organic dissolved (mg/L as C)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Aluminum, total recoverable (μg/L as Al)	Arsenic, total (μg/L as As)	Barium, total recoverable (μg/L as Ba)
4	240	0.0	1.0	294	312	1,100	21	200
5	380	61	2.0	403	461	5,000	2	200
6	190	3.0	2.9	228	226	--	13	300
7	100	.0	3.0	188	193	16,000	13	300
8D	190	.0	.9	210	201	300	9	100
8S	380	130	.3	481	489	<100	3	200
9	110	34	1.0	143	169	5,000	3	100
11	310	110	9.0	752	878	8,000	3	500
12	110	19	2.8	130	149	1,700	2	100
13	160	52	.4	187	241	40	3	100
15	100	22	--	117	120	30	2	<100
17	240	26	2.1	254	263	<200	2	100
19	260	74	1.0	269	305	2,500	2	<100
20	280	21	.7	309	320	<100	6	200
21	360	210	1.1	433	663	2,200	3	200
22	390	70	1.1	378	485	20	3	100
23	270	4.0	1.3	304	292	100	12	100
26	250	44	.7	270	269	1,500	3	100
27	250	43	.7	294	294	100	16	400
28	210	11	1.7	232	221	400	3	100
29	190	19	.4	209	203	30	3	100

Table 34.--Chemical and physical characteristics of water from U.S. Geological Survey observation wells, 1981-82--Continued

Well number	Beryllium, total recoverable (µg/L as Be)	Boron, total recoverable (µg/L as B)	Cadmium, total recoverable (µg/L as Cd)	Chromium, total recoverable (µg/L as Cr)	Cobalt, total recoverable (µg/L as Co)	Copper, total recoverable (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)
4	<10	40	<1	20	1	5	1,200	740
5	<10	70	<1	20	<1	8	2,500	3
6	<10	20	<1	10	4	13	6,000	180
7	<10	280	<1	70	14	530	25,000	34
8D	<10	10	<1	10	<1	10	890	140
8S	<10	140	<1	10	<1	8	790	680
9	<10	<10	<1	20	<1	7	3,300	55
11	<10	540	<1	20	1	9	8,100	3
12	<10	100	<1	10	2	6	2,500	850
13	<10	240	<1	10	<1	8	90	18
15	<10	<20	<1	20	<1	4	410	180
17	<10	<10	<1	10	<1	3	1,300	1,300
19	<10	90	<1	10	2	5	7,000	19
20	<10	10	<1	10	<1	4	1,000	770
21	<10	30	<1	10	3	10	3,000	7
22	<10	<10	<1	10	<1	8	130	12
23	<10	20	<1	10	1	4	2,500	1,600
26	<10	<10	<1	10	<1	8	2,700	400
27	<10	10	<1	<10	<1	14	2,000	1,700
28	<10	<10	<1	10	1	14	2,100	1,400
29	<10	10	<1	10	1	6	610	200

Well number	Lead, total recoverable (µg/L as Pb)	Lithium, total recoverable (µg/L as Li)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, total recoverable (µg/L as Hg)	Molybdenum, total recoverable (µg/L as Mo)	Nickel, total recoverable (µg/L as Ni)	Selenium, total (µg/L as Se)
4	4	20	20	17	<0.1	5	6	<1
5	92	10	70	19	<.1	2	7	<1
6	180	10	200	38	<.1	4	16	<1
7	70	50	620	48	.1	5	59	<1
8D	5	10	40	22	<.1	5	8	1
8S	1	10	70	76	<.1	3	6	<1
9	8	10	160	59	<.1	3	7	<1
11	26	10	310	1	<.1	3	13	<1
12	6	<10	120	70	.1	3	7	<1
13	<1	<10	10	3	<.1	4	3	<1
15	4	<10	40	35	<.1	1	3	<1
17	3	10	40	35	<.1	3	4	<1
19	3	<10	230	5	<.1	<1	2	<1
20	3	<10	40	29	<.1	4	4	1
21	17	<10	110	4	.1	3	9	<1
22	4	<10	10	5	<.1	3	3	<1
23	4	<10	40	29	<.1	5	3	<1
26	53	10	110	56	.1	4	15	<1
27	3	10	50	40	<.1	1	<1	<1
28	4	10	70	54	<.1	2	2	<1
29	5	<10	80	77	<.1	4	8	<1

Table 34.--Chemical and physical characteristics of water from U.S. Geological Survey observation wells, 1981-82--Continued

Well number	Silver, total recoverable (μg/L as Ag)	Strontium, total recoverable (μg/L as Sr)	Zinc, total recoverable (μg/L as Zn)
4	<1	800	30
5	<1	140	2,300
6	<1	420	600
7	<1	3,500	2,000
8D	<1	160	40
8S	<1	180	100
9	<1	80	210
11	<1	280	630
12	<1	60	110
13	<1	80	40
15	<1	40	20
17	<1	140	60
19	<1	90	2,000
20	<1	150	40
21	<1	220	250
22	<1	90	40
23	<1	250	40
26	<1	70	840
27	<1	240	80
28	<1	80	100
29	<1	70	50

Table 35.--Chemical and physical characteristics of water from domestic wells, 1982 [Analyses by U.S. Geological Survey]

Well number	Date of sample	Temperature (deg C)	Turbidity (FTU)	Color (platinum-cobalt units)	Specific conductance (umhos)	pH (units)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
D-30	July 12, 1982	15.0	23	5	420	7.7	8.8	65
D-31	July 12, 1982	16.0	<1.0	3	340	8.0	9.3	39
D-32	July 14, 1982	16.0	5.4	5	460	7.5	12	60
D-33	Sept. 7, 1982	15.0	<1.0	6	605	7.4	11	86
D-34	July 14, 1982	18.5	6.6	3	620	7.4	14	73
D-35	July 13, 1982	18.0	<1.0	5	440	7.7	9.4	54
D-36	Sept. 7, 1982	17.0	<1.0	5	160	7.5	10	21
D-37	July 13, 1982	18.0	<1.0	5	220	7.8	6.1	29
D-38	July 13, 1982	16.0	<1.0	5	465	8.0	11	20
D-39	July 15, 1982	15.0	3.5	5	470	8.0	16	55
D-40	July 29, 1982	15.0	4.9	5	500	7.6	13	60
D-41	Sept. 7, 1982	17.0	<1.0	5	600	7.6	16	57
D-42	July 13, 1982	21.0	<1.0	5	215	8.0	7.7	26
D-43	July 7, 1982	12.0	6.0	5	450	7.8	16	54
D-44	July 14, 1982	19.0	1.1	3	575	7.5	11	69
D-45	July 8, 1982	15.0	<1.0	8	225	7.9	10	31
D-46	Sept. 8, 1982	14.0	4.5	5	500	7.4	8.7	74
D-47	July 8, 1982	12.0	6.8	3	420	7.9	13	56
D-48	July 14, 1982	16.0	<1.0	3	560	7.4	11	72
D-49	Sept. 8, 1982	17.0	<1.0	4	370	8.0	8.9	48
D-50	Sept. 3, 1982	21.0	<1.0	8	850	7.3	12	110

Well number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)
D-30	18	3.8	1.1	11	6.0	<0.1	0.16	<0.01
D-31	12	11	.8	30	16	<.1	<.01	<.01
D-32	21	4.0	.2	7.7	18	<.1	.32	.01
D-33	31	3.6	15	19	24	.2	.03	<.01
D-34	38	3.2	.7	8.4	52	.2	.04	<.01
D-35	21	5.5	.6	6.9	55	.2	.02	<.01
D-36	5.2	1.3	6.2	2.9	35	<.1	.01	<.01
D-37	7.3	3.3	2.9	4.5	18	.1	.02	.02
D-38	7.7	65	2.3	33	30	1.5	.48	<.01
D-39	24	13	1.0	5.9	7.0	.3	.20	<.01
D-40	23	4.7	.5	7.0	18	.1	.14	.01
D-41	33	44	2.2	47	11	.5	.29	<.01
D-42	7.5	4.5	1.2	12	13	<.1	.07	<.01
D-43	23	6.5	.6	3.5	14	.2	.16	.01
D-44	32	2.3	.7	4.0	58	.2	.02	<.01
D-45	9.8	1.4	.5	1.6	15	<.1	.02	<.01
D-46	29	3.0	.8	8.3	62	.2	<.01	<.01
D-47	19	3.4	.4	2.6	19	.1	--	--
D-48	27	4.7	2.3	11	26	.1	.02	<.01
D-49	17	2.6	.2	8.5	25	.1	<.01	<.01
D-50	32	55	6.0	82	76	.1	.10	<.01

Table 35.--Chemical and physical characteristics of water from domestic wells, 1982--Continued

Well number	Nitrogen, nitrate total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, total (mg/L as PO_4)	Cyanide, total (mg/L as Cn)	Phenols (µg/l)	Alkalinity (mg/l as $CaCO_3$)
D-30	<0.01	0.74	0.90	0.04	0.12	<0.01	2	231
D-31	1.5	.70	2.2	.02	.06	<.01	<1	112
D-32	<.01	.08	.40	.04	.15	<.01	1	232
D-33	25	.17	25	<.01	--	<.01	<1	260
D-34	<.01	.16	.20	<.01	--	<.01	6	293
D-35	<.01	.28	.30	<.01	--	<.01	<1	152
D-36	5.7	.29	6.0	<.01	--	<.01	<1	27
D-37	.72	.48	1.2	<.01	--	.01	5	86
D-38	<.01	.42	.90	<.01	.03	<.01	<1	120
D-39	<.01	.20	.40	<.01	.03	<.01	<1	195
D-40	<.01	.16	.30	.02	.09	<.01	<1	254
D-41	<.01	.21	.50	.02	.18	<.01	<1	298
D-42	<.01	.23	.30	.02	.25	<.01	<1	78
D-43	<.01	<.01	.17	<.01	.03	<.01	1	238
D-44	<.01	.08	.10	<.01	--	<.01	<1	261
D-45	.34	--	.36	.03	.09	<.01	<1	106
D-46	<.01	.20	.20	<.01	.03	<.01	<1	272
D-47	--	--	--	--	--	<.01	1	194
D-48	7.0	.28	7.3	<.01	--	<.01	<1	248
D-49	14	.20	14	<.01	--	<.01	<1	121
D-50	15	.30	15	<.01	.09	<.01	<1	278

Well number	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Carbon, organic dissolved (mg/L as C)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Aluminum, total recoverable (µg/L as Al)	Arsenic, total (µg/L as As)	Barium, total recoverable (µg/L as Ba)
D-30	240	5.0	1.8	254	268	20	2	<100
D-31	150	35	1.0	185	245	20	1	<100
D-32	240	4.0	2.9	263	283	100	4	<100
D-33	340	82	1.4	346	351	30	1	200
D-34	340	46	.9	366	395	10	11	100
D-35	220	69	1.0	244	283	10	1	<100
D-36	74	47	1.7	98	112	70	1	100
D-37	100	16	4.2	123	141	20	<1	<100
D-38	82	.0	2.2	243	288	20	7	200
D-39	240	41	1.8	240	290	<100	18	100
D-40	240	.0	4.2	279	289	100	3	200
D-41	280	.0	1.1	390	380	30	14	200
D-42	96	18	1.5	119	138	30	1	<100
D-43	230	.0	.8	261	266	--	9	100
D-44	300	43	1.0	334	378	<10	1	<100
D-45	120	12	1.0	133	145	20	2	<100
D-46	300	32	1.0	350	354	30	2	100
D-47	220	24	1.0	230	242	30	2	<100
D-48	290	43	1.1	303	374	<10	1	<100
D-49	190	69	.8	183	300	30	1	<100
D-50	410	130	1.5	540	623	20	1	<100

Table 35.--Chemical and physical characteristics of water from domestic wells, 1982--Continued

Well number	Boron, total recoverable (μg/L as B)	Chromium, total recoverable (μg/L as Cr)	Cobalt, total recoverable (μg/L as Co)	Copper, total recoverable (μg/L as Cu)	Iron, total recoverable (μg/L as Fe)	Iron, dissolved (μg/L as Fe)	Lead, total recoverable (μg/L as Pb)	Manganese, total recoverable (μg/L as Mn)
D-30	10	10	1	6	2,400	1,400	5	120
D-31	10	10	5	10	200	<3	6	<10
D-32	40	20	4	12	1,800	33	5	110
D-33	20	10	4	9	160	9	5	<10
D-34	30	10	3	12	880	270	4	50
D-35	10	10	2	19	330	13	4	30
D-36	20	10	4	5	50	16	5	340
D-37	40	10	2	27	110	42	4	50
D-38	710	10	4	13	310	18	4	<10
D-39	80	<10	3	21	1,600	340	5	30
D-40	<10	10	<1	23	1,800	130	6	60
D-41	170	10	2	4	560	70	7	20
D-42	20	10	4	12	300	160	3	120
D-43	20	10	<1	3	1,100	490	<1	30
D-44	10	<10	1	2	790	130	5	20
D-45	20	10	<1	4	80	12	<1	10
D-46	20	20	2	13	1,000	760	13	160
D-47	20	10	<1	4	1,700	20	<1	30
D-48	20	<10	1	7	100	19	4	10
D-49	220	10	1	6	190	8	10	10
D-50	440	20	<1	15	160	<3	3	10

Well number	Manganese, dissolved (μg/L as Mn)	Nickel, total recoverable (μg/L as Ni)	Strontium, total recoverable (μg/L as Sr)	Zinc, total recoverable (μg/L as Zn)
D-30	130	2	40	130
D-31	2	2	<10	270
D-32	85	4	90	320
D-33	1	2	90	90
D-34	46	3	100	420
D-35	18	1	50	220
D-36	330	3	80	60
D-37	49	2	40	120
D-38	6	2	5,600	230
D-39	19	1	380	170
D-40	63	<1	160	120
D-41	18	3	1,100	400
D-42	110	4	40	40
D-43	29	3	140	40
D-44	18	2	60	560
D-45	1	3	70	60
D-46	140	5	70	370
D-47	28	2	80	150
D-48	<1	2	50	140
D-49	1	3	60	200
D-50	5	2	150	150