

STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

**WATER SUPPLY REPORT NUMBER ONE
SUMMARY OF GROUND-WATER CONDITIONS
IN MICHIGAN
1956**

by
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U. S. Geological Survey

*Prepared in cooperation with the
United States Department of the Interior
Geological Survey*

1957

Contents

INTRODUCTION.....	1
<i>Scope of this Report</i>	<i>2</i>
<i>Open-File Data</i>	<i>2</i>
<i>Well-Numbering Systems</i>	<i>2</i>
<i>Acknowledgements</i>	<i>3</i>
PRECIPITATION AND TEMPERATURE	3
PUMPAGE	3
PRINCIPLES OF OCCURRENCE OF GROUND WATER	3
INTERPRETATIONS OF WATER-LEVEL FLUCTUATIONS	4
<i>Climatic Influences</i>	<i>4</i>
<i>Fluctuations Due to Discharge from Wells</i>	<i>4</i>
<i>Monthly Statements of Conditions.....</i>	<i>4</i>
<i>Northern Peninsula.....</i>	<i>5</i>
Western Half	5
Menominee River Basin	5
Eastern Half	6
Chippewa County	6
Mackinac County.....	6
Schoolcraft County	6
<i>Southern Peninsula</i>	<i>7</i>
Northern Half.....	7
Southern Half	7
Branch County.....	7
Calhoun County.....	7
Cass County.....	8
Clinton County	8
Eaton County.....	8
Genesee County	9
Gratiot County	9
Ingham County	10
Kalamazoo County	10
Oakland County.....	11
St. Joseph County	11
Washtenaw County	11

Figures

Figure 1. <i>Location of observation wells in Michigan, 1956.</i>	<i>3</i>
Figure 2. <i>Hydrographs of selected water-table observation wells tapping the glacial drift, levels of Lakes Michigan and Huron, and cumulative departure of precipitation from the statewide long-term mean, 1937-56.</i>	<i>4</i>
Figure 3. <i>Hydrograph of well 43N 35W 20-1 near Iron River, and cumulative departure of precipitation from long-term mean at Stambaugh, 1947-1956.</i>	<i>6</i>
Figure 4. <i>Hydrograph of well 46N 4W 24-1 near Racoon and graphs of temperature and precipitation recorded at Sault Ste. Marie, 1952-1956.</i>	<i>6</i>
Figure 5. <i>Hydrograph of well 45N 13W 16-1 near Germfask, and total monthly precipitation at Germfask, 1956.</i>	<i>6</i>
Figure 6. <i>Hydrograph of well 24N 2W 20-1 near Roscommon, daily precipitation, and maximum and minimum temperatures at Grayling Military Reservation, 1956.</i>	<i>7</i>
Figure 7. <i>Hydrograph of well 6S 6W 22-1, monthly precipitation, and pumpage at Coldwater, 1949-1956.</i>	<i>7</i>
Figure 8. <i>Hydrograph of well 2S 8W 2-1 at Battle Creek, 1947-1956.</i>	<i>8</i>
Figure 9. <i>Hydrograph of well 2S 8W 14-1 showing effects of gradual discontinuance of municipal pumping from the drift at Goguac well field by the City of Battle Creek, 1947-1956.</i>	<i>8</i>
Figure 10. <i>Hydrograph of well 1S 7W 10-1 near Battle Creek, and monthly precipitation at Battle Creek, 1947-1956.</i>	<i>8</i>
Figure 11. <i>Hydrograph of well 6S 16W 1-1, monthly pumpage at Dowagiac and precipitation at Eau Claire, 1949-1956.</i>	<i>9</i>
Figure 12. <i>Hydrograph of well 4N 4W 2-1 at Grand Ledge, 1948-1956.</i>	<i>9</i>
Figure 13. <i>Hydrographs of wells 7N 7E 20-2 and 17-1, monthly precipitation, and cumulative departure of precipitation from long-term mean, at Flint, 1947-1956.</i>	<i>9</i>
Figure 14. <i>Hydrographs of wells 11N 3W 3-5 and 12N 3W 33-1, monthly pumpage, and cumulative departure of precipitation from long-term mean, at Alma, 1947-1956.</i>	<i>9</i>
Figure 15. <i>Hydrograph of well 4N 2W 22-1, cumulative pumpage, and cumulative departure of precipitation from long-term mean, at Lansing, 1947-1956.</i>	<i>10</i>
Figure 16. <i>Hydrograph of well 4N 2W 31-1 near Lansing, 1947-1956.</i>	<i>10</i>
Figure 17. <i>Hydrograph of well 2N 1W 5-1 at Mason, 1948-1956.</i>	<i>10</i>
Figure 18. <i>Hydrograph of wells 2S 11W 20-7 and 27-52, and cumulative departure of precipitation from long-mean, at Kalamazoo, 1947-1956.</i>	<i>11</i>
Figure 19. <i>Hydrograph of well 3N 10E 32-1 at Pontiac, 1947-1956.</i>	<i>11</i>
Figure 20. <i>Hydrograph of well 4S 6E 9-1 at Ypsilanti State Hospital, Washtenaw County, showing effects of pumping from the hospital well field, 1947-1956.</i>	<i>11</i>
Figure 21. <i>Hydrograph of well 3S 7E 24-5 at Ypsilanti Township well field, pumpage, and cumulative departure</i>	

INTRODUCTION

This paper is the first of a series of reports of ground-water levels and related hydrologic data covering the State of Michigan to be published by the Department of Conservation. The program of measurement of ground-water levels and collection of other pertinent information in Michigan by the United States Geological Survey is maintained in cooperation with the Michigan Department of Conservation, and the Water Resources Commission of Michigan.

Records and interpretations of water levels and artesian pressures from 1935 through 1955 have been published in the annual series of U. S. Geological Survey Water-Supply Papers entitled "Water levels and artesian pressures in the United States". The following tabulation gives the numbers of those papers containing water-level data for Michigan:

<u>Year</u>	<u>No.</u>	<u>Year</u>	<u>No.</u>	<u>Year</u>	<u>No.</u>
1935	777	1942	944	1949	1156
1936	817	1943	986	1950	1165
1937	840	1944	1016	1951	1191
1938	845	1945	1023	1952	1221
1939	886	1946	1071	1953	1265
1940	906	1947	1096	1954	1321
1941	936	1948	1126	1955	1404

Beginning in 1956, the U. S. Geological Survey discontinued publication of its series of annual reports preparatory to publishing water-level records at five-year intervals. The new Federal series will contain records collected from a basic network of about 50 to 75 observation wells in Michigan that were chosen to reflect general conditions of ground-water trends and storage in the State. Interpretive texts and illustrations were discontinued.

The needs of the State, however, call for a more comprehensive background of ground-water information, and as a result the present report is based on periodic measurements made during 1956 in about 275 observation wells including those in the Federal network. Continuous recording gages were in operation on 18 of the wells. The present report is designed to supplement the new Federal report series, to provide for a continuation of publications of interpretive text and illustrations, and to make basic information concerning ground-water conditions in Michigan readily available to Federal and State agencies, municipalities, industries, well drillers, farmers, and the general public.

Scope of this Report

The present report summarizes ground-water conditions in selected urban areas and in other areas which are deemed representative of general ground-water conditions in the State. Hydrographs showing trends of ground-water level in selected wells are included herein in lieu of tabulations of measurements. These hydrographs show fluctuations in response to climate, pumpage, and other factors. Table 1 gives the location and other pertinent information for observation wells in which water-level measurements were made in 1956 and table 2 gives the extremes of water levels in each observation well.

Open-File Data

Hydrologic data including tabulations of chemical analyses, water level measurements and hydrographs, temperature measurements, well-records, well logs, aquifer-test data, and unpublished reports are retained on file for public inspection. They may be consulted at the Ground Water Branch office of the U. S. Geological Survey, 407 Capitol Savings and Loan Building, Lansing; or at the Water Resources Section of the Michigan Geological Survey, Mason Building, Lansing. Records for the Northern Peninsula are also on file in the office of the Michigan Geological Survey, State Office Building, Escanaba.

U. S. Geological Survey Water-Supply Papers may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., or consulted at any of the above-listed offices, and in major university and municipal libraries in the State. The Federal survey also publishes monthly a summary statement entitled "Water Resources Review" which evaluates streamflow and ground-water levels in the United States. Those statements, along with spring and annual summaries may be obtained free on application to the Director, U. S. Geological Survey, Washington 25, D. C.

Progress reports of cooperative ground-water investigations covering specific areas of the State are published from time to time by the Michigan Department of Conservation. Those reports also are available for inspection at the offices of the Department and in major university and municipal libraries, and, if not out of print, may be purchased from the Department.

Well-Numbering Systems

The well-numbering system now used in Michigan indicates the location of wells within the rectangular subdivisions of the public lands, with reference to the Michigan meridian and base line (fig. 1). The first two segments of a well number designate the township and range; the third segment designates both the section and a serial number assigned arbitrarily to each well within the section. Thus, well number 32N 6E 16-1 is well number 1 in section 16, Township 32 North, Range

6 East. In the several small areas of the State where the rectangular subdivisions have not been made, wells are numbered as above by projection of the rectangular subdivisions to those areas.

The system outlined above supersedes the well-numbering system formerly used. In that system, wells were numbered according to the county, city, or township in which they are situated. The first segment of the well number consisted of an upper and a lower-case letter indicating the county in which the well is located. The second segment indicated the city or political township. Uppercase letters were used for cities, villages, or towns. An uppercase letter followed by a lower-case letter was used for the township designation. Numbers formerly assigned to each well are listed in table 1.

Acknowledgements

Cooperative ground-water investigations by the U. S. Geological Survey in Michigan are directed jointly by A. N. Sayre, Chief of the Ground Water Branch, U. S. Geological Survey, Washington, D. C., and W. L. Daoust, State Geologist, Michigan Department of Conservation, Lansing, and are under the direct supervision of Morris Deutsch, Acting District Geologist, Lansing.

Special thanks are given to Messrs, J. G. Rulison, Chief, Water Resources Section, Lansing, and A. E. Slaughter, Geologist, Escanaba, both of the Michigan Geological Survey, who helped in the planning of this report. Appreciation is extended also to personnel of the Federal and State agencies, and of various industrial concerns and municipalities who serve as volunteer water-level observers.

PRECIPITATION AND TEMPERATURE

Precipitation in 1956 ranged from 63 percent of the long-term mean at Paw Paw to 119 percent at Flint. The southeast and east-central part of the Southern Peninsula received more than the usual precipitation, whereas small to large deficiencies were recorded in the remainder of the State. Deficiencies were large in the southwestern part of the Southern Peninsula.

Precipitation was comparatively light during the winter, but unseasonably cool, wet weather followed in the spring and early summer months. During late August rainfall was below normal, and in September and October was reported to be the lightest on record at many locations. Precipitation continued to be below average for the remainder of the year, except during November in the northern part of the State.

Temperatures for the year were near or somewhat below the long-term averages.

Precipitation and temperature figures in this report are based on averages compiled by the U. S. Weather Bureau. The Weather Bureau's figures for the cities of Lansing and Sault Ste. Marie are based on a normal for the period 1921 to 1950.

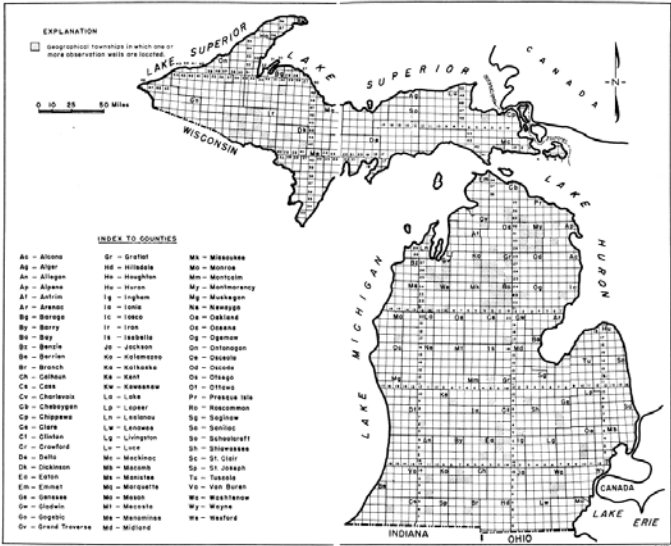


Figure 1. Location of observation wells in Michigan, 1956.

PUMPAGE

Trends of ground-water withdrawal in selected urban areas are discussed under the appropriate county headings, and in addition, some of the pumpage figures are graphically depicted with appropriate water-level hydrographs for the last decade of record. Cool, wet weather during the spring and summer months resulted in increased recharge, decreased evapotranspiration losses, and reduced ground-water withdrawals for sprinkling, air conditioning, and other warm weather uses. Restrictions on lawn sprinkling were few and occurred only where facilities were inadequate for peak demands.

PRINCIPLES OF OCCURRENCE OF GROUND WATER

The source of the ground water of Michigan is precipitation. The average annual precipitation over the State is about 30 inches. However, much of this water is lost by evaporation, by transpiration, and by surface runoff before it can enter the ground-water reservoirs.

The amount of precipitation which becomes ground water is influenced by a number of factors: the duration, intensity, and type of precipitation; the density and types of vegetation; the topography; and the porosity and permeability of the soil, subsoil, and underlying rock formations in the areas receiving precipitation.

A water-bearing bed that yields water in usable quantities is termed an aquifer. On the basis of water occurrence, aquifers may be classified as water table or

artesian. In a water-table aquifer, ground water is unconfined and the upper surface of the saturated zone is termed the water table. In an artesian aquifer, ground water is confined under pressure between relatively impermeable strata (strata through which water does not move readily). The water in a tightly cased well finished in an artesian aquifer will rise above the bottom of that bed, and, if under sufficient pressure, will flow at or above land surface.

INTERPRETATIONS OF WATER-LEVEL FLUCTUATIONS

Climatic Influences

Water levels in the State fluctuate with seasonal changes in the rate of recharge to, and discharge from, the aquifers. During the spring thaw, water levels in wells normally rise in response to the infiltration of rain and melting snow. Summer temperatures cause an increase in evapotranspiration resulting in declines in water levels. Rainfall during the growing season generally has slight effect on the rate of decline as vegetation tends to utilize most of the available moisture. Water from rains of high intensity and short duration tend to run off to surface streams. In the fall, after freezing temperatures end the growing season and transpiration ceases, precipitation may cause rises in water levels. However, the usual summer decline in stage may be continued by a deficiency of precipitation or by an early general freeze which tends to impede infiltration.

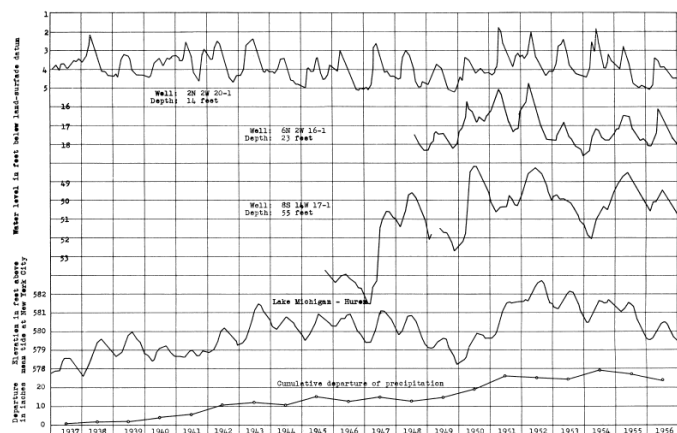


Figure 2. Hydrographs of selected water-table observation wells tapping the glacial drift, levels of Lakes Michigan and Huron, and cumulative departure of precipitation from the statewide long-term mean, 1937-56.

Fluctuations Due to Discharge from Wells

Generally, ground water is a renewable natural resource as it is intermittently or continually being replaced directly or indirectly by precipitation. If an aquifer is to be developed by means of wells so that a long-term yield can be obtained without substantially dewatering the aquifer, then equilibrium must exist between the rate of

recharge to the aquifer and the rate of discharge from the aquifer. Any aquifer in its natural state (before it is tapped by wells) is in approximate dynamic equilibrium. When water is discharged from an aquifer by means of a well, an increase results, at least temporarily, in the rate of total discharge from the aquifer. Pumping causes a cone-shaped depression in the water table or piezometric surface that expands with time around the discharging well. With continued discharge, the cone of depression will continue to expand until the resultant lowering of water levels causes a decrease in discharge from the aquifer, or an increase in recharge to the aquifer, or a combination of both, which restores the aquifer to a state of equilibrium.

Wells within the cone of depression are affected by the lowering of water levels or artesian pressures. Thus, a well tapping an aquifer may be affected by the discharge of other wells that tap the same aquifer. In the case of several or many discharging wells, a composite cone of depression results, that may extend over a large area. The result of the lowering of water levels over a large area may cause a considerable increase in the rate of recharge to, or a considerable decrease in the rate of natural discharge from, the aquifer. A lowering of the water level, therefore, is necessary in the utilization of a ground-water reservoir or aquifer.

Figure 2 shows water levels in selected observation wells tapping the glacial drift in Roscommon, Clinton, and Cass Counties, the cumulative departure from normal precipitation, and the Lake Michigan-Huron levels for the period 1937 to 1956, inclusive. As shown by the illustration considerable correlation exists between these water-table wells, annual precipitation, and lake levels.

Monthly Statements of Conditions

Following are general statements of ground-water conditions in the State for each month of the year. The statements are based, for the most part, on ground-water levels which fluctuate in response to natural conditions of recharge, storage, and discharge.

January. Seasonal declines of ground-water levels continued throughout most of the State. Stages generally were well below average and in the Thumb area reached a new low for the period of record.

February. In the southern third of the State, recharge from snowmelt during the latter part of the month was indicated by a rise of stage in ground-water reservoirs of shallow depth. However, in aquifers where the depth to water is appreciable, declines in stage were generally prevalent, and a significant proportion of the wells reached the lowest stage of the past 5 to 10 years of record.

In the northern two-thirds of the State, cold weather limited recharge opportunity and most observation wells showed declines in stage. Although February stages were considerably below average in most of this

northerly area, the water levels in surficial aquifers of the western part of the Northern Peninsula remained at stages above the average of the past decade.

March. In the Southern Peninsula the recent trend of low ground-water levels continued, resulting in record and near-record lows for March. Although above-average temperatures and heavy precipitation early in the month caused ground-water stages to rise somewhat, the principal result was high surface runoff rather than substantial recharge to the ground. Low temperatures during the latter part of the month effectively impeded early spring recharge.

Seasonal declines continued in the Northern Peninsula as winter conditions prevailed. Ground-water levels were above average in the western half of the Peninsula and below average in the eastern half.

April. Seasonal rises of ground-water levels were observed in the drift aquifers of the Northern Peninsula and in those of the northern half of the Southern Peninsula. In the southern half of the Southern Peninsula, ground-water levels remained low throughout most of the month, but rose sharply in shallow drift aquifers after several days of intense precipitation at the close of the month. However, month-end stages in most wells throughout the State were below average for the period of record.

May. In the southern half of the Southern Peninsula, ground-water levels in most wells rose sharply in response to intense precipitation during the first two weeks of the month. The highest stages since 1952 were observed in wells tapping the surficial sands and gravels. Although average to below-average levels persisted in the deeper drift and rock aquifers, the levels generally rose toward the end of the month. Elsewhere, precipitation was deficient and water levels were below average, except in the western half of the Northern Peninsula.

June. In the western half of the Northern Peninsula, ground-water levels were at average stages, but in the eastern half of the Peninsula stages were below average.

In the northern half of the Southern Peninsula, the water level in the index well at Roscommon declined to a near-record low stage. In the southern half of the Southern Peninsula, water levels declined seasonally. Levels in most shallow wells in the glacial drift were at above-average stages, but levels in deeper wells tapping the rock aquifers remained below average.

July. In the Northern Peninsula and northern half of the Southern Peninsula, water levels in observation wells rose slightly during the month. Stages in many wells in the southern half of the Southern Peninsula declined somewhat, but the declines were less than usual for the season and resulted in the highest July stages since 1952.

At the end of the month, water levels throughout the state were generally near the average for the period of record.

August. Seasonal declines of water level in most wells were somewhat less than usual and at the end of the month the levels were at or above the average for the period of record. Local rises in stage were observed in the drift aquifers of the Northern Peninsula and in the shallow drift aquifers of the Southern Peninsula.

September. In the Southern Peninsula, water levels declined seasonally but remained at average to above-average stages, although precipitation was deficient. For the most part, the effects of the deficiency of precipitation were offset by low temperatures which resulted in reduced evapotranspiration demands.

In the Northern Peninsula, water levels rose in response to moderate rainfall, and at the end of the month the levels were above average for the period of record.

October. Ground-water levels throughout most of the State declined from the relatively high levels of the summer to about-average stages by the end of October. Locally, in the western half of the Northern Peninsula and in the southwestern part of the Southern Peninsula, water levels were above average despite seasonal declines. Although the weather was unusually dry and warm, the declines of ground-water level were moderate because evapotranspiration losses were rather small since the growing season was effectively halted by the killing frosts of September.

November. Ground-water levels continued to decline in most areas of the State. Notwithstanding the appreciable deficiency of precipitation over the past several months, stages in ground-water reservoirs are, in general, only slightly below average in the Southern Peninsula and at or above average in the Northern Peninsula.

December. In the Southern Peninsula at the close of the year, ground-water levels generally were at or only slightly below average stages of the past decade despite the considerable deficiency of precipitation during the latter half of the year. The high stages of last Spring coupled with a short growing season sustained ground-water reservoirs through the recent drought period.

In the Northern Peninsula, ground-water stages remained above average through the end of the year.

Northern Peninsula

Western Half

Menominee River Basin. Most observation wells in this basin are finished at shallow depth in glacial sand and gravel deposits of Pleistocene age. The water levels are a reflection of natural storage.

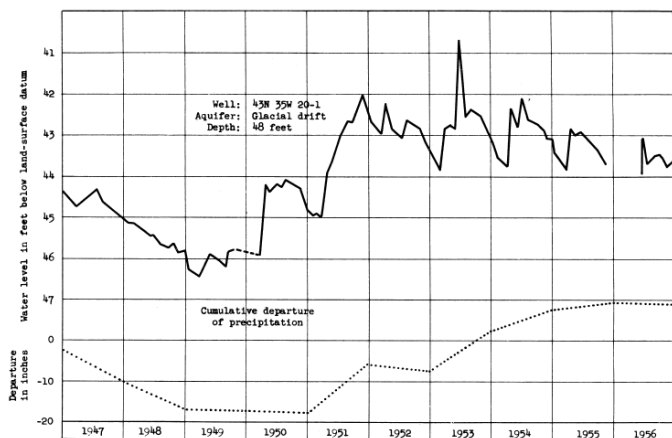


Figure 3. Hydrograph of well 43N 35W 20-1 near Iron River, and cumulative departure of precipitation from long-term mean at Sambaugh, 1947-1956.

Seasonal winter declines of water levels continued until April when sharp rises from infiltration of snowmelt and rainfall were observed. The decline in water levels which normally occurs during the growing season was tempered by recharge derived from above-average precipitation in the May to August period, and as a result, summer levels were above average. The early fall months were dry, but some rainfall and snowmelt was recharged to the aquifers during November. At the end of the year, levels were about average and a foot higher than at the end of 1955.

Figure 3 shows the hydrograph of well 43N 35W 20-1, and the cumulative departure of precipitation from the long-term mean. This well is used as an index of trends of water level for the area.

Northern Peninsula

Eastern Half

Chippewa County. Well 46N 4W 24-1, near Raco, is finished in glacial drift. The decline in water levels which began in May 1955 continued until April 1956 as a result of deficient precipitation (fig. 4). The subsequent rise that continued until mid-August was the result of spring thaws and above-average precipitation during the late spring and most of the summer. The decline which followed continued to the end of the year and was due to deficient precipitation in October and to normal seasonal influences in November and December.

Mackinac County. Observations in two wells (42N 2W 7-1 and 5W 23-1) in Mackinac County were begun in 1956. Although the periods of record for these wells are short, it is believed that the water levels fluctuate principally in response to climatic conditions.

Observations were begun in June, 1956 in well 42N 2W 7-1 which taps the Engadine formation of Silurian age. The water level in the well rose sharply in response to heavy rains in late June and early July. Much of the precipitation during this period entered the ground-water reservoir, as the soil moisture and plant requirements

had been supplied by snowmelt and earlier spring rains. Locally solution openings along joint fractures in the Engadine formation provide direct avenues for movement of water to the aquifer. Precipitation during later summer months was of insufficient quantity to materially affect the water level in the well. Fall rains following the end of the growing season caused a slight rise in the water level. The advent of cold weather and precipitation in the form of snow impeded recharge and a seasonal decline continued to the end of the year.

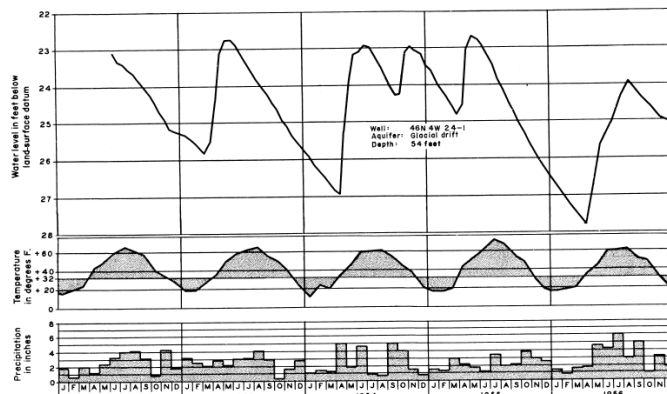


Figure 4. Hydrograph of well 46N 4W 24-1 near Raco and graphs of temperature and precipitation recorded at Sault Ste. Marie, 1952-1956.

Schoolcraft County. Well 45N 13W 16-1, near Germfask, is finished in shales and limestones of Richmond age (Ordovician). Water levels in the observation well reflect changes in artesian pressure of the water in the limestone strata in the upper part of the rocks of Richmond age. Snowmelt and rainfall in the spring caused a rise in early April (fig. 5). Cool, wet weather during the summer months resulted in less than the usual seasonal declines of previous years. Water levels declined during late summer and fall, and rose from October to December, and the year-end stage was higher than at the end of 1955.

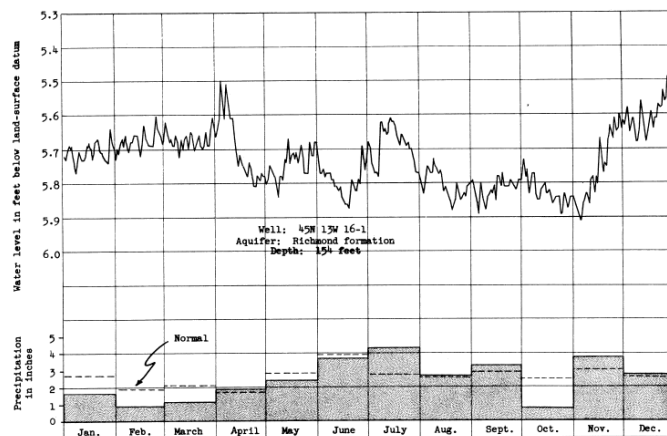


Figure 5. Hydrograph of well 45N 13W 16-1 near Germfask, and total monthly precipitation at Germfask, 1956.

Southern Peninsula

Northern Half

Well 24N 2W 20-1, near Roscommon, is used as an index of trends of ground-water level in the shallow drift aquifers in the northern half of the Southern Peninsula. Figure 6 is a graph of the daily water level for this index well, of precipitation, and of maximum and minimum temperatures at the Grayling Military Reservation for 1956. A decline in water level that began in July 1955, continued during the early part of the year. By the end of February, the water level in this well was only slightly above the lowest recorded for the past 22 years. Snowmelt in March induced a slight rise in stage. The water level rose sharply in April but the spring high water-level reading was below average. The seasonal decline which followed was gradual but levels were well below average for June. In August the water level rose above average for the first time since September 1955 in response to more than 13 inches of rain which fell in July and August. Relatively dry weather in September and October precluded the usual fall recharge to the aquifer and by the end of the year levels were about 0.3 foot below average but about 0.5 foot above the level recorded at the end of 1955.

Elsewhere in the northern half of the Southern Peninsula record and near-record low water levels were observed locally during the year (see table 2).

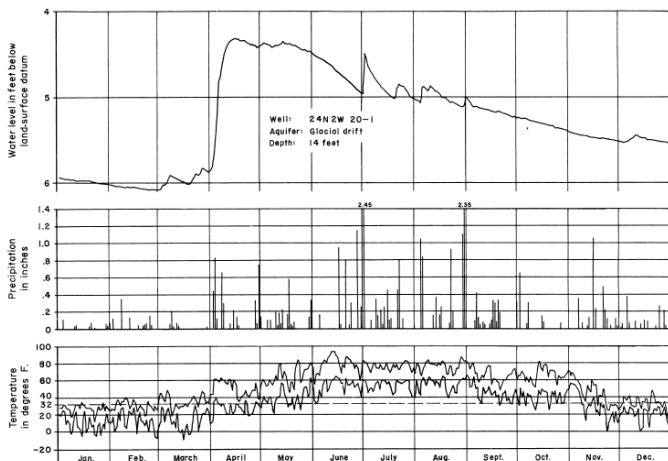


Figure 6. Hydrograph of well 24N 2W 20-1 near Roscommon, daily precipitation, and maximum and minimum temperatures at Grayling Military Reservation, 1956.

Southern Peninsula

Southern Half

In the southern half of the Southern Peninsula, seasonal declines and a general trend of low water levels continued from the previous year through March. At the end of April, intense precipitation caused sharp rises of water levels in shallow drift aquifers, and as rainfall continued into early May, most water levels in the shallower aquifers reached the highest stages observed

since 1952. June was comparatively warm but July and August were cool and wet, and as a result, the summer seasonal decline was moderate. Very little recharge occurred during the fall months when record-low precipitation was recorded in much of the area. Deficiencies were especially large in the southwestern counties. The water levels declined to stages generally below those of early April, except in the Thumb area and southeastern counties, where the total annual precipitation ranged from 2 to 5 inches above average despite the dry fall weather.

Branch County, City of Coldwater. Observation well 6S 6W 22-1, in the municipal well field, is finished in glacial drift. The water level is affected by withdrawals of ground water from municipal wells tapping the drift deposits. As shown on the hydrograph (fig. 7), spring rains caused the water level to rise several feet. A seasonal decline that began in late May was due to the normal increase of municipal pumping during the summer months. Owing to deficient precipitation in the fall and winter, this decline continued through the end of the year. A total of less than 1 inch of rain fell in September and October. In addition to precluding recharge to the aquifer, the dryness resulted in increased demands for water for lawn and garden sprinkling and other uses. Municipal withdrawal of ground water totaled 457 million gallons for the year, the highest since 1953, and reflected the abnormally high demands during the fall months.

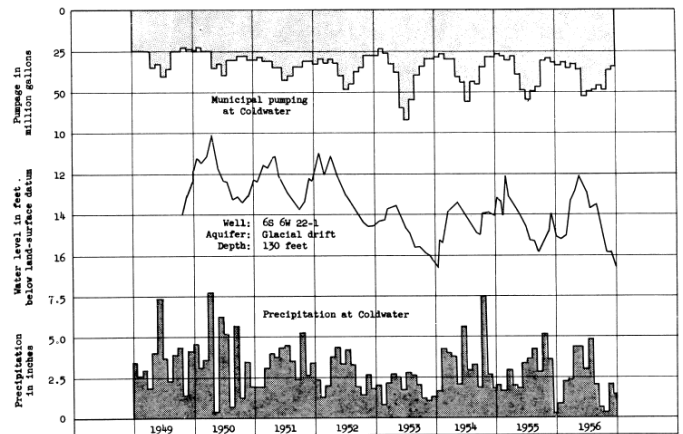


Figure 7. Hydrograph of well 6S 6W 22-1, monthly precipitation, and pumpage at Coldwater, 1949-1956.

Calhoun County, Battle Creek area. Most observation wells and municipal and industrial wells in the Battle Creek area obtain water from the Marshall sandstone of Mississippian age, but a few are finished in the overlying glacial drift.

Water levels rose in response to decreased pumping and spring rains and in some wells reached the highest stages observed since 1950. The normal summer seasonal decline which followed continued through the end of the year as the dry fall precluded appreciable recharge. Precipitation was more than 8 inches below average for the last 5 months of the year and a total rainfall of only 0.7 inch was reported for September and

October. Record and near-record lows were observed in some wells. Year-end water levels averaged about 0.7 foot below those observed at the end of 1955.

Municipal pumpage from the Marshall sandstone by the City of Battle Creek in June and September of 1956 were the largest of record for those months, and the yearly total of 2,498 million gallons was surpassed only in 1953 and 1955. The township of Battle Creek pumped about 318 million gallons during the year. In addition to municipal pumpage in the area, large withdrawals of ground water are made by industry.

Figure 8 is a hydrograph of observation well 2S 8W 2-1 for the 1947 to 1956 period. This hydrograph is based on the water level records obtained from a continuous water-stage recorder on a well finished in the Marshall sandstone. The water level is affected by municipal and industrial pumping from the Marshall sandstone. Figure 9 is a hydrograph of observation well 2S 8W 14-1 for the 1947 to 1956 period. The well is finished in glacial drift. This hydrograph illustrates the effect of the gradual abandonment of the Goguac municipal well field by the City of Battle Creek. The Goguac well field now is on a standby basis.

Figure 10 is a hydrograph of observation well 1S 7W 10-1, near Battle Creek and a graph of total monthly precipitation. The well is finished at shallow depth in surficial drift deposits. This hydrograph is used as an index of water levels in the shallow, unconfined glacial aquifers in the area.

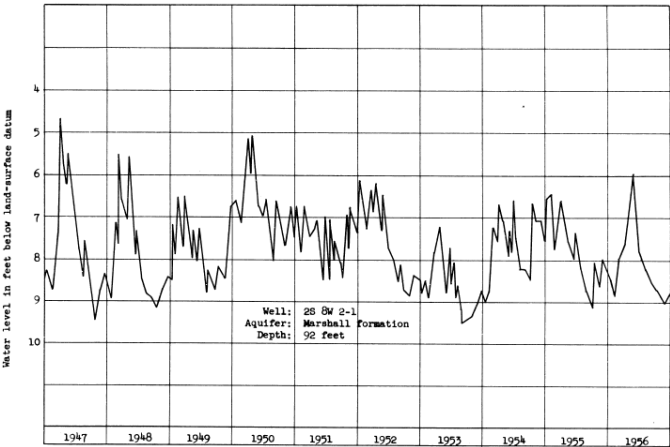


Figure 8. Hydrograph of well 2S 8W 2-1 at Battle Creek, 1947-1956.

Cass County, City of Dowagiac. The observation well 6S 16W 1-1, in Dowagiac, is finished in sand and gravel of Pleistocene age and is affected by nearby municipal wells tapping the same aquifer.

As indicated on figure 11, the water level is influenced by precipitation and pumping. The low water levels observed in mid-1953 resulted from a combination of heavy municipal withdrawals and deficiencies in precipitation. Levels at the end of 1956 were lower than those of the past few years and reflected the dry weather during the latter part of the year. Municipal pumpage of ground water in 1956 was about 645,000 gallons per

day, the lowest pumpage of the 1950 to 1956 period. Municipal pumping has been curtailed since 1954 when a local industry discontinued use of city water.

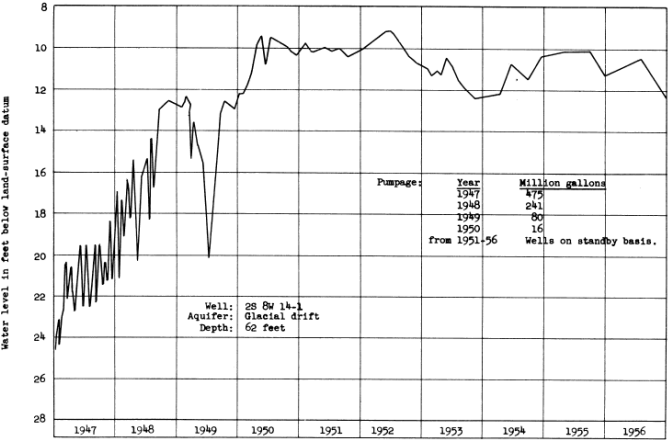


Figure 9. Hydrograph of well 2S 8W 14-1 showing effects of gradual discontinuance of municipal pumping from the drift at Goguac well field by the City of Battle Creek, 1947-1956.

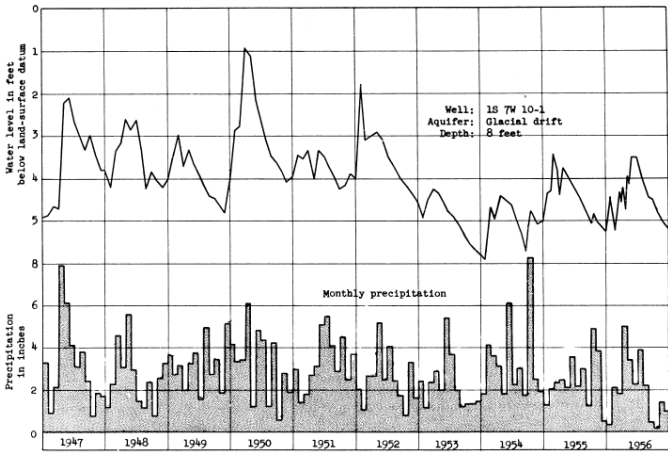


Figure 10. Hydrograph of well 1S 7W 10-1 near Battle Creek, and monthly precipitation at Battle Creek, 1947-1956.

Clinton County, Village of Elsie. In Elsie, water levels in observation wells 8N 1W 13-1 and 13-3 are influenced by municipal pumping from the Saginaw formation and from the glacial drift, respectively. Based on quarterly observations the water levels during much of 1956 were several feet higher than in 1955.

Water levels in other wells in southern Clinton County are discussed in the section headed Ingham County, Lansing metropolitan area.

Eaton County, City of Charlotte. Observation well 2N 4W 19-1 and all municipal wells are at Waterworks Park in Charlotte and are finished in the glacial drift. A deficiency of precipitation of more than 8 inches, most of which occurred during the fall months, sharply curtailed the usual fall recharge to the aquifer and as a result, the year-end level was about 1 foot lower than that observed at the end of 1955 and only 0.3 foot above the lowest level observed at the end of 1947.

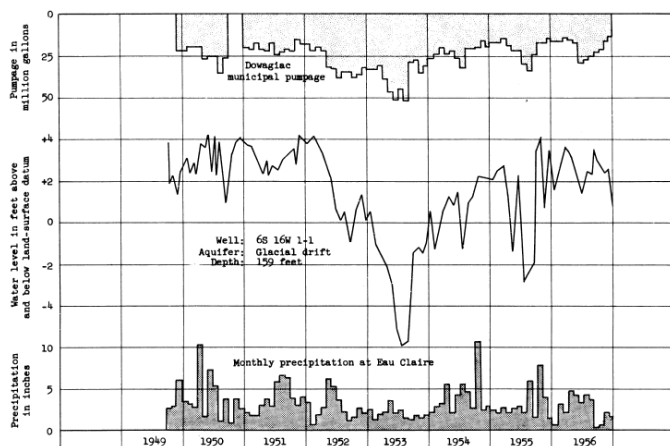


Figure 11. Hydrograph of well 6S 16W 1-1, monthly pumpage at Dowagiac and precipitation at Eau Claire, 1949-1956.

City of Grand Ledge. Observation well 4N 4W 2-1 in Grand Ledge is finished in the Saginaw formation of Pennsylvanian age, as are the municipal wells. In 1956 water levels rose sharply from February until May when the highest levels since May, 1952, were reached. This resulted from more than 10 inches of precipitation and decreased municipal pumping during the winter months (fig. 12). Although levels declined from May to December, levels at the end of 1956 were slightly higher than those at the end of 1955. Owing to a comparatively cool summer, municipal withdrawals of ground water totaled 165 million gallons in 1956 as compared to 176 million gallons in 1955.

Water levels in other wells in northeast Eaton County are included under the Ingham County, Lansing metropolitan area heading.

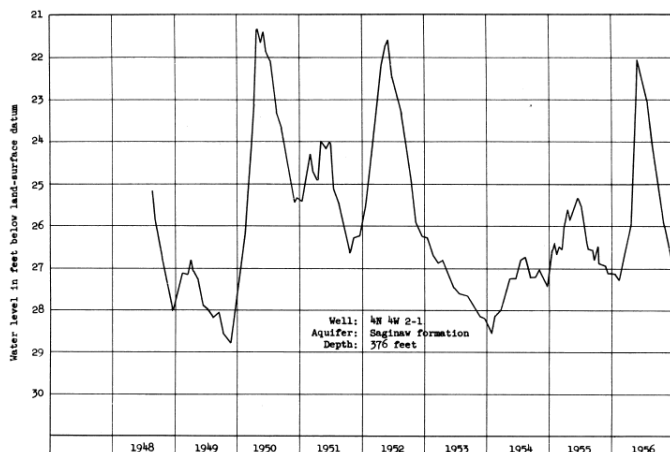


Figure 12. Hydrograph of well 4N 4W 2-1 at Grand Ledge, 1948-1956.

Genesee County, Flint metropolitan area. The City of obtains its water supply from the Flint River. However, Burton Township to the south, the Beecher Metropolitan Water District to the north, and many industries obtain water from the Saginaw formation. Observation wells in the Flint area are finished in the Saginaw formation, deep glacial drift deposits, and a few in the shallow drift aquifers. The water levels in the Saginaw formation were more than 1 foot higher at the end of 1956 than at

the end of 1955 and approximately 4 feet below the high of record in the spring of 1950 (fig. 13). In the artesian drift aquifer (fig. 13) the water level in the spring of 1956 was the highest since 1953 and the year-end level was higher than at the end of 1955. In the water-table aquifers, levels were higher throughout 1956 than they were in 1955. These increases in stage from 1955 to 1956 were due primarily to above-average precipitation. A general trend of declining water levels is in evidence for the period 1950 to 1955. The correlation between the two wells shown on figure 13 indicates that the two aquifers are connected hydraulically. Municipal withdrawals of ground water by Burton Township and the Beecher Metropolitan Water District totaled 294 million gallons for the year 1956.

Gratiot County, City of Alma. Observation wells in the Alma area are finished in the surficial drift deposits or in the buried outwash aquifers. Municipal and industrial wells tap the buried outwash. One deep municipal well taps the Saginaw formation. Artesian pressures in the buried outwash are affected by municipal and industrial pumpage whereas the water level in the surficial drift primarily reflects climatic conditions (fig. 14).

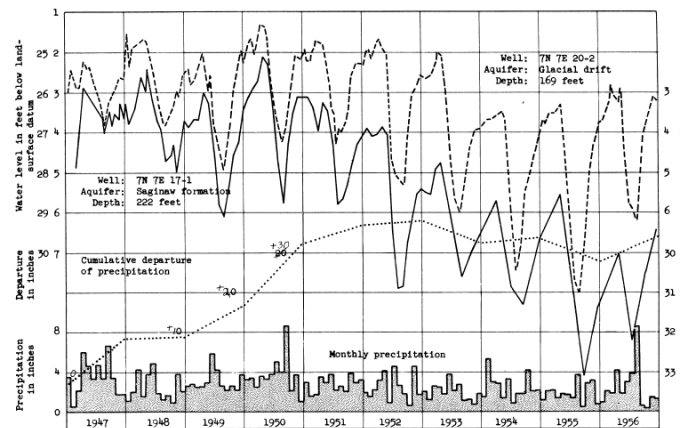


Figure 13. Hydrographs of wells 7N 7E 20-2 and 17-1, monthly precipitation, and cumulative departure of precipitation from long-term mean, at Flint, 1947-1956.

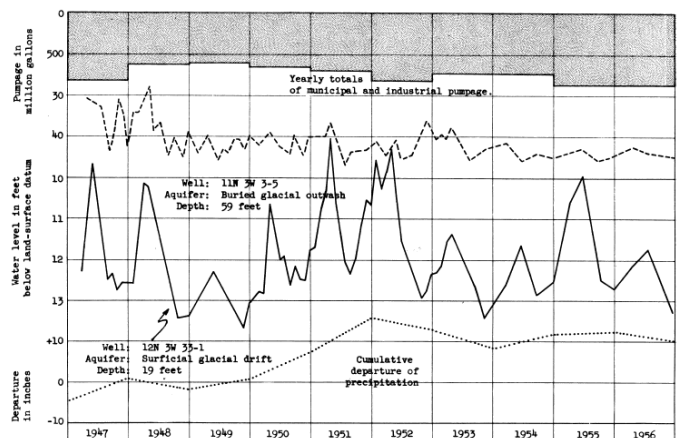


Figure 14. Hydrographs of wells 11N 3W 3-5 and 12N 3W 33-1, monthly pumpage, and cumulative departure of precipitation from long-term mean, at Alma, 1947-1956.

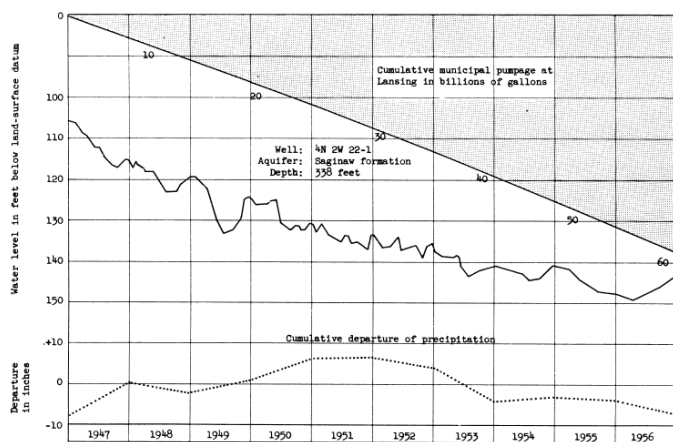


Figure 15. Hydrograph of well 4N 2W 22-1, cumulative pumpage, and cumulative departure of precipitation from long-term mean, at Lansing, 1947-1956.

A deficiency of about 5 inches in precipitation during the period September to December precluded substantial fall recharge and as a result water levels in shallow observation wells at the end of 1956 were from 0.2 to 0.5 foot lower than the levels at the end of 1955 and a few were the lowest of record. The piezometric surface in the deep artesian drift aquifer responded to changes in municipal pumping. Following the installation of two new municipal wells on the west side of Alma, pumping in the center of the city was decreased, and this change in pumping pattern was reflected in higher levels in nearby observation wells (table 2).

Although municipal withdrawals in June and July were considerably lower than in 1955, increased consumption from August through October raised the total pumpage for 1956 to about 660 million gallons, which was slightly more than in 1955.

Ingham County, Lansing metropolitan area. The Saginaw formation of Pennsylvanian age is the principal source of water for municipal and industrial wells in the area, although a few wells derive small quantities from the overlying glacial drift. The levels in observation wells drilled into the Saginaw formation reflect nearby pumping (fig. 15) as well as general climatic conditions. Generally, water levels in the winter months were near, or at, the lowest stages observed in the past decade. The levels rose sharply in the spring and in many wells reached the highest observed stages since the spring of 1952 (fig. 16). However, the levels declined during the balance of the year. The decline was started by hot weather in June and although the remainder of the summer was relatively cool and wet, a record-dry fall and attendant pumping caused levels to dip sharply and cancelled out earlier gains. End of the year levels were at, or slightly lower than, the stages at the end of 1955.

Changes in pumping pattern by the City of Lansing resulted in several feet of recovery in some wells on the northwest side, while declines were observed in wells located in the south and central portions of the city. The average daily pumpage of ground water for municipal use by Lansing, East Lansing, Lansing Township,

Meridian Township, and Michigan State University was about 22.2 million gallons during 1956, and ranged from about 21.4 million gallons for December to about 25.5 million gallons for June. Total municipal pumpage for the year was 8.1 billion gallons.

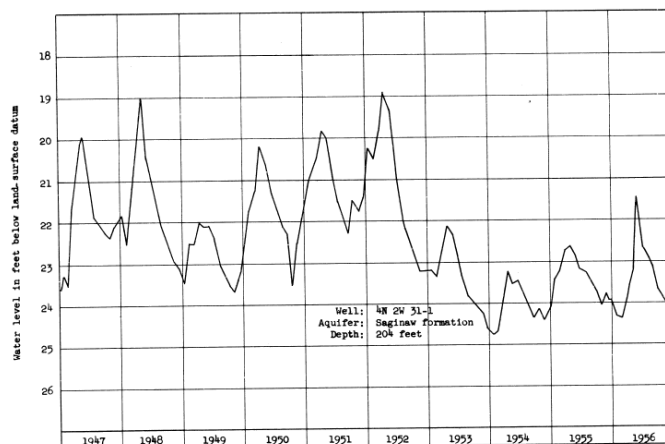


Figure 16. Hydrograph of well 4N 2W 31-1 near Lansing, 1947-1956.

City of Mason. Observation well 2N 1W 5-1, in Mason, is finished in the Saginaw formation underlying the glacial drift. The fluctuation in water levels in this well (fig. 17) is due primarily to withdrawals of ground water from the Saginaw formation by local industries. The municipal supply is derived from the glacial drift. Water levels in the observation well rose in response to a wet spring until in mid-May the level was the highest observed since mid-1953. The low stage for the year was reached in mid-July as the result of peak industrial pumping for cooling during the warm summer months. Decreased pumping after the low July stage allowed water levels to recover despite the dry fall weather, and by the end of 1956 levels were nearly 1 foot above those observed at the end of 1955 and higher than any year-end level since 1951. Average municipal pumpage of ground water from the drift in 1956 was 380,000 gallons per day (gpd) or about 30,000 gpd more than in 1955.

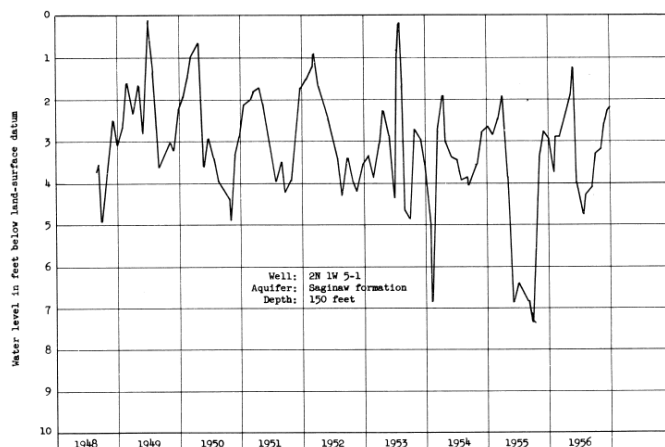


Figure 17. Hydrograph of well 2N 1W 5-1 at Mason, 1948-1956.

Kalamazoo County, City of Kalamazoo. All municipal, industrial, and observation wells in the Kalamazoo area are finished in glacial drift. Although precipitation in the winter and spring caused ground-water levels to rise appreciably during the early part of the year, a precipitation deficiency of about 9 inches during August through December cancelled out earlier gains and caused levels to decline sharply (fig. 18). By the end of 1956, the water level in some wells was at or near the lowest levels of the past decade (table 2). Since 1952, ground-water levels have been comparatively low, owing mostly to a cumulative deficiency of more than 2.5 inches of precipitation from the long-term mean (fig. 18) and to four consecutive years (1952-1955) of above-normal temperatures.

Total municipal pumpage, including Millwood Community, averaged 11.4 mgd in 1956 and ranged from 8.4 mgd in January to 17.3 mgd in June. The 4.2 billion gallons pumped by the City of Kalamazoo during 1956 was a record high.

Oakland County, City of Pontiac. The observation wells in Pontiac are finished in the glacial drift as are the municipal and most industrial wells in the area. A long general decline of water levels persisted from 1939 when observations were begun until 1955, and was due to heavy pumping from the aquifer. A rise in level of about 9 feet in observation well 3N 10E 32-1 since August 1955 (fig. 19) illustrates the combined effect of decreased pumping in the area adjacent to the observation well and above-average precipitation in the fall of 1955 and during most of 1956. Municipal withdrawal of ground water from the glacial drift for the year 1956 was 3.2 billion gallons.

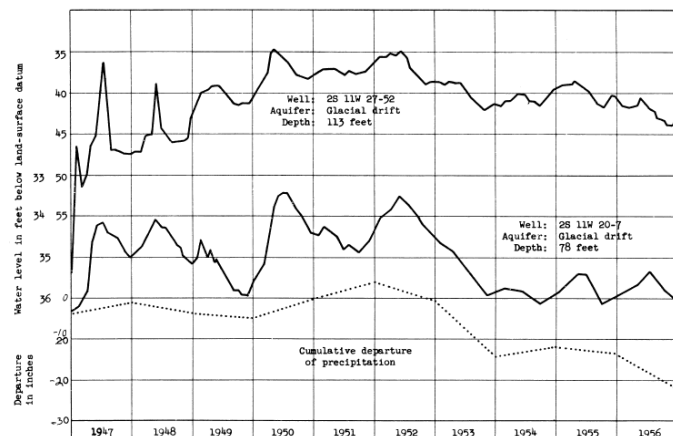


Figure 18. Hydrograph of wells 2S 11W 20-7 and 27-52, and cumulative departure of precipitation from long-mean, at Kalamazoo, 1947-1956.

St. Joseph County, City of Three Rivers. Observation well 6N 11W 18-1 at Scidmore Park in Three Rivers is finished in glacial drift and reflects withdrawals of ground water by the city. The levels in the well generally were higher throughout the year than in 1955. Measurements since 1939 show that no significant lowering of water levels have been caused by municipal pumping.

Washtenaw County. Observation wells in this county are south of Ann Arbor at the municipal well field, at the Ypsilanti State Hospital, and at the Ypsilanti Township well field. The wells are finished in the glacial drift and reflect withdrawals of ground water from the drift.

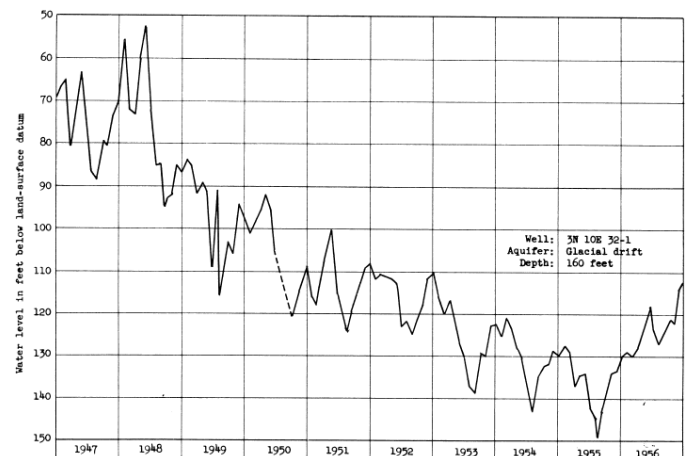


Figure 19. Hydrograph of well 3N 10E 32-1 at Pontiac, 1947-1956.

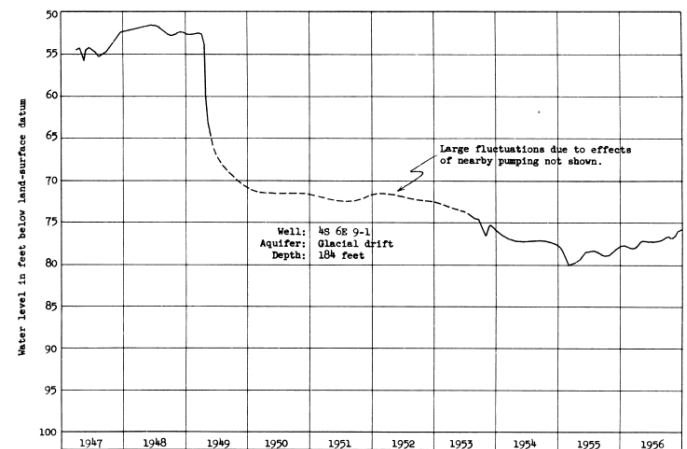


Figure 20. Hydrograph of well 4S 6E 9-1 at Ypsilanti State Hospital, Washtenaw County, showing effects of pumping from the hospital well field, 1947-1956.

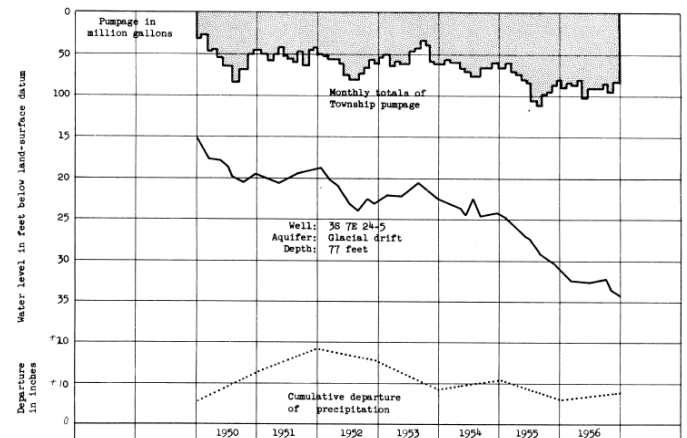


Figure 21. Hydrograph of well 3S 7E 24-5 at Ypsilanti Township well field, pumpage, and cumulative departure of precipitation, from long-term mean at Detroit, 1950-1956.

At the City of Ann Arbor's Steere Farm well field, the two observation wells (3S 6E 16-1 and 16-2) reflect changes in municipal pumpage. Spring water levels were higher in 1956 than in 1955. However, dry weather during the fall months effectively limited recharge and the levels at the end of 1956 were not substantially different from those observed at the end of 1955.

At Ypsilanti State Hospital, water levels in the two observation wells reflect pumping of ground water from the glacial drift by the hospital. Levels at the end of 1956 were several feet higher than at the end of 1955, owing to above-average total annual precipitation and a decrease in pumping as a result of a relatively cool and wet summer. The hydrograph of well 45 6E 9-1 (fig. 20), however, shows a net decline in water levels of more than 20 feet during the period of record 1947-1956. Large fluctuations in water levels due to the effects of nearby pumping during the 1949 to 1953 period are not shown on the hydrograph.

At the Ypsilanti Township well field the observation wells and the supply wells tap the glacial drift aquifer. Increased withdrawals of ground water from this field during 1955 and 1956 resulted in sharp declines of water levels during this period (fig. 21).



STATE OF MICHIGAN

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