Water Resources of the Flint Area Michigan

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499-E

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WATER RESOURCES
FLINT AREA
MICHIGAN

Flood of April 6, 1947, in downtown Flint

Water Resources of the Flint Area Michigan

By S. W. WIITALA, K. E. VANLIER, *and* R. A. KRIEGER

WATER RESOURCES OF INDUSTRIAL AREAS

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1499-E

A guide for initial location or expansion of industrial and municipal facilities and an aid to defense planning and the location of emergency water supplies

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By S. W. WIITALA, K. E. VANLIER, and R. A. KRIEGER

ABSTRACT

This report describes the water resources of Genesee County, Mich., whose principal city is Flint. The sources of water available to the county are the Flint and Shiawassee Rivers and their tributaries, inland lakes, ground water, and Lake Huron. The withdrawal use of water in the county in 1958 amounted to about 45 mgd. Of this amount, 36 mgd was withdrawn from the Flint River by the Flint public water-supply system. The rest was supplied by wells. At present (1959) the Shiawassee River and its tributaries and the inland lakes are not used for water supply.

Flint River water is used for domestic, industrial, and waste-dilution requirements in Flint. About 60 percent of the water supplied by the Flint public water system is used by Flint industry. At least 30 mgd of river water is needed for waste dilution in the Flint River during warm weather.

Water from Holloway Reservoir, which has a storage capacity of 5,760 million gallons, is used to supplement low flows in the Flint River to meet water-supply and waste-dilution requirements. About 650 million gallons in Kearsley Reservoir, on a Flint River tributary, is held in reserve for emergency use. Based on records for the lowest flows during the period 1930–52, the Flint River system, with the two reservoirs in operation, is capable of supplying about 60 mgd at Flint, less evaporation and seepage losses. The 1958 water demands exceeded this amount. Development of additional storage in the Flint River basin is unlikely because of lack of suitable storage sites. Plans are underway to supply Flint and most of Genesee County with water from Lake Huron.

The principal tributaries of the Flint River in and near Flint could furnish small supplies of water. Butternut Creek, with the largest flow of those studied, has an estimated firm yield of 0.054 mgd per sq mi for 95 percent of the time. The Shiawassee River at Byron is capable of supplying at least 29 mgd for 95 percent of the time.

Floods are a serious problem in Flint. The April 1947 flood, the largest on record, caused nearly $4 million flood damage in Flint. A proposed flood-control plan for Flint calls for channel, floodwall, and levee improvements and the removal or modification of some bridges.

Analyses of water samples taken from selected streams and lakes in the Flint area indicate that the waters are of the calcium bicarbonate type and generally hard to very hard. Flint River water is relatively uniform in quality although a progressive increase in iron, sodium, and chloride concentrations was noted between Otisville and Montrose. Downstream from Flint, the dissolved oxygen

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content may be low during low flows. At times, concentrations of iron, manganese, phenols, color, and turbidity in Flint River water exceed the limits recommended in drinking water standards. Water temperatures ranged from freezing to 86°F in a 4-year period. The finished water supplied by the Flint water-treatment plant is fairly uniform in quality, moderately soft, alkaline, and low in color and turbidity. The pH is nearly always above 10. Further softening and removal of iron and related minerals would be desirable for certain industrial uses.

The quality of the water sampled in the Flint River tributaries was generally similar to that of the Flint River. However, no phenols or oils and waxes were found. Softening and other treatment dependent upon use would be required if these streams were developed for water supply.

Waters sampled in the Shiawassee River and selected lakes were generally less mineralized than Flint River water. Water from the lakes showed the lowest concentrations of dissolved solids. Softening would be required for nearly all uses. Additional treatment would depend upon contemplated use.

Shallow deposits of sand and gravel deposited as outwash along glacial meltwater streams and as deltas in the glacial lakes that covered the northwestern part of the county are sources of water to moderate- and large-capacity wells. Thick deposits of sand and gravel also fill some of the valleys in the bedrock surface and yield moderate to large supplies of water. Production from public supply wells tapping the drift aquifers in the area ranges from about 50 to 1,200 gpm. The water from the drift aquifer is hard or very hard and commonly contains objectionable amounts of iron.

The Saginaw formation is a source of water to wells supplying some of the small communities and industries in the county. The Saginaw, which is the uppermost bedrock formation in the area, underlies most of the county. It is composed of layers of sandstone, shale, and limestone and some beds of coal. The formation is composed principally of sandstone in some areas of the county, and shale in others. Production from wells tapping the Saginaw ranges from a few to about 500 gpm. The water produced is generally moderately hard or hard and commonly contains objectionable amounts of chloride. The quality of the water limits its development for water supply. Overdrafts from the Saginaw result in a lowering of the piezometric surface and commonly cause an upward migration of water high in chloride.

The Michigan and Marshall formations are generally not sources of fresh water where they are overlain by the Saginaw formation. In the southern and eastern parts of the county where they are overlain by glacial deposits, they are a source of water of good quality. The quantity of water obtainable from these formations is not fully known. However, the Marshall may be a source of large supplies of water in the southeastern part of the county.

An ample supply of water is available in lakes, ponds, and streams in the metropolitan area of Flint to meet requirements for domestic, sanitary, and fire-fighting use in civil defense emergencies. The extent of emergency use of water from these sources would depend upon the pumping, distribution, and treatment facilities available. Enough private industrial and commercial, and public wells are present in the area normally supplied by the Flint public water system to meet emergency requirements for domestic and sanitary use. Use of these wells would also depend upon available pumping and distribution facilities. Water from many of these wells contains objectionable amounts of chloride, but it could be used without treatment in an emergency.

INTRODUCTION

PURPOSE AND SCOPE

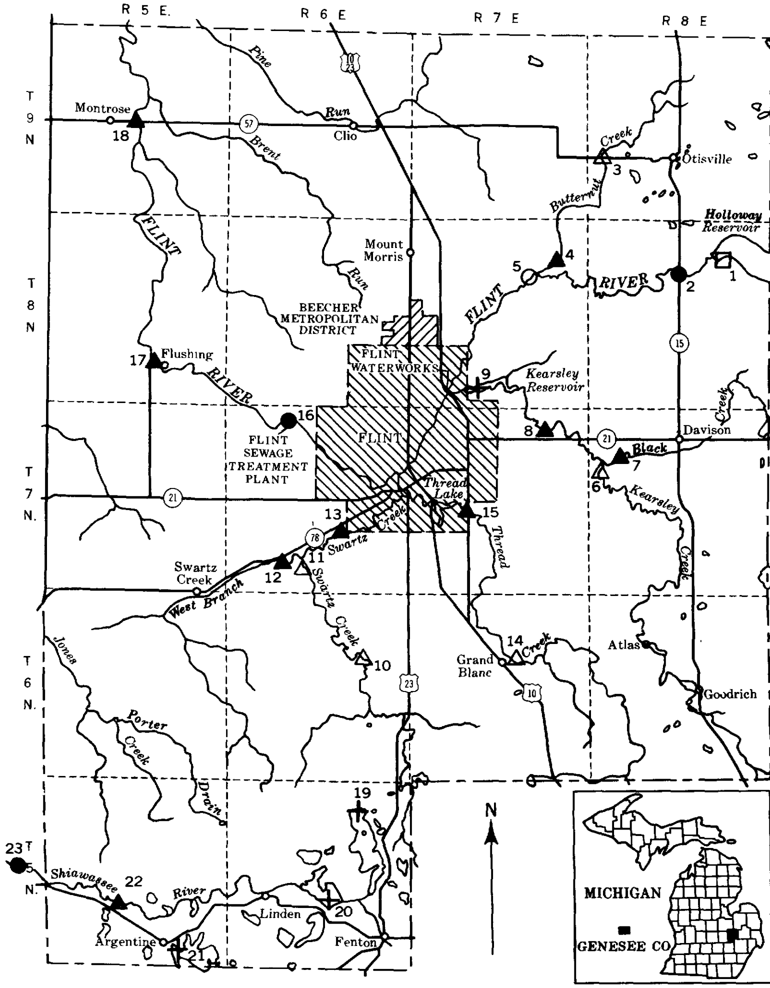
With the ever-increasing demand and competition for water, city and industrial planners, waterworks managers, and those concerned with the Nation's water resources need information upon which to make appraisals of the water situation in various highly populated industrial areas. The purpose of this report is to summarize the available information on water resources of the Flint area.

This report attempts to answer the questions, how much?, what kind?, where?, and when?, regarding the water resources of the Flint area. It is intended to be used for initial guidance for location or expansion of industrial and municipal facilities and as an aid to defense planning and the location of emergency water supplies. It is intended to serve as a basis for general planning; it is not a complete hydrologic record of the area. More comprehensive and detailed investigation will probably be necessary to solve specific water-supply problems.

ACKNOWLEDGMENTS

This report is one of a series summarizing the available information on the water resources of selected industrial areas of national importance. The reports have been prepared at the request of and in consultation with the Water and Sewerage Industry and Utilities Division of the Business and Defense Services Administration of the Department of Commerce. This report was prepared by S. W. Wiitala under the supervision of A. D. Ash, district engineer (Surface Water), by K. E. Vanlier under the supervision of Morris Deutsch, district geologist (Ground Water), and by R. A. Krieger under the supervision of G. W. Whetstone, district chemist (Quality of Water).

Most of the data used in this report were collected over a period of many years for other investigations by the Geological Survey in cooperation with the Michigan Water Resources Commission, Michigan Department of Conservation, Michigan State Highway Department, and the U.S. Corps of Engineers. A Michigan Water Resources Commission report (1956), "Water Resource Conditions and Uses in the Flint River Basin," was consulted freely in the preparation of this report. The Corps of Engineers' survey report (1954) on floods in the Saginaw River basin was used extensively in the preparation of the section on floods in Flint. The illustrations showing the flood profiles and area inundated by the 1947 flood in Flint were taken from the Corps of Engineers report. Chemical analyses were made by the



EXPLANATION

Type of record obtained at points where data were collected

□ Stage only

○ Stage and discharge

● Stage, discharge, and chemical quality

△ Discharge measurements only

▲ Discharge measurements and chemical quality

+ Chemical quality

Numbers beside symbols referred to in text tables

0 5 MILES

FIGURE 1.—Map of Genesee County showing where data on streams and lakes have been collected.

Geological Survey and, in addition, liberal use was made of the records of chemical quality contained in the files of the Michigan Department of Health.

Many persons and organizations contributed information. Special acknowledgment is due Mr. H. O. Self, superintendent, and Mr. G. F. Greenwood, hydraulic engineer, of the Division of Water Supply, Flint Department of Public Works and Utilities, for much of the data on the municipal water-supply system and Flint water use and for permitting use of the information contained in the reports of the city's consulting engineers. Special acknowledgments are also due to Messrs. George Torr, of Flint, and Lawrence Haddrill, of Goodrich, well drillers, who furnished much valuable data on the ground-water resources of the area.

In addition, thanks are due many other well drillers, individuals, and industries for furnishing information from their files.

DESCRIPTION OF THE AREA

The area covered by this report comprises all 644 square miles of Genesee County, which lies in southeastern Michigan about midway between Saginaw Bay and Detroit (fig. 1). Flint, the largest city in the county and the second largest in the State, is almost in the geographical center of this report area.

The greater part of Genesee County is level to gently undulating except in the northeastern and southernmost parts of the county, where the land ranges from broken to comparatively rough and hilly. Land elevations range from about 610 to 1,170 feet above mean sea level. Heavy clay and silt-loam soils with poor drainage predominate. However, artificial drainage has made most of these soils good for agriculture.

Almost the entire county is drained through the Flint and Shiawassee Rivers and their tributaries into the Saginaw River and thence into Lake Huron. The principal stream is the Flint River, which has about 40 miles of its length in Genesee County. The Shiawassee River, which flows westward through the two southernmost townships, drains a relatively small part of the county.

POPULATION, INDUSTRY, AND AGRICULTURE

Genesee County was organized in 1835 and Flint was incorporated as a city in 1855. The city and county grew very rapidly between 1910 and 1930 and again in the 1950's (fig. 2). The 1959 populations of Genesee County and Flint are estimated as 340,000 and 198,000 respectively (from Flint's planning consultants and Flint Chamber of Commerce).

Near the end of the lumbering era, in the late 1800's, manufacturing first supplemented and finally supplanted the timber industry as the principal source of employment in the urban areas. In 1900, Flint was the center of a thriving carriage-building industry and produced

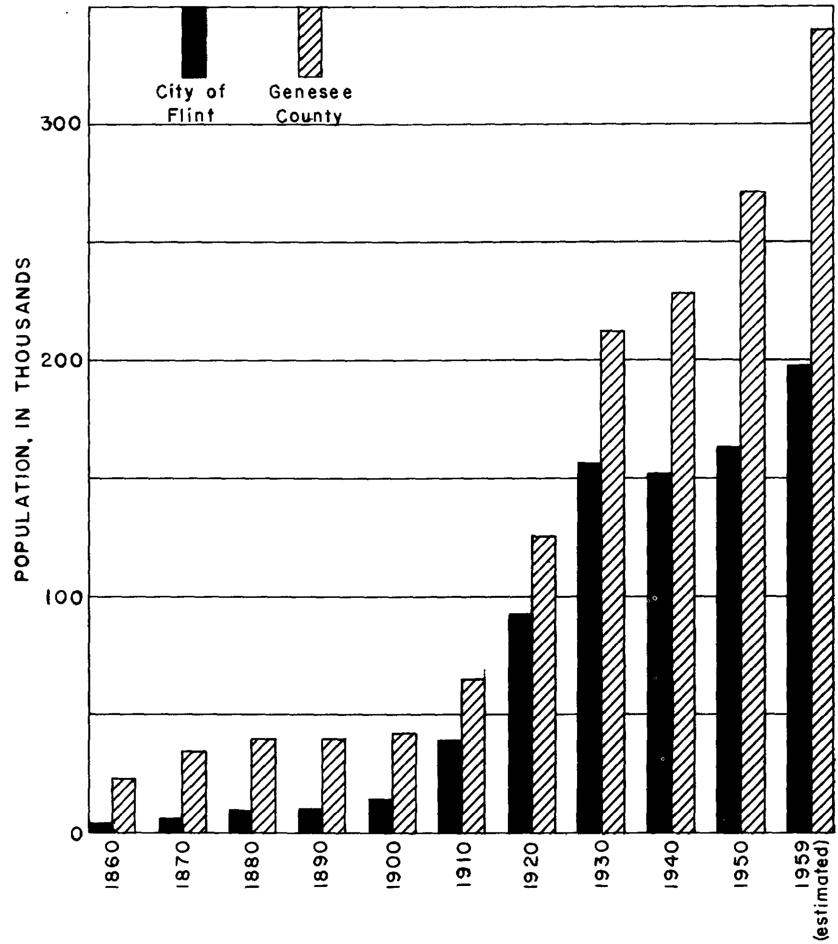


FIGURE 2.—Growth in population, Flint and Genesee County.

150,000 vehicles per year (Crow, 1945, p. 36). Thus, the transition from carriage building to automobile building was natural. Flint is now second only to Detroit in the production of automobiles. Other manufacturing plants produce a variety of products that include chemicals, paints and varnishes, cotton textiles, tools, dies, screw machine products, and concrete and steel products. Approximately 73,000 wage earners in the Flint metropolitan area were engaged in some type of manufacturing in 1959 (mimeographed notes, Flint Chamber of Commerce). Total employment in the same area exceeded 132,000 in the mid-1950's when automobile production was at its peak. Of the 106 manufacturing establishments in Flint listed by the Chamber of Commerce in 1959, 10 employed more than 1,000 workers.

The principal natural resource of the county is agricultural land. In 1950, the 3,691 farms in the county averaged 79.4 acres in size (U.S. Bur. Census, 1952, p. 49). Hay and grains are the principal crops, and the major farming enterprises are dairying and poultry production. Many of the farm residents in Genesee County have some other employment of a nonagricultural nature.

Large sand and gravel deposits are found along the Flint River and Butternut Creek. Slightly more than 500,000 tons of sand and gravel was produced in the county in 1958.

SOURCES OF WATER

The sources of water available to the Flint area are the Flint and Shiawassee Rivers and their tributaries, inland lakes, ground water, and Lake Huron. All sources, except Lake Huron, are dependent largely upon the precipitation that falls in, or near, the area. Lake Huron draws its supply from the vast area draining into Lakes Superior, Michigan, and Huron.

At the present time (1959), the Flint River is, by far, the most important of these water-supply sources. Most of the water for industrial and municipal use comes from the Flint River system. The average annual precipitation over the basin is about 30 inches. About 8 inches of this runs off and is available for use. The Shiawassee River is not used as a source of supply in Genesee County.

The natural lakes in the eastern and southern parts of the county have small tributary areas. They are not used as sources of water supply now but are important for recreation.

Deposits of sand and gravel in the glacial drift are the main source of supply for many of the small public water-supply systems in the county. The drift deposits are also tapped by many domestic and a few small-capacity industrial wells.

The Saginaw, Michigan, and Marshall formations, which are composed principally of sandstone and shale, are the sources of water for some of the small water utilities of the county. These formations supply most of the industrial and domestic wells in the county. Commonly, wells are completed in bedrock aquifers even though water is also available in the overlying glacial drift, mainly because bedrock wells are easy to maintain.

Lake Huron is a source of practically unlimited supply of water of good quality. It is looked to as the eventual answer to the area's rapidly expanding water requirements.

Surface and ground waters are closely interrelated and have precipitation as a common source. Of the part of precipitation that does not run off directly into stream systems, some is evaporated; some is transpired by vegetation; and some percolates to the ground-water table, where it may be held in storage for a long time. Ground water is discharged through wells, through seepage into stream channels, and through seeps and springs. The dry-weather flow of most streams is supported by ground-water seepage. Surface water is generally subject to greater variations in quantity, quality, and temperature than ground water. However, ground water is apt to be more mineralized because, in percolating through the soil, a greater opportunity is afforded for dissolving mineral matter.

FLINT RIVER

The Flint River is the second largest tributary of the Saginaw River. It begins in western Lapeer County at the confluence of the North and South Branches about 30 river miles upstream from Flint. It enters Genesee County about 8 miles south of the northeast corner of the county, flows southwestward to about the center of the county at Flint, thence northwestward and northward, and crosses the north-

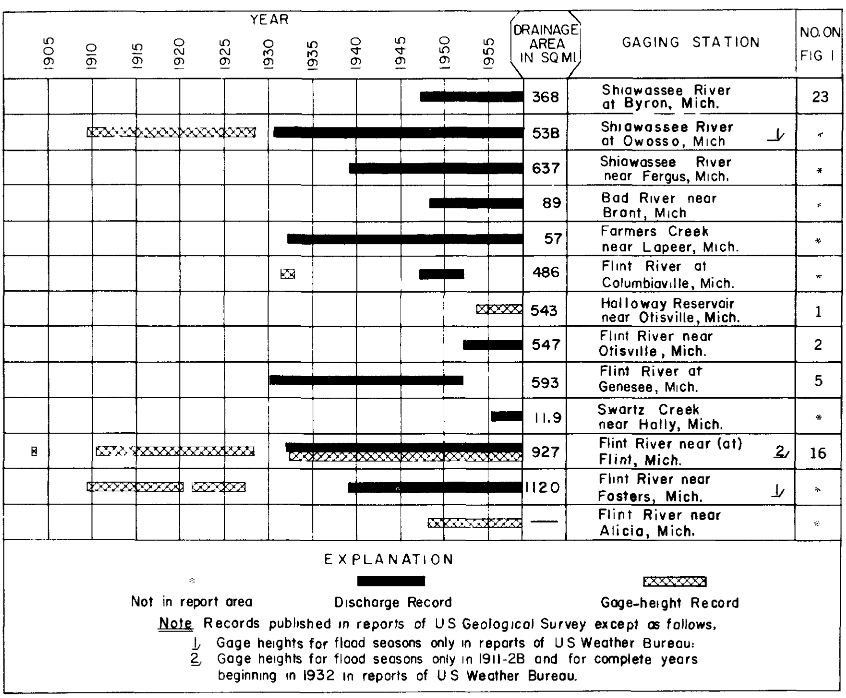


FIGURE 3.—Bar chart of published gaging-station records in the Flint and Shiawassee River basins.

ern boundary of the county about 3 miles from the northwest corner. The drainage area at the western limits of Flint is 927 square miles. From Columbiaville to the western limits of Flint the stream slope averages about 2 feet per mile; from there to Flushing the slope averages about 4 feet per mile; and for the remainder of its course through the county, it averages about 3 feet per mile.

At present (1959), five gaging stations, at which continuous streamflow records are obtained, are operated on the Flint River and its tributaries. (See fig. 3.) Records for two discontinued stations are also available. The gaging station near Flint is located at the city's sewage-treatment plant. The flow at this station includes the effluent discharged from the plant. Spot measurements of streamflow were made on four small streams in the Flint River basin. These streams seem best suited for possible development because they are close to the Flint metropolitan area. Chemical analyses of the water from selected streams and lakes were also made for the purpose of this report. Measuring and sampling sites are shown in figure 1.

STORAGE IN THE FLINT RIVER BASIN

The Earl L. Holloway Reservoir, owned and operated by the city of Flint, is about 10 miles upstream from the Flint waterworks. It affects the hydrology of the Flint River more than any other storage development in the basin. Releases from the reservoir supplement the low-water flow of the Flint River for the dual purpose of water supply and sewage dilution. It cannot provide effective flood control because the maximum storage in the reservoir amounts to only 0.99 inch of runoff from its watershed. It has little value for recreation because of possible large fluctuations in pond levels during the recreation season.

The drainage area of the Flint River at Holloway Dam is 543 square miles. Reservoir storage can be determined from the capacity curve (fig. 4). The dam, a rolled-fill embankment with concrete spillway section, was completed in 1953, but normal reservoir operation did not begin until 1955. Normal operation calls for lowering the reservoir to meet the water demands during the summer and early fall; filling, and holding it at elevation 751 feet during late fall and through the winter; refilling to normal pond elevation of 755 feet in the spring; and holding at this level until the season of storage demand begins.

The storage in Holloway Reservoir at normal pond elevation (755 feet) is equivalent to only 0.61 inch of runoff from the basin. Streamflow records indicate that the reservoir could have been filled to normal pond elevation each spring since 1932 even if it had been completely empty at the end of February.

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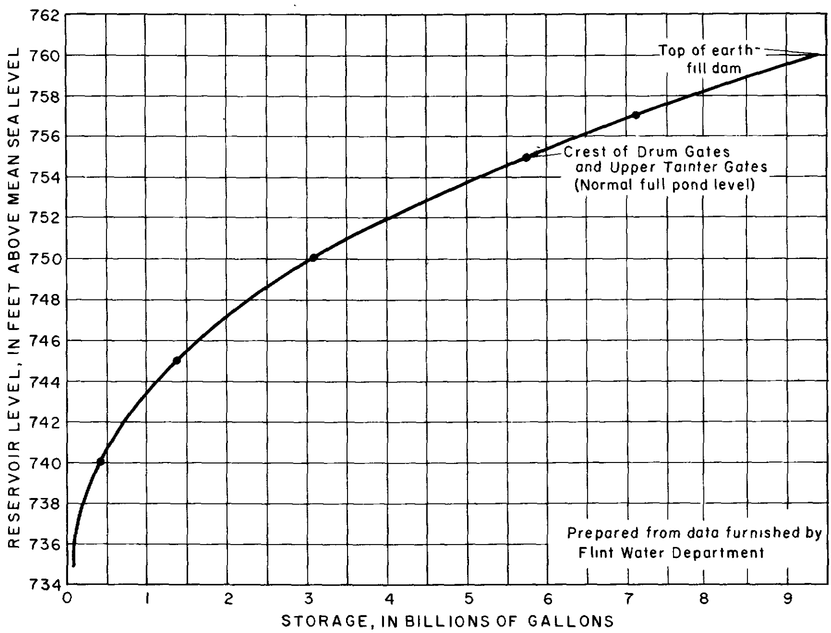

FIGURE 4.—Capacity curve for Holloway Reservoir.

The effect of regulation from Holloway Reservoir during a drought year is shown in figure 5. The hydrograph very nearly represents the flow at the Flint waterworks upstream from Kearsley Creek during dry periods because there is practically no inflow between the gaging station and Kearsley Creek. The regulated hydrograph was computed for the following water requirements:

1. 45 mgd at Flint waterworks for water supply—approximately equal to the average daily pumpage for the maximum month for year ending June 30, 1958.
2. 75 mgd, including plant effluent, just downstream from the Flint sewage-treatment plant.

The second requirement is effective only for severe drought conditions when operations are geared to conserving water for water supply. In normal years regulated flow can probably be maintained at higher levels so that more water would be available for waste dilution.

The flow recorded at Genesee during the last 6 months of 1939 varied from 20 to 72 mgd, whereas the regulated flow would have varied from 45 to 70 mgd. The minimum flow would have been more than doubled by regulation. Although January and February 1940 continued to be dry, there was still sufficient water available in the reservoir on January 1st to supply the water demands for those

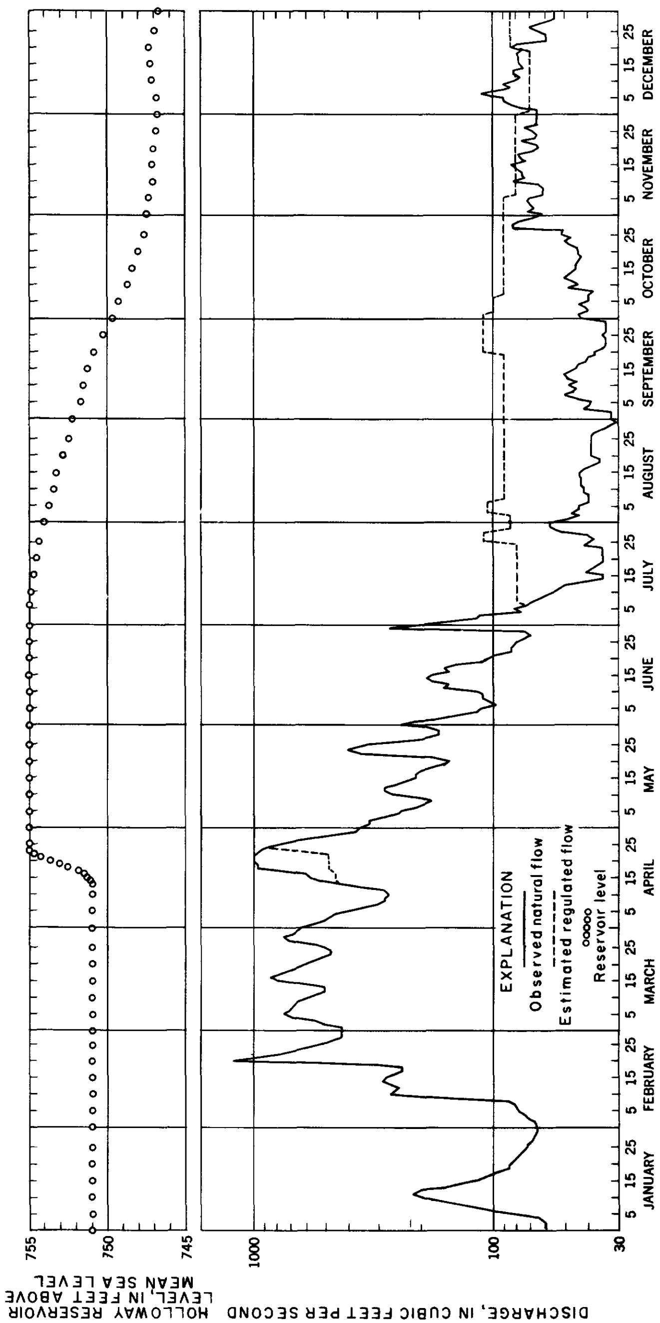

FIGURE 5.—Observed hydrograph and computed hydrograph for regulated flow for drought year 1939, Flint River at Genesee.

two months. Evaporation losses from the reservoir were disregarded in making the computations.

Flint also owns a reservoir in the northeast part of the city on Kearsley Creek about a mile upstream from the mouth. The drainage area at the dam is 108 square miles. From its completion in 1928 until 1954, Kearsley Reservoir was used solely for water supply. The storage available is about 650 million gallons, enough to supply the Flint waterworks for about 2 weeks on the basis of an average demand of 45 mgd. Since completion of the Holloway Reservoir, the city has not used Kearsley Reservoir for water supply because of the poor quality of the water.

There are two other small impoundments on Kearsley Creek, at Atlas and at Goodrich. Flint owns the dam and pond at Goodrich but does not use it. The dam and reservoir at Atlas are at the site of an old mill which is no longer used.

A lake is formed within Flint by a dam with gated spillway on Thread Creek in the southeast part of the city, about 2 miles upstream from the mouth. The dam is operated by the Flint Department of Public Works, which tries to maintain a normal pond elevation of 749 feet above mean sea level and tries to limit maximum drawdown to 746 feet.

WITHDRAWAL USE OF WATER

Withdrawal uses of water are uses that require the removal of the water from its place of occurrence. Water is withdrawn from the Flint River by the Flint public water-supply system for domestic, municipal, and industrial uses. The average daily withdrawal was almost 45 million gallons in the year ended June 30, 1956, the year of maximum water use, and it was almost 36 million gallons in the year ended June 30, 1958. Some water for cooling and firefighting is also obtained directly from the river. These uses are largely nonconsumptive, so that the used water is returned nearly undiminished in quantity to the stream although its quality may be impaired and its temperature raised. The water thus becomes available for reuse farther downstream. Irrigation, however, is a consumptive use from which there is little or no return flow, but in Genessee County it is only a minor use. As of 1957 there were 19 irrigation systems in the county for irrigating a total of 450 acres (Michigan Water Resources Comm., 1959, table 1). Surface-water sources were used by 17 of the 19 systems, but it is not known how many of the systems were in the Flint River basin.

NONWITHDRAWAL USE OF WATER

Navigation, production of hydroelectric power, recreation, and waste disposal are examples of nonwithdrawal uses. Only waste disposal is of importance in the Flint River basin.

The Flint River receives most of its pollution from two sources, industrial plants and the Flint sewage-treatment plant. In recent years the Flint sewage-treatment plant has operated at, or near, its rated capacity of 25 mgd. Assuming water pumpage in summer at the Flint waterworks as 45 mgd, sewage-treatment plant operation at rated capacity, and no consumption or loss of water, about 20 mgd of used water is discharged directly into the river and its tributaries above the sewage-treatment plant. Therefore, in order to provide for a dilution ratio of two volumes of river water to one volume of effluent from the sewage-treatment plant, or a total flow of 75 mgd at the sewage-treatment plant, an additional 30 mgd of river water is needed. Although the river water just upstream from the sewage-treatment plant is polluted to some extent by the industrial wastes, the amount and character of the industrial pollution are such that they do not completely impair the water's effectiveness as a dilution medium for sanitary wastes. These conditions probably represent minimum dilution-water requirements needed in drought periods (as depicted in fig. 5), when the maintenance of an adequate water supply would be of primary importance. In order to maintain the dissolved oxygen content at 4.0 ppm (parts per million) for a flow of 75 mgd in the critical reach below the sewage-treatment plant, the biochemical oxygen demand of sewage-treatment plant effluent would have to be limited to somewhat less than half of that observed in a pollution survey made in July 1959 (Michigan Water Resources Comm., 1960). The biochemical oxygen demand of the plant effluent could be reduced by improvements in and additions to sewage-treatment facilities.

In general, more water than the minimum indicated is available for waste dilution. For example, since 1955 the releases from Holloway Reservoir during the summer dry periods have averaged about 78 mgd (120 cfs) instead of the average of about 58 mgd (90 cfs) shown in figure 5. An additional 20 mgd of dilution water has, therefore, been provided from storage. During the same period the flow at the Flint gage has averaged about 100 mgd. Thus, for the same conditions of water and sewage-treatment plant operation assumed in the preceding paragraph, an average flow of about 75 mgd, instead of 50 mgd as used in figure 5, has been available for dilution of the effluent from the sewage-treatment plant.

Since 1950 most of the large industrial plants in Flint have installed facilities for treating their wastes. Some of them are already recirculating their treated waste waters, and others are planning to do so. Consequently, the dilution requirements for the plant wastes in the future may be somewhat less. However, dilution-water requirements will probably continue to increase because of expanding population and greater demand for water. Consulting engineers studying

Flint's water-supply problem estimate that about 144 mgd of dilution water will be needed by 1965, assuming that most of the sewage of Genesee County will be treated by a plant at Flint at that time. A Genesee County Sewage Disposal District was organized in 1955 to plan, construct, and operate a consolidated sewage collection and treatment system for the area (Michigan Water Resources Comm., 1956).

FLOW CHARACTERISTICS

The flow of the Flint River near the upstream limits of the city was measured at the gaging station, Flint River at Genesee, and the data collected there very nearly represent the flow available in the Flint River a short distance upstream from the Flint waterworks. The flow as it leaves the city is measured at the gaging station, Flint River near Flint. The recorded averages and extremes of flow at the two stations are as follows:

	Length of record (years)	*Flow*		
		Average (mgd)	*Maximum (mgd)*	*Minimum (mgd)*
Flint River at Genessee	22	231	5, 590	9. 7
Flint River near Flint	26	362	9, 630	5. 8

The inflow from Kearsley Creek would have to be added to obtain the total flow available at the waterworks. The minimum flow for the station, Flint River near Flint, may have been affected by regulation from dams within the city.

Streamflow varies greatly from year to year, season to season, and sometimes even from day to day. The relative distribution of flow for a given period of time is effectively shown by a flow-duration curve which is fundamentally a cumulative frequency curve that shows the percentage of time during which various rates of daily flow were equaled or exceeded. This information on how the flow is distributed is useful to the designers and operators of water-supply facilities. The curve is also used to estimate future streamflow from past records. A disadvantage of the flow-duration curve is that it provides no information on the sequence of flow. It fails to indicate, for example, whether the days of extreme low flow were concentrated in a few severe drought periods or whether they are well scattered throughout the period of record. Such information is shown in a low-flow frequency curve, which gives the average frequency with which the mean flow for selected time intervals can be expected to occur.

Flow-duration curves for gaging stations, Flint River near Otisville and Flint River near Flint, were prepared for the period 1930–52 (figs. 6 and 7). This period is one when the flow was unaffected by

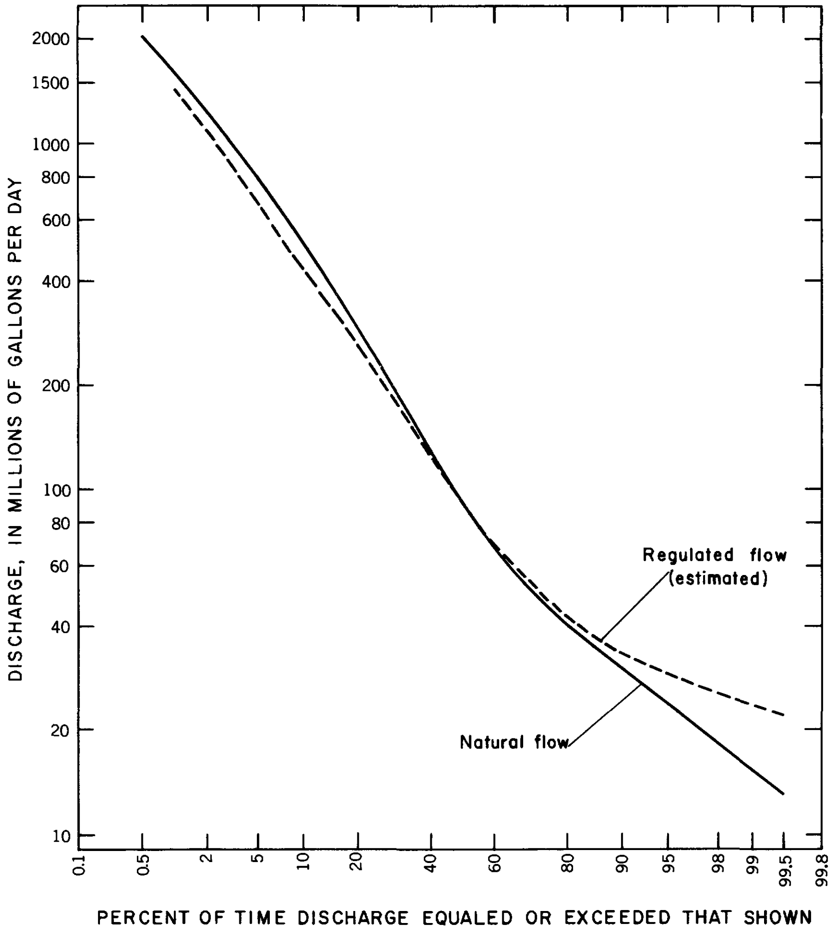

FIGURE 6.—Duration curves of daily discharge, Flint River near Otisville, 1930–52.

regulation from Holloway Reservoir and includes the drought years of the 1930's and the wet years of the late 1940's and early 1950's. It is probably representative of long-term natural flow-conditions. The solid curves show the flow duration for natural streamflow, and the dashed curves show how they would have been modified by regulation from Holloway Reservoir. The curve of natural flow for the Otisville station was computed from the records for adjacent gaging stations on the Flint River at Columbiaville and at Genesee.

The Otisville curve (solid line, fig. 6) shows that a flow of 38 mgd (equivalent to 45 mgd at the Flint waterworks, excluding the flow of Kearsley Creek) is equaled or exceeded about 82 percent of the time. Thus, withdrawal from storage would supplement natural river flow

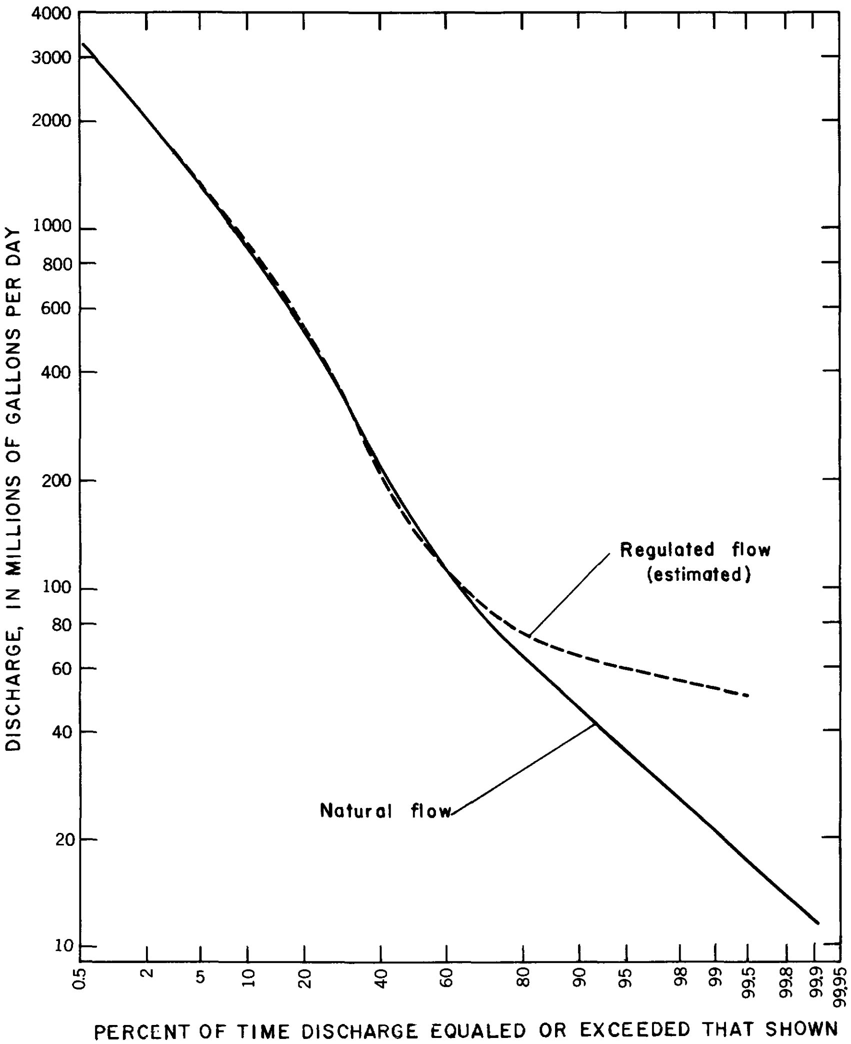

FIGURE 7.—Duration curves of daily discharge, Flint River near Flint, 1930–52.

during about 18 percent of the time to meet this demand for water supply. A total flow of about 75 mgd is needed just below the city sewage-treatment plant to meet minimum dilution requirements during warm weather. This flow is equaled or exceeded about 75 percent of the time at the gage near Flint (solid line, fig. 7). Therefore, water would be withdrawn from storage during about 25 percent of the time to meet this flow requirement at the sewage-treatment plant. These examples illustrate the use of flow-duration curves. In practice, because water-supply and sewage dilution demands vary considerably throughout the year, it is difficult to pinpoint requirements.

The slope of duration curves is a good index of the storage, both surface and underground, in a drainage basin. The dashed curves of figures 6 and 7 illustrate the flattening of slope by artificial storage. These curves, although only approximations, depict the beneficial increase in low flow accountable to storage.

The low-flow frequency curves for Flint River near Otisville and Flint River near Flint (figs. 8 and 9) represent natural low flow unaf-

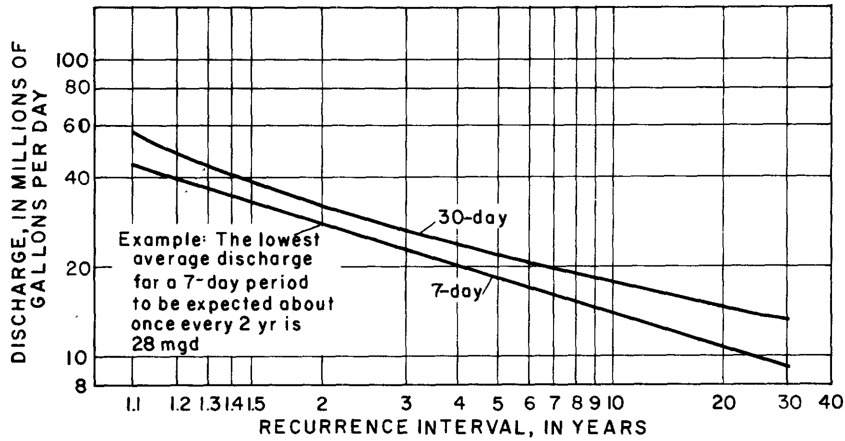

FIGURE 8.—Magnitude and frequency of 7- and 30-day low flows, Flint River near Otisville.

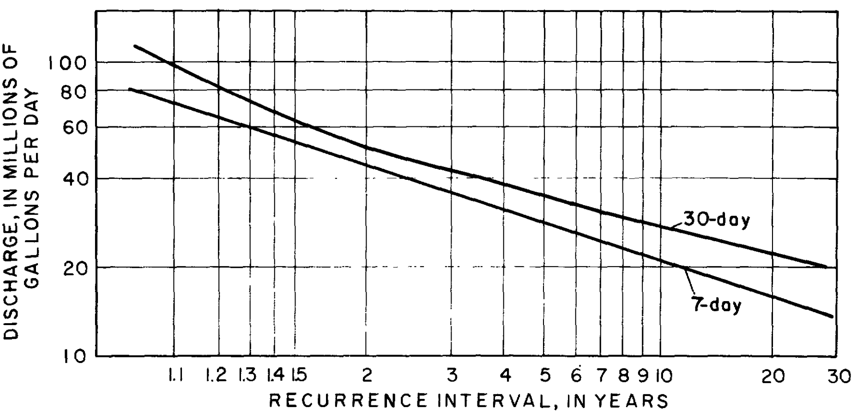

FIGURE 9.—Magnitude and frequency of 7- and 30-day low flows, Flint River near Flint.

fected by regulation from Holloway Reservoir. They are composite curves that are based on the integrated low-flow experience recorded at seven long-term gaging stations in central and southeastern Michigan for the period 1931–59. Such curves are more reliable than those computed from an individual record. Whereas flow-duration curves show the percentage of time that a specified flow is equaled or exceeded,

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these curves show how often, on an average, certain flows occur. For example, an average 7-day flow of 38 mgd at Otisville (45 mgd at the Flint waterworks) can be expected to occur about once in every 1¼ years. The average flow for a 30-day period could be expected to be as low as 38 mgd at average intervals of about 1½ years. At the Flint gage an average flow of 75 mgd for 7- and 30-day periods can be expected about once every 1.1 and 1.3 years, respectively. These examples emphasize that low-flow supplementation from storage in Holloway Reservoir is needed almost every year, depending upon water-supply and dilution requirements.

STORAGE REQUIREMENTS

The water requirements of the Flint area cannot be supplied by the Flint River without storage. In order to appraise the adequacy of the storage already provided and to indicate the additional use that can be supported by increasing the storage, the draft-storage curve for the Otisville gaging station (fig. 10) was prepared. The

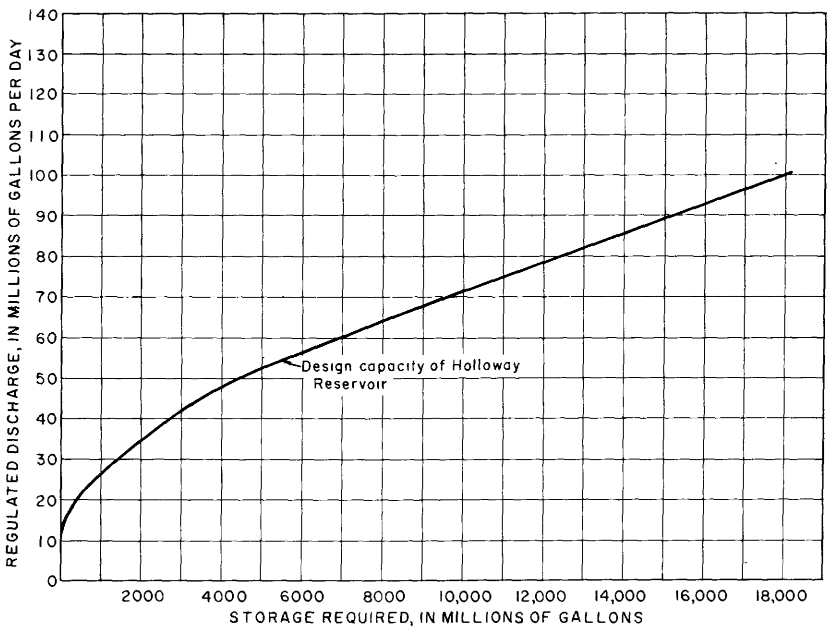

FIGURE 10.—Draft-storage curve, Flint River near Otisville. Based on lowest flow during 1930–52.

curve represents the storage that would have been required during the most critical periods of low flow recorded at Genesee during the period 1930–52, adjusted to represent the flow at the Otisville gage. This curve shows that during that period the storage (5,760 million gallons) in Holloway Reservoir at full-pond level (755 ft) could have supported a supply rate of about 55 mgd at the dam, less evaporation and seepage losses. Use of the storage of an additional 650 million gallons in Kearsley Reservoir would have increased the assured supply to about 58 mgd. During hot summers, evaporation loss from the reservoir surface would be about 5 mgd, so that the supply rates cited above should, in practice, be reduced accordingly. Assuming ideal reservoir operation, the summer minimum regulated flow could be about 58 mgd (58−5+5 for inflow) at the Flint sewage treatment plant and about 56 mgd (58−5+3 for inflow) at the waterworks. By raising the Holloway pond level to 760 feet, thereby increasing Holloway storage to 9,400 and total storage to 10,050 million gallons, the assured supply would be raised to about 72 mgd, less losses.

Draft-storage curves in which frequency is an element are useful for economic analyses of water-storage projects and permit the cost of storage to be weighed against the expected benefits accruing from the storage. The average recurrence intervals of regulated minimum flows at Otisville provided by various amounts of storage equal to or greater than that of Holloway Reservoir can be obtained from the curve of figure 11. Extensions of the storage-required frequency curves in figure 11 indicate that the draft-storage curve of figure 10 is for a recurrence interval of about 30 years.

FLOODS

Floods in the Flint area occur generally in the winter and spring. In 50 years, 1909–58, 37 of the annual flood peaks on the Flint River occurred between February 1 and June 1. Of the rest, only

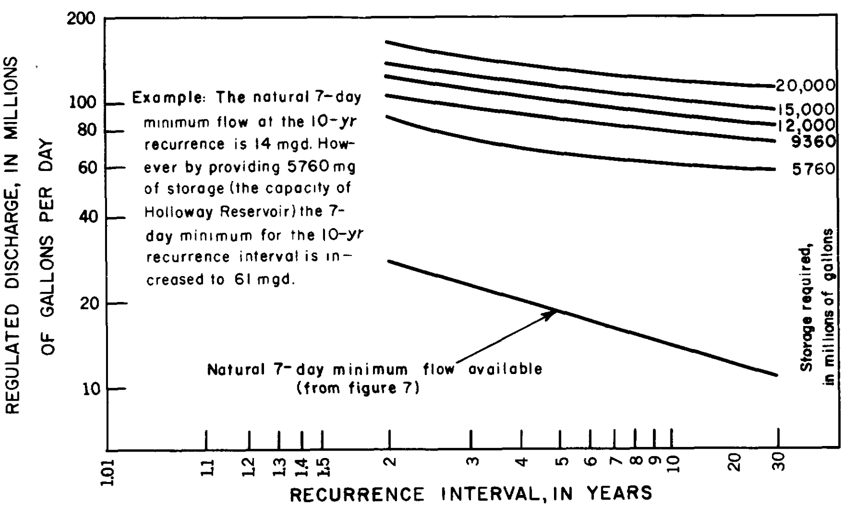

FIGURE 11.—Storage-required frequency curves, Flint River near Otisville. Storage computations based on records for 1930–52.

one exceeded flood stage, which is defined by the U.S. Weather Bureau as bankfull stage and corresponds to a gage height of 11 feet at the Flint gage (689.8 ft above sea level). The greatest rainstorm in the area since beginning of weather records at Flint in 1888 occurred on September 10–14, 1950, when 8.04 inches fell on Flint in a 90-hour period. Although precipitation over the basin above Flint was estimated as 5.3 inches for this storm, the discharge at the Flint gage was less than 2,900 mgd (4,500 cfs), and the peak stage was more than 2 feet below flood stage. By way of contrast, the greatest flood of record on the Flint River, in April 1947, resulted from an average of 2.3 inches of precipitation over the basin. Although the possibility of severe summer floods on the Flint River and its tributaries cannot be entirely discounted, especially on the smaller streams, the likelihood of their occurrence is much less than that for the late winter and early spring floods.

In Flint, flooding is aggravated by inadequate channel capacity or encroachments on the natural channel and flood plain or a combination of these factors. Channel encroachments in the downtown area are shown in the frontispiece. Five bridges with waterway area completely filled are clearly visible on the photograph. In many places foundation walls of buildings confine the Flint River. Inadequate waterway openings at many bridges also impede the passage of floodwaters. The flood plain is relatively narrow along the main stream in Flint, so that the overflow area on each bank is generally one block or less in width. Along the Swartz and Thread Creeks in Flint, where flooding has occurred on an average of about 4 years out of 10, the overflow area is mostly parks and playgrounds.

The flood of April 6, 1947, caused damages estimated at nearly $4 million in Flint (Corps of Engineers, 1954). The city waterworks, the Buick plant, the Chevrolet plant, and many other industrial plants, warehouses, stores, and other commercial buildings were affected by the flood. Production at the Chevrolet plant was halted for 4 days. Only 2 of the 14 bridges over the Flint River in the city were open to traffic at the height of the flood. The water-surface profile of the April 1947 flood crest through Flint and the areas inundated by the flood are shown in plates 5 and 6. The flood of March 1948 was about 2.4 feet lower than the 1947 flood at the Flint gage and was the second-highest flood since 1930. The flood damage at Flint was estimated as less than $300,000 by the Corps of Engineers.

Existing flood-protection works along the mainstream in Flint consist of retaining walls that are almost continuous through the business district to the lower limits of the Chevrolet property. Low levees have been constructed along the lower reaches of Swartz and Thread Creeks in Flint to protect residential areas. These, however, have been breached on several occasions. The city cleaned the lower reaches of the Swartz and Thread Creek channels in 1953–54. At Flushing the channel has been widened upstream from the ruins of an old mill dam, and the excavated material has been used to fill adjacent low areas.

The Corps of Engineers' survey report on the control of floods in the Saginaw River basin (1954) contains a proposed flood-control plan for Flint. Along the mainstream in Flint, the proposed plan calls for the enlargement and straightening of the channel from Hamilton Dam to Third Avenue Bridge, the improvement and extension of existing floodwalls, and the removal or modification of the bridges having inadequate waterway openings. Extending downstream from 12th Street on Thread Creek and thence to junction with Swartz Creek and to the mouth, the flood-control plan calls for enlargement of the channel, improvement of existing levees, and removal or modification of several bridges. The Corps estimates that the proposed improvements would reduce the stage of a flood equal to that of April 1947 (discharge of 9,630 mgd, 14,900 cfs, at gaging station, Flint River near Flint) by about 3 feet at the waterworks and by about 7 feet at the mouth of Swartz Creek. The plan for Swartz Creek downstream from the mouth of Thread Creek provides for protection from inundation from floods about 20 percent greater than the estimated previous maximum flood.

The flood-frequency curve (fig. 12) shows the average interval, in years, between floods that equal or exceed a given elevation at the Flint gage. Flood stage, for example, can be expected to occur at average intervals of about 3.3 years. The recurrence interval shown on flood-frequency curves is not intended to mean a regularity of occurrence. The 10-year flood, for example, is not expected to occur exactly every 10 years, but the chances are that 10 floods of equal or greater magnitude will occur in 100 years. The upper end of the Flint flood-frequency curve is based largely upon the flood of April 1947, which was probably the greatest flood in Flint since 1904. Weather Bureau records indicate that the March 1904 flood exceeded the April 1947 flood by 0.2 foot at the station, Flint River near Fosters, about 40 miles downstream from Flint.

CHEMICAL QUALITY AND TEMPERATURE

Water of the Flint River is of the calcium bicarbonate type and very hard. Hardness generally ranges from about 240 to 300 ppm except for short periods of high flows. Analyses of samples taken from the Flint River near Otisville, at Flint, at Flushing, and at Montrose (table 1) show a noticeable and consistent increase in iron, sodium, and chloride concentration as the water moves downstream.

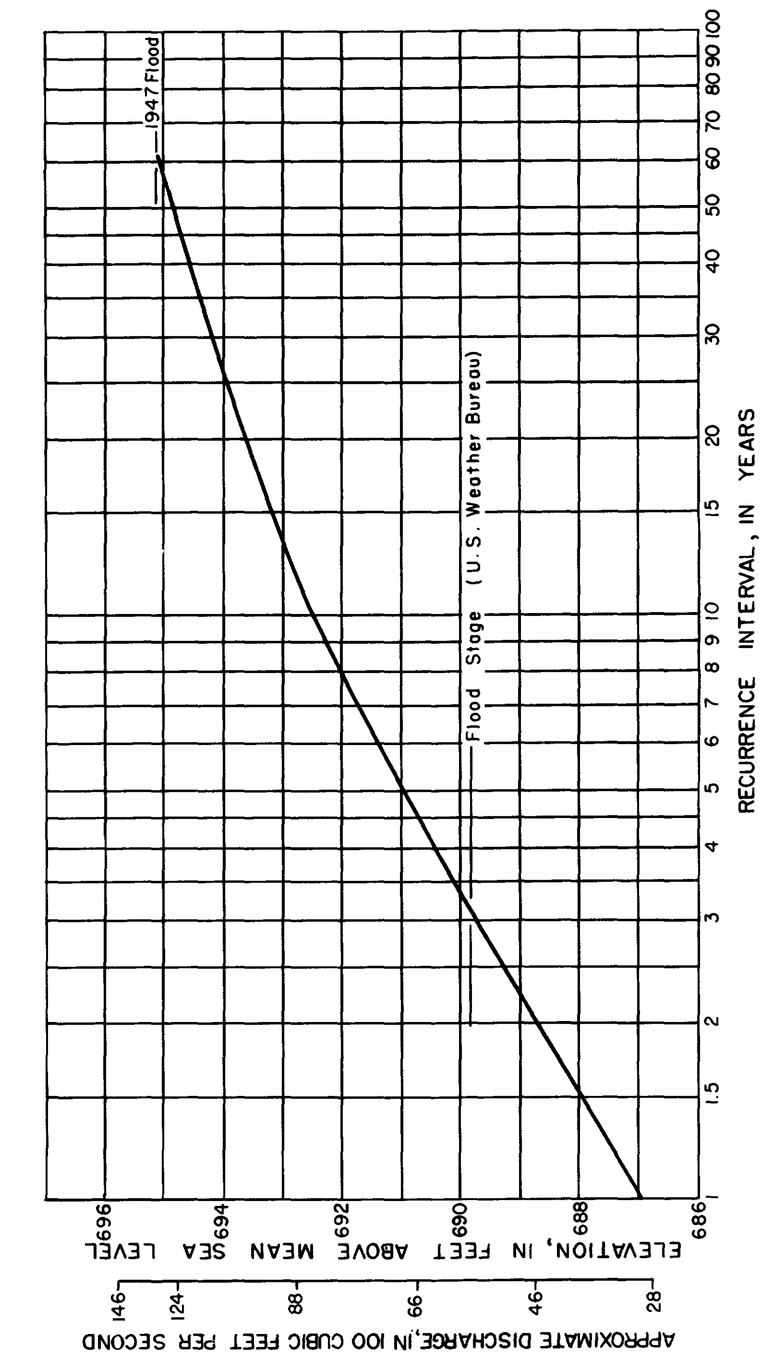

FIGURE 12.—Flood-crest frequencies on the Flint River near Flint

TABLE 1.—*Chemical analysis of water of Flint River*

[Results in parts per million except as indicated; analyses by U.S. Geol. Survey except as indicated]

Sampling date	Discharge (cfs)	Temp (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Ca,Mg	Hardness as $CaCO_3$: Noncarbonate	Phosphate (PO_4)	Specific conductance (micromhos at 25°C)	pH	Color
Flint River near Otisville (No. 2, fig. 1)																					
Dec. 15, 1953	142	------	9.3	0.09	------	76	25	12	1.8	304	51	16	0.4	1.4	356	294	43	------	576	7.7	10
Mar. 27, 1954	1,060	------	4.4	.06	------	58	18	5.3	1.8	184	58	8.5	.0	2.9	261	220	68	------	419	7.2	25
Sept. 6, 1956 [1]	[2] 144	------	8	.2	0.0	72	22	13	2.0	277	43	16	------	Tr	340	270	------	------	600	8.2	45
June 3, 1957 [1]	[2] 442	------	8	.1	.0	67	21.5	6.7	2.0	230	58	11	.0	3	330	255	------	------	500	7.8	75
Oct. 21, 1958	116	56	------	.06	.08	------	------	------	------	288	------	------	------	------	------	286	------	0.15	585	8.1	20
Apr. 2, 1959	1,750	35	5.0	.20	.08	46	13	3.5	2.1	131	50	7.5	.1	4.9	212	169	61	------	342	7.3	38
Flint River at Flint (No. 16, fig. 1)																					
Dec. 15, 1953	220	------	6.4	0.20	------	61	23	24	2.4	230	62	28	0.4	1.4	335	246	58	------	559	7.3	17
Mar. 27, 1954	1,900	------	6.1	.15	0.08	59	18	8.6	2.2	172	66	14	.2	5.3	288	220	80	------	448	7.2	30
Oct. 21, 1958	137	56	------	.28	.03	------	------	------	------	222	------	59	------	[3] 28	------	246	------	11	684	7.0	20
Apr. 2, 1959	4,280	37	5.4	2.1	.03	48	13	8.0	3.0	128	51	20	.1	5.8	220	174	68	------	380	7.2	28
Flint River at Flushing (No. 17, fig. 1)																					
May 25, 1954	190	72	3.5	[4] 0.45	------	70	23	32	3.9	242	72	36	0.3	7.2	386	270	72	------	641	7.5	25
Sept. 6, 1956 [1]	[5] 380	------	10	.5	0.0	68	23	19	2.7	261	52	25	------	Tr	360	265	------	------	650	8.4	70
Oct. 21, 1958	108	55	------	.18	.06	------	------	------	------	268	------	------	------	------	------	272	------	1.1	605	7.7	15
Apr. 2, 1959	4,740	37	5.6	1.8	.00	48	13	9.6	2.9	127	52	22	.1	5.8	242	174	70	------	393	7.2	28
Flint River at Montrose (No. 18, fig. 1)																					
Apr. 2, 1959	5,290	39	5.3	2.1	0.01	47	12	9.4	2.8	124	50	21	0.1	5.8	234	167	65	------	372	7.3	32

[1] Anal. by Michigan Dept. of Health.
[2] Daily mean discharge.
[3] Also 0.00 ppm NO_2 and 0.0 ppm NH_4.
[4] Also 0.07 ppm hexavalent chromium.
[5] Estimated.

Most of the other dissolved constituents show only minor changes in concentration between Otisville and Montrose.

The variation in quality at a single point is shown by daily sampling and chemical analyses made by the Flint Division of Water Supply. The daily samples were obtained from the raw-water intake at the Flint water-treatment plant. Cumulative frequency, or duration, curves were prepared from the daily analyses for the period January 1957 to December 1958, and table 2 was prepared from these curves. The table shows the percentage of time that a water user could expect certain values of hardness, color, and other constituents to occur. The greatest variation is in noncarbonate hardness, color, and turbidity, whereas pH is the most uniform. The values of calcium, magnesium, total alkalinity (as $CaCO_3$), and total hardness (as $CaCO_3$) that are exceeded 5 percent of the time are only one-third greater than the values that occur 95 percent of the time. Seasonal variations of several chemical and physical characteristics are shown in figure 13.

TABLE 2.—*Chemical and physical characteristics of raw water from the Flint River at Flint, January 1957 to December 1958*

[Calculated from daily analyses made by the Flint Water Department]

Chemical constituent or physical property	Concentrations or values in ppm or conventional units equaled or exceeded for percent of time indicated						
	5	10	25	50	75	90	95
Calcium	88	84	78	73	71	69	67
Magnesium	31	30	28	25	23	21	20
Total alkalinity (as $CaCO_3$)	265	258	244	229	213	199	190
Total hardness (as $CaCO_3$)	331	321	306	289	275	264	257
Noncarbonate hardness (as $CaCO_3$)	93	81	72	63	53	48	47
pH	8.6	8.5	8.4	8.3	8.2	8.1	8.0
Color	67	59	44	39	35	32	32
Turbidity	68	44	30	23	18	14	12

Holloway Reservoir and, perhaps to some extent, the natural characteristics of the basin tend to give the water a uniform quality. Although the Flint River near Otisville had a discharge on October 21, 1958, that was about a tenth of that on March 27, 1954, the specific conductance, as a measure of dissolved mineral concentration, increased only from 419 to 585 micromhos.

The large industries and the city of Flint add certain constituents to the dissolved load of the Flint River. As a measure of the pollution of the river, one or more samples at each of the sampling stations were analyzed for phenols, phosphate, oils and waxes, and dissolved oxygen (table 3). Despite treatment of sewage and plant wastes, the Flint River receives some pollution in the Flint area. On the basis of the samples taken October 21, 1958, dissolved oxygen may

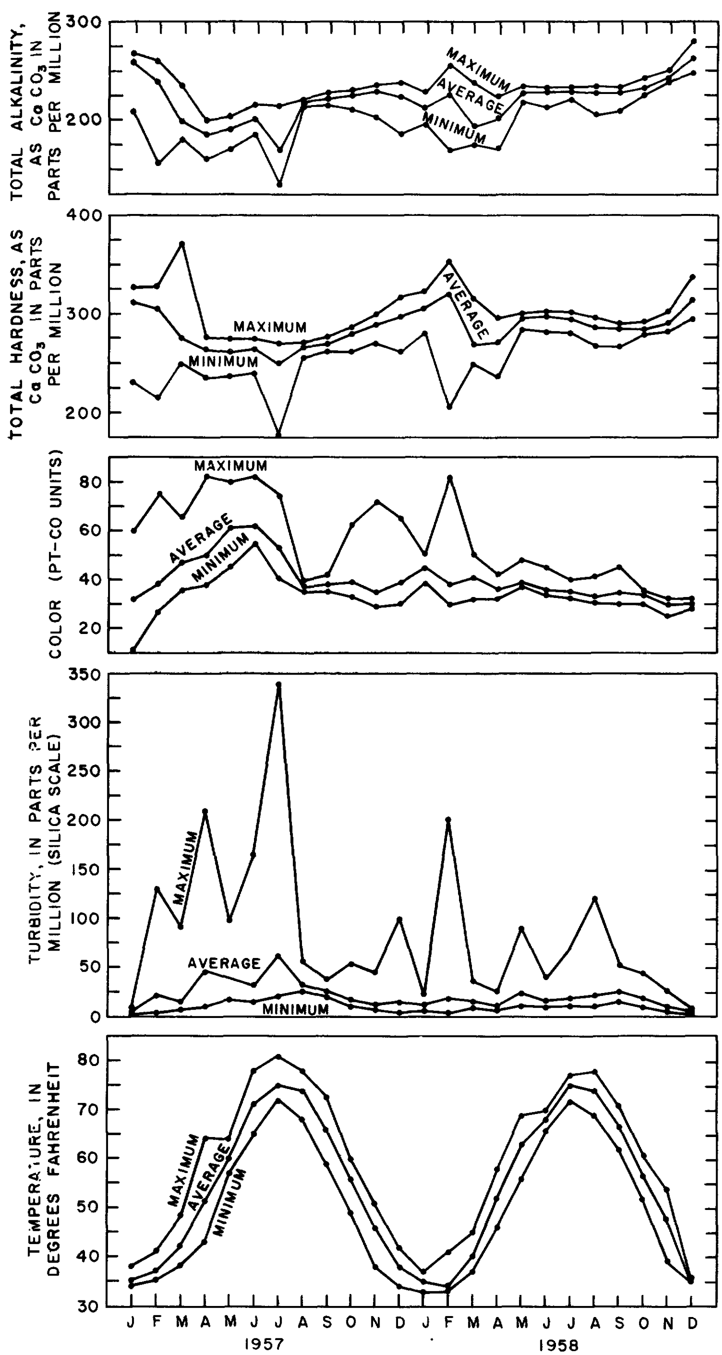

FIGURE 13.—Maximum, minimum, and average values of several chemical and physical characteristics of raw water from the Flint River, January 1957 to December 1958. Analyses by city of Flint, Division of Water Supply.

be low at Flushing during periods of low flow. Eleven samples taken at Flint in 1954, 1958, and 1959 indicate that phenol content has been highly variable, for the concentration ranged from 0.000 ppm to 0.040 ppm. Federal Drinking Water Standards (U.S. Public Health Service, 1946) call for not more than 0.001 ppm phenol because of the tastes and odors resulting from chlorination of such waters. Nitrate and chloride did not reach objectionable concentrations in the few samples examined.

TABLE 3.—*Chemical pollutants, in parts per million, of the Flint River*

Sampling date	Discharge (cfs)	Temp (°F)	Chloride (Cl)	Nitrate (NO_3)	Phosphate (PO_4)	Phenols (as C_6H_5OH)	Oils and waxes	Dissolved oxygen	
								ppm	Percent saturation
Flint River near Otisville (No. 2, fig. 1)									
Oct. 21, 1958	116	56	--	--	0.15	0.000	26	11.4	108
Apr. 2, 1959	1,750	35	7.5	4.9	--	.000	1	11.6	83
Flint River at Flint (No. 16, fig. 1)									
Jan. 25, 1954	[1] 166	35	--	--	--	--	4	--	--
Feb. 24, 1954	2,590	34	--	--	--	0.000	6	--	--
Mar. 27, 1954	1,900	--	14	5.3	--	.008	12	--	--
Apr. 22, 1954	640	54	--	--	--	.010	3	--	--
May 14, 1954	308	59	--	--	--	.040	5	--	--
June 12, 1954	218	--	--	--	--	.010	2	--	--
July 12, 1954	145	76	--	--	--	.038	6	--	--
Aug. 9, 1954	89.6	75	--	--	--	.000	6	--	--
Sept. 9, 1954	56.7	--	--	--	--	.003	6	--	--
Oct. 8, 1954	368	--	--	--	--	.011	5	--	--
Oct. 21, 1958	108	55	--	--	1.1	.001	13	9.5	90
Apr. 2, 1959	4,280	37	20	5.8	--	.000	7	11.8	87
Flint River at Flushing (No. 17, fig. 1)									
May 25, 1954	190	72	36	7.2	--	0.038	6	--	--
Oct. 21, 1958	137	56	59	[2] 28	11	.001	14	4.3	41
Apr. 2, 1959	4,740	37	22	5.8	--	.000	1	11.6	86
Flint River at Montrose (No. 18, fig. 1)									
Apr. 2, 1959	5,290	39	21	5.8	--	0.000	6	11.4	87

[1] Estimated.
[2] Also 0.00 ppm NO_2 and 0.0 ppm NH_4.

The quality of the Flint River water, without treatment, certainly limits its use in some industries. The water requires softening at nearly all times to prevent scale formation in boilers and cooling equipment. Table 4 gives criteria for use by various industries commonly found in the Flint area. In addition to softening, the water needs to be treated to reduce one or more of the following: Phenols, color, turbidity, iron, and manganese. Other uses may require additional treatment. A survey of the larger water users in the Flint area shows that other factors of quality such as dissolved solids and chloride would be critical in the city supply especially if pollution of the Flint River increased, which could occur through greater industrial development in the Flint area. The survey also showed that many industrial plants recirculate some of their water and that some treat the plant effluents. At times concentrations of iron, manganese, and phenol and color and turbidity in the Flint River water exceed the limits recommended in drinking water standards.

The only daily water temperatures available for the Flint River were those taken in the Flint water-treatment plant, consequently, these temperatures may be slightly higher, especially in the winter, than the true temperatures of the river. Daily temperatures from October 1954 to September 1958 were compiled, and a cumulative frequency curve was prepared. Temperatures during the 4-year period ranged from freezing to 86°F, however, temperatures above 79°F could be expected only 1 percent of the time. (See table 5.) At most of the industrial plants officials questioned expressed an optimum operating water temperature of between 50° and 60°F, but all stated that the plants could operate on a maximum of as much as 75° to 85°F. These maximum temperatures would occur less than 5 percent of the time. Optimum operating temperature of 50°F would be exceeded 54 percent of the time and for 60°F, 37 percent of the time. Much of the cooling water is recirculated, so that temperature of the make-up water is not as critical as it might seem.

SMALL STREAMS TRIBUTARY TO FLINT RIVER

The most important small streams in the Flint area are Butternut, Kearsley, Thread, and Swartz Creeks (fig. 1). Butternut Creek, the smallest, drains an area in the northeast corner of Genesee County and enters the Flint River near Genesee. Kearsley, Thread, and Swartz Creeks, draining from the southeast and south, all have their headwaters in the morainic terrain of northwestern Oakland County. Kearsley Creek enters the Flint River just below the city waterworks. Thread Creek enters Swartz Creek about a mile upstream from the Flint River in the south part of the city and together with Swartz Creek forms the largest tributary to the main stem of the Flint River.

The Butternut Creek basin, mantled mostly by moraines, is predominantly agricultural. A few small lakes and ponds are in the basin. Many small lakes and ponds are found in the hilly, broken terrain that comprises the headwater areas of the other three streams. The downstream ends of the Kearsley, Thread, and Swartz Creek basins are in and on the fringe of urban Flint. Rather extensive suburban development has taken place in the middle parts of the Kearsley and Thread Creek basins, but there are also many farms in

TABLE 4.—*Quality of water criteria for domestic and several industrial uses*

[References: U.S. Public Health Service (1946), California State Water Pollution Control Board (1952)]

Constituent or property	Drinking water standards (Maximum allowable concentration, in ppm)	Boiler feed waters (Suggested limits of tolerance, in ppm, for boilers of indicated pressures)				Food canning and freezing (Range of recommended threshold values, in ppm)	Steel manufacturing (Recommended limits)	Cooling water (Limiting concentrations, in ppm)
		0–150 psi	150–250 psi	250–400 psi	>400 psi			
Metals:								
Iron (Fe)						0.2		0.5
Manganese (Mn)						0.2		0.5
Iron and manganese	0.3					0.2		0.5
Aluminum oxide (Al_2O_3)		5	0.5	0.05	0.01			
Silica (SiO_2)		40	20	5	1			
Magnesium (Mg)	125							
Sulfate (SO_4)	250							
Chloride (Cl)	250						<175 ppm	
Fluoride (F)	1.5					1.0		
Sodium chloride (NaCl)						1,000–1,500		
Alkalinity:								
Bicarbonate (HCO_3)		50	30	5	0			
Carbonate (CO_3)	120	200	100	40	20			
Hydroxide (OH)		50	40	30	15			
Hardness (as $CaCO_3$)						50–85 (general) 200–400 (peas) 100–200 (fruits and vegetables) 25–75 (legumes)	<50 ppm	50
Total		80	40	10	2			
Solids:								
Total	[1] 500	3,000–500	2,500–500	1,500–100	50			
Suspended							<25 ppm	
Gases:								
Hydrogen sulfide (H_2S)		5	3	0	0	1.0		
Oxygen, dissolved		2.0	0.2	0.0	0.0			
Oxygen, consumed		15	10	4	3			
Taste and odor						None–low		

Organics:								
Materials							Low as possible	
Phenols, as C_6H_5OH	0.001							
Color (units)	20	80	40	5	2			
Turbidity (silica scale)	10	20	10	5	1	1.0–10		50
Corrosion:								
Potential							Lowest possible level	
pH	10.6	8.0 (min)	8.4 (min)	9.0 (min)	9.6 (min)	≮7.5	6.8–7.0	6.5–7.5
Temperature (°F)							<75°F	Noncorrosive or "nonaggressive"

[1] 1,000 ppm permitted if no other water is available.

Electroplating (Recommended quality)	Plastics manufacture: Constituent or property	Plastics manufacture: Range of recommended threshold and limiting concentrations, in ppm
Water should be soft. Under certain conditions traces of iron, aluminum, sodium, potassium, carbonate, sulfite, sulfate, chloride, copper, lead, dissolved oxygen, and nitrogen compounds cause difficulties in plating.	Turbidity	2
	Color	2
	Iron and manganese	.02
	Manganese	.02
	Total solids	200

TABLE 5.—*Water temperatures of the Flint public supply, October 1954 to September 1958*

[Water temperatures at tap in Flint waterworks by Flint Water Department]

Percent of time	*Temperatures equaled or exceeded*
1	79
5	76
10	73
25	67
50	53
75	37
90	34
95	33
99	32

these areas. Except for the headwater lake area and the area downstream from the mouth of the West Branch, the Swartz Creek basin is primarily agricultural. This basin, for the most part, is on a till plain where the ground is level to gently undulating and stream slopes are flat.

FLOW CHARACTERISTICS

No gaging stations have been operated on Butternut, Kearsley, Thread, and Swartz Creeks within the report area. Discharge measurements were made at one or more points on each of the four tributary streams during 1952–54 and 1958–59. Eighteen discharge measurements were made at the downstream point in each basin to study flow characteristics. Chemical analyses were also made of water samples taken at selected sites on these streams and their tributaries.

Estimated flow-duration and low-flow frequency data for the four principal small streams in the Flint area are given in tables 6 and 7. Units of million gallons per day per square mile are used to facilitate comparison between streams and for estimation of like data for other ungaged streams having similar physical and cultural characteristics. The flow-duration data given represent base flow, that part of streamflow which is derived from ground-water seepage. The data contained in tables 6 and 7 are not as accurate as similar data computed from continuous gaging-station records.

The low-flow yield decreases progressively from the upstream to the downstream tributaries. For example, the unit yield of Butternut Creek (table 6) is four times greater than that of Swartz Creek at the

TABLE 6.—*Estimated duration of flow, small streams in Flint area, 1931–59*

Stream	Loc. No. on fig. 1	Drainage area (sq mi)	Discharge equaled or exceeded for percent of time shown (mgd per sq mi)				
			70	80	90	95	98
Butternut Creek near Genesee	4	40.6	0.112	0.089	0.067	0.054	0.042
Kearsley Creek near Flint	8	99.6	.095	.069	.045	.033	.022
Thread Creek at Flint	15	61.8	.066	.047	.030	.022	.015
Swartz Creek at Flint	13	108	.047	.032	.019	.013	.0083

TABLE 7.—*Estimated low-flow frequency, small streams in Flint area, 1931–59*

Stream	Loc. No. on fig. 1	Drainage area (sq mi)	Period (consecutive days)	Average flow for recurrence interval shown (mgd per sq mi)		
				2-yr	5-yr	10-yr
Butternut Creek near Genesee	4	40.6	7	0.060	0.040	0.033
			30	.070	.049	.040
Kearsley Creek near Flint	8	99.6	7	.038	.021	.015
			30	.047	.028	.021
Thread Creek at Flint	15	61.8	7	.025	.014	.010
			30	.032	.019	.014
Swartz Creek at Flint	13	108	7	.016	.008	.005
			30	.021	.011	.007

95-percent point on the duration curve. Similarly, the minimum average 7-day flow per square mile for Butternut Creek (table 7) at the 10-year recurrence interval is seven times greater than that for Swartz Creek. Obviously, Butternut Creek is a much better potential source for small to moderate water supplies than Swartz Creek even though it has a drainage area only 0.4 times as large as that of Swartz Creek. The base flows of Kearsley and Thread Creeks are intermediate between those of Butternut and Swartz Creeks.

The reason, or reasons, for the wide variation in the base-flow yields of these streams is obscure. Surely there are no large differences in the climatological and meterological factors to account for the variations within so small an area. They may be due to differences in one or more of the following factors: Topography, geology, coincidence of surface-water and ground-water drainage divides, and the amount of water withdrawn by wells tapping the deposits that normally provide seepage to streams. There may be other unknown contributing factors also.

CHEMICAL QUALITY AND TEMPERATURE

Water in the small streams tributary to Flint River is generally of the calcium bicarbonate type (table 8). The waters are hard to very hard and, at times, contain objectionable amounts, depending on the use, of iron, manganese, color, and other constituents. Analyses of samples taken at a low and a medium or high flow indicate the chemical character of the water and the approximate ranges of concentration of dissolved constituents. Highest concentrations of dissolved solids were found in the Kearsley and Swartz Creek basins. The range and order of concentration of the various dissolved constituents are similar to those of the Flint River. However, no phenols or oils and waxes were found in the three samples examined for these pollutants.

Water from these four creeks would require treatment for municipal or industrial use. Softening, disinfection, and the occasional removal or iron, manganese, color, and turbidity would be required for domestic

TABLE 8.—*Chemical analyses of small streams tributary to Flint River*

[Results in parts per million except as indicated; analyses by U.S. Geol. Survey except as indicated]

Date of collection	Discharge (cfs)	Temp (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phenols as C_6H_5OH	Oils and waxes	Dissolved solids residue (due on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Turbidity	Dissolved oxygen: ppm	Dissolved oxygen: percent saturation
Black Creek near Davison (No. 7 fig. 1)																									
Dec. 15, 1953	10.7	----	12	0.02	------	64	25	62	5.3	280	40	70	0.8	24	------	----	461	264	33	772	7.0	15	------	------	------
Mar. 26, 1954	72.6	----	4.9	.18	0.21	56	16	6.4	3.4	130	84	11	.2	11	------	----	289	206	99	429	6.9	60	------	------	------
Butternut Creek near Genesee (No. 4 fig. 1)																									
Dec. 15, 1953	5.79	----	12	0.07	------	81	28	6.7	1.6	318	65	6.0	0.2	1.8	------	----	365	316	57	580	7.9	7	------	------	------
Mar. 26, 1954	128	----	6.1	.28	0.18	47	12	3.4	2.6	130	54	6.8	.1	5.0	------	----	226	167	60	335	7.2	60	------	------	------
Kearsley Creek near Flint (No. 8 fig. 1)																									
Dec. 15, 1953	22.4	----	9.0	0.04	------	66	23	14	1.6	278	39	14	0.3	2.2	------	----	311	260	31	521	7.8	8	------	------	------
Mar. 26, 1954	260	----	5.1	.08	------	59	17	6.4	2.4	156	73	11	.0	8.7	------	----	276	220	89	435	7.1	48	------	------	------
Sept. 6, 1956 [1]	--------	----	8	.6	0.0	80	22	12	2	283	50	18	------	.0	------	----	390	290	---	650	8.3	75	31	------	------
Apr. 2, 1959	591	41	7.1	.66	.64	46	13	5.8	3.1	132	50	16	.1	6.4	0.000	0	223	169	60	352	7.2	35	------	10.8	84
Kearsley Reservoir (No. 9 fig. 1)																									
Dec. 15, 1953	--------	----	5.2	0.01	------	57	25	17	2.0	266	36	19	0.3	1.0	------	----	298	244	27	512	7.9	7	------	------	------

Thread Creek at Flint (No. 15 fig. 1)																									
Mar. 25, 1953[1]			4	0.6		72	18.3	11.5		239	60	12	0.1	Trace			334	255		590	8.1	25	2.5		
Aug. 18, 1953[1]												24								550					
Dec. 15, 1953	11.9		11	.03		69	24	13	1.6	280	42	12	.3	7.4			330	270	41	540	7.2	10			
Mar. 26, 1954	161		5.8	.07		55	16	6.0	2.4	151	65	12	.1	5.3			260	204	79	413	7.2	40			
Sept. 6, 1956[1]			10	.6	0.0	88	29	39	3	310	63	68					530	330		850	8.3	80	21		
Apr. 1, 1959	95.5	39	6.3	.13	.08	70	20	9.9	1.9	182	77	26	.1	4.2	0.000	0	336	257	108	521	7.7	33		11.6	88
West Branch Swartz Creek near Otterburn (No. 12 fig. 1)																									
Dec. 15, 1953	1.10		7.1	0.04		82	36	66	3.9	344	113	64	0.6	5.9			560	354	71	911	7.5	8			
Mar. 26, 1954	119		6.1	.11		53	15	6.2	2.7	124	74	11	.1	13			252	195	92	401	6.6	55			
Swartz Creek at Flint (No. 13 fig. 1)																									
Dec. 15, 1953	8.49		4.9	0.03		61	23	19	1.8	262	41	21	0.4	0.4			316	248	32	529	7.7	9			
Mar. 27, 1954	249		4.5	.06		58	16	5.6	2.2	146	75	10	.0	9.2			273	210	91	423	7.2	45			
Sept. 6, 1956[1]			6	.8	0.0	80	25	14	2.2	295	55	20		.0			414	300		630	8.4	40	20		
Apr. 1, 1959	194	42	6.0	.83	.10	65	19	9.4	2.1	176	74	22	.1	6.4	0.000	0	308	240	96	501	7.5	30		11.7	93

[1] Analyses by Michigan Department of Health.

use. For industry the treatment may be more extensive, depending on the use and type of industry. Water for almost every industry in the Flint area would require softening to prevent scale formation, and iron, manganese, color, and turbidity would have to be removed or reduced. Boiler feed waters and water for plastics manufacture would require the most treatment. For the plastics industry, some demineralization with ion exchange resins probably would be required.

Water-temperature records for these creeks are not available; however, these streams are small, and the water temperatures will approach daily average air temperatures when air temperatures are above freezing. Maximum water temperatures in summer would usually range from 80° to 85° F for a few days in June, July, and August. Water temperatures could be expected to be at or near freezing at times or continually from November to March.

SHIAWASSEE RIVER

The Shiawassee River originates in Oakland County, flows westward through the extreme southern part of Genesee County, thence turns northwest and north, and empties into the Saginaw River. The river lies in a glacial outwash channel, and the basin is predominantly morainic, studded with numerous small lakes, some of which have no outlet.

The continuous sreamflow records collected at Byron, just outside the western limits of Genesee County have been analyzed for this report. The South Branch, the largest tributary of the Shiawassee River, enters the stream just above the Byron gage. Additional records are available for stations farther downstream. (See fig. 3.)

STORAGE IN THE BASIN

The largest lakes are Lobdell, Silver, Ponemah, and Fenton Lakes. No records are available to indicate the fluctuation in the levels of these and other lakes in the area. The total natural storage in the lakes of the basin is large in relation to the size of the basin; this storage reduces flood flow and increases the dry-weather flow.

Artifical impoundments are few and small in the Genesee County part of the basin. A dam on the Shiawassee River in Fenton forms a small pond. Another small pond, in the village of Linden at the site of an old recently abandon grist mill, was drained. A small reservoir is formed by a dam at Byron, just outside the county. A dam with gated spillway controls the level of Lobdell Lake, so that a part of the storage contained in this lake can be controlled artificially.

USE OF WATER

Recreation is the most important nonwithdrawal use of water. Being so close to Flint, the lakes in the Shiawassee River basin afford excellent recreational opportunities for the populace of Flint and the surrounding area. Some of the larger lakes such as Lobdell, Ponemah, and Fenton are well developed with resorts, cottages and year-round residences. Some lakes have excellent sand beaches for swimmers. They and many others are also used for fishing, boating, and picnicking.

A grist mill in Argentine, utilizing 14 feet of head at the outlet of Lobdell Lake, generates about 100 horsepower. Possibly some minor use of the streams is made for waste disposal.

Except for possibly a few small irrigation systems, there is no withdrawal use of water from the Shiawassee River and its tributaries in Genesee County.

FLOW CHARACTERISTICS

The average, maximum, and minimum flows recorded at the gaging station on the Shiawassee River at Byron, 1947–58, were 185, 1,850 (2,860 cfs), and 16 mgd, respectively. The flow characteristics are shown by flow-duration curves (fig. 14) and low-flow frequency curves

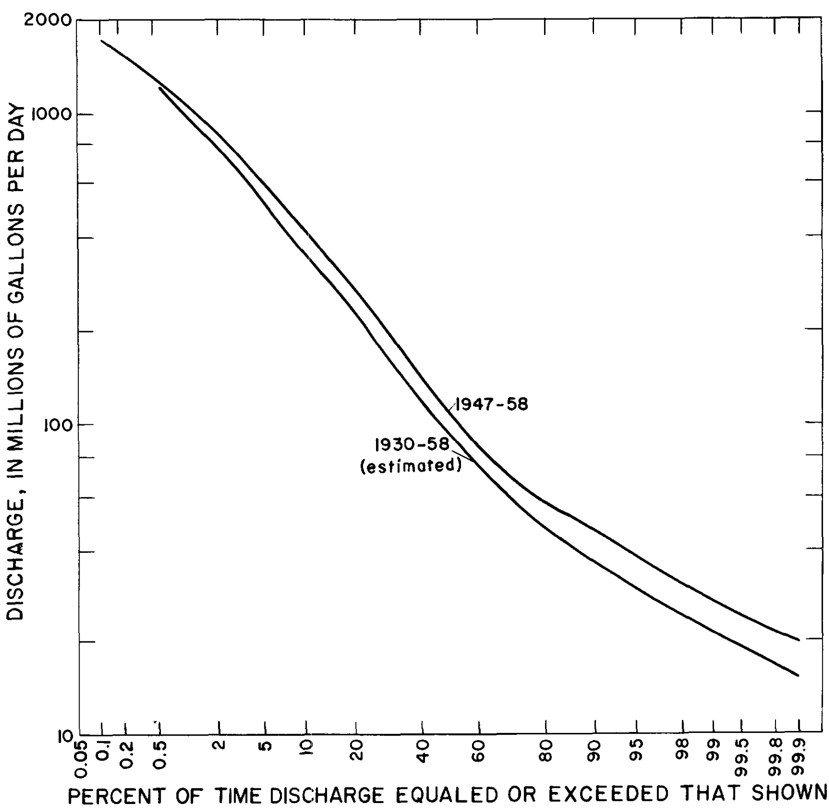

FIGURE 14.—Duration curves of daily discharge, Shiawassee River at Byron, 1930–58 and 1947–58.

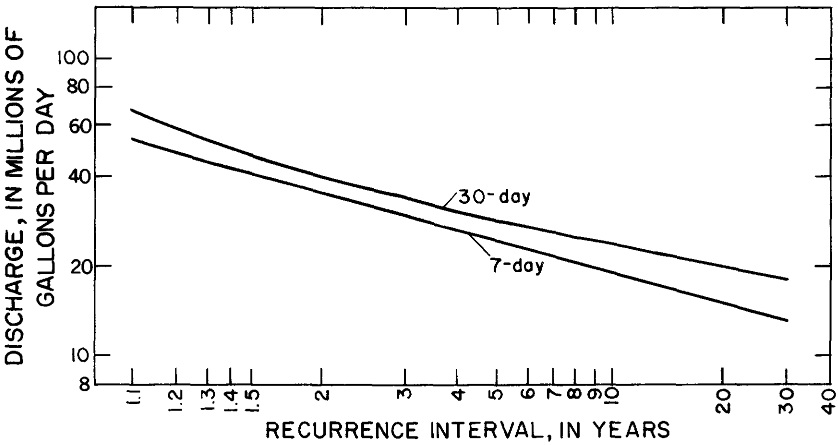

FIGURE 15.—Magnitude and frequency of 7- and 30-day low flows, Shiawassee River at Byron.

(fig. 15). Because the last 11 years have been relatively wet, a flow-duration curve was estimated for the period 1930–58, which is believed to be a more representative period. A potential water user would be safer in using the estimated long-term duration curve than the short-term curve in assessing the water-supply possibilities of the basin. The effect of the natural storage in this basin is shown by the somewhat flatter slope of these flow-duration curves in comparison with those for the Flint River stations. The low-flow frequency curves, based on correlation with the Flint River stations and the regionalized low-flow frequency curves developed for them, also illustrate the beneficial effect of storage. For example, the minimum average discharge for a 7-day period to be expected about once in 10 years is 19 mgd for Byron (fig. 15) and 14 mgd for Flint River near Otisville (fig. 8) even though the drainage area at Byron is only two-thirds of that for Otisville.

STORAGE REQUIREMENTS

The records for the Flint River at Genesee were used to prepare an estimated curve of storage requirements for the Shiawassee River at Byron (fig. 16), because the records for the Shiawassee River at Owosso were affected too much by regulation during the critical low-flow periods of the 1930's to be used for this purpose. The curve, although not as accurately defined as that for the Flint River near Otisville, represents a reasonable estimate of storage needed for various draft rates at Byron for a recurrence interval of about 30 years. This estimate of a recurrence interval of 30 years for the amount of storage required during the most critical droughts of record is based on the comparison between the storage-required frequency

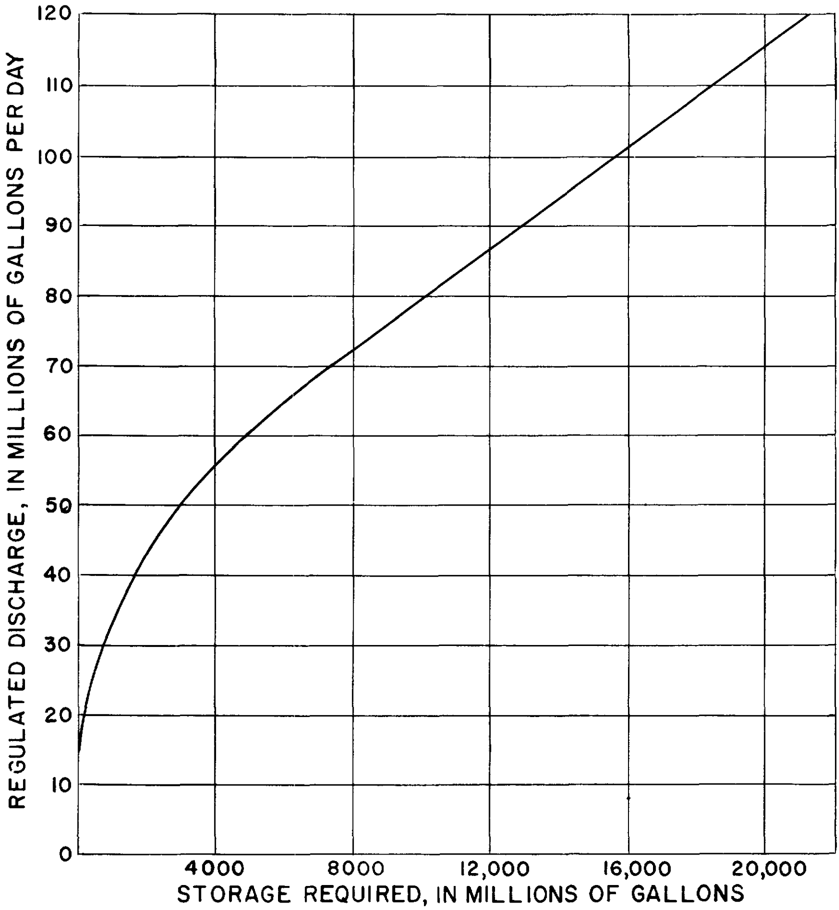

FIGURE 16.—Estimated draft-storage curve, Shiawassee River at Byron.

curves and draft-storage curve for Flint River near Otisville (figs. 10 and 11).

FLOODS

No serious floods have been reported on the Shiawassee River above Byron, another manifestation of the beneficial effect of the large natural storage in the basin. Damaging floods have occurred farther downstream at Corunna and Owosso in Shiawassee County, where the moderating influence of the storage in the headwater basin is no longer so pronounced. Based on a correlation of peak discharges with the station at Owosso, the peak for the April 1947 flood, the largest flood of record in the basin, is estimated as about 2,600 mgd (4,000 cfs) at Byron.

CHEMICAL QUALITY AND TEMPERATURE

Waters in the Shiawassee River basin are of the calcium bicarbonate type and are generally less mineralized than waters of the Flint River and its small tributaries. As indicated by the analyses of only two samples of each (table 9), water from Lakes Fenton, Ponemah, and Lobdell ranges in hardness from 60 ppm (Lake Fenton) to 206 ppm (Lake Ponemah). The lakes were more mineralized in the fall than in the spring. Samples from the Shiawassee River near Argentine and at Byron had a higher dissolved solids content than the lakes. The samples of river water had a hardness of 200 ppm or more. Iron concentrations were higher both in the lakes and in the Shiawassee River in April 1958 than in October 1959.

According to the criteria given in table 4, some treatment, particularly softening, would be required for municipal or industrial use. Additional treatment such as color removal, pH adjustment, and demineralization would depend on the use of the water and the type of industry. Present use of the water in the lakes for boating, fishing, swimming, and the like would probably forestall any real municipal or industrial use. However, under rigid controls the lakes could prove to be a valuable reserve or emergency supply for municipalities and certain industries. The quality is such that the water could be used with little or no treatment, except chlorination, for domestic and some industrial use.

Temperature records are not available for surface waters in the Shiawassee River basin. Water temperatures would be about the same as the Flint River and its tributaries. However, the river and lakes would probably have a more even temperature.

MISCELLANEOUS SMALL STREAMS

There are a few other streams in the county that could be used as a source of water. Jones Creek, a tributary of the Shiawassee River lying in the southwestern part of the county, drains about 28 square miles at the Genesee County line. Brent Run, which enters the Flint River from the east about a mile below Montrose, drains an area of about 37 square miles in the northwestern part of the county. Pine Run, which flows through the village of Clio in the north-central part of the county, also drains an area of about 37 square miles.

Streamflow information is not available for these streams. Their dry-weather flow is probably very small; some may even go dry during long hot, dry periods. Without storage they could support only small uses that would not be adversely affected by occasional interruption in flow.

LAKE HURON

The tremendous quantity of fresh water in the Great Lakes seemingly would be almost inexhaustible As water needs in the Flint

TABLE 9.—*Chemical analyses of streams and lakes in the Shiawassee River basin*

[Results in parts per million except as indicated. Agency making analysis: MDH, Michigan Dept. Health; USGS, U.S. Geol. Survey]

	Lake Fenton (No. 19, fig. 1)		Lake Ponemah (No. 20, fig. 1)		Lobdell Lake (No. 21, fig. 1)		Shiawassee River near Argentine (No. 22, fig. 1)		Shiawassee River at Byron (No. 23, fig. 1)	
Date of collection	10-21-58	4-1-59	10-21-58	4-1-59	10-21-58	4-1-59	10-21-58	4-1-59	12-15-53	3-27-54
Agency making analysis	MDH	USGS	MDH	USGS	MDH	USGS	USGS	USGS	USGS	USGS
Discharge cfs							19.3	310	122	1,030
Temperature, ° F	58	38	57	38	55	39	51	49		
Silica (SiO_2)	3	1.2	8	5.7	4	6.8		6.6	8.1	6.8
Iron (Fe)	.0	.21	0	.05	.0	.15	.07	.17	.03	.07
Manganese (Mn)		.01		.00		.03	.05	.04		
Calcium (Ca)		14		35		46		50	63	56
Magnesium (Mg)		6.1		14		14		16	24	15
Sodium (Na)		8.1		5.2		3.2		5.4	12	4.2
Potassium (K)		1.2		1.5		1.4		1.4	1.6	1.8
Bicarbonate (HCO_3)	145	58	220	144	222	184	230	190	276	170
Carbonate (CO_3)		0		0		0	0	0	0	0
Sulfate (SO_4)		6.0		24		21		31	36	53
Chloride (Cl)	17	18	15	9.5	5	3.0		9.0	13	5.0
Nitrate (NO_3)	.0	.4	0	.1	0	.6		.2	.2	.0
Phosphate (PO_4)							.42		1.0	6.4
Phenols as C_6H_5OH		.000		.000		.000	.002	.000		
Oils and waxes		2		1		4	.3	4		
Dissolved solids (residue on evaporation at 180°C)	188	87	260	167	246	183		216	298	244
Hardness as $CaCO_3$:										
Calcium, magnesium	140	60	206	145	200	173	208	191	254	200
Noncarbonate		12		27		22		36	30	62
Specific conductance (micromhos at 25 °C)	325	169	450	302	400	332	427	379	503	388
pH	8.1	7.2	7.7	7.6	8.0	7.5	7.6	7.4	7.8	7.1
Color		4		13		12	15	18	6	45
Turbidity										
Dissolved oxygen:										
ppm		11.6		19.6		10.2	7.6	10.8		
Percent saturation		86		146		78	68	94		

area rapidly approach the limits of the existing facilities, it is natural that the area should turn to Lake Huron in its search for another source of water. The city's tentative plans envision a 65-mile pipeline from the southern arm of Lake Huron near Port Huron to serve Flint, and eventually most of Genesee County. The capacity of the proposed system would be sufficient to supply the anticipated water needs of Flint to about the year 1990. Cities and communities along, or near, the route of the proposed pipeline would be invited to join this venture. When the Lake Huron source is developed and construction completed, the water in Holloway Reservoir would be used only for sewage dilution.

The level of Lake Huron is subject to long-term, seasonal, and short-period fluctuations. The high level generally occurs in July, and the low in February although there can be considerable divergence from this pattern. The average seasonal range is about 1.1 feet. On a long-term basis, however, the average monthly level has varied over a range of 6.33 feet—from a high of 583.68 feet above mean tide at New York (1935 datum) in 1886 to a low of 577.35 feet in 1926 (U.S. Lake Survey, 1952, p. 10). The average level for the period 1860 to 1951 was 580.57 feet. Superimposed upon the long-term and seasonal trends are short-period fluctuations, daily or even hourly, caused by winds, difference in barometric pressure, and tides. Tides are of little consequence, but rapid barometric pressure changes, accompanied by squalls, may on occasion cause very rapid and severe rise and fall in the lake level. On May 5, 1952, the gage at Harbor Beach, Mich., on the southern arm of Lake Huron, showed a rise of about 2 feet followed by a fall of equal amount, all in a period of about a half an hour (Gallagher, 1955, p. 27). Such fluctuations imposed upon lake levels that are generally high or low may cause excessive extremes in either direction. The greatest fluctuations caused by winds and pressure gradients occur in bays and areas of shallow water. The amplitude of the short-period fluctuations is dependent upon the configuration of the shores and bottom of the lake and upon the direction, velocity, duration, and fetch length of the wind. Thus, each locality may be affected differently. All these fluctuations must be considered in the design of lake-water intakes.

CHEMICAL QUALITY AND TEMPERATURE

The quality of Lake Huron water is definitely superior to that of the Flint River. In fact, Lake Huron water is of higher quality than that supplied by Flint after treatment; dissolved solids content is about half of that of the present finished water in Flint, and the natural hardness is about equal to or only slightly higher than the softened water supplied in Flint. Use of water from Lake Huron would greatly reduce treatment costs; the treated water would be of better quality, and the supply would be dependable. A number of communities on Lake Huron pump lake water into their distribution systems without any treatment but chlorination.

Comparison of raw-water analyses (table 10) of the Saginaw-Midland supply with those of Harbor Beach and Port Hope indicates some possible pollution of Saginaw Bay. The proposed site for the intake on Lake Huron somewhere between Harbor Beach and Port Huron is apparently a good location.

The survey of industrial users in the Flint area indicated there was little interest in utilizing saline ground waters to augment present supplies. Therefore, improved quality is another reason for development of a Lake Huron supply.

TABLE 10.—*Chemical analyses of samples from Lake Huron*

[Results in parts per million. Agency making analysis: MDH, Michigan Dept. Health; USGS, U.S. Geol. Survey]

	Harbor Beach		Saginaw-Midland raw-water supply at Whitestone Point[3]	Port Hope, raw water
	Raw-water supply[1]	Finished water[2]		
Analysis by	MDH	MDH	USGS	MDH
Date	1954	Dec. 1941	June 1951	7-21-58
Silica (SiO_2)	3.7	1.2	5.7	5
Iron (Fe)	.05	Tr	.07	.0
Manganese (Mn)			.00	.0
Calcium (Ca)	24	30.0	33	26
Magnesium (Mg)	7.8	8.5	8.6	7
Sodium (Na)	5.5	} 2.3	{ 6.1	3.9
Potassium (K)		}	{ 3.1	.7
Bicarbonate (HCO_3)	100	92.0	109	93
Sulfate (SO_4)	12.0	24	17	20
Chloride (Cl)	5.0	10	16	6
Fluoride (F)	.0		.1	.0
Nitrate (NO_3)	0	None	.5	0
Dissolved solids (residue on evaporation at 180°C)	108	132	164	130
Hardness as $CaCO_3$:				
Calcium, magnesium	92.0	110	117	95
Noncarbonate			28	
Specific conductance (micromhos at 25°C)	270		259	240
pH	7.6		8.1	7.9
Color			3	5

[1] Michigan Water Resources Comm. (1954).
[2] Michigan Department of Health (1948).
[3] Lohr and Love (1954).

Temperatures of Lake Huron water taken at the Harbor Beach intake are given in table 11. Temperatures of this water delivered in Flint probably would be somewhat higher than those shown, and more uniform than those of Flint River water.

GLACIAL-DRIFT AQUIFER

DESCRIPTION

Glacial drift of generally low permeability mantles the bedrock in nearly all parts of Genesee County. These deposits consist of clay,

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TABLE 11.—*Temperatures of Lake Huron water at Harbor Beach, 1952, in degrees Fahrenheit*

[After Michigan Water Resources Comm. (1954)]

Month	Maximum	Minimum	Average
January	34	32	32. 8
February	34	32	33
March	39	32	35
April	46	38	42
May	52	43	47
June	62	47	53
July	69	54	64
August	74	55	68
September	74	60	65
October	61	53	56
November	54	42	48
December	43	32	37

silt, sand, gravel, and boulders. In much of the county thin lenses of permeable sand and gravel that will yield adequate water for domestic use are present in the drift. In some places the drift includes thick lenses of permeable sand and gravel which yield as much as 1,200 gpm (gallons per minute) to wells.

Plate 1 is a map of the surficial deposits of glacial origin in the county. Gently rolling till plains predominate in the southern half of the county. The northern half includes some extensive lake plains and a number of bars, beaches, deltas, and other features associated with the lake plains. Deltas were formed where glacial melt-water streams flowed into the glacial lakes that covered the northwestern part of the county. Glacial outwash and spillway deposits occur along the Flint and Shiawassee Rivers. Uplands of morainal origin cross the county from the northeast to the southwest.

Most of the glacial materials underlying the till plains, lake plains, and moraines are composed of clay, silt, and sand of low permeability. The areas mapped as outwash and delta deposits include beds of sand and gravel that are at shallow depths and that will yield moderate to large supplies of water. For many years, the city of Flushing obtained most of its water supply from a shallow gravel deposit northeast of the village, and it recently completed another well in a similar deposit east of the village. The village of Montrose also developed its water supply from relatively shallow deposits of sand and gravel associated with the deltaic deposits that underlie that part of the county. Test drilling and aquifer testing would be necessary to determine adequately the potential yields from other shallow sand and gravel deposits.

Many of the deposits of sand and gravel on the county are buried beneath other types of glacial material and hence are not shown on plate 1. The most extensive of these deposits of buried sand and gravel are in preglacial or interglacial valleys eroded in the bedrock surface. Several such valleys exist in the area (pl. 2). Deposits of sand and gravel fill the bedrock valley which extends northward from Lake Fenton through the eastern part of the city of Flint. Figure 17 shows the thickness of premeable material in part of this bedrock valley. This deposit is presently tapped by a number of wells,

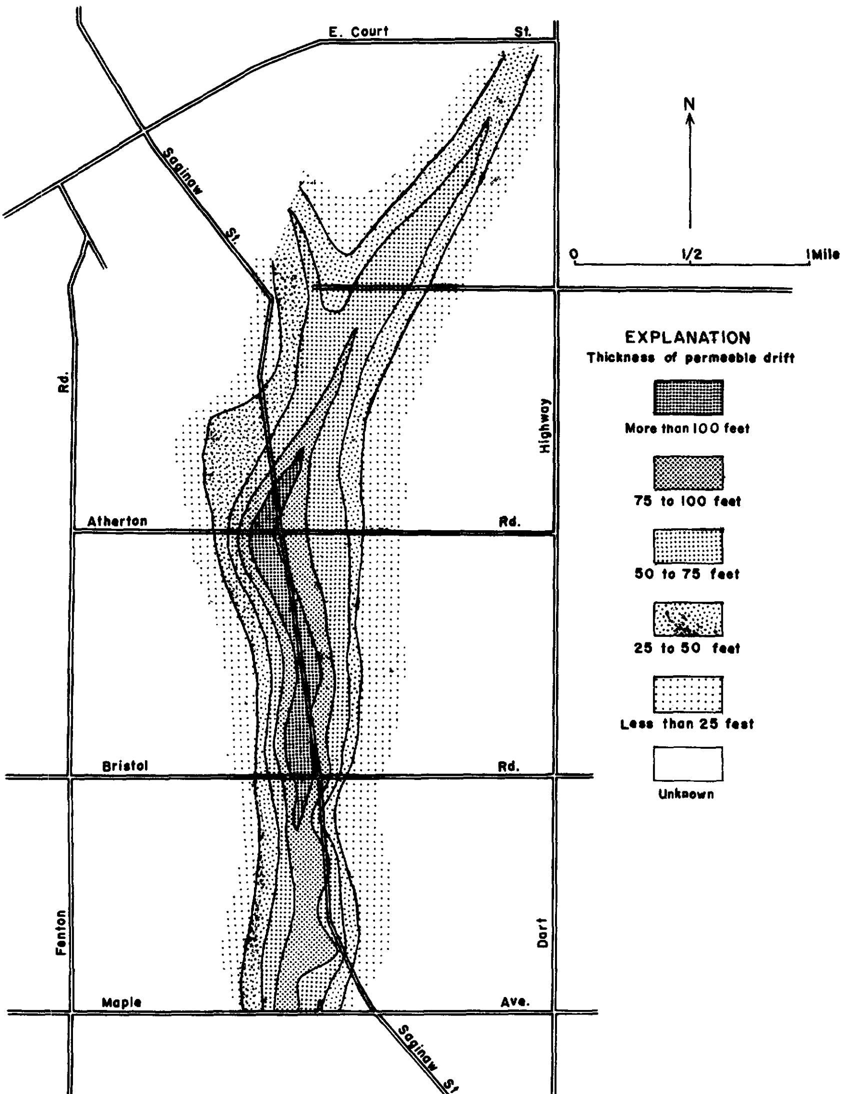

FIGURE 17.—Map showing thickness of permeable drift in the bedrock valley in eastern part of Flint.

including the two wells that are supplying water for Burton Township. Records of wells indicate that sand and gravel are present in the buried valley south of the area shown on figure 17. The amount of sand and gravel present in the other buried valleys is not fully known. In many areas, relatively thick deposits of permeable sand and gravel have been cased off in wells tapping deeper aquifers. Some of the sand and gravel would yield moderate to large amounts of water if properly screened and developed.

Permeability varies considerably both laterally and vertically in the buried and the surficial sand and gravel deposits. Some of the beds of sand and gravel have been cemented with calcium carbonate precipitated from percolating ground water. These beds are called cement rock by drillers. The cementing material reduces the permeability of the deposits and probably accounts for some of the variation in permeability.

The present trend in the development of large ground-water supplies in the area is to utilize the glacial-drift aquifers. In 1958 Burton Township, which for many years had obtained its water from wells tapping the Saginaw formation, began to use the glacial aquifer for its main source of supply. The Beecher Metropolitan District, which prior to 1955 obtained all its water from bedrock wells, now obtains about half its supply from wells tapping glacial sand and gravel. Flushing formerly obtained all its water from the Saginaw formation, but since about 1928 has obtained nearly all its supply from shallow glacial-drift deposits.

PRODUCTION FROM WELLS

Production from municipal wells tapping the glacial aquifers of the county ranges from about 50 to 1,200 gpm. The range results from differences in permeability, thickness of saturated aquifer, well construction and maintenance, and, of course, amount of water required. Figure 18 shows production from and specific capacities of some of the drift wells in the county. Specific capacity is defined as the yield of water in gallons per minute for each foot of drawdown caused by pumping of the well. Records of the wells in figure 18 are given in table 12. The coefficient of transmissibility calculated for the aquifer at some of the well sites also is shown. The coefficient of transmissibility is defined as the number of gallons of water per day, at the prevailing temperature that will move through a vertical strip of the aquifer 1 foot wide, under a hydraulic gradient of 100 percent, or 1 foot per foot.

The long-term yield from wells tapping the elongated sand and gravel deposits which fill the bedrock valleys is considerably less than that indicated by a short-term pumping test. As shown by Ferris (1948) the water levels in the sand and gravel deposit in the eastern

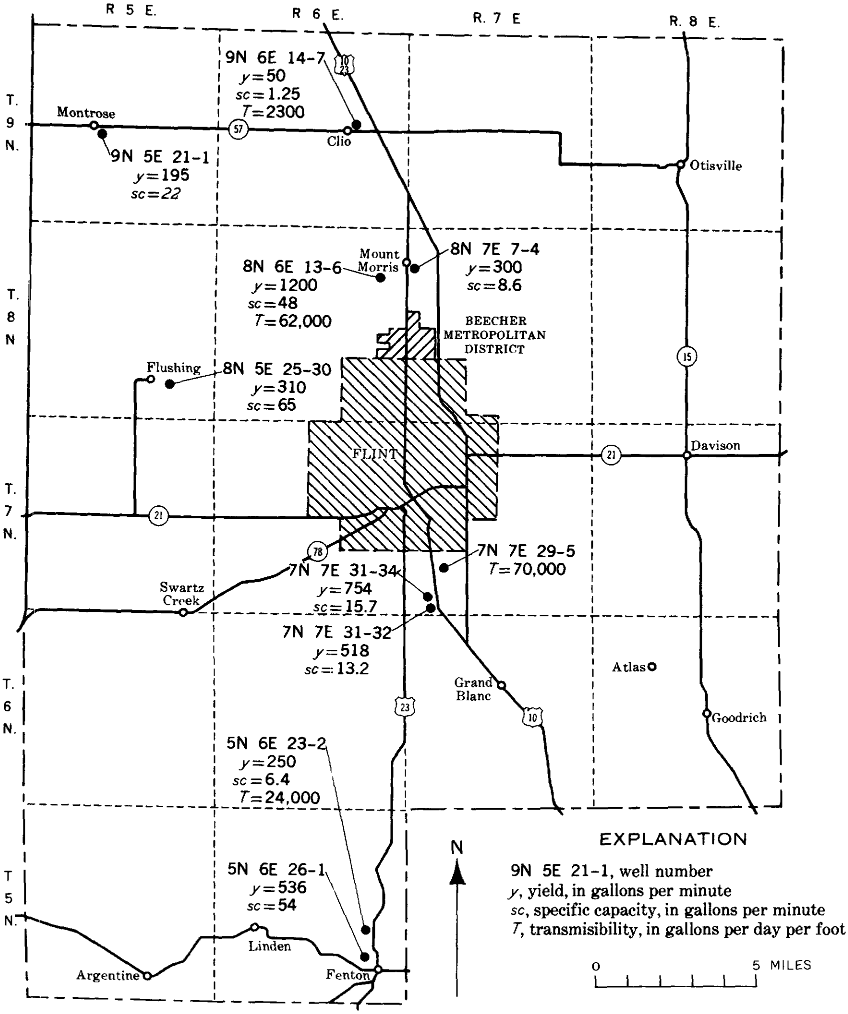

FIGURE 18.—Production from and specific capacities of selected wells in glacial drift and the transmissibility of the drift aquifer at five sites.

part of the city of Flint (fig. 17) will decline at a relatively rapid rate in response to long-term pumping because the buried valley walls form impermeable boundaries on two sides of the aquifer.

WATER LEVELS

The glacial-drift aquifers are connected hydraulically to the underlying bedrock aquifers (water may flow from one aquifer to the other). Over much of the area the water levels in the drift aquifers are at about the same elevation as the water levels in the bedrock aquifers. Differences occur especially in the areas of heavy pumping. However, if water levels in wells tapping the bedrock aquifers are lowered through

TABLE 12.—*Well data for figures 18 and 20*

Well	Owner	Name or number	Year drilled	Depth (ft)	Dia. (in.)	Screen data		Remarks
						Dia. (in.)	Interval screened (ft)	
9N 5E 21-1	Village of Montrose	1	1928	77	8	8	59–74	
9N 6E 14-7	City of Clio	4A	1958	144	8	8	134–139	
9N 6E 15-2	do	1		125	10			
8N 5E 25-7	Village of Flushing	Plant well	1939	32	30			Gravel pack.
8N 5E 25-30	do		1959	23	34	16	17–22	Do.
8N 6E 13-6	Beecher Metropolitan District.	5	1958	124	14	12	94–124	
8N 6E 23-2	do	4	1955	102	16	16	87–102	
8N 7E 7-4	City of Mount Morris	3	1949	71	16	16	60–70	
7N 7E 29-5	City of Flint	TW 36	1946	221	6	5		
7N 7E 31-32	Burton Township	3A	1958	198	26	26	178–198	
7N 7E 31-34	do	5	1958	169	26	12	148–168	Gravel pack.
5N 6E 20-3	Village of Linden		1950	96	10			
5N 6E 23-2	Lake Fenton Orchards Subdivision.	5	1958	73	8	8	58–73	
5N 6E 26-1	City of Fenton	3	1953	60	36			Gravel pack.

pumping, the water levels in wells tapping the overlying drift aquifers also decline. Examples of declining water levels in wells tapping drift aquifers are shown in figure 19. Water levels in these wells declined principally in response to pumping from wells tapping the bedrock aquifer rather than from pumping of drift wells. It appears that in some areas the drift and the bedrock act as a single aquifer.

CHEMICAL QUALITY

Some of the waters of the glacial-drift aquifers (table 13) are excessively hard and contain objectionable amounts of chloride and iron. Hydrogen sulfide, which gives the water a particularly obnoxious odor, also has been reported. The hardness of water from the glacial drift ranges from about 150 to 700 ppm. Most of the water produced, however, has a hardness of 200 to 500 ppm. Chloride ranges from a few parts per million to 450 ppm. Throughout most of the county, water in the drift aquifer contains less than 25 ppm of chloride. However, the sand and gravel deposit in the bedrock valley that underlies the eastern part of Flint yields water which contains from about 100 to 200 ppm of chloride. A well near Lake Fenton contained 450 ppm. Iron content ranges from about 0.1 to 2.2 ppm. The temperature of water in the drift aquifer ranges from about 49° to 51°F.

Figure 20 shows the hardness and iron content of waters from several wells tapping the drift.

WITHDRAWAL USE OF WATER

Nearly all the water withdrawn from large-capacity wells tapping the glacial drift is used as public supply serving mainly household users. Only a few small industrial wells tap the drift.

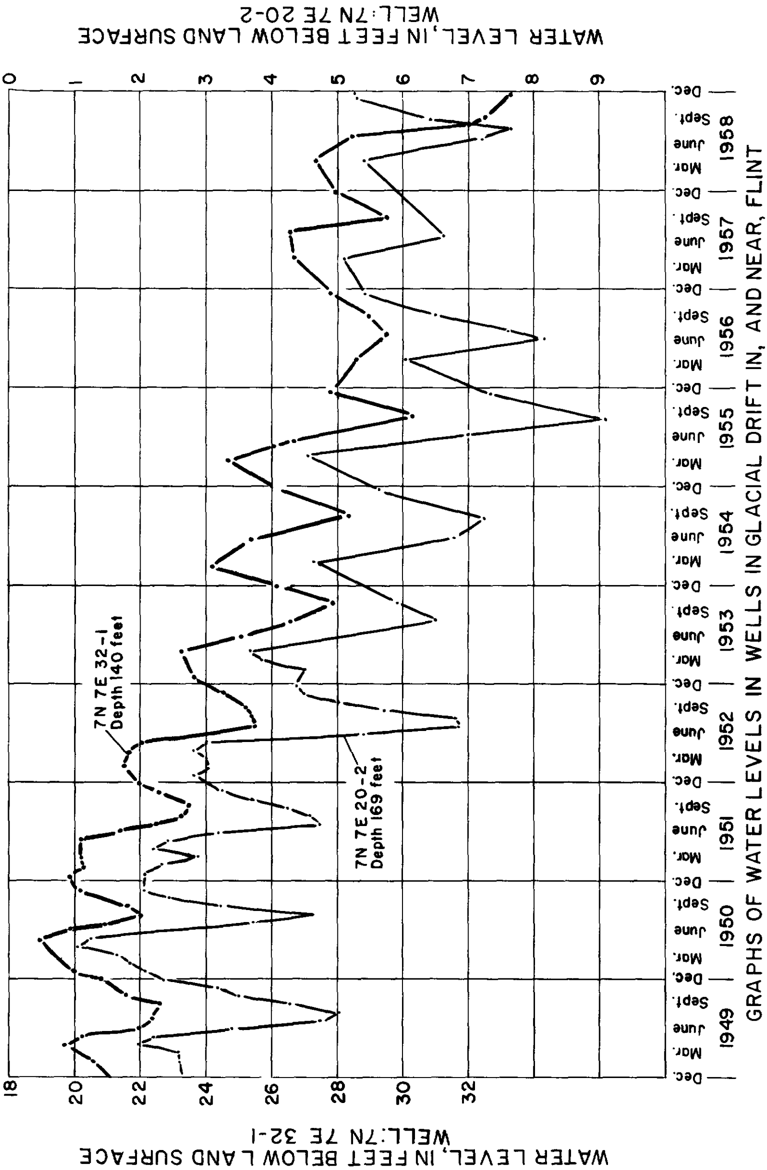

FIGURE 19.—Graphs of water levels in wells in glacial drift in and near Flint.

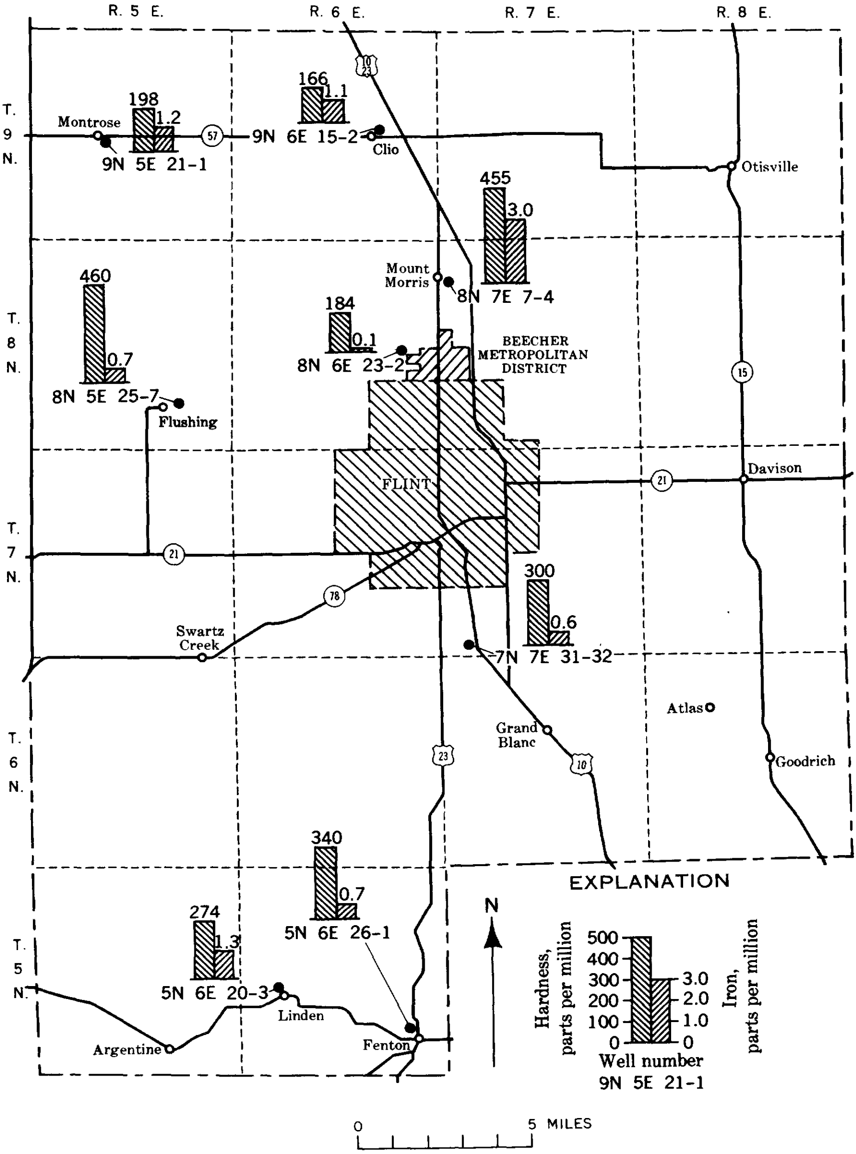

FIGURE 20.—Hardness and iron content of water from selected wells in glacial drift.

OVERDRAFTS

Although water levels are declining in some places as a result of pumping, only one serious overdraft has been accurately documented. The village of Flushing obtains its water from two wells tapping relatively shallow deposits of sand and gravel outwash. A declining trend in water level has been recorded in one of the wells since 1955

TABLE 13.—*Chemical analyses of water from selected wells in glacial drift*

[Results in parts per million except as indicated. Agency making analysis: MDH, Michigan Dept. of Health; USGS, U.S. Geol. Survey]

Well	Agency making analysis	Date collected	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total solids	Hardness as ($CaCO_3$)	Specific conductance (micromhos at 25°C)	pH	Temperature (°F)
9N 5E 21-1	USGS	3-12-54	18	1.2	0.13	53	16	21	1.0	266	15	3.1	0.5	------	264	198	430	7.4	51
9N 6E 15-2	USGS	3-11-54	12	1.1	.04	37	18	50	1.7	226	28	12	1.2	1.2	286	166	498	7.4	50
8N 5E 25-7	USGS	3-29-53	6	.7	.32	121	38	6.5	2.5	330	158	21	0	.3	527	460	824	6.7	50
8N 6E 23-2	MDH	3-26-56	12	.1	.0	43	18	35	1.9	295	7	2	.8	0	270	184	500	8.4	------
8N 7E 7-4	MDH	1-30-59	14	3.0	.0	114	41	15	1.2	460	99	0	0	0	532	455	885	7.2	------
7N 7E 31-32	MDH	11-6-58	13	.6	.0	59	37	103	2.1	366	59	109	1.0	.5	586	300	1,000	7.6	------
5N 6E 20-3	USGS	3-12-54	17	1.3	.13	62	29	18	1.4	312	26	14	.4	.5	323	274	601	7.6	51
5N 6E 26-1	MDH	3-10-53	13	.7	------	88	29	4.5	------	353	55	6	.2	0	388	340	680	7.3	------

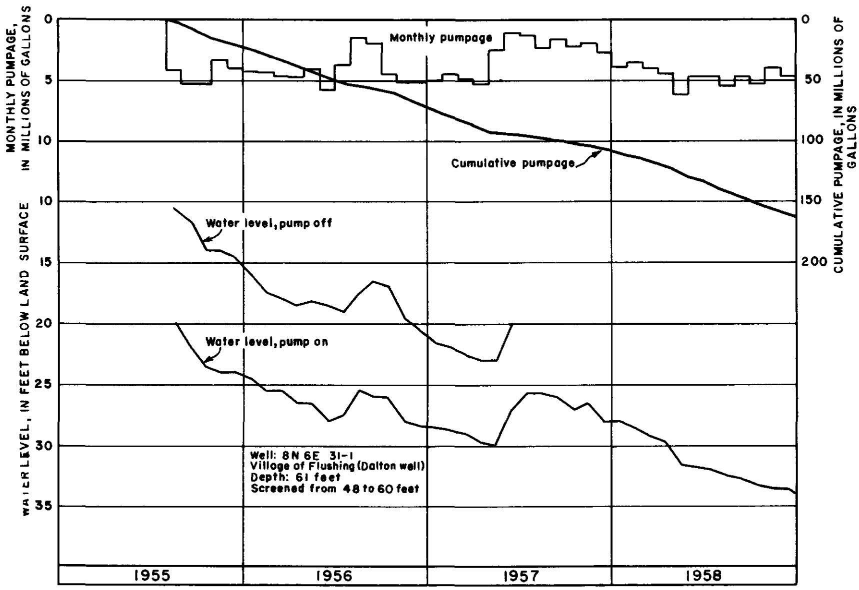

FIGURE 21.—Graph showing effect of pumpage on water level in well in glacial drift near Flushing.

(fig. 21). The decline was caused by withdrawal of water in amounts considerably in excess of recharge to the sand and gravel deposit tapped by the well. Reversals in the declining trend have been recorded only when the rate of withdrawal from this well was reduced to 2.5 million gallons per month or less. If this declining trend continues for another 3 years, the water level will be at or below the top of the screen when the well is pumped.

INDUCED MIGRATION OF SALINE WATER

Locally, the drift aquifers are hydraulically connected to bedrock aquifers which contain water of high chloride content. Pumping that causes lowering of water levels in drift aquifers may induce migration of saline water from underlying bedrock formations. However, considerable additional water may be withdrawn from the drift without serious contamination by induced migration of saline waters if wells are spaced to prevent excessive drawdown.

SAGINAW FORMATION

The Saginaw formation, which is the uppermost bedrock formation in most of the county (pl. 3), is composed of sandstone, sandy shale, shale, coal, and limestone. Sandstone layers are the source of most of the water from the formation. The water in the sandstone beds moves through secondary openings along fractures and bedding planes as well as through the primary openings (interstices) between the sand grains. The wide range in permeability of the formation may be caused by the variation in the number and size of secondary openings. The shale strata within the formation are of low permeability and generally are not a source of water to wells; however, some of the shale beds reported in well records yield water. The "sandy shale" beds described in these records are probably thin alternating beds of shale and sandstone. The beds of limestone present in the formation are of small areal extent and are generally less than 10 feet thick. The limestone beds yield water from solution openings along joints and bedding planes. Some of these openings yield moderate amounts of water to wells. The beds of coal in the formation are generally thin, although a coal seam 4 feet thick was mined in the What Cheer mine in the southeastern part of Flint. The coal beds are of small area.

According to Kelley (1936) the Saginaw formation represents cyclical sedimentation and consists of numerous successions of sandstone overlain by sandy shale, gray shale, underclay, coal, black shale, and limestone. Commonly, any thick sandstone bed below the lowest shale or coal-bearing bed of the Saginaw has been referred to as the "Parma sandstone" in well records from Genesee County. The so-called Parma sandstone, however, appears to be the first unit of a cyclical succession, the remaining units of which are included on the Saginaw; hence, in this report, the so-called Parma sandstone is considered to be the basal stratigraphic unit of the Saginaw. The so-called Parma sandstone here mentioned should not be confused with the outcropping Parma sandstone of south-central Michigan.

Some of the sandstone members of the Saginaw can be traced over a considerable area (fig. 22). In general, however, because the cyclic successions of the formation are incomplete and erosional unconformities are present, it is difficult to trace an individual bed from one well to another well only a short distance away. Test drilling may therefore be necessary to determine the water-yield potential of the formation in areas for which adequate geologic data are not available.

The Saginaw formation is thickest in the northwest corner of the report area. Cohee (and others, 1951, fig. 21) shows 323 feet of the Saginaw in this area. The thickness is least along the contact with the Michigan formation (pl. 3). The thickness of the formation differs considerably throughout the area because several deep valleys were eroded in the formation.

PRODUCTION FROM WELLS

Wells tapping the Saginaw formation yield as much as 500 gpm in areas where the formation is composed principally of sandstone (fig. 23). In areas where the formation is composed principally of shale, production from small domestic wells is commonly less than 5 gpm. Production from and specific capacities of a number of wells

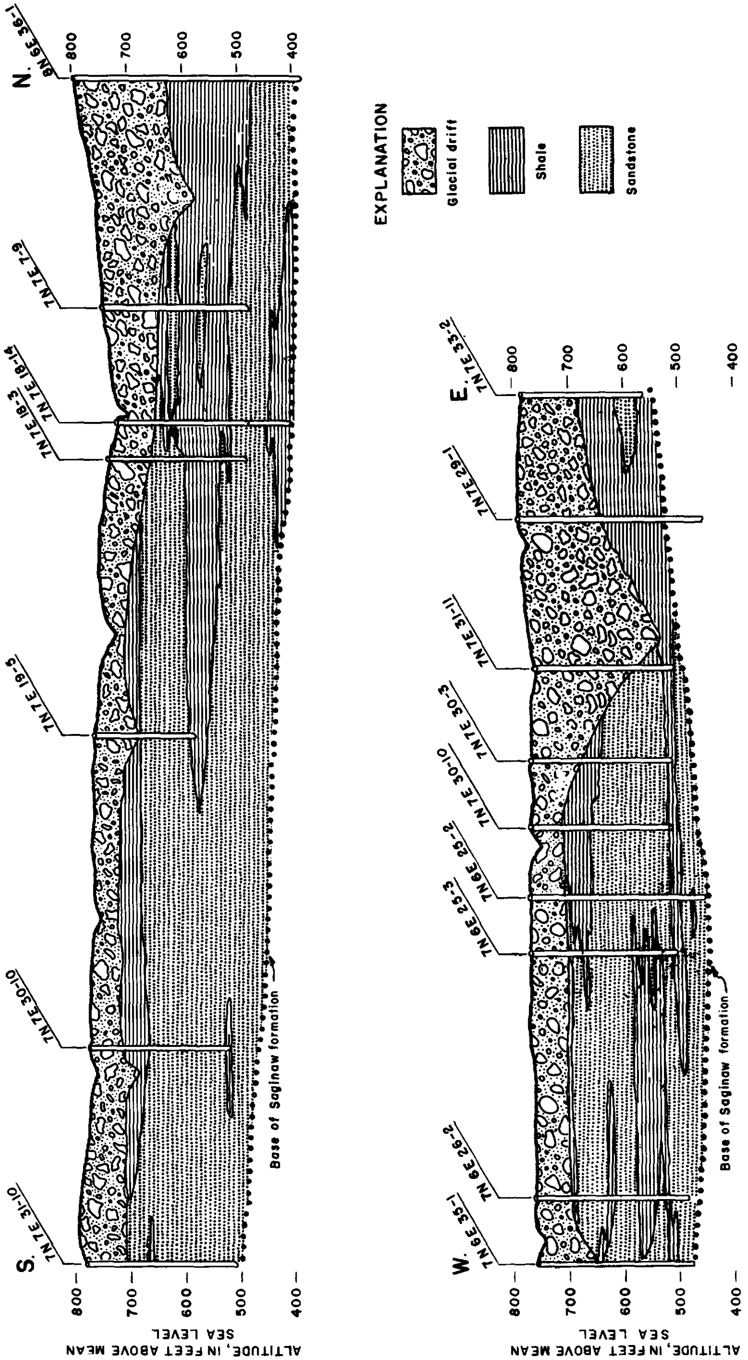

FIGURE 22.—Generalized geologic sections through the Saginaw formation along lines N–S and W–E, plate 3.

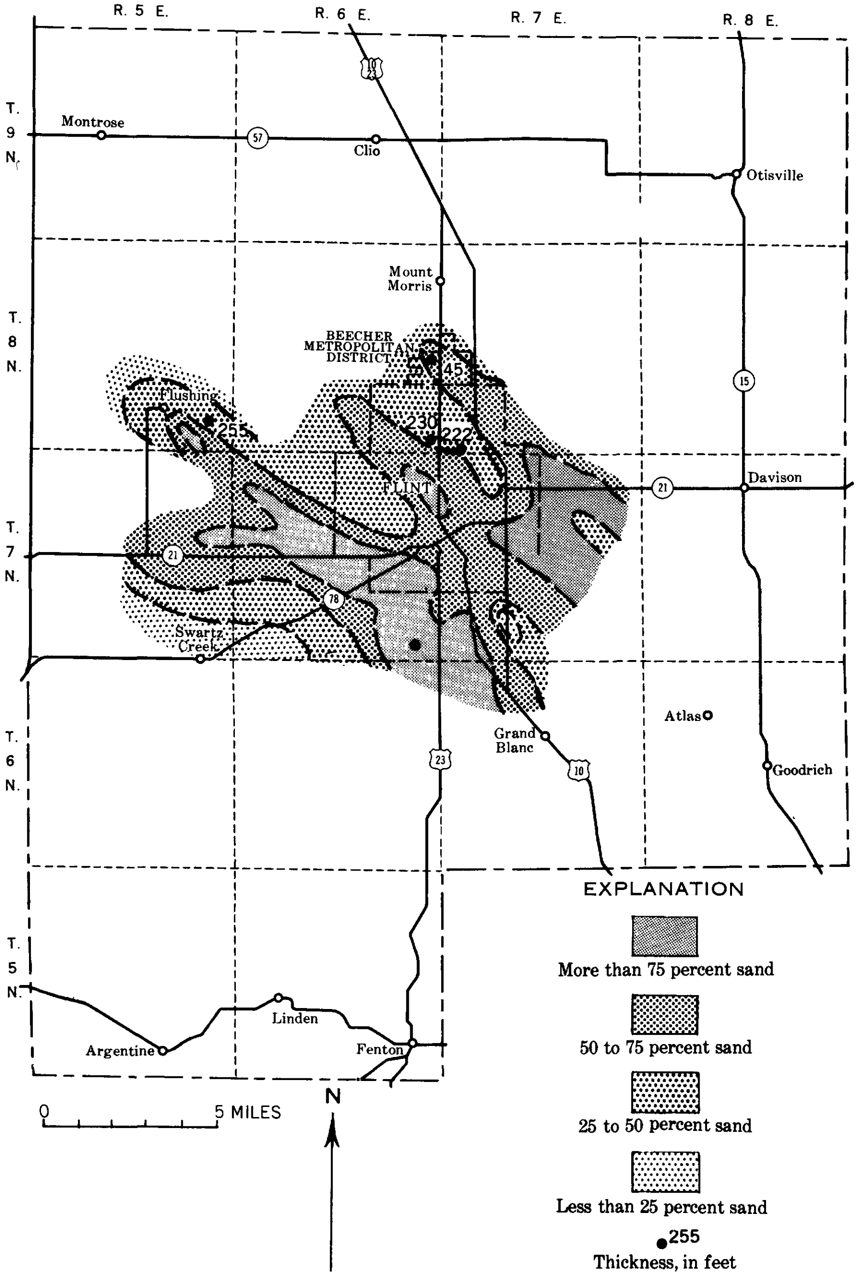

FIGURE 23.—Map showing the percentage of sand in the Saginaw formation.

tapping the formation are shown on figure 24. Records of these wells are given in table 14.

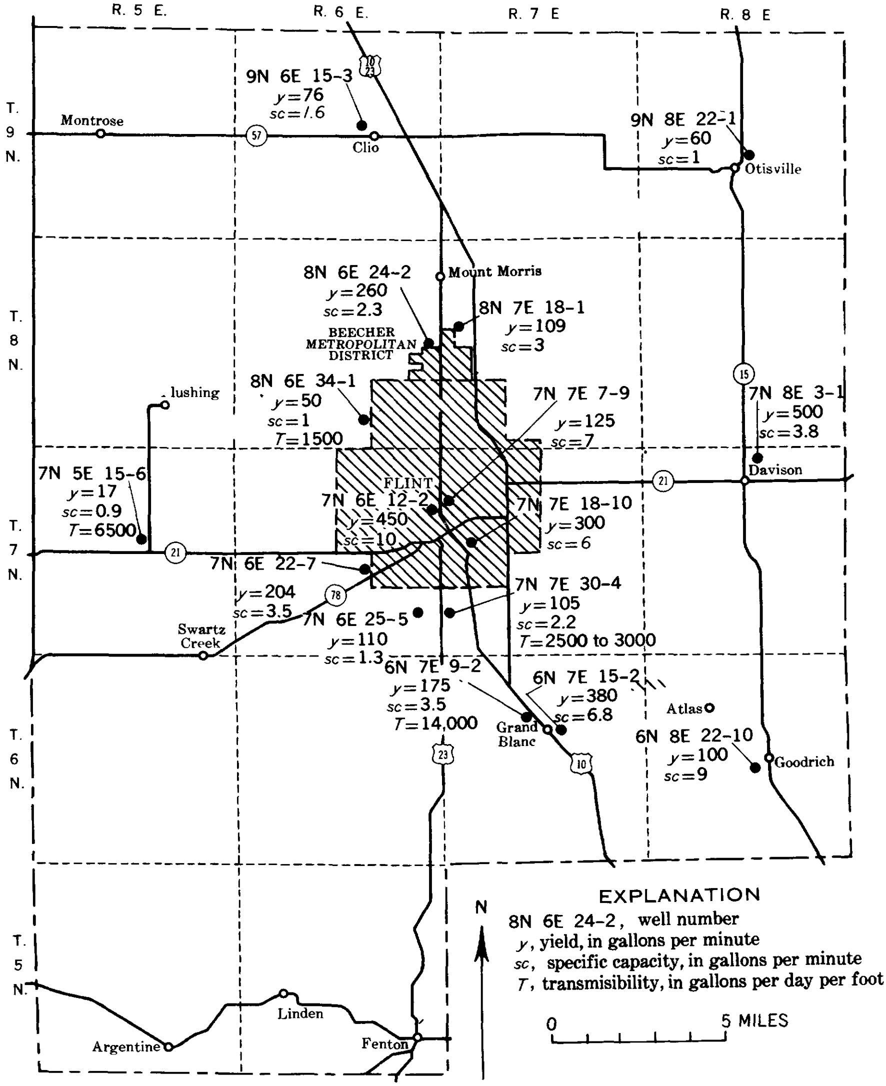

FIGURE 24.—Production from and specific capacities of selected bedrock wells and the transmissibility of the Saginaw formation at four sites.

WATER LEVELS

The Saginaw formation is recharged by precipitation infiltrating through the overlying glacial drift. Plate 4 shows the contours of the piezometric (pressure-head-indicating) surface of the water in the bedrock aquifers. The pressure heads of the different bedrock formations are similar and are taken to indicate a single piezometric surface. Generally, the uplands are areas of recharge, and the lowlands along streams and lakes are areas of discharge. Over most of the

TABLE 14.—*Well data for figure 24 and table 15*

Well	Owner	Diameter (in.)	Depth (ft)	Aquifer (formation)	Use
9N 5E 21-4	H. A. Vantine	2	162	Saginaw	Domestic.
9N 6E 15-3	City of Clio	8	143	do	Public supply.
9N 8E 22-1	Village of Otisville	10	415	Saginaw-Marshall	Do.
8N 6E 12-2	Mt. Morris Frozen Food Locker.	3	217	Saginaw	Industrial.
8N 6E 24-2	Beecher Metropolitan Dist.	10	428	Saginaw-Michigan-Marshall.	Public supply
8N 6E 34-1	Flint Land Co	8	200	Saginaw	Domestic.
8N 7E 18-1	Beecher Metropolitan Dist.	6	436	Saginaw-Michigan-Marshall.	Public supply.
7N 5E 15-6	Clayton Village Subdivision.	4	160	Saginaw	Domestic.
7N 6E 12-2	Sears Roebuck Co	12	278	do	Air conditioning.
7N 6E 22-7	Westgate Shopping Center.	8	194	do	Public supply.
7N 6E 25-5	Manderville Park Subdivision.	8	160	do	Do.
7N 7E 7-9	Regent Theatre	8	259	do	
7N 7E 9-7	A. C. Spark Plug	6	427	Saginaw-Michigan-Marshall.	Industrial.
7N 7E 14-1	Winstanley and Booth	3	154	Saginaw	Public supply.
7N 7E 18-10	White Seal Brewery	8	224	do	
7N 7E 30-2	Burton Township	10	220	do	Do.
7N 7E 30-4	do	6	191	do	Do.
7N 8E 3-1	City of Davison	12	260	Saginaw-Michigan	Do.
6N 7E 9-2	Grand Blanc Tank Plant.	8	255	Saginaw	Industrial.
6N 7E 15-2	City of Grand Blanc	10	307	do	Public supply.
6N 8E 15-1	Goodrich High School	4	238	Saginaw-Michigan-Marshall.	Do.
6N 8E 22-10	Lawrence Haddrill	3	250	do	Domestic.

Flint metropolitan area, the piezometric surface has been lowered as a result of withdrawal of water from the formation. Hydrographs of two wells tapping the Saginaw in Flint are shown in figure 25. The

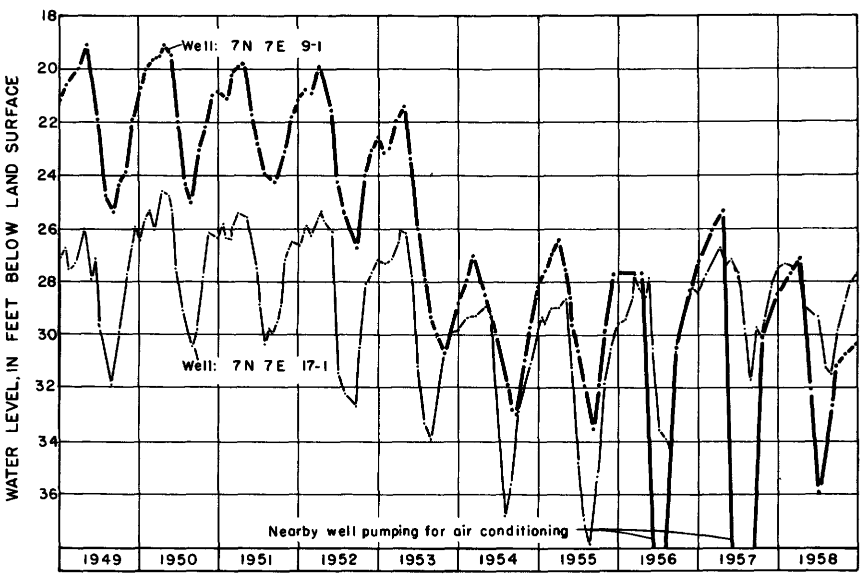

FIGURE 25.—Graphs of water levels in wells tapping the Saginaw formation.

water level in well 7N 7E 9–1 has declined in response to pumping from wells supplying water for industrial, air conditioning, and domestic use in the immediate area. Well 7N 7E 17–1 is in the area where most of the water supplies are obtained from the Flint municipal system. The decline in water level in this well is caused primarily by lack of precipitation rather than pumping (Giroux, 1958).

Figure 26 illustrates the effect of pumping and precipitation on the water level in observation well 6N 7E 9–1, at the Fisher Body Plant

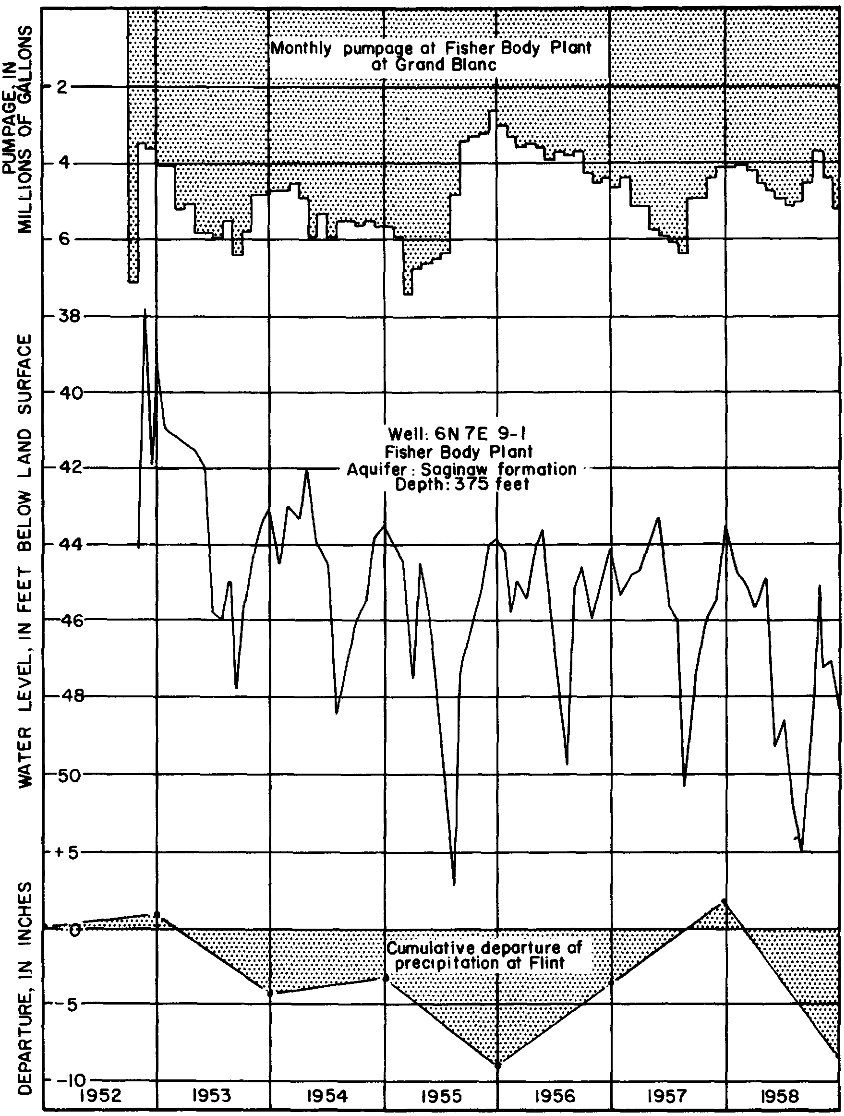

FIGURE 26.—The effect of pumping and deficient precipitation on water level in a well at Grand Blanc.

near Grand Blanc. Heavy pumping at the plant and a general decline in precipitation culminated in a low water level in this well in 1955. The water level remained relatively steady until 1958, when it again declined, owing principally to lack of precipitation. It appears that the long-term recharge of the aquifer in the area affected by this well is about equal to the present rate of discharge.

CHEMICAL QUALITY

Excessive hardness and objectionable amounts of chloride and iron are present in the water from the Saginaw formation (table 15), but its water is generally softer and contains less iron than the water from the drift although chloride in objectionable quantities is more common in waters from the Saginaw formation. Any well drilled in the area to sufficient depth will produce salty water. In many places in the county, even the upper part of the Saginaw contains salty water. If the drift will not yield water in these places, it is commonly very difficult and sometimes impossible to obtain ground water of good quality.

The occurrence of chloride in the waters in the Saginaw formation is quite complex. The chloride probably originates from the connate waters (water entrapped at the time the sediment was deposited) that are present in all the bedrock formations of the Michigan basin; beds of salt also are present in some of the formations. Ground water containing objectionable amounts of chloride occurs at shallow depth in many topographically low areas in the State, especially in the Saginaw Bay area and southeastern Michigan.

The specific gravity of water increases with the amount of dissolved mineral matter. Thus, fresh water which is recharged to the Saginaw formation from precipitation is lighter and tends to "float" on the heavier mineralized water in the formation. The zone of contact between the fresh water and the salt water is called the salt-water interface. The depth to this interface depends on the head of the fresh water above the interface. Lowering the head of fresh water 1 foot may cause the salt water to rise many feet. In many places the salt-water interface in the Saginaw is in a layer of shale or other rocks of low permeability. Fresh water is present in the sandstones above the layer of shale and salt water in the sandstones below it. In these places the salt water leaks slowly through the shale layer from the lower to the upper sandstone when the fresh-water head is lowered. Where the vertical movement of salt water is not impeded by a bed of shale or other stratum of low permeability, the upward migration of salt water is more rapid.

Locally, the Saginaw formation will yield moderate or large amounts of water to wells. The limiting factor in developing the Saginaw as a source of water supply, however, is more commonly one of quality than of quantity. The permeability of the formation is relatively low;

TABLE 15.—*Chemical analyses of water from selected bedrock wells*

[Results in parts per million except as indicated. Agency making analysis: MDH, Michigan Dept. of Health; USGS, U.S. Geol. Survey]

Well	Agency making analysis	Date collected	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total solids	Hardness as $CaCO_3$	Specific conductance (micromhos 25°C)	pH	Temperature (°F)
9N 5E 21-4	USGS	3-12-54	8.9	0.18	0.01	3.8	1.4	402	3.1	505	27	296	2.2	6.0	1,020	15	1,780	8.2	51
9N 6E 15-3	MDH	4-25-58	13	.5	0	52	23	29	1.6	258	54	10	.7	.0	320	225	530	7.8	------
9N 6E 22-1	MDH	3-29-55	8	1.0	------	320	30	792 (Na + K)		283	790	1,090	.8	.0	3,250	925	5,000	7.4	------
8N 6E 12-2	USGS	3-11-54	10	.1	------	31	12	42	2.2	240	16	3.1	1.1	.6	229	128	403	7.3	52
8N 6E 24-2	USGS	3-11-54	12	.33	.06	65	15	272	4.6	280	108	328	1.2	.6	948	224	1,680	7.3	51
7N 6E 25-5	MDH	11-6-58	11	.2	.0	48	28	45	1.6	320	33	29	1.0	.0	370	235	610	7.6	------
7N 7E 14-1	USGS	3-12-54	11	.25	.03	37	15	69	2.0	200	41	1.2	1.2	.5	338	154	608	7.4	------
7N 7E 30-2	MDH	2-11-53	9	.4	------	66	28	141	------	317	63	190	1.0	.0	634	280	1,250	7.6	------
7N 8E 3-1	MDH	9-19-58	8	.7	.0	56	26	33	2.0	335	8	20	.6	.0	320	245	600	7.6	------
6N 7E 15-2	USGS	3-11-55	6.7	.06	.0	97	39	125	3.5	456	57	157	.5	.1	694	402	1,260	7.3	51
6N 8E 15-1	USGS	3-12-54	11	1.3	.03	67	25	114	3.4	354	21	136	.4	.6	541	268	985	7.5	------

therefore, when moderate or large amounts of water are pumped from a well, the water level in the well is generally lowered many tens of feet. The lowering of the water level creates the necessary gradient in the piezometric surface which causes the water to move through the formation to the well. However, the lowering of piezometric surface may also cause water of high chloride content to migrate upward toward the well. In some areas where the salt-water interface is at shallow depth, a substantial quantity of fresh water can be obtained only by means of a large number of wells, each pumped at a low rate, which tend to skim the fresh water off the salty water.

Water high in chloride is at shallow depth in many of the lower areas along the Flint River and its tributaries in Genesee County. However, water high in chloride is produced from a relatively shallow depth in some of the upland areas also. In some places this may be the result of upward leakage or migration of saline water along old coal borings or abandoned wells (Smith, 1944).

Figure 27 shows the amount of chloride in water from wells tapping the bedrock aquifers and the relationship of the depth of the well to the amount of chloride.

WITHDRAWAL USE OF WATER

The Saginaw formation is the source of water for several small communities and most of the industrial wells in the county. Two small communities, however, have abandoned the Saginaw as a source of supply, and use of water from the Saginaw by industry has decreased in recent years because of the poor quality of the water. The Saginaw formation is an important source of water to industry in the areas not served by the Flint municipal system.

A relatively large number of wells which supply water for air conditioning tap the Saginaw. The water used for air conditioning can be of relatively poor quality; therefore, the formation is and will continue to be an important source of water for air conditioning.

Many of the thousands of domestic wells in the county tap the Saginaw. Although the formation yields water containing objectionable amounts of chloride in a number of places, it yields water of good quality to domestic wells over most of the area.

OVERDRAFTS

Local overdrafts from the Saginaw formation are commonly indicated by deterioration in the quality of the water. The lowering of the piezometric surface and resultant upward migration of saline water effectively limits the amount of fresh water that can be withdrawn from any given area. Some wells tapping the Saginaw have been abandoned because overdrafts have caused an increase in the chloride content. Table 16 shows the concentrations of chloride in

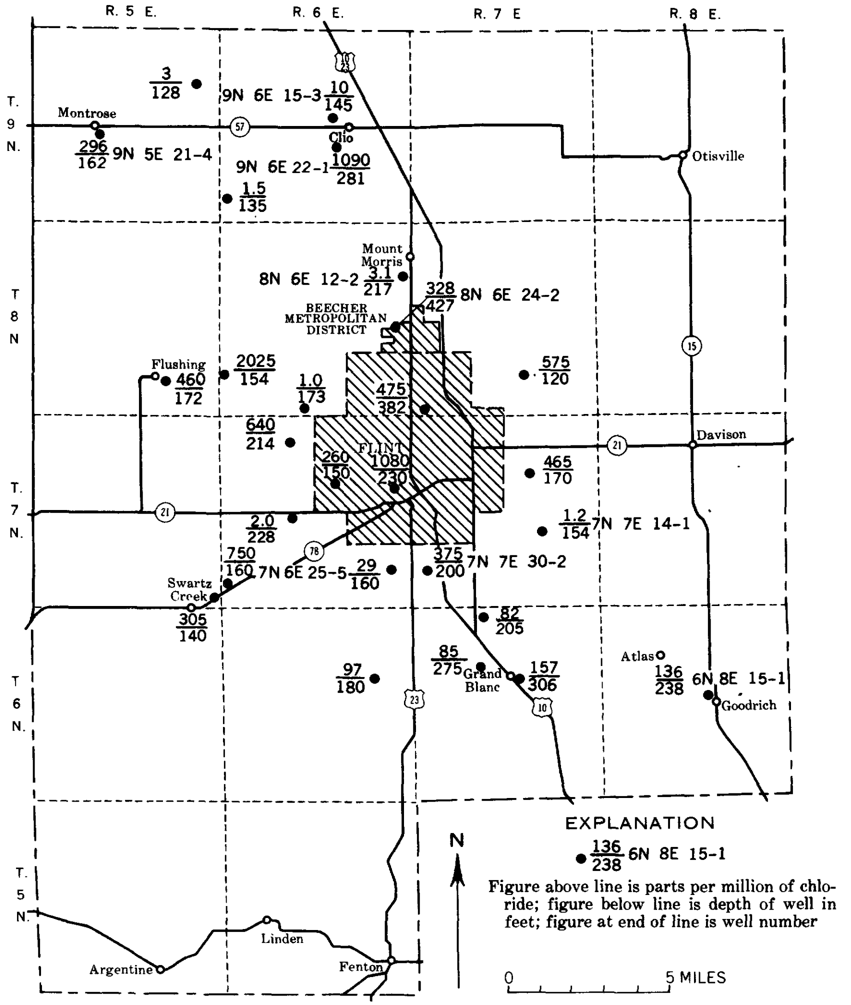

FIGURE 27.—Chloride content of selected bedrock wells. Well numbers are shown for wells in table 15.

samples of water from well 7N 7E 30-2 (Burton Township well 2). The chloride content increased nearly 300 percent from 1946 through 1956. The township now uses the glacial-drift aquifer as its main source of supply.

TABLE 16.—*Chloride in water from Burton Township well 2*

Date collected	*Chloride (ppm)*
Nov. 5, 1946	135
Feb. 11, 1953	190
Aug. 18, 1953	230
June 13, 1955	240
Dec. 12, 1956	375

MICHIGAN FORMATION

The Michigan formation underlies the entire county except the area mapped as Marshall formation on plate 2. The formation is composed principally of gray shale and some green and blue shale. Some thick beds of dolomite also are present. In other areas of the State, the Michigan includes some thick beds of gypsum. However, only a few feet of gypsiferous shales are reported in records of wells in Genesee County. The most persistent member of the Michigan in the county is a dark-brown dolomite which occurs at the base of the formation. Other dolomite layers in the formation generally cannot be traced over long distances. Logs of some wells show little or no dolomite; others show a relatively large percentage. Records of wells in the county indicate that the aggregate thickness of sandstone within the formation differs considerably from place to place. In parts of Grand Blanc township, the Michigan appears to include more sandstone than shale.

A bed of limestone and sandy limestone which was deposited conformably on the Michigan formation has been designated as the Bayport limestone. In some places the Bayport has been completely removed by erosion (Newcombe 1933, p. 85). Only a few data are available concerning the thickness, extent, and water-bearing characteristics of the Bayport limestone in the area. For the purpose of this report, the Bayport is mapped with the Michigan formation.

The maximum thickness of the Michigan formation reported was 210 feet in a well in sec. 11 of Thetford Township. Throughout most of the area where the Michigan is overlain by the Saginaw formation the thickness is about 100 feet; however, in the southern part of the county, well records show the thickness to be less than 50 feet.

PRODUCTION FROM WELLS

Where the Michigan formation forms the bedrock surface, it is a source of water to numerous domestic wells; and where solution openings have developed in the limestone and dolomite beds of the formation, it may yield moderate supplies of water. Several large-capacity wells in the county are drilled into or through the Michigan formation (table 14). Most of the water produced from these wells is derived, however, from the Saginaw and Marshall formations.

WATER LEVELS

Water may migrate from permeable zones within the Michigan formation to the Saginaw formation or to the Marshall formation. In some areas the three formations act as a single aquifer. Plate 4 shows the generalized piezometric surface, which represents a combination of the piezometric surfaces of the bedrock formations in the southeastern part of the county.

QUALITY OF WATER

The Michigan formation yields fresh water in the area where it is mantled by drift. In most of the area where it is mantled by the Saginaw, it is believed to yield saline water.

MARSHALL FORMATION

The Marshall formation underlies all except the extreme southern part of Genesee County, where the Coldwater shale forms the bedrock surface.

The Marshall is composed principally of white to gray fine- to coarse-grained sandstone and some beds of conglomerate, shale, and dolomite. The formation has been divided into two members; the upper strata have been designated the Napoleon sandstone member and the lower part simply the lower member of the Marshall. The Napoleon is composed principally of thick and extensive sandstone beds. It has not been differentiated in records of most of the wells drilled through the Marshall in the county, as the contact between it and the lower member of the Marshall is not readily recognized. Most of the records of wells that penetrate the Marshall indicate that throughout much of Genesee County the Napoleon may constitute most of the Marshall section. Records of wells in Grand Blanc Township and in the southern part of Flint Township show, however, a predominance of shale and dolomite in the Marshall section where present.

The contact between the lower member of the Marshall and the underlying Coldwater shale also is difficult to identify; hence, the thickness of the Marshall over most of the county can only be estimated. Well logs show that it is thickest in the northern part of the county, where as much as 200 feet of the formation is reported in logs of oil test wells. Throughout most of the area where it is overlain by the Michigan formation, the Marshall ranges from about 100 to 150 feet in thickness. Records of deep wells in Grand Blanc Township and in the southern part of Flint Township, however, report less than 70 feet of the Marshall. The thickness of the Marshall in the areas where the formation is mantled directly by glacial drift differs considerably from place to place, as the bedrock surface is uneven.

PRODUCTION FROM WELLS

The Marshall formation is the source of part of the water yielded by several industrial, air-conditioning, and public-supply wells in the county. All these wells, however, obtain water from the Michigan and Saginaw formations also. None of the known large-capacity wells in the county obtain all their production from the Marshall. Thus, the amount of water that the Marshall will yield can only be estimated. Several small-diameter wells in the vicinity of Goodrich yield moderate supplies of water, and most of this water is obtained from the Marshall. It appears that the formation may yield moderate to large supplies of water to properly constructed wells in the Goodrich area. Elsewhere in the county few data are available on the potential of the Marshall as a source of water.

WATER LEVELS

The Marshall formation has not been extensively developed as a source of water in Genesee County, and the water levels in the aquifer probably fluctuate principally in response to climatic changes rather than to withdrawal of water from wells. In a number of topographically low areas in the southeastern part of the county, wells tapping the Marshall flow at the land surface.

QUALITY AND TEMPERATURE

Most of the water produced from wells 9N 8E 22–1 and 6N 8E 15–1 is obtained from the Marshall formation, although other rocks also contribute water to these wells. The analyses of the water from these wells indicate that the quality of water is similar to that of the Saginaw formation.

Most of the wells that produce water from the Marshall are in the eastern and southern parts of the county. In this area the water from the Marshall is of the calcium magnesium bicarbonate type, and chloride is not present in objectionable amounts. Where the Marshall is overlain by younger bedrock formations, it commonly yields salty water and is of little use as a source of fresh water.

The occurrence of chloride in the water from the Marshall is similar to that in the Saginaw; therefore, withdrawal of water from the Marshall at a rate that causes excessive lowering of the water level probably would also result in the upward migration of saline water.

WITHDRAWAL USE OF WATER

Water from the Marshall is used principally for domestic purposes. A few deep wells in Flint which are used for air conditioning and industrial purposes obtain some water from the Marshall formation.

PUBLIC WATER-SUPPLY SYSTEMS

CITY OF FLINT

The source of the public water supply is the Flint River. Nearly all the water used by industry, and even most of the water used for air conditioning, is furnished by the public supply. The population served in 1959 is estimated at about 198,000. The Flint City Commission at present discourages the extension of public water-supply facilities beyond the corporate limits. Four Chevrolet plants and the Ternstedt Division of General Motors Corp. are the largest industrial users among those outside the city.

The intakes, pumping stations, and water-treatment plant are on the right bank of the Flint River a short distance upstream from the mouth of Kearsley Creek. Hamilton Dam, about 3 miles downstream, is used to create a pool over the intakes. Utah Dam, about half a mile downstream, is used to prevent industrial wastes that enter the pool below the dam from being blown upstream by winds and reaching the water intakes. Total intake capacity is about 138 mgd. Raw water is stored in the 650-million gallon Kearsley Reservoir and the 5,760-million gallon Holloway Reservoir. Kearsley Reservoir has been consigned to emergency status since the completion of Holloway Reservoir.

Treatment consists of prechlorination and postchlorination, coagulation with alum, lime-soda ash softening, clarification, recarbonation, filtration, addition of polyphosphate for corrosion control. Activated carbon, ammonia, and sodium chlorite are used to remove tastes and odors. Rated capacity of the treatment works is 59 mgd, and the maximum overload capacity is 86 mgd.

A water-pumpage graph of the average daily, the maximum daily, the average daily for the maximum month, and the maximum hourly pumping rates from the river by years is shown in figure 28. The effects of the 1958 business recession on water consumption is clearly shown on this graph. For the peak year of 1956, when automobile production was also at its zenith, the average daily pumpage was almost 45 mgd, and the maximum daily for the year was 74.4 mgd. In 1958, these pumping rates had dropped to 35.9 and 53.5 mgd, respectively. The 1956 and 1958 per capita use averaged as about 236 and 189 gallons per day, respectively. These figures are well above the average per capita water use in urban areas of this country.

Figure 29 is the daily pumping record for the year ended June 30, 1958. This graph shows a greater demand during the summer, a normal pattern. The sharp declines in pumpage on weekends when industry is closed down indicate that industry in Flint is a heavy user of water.

Certain improvements and modifications to the Flint water treatment and distribution facilities will be necessary when the Lake Huron supply system is completed. The proposed scheme provides for the retention of the existing pumping facilities at the water treatment plant for pumping water from the Flint River as an emergency supply.

WATER QUALITY AND TEMPERATURE

The effectiveness of the Flint water-treatment plant can be evaluated to some extent by a comparison of the quality of raw and finished water based on analyses published by Lohr and Love (1954) or from the more recent analyses given for the raw water in table 1 and for

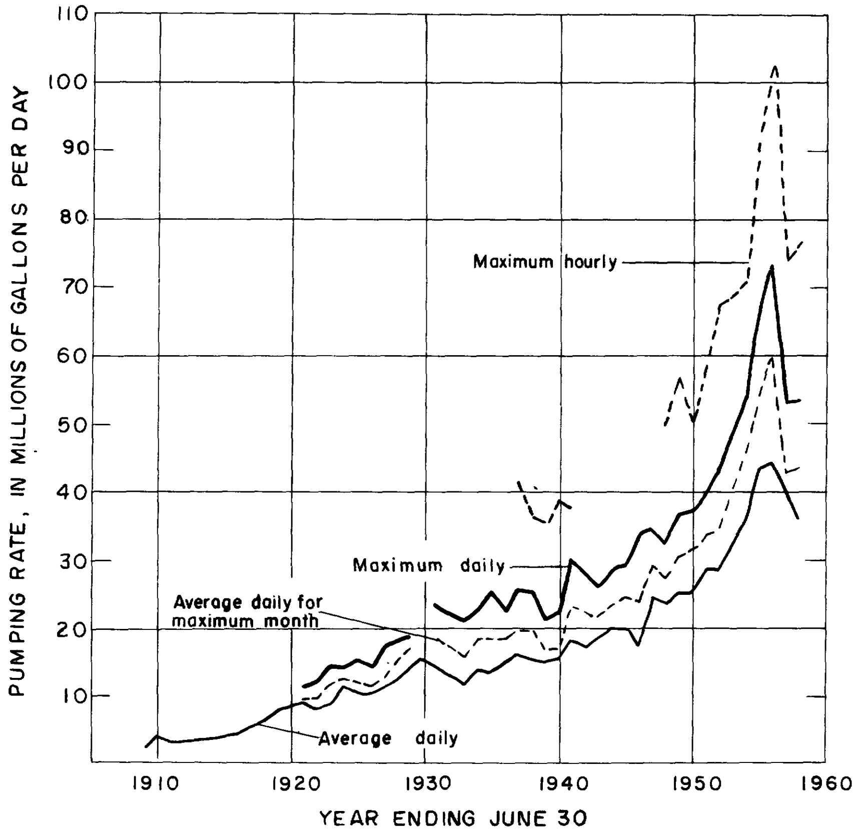

FIGURE 28.—Water pumpage from the Flint River at the Flint waterworks.

the finished water in table 17. Cumulative frequency data for several chemical and physical characteristics have been prepared from chemical analyses made by the Flint Water Department (table 18). City water is fairly uniform in quality, moderately hard, and low in color and turbidity. The pH is nearly always above 10.0, and consequently, the alkalinity is mostly in the form of carbonates with relatively small amounts of bicarbonate and hydroxide ions present.

The quality of the water generally meets Federal drinking water standards except for occasional excessive amounts of iron. Its use in high-pressure boilers would require further softening and removal of iron and related metals (R_2O_3 group). Further softening would also be desirable in some types of food canning and freezing, electroplating, and cooling. Water temperatures at the tap would, in general, be similar to those of the Flint River (table 5). However, they would be more uniform, a little warmer in winter, and possibly a little cooler in summer.

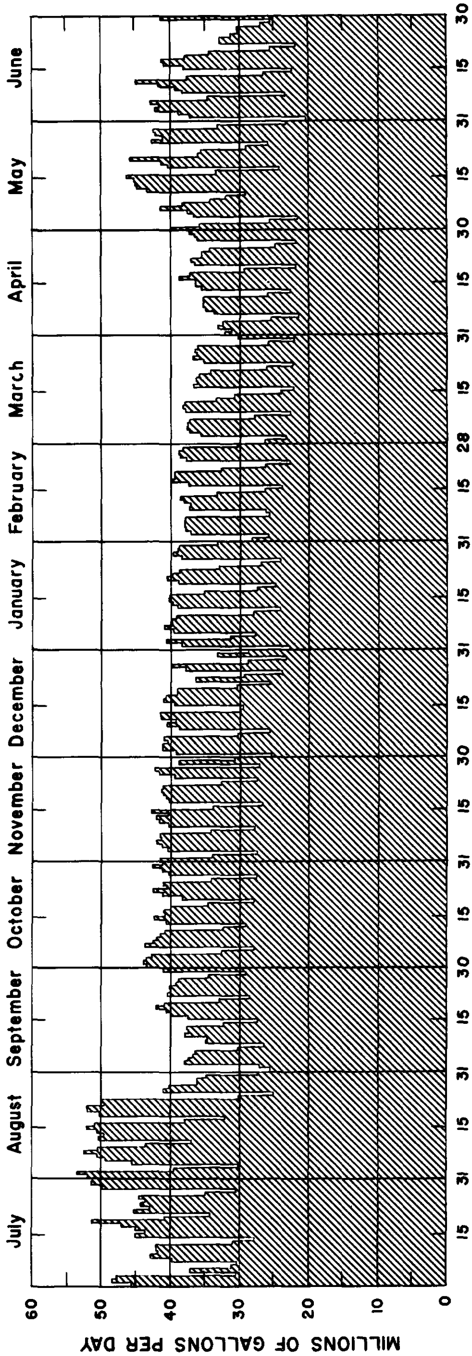

FIGURE 29.—Daily pumpage from the Flint River into the Flint public water-supply system for year ending June 30, 1958.

TABLE 17.—*Chemical analyses of monthly composites of daily samples of tap water in Flint, July 1, 1957, to June 30, 1958*

[Results in parts per million. From Flint Div. of Water Supply, 1958]

Chemical constituent or physical property	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Avg.
Insoluble in HCl	17.8	8.2	8.0	5.2	7.2	8.0	6.6	9.6	10.6	10.4	12.8	9.6	9.5
R_2O_3 group	6.4	1.0	10.8	1.6	10.0	3.0	2.0	1.8	5.2	3.0	3.6	2.8	4.3
Iron (Fe)	.45	Tr	.3	.1	.5	.05	.05	Tr	Tr	.05	.1	.05	.14
Aluminum (Al)	2.05	.5	5.7	.8	4.9	1.6	1.0	.95	2.8	1.6	1.86	1.5	2.11
Calcium (Ca)	24.4	25.1	19.1	23.4	21.4	24.4	27.8	24.6	27.0	30.2	27.6	31.4	25.5
Magnesium (Mg)	6.1	6.1	7.9	9.0	9.8	7.8	6.7	5.2	6.9	8.9	9.7	8.6	7.7
Alkalinity (as $CaCO_3$)	40	42	37	40	38	48	44	46	38	30	30	29	38.5
Sulfate (SO_4)	54.1	55.1	53.1	52.3	63.7	83.2	93.8	95.9	64.4	77.4	75.9	65.5	69.5
Chloride (Cl)	26	24	24	26	27.0	26	27	26	22	20	22	26	24.7
Total hardness (as $CaCO_3$)	84	86	86	84	82	88	90	84	84	84	80	86	84.8
Noncarbonate hardness (as $CaCO_3$)	44	44	49	44	44	40	46	38	46	54	50	57	46.3
Total residue	175	208	153	180	175	229	237	256	182	183	189	192	197
Loss on ignition	49	108	100	45	69	83	43	138	55	145	99	40	81.2

TABLE 18.—*Chemical and physical characteristics of tap water in Flint, January 1957 to December 1958*

[Calculated from daily analyses made by the Flint Water Department]

Chemical constituent or physical property	(Concentrations and values, in ppm, or conventional units equaled or exceeded for percent of time indicated)						
	5	10	25	50	75	90	95
Calcium	29.6	28.3	26.4	24.5	22.9	21.7	20.8
Magnesium	9.0	8.2	6.8	5.6	4.6	3.7	3.2
Bicarbonate	11.5	10.2	8.1	5.8	3.3	.5	-------
Carbonate	47	44	39	34	30	27	25
Hydroxide	2.3	1.0	.4	.2	.2	.1	.1
Total hardness (as $CaCO_3$)	93	92	89	86	84	82	82
Noncarbonate hardness (as $CaCO_3$)	59	57	53	49	45	41	38
pH	10.6	10.5	10.4	10.3	10.2	10.1	10.0
Color units	3	3	2	2	2	1	1
Turbidity, ppm, silica scale	.4	.3	.2	.1	.1	0	0

OTHER PUBLIC WATER-SUPPLY SYSTEMS

All the small public water-supply systems in the county obtain water from wells. Most of these systems have adequate water for present needs and for some additional expansion. Clio and Flushing, however, need additional facilities to meet present and anticipated demands. Table 19 gives data for the small public water systems in the county.

SUMMARY OF WATER USE

About 45 mgd of water was withdrawn for use in Genesee County in 1958. Of this amount, about 81 percent was supplied from streams, and the remaining 19 percent from wells (fig. 30). Aside from the normal trend of increasing water use for an expanding population, water use in this area is subject to relatively large fluctuations that are dependent mainly on industrial activity. For example, in the year ended June 30, 1956, the water pumped by the Flint public system alone was as much as the total use in the county in 1958. Assuming that water demands other than industrial were the same in 1956 and 1958, the total water use in the county in 1956 would have been approximately 54 mgd, or about 20 percent greater than in 1958.

Industry uses nearly half of the water supplied to Genesee County (fig. 30). About 97 percent of the water used by industry is from streams, and the rest is from wells. The various divisions of General Motors Corp. account for nearly 95 percent of the water used by industry. Flint industry uses water principally for cooling, steam-power generation, electroplating, and the washing and cleaning of metal. A relatively small amount of ground water is used by industry in special cooling and processing operations where the temperature of the water is a critical factor.

A major water use in the Flint area is sewage dilution. Flint's population is greater in relation to the low flow of its principal stream

TABLE 19.—*Summary of public water systems using ground water in Genesee County, Mich.*

System	Estimated population served	Source of supply Aquifer	No. of wells	Treatment	1958 average use gal. per day	Remarks
Beecher Metropolitan District.	13,500	Glacial drift	2	Chlorination	596,000	
		Saginaw-Michigan-Marshall.	2			
		Saginaw-Michigan.	1			
Burton Township	10,500	Glacial drift	2	None	440,000	Saginaw wells standby for emergency use.
		Saginaw	2			
Clio	2,100	Glacial drift	2	None	100,000	
		Saginaw	3			
Davison	3,400	Saginaw-Michigan.	3	None	292,000	
Fenton	5,800	Glacial drift	2		547,000	
		Drift-Marshall	1			
Flushing	3,100	Glacial drift	3	Softening chlorination, iron reduction.	236,000	
Grand Blanc	1,300	Saginaw	2		100,000	
James Elliott Subdivision (Genesee Twp.).		Saginaw	1			
Lake Fentons Orchards Subdivision (Fenton Twp.).	300	Glacial drift	2		13,500	
Linden	1,000	Glacial drift	1	None	50,000	
Montrose	1,200	Glacial drift	2	None	70,500	
Mount Morris	4,600	Glacial drift	3	Softening, iron removal.	198,000	One well is standby.
National Estates Subdivision (Grand Blanc Twp.).	650	Saginaw	2		32,000	
Otisville	700	Saginaw-Marshall.	1	Chlorination	31,400	
Southhampton Subdivision (Grand Blanc Twp.).	120	Saginaw	1		6,000	
Wildwood Subdivision (Grand Blanc Twp.).	320	Saginaw	1		16,000	
Winchester Village (Gaines Twp.).	870	Glacial drift	2	Iron removal, chlorination.		Water supply from wells in Shiawassee County.

than that of many cities of comparable size and industrial development. The season of maximum demand for water supply generally coincides with the season when the greatest dilution is required. Thus, a heavy load is imposed upon the water resources of the area in hot, dry weather.

Industry uses a relatively small amount of water in the smaller cities and villages of Genesee County. Irrigation is still a very minor water use. The few irrigation systems in operation rely mostly upon surface water obtained from ponds and creeks.

The natural and waste waters in the Flint area contain many dissolved and suspended mineral and organic materials. The importance of each constituent depends upon the amount present and the use of the water. Some constituents, like chloride, do not seriously affect domestic or industrial use of water unless present in tens and hundreds of parts per million, whereas others, like phenols, are objectionable in concentrations of only several parts per billion. Water samples in the Flint area were analyzed for suspended and dissolved materials that would characterize the water quality and provide information on pollution and the suitability of the water for various uses. The source and significance of each determined constituent is given in table 20.

URBAN WATER USE

Of the 45 mgd of water used in Genesee County in 1958, almost 36 mgd was supplied by the Flint public water-supply system. During the past decade, residential use of water from the Flint public supply has ranged from about 24 to 28 percent of the total, and industrial use has ranged from about 52 to 59 percent of the total pumped

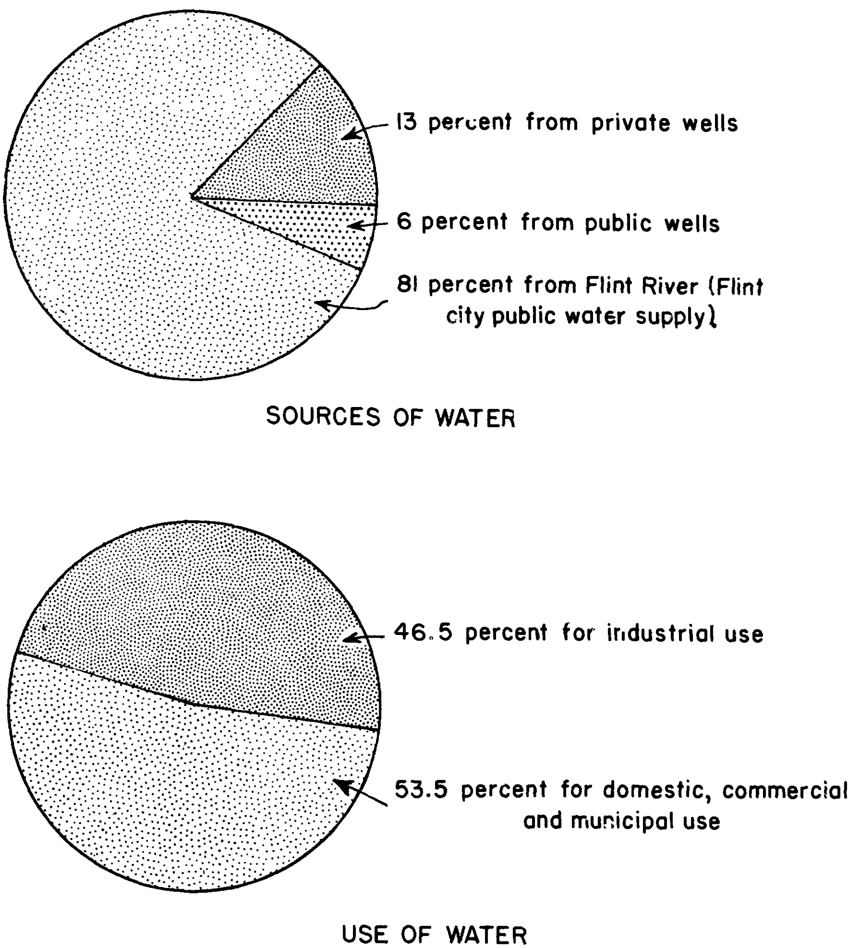

FIGURE 30.—Source and use of water in Genesee County, 1958.

TABLE 20.—*Source and significance of dissolved constituents and physical properties of natural waters*

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in small amounts—1–30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface waters usually indicate acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing and other processes. Federal drinking water standards state that iron and manganese together should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn)	Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark brown or black stain. Federal drinking water standards provide that iron and manganese together should not exceed 0.3 ppm.
Calcium (Ca) and magnesium (Mg).	Dissolved from practically all soils and rocks but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See hardness.) Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and Potassium (K).	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, some industrial brines, and sewage.	Large amounts as chlorides give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium ratio may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. Federal drinking water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts chloride salts give salty taste to water. In large quantities increases the corrosiveness of water. Federal drinking water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, 1950).
Nitrate (NO_3)	Decaying organic matter, sewage, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 45 ppm of nitrate (NO_3) may cause a type of methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, 1950, p. 265, App. D). Nitrate has shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.

TABLE 20.—*Source and significance of dissolved constituents and physical properties of natural waters*—Continued

Constituent or physical property	Source or cause	Significance
Phosphate (PO_4)	Dissolved from rocks and fertilizers. Detergents, treated waters, and wastes in domestic and industrial service effluents.	Inhibits scale formation in industrial processes and cooling waters. Encourages bacterial growth.
Phenols as C_6H_5OH	From gas works, coke ovens, oil refineries, chemical plants, and human and animal wastes.	Causes odors and tastes, especially when chlorinated, in food and beverages. Above above 5.0 ppm harmful to fish; below 1.0 ppm safe for fish.
Oils and waxes	Refineries, oil wells, boats, chemical plants, dumps, and many manufacturing operations.	Coat fish, birds and other objects in the water. Affects taste and odors of drinking water and food-processing waters.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter and some water of crystallization.	Federal drinking water standards recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Hard water consumes soap before a lather will form; deposits soap curd on bathtubs; forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; more than 200 ppm, very hard.
Specific conductance (micromhos per centimeter at 25°C).	Mineral content of the water.	Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents. Varies with temperature; reported at 25°C.
Hydrogen-ion concentration (pH).	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Color	Mineral, organic, and metallic compounds in solution from natural, municipal, industrial and mining sources.	Undesirable in laundries, drinking water, food and industrial processes, especially photography, textiles, pulp and paper making, and some chemical processes because it discolors the product.
Turbidity	Turbidity is due to suspended mineral and organic material such as clay, silt, silica particles, sawdust, fibers, sewage wastes, bacteria, and plankton.	Reduces penetration of light in water. Causes discoloration or sedimentary deposits in laundries, ice making, bottled beverages, textiles, paper making, boilers, and various industrial processes.
Dissolved oxygen	Oxygen derived from air and aeration processes.	Lack of dissolved oxygen is an indication of pollution from organic materials. Dissolved oxygen corrosive in boilers, piping, cooling equipment.
Temperature		Affects usefulness of water for many purposes. For most uses a water of uniformly low temperature is desired. Shallow wells show some seasonal fluctuations in water temperature. Ground waters from moderate depths usually are nearly constant in temperature, which is near the mean annual air temperature of the area. In very deep wells the water temperature generally increases on the average about 1°F with each 60-foot increment of depth. Seasonal fluctuations in temperature of surface waters are comparatively large depending on the depth of water but do not reach the extremes of air temperature.

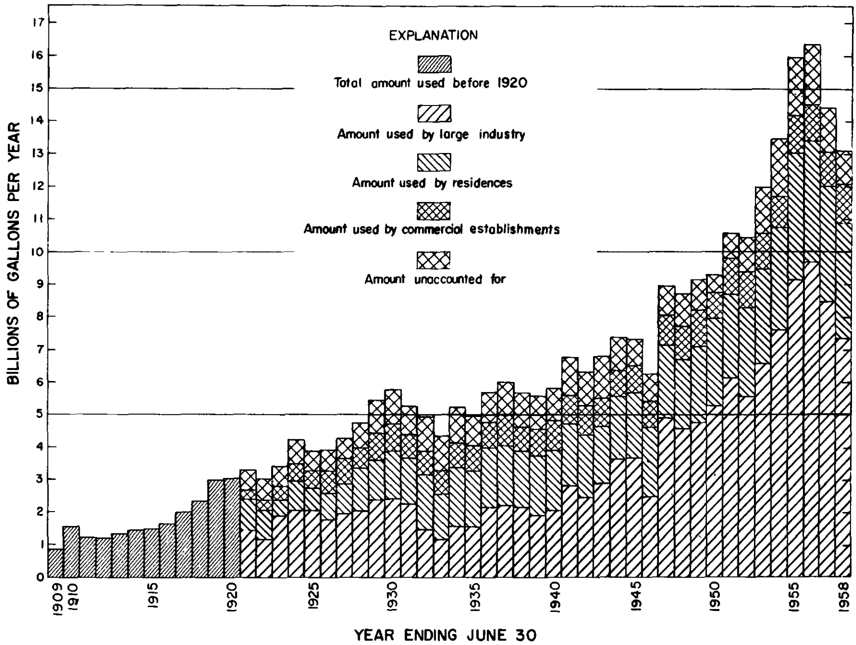

FIGURE 31.—Use of water delivered by the Flint public water-supply system.

(fig. 31). Use by commercial establishments, municipal facilities, railroads, and losses including water used for fire protection account for the remainder of the water delivered by the public supply.

INDUSTRIAL USE

Flint industry, geared to the manufacturing of automobiles, automobile parts, and related products, has water uses characteristic of metal-working activities. Cooling, electroplating, and the washing and cleaning of metal are the largest industrial uses of water. Water used from the Flint public supply by the principal industrial establishments in the area for the most recent year of record, 1958, and for the year of peak water use, 1956, was as follows:

	Water used in mgd	
	1958	*1956*
Buick Division of General Motors Corp	7. 0	11. 55
Chevrolet Division of General Motors Corp	5. 46	5. 83
AC Spark Plug Division of General Motors Corp	3. 9	5. 56
Ternstedt Division of General Motors Corp	1. 5	2. 02
Fisher Body Division of General Motors Corp	. 97	1. 03
Dupont	. 26	. 29

In 1958, General Motors Corp. accounted for 94 percent of the water used by industry from the Flint public supply. In addition to the water supplied by the Flint public system, AC Spark Plug, Fisher

Body, and Dupont in 1958 used about 0.04, 0.18, and 0.22 mgd, respectively, from private wells. The 0.18 mgd for Fisher Body is the total water use at their Grand Blanc plant, which is dependent entirely upon well supplies. Information is not available for other private industrial supplies. However, their water use would be a very small part of the total used by industry.

Some of the decrease in water use since 1956 may be ascribed to the installation of water-conserving devices and processes in industry. AC Spark Plug, for instance, recently installed a recirculation system that has resulted in the reduction of the amount of water purchased by more than 20 percent. Demand for air-conditioning water, although relatively small, occurs during the season of maximum demand on the water-supply system. A 1956 city ordinance is aimed at water conservation in this area of use. The ordinance requires that all air-conditioning systems of 3 horsepower capacity or more be equipped with a water-conserving device if the water used is drawn from the public supply.

WATER USE FOR SEWAGE DILUTION

Sewage dilution could be classed as an urban water use because large quantities of sanitary and industrial wastes are dumped into streams in urban areas. It is difficult to estimate the quantity of water used for this purpose because it depends upon temperature, amount and distribution of precipitation, and other factors which fluctuate widely from season to season, and from year to year. For 1958 conditions of water demand and waste discharge, a maximum of about 55 mgd of dilution water from storage would have been necessary during critical periods in hot, dry weather. On the other hand, no stored water would be needed for waste dilution in occasional wet years. The flow-duration curve of natural flow at the Flint gaging station (fig. 7), indicates that an average of 17 mgd of stored water would be needed for sewage dilution for 25 percent of the time, on the assumption that minimum dilution-water requirements were 75 mgd total flow at sewage-treatment plant, that the water demand for Flint was 45 mgd, and that the capacity of the sewage-treatment plant was 25 mgd. In most years the dilution water provided from storage will be somewhere between 17 and 55 mgd depending upon flow conditions and the prevailing permissible degree of pollution.

OTHER WATER USES

About 3 mgd was supplied by public water-supply systems in the smaller communities in Genesee County in 1958. It was all from wells, and most of it was used for domestic purposes. Industrial use is relatively small in these communities.

Water used in the rural areas in the county is supplied entirely by wells and is estimated at 5 mgd for 1958 on the basis of 50 gpd for each person.

The few irrigation systems in operation use an insignificant quantity of water, mostly from streams and ponds. Irrigation use, though very small as of 1958, can be expected to increase because it has been demonstrated that supplemental irrigation in Michigan can be profitable.

Many of the lakes and ponds of the county are used for recreation one of the necessary amenities of life. It is fortunate that such facilities exist so close and are accessible to an urban center like Flint.

EMERGENCY WATER SUPPLIES FOR CIVIL DEFENSE

EMERGENCY SUPPLIES FOR DOMESTIC AND SANITARY USE

The Office of Civil and Defense Mobilization (1958, p. 1, 2) has made recommendations regarding the minimum potable water supply requirements in civil defense emergencies arising from enemy attack or natural disasters. The top priority on available water supplies is consigned to hospitals and medical-care facilities. Next in priority, but of almost equal importance, are the water requirements of disaster workers and persons being cared for at mass care centers and similar installations. The general public comes last in priority. Water requirements for the first day or so after the disaster may be as low as 5 to 10 gallons per day per capita but thereafter will increase so that at least 25 gallons per day per capita will be needed for drinking, cleaning, cooking, laundry work, and for the use of sanitary facilities. For Flint, which has a population of about 200,000, the emergency water supply requirement would be approximately 5 mgd.

In the event of an enemy attack, biological and chemical warfare agents present hazards to emergency water supplies. Also, supplies must be monitored for radiation. Until proper tests can be made, all untreated emergency water supplies must be heavily chlorinated. For hospital use, water must be of good quality chemically, physically, and bacteriologically. Water from streams and ponds should therefore be filtered as well as chlorinated for hospital use. For other users, bacteriological safety will be of paramount importance in consideration of the quality of emergency water supplies.

Surface-water supplies are readily available in the Flint area to meet the quantity requirements for emergency use. The natural flow in the Flint River is more than sufficient to meet this demand. Release of stored water from Holloway and Kearsley Reservoirs could augment the natural flow to satisfy almost any foreseeable emergency use. In addition, roughly 100 to 150 million gallons of water is available in Thread Lake as a potential supply. If radioactive contamination were not a factor, the utilization of surface water for emergency supplies in the Flint area would be limited only by the pumping, distribution, chlorination, and filtration facilities available. Standby diesel generators to drive the pumps in event of electric power failure are in place at the city waterworks (fig. 32). At the Buick plant, a little farther downstream, there are both diesel and gasoline standby generators installed to provide power to pump water from the Flint River. Consideration might be given to the acquisition of mobile water filtration units with chlorinators to provide the necessary emergency water treatment facilities.

Because radioactive contamination of surface waters must be considered as a definite possibility in case of enemy attack, ground-water sources are better for meeting emergency water-supply requirements, at least for the period of time needed for attenuation of the contamination to safe levels. The need for well supplies is greatest in those sections normally served by the Flint public water system. A number of existing ground-water facilities in the Flint metropolitan area can be used to provide emergency water supplies. A summary description of these facilities is given in the following paragraphs. The number in parentheses for each facility is the location number on figure 32.

Buick (5).—The Buick plant has several wells that tap the Saginaw formation. These wells are not used and are not equipped with pumps. They would produce 200 to 300 gpm if equipped with deep-well pumps. The water produced would contain objectionable amounts of chloride. However, the water is suitable for human consumption in an emergency.

Dupont and AC Spark Plug (6).—Both of these plants have wells tapping the Saginaw formation. The Dupont well is 12 inches in diameter, the AC Spark Plug well is 8 inches in diameter. The wells are equipped with electric-powered deep-well pumps, and each produces about 100 gpm. The water is relatively high in chloride content but could be used in an emergency.

AC Spark Plug (7).—This plant has three 6-inch wells, equipped with electric-powered deep-well pumps, and each well produces about 100 gpm. The water obtained from these wells contains objectionable amounts of chloride. The water is suitable for human consumption in an emergency.

Chevrolet (8).—The downtown Chevrolet plant has several 8- and 10-inch wells that are not used. These wells could be used for an emergency supply although the water is of relatively poor quality. The present status of pumping equipment at the plant is not known, but deep-well pumps would be needed to produce water from these wells.

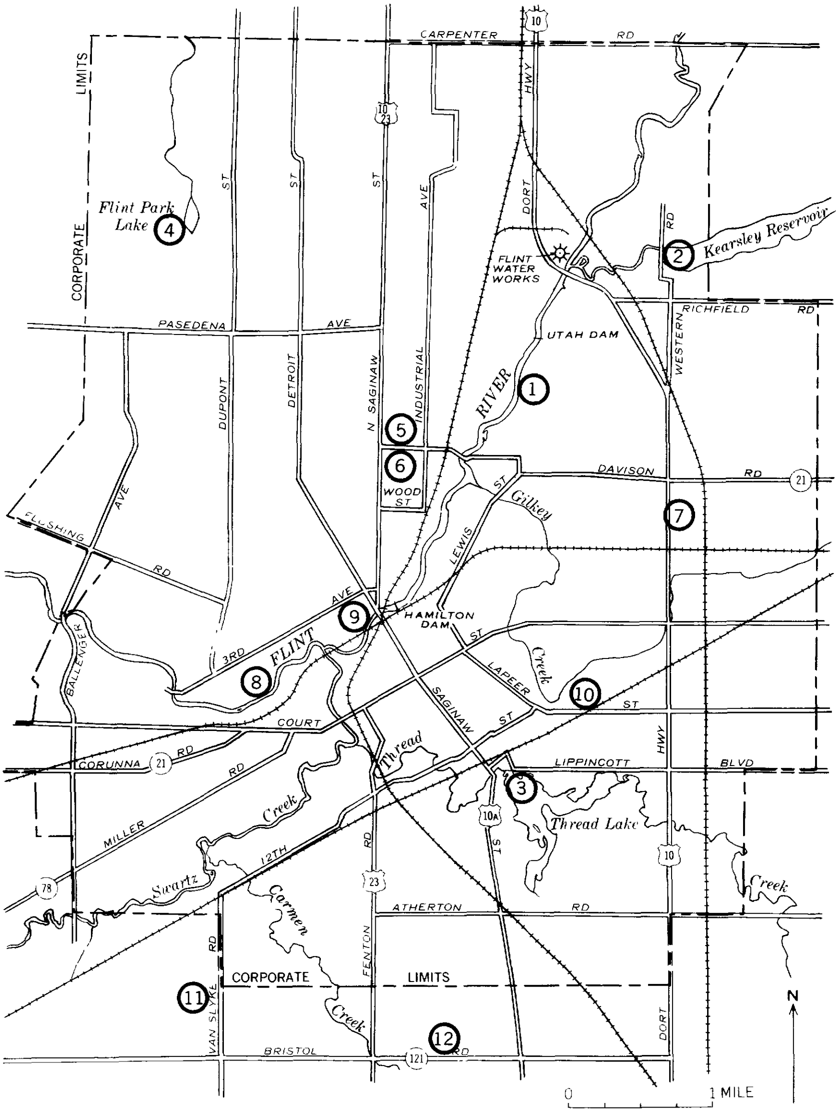

FIGURE 32.—Possible sources of emergency water supplies in Flint.

1. Flint River
2. Kearsley Reservoir
3. Thread Lake
4. Flint Park Lake
5. Buick Plant, wells
6. Dupont Co. B & AC Spark plug, industrial plant wells.
7. AC Spark Plug, Dort Hwy. Plant, wells
8. Chevrolet, downtown plant, wells
9. Downtown area, private wells for air-conditioning water.
10. What Cheer mine, wells for dewatering mine
11. Chevrolet, assembly, framing and stamping plants, wells.
12. Burton Township, public water-supply wells

Wells in downtown Flint (9).—Many of the stores, theaters, banks, and office buildings in the downtown Flint area have wells which supply water for air-conditioning use. Most of these wells are 6 inches in diameter or larger. They are equipped with electric-powered pumps and produce water with objectionable amounts of chloride. However, most of the water would be suitable for human consumption in an emergency.

What Cheer coal mine (10).—The workings of the What Cheer mine extend over an area about 2,000 feet long and 600 feet wide. These old workings are filled with water and are a potential source of large supplies of water. The quality of the water is not known, but it is assumed that chlorination would be necessary to make the water safe for human consumption. The wells used to dewater the mine are at the south end of Franklin St. near the Grand Trunk Railway tracks. The condition of the wells and the rate of yield must be determined before the full potential of this emergency source can be established. The mine probably would yield a million gallons a day for about 2 months and more water for a shorter period if necessary.

Chevrolet (11).—Two wells, 8 and 10 inches in diameter, are used for lawn irrigation at the Chevrolet frame and stamping, and assembly plants. They are equipped with electric-powered deep-well pumps. The wells each yield about 100 gpm. The water is of relatively good quality.

Burton Township (12).—The Burton Township public water system has two wells in glacial drift and two wells in the Saginaw formation. The wells in the Saginaw formation, which are maintained on a standby basis, will each yield about 200 gpm. The water is hard and contains significant amounts of chloride. The wells in glacial drift will yield a total of about 1,000 gpm. All the wells are equipped with electric-powered deep-well pumps. If the use of water in Burton Township can be reduced, from 700 to 800 gpm might be made available to Flint in an emergency.

If the use of water were restricted to essential use, the small public water utilities in the county would be able to supply Flint with a considerable amount of water. The data for the small public water systems in the county are given in table 10.

AUXILIARY WATER SUPPLIES FOR FIREFIGHTING

Quantity, not quality, is of primary importance in considering possible sources of water supplies for firefighting. Of nearly equal importance is the accessibility or availability of the supply. In this regard, Flint is very fortunate in having the Flint River flowing through the heart of the city almost bisecting the urban area. Water from the Flint River is thus readily available to downtown Flint and contiguous areas containing the heaviest concentration of population in the city. Utah and Hamilton Dams on the Flint River, both gated structures in the central and northeast parts of the city (fig. 32), can be regulated to provide the necessary water depth over any auxiliary water intakes installed upstream from them. As noted in the previous section, auxiliary diesel- and gasoline-powered units for operating pumps drawing water from the Flint River are already in place at the city waterworks and at the Buick plant. Below Hamilton Dam, water would have to be withdrawn from the natural pools in the channel. The approximate height of the river banks through the city can be estimated from plate 5. Release of stored water from Holloway and Kearsley Reservoirs could also be used to maintain depth over auxiliary water intakes installed below Hamilton Dam. Mobile pumping units would also be required.

The natural flow of the Flint River plus the stored water available in Holloway and Kearsley Reservoirs would normally be more than enough to meet any foreseeable emergency. Firefighting requires large quantities of water for relatively short periods of time, so that even small impoundments can support a heavy demand from this use. Two other lakes (besides Kearsley Reservoir) strategically located within the city could be tapped for emergency use. Thread Lake (No. 3, fig. 32), in the southeast quarter of the city, has a surface area of about 110 acres and roughly 140 million gallons of water in storage at full-pond level (assuming average depth of 4 ft). The dam at the outlet of the lake could be operated to provide the necessary depth of water over temporary intakes placed in the reach of stream below the dam. Flint Park Lake (No. 4, fig. 32) is in the northwest corner of the city. Although the storage in this lake is small, probably less than 10 million gallons, it may be useful to the immediately adjacent residential area as an emergency supply.

Some of the other communities in the county are similarly situated with respect to surface-water supplies for emergency firefighting use. Flushing and Montrose have the Flint River to draw upon. Fenton and Linden have the Shiawassee River. Argentine, Atlas, Goodrich, Otisville, and Otter Lake have natural or artificial lakes nearby. The other communities and the rural populace in the county would have to depend upon their well supplies.

POSSIBILITY OF FURTHER DEVELOPMENT

STREAMS AND LAKES

The dependable yield of the Flint River with Holloway and Kearsley Reservoirs in operation is almost exactly equal to the rated capacity of the Flint water treatment plant (59 mgd). When the impounded storge must be apportioned between water-supply and sewage-dilution demands at least one of the uses has to be curtailed during a prolonged drought. With 1958 water-supply requirements averaging about 45 mgd during the summer coincident with sewage-dilution requirements of from 20 to 30 mgd, it is evident that water demands already exceed the assured yield of the Flint River system. By modifying Holloway Dam to accomodate a normal full-pond level of 760 feet, the dependable yield of the existing system could be increased to about 72 mgd. However, such modification may cause undesirably high river levels at Columbiaville and at other points above the reservoir. Any other sizeable development in the Flint River basin is unlikely because of the lack of suitable storage sites.

Without storage, the Shiawassee River at Byron is capable of supplying at least 29 mgd for 95 percent of the time. Diversion of this amount from the Shiawassee River basin to the Flint area would increase the dependable flow at the Flint waterworks to about 88 mgd, or almost a 50 percent increase. Any plans for diversion from the Shiawassee River basin must necessarily take into account the water needs of that basin, especially those of the city of Owosso. The increase in yield obtainable by providing various amounts of storage can be determined by reference to the graph showing storage requirements (fig. 16).

Small water supplies could be developed from the small streams. The yield of Butternut Creek per square mile is the best of those studied. A flow equal to or greater than about 2.2 mgd, without storage, at the mouth of Butternut Creek could be expected during 95 percent of the time. Swartz Creek at the mouth of the West Branch, though draining an area more than 2½ times the size of Butternut Creek, is capable of providing a firm yield of only about 1.4 mgd during 95 percent of the time. The well-sustained dry-weather flow of Butternut Creek would seem to indicate the possibility of developing additional ground-water supplies from the shallow aquifers of that basin.

The lakes in the county could support some development if the fluctuations in lake levels induced by use would not adversely affect the rights of riparian owners. Any contemplated use of lake water should take into consideration their present recreational use.

It is apparent that the possibility of further exploitation of the streams of Genesee County is limited. Lake Huron is a possible source of large quantities of water of good quality. Plans for developing this source to supply Flint and eventually much of Genesee County are already well advanced. The quantity of water obtainable from Lake Huron is restricted only by economic considerations, as it is probable that almost all of it would be returned to the lake eventually.

GLACIAL DRIFT

The glacial-drift aquifer has considerable potential for additional development. The recent success achieved by the Beecher metropolitan district and Burton Township in developing large-capacity wells in glacial sands and gravels should stimulate the search for other areas where large supplies can be obtained from the drift. Many of the extensive deposits of permeable sand and gravel in the county occupy the valleys in the bedrock surface. Before the full potential of the drift aquifer could be determined, test drilling would be necessary to define more adequately the configuration of the bedrock surface and the composition of the drift materials that fill the bedrock valleys.

Test drilling in the outwash and delta deposits in the northwestern part of the county would probably locate additional bodies of sand and gravel that would yield moderate or large supplies of water.

The source and rate of recharge also should be considered in estimating the potential of the drift aquifer. Most of the sand and gravel deposits presently tapped by wells are recharged directly by precipitation. The greatest potential for additional development is offered where permeable drift is hydraulically connected to surface waters. Withdrawal of water from wells tapping such a deposit would induce recharge from the surface source. The amount of water that could be obtained from this type of installation is limited mainly by the amount of surface water available. The best potential for developments of this kind is in the Shiawassee River basin where little use is made of the available surface-water resources.

The large-capacity drift wells in the county are presently capable of producing a total of 5 to 6 mgd of water. It seems reasonable that an additional 5 or even 10 mgd might be developed from the drift aquifers without seriously affecting the flow of surface streams, especially in the Shiawassee River basin and in drainage basins tributary to the Flint River downstream from Flint.

SAGINAW FORMATION

The Saginaw formation has only small potential for additional development as a source of large or moderate supplies of water of good quality. Most of the present production from the Saginaw for industrial and public supply use comes from wells in the southeastern part of the county. The sandstone has some potential for additional use in this area if precautions are taken to minimize upward migration of saline water. This may be accomplished by utilizing widely spaced wells of low capacity instead of closely spaced wells of high capacity. Production from large-capacity wells tapping this aquifer in the rest of the county, however, has declined in the past decade mainly because of the poor quality of the water yielded by the sandstone. There is considerable potential for uses which do not demand water of good quality, such as air conditioning.

MICHIGAN FORMATION

The Michigan formation is not an important source of large supplies of water and offers little potential for additional development in the area.

MARSHALL FORMATION

The Marshall formation yields only a small part of the ground water presently used in the county. Only few data on the water-bearing characteristics of the Marshall are available. These data indicate, however, that the Marshall may be the source of moderate to large supplies of water in the eastern part of Davison Township and in Atlas Township.

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