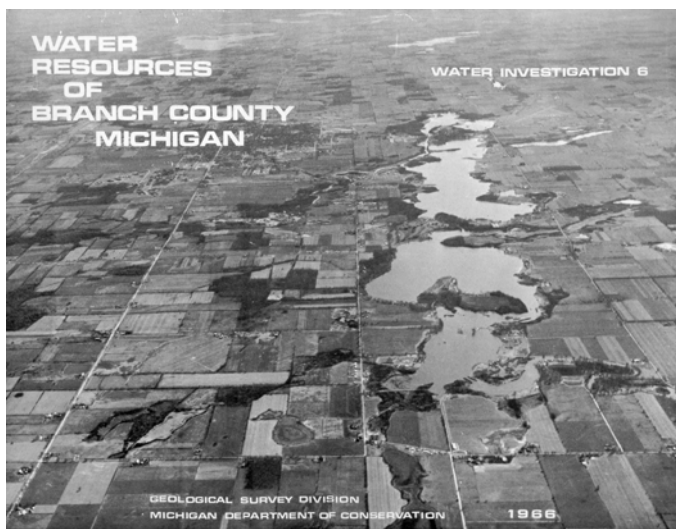




About the cover: Aerial view of Branch County from the village of Girard, south to the Indiana State line. The city of Coldwater is in the left center, and to the right is one of the County's large lake chains.

Photo courtesy of Richard Aldrich

Photo-graphics, Coldwater, Michigan



GEOLOGICAL SURVEY DIVISION

WATER INVESTIGATION 6 WATER RESOURCES OF BRANCH COUNTY, MICHIGAN

By

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Prepared by U. S. Geological Survey

In cooperation with County of Branch, and Michigan Geological Survey

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of the waters; and the present and future effects of irrigation on water supplies.

The purpose of this report is to describe the county's hydrologic system and to provide a general appraisal of its water resources for those who need a basic understanding of these to plan effectively for development, conservation, and management of the water resources.

Cooperation by personnel of Federal, State, Branch County agencies and municipalities; by drillers and many others is gratefully acknowledged.

The authors also appreciate the assistance in the review of this report by Messrs. G. E. Eddy, J. G. Rulison, of the Michigan Geological Survey, and Norman Billings of the Michigan Water Resources Commission.

This investigation was made in cooperation with the County of Branch and the Michigan Geological Survey. The continuing cooperative program between the State and Federal Geological Survey is under the joint direction of G. E. Eddy, State Geologist, and A. D. Ash, District Chief for the U. S. Geological Survey in Michigan.

ABSTRACT

Branch County has abundant water resources throughout most of its area. Almost all the water used is supplied by wells that obtain water from glacial drift deposits and locally from fractures and sandy beds in the Coldwater Shale. Glacial drift in buried bedrock valleys may yield large quantities of water to wells. Well yields are generally adequate for domestic and farm supplies. Properly developed large-diameter wells tapping thick beds of sand and gravel of the glacial drift can yield up to several thousands of gallons per minute locally. The hundreds of lakes and the many perennial streams have great recreational value. They are also a large potential source of water for some supplies. For example, it is estimated that 88 billion gallons of water runs off in streams of the county in an average year, and the lakes of the county hold about 42 billion gallons of water in storage.

Problems of water supply to wells exist locally in some moraine and till areas or where the glacial drift is thin and the underlying bedrock yields only small quantities of water or none at all.

Ground water is generally hard to very hard and often contains excessive iron. Salty water is mainly a problem in areas where bedrock is the chief source.

Floods are not a serious problem largely because of the storage capacity of the lakes and the permeable materials in some stream basins. Based on measurements at eight stream sites the estimated amount of flow for 90 percent of the time ranges from 80,000 to 150,000 gallons per day per square mile of drainage area.

A special study of low levels in land-locked Gilead Lake indicated that this lake is semiperched and mostly dependent upon the water table for its levels.

CONCLUSIONS

1. Glacial drift is the main source of fresh water in Branch County. Large yields can be obtained from sand and gravel in the outwash deposits. Locally, where the drift is thin, the drift may yield little or no water.
2. The thickness of the glacial drift deposits generally ranges from 50 to 250 feet. Locally, however, the drift may be much thinner and water supplies difficult, if not impossible, to obtain. Land may be zoned to preclude building of subdivisions or industry in areas where the water resources are inadequate.
3. Water levels in wells are generally high, most being less than 25 feet below land surface.
4. Municipal ground-water supplies in the county are all from glacial drift, and are capable of supplying more water than is presently used. If needed, additional wells could provide more water.
5. Large-capacity wells tapping coarse sands and gravels in a buried bedrock valley at Coldwater can yield up to 5,000 gallons per minute. Other buried valleys in the county may yield large quantities of water and their potentials need to be explored.
6. Bedrock in Branch County is the Coldwater Shale and can provide only small quantities of water, which often are salty.
7. Streams in the county are characterized by relatively high base flows. Most of the streams can provide large quantities of water; however, large withdrawals may adversely affect other users. Large withdrawals of ground water could reduce the flow of nearby streams and also cause some lowering of lake levels.
8. Although floods are not a major problem, this report describes a method of estimating magnitude and frequency of floods for use in the design of bridges and drainage structures.
9. During the early part of this study, the water regimen was low as a result of large deficiencies of precipitation during the 1962-64 period. Above average precipitation in 1965 brought substantial rises in the water regimen.
10. A study of land-locked Gilead Lake revealed that this lake is semi-perched and is part of the local water table. No practical solution of low lake levels at this lake during periods of drought was found. Most other lakes in the county were stream-connected and levels were not critically low during 1964-65.
11. No evidence of serious effects on streamflow or lake levels by irrigation use was found at the present rate of withdrawal. However, the use of ground water for irrigation is very small at this time. Any future large increase in irrigation may have serious local effects on

the water regimen. Thus, streamflows, lake levels and ground-water levels should be monitored to observe the trends and take corrective or regulatory action.

12. Water from the glacial drift is hard to very hard and sometimes contains excessive iron. Fortunately, modern treatment can eliminate most of the hardness and iron from water. There is no economical way to eliminate high chlorides or "salty" water in wells. As this salty water mostly occurs in the Coldwater Shale, every effort should be made to drill wells only in the overlying glacial deposits.

13. The maps showing the type and thickness of glacial drift, the altitude of the bedrock, and the availability of ground water, and the tables showing streamflows can serve as a guide to proper zoning for subdivision and industrial sites and the adequacy of streamflows for waste disposal.

14. Most water problems in Branch County can be solved by more fully utilizing and conserving known sources, exploring for additional large ground-water sources, and guarding against contamination of the water. It is important for future water management that all the facts on water use and its possible effects on other users be made known.

HOW THIS REPORT CAN BE USED



The data in this report should be useful to county officials, engineers, well drillers, and water users in solving water problems and in the future management of water resources of the county.

Anyone desiring to develop a water supply can use this report to determine approximately how much water can be obtained from wells at a given site, how much water is available for diversion from a stream, and whether the quality of water from either source will be suitable for its intended use.

For example, Farmer A needs to develop a water supply for irrigation on his farm in Bethel Township. Assuming that he has at least thumbed through the report to become familiar with its contents, he turns to the ground-water availability map (fig. 12). He finds that his farm is in an area labeled "good" and where large-diameter wells (6 inches or more) drilled to a depth of less than 75 feet have a better than even chance of producing over 100 gallons per minute (gpm). He looks at table 3, "Records of Wells" in the appendix, and finds that the large-diameter municipal wells at Bronson, about a mile away, produce over 700 gpm. From the logs of these municipal wells (table 2) he finds that a bed of sand and gravel at a depth of 30 to 62 feet is the chief aquifer. The water quality maps (figs. 34-36) indicate that the water in the area of Farmer A's farm is low in chlorides

and generally suitable for irrigation use although it is very hard and contains iron. Thus, he finds that he has a better than even chance of obtaining both the quantity and quality of water he needs from a large-diameter well drilled to a depth of 65 feet.

However, an alternate supply is available to Farmer A from a creek that runs through his farm. Table 6 shows that the dry-weather flow of this creek, at a point just upstream from his farm, was 2.1 cubic feet per second (cfs), or about a thousand gpm. From table 5, he finds that this flow could be expected to be 6 cfs, or over 2,500 gpm, for 90 per cent of the time. In addition, the water from the creek is of suitable chemical quality (table 9). On the basis of the data in this report, he decides to use the creek, taking out about 300 gpm on days when irrigation is needed. This use would deplete the stream by about 0.7 cfs while he is pumping from it and his downstream neighbors would still have about 5.3 cfs for their use 90 per cent of the time. He keeps in mind that in case of valid objections by downstream users he can develop a ground-water supply as a second choice. Having read the section on the interrelationship of ground and surface water he also realizes that a future well or wells should be located as far from the stream as his irrigation needs permit so as to minimize effects of ground-water withdrawals on the stream (fig. 31).

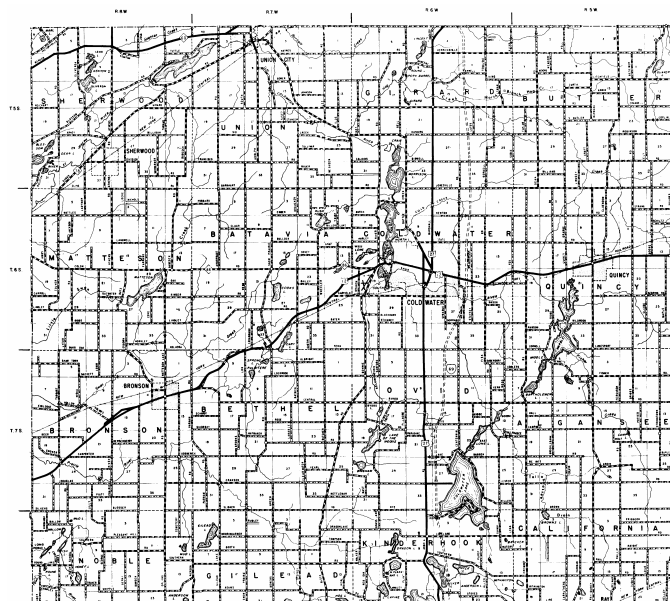
As another example, village B finds that their two municipal wells pumped together cannot maintain sufficient pressures during peak demand periods in the hot summer months. A consultant is called in. Using the availability map (fig. 12) in this report, he decides that a test well should be installed in a nearby area labeled "excellent". The water-quality maps (figs. 35-36) and the analyses of water from both the city wells and nearby domestic wells indicate that the water from the new well is likely to be very hard and high in iron but otherwise suitable for public supply. The consultant may also decide, from the description of the municipal supplies in the appendix, that a well could be added at one of the municipal well fields where the yield is high. This can be done, if land is available so that the new well can be located at such a distance from existing wells that their yields are not seriously diminished.

Contractor developer C has an option on some acreage and intends to build a subdivision of homes. He consults county and township officials. Using this report, they find that the area in question has a thin glacial drift cover (fig. 11). Because water levels are low in the area (table 3), and because this report indicates that the underlying bedrock yields but little water to wells, the officials conclude that a sufficient water supply probably cannot be developed. Also, the chemical quality map and tables indicate that the water from the bedrock is salty. Based upon this information, the township board having jurisdiction disapproves the site unless the contractor can prove by test drilling and aquifer tests that there is sufficient water of good quality available to serve the needs of the subdivision.

Industrial manager D is considering the location of a new plant site. He needs at least 600 gpm from a well with possible expansion later to 1,000 gpm from additional wells. A consultant is called in. From information contained in this report, it is determined that the site is underlain by a buried bedrock valley with a considerable thickness of glacial deposits. An option is taken on the land and a test well drilled. As a result of the test, a large supply of water is located and a 12-inch diameter well is installed to a depth of 150 feet and screened into a thick section of saturated coarse sands and gravels.

Some of the plant's water will result in wastes that will have to be disposed of -- to a stream if possible. However, the low flow of the nearby stream is less than 0.4 cfs which would not be suitable for the amount of waste to be disposed of. From inspection of the map of the surface geology (Plate 1, in pocket), it is found that part of the land would be suitable for a sewage lagoon system because of the abundance of clays. Upon investigation the consultant finds that the type of wastes are such as can be safely disposed of by such a system, so a sewage lagoon is built.

Individual E is looking for a small lot in the country to build a house. He finds several good locations and consults with county officials as to the availability of water for a domestic well. Using this report, they find one of the sites to be a bedrock high with thin glacial drift and the quality of the ground water to be "salty". At the other site, they find that the availability of ground water is only fair but owing to the small quantity of water needed by individual E, a well drilled less than 100 feet deep can be expected to supply his needs satisfactorily. Although the water probably will be hard and contain some iron it will be otherwise suited for domestic use, as the hardness and iron can be removed with modern softening and iron removal equipment.



BRANCH COUNTY, MICHIGAN

A DESCRIPTION OF BRANCH COUNTY

Branch County, an area of 506 square miles in southern Michigan, borders Indiana. Most of the county lies in the St. Joseph River watershed. The topography ranges from flat till plains to rolling hills. Land elevations range from 1,110 feet in the eastern part to 840 feet in the northwestern part, near Sherwood, where the St. Joseph River flows out of the county (fig. 1). Some 100 lakes dot the county, most connecting to creeks and streams which then flow into the St. Joseph River drainage system (fig. 2). The Coldwater and Sauk Rivers originate in the Coldwater and Marble Lake chain of lakes. About 85 of the lakes have substantial developments or are capable of future development. The remainder are rather small in size and are either too shallow or are surrounded by low swampy areas which hinder their development.

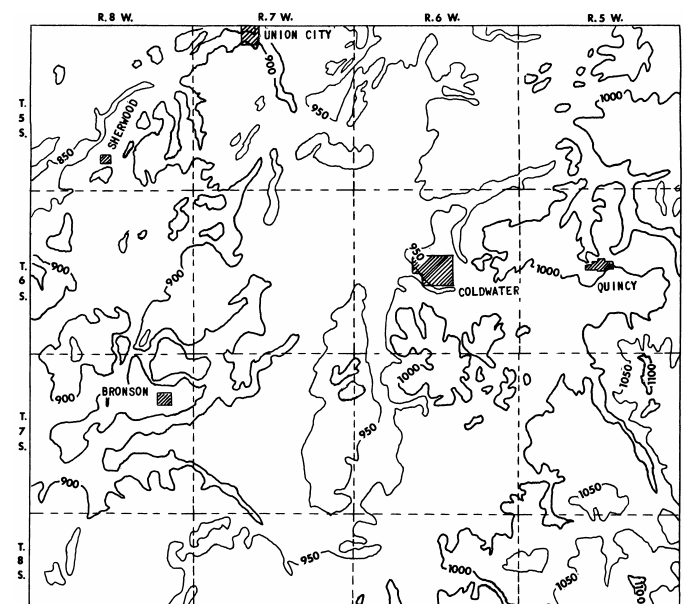


Figure 1. Elevations of the land surface.

Contour interval 50 feet. Datum is mean sea level.
Elevations are highest in the southeast part of the county and lowest in the northwest part near Sherwood.

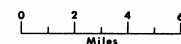


Figure 1. Elevations of the land surface.

The county had a population of about 35,000 in 1960, nearly 15,000 of which lived in incorporated cities and villages (fig. 3). Much of the population is centered in the Coldwater area. The summer population is augmented by a substantial number of cottage owners from other areas and by many tourists attracted to the lakes. The county has two cities -- Coldwater (the county seat) and Bronson, and three villages -- Sherwood, Union City, and Quincy. Crisscrossing the county are two Federal and three State highways, and 965 miles of county roads. Work was begun in 1964 on an interstate highway that will traverse the center of the county in a north-south direction. The New York Central Railroad serves the five incorporated cities and villages.

Land use in the county is predominantly agricultural, being composed mainly of cultivated fields, orchards, woodlands, and pastures. In 1960, there were 1,942 farms occupying a land area of about 280,600 acres or about 87 percent of the area of the county. About one-third of the workers are agriculturally employed. However, the economy is principally industrial with approximately 70 manufacturing industries.

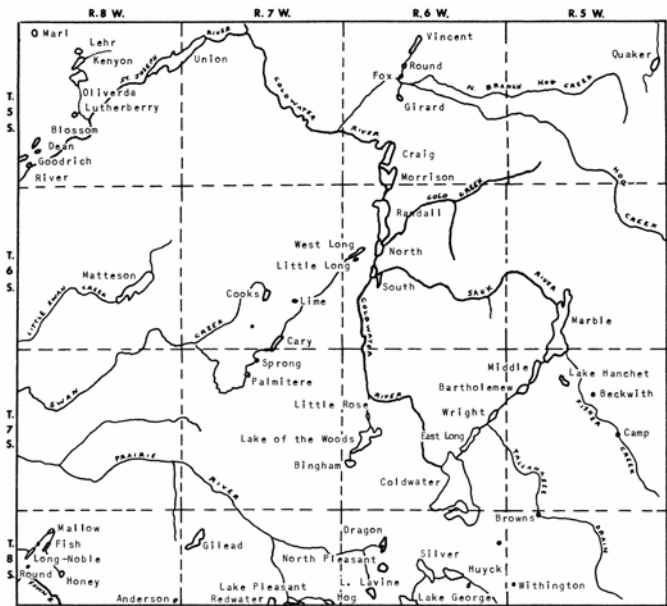


Figure 2. Location of lakes and streams.

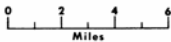


Figure 2. Location of lakes and streams.

	R. 8 W.	R. 7 W.	R. 6 W.	R. 5 W.
T. 5 S.	SHERWOOD (1,320) SHERWOOD (356)	UNION CITY (1,648) UNION (2,708)	GIRARD (1,372)	BUTLER (995)
T. 6 S.	MATTESON (1,059)	BATAVIA (1,225)	COLDWATER (8,800) COLDWATER (13,896)	QUINCY (1,602) QUINCY (3,129)
T. 7 S.	BRONSON (2,267) BRONSON (3,420)	BETHEL (995)	OVID (1,318)	ALGANSEE (1,205)
T. 8 S.	NOBLE (434)	GILEAD (562)	KINDERHOOK (600)	CALIFORNIA (668)

Figure 3. Township and municipal populations.
(Based on the 1960 census.)

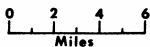


Figure 3. Township and municipal populations.

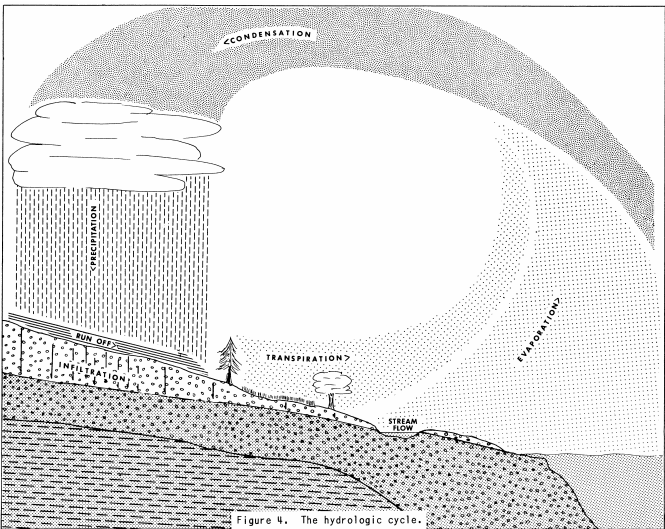
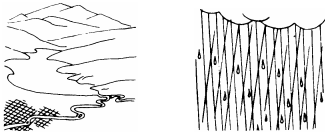


Figure 4. The hydrologic cycle.

WATER -- ITS OCCURRENCE AND AVAILABILITY



Climate’s Effect on Water Resources

The source of all water in Branch County is precipitation. Some of this water runs off over the surface into streams, lakes, and swamps; some soaks into the ground and becomes part of the ground-water table; some is lost to the atmosphere by evaporation or transpiration by plants. An average of 34 inches of precipitation falls on the county's land surface each year. Of this, about 24 inches are lost through evaporation and transpiration; about 7 inches run off overland to streams, and about 3 inches enter the ground (fig. 4). During prolonged dry-weather periods, the seepage of water from the ground is the only source of water to streams, lakes, and swamps.

Water levels in wells and lakes, and streamflows respond to variations in precipitation. Large variations in annual and monthly precipitation often occur. For example, during the 1897-1965 period of record, monthly totals have varied from as little as 0.10 inch to as much as 9.50 inches, and annual totals from 18 inches in 1930 to over 46 inches in 1905 (fig. 5).

The variations in annual precipitation were large during the 1956-65 period as is shown on the precipitation departure graph (fig. 6). This graph was constructed by adding algebraically the annual departures from the U. S. Weather Bureau published normal precipitation of 34.12 inches at Coldwater. The zero line is used as a base indicating the normal. For the ten-year period illustrated there was a total accumulated deficiency of 22

inches. In the 1959-61 period the departure above normal was about 19 inches. However, the 1962-64 period, a time of drought, had a total deficiency of about 33 inches -- nearly a year's rainfall lost. This recent large deficiency caused ground-water levels to be lowered. Many shallow wells "went dry" and had to be deepened or new wells drilled. Many lakes, especially Gilead Lake, fell to low levels, causing great concern. Very low streamflows were also experienced, especially during the dry summer periods. However, subsequent periods of above-normal precipitation in the winter, late summer and in December of 1965 resulted in great benefit to the water regimen.

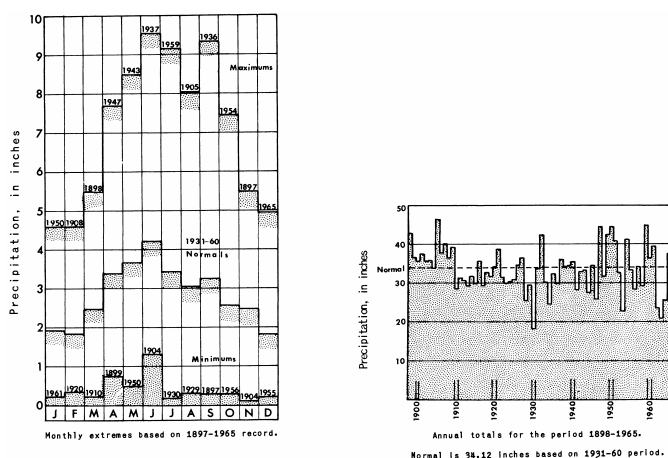


Figure 5. Variations in precipitation at Coldwater.

Figure 5. Variations in precipitation at Coldwater.

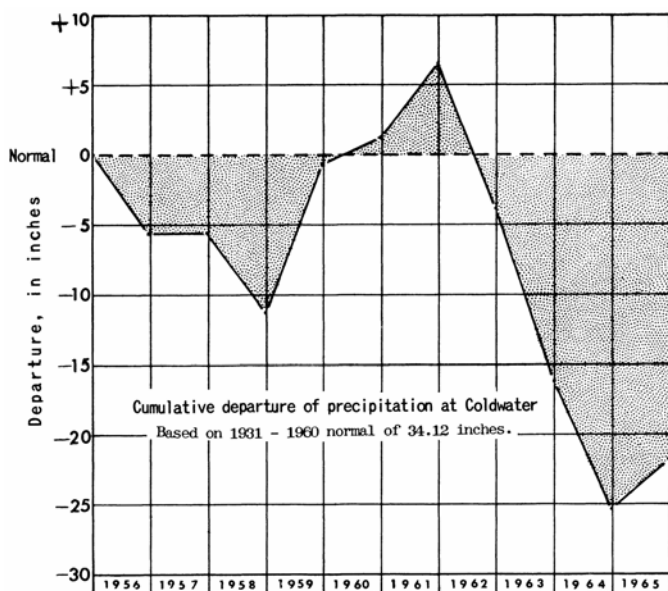


Figure 6. Departures of precipitation from normal.

A line sloping upwards indicates above-normal precipitation, while a line sloping downwards indicates below-normal conditions.

Figure 6. Departures of precipitation from normal.

Ground-water levels in the county respond not only to varying amounts of precipitation but also to the effects of the seasonal changes in weather. Levels in wells are highest in the spring when water from both snowmelt

and precipitation percolate to the ground-water reservoir. Precipitation is heaviest during the growing seasons (about 62 per cent of the annual total falls during the six months from April through September), but most of the water is transpired by vegetation, evaporates, or is absorbed in the soil zone -- thus, little water is added to the ground-water reservoir and the levels decline. After the growing season, precipitation again finds its way to the water table until the frozen ground in winter impedes its percolation. Frequent thaws during the winter months, however, usually accompanied by rain and snowmelt, can make important contributions to the water table. For example, sharp rises in ground-water levels (figs. 13-15) resulted from record-breaking rains in December 1965.

The movement of large air masses over Michigan plays an important role in the quantity of water received from precipitation and thus, indirectly, affects the water regimen. The prevailing westerly winds, cooled in the summer and warmed in the winter as they cross Lake Michigan, are often moisture laden and produce precipitation. However, warm winds from the south, which travel overland for long distances, tend to be drier and result in increased evaporation.

Geologic Considerations



The disposition or route that water from precipitation follows in the hydrologic cycle is influenced by geologic characteristics. By studying the surficial geology of the county the relationships and availability of water to wells and streams are better understood (Plate 1, in pocket). Sandy or gravelly earth materials allow water to seep readily into the ground; whereas heavy clays cause water to run off rapidly. Thus, wells in sandy, gravelly areas produce more water than those in less permeable clayey areas. In sandy areas flooding generally is not a problem and the base flow of streams is well maintained, while in clay areas flooding is more frequent, base flows are lower and drains may completely "dry up" in dry periods of the year.

Origin of the Glacial Drift

The configurations of the land surface in the county -- its rolling till plains, moraines, outwash areas, valleys, lakes, and streams -- all owe their origin to the glaciers that covered the county. Michigan was alternately covered and uncovered at least four times during the glacial (Pleistocene) epoch which began a million years ago. Each advance of the great ice sheets buried or destroyed most of the land forms sculptured by the preceding stages, so that much of the present landscape is due to the last advance of ice, the Wisconsin Glaciation, that began some 65,000 years ago. The front of this great ice sheet, which advanced unevenly, split into several separate tongues or lobes. Two of these ice lobes sculptured the land surface of Branch County -- the Saginaw lobe advancing and retreating

from the northeast, and the Erie lobe from the southeast (fig. 7).

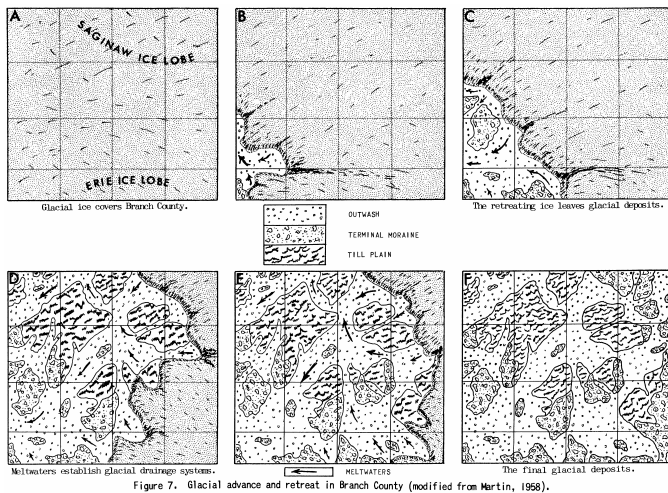


Figure 7. Glacial advance and retreat in Branch County (modified from Martin, 1958).

Figure 7. Glacial advance and retreat in Branch County (modified from Martin, 1958).

How Glacial Materials Were Deposited

The effects on the landscape during glaciation and the resulting forms left after the retreat of the ice are idealized in figure 8.

Terminal Moraines

The ice eroded the land over which it moved, picking up, scraping, and plucking the bedrock to make up its load of clay, silt, sand, and rock fragments. This load was moved forward along the bottom of the ice and some was pushed to the front of the advancing tongues. When the rate of melting of the ice front was approximately equal to the rate of ice advance, terminal moraines were formed at the ice front. In Branch County the moraines are long hills that trend north to northwesterly throughout most of the county except in the southern part where they trend north to northeasterly. Because the materials in these moraines were dumped from the melting ice with little or no sorting, they are generally a random mixture of clay, silt, sand, and rock fragments called "till".

Outwash

The waters issuing from the melting front of the glacier carried a suspended load of clay, silt, sand, and gravel. The coarse materials -- the sands and gravels -- were generally deposited near the front of the ice and the finer materials -- the silts and clays -- were carried further out. These water-sorted materials are generally stratified or layered and consist of beds and lenses of sand, gravel, silt, and some clay. Because they were "washed out" from the ice front they are called outwash deposits and often appear as generally flat plains that are interrupted here and there by numerous depressions, some containing lakes of small to moderate size.

Lake Beds

Almost all lakes in the county are located in the outwash plain deposits. Most of the lakes were laid out with their length trending in a south and southwesterly direction in line with the direction of predominant glacial movement. Meltwaters deposited water-sorted sediments, chiefly sand and silt, in these lakes. Temporary blocking of glacial meltwater drainageways caused ponding and left lake beds composed of muck, silt, and other fine materials. These lake beds usually occupy small areas that are quite level.

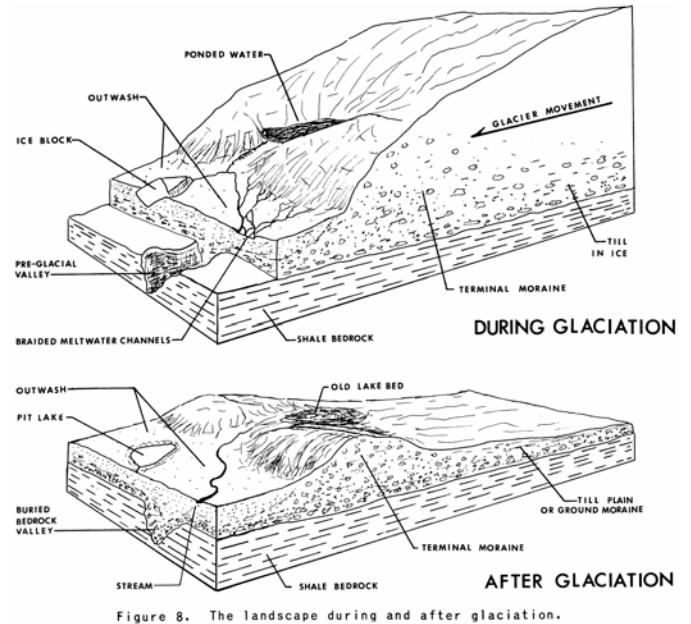


Figure 8. The landscape during and after glaciation.

Till Plains and Drumlins

With the wasting of the glacial ice, the material carried within and on the ice was dropped or deposited in a mixture with little or no sorting to form till plains or ground moraines. In Branch County these plains are characterized by gently-rolling topography. The materials in the till plains are much like those in terminal moraines. Some till plains, as in the northern part of the county, are marked by long streamlined hills or drumlins that have their long dimension parallel to the direction of ice movement; these were sculptured out of the till by the moving ice.

Types of Glacial Deposits

Because two lobes of the ice sheet, the Erie and the Saginaw, covered Branch County (fig. 7), the composition of the materials deposited from the ice and the associated meltwater differs. The materials from the Erie lobe, which are mostly in the southern part of the county, consist of limestone and other sedimentary rock fragments; those from the Saginaw lobe, which are in the northern part of the county, are mainly from granites and other harder rocks. The difference in the composition of the materials has resulted in differences in the dissolved minerals in water from these two areas

as explained in the section of this report entitled "Quality of Water".

The surface soils are generally well related to the underlying glacial materials, with well-drained sandy soils overlying the outwash deposits and silty clayey soils overlying the till and shallow subcrops of the Coldwater Shale.

The Bedrock

The Coldwater Shale immediately underlies the glacial deposits.

Composition

These shales, which are predominantly blue to gray, were formed in shallow marine seas that covered Michigan during the Mississippian Period of geologic time about 250 million years ago. Interspersed with the shale are thin limestone, dolomite, and sandstone lenses which reflect local changes in currents, sediments, and shoreline features at the time of deposition. Thin beds of siltstones and fossiliferous iron-carbonate concretions are notable near the top of the Coldwater Shale, and cuttings of these materials may be mistaken for sandstone beds by some well drillers. The surface of the shale is generally soft due to the weathering that occurred before its burial under the glacial drift and it is often difficult to distinguish it from clays in the till.

Altitude

The altitude of the shale surface varies from 600 feet above mean sea level, in a deep valley in Kinderhook Township, to 1,050 in the southeast part of the county (fig. 9).

The Coldwater Shale is near land surface in many areas. The depth to bedrock averages from 50 feet in the northeast to over 250 feet in the southern part of the county. Several deep preglacial stream valleys were cut into the shale surface and were later filled with thick deposits of glacial drift.

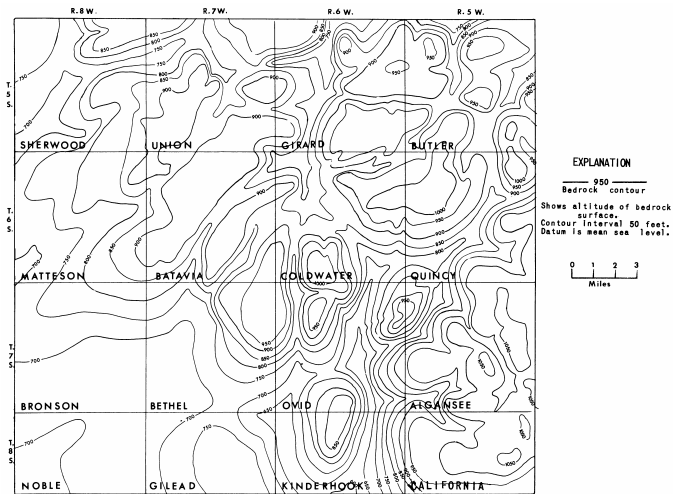
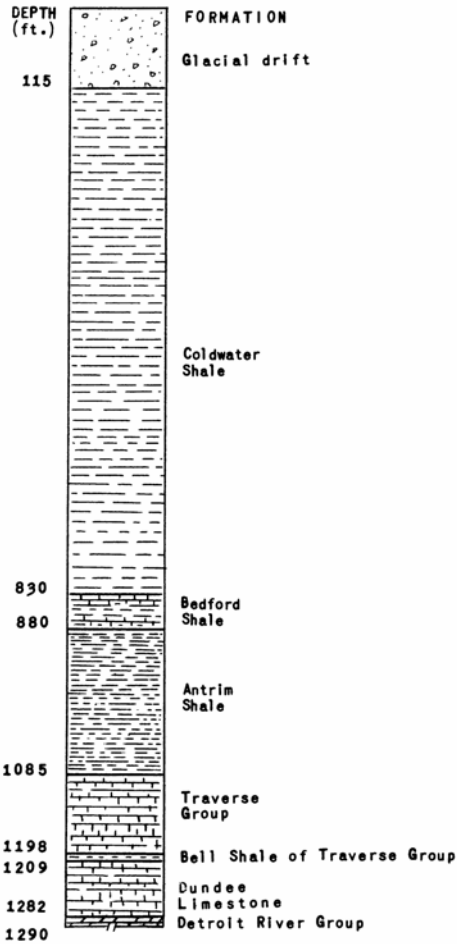


Figure 9. Altitude of the bedrock surface. Bedrock valleys are filled with thick glacial deposits which are potentially large sources of ground water.

Figure 9. Altitude of the bedrock surface.

Thickness

The thickness of the Coldwater Shale, as determined from oil well logs, varies from 440 to 1,000 feet. Underlying the Coldwater are at least 4,000 feet of other Paleozoic sediments, as illustrated in the generalized log of the Bromo-Hygiea mineral water well in Coldwater (see cut). Water from any productive zone below the Coldwater is generally so highly mineralized as to preclude any practical industrial or domestic use.



Generalized log of Bromo-Hygiea mineral water well at Coldwater

Ground Water



Now that we know the nature of the climate and the geologic materials in the county and how these factors can affect the occurrence and availability of water, let's examine ground water -- what it is and how it occurs, its location, quantity, availability to wells, and how it is interrelated with streams, lakes, and swamps.

What is Ground Water and How Does It Occur?

Ground water is the water that completely fills the spaces between the grains of sand, gravel, and other materials in the glacial drift and fills the cracks, crevices, and fractures in the Coldwater Shale below the drift. The top surface of the water, below which all materials in the ground are completely saturated, is the water table. The water table appears at the land surface in streams, lakes, and swamps.

A bed of saturated material that will yield water in usable quantities to wells is called an aquifer. The surface to which water in an aquifer will rise in a well is called the piezometric surface. This surface can be either that of the water table, where water is unconfined and does not rise above the point where it was found, or that of an artesian (piezometric) surface where water is confined under pressure and rises above the point where it was struck. An artesian surface results when water enters the ground at an elevation that is higher than that of the level where it is being obtained and is then confined under pressure by relatively impervious strata such as clay layers. In places where the difference in pressure is great enough, the water will flow above the land surface if the impermeable stratum is penetrated by a well.

In figure 10, water from precipitation enters the ground at "A" and "B" and becomes part of the ground water reservoir. As the water from "A" flows downhill it becomes trapped below relatively impermeable clays and silts. The imaginary surface to which the water would rise if it were not confined, the piezometric surface, is shown by the dashed line. At "C" a well is drilled through the confining clays and the water flows out of the well above the land surface as the result of the pressure of the trapped water. A well drilled below the clay between points "A" and "C" would not flow, as the land elevation at this point is too high and the water in the well would only rise to the dashed line or piezometric surface. At "D" the stream is receiving water from the aquifer but a pumped well "E" is drawing down water in a cone-shaped manner so that part of the stream flow is contributing to the well. The bedrock valley tapped by well "E" is full of saturated, very permeable materials; thus, this well can produce large quantities of water. An example of this condition is the Coldwater municipal well field.

The dug well "F" is tapping a water table of limited extent and depth which is perched on the clay layers. In drought periods, or when heavily pumped, such a well may go dry. Well "G" is cased through the drift and thus receives most of its water from bedrock aquifers. Water in the sandstone or limestone lenses has entered at some distant point (not shown) so that the piezometric surface is different than the upper piezometric surface of the water in the drift. If a well were drilled into the shale at point "C", it probably would be a "dry" hole as the sandstone and limestone lenses are absent at this point and the tight shale will yield little water to wells. Even if a well at this point should fill with water seeping slowly from the tight shale, it would probably go "dry" upon

pumping due to the slow rate of replenishment. Of course, a well tapping the bedrock would be drilled only if the glacial drift were thin and did not produce sufficient water.

At the left edge of the perched water table section is an example of a spring issuing above the clay. During dry periods the water table would be low and the spring would stop flowing.

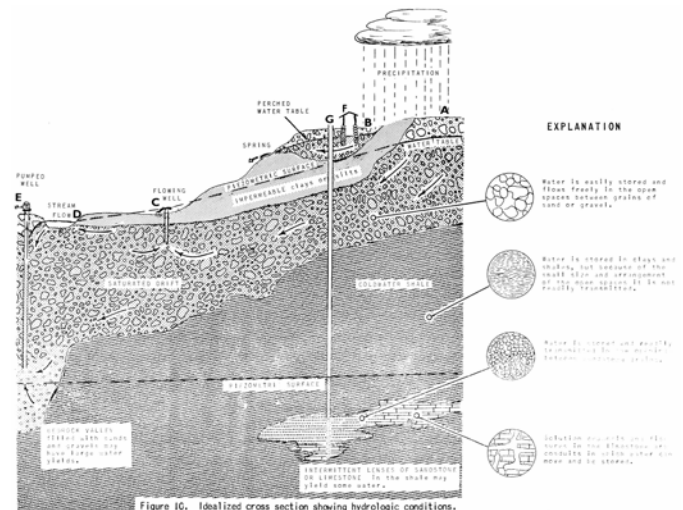


Figure 10. Idealized cross section showing hydrologic conditions.

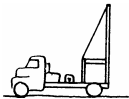
Where Can Ground Water Be Found?

Ground water can be found almost everywhere in the county. Most of the water available to wells occurs in the sands and gravels of the glacial drift. The thickness of the drift ranges from a few feet to as much as 400 feet (fig. 11), a fact which has a significant bearing on the water-producing capabilities of the glacial deposits. Generally, the thicker the drift the greater the possible number of sand and gravel beds and the more chance there is of locating a water-bearing bed. As an example, the thick deposit of glacial drift in the buried valley that underlies the city of Coldwater yields large quantities of water. Other buried valleys, if filled with materials similar to those at Coldwater, also may yield large supplies. In places where the drift cover is thin or where thick beds of clay are encountered, ground water is difficult or impossible to obtain from the drift in usable quantities. In these areas many wells are drilled into the Coldwater Shale, but yields are usually small and the water may be "salty". Ordinarily, shale is a "tight" aquifer which may be water saturated but too impermeable to yield the water locked within it. Successful wells finished in the Coldwater probably tap more permeable lenses of sandstone, limestone, or fractured shale zones.

The geologic formations and their value as a source of water are given in Table 1. The outwash deposits are the best aquifers in Branch County and often will yield large quantities of water. Moraines and till contain some water, but the yield to wells usually is small. Lake beds are a poor source of ground water but if outwash lies

below the lake beds, good quantities may be obtained by wells penetrating into this buried outwash. The Coldwater Shale underlying the glacial drift also is generally a poor source of water -- yielding only 2-3 gpm to wells in many instances, but it has been reported to yield as much as 10-30 gpm.

Logs of Wells



Since the materials that underlie the land surface cannot be seen, drillers logs of wells are used to locate the water-bearing beds and to determine their depth and thickness. The selected logs in table 2 (in appendix) show that beds of sand or gravel are encountered in many wells, but that their areal extent, depth, and thickness vary greatly. However, because these logs give the general character of the glacial materials in a given area, they may be very helpful when planning a well near one that is logged. It should not be expected that the new well will encounter exactly the same materials as the logged well, even if the two wells are only a few hundred feet apart. To obtain supplementary information on the geology and ground water in the county, some 40 holes were augered (see cut) as a part of the present study. Logs of some of these wells are included in table 2.

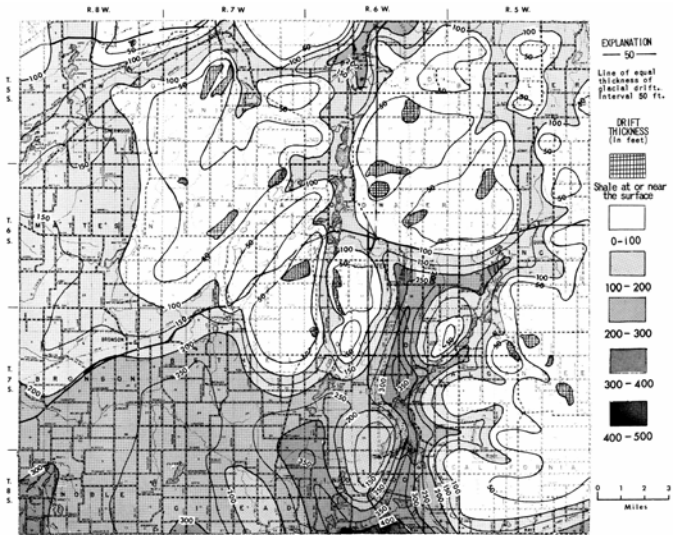


Figure 11. Thickness of the glacial drift.

How Much Ground Water is Available?

The amount of ground water stored in the first 25 feet of glacial drift below the water table is estimated to be equal to 5 feet of water over the entire county or roughly 530 billion gallons -- more than 15 million gallons for each resident in the county. Of course, it is not possible to recover all this water. Furthermore, if we were to use all the natural recharge, we would dry up all the streams and swamps, and lower the level of all the lakes.

Assuming a per capita consumption of 300 gpd, which would include all industrial, domestic, and agricultural use, it is estimated that the use of ground water in the county would be 4 billion gallons per year. On this basis alone, our ground water would last for more than 100 years. However, when we consider that each year another 88 billion gallons of water from precipitation reaches the ground-water reservoir, we can see that our total supply is practically unlimited although locally supplies may be limited or even inadequate because of geologic conditions.

SYSTEM SERIES	FORMATION Thickness (feet)	LITHOLOGY	HYDROLOGY
PLEISTOCENE	GLACIAL DRIFT 0 to 500	TERMINAL MORAIN DEPOSITS: Composed of glacial till; a heterogeneous mass of boulders, gravel, and sand embedded in a matrix of clay and silt. Locally lenses of permeable outwash are interbedded within the till.	Generally a poor source of water, but local outwash deposits within moraines will yield moderate quantities of water, 10-40 gpm.
		TILL PLAIN DEPOSITS: Deposits similar in lithology to morainal till, but contain more clay and generally void of permeable lenses.	Generally a poor source of water, 0-15 gpm.
		OUTWASH DEPOSITS: Channel and deltaic deposits of well-sorted sand and gravel and some finer sediments.	Permeability moderate to high. Major source of ground water in the county. Yields up to 5,000 gpm.
		LAKE BEDS AND SHAPE DEPOSITS: Deposits of fine sand, clay, silt, or muck.	Generally of low permeability. Locally a source of small supplies of water. May yield moderate supplies where water can infiltrate from surface streams.
MISSISSIPPIAN	COLDWATER SHALE 500 to 1,100	Blue-gray to green shale with thin lenses of sandstone, siltstone, limestone, or dolomite.	Generally a poor source of water, but locally may give 10-30 gpm. Water in the formation is often too highly mineralized for most uses. Where the glacial drift cover is thin it may be the only source of water.

Table 1.--Lithology and hydrology of the geologic units underlying Branch County.



Drilling for geologic information.

The availability of water map (Plate 2, in pocket) shows the general availability of water in all parts of the county. In using this map it must be remembered that "generally" does not mean "invariably". It is characteristic of the glacial formations that they can vary greatly over short distances in their ability to yield water to wells. This is especially true of the moraine and till plain areas and of the Coldwater Shale which may vary locally in yield from a dry hole to over 20 gallons a minute. The availability map tells whether the chances of obtaining an adequate water supply are favorable or unfavorable.

Records of selected wells, which also can serve as a guide to the availability of water, are given in table 3 in

the appendix. This table summarizes data on the hundreds of wells collected in the field and from drillers' records.

For Municipal Supplies

One of the most productive well fields in Michigan is the municipal well field located in the southeast part of the city of Coldwater. Here four wells tap coarse gravel and sand in a buried channel aquifer to depths of about 132 feet. These wells yield large amounts of water -- for example, one well was reportedly test pumped at a rate of 5,000 gpm for 35 hours with a drawdown of only about 21 feet. With present pumps these four wells pumped together could probably yield 7,700 gpm or a hypothetical production of 11 million gallons per day, or 4 billion gallons per year.

Several other areas in Branch County have good producing wells in the glacial aquifers. The three municipal wells in the city of Bronson together produce about 2,200 gpm; the two in Quincy 1,000 gpm; the two in Union City 1,000 gpm; and the three at the Coldwater State Home 750 gpm.

Municipal wells at Coldwater and Union City are near perennial streams, and drawdowns of water level in these wells are much less than where wells are located far from streams. Pumpage from these wells reduces the ground-water discharge to streams or, in the case of Coldwater, induces flow from the stream to the wells. Measurements made upstream and just downstream from the Coldwater field showed a net loss of about 0.6 cubic feet per second on July 29, 1964. At Union City static water levels are near the surface at the Athletic Field well (No. 2) near the river and production per foot of drawdown is about twice that of the Railroad Street well which is further away from the river.

Pumpage of ground water at Coldwater at present is equivalent to about 4.3 cubic feet per second of streamflow on the average. This is more water than some base flows of the Sauk River and is roughly 20 per cent of the low flow figures at the Hodunk Station on the Coldwater River. Much of the water, however, is returned to the stream below the water works by the sewage plant and in addition some 1 mgd is returned to South Lake by means of an intermittent stream or ditch by one large industry.

Complete descriptions of municipal and institutional well fields are contained in the appendix to this report.

For Domestic and Stock Supplies

Although most areas of the county can furnish adequate supplies there are many problem areas where "dry" holes are encountered or where wells will only produce a few gallons a minute because of the slow infiltration of water into the well. Such wells will virtually dry up after several hours of pumping. This is particularly true of areas where the Coldwater Shale is near the surface. Some wells drilled in the shale will produce good quantities of water from cracks and fissures or layers of sandstone, but many will produce hardly any water.

In the subdivided area just west of Coldwater in the north half of section 19 south of Highway M-86 the glacial drift cover is about 30 to 50 feet thick. Here, ground-water levels were low and wells were rapidly depleted by continuous pumping during the drought period. When water levels rose following the drought, considerably more water was available, but this problem will undoubtedly recur during dry years. Zoning of areas to permit subdivisions only where ample water is available, or piping of water by municipal or township systems are possible solutions to problems such as this.

In isolated areas, properly constructed dug wells would allow for more storage and prevent rapid depletion from small-diameter wells when pumping occurs. Drilling into the underlying shale may provide adequate water for domestic or farm supply if the shale is fractured or has sandstone layers, but this generally is risky and may be expensive. Also, the water struck may be too "salty" for most uses.

By consulting the availability map (Plate 2, in pocket) and examining the record of wells in table 3 some idea of what to expect in a specific area can be obtained.

For Irrigation Supplies

The possibility of large ground-water supplies for irrigation by wells has not been fully explored in Branch County. Only a few small ground-water systems have been installed, and several of these are no longer used. Most of the water for this use is from surface sources such as streams, lakes, ditches, and ponds.

The buried bedrock valleys (figs. 9 and 11) offer the best chance of locating large supplies for irrigation purposes where such valleys are available at the sites desired. Elsewhere, the drift is not generally thick enough to promise large supplies although moderate supplies in outwash areas could be obtained.

For Industrial Supplies

Although most of the water used by industry at present is from municipal supplies (see section of this report entitled "Water Use") there are possibilities of obtaining large supplies of ground water in areas where buried bedrock valleys are present. Here, as with large irrigation supplies, test drilling would be needed to determine the potentials of these areas. As very few deep, large-diameter wells have been drilled in the outwash outside of urban areas, test holes in this material may also uncover large quantities of ground water.

Are Ground-Water Levels Falling?

About 40 observation wells were used to measure ground-water levels during this study. In the fall of 1964 water levels, in most wells in Michigan, were at or near record low stages as the result of accumulated deficiencies of precipitation. This was also true in Branch County and many shallow wells had to be deepened or pump settings lowered in others. However,

above-average precipitation in the winter and early spring of 1964-65 resulted in sharp rises of water levels (figs. 12-13). Levels subsequently declined during the growing season until August when twice the normal amount (more than six inches) of rain fell. Although summer rains do not usually benefit the water table, these heavy rains were in excess of the normal evapotranspiration losses and blunted or reversed the declining trend in most of the observation wells. The general rise was steepened by a record December 1965 rainfall of nearly five inches (as against a normal of 1.82 inches). Although the January - March, 1966 period had below average precipitation and levels fell somewhat, a larger benefit was obtained from the precipitation because of the already saturated condition of the ground from the December rains.

The hydrographs in figures 12 and 13 show that the ground-water levels have recovered considerably since the fall of 1964 and that an overall upward trend has occurred. However, precipitation variations do not occur in regular cycles and water levels may again suffer from drought periods in future years.

Three observation wells in the Coldwater area were equipped with continuous recording gages. Four recorder charts from these three gages are shown in figure 14. The two charts in the upper part of the figure show the general seasonal decline of water levels, and the recoveries from decreased area pumpage on week-ends. The small vertical fluctuations of well 21-1 are the results of compressional loading on the aquifer by passing trains. The two lower charts are from a well located at the city of Coldwater's well field. Here, the water levels fluctuate sharply from the effects of heavy pumping by three wells varying from 10 to 500 feet in distance from the observation well. It is interesting to note the effects of pumping by one or combinations of the three municipal wells and also the difference in the average water levels in the observation well in the winter and summer seasons. On the left-hand lower chart point "A" is the static level when all pumps are off; point "B" the effects of pumping of the most distant well; point "C" the combination of two wells; and point "D" pumping effects from the well 10 feet from the observation well. The pattern of "C" and "D" on the summer chart is less distinct and is not labeled. Week-end decreases in pumpage are more evident in the winter than in the summer because of the increased summer week-end use. In 1964 the three municipal wells were being pumped at rates of 1,200 to 2,250 gallons per minute.

No serious decline of water levels has occurred in areas of municipal and industrial pumping. The long-term hydrograph of ground-water levels at the Coldwater well field do not indicate any large decline of water levels (fig. 15), despite deficient precipitation and an increase in annual pumpage of from 610 to 990 million gallons from 1962 to 1965. At Bronson, water levels in the vicinity of wells No. 3 and 4 are still about as high as when the wells were installed.

Water levels have been relatively unaffected by irrigation although much of the use of water for this purpose is consumptive, as most is lost through evapotranspiration. However, for most irrigation, the frequency of use is low and in some cases the water is used mostly for frost protection in the spring, as in orchards and for strawberries.

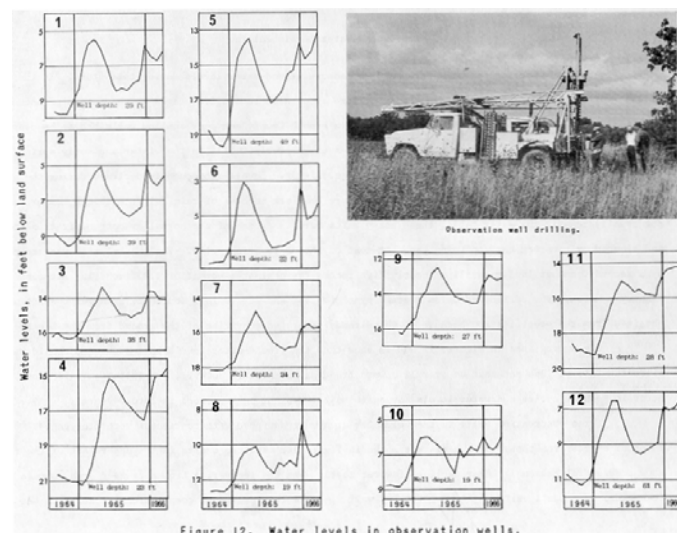


Figure 12. Water levels in observation wells.

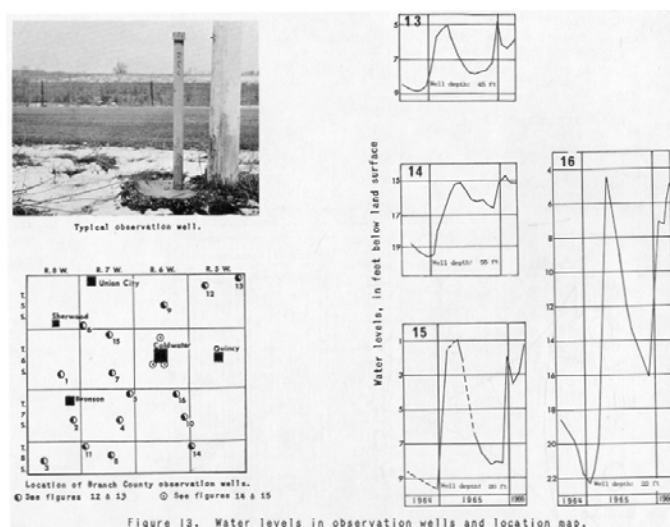


Figure 13. Water levels in observation wells and location map.

If and when large irrigation ground-water systems are used, the lowering of the water table could be minimized or eliminated by intercepting ground-water discharge to streams, or by increasing the ground-water recharge by use of surface water impoundments. This may be impractical or too costly if the areas to be irrigated are too far from streams.

If the areas to be irrigated are near swamps, large use of ground water would tend to dry up the swamps by intercepting the water discharging to them. The use of the swampland would be lost as wildlife habitat. The decision as to which is more important -- the irrigation or the wildlife habitat -- would then have to be made.

systems has been tested and proved by the city of Kalamazoo. Figure 16, taken from a report on the Kalamazoo area (Deutsch and others, 1960), illustrates one of the several recharge systems used by the city. Here, despite pumpage of billions of gallons annually, no significant decline of ground-water levels has occurred.

Another method of increasing ground-water recharge is by direct recharge into the aquifer, through return wells, of river water that has been filtered and chlorinated. The water is recharged during the winter and spring when the water is cold and relatively abundant in the streams. The advantage of the uniform temperature of ground water is thus retained. This method, however, is usually more expensive than recharging by natural infiltration from ponds.

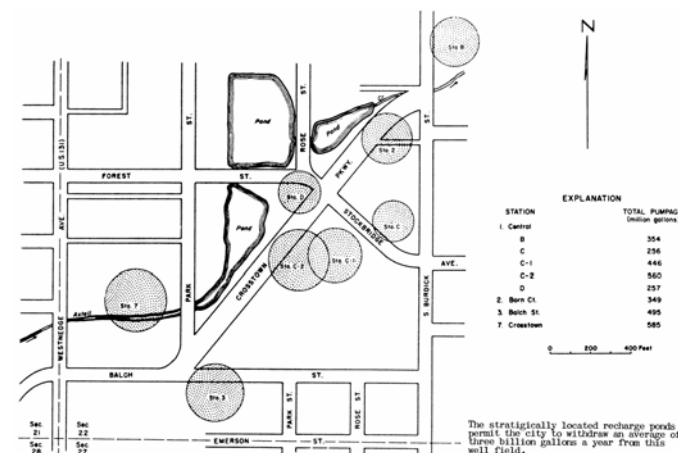


Figure 16. Recharge ponds, distribution and magnitude of municipal groundwater pumpage in the Axtell Creek area, Kalamazoo, Mich., 1957 (after Deutsch, Morris, 1960).

Figure 16. Recharge ponds, distribution and magnitude of municipal groundwater pumpage in the Axtell Creek area, Kalamazoo, Mich., 1957 (after Deutsch, Morris, 1960).

Streams

Quantity of Water Available

The major streams of the county can furnish large quantities of water. Large withdrawals of water, however, tend to diminish the waste-assimilating capacity of the streams. As population and industry increase, both water withdrawals and waste treatment needs will increase.

Major Streams and Their Drainage Areas

Except for a few square miles in the southeast corner, all of Branch County ultimately drains to the St. Joseph River which passes through the northwest corner of the county. The major tributary to the St. Joseph River in Branch County is the Coldwater River and its tributaries which drain 300 square miles, or about 60 per cent of the county. Prairie River, Swan Creek, and Little Swan Creek drain the southwestern part of the area. Almost all of the major lakes in the county are part of some stream system (fig. 2). Drainage areas of segments of

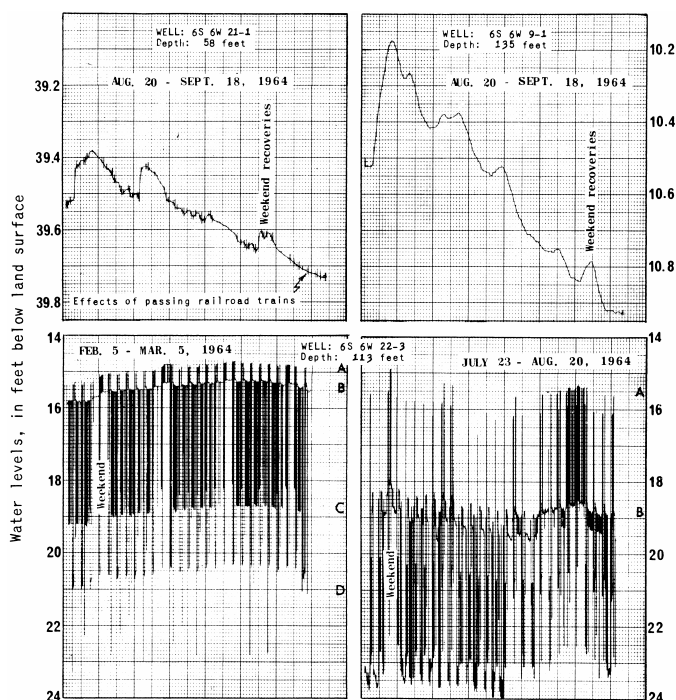


Figure 14. Recorder charts showing fluctuations of water levels in three wells in the Coldwater area. (Charts about 1/3 actual size.)

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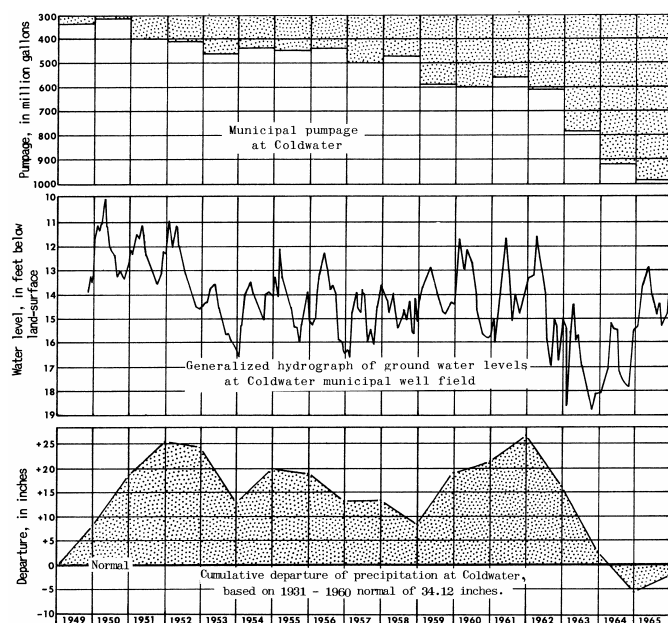


Figure 15. Pumpage, ground-water levels, and precipitation, at Coldwater.

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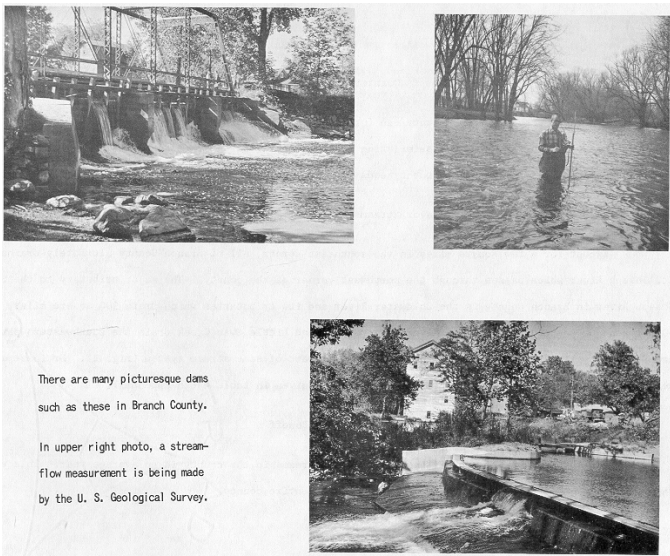
Increasing the Ground-Water Recharge

Ground-water recharge can be increased in some areas by constructing recharge channels and recharge ponds to intercept and divert surface water to ground-water storage. Where permeable outwash occurs in the county and a stream is available this practice would be a means of increasing recharge. The efficiency of such

the major streams and their tributaries are given in table 4 (in appendix).

Annual Runoff

An estimated 89 billion gallons runs off in streams in the county in an average year. This volume represents a depth of about 10 inches of water over the entire county.



There are many picturesque dams such as these in Branch County.

In upper right photo, a stream-flow measurement is being made by the U. S. Geological Survey.

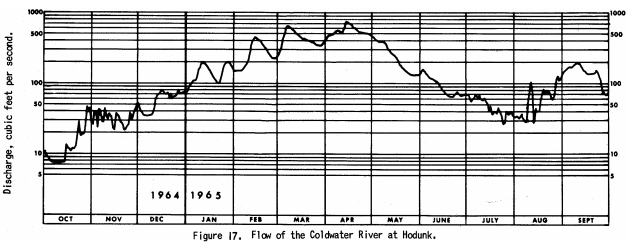


Figure 17. Flow of the Coldwater River at Hodunk.

Streamflow Characteristics

Seasonal variations in streamflow are closely related to climate. Thus, streamflows have similar flow patterns over relatively large areas. For example, throughout the entire southern part of Michigan, streamflow is usually lowest during late summer or early fall when evapotranspiration is high, and flow is highest in the spring during and immediately following the spring break-up when the snow melts and rain falls on frozen soil. Some local variations occur, especially during the summer months, when intense thunderstorms in limited areas cause high streamflows. The flow of the Coldwater River at Hodunk (fig. 17) illustrates the yearly cycle of streamflow typical of streams in Branch County.

Figure 17 also illustrates another characteristic of streamflow -- its wide variability above and below the average flow. Flood stages and discharges are primary considerations in the design of highways, bridges, and

dams; low flows govern the use of a stream for water supply or waste disposal. Consequently, this report is concerned primarily with extremes of flow.

The many lakes and ponds in the county moderate the severity of floods and droughts. Comparisons of figure 17 with hydrographs of streams draining areas of relatively few lakes and ponds show that the Coldwater River is less “flashy”, (sudden rises and falls), has higher September and lower October flows. These latter two differences often are due to operation of upstream dams.

Streamflow represents the integrated effects of many factors. Not only climate, but such physical variables as geology, vegetation, and land use also affect the rate and volume of streamflow. Relatively impermeable clayey deposits in Branch County such as moraines, till plains, and bedrock, yield high flows to streams during periods of heavy rains or snowmelt but yield low flows during dry periods. On the other hand, permeable sand and gravel deposits, such as outwash, yield lower flood flows but higher base flows. Because of the differences in geologic conditions in the county over relatively short distances and the severity of the drought experienced during this period of study, base-flow measurements failed to show a clear correlation between geology and streamflow.

Floods

A knowledge of the magnitude and frequency of floods is essential to the design of such structures as dams, culverts, bridges, water-supply intakes, and highway embankments. Such knowledge enables designers to balance the cost of larger structures against expected reduction in damages. Although floods are not a major problem in the county, they do occur.

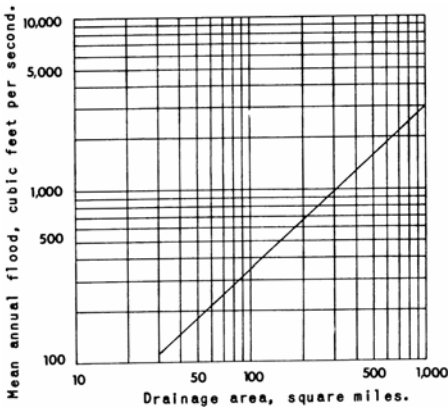


Figure 18. Variation of mean annual flood with drainage area (after Wiitala, S.W., 1965).

Figure 18. Variation of mean annual flood with drainage area (after Wiitala, S.W., 1965).

Estimates of flood frequencies involve the use of two curves -- one denoting the relation between size of drainage area and magnitude of the mean annual flood, and the second showing the relation between recurrence interval and the ratio to the mean annual flood. These

relationships as they apply to Branch County were abstracted from a report on the magnitude and frequency of floods in the St. Lawrence River basin (Wiitala, 1965), and are illustrated in figures 18 and 19, respectively. The curves are based on a regionalized analysis of flood data for many gaged streams in southern Michigan. Thus, even though flood data are lacking in the county, the relationships expressed in the curves afford a means of making flood frequency estimates.

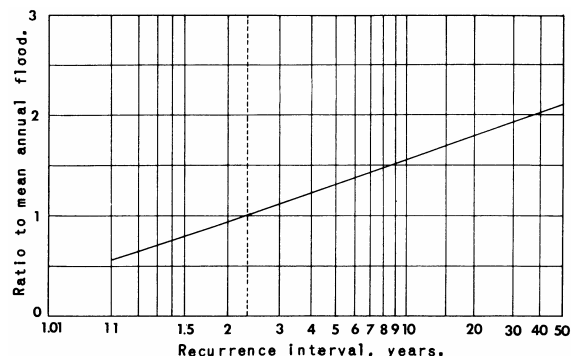


Figure 19. Frequency of annual floods (after Wiitala, S.W., 1965).

The intersection of the vertical dashed line and the number 1 ratio line shows that the mean annual (or index) flood is expected to occur about every 2 1/3 years. From the graph, then, a flood of twice this index flood can be expected about every 30 years.

Figure 19. Frequency of annual floods (after Wiitala, S.W., 1965).

To determine the magnitude of a flood of given frequency, the following procedure is suggested:

1. Determine the drainage area in square miles above the selected site (see table 4 in appendix).
2. Determine the mean annual flood for the site from figure 18.
3. Determine the ratio to mean annual flood for the flood of the selected recurrence interval from figure 19.
4. Multiply the ratio to mean annual flood (step 3) by the mean annual flood (step 2) to obtain the desired flood magnitude.

As an example, assume that the magnitude of the 30-year flood for Hog Creek at Bidwell Road is desired. The drainage area at the site is 74.7 square miles (table 4). The mean annual flood, from figure 18, is 260 cfs (cubic feet per second). The ratio of the 30-year flood at the site is $260 \times 1.93 = 500$ cfs. A complete flood-frequency curve for a site can be obtained by repeating steps 3 and 4 for various recurrence intervals.

When will floods of a given size occur? The recurrence interval of floods, in these examples, is the average interval of time, in years, during which a given flood is equaled or exceeded once. No periodicity is implied. For example, the 30-year flood will not be equaled or exceeded at exactly 30-year intervals, but chances are that four floods of equal or greater magnitude will occur in 120 years. In other words, there is one chance in 30 that a flood of equal or greater magnitude will occur in any one year.

The curves in figures 18 and 19 do not apply to streams that are materially affected by man-made regulations or diversions. Neither do they apply to Coldwater River drainage above the mouth of Sauk River since the Marble-Coldwater chain of lakes drains from each end of the chain rendering drainage areas indeterminate.

Low Flows

More than 200 streamflow measurements were made to determine the contribution of ground-water to the streams during base-flow or low-flow conditions, and to define the base-flow characteristics at eight partial-record stations. Sites were selected to provide areal coverage and to sample streams draining the various surface formations. Records of these measurements are shown in table 5 (in appendix). These measurements were made during different seasons of the year. Seepage runs, (the making of measurements at all sites within a short period of time during base-flow conditions), were made in July and October of 1964. Partial-record stations were measured quarterly. The sites at which stream measurements were made along with the identification number at each site and the lowest discharge measured are shown in figure 20. Only one station in the county has complete discharge records -- gaging station 966 on Coldwater River near Hodunk. Records for that station began in October 1962.

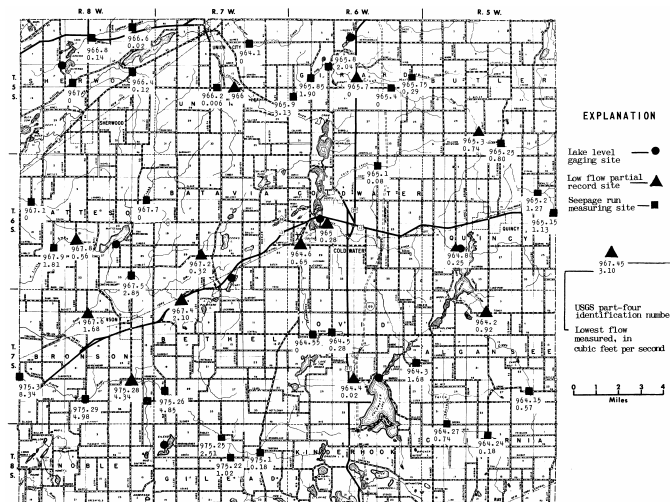


Figure 20. Stream and lake measurement sites.

Figure 20. Stream and lake measurement sites.

The contribution of ground water to streamflow during low-flow conditions is generalized in figure 21. This map is based on the seepage run of October 26-27, 1964.

Information on low flow can be presented either in the form of a flow-duration curve or as a low-flow frequency curve. The flow-duration curve shows the per cent of time during which specified discharges were equaled or exceeded in a given period. The low-flow frequency curve shows the magnitude and frequency of minimum flows for a period of given length. Flow-duration curves differ from low-flow frequency curves, in that the duration curve does not indicate whether the lowest 60 days of

record occurred consecutively in one rare drought year or as a few days in nearly every year; the frequency curve treats consecutive days as a unit.

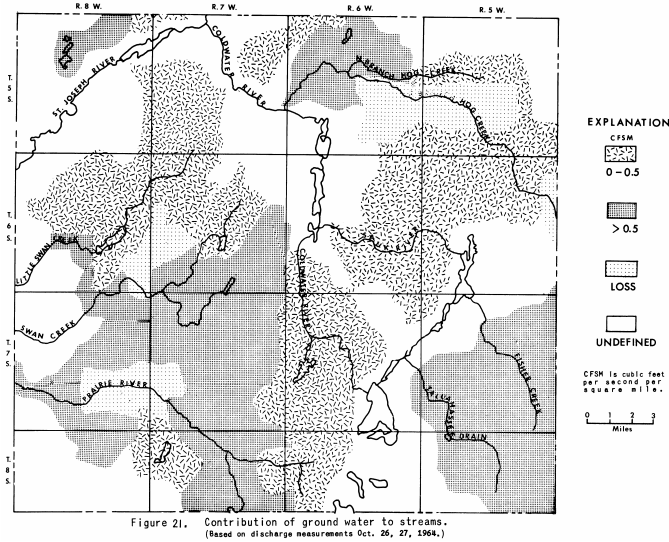


Figure 21. Contribution of ground water to streams. (Based on discharge measurements Oct. 26, 27, 1964.)

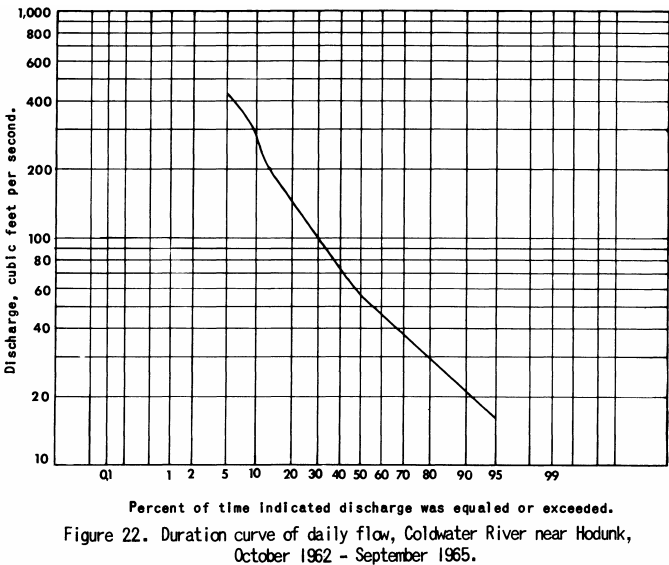


Figure 22. Duration curve of daily flow, Coldwater River near Hodunk, October 1962 - September 1965.

The flow-duration curve for station 966 for the 3 water years 1963-65 is shown on figure 22. It has not been drawn beyond the 5 per cent and 95 per cent points because of the short record. This curve shows, for example, that during the period October 1962 through September 1965, a mean daily discharge of 21 cfs was equaled or exceeded 90 per cent of the time.

Table 6 gives the 90 per cent flow-duration values and the mean annual 7-day minimums for the partial-record stations. The mean annual 7-day minimums are the lowest annual 7-day average flow which can be expected to occur, on the average, once every two years. For example, for station 964.2 on Fisher Creek, a flow of 2.2 cfs could be expected to occur as an annual

minimum 7-day average about 25 times in the next 50 years.

Station number	Drainage area (sq.mi.)	Mean annual 7-day minimums		90% flow-duration value	
		cfs	cfsm	cfs	cfsm
964.2	16.8	2.2	0.131	2.4	0.143
965.3	74.7	9.2	.123	11	.147
965.7	89.8	9.5	.106	11	.122
967.2	8.01	1.4	.175	1.6	.200
967.4	33.2	5.4	.163	6.0	.181
967.6	57.4	9.0	.157	10	.174
967.8	19.4	2.3	.119	2.7	.139
975.28	42.5	9.5	.224	10	.235

Note: Above figures are derived from correlations with long-term gaging-station records, adjusted to the period 1935-64. Expressing streamflow in cfsm (cubic feet per second per square mile) facilitates comparison. Stations 964.4, 964.5, 964.8 and 965 could not be used in this phase of the analysis.

Table 6.--Mean annual 7-day minimums and 90% flow-duration values at partial-record sites.

Use of Impoundments to Augment Low Flows

The topography and soils of the county are not generally favorable for reservoir sites. To be suitable for reservoir development a site must meet certain requirements as follows:

- 1. Damsite -- This requires a topographic constriction or bottleneck in the stream valley.
- 2. Storage area -- The valley upstream from the dam must be sufficiently wide and deep to store significant volumes of water without flooding unreasonably large areas of land and without overflowing into other drainage areas.
- 3. Catchment area -- Sufficient area must contribute flow to the stream above the damsite to ensure that the reservoir can be filled and maintained by minimum rates of runoff.
- 4. Geology -- The type and cost of a dam are dependent to some extent on the soils and the sub-surface geology at the damsite and reservoir area. The soils and glacial drift of the impoundment area must be sufficiently tight to prevent large losses of surface water to the ground.

The probably relative merit of the surface formations in Branch County for reservoir sites is as follows: till plains; lake plains and drainageways; moraine; outwash.

In addition to the physical requirements, the reservoir site must be available at reasonable cost, and its use for water storage must not inflict unreasonable damages on other present or potential values.

Lakes

"A lake is a landscape's most beautiful and expressive feature; it is earth's eye on looking into which the beholder measures the depth of his own nature"

-- Thoreau "Walden", 1854

There are more than 100 lakes in the county (fig. 2) containing an estimated 130,000 acre feet or about 42 billion gallons of water in storage. Except for a few land-locked lakes, almost all the lakes have outlets and most have inlets.

The Origin and Life Span of Lakes

Lakes are formed in glaciated areas by ice blocks or drift deposits damming glacial meltwaters, by meltwaters filling in surface depressions left in the drift behind the retreating glacier, or by the filling of pits formed in the drift by melting blocks of ice.

Many lakes in Branch County appear to be in depressions formed by the isolation of large ice blocks covered with drift and left to melt after the glacier retreated (fig. 8). These depressions range in size from relatively large, such as those containing the lakes of the Coldwater and Randall Lake chains, to small, such as that containing Round Lake (section 18, Noble Township). More detailed information on the origin of Michigan lakes, including some in Branch County, may be found in the report "Inland Lakes of Michigan" (Scott, 1920).

Much recent concern has been voiced about some of our "aging" or "dying" lakes. Actually all lakes begin to age as soon as they are formed due to a combination of several factors. The aging process may be the result of lake basins being filled by sediments brought in by surface runoff, by deposition of organic matter, or by precipitation of minerals from the water. Grass Lake in Ovid Township and Miller's Lake (Rush Pond) in Batavia Township are examples of lakes whose current "old age" is largely due to the filling by organic matter. Deposits of marl, produced by the precipitation of calcium carbonate from lake water, have partially filled other lakes. (Marl beds up to 50 feet thick were dredged from some lakes, such as Marble and South Lakes and a former lake along Swan Creek, for use in the county's once thriving cement industry.) Lake aging also may result from the lowering of a lake's water level either by drainage due to downcutting of surface outlets or by a general lowering of the ground-water reservoir throughout the surrounding area.

The ordinary life span of a lake, while short in the geologic time scale, is usually quite long in human terms. Unfortunately, the activities of man may considerably increase the rate of natural aging processes, sometimes to such an extent that a lake may appreciably degenerate within a single human generation. For example, local drainage projects may lower the ground-water table and thus the water level in

some lakes, especially those that are land-locked. Agricultural or construction activities may increase the sediment load brought into a lake basin by surface runoff. Municipal, industrial or domestic pollution of a lake may stimulate plant and algae growth, thus increasing the rate of organic fill.

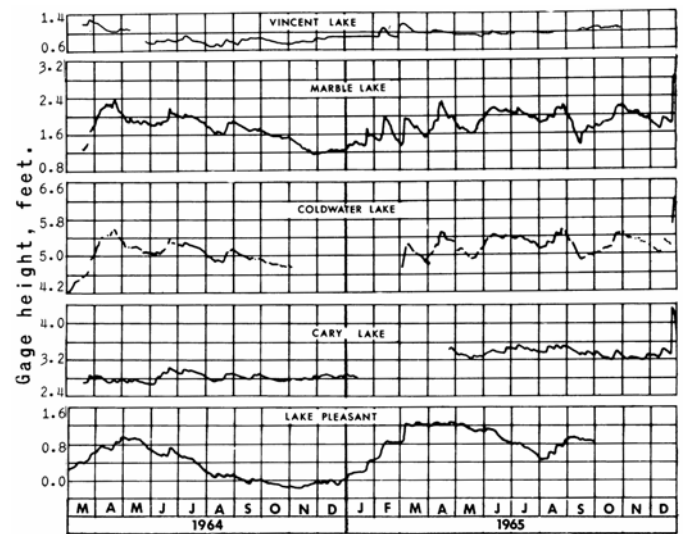


Figure 23. Water levels in lakes.
(Hydrographs based on daily staff gage readings.)

Figure 23. Water levels in lakes.



Are Lake Levels Falling?

In Michigan most lakes were at rather low stages during the latter part of 1964 because of so-called drought conditions in the 1962-64 period. Branch County's lakes were no exception (figs. 23, 24). Falling levels in inland lakes during periods of drought are inevitable. Most, if not all, the lakes in the county are at water-table levels, and stages lower as the water table declines. This decline is larger in land-locked lakes than in lakes having stream connections -- for example, Vincent Lake fluctuated only 0.6 foot, while land-locked Gilead Lake fluctuated as much as 2.5 feet (figs. 23, 24).

Gilead Lake

Because of the serious effect of low levels upon Gilead Lake's recreational and economic values (see cuts), this lake was selected for more detailed study.

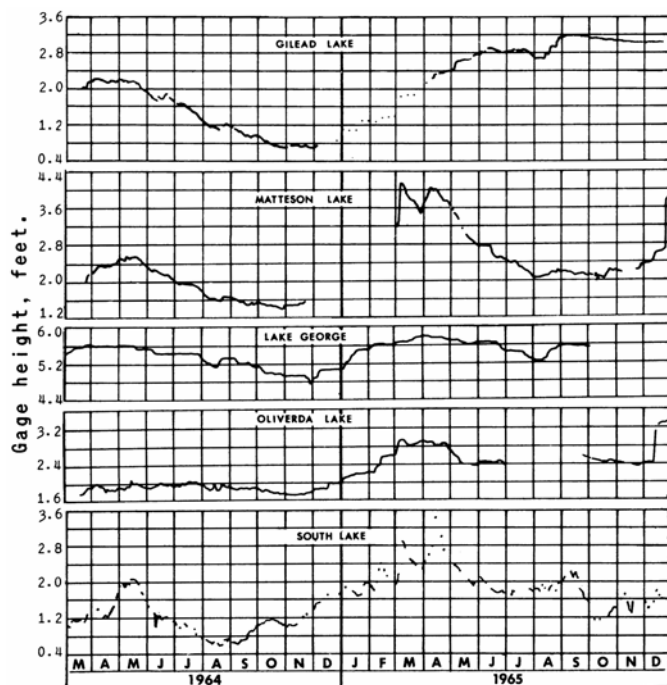


Figure 24. Water levels in lakes.
(Hydrographs based on daily staff gage readings.)

Figure 24. Water levels in lakes.



Closeup of exposed shoreline at north end of Gilead Lake, summer of 1964.



Aerial view of Gilead Lake showing exposed shorelines during low-water stages in summer of 1964.

A group of six wells were augered and three abandoned private wells located in order to observe ground-water levels. The measurements were used to determine the relationship of the lake levels to the ground-water table and the direction of ground-water movement to and from the lake.

The similarity in trends between the observation well hydrographs and that of Gilead Lake (fig. 25) indicates

that some connection exists between the lake's levels and the local ground-water table. Chemical analyses of the lake and surrounding ground waters also confirm this interrelationship.



Closeup of exposed shoreline at north end of Gilead Lake, summer of 1964.

Ground-water table contours were drawn for the time when the lake levels were the lowest of the study period; and profiles were made at both the lowest and highest lake levels observed (fig. 26). The contours show that the water table slopes to the north and northwest, with a rather steep local gradient at the north-east end of the lake. Ordinarily, ground water flows into the lake from the south and out to the northwest and northeast. At extremely low water-table levels, however, the profiles of figure 26 indicate that the lake is "semi-perched" with a slight flow from the lake to the water table. The rather impervious lake-bottom sediments apparently have the greatest sealing effect upon the connection between lake and ground waters during periods of low lake levels. During low water-table conditions the sediments serve to lessen the loss of lake water to the table. When the water table is higher than the sealing sediments the lake receives ground water from the south. If it were not for these sediments, the lake levels in the fall of 1964 would have been even lower due to lake waters recharging the ground-water table.

The important natural factors influencing the levels of Gilead Lake thus seem to be the level of the surrounding water table and precipitation effects. The effects of precipitation increase in importance as the lake falls to low levels and its ground-water connections decrease. The precipitation departure graph trends (fig. 25) closely approximate those of the lake and water table.

Possible Solutions to Low Lake Levels

This decline in land-locked lakes caused by drought generally cannot be avoided without prohibitive cost. Pumping of water from a stream into a lake is often suggested, but most of the land-locked lakes are not located near streams. Another objection is that water from streams may contain enough nutrients to change the character of the lake water. Pumping of ground-water from a deep aquifer into the lake is another

frequently suggested remedy for falling lake levels. The theory is that the deep aquifer is separated from the lake by impermeable beds, and that water pumped from this aquifer will be replaced by recharge at considerable distance from the lake. In some cases this may be practical. Unfortunately, even the clay and till in the glacial deposits are slightly permeable, and much of the water pumped from the deep aquifer may be replaced by water from the lake.

and surface water, then control of such withdrawals may be the only feasible solution.



Lake-level control

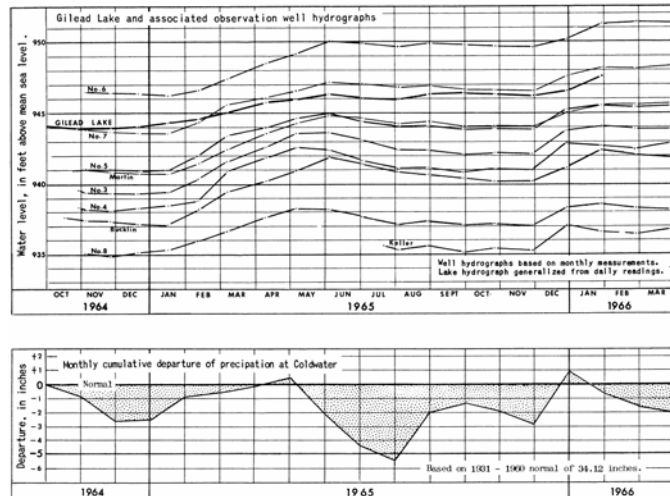


Figure 25. Water levels of Gilead Lake and observation wells, and precipitation.

Figure 25. Water levels of Gilead Lake and observation wells, and precipitation.

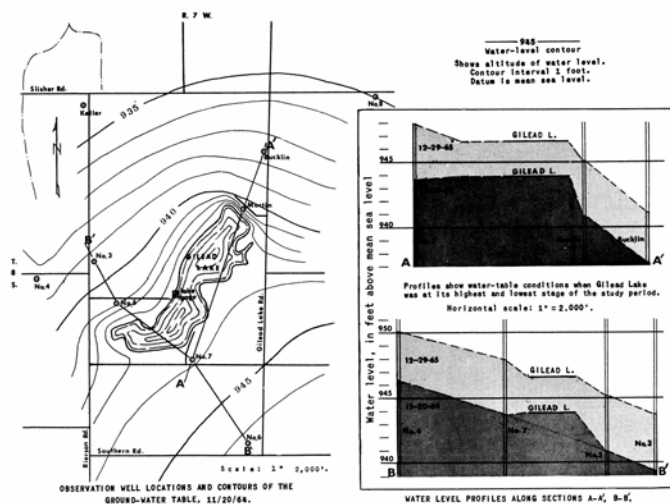


Figure 26. Water-level contours and profiles of the Gilead Lake area.

Figure 26. Water-level contours and profiles of the Gilead Lake area.

Decline of water levels in lakes having outlets can be partially controlled by constructing regulating dams at the outlets (see cut). This can be accomplished under the procedure for "STABILIZING INLAND LAKE LEVELS" Act 146, Public Acts, 1961, of the State of Michigan. If the water level in the lake should fall below the level of the natural lake outlet, the control obviously is no longer effective.

If long-term water-level records show a continuous decline in lake levels caused by withdrawals of ground

A frequently suggested alternative to maintaining lake levels is to provide the desirable depth of water by dredging the lake bottom. This has been done in many lakes in Michigan. The material removed is commonly used to build up low swampy areas along the lake, thus adding to the amount of lakeshore available for development. Dredging also can remove bottom sediments which may have sealed off ground-water inflow. Such dredging and filling tends to artificialize the lake and to change some fish and wildlife habitats. Thus, the advantages of deeper water and additional developed shoreline in the dredged lake must be balanced against the possible sacrifice of natural beauty and of fish and wildlife habitats. Again, it should be remembered that once natural conditions are destroyed they can never be entirely restored.

Many of the older inhabitants in Branch County, as in other areas of Michigan, remember other periods of low lake levels that have occurred in their lifetime and how the lakes have always recovered from these low stages. However, when low levels are the result of man's interference by structures, drainage, irrigation, consumption, or other factors then perhaps some permanent lowering is to be expected.

Farm Ponds

There are reportedly about 15 farm ponds in Branch County. They have an average size of about $\frac{1}{4}$ acre and most are dug below the water table to an average depth of about 10 feet. Water in the ponds is used either for irrigation and/or recreational purposes.

Interrelation of Ground and Surface Waters

Water stored in the ground moves slowly to points of discharge, where it seeps out of the ground to springs, swamps, lakes, and streams. During periods of little or no rainfall this seepage supports the flow of streams. Because this report covered a period of low rainfall, the base flows of streams reported herein are probably

among the lowest that have occurred. Owing to the low water table in the east-central part of Girard Township, it would appear that Hog Creek, rather than receiving water from ground storage, actually was recharging water to the ground-water reservoir. Another example of a stream recharging the ground-water reservoir is at the Coldwater well field. Some of the flow of the Sauk River at times is lost to the well field entering the gravel and sand aquifer. Examples of the relations of ground water and surface water are given in figure 27.

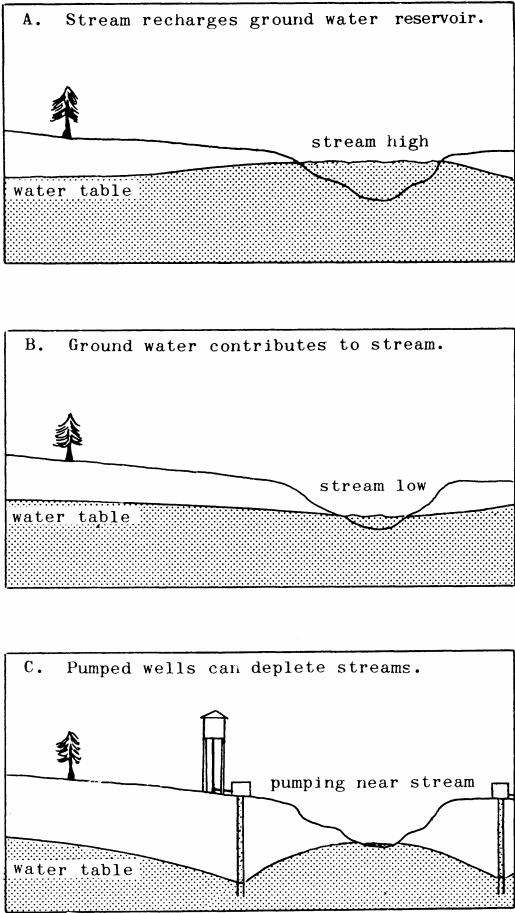
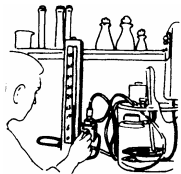


Figure 27. Relation of ground and surface water.
Figure 27. Relation of ground and surface water.

QUALITY OF WATER



To adequately develop and manage water resources, it is necessary to know not only the availability of water, but also its quality. The chemical and physical characteristics of water control to a large extent the usability of water, the costs of treatment, and the needs of management.

The Source and Significance and Source of Dissolved Minerals in the County's Water Supplies

The important dissolved minerals in waters of the county are mainly calcium carbonate, magnesium carbonate, iron, sodium chloride, calcium chloride, and sulfates. The significance of dissolved minerals in water and their general source is given in table 7.

Dissolved minerals are derived chiefly from the earth materials which the water comes in contact with. In Branch County these materials consist mostly of surface soils and the sands, gravels, clays, and silts of the glacial drift. Materials in the drift deposited by the Saginaw lobe differ from those deposited by the Erie lobe; the materials from the Erie lobe contain a great deal of limestone, whereas the materials from the Saginaw lobe are sandy. In addition, some dissolved minerals, such as chlorides, come from the Coldwater Shale which underlies the glacial drift at shallow depth in many places.

Calcium and magnesium, which contribute to the hardness of the water, are dissolved from practically all earth materials but especially from earth materials high in limestone, dolomite, and gypsum. Iron also is dissolved from most earth materials. Sulfates, however, are derived chiefly from soils and rocks containing gypsum, iron sulfides, and other sulphur compounds. Chlorides, which cause "salty water" locally, are derived from the salty seas which covered the area millions of years ago during Mississippian time.

Table 7.--Source and significance of dissolved minerals and physical properties commonly occurring in natural surface and ground waters.

Constituent or Property	Source or cause	Significance
Nitric (NO ₃)	Dissolved from nearly all rocks and soils.	Contributes to formation of boiler scale. Inhibits deterioration of metal-type water softeners.
Iron (Fe)	Dissolved from the common iron-bearing minerals present in most formations.	Oxidizes to a reddish-brown sediment. Stains utensils, enamelware, clothing, etc. Unsatisfactory for food processing, dyeing, laundering, bleaching, beverages, textiles, processing of raw. USPHS (1962) drinking water standards suggest that iron should not exceed 0.3 ppm.
Calcium (Ca) and Magnesium (Mg)	Dissolved principally from gypsum, limestone, and dolomite formations. Also found in some quantity in almost all formations. Large quantities are found in limestones.	Impart hardness and scale-forming properties to water. Soap consuming (see hardness). Unsuitable for laundries, steam plants, textile processing, and dyeing.
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in sea water, brines, and sewage.	Cause boiler foaming when present in large amounts. Combined with chloride to give a salty taste. Large quantities may limit use for irrigation.
Bicarbonate (HCO ₃) and Carbonate (CO ₃)	Action of carbon dioxide in water on carbonate minerals such as limestone and dolomite.	Raises the alkalinity and usually pH of water. In combination with calcium and magnesium, causes carbonate scale. Releases corrosive carbon dioxide gas on heating. Causes carbonate hardness when combined with calcium and magnesium.
Sulfate (SO ₄)	Derived from shales and gypsum. Oxidation of sulfides. Commonly associated with sulfonitrates. Contributed by some industrial water.	With calcium, forms hard scale in steam boilers. Imparts cloudiness to rice. Causes bitter taste when combined in large amounts with other ions. Calcium sulfate considered beneficial in brewing processes. USPHS (1962) drinking water standards recommend that sulfate content not exceed 250 ppm.
Chloride (Cl)	Dissolved in varying amounts in all soils and rocks. Also found in brines, sea water, and sewage.	Calcium and magnesium chloride may hydrolyze and increase the corrosive activity of water. In large amounts gives salty taste. USPHS (1962) drinking water standards recommend that chloride content should not exceed 250 ppm.
Fluoride (F)	Small amount available from most rocks and soils. Most fluoride concentrations over 1 ppm usually found in sodium waters. Primary source of high concentrations is industrial pollution. Added to many municipal supplies by fluoridation.	May cause mottling of enamel on teeth of children if present in amounts in excess of about 1.5 ppm. About 1 ppm reduces incidence of tooth decay in children (Meyer, 1950). USPHS recommends control limits based upon annual average of maximum daily air temperature (see USPHS advisory committee report, 1962: Publication no. 956, p. 81).
Nitrate (NO ₃)	Decaying organic matter. Nitrate fertilizers. Sewage.	Investigations by Gandy (1945) indicate that high concentrations (more than 40 ppm expressed as NO ₃) may cause methemoglobinemia (infant cyanosis). USPHS (1962) drinking water standards suggest a limit of 45 ppm. Discourages growth of algae and other organisms which produce undesirable tastes and odors. Higher than local average may suggest pollution.
Residual solids	Chiefly mineral constituents dissolved from rocks and soils.	USPHS (1962) drinking water standards recommend that the dissolved solids should not exceed 500 ppm. However, 1,000 ppm is permitted under certain circumstances. Water 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 of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap scum on bathtubs. Hard water 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 non-carbonate hardness. Waters of hardness up to 50 ppm are considered soft; 51 to 120 ppm, moderately hard; 121 to 180 ppm, hard; more than 181 ppm, very hard (U. S. Geological Survey).
Specific conductance (microhm/cm at 25°C)	Dissolved mineral content of the water.	Indicates degree of mineralization. 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.
pH (hydrogen ion concentration or activity)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates generally 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, extremely alkaline waters may also attack metals.

Table 7.--Source and significance of dissolved minerals and physical properties commonly occurring in natural surface and ground waters.

General Suitability of the Water in the County

Most ground and surface water in the county is hard to very hard. Locally, iron is a problem in well water. Water from streams and lakes is mostly free of dissolved iron, and generally softer than well water. "Salty water" or chlorides occurs in water from a number of wells finished in the Coldwater Shale. Water from wells can be processed through softeners to reduce the hardness and iron content. Chlorides (salty water) however, cannot be removed economically with present-day methods.

Quality of Water from Wells

Hundreds of samples of water from wells were collected and analyzed in the field or in the laboratory. The areal distribution of these selected sites is shown in figure 28.

The results of the field analyses are included in table 3 (in appendix), and the results of laboratory analyses are in table 8 (in appendix).

The only significant problems with ground-water quality in the county at present are excessive hardness, iron, and some chlorides. Although sulfates are present, they generally are not a problem to most users.

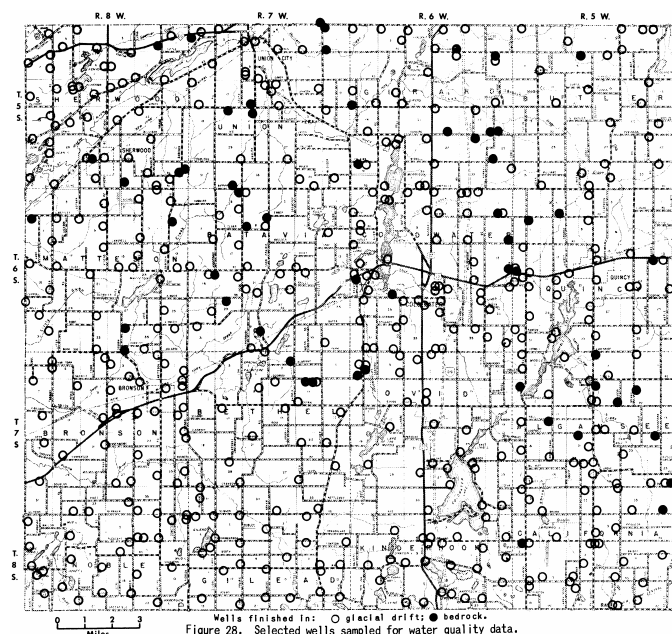


Figure 28. Selected wells sampled for water quality data.

The County Health Department encourages families with infants to submit samples of their well water for analysis to determine nitrate content, as concentrations in excess of 45 ppm can cause methomoglobinemia, a blood disorder, which can be fatal to infants. Fortunately, no cases of this high a concentration of nitrates have been reported to date.

The relation between specific conductance (Tables 3, 8, 9, 10) and the amount of dissolved mineral solids is

shown graphically in figure 29. This relation is useful in detecting changes in quality of water where monitoring is desirable. Further field or laboratory analyses can then be made to determine the minerals causing the change in conductance.

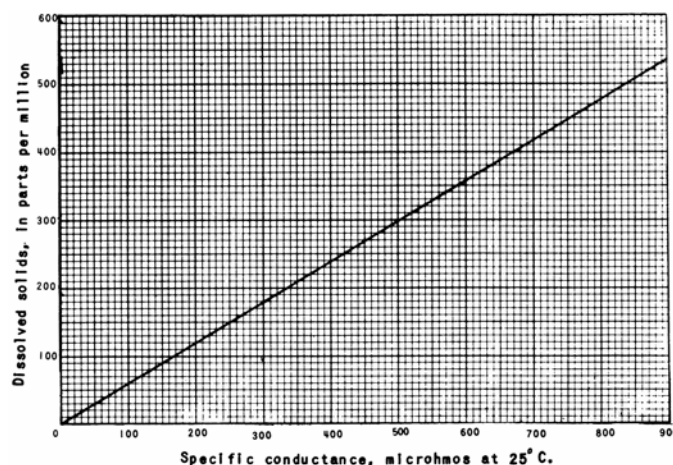


Figure 29. Relation of dissolved solids to specific conductance in wells and streams of Branch County.

Figure 29. Relation of dissolved solids to specific conductance in wells and streams of Branch County.

The variations in hardness, iron, and chloride in water from wells are generalized on maps (figs. 30- 32) and discussed below.

Hardness in Water from Wells

The hardness of well waters sampled in the county ranged from as little as 33 parts per million (ppm) to as much as 1,200 ppm. The areal distribution of hardness in the county is shown in figure 30. Based on some 500 samples, well water averaged about 300 ppm (17 grains) hardness with most ranging from 200 to 400 ppm. The U. S. Geological Survey classified hardness, in terms of the amount of calcium carbonate or its equivalent that would be formed if the water were evaporated, as follows:

Parts per million	
0-60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

If a gallon of water containing 500 ppm hardness were boiled away, a residue of about 1/16 ounce of limy material would be left.

Hardness is a problem common to most ground water in the county. The harder water usually occurs in moraines and till; the softer water in Coldwater Shale. Softer water in the Coldwater may be the result of sodium ions in the shale replacing the calcium and magnesium ions to create a softer sodium bicarbonate water -- a reaction that is very similar to the one occurring in common domestic water softeners. However, the softer water found in the shale may contain objectionable amounts of chlorides.

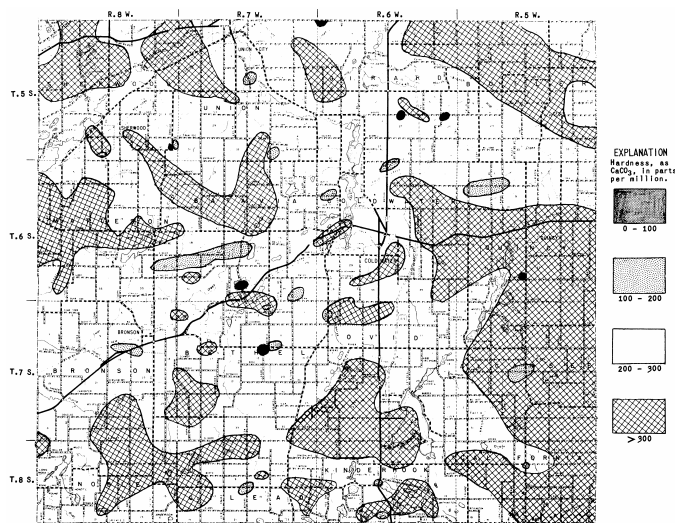


Figure 30. Distribution of hardness in ground water.

Iron in Water from Wells

Iron in excess of about 0.3 ppm is a problem with water from many wells in the county (fig. 31). Dissolved iron oxidizes upon exposure to air and results in reddish-brown sediments and stains.

Use of water softeners and iron removal equipment seems to be the most practical solution to problems of hardness and iron content. There is no apparent correlation of either hardness or iron content with depth of wells, so it may be futile to drill shallower or deeper wells in the hope of obtaining better water.

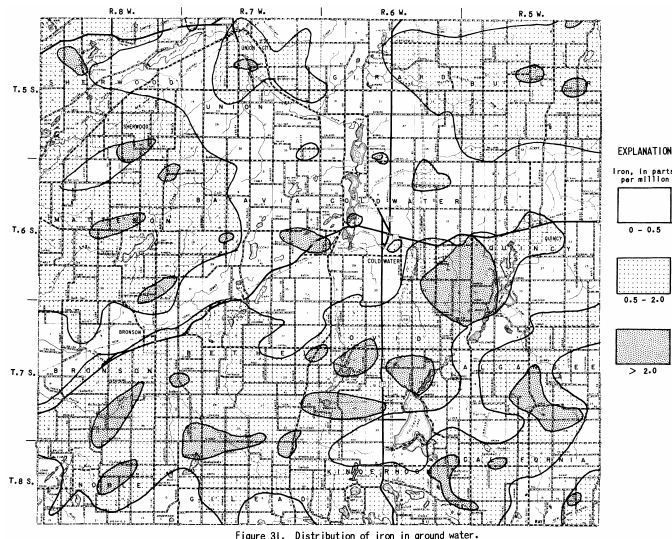


Figure 31. Distribution of iron in ground water.

Chlorides in Water from Wells

Water containing high chlorides usually is associated with the Coldwater Shale and problems of high chlorides or "salty water" are typical of areas where the Coldwater is near the land surface. Very few incidents of high chlorides were found in wells finished in glacial drift. The concentrations of chlorides in wells is shown on figure 32. The areas of high chlorides are generalized and further study is needed for accurate delineation. Where

salty water is encountered in glacial drift wells, it may be the result of ground water infiltration from nearby bedrock highs. Normally, water from wells in glacial drift contain concentrations of chlorides varying from 5 to 15 parts per million. In a few cases, moderately high chlorides in shallow wells may be an indication of contamination from sewage disposal systems, industrial wastes, or possibly from oil field operations with improperly plugged wells.

As there is no inexpensive way to eliminate salt from water at present, wells should not be drilled to obtain water supplies from the Coldwater Shale in areas where the water in the shale is salty (see fig. 32). Properly constructed dug wells in the glacial drift overlying the shale would be one solution. Screening the well above the shale even though the well penetrated shale would perhaps in some cases introduce a freshwater head on top of the salty water, or dilute the salt content to reasonable proportions. The drinking water limits by the U. S. Public Health Service recommends not over 250 parts per million of chlorides in water. However, water for stock could probably exceed this limit. Persons who are on salt-free diets probably should import their drinking water from a more potable source.

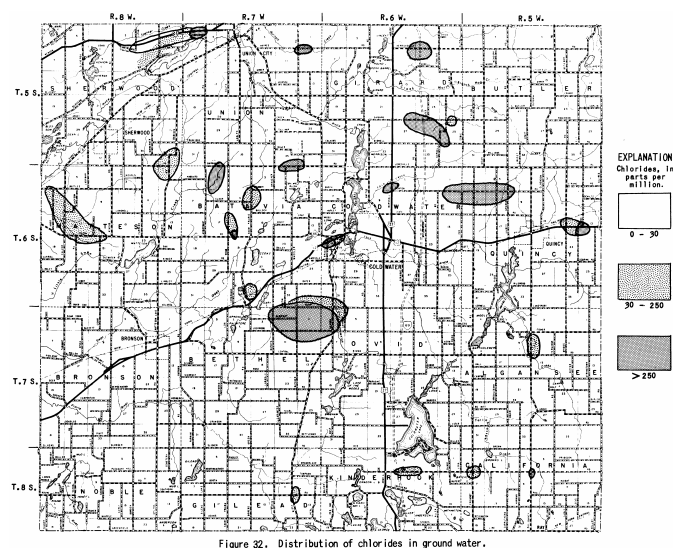


Figure 32. Distribution of chlorides in ground water.

Quality of Water from Streams

Water from streams in Branch County is generally softer than ground water, with virtually no iron and little chloride in solution (table 9, in appendix). The chemical quality of water from streams is summarized below.

Constituent or property	Maximum	Minimum	Median
Sulphate (SO_4)	194	52	84
Chloride (Cl)	36	1	10
Dissolved solids	565	240	336
Total hardness (as CaCO_3)	448	186	270
pH	8.4	6.6	7.7
(Results in parts per million except pH)			

The concentrations of hardness and chloride increase somewhat during periods of dry weather when the streams are fed almost entirely by ground-water seepage. During periods of heavy runoff from intense precipitation the stream water is less mineralized.

Large variations in quality may result from contaminants introduced to the streams by sewage, by run-off from swampy areas which increases sulfate content, and by introduction of industrial wastes. For example, a large increase in chlorides may be introduced into a stream by back washing and discharge in softening processes by public or industrial plants. An example is the drain at the Coldwater State Home and Training School which empties into Cold Creek to the north. In another case, a large increase in sulfates in Swan Creek, Fisher Creek, and Tallahassee Drain occurred in the spring of 1965 when heavy precipitation flushed sulfate-laden materials from swamps into these streams.

What Can Be Done About Contamination of Streams by Sewage and Other Wastes?

Contamination of streams can best be detected by periodic sampling and analysis of the water. If contamination is found to exceed tolerable limits, the State Water Resources Commission should be informed.

Knowledge of the flow of streams is essential in the determination of the amount of wastes a stream can assimilate safely. If a stream is overloaded, additional waste treatment must be provided, another disposal site found, or the flow augmented by reservoirs.

The Quality of Water from Lakes

Water from lakes in Branch County ranged in hardness from as little as 24 ppm in Round Lake, a small land-locked lake in Noble Township, to as much as 430 ppm in Brown's Lake in California Township (table 10, in appendix). The low hardness in Round Lake is probably the result of the recharge to the lake being mostly direct precipitation whereas, Brown's Lake is actually a wide place in Tallahassee Drain, which also has about 430 ppm hardness.

Round Lake was also the only lake checked where the pH value was on the acid side. This is more or less typical of soft-water, land-locked lakes in other areas of Michigan.

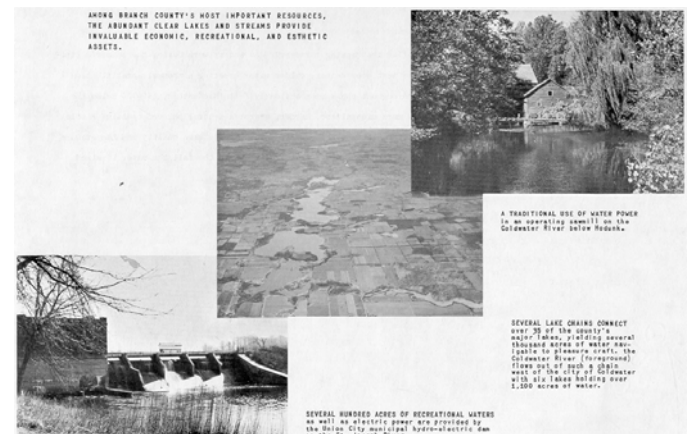
Chlorides in lakes ranged from 3 to 25 ppm. The higher chlorides are probably the result of sewage effluent, as in the chain of lakes west and north of Coldwater.

The chemical quality of water from lakes is summarized below:

Constituent or property	Maximum	Minimum	Median
Chloride (Cl)	25	3	10
Dissolved solids	445	32	250
Total hardness (as CaCO ₃)	430	20	220
pH	9.8	6.1	7.8
(Results in parts per million, except pH)			

Thermoclines in lakes

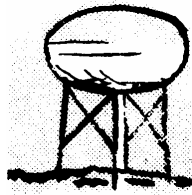
Depth, temperature, and dissolved oxygen were used to determine thermoclines in four of the county's deeper lakes -- Lakes George, North Pleasant, Coldwater, and Gilead (table 10). A thermocline is defined in Webster's dictionary as "a temperature gradient, especially one marking sharp change; also any of the layers of water exhibiting this". Seasonal changes in temperature cause physical and chemical changes in water. During the winter months, waters in lakes have no definite temperature stratification, but rather there is a gradation in temperature from about 32° F. near the surface to about 39° F. on the bottom. For a few weeks in the spring water temperatures are homogeneous and the water is mixed, distributing nutrients and flocculent bottom solids from deeper waters -- this is popularly called the "spring turnover". As waters warm during the summer a stratification takes place -- the warmer waters rest over denser, colder water creating a thermal stratification and a thermocline. This layering exists throughout the summer and early fall (MacKenthun, 1964). Below the thermocline, the colder water is generally more mineralized, harder, nearer a neutral pH, and contains little or no dissolved oxygen. Above the thermocline, the water is usually of about the same quality and temperature as streams in the area and has abundant dissolved oxygen. For several weeks in the fall the water is mixed again -- this is the "fall turnover".



WATER USE

Almost all water used in Branch County is from wells. The total pumpage from wells for municipal and industrial supplies in 1965 was about 1.8 billion gallons. Some surface water is used for irrigation and for generation of electricity. A major non-consumptive use of water is for recreation at the numerous lakes.

Municipal and Institutional Use



All municipal and institutional water supplies in the county are from wells in the glacial deposits. In 1965, about 1,651 million gallons was pumped for these supplies; of this about 854 million gallons went to industrial use. One village, Sherwood, has no municipal supply and water is obtained from individual wells in the glacial deposits. A summary of municipal and institutional water systems is given below; a more complete description of these systems is given in the appendix.

City, Village or Institution	Number of wells	Range in depths of wells (feet)	Range in depths to water (feet)	Range in pumpage of wells (gpm)	Total pumpage in 1965 (million gallons)
Bronson	3	60-97	7-15	675-810	319
Coldwater	4	121-132	9-17	1,200-2,850	984
Coldwater State School	3	50-59	18	250-300	168
Quincy	2	65-102	8	350-650	46
Union City	2	98-138	7-38	475-480	134

Peak demand days on municipal plants have an important bearing on the complete water system. However, these demands usually can be handled through increased storage facilities. For example, in 1965 Coldwater increased its storage from 300,000 gallons to a million gallons to insure that water would be available during periods of peak demands.

Industrial Use



Industry is the big user of water in the county, using about 1,009 million gallons in 1965. Most of the water was from municipal supplies; one industry during certain periods of the year uses as much as a million gallons a day from the municipal supply in Coldwater. Only about 155 million gallons of the industrial use was from private wells. Table 11 gives water use by industry. Most water used by industry is from wells except that some flour and feed-grinding mills, as at Hodunk, use surface water. In addition, surface water is used for industrial cooling in the municipal power plants at Coldwater and Union City.

Irrigation Use



In 1965 there were 16 irrigation systems in the county (personal communication, State Water Resources Commission). Only two used ground water to irrigate a

total of about 11 acres. The remaining systems used streams, lakes, ponds, and ditches to irrigate about 600 acres. Crops irrigated were gladiolas, truck crops, strawberries, and corn. Water was also used to irrigate cemeteries and golf courses. The use of ground water is on the order of 2 million gallons a year while surface water use is about 140 million gallons a year. The location of irrigation systems and sources of supply are shown in figure 33.

(Data collected from the Michigan Water Resources Commission.)

Industry	Consumption (million gallons per year)	
	Municipal supply	Private wells
City of Bronson		
Bronson Laundromat	1.0	
Bronson Plating Company	57.5	
Bronson Reel Company	14.0	
Darling, L. A., Company	170.0	
Douglas Mfg. Company	3.4	134.8
Econowash	0.7	
City of Coldwater		
American Int. Alum.	330.0	
Branch County Jail	2.6	
Climax Molybdenum Co. of Mich.	42.0	
Coldwater Brass Company	1.9	
Coldwater Livestock Auction	1.7	
Culligan Water Conditioning	8.9	
Federal-Mogul Service	10.5	
Kroger Egg Plant	2.1	
Maple Lawn Hospital	3.6	
Midwest Foundry Company	125.7	
Powered Metal Products, R. B. & W.	1.2	
Quality Spring Products	1.2	
Shaw, M. T. Inc.	1.0	
Speed-Queen Laundry	5.4	
Wash-King Laundry	2.8	
Wash-N-Dry	3.3	
Wayne Co-op Milk Products	12.3	
Woodward-Pollack Concrete	1.4	
Village of Quincy		
General Cable Company		20.5
Village of Union City		
Duo-Coach Corp.	38.6	
Schafer Mfg. Company	4.7	

Table 11.--Major industrial uses of ground water in Branch County in 1965.



Figure 33. Irrigation and farm pond sites.

Figure 33. Irrigation and farm pond sites.

At the present rate of use, withdrawals of water for irrigation should not significantly affect other water supplies. However, increased use could adversely affect streamflow and lake levels, especially as demand is usually greatest when streams are at low flows and lake levels are low.

Livestock	Use per head (gpd)
Milk cows -----	20
Beef cattle -----	10
Horses and mules -	10
Hogs -----	3
Sheep -----	2
Chickens -----	.04

Stock Use



Water for stock often is obtained from streams and ponds, but a considerable amount also is derived from wells. The amount of water used by stock is quite large; the following tabulation gives the daily average use per head of livestock in most states ("Estimated Use of Water in the United States", 1961).

The number of livestock in Branch County in 1959 (U. S. Census, 1960) was as follows:

Cattle, cows, calves -----	29,900
Horses, mules -----	764
Hogs -----	40,204
Sheep and lambs -----	16,363
Chickens -----	156,411

On the basis of the above data, it is estimated that the amount of water used by livestock in 1959 was about ½ million gallons a day or nearly 200 million gallons a year. In addition, large amounts of water from wells are used for clean-up purposes, such as for cleaning stables and milk houses.

Recreational Use



Recreational use of lakes and streams is a non-consumptive use, but it has great esthetic and economic value. Some indication of the economic value of lakes and streams is the large number of summer cottages, permanent lakeshore homes, sandy beaches, resorts, boat liveries, and public fishing sites, and the large number of fishing licenses sold. Summer residents and tourists from other areas flock to Branch County during the warmer months. Many of the lakes and streams are valuable for fishing, canoeing, boating, and water skiing. Winter sports, such as ice fishing, attract many sportsmen during the colder months. Some 20,000 fishing licenses were sold in the county in 1964, of which 13,000 were to non-residents. The State Conservation Department maintains nine public fishing sites.

The business generated by the lakes and streams forms a large part of the county's income. Although many of the larger lakes have substantial developments, there is still room for much future development on the numerous, smaller lakes. Detailed information on the recreation possibilities in the county is contained in a recent publication "Lake and Stream Guide, Branch County".

SUGGESTIONS FOR THE FUTURE

Solution of water problems requires an understanding of the hydrologic environment that controls the occurrence of water, along with records of the changes and trends in ground-water levels, lake levels, stream-flow, and water quality. This report describes the general water environment of the county, but the two years of study was not enough to determine all the probable ranges and trends in the hydrologic variables. To obtain meaningful information on these variables a longer period of recorded data is needed. Recording stations must be selected with care so that the information obtained will be truly representative of a problem area or condition. The study of the county just completed provides the information needed for the selection of these stations.

Ground Water

Observation wells should be established in areas where man-made influences, such as heavy pumping, affect water levels and also in areas away from man's influence where natural fluctuations of the water table occur. The natural fluctuations must be determined in order to evaluate those fluctuations caused by the works of man.

At least one observation well should be established in every community using ground water for municipal supply. This is desirable in order to determine the long-term effects of pumping the municipal wells. These observation wells should be located near the center of pumping, but should not be so close to a pumping well that the long-term fluctuations are masked by the large changes caused by turning the pumping well on and off. Because large variations in water levels may occur in a short period of time, these observation wells should be equipped with continuous recording instruments.

Observation wells equipped with continuous recorders should also be established in areas wherever and whenever large quantities of ground water are pumped for irrigation or industrial use.

Finally, a small network of observation wells should be maintained in relatively unpumped areas to record the natural fluctuations in the water table. These should be selected to reflect conditions in each major topographic and geologic area. These wells could be measured monthly or equipped with continuous recorders for only such time as needed to determine the type of fluctuation pattern.

Streams

In order to expand the present knowledge of surface-water resources and to document future trends and occurrences, a continuing program of stream-gaging is recommended. The program should be comprised of stream-gaging stations and partial-record stations. The location and number of such stations would be

dependent on the needs and desires of those concerned with development and management of the water resources.

Lakes

Records of fluctuations of lake levels in the county also should be obtained. Greatest fluctuations in levels generally occur in lakes having no surface outlets, so records should be obtained from such lakes. As a minimum sampling, records should be obtained from at least one lake in each political township of the county where lakes occur.

Quality of Water

At regular intervals water from representative wells, streams, and lakes should be checked with specific conductance meters for any changes in chemical quality and samples collected (when changes occur in conductance) for laboratory or field analysis to determine both short-term changes and long-term trends in quality of water. Dissolved oxygen and sediment load tests should be made on streams at regular intervals to determine the condition of the streams and preserve them for multiple use.

Using the Recorded Information

Of course, records of water levels, streamflow, and quality of waters must be interpreted to justify their collection. The old adage of "a stitch in time saves nine" is particularly applicable to water resources. It is far better to take preventive measures to guarantee the maintenance of water levels, streamflow, and the quality of the water than to try to rectify problems after they have become serious.

A monitoring program should be maintained and immediate steps should be taken, if practicable, to correct any serious lowering of ground-water levels and lake levels, large decreases in streamflow, or impairment of the quality of any of the waters of the county.

This report makes available most of the information known about the water resources of the county at this time. However, more data is constantly becoming available from drilling operations, water level and stream-flow records, and quality determinations. This additional data should be summarized and interpreted in a continuous program of updating the report information. Informal progress reports should be prepared at regular intervals of a year or so. At five-year intervals a more comprehensive progress report should be prepared. The people of Branch County and others interested in its water resources could then have available up-dated evaluations of the water resources.

One cannot foresee the time when water problems will not occur. It is difficult to provide for the solution of unknown future water problems. Technological advances may render solutions of some future problems

easy. For example, extremely cheap power, as may occur by the fission of deuterium and tritium may facilitate processing of sewage waters into pure water, or allow the cheap desalination of heavily mineralized waters or eliminate the use of water for industrial and air conditioning uses. Weather control may solve problems caused by increased uses of irrigation.

As the cost of water rises, modern technology may find additional ways to conserve water for industrial, public, and domestic uses.

The use of dams to hold back water for low-flow supplementation during dry periods, and ponds to recharge water to the ground will undoubtedly be increased, as will the use of synthetic films to lower evaporation from open bodies of water. The use of plastic film to conserve moisture on truck gardens eliminates some irrigation, and is already practical in certain areas of the country.

In the final analysis, knowledge of our water environment should lead to the wisest use for all persons concerned, now and for future generations.

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