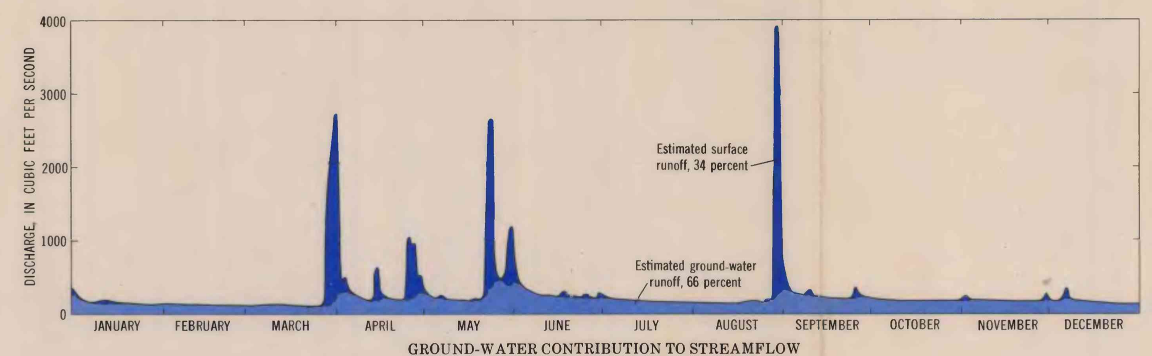
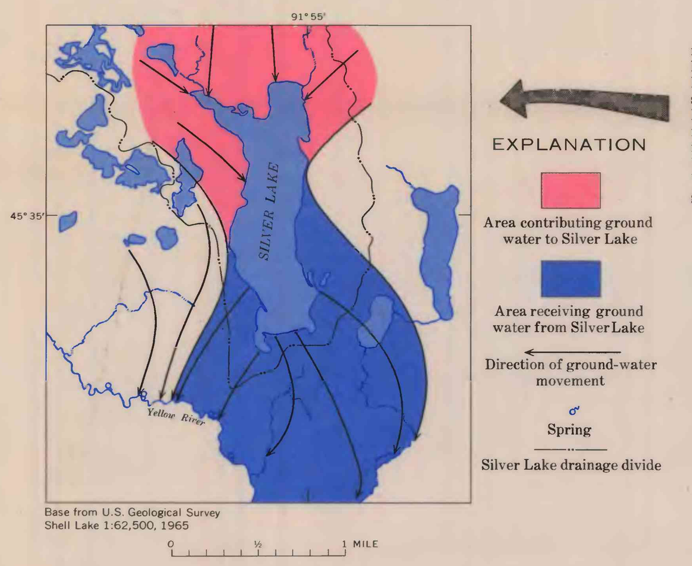
GROUND-WATER—SURFACE-WATER RELATIONSHIPS



GROUND-WATER CONTRIBUTION TO STREAMFLOW

The surface- and ground-water runoff components of streamflow are determined approximately in the separation of a streamflow hydrograph. After precipitation stops, surface runoff continues only a few days, but ground-water runoff is slower and continues through a much longer period. The important features of the 1960 hydrograph for the Hay River at Wheeler are the consistent contribution of ground water to low flow for almost 9 of the 12 months and the extremely high surface runoff for short periods. Snowmelt in late March and heavy rainfall in May and August produced the major high flows of the year. Ground-water runoff also increased sharply during the periods of high flow but receded more slowly after the flood crest had passed. The 1960 discharge of the Hay River past Wheeler was about 66 percent ground-water runoff and 34 percent surface runoff.



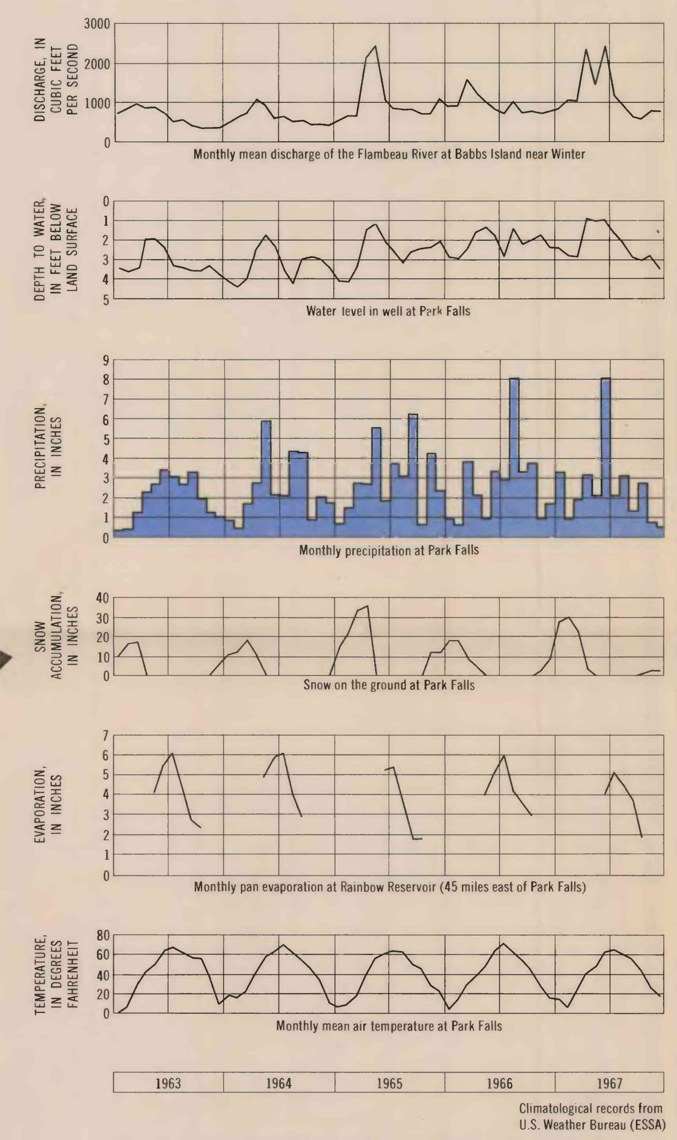
GROUND-WATER MOVEMENT AT SILVER LAKE, BARRON COUNTY

A direct relationship exists between lakes and the ground-water reservoir. Seepage lakes, those having neither surface inlets nor outlets, have ground-water inflow and outflow and little surface inflow. Drainage lakes, those having surface inlets and outlets, have both surface- and ground-water inflow and outflow. For example, Silver Lake in north-central Barron County, is a seepage lake and water moves in and out of the lake almost entirely as ground water. The map illustrates the general movement of ground water to and from the lake. Water from the southern part of the lake moves as ground water to the Yellow River, which is about 70 feet below lake level. Some of this ground water discharges as small springs at the base of the river bluff.

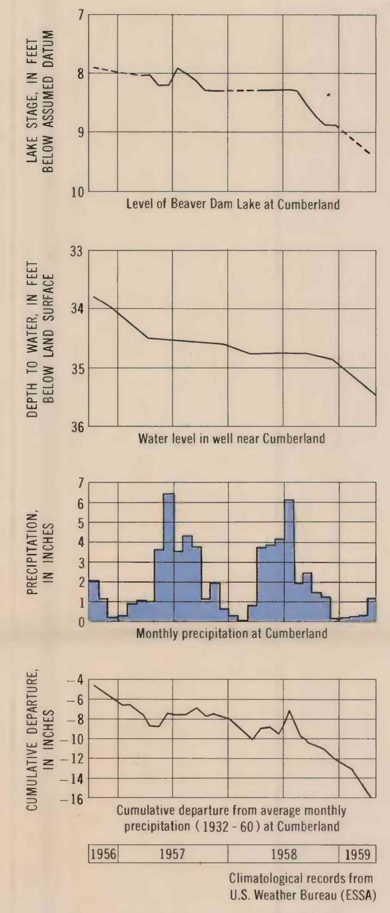
The direct relationship between streamflow, ground-water level, and climatological factors is shown by a comparison of detailed records of several years. Fluctuations of ground-water level and stream discharge correspond closely, but, because the rate of percolation to the water table is very slow, the response of ground-water level to precipitation is slower than that of streamflow. Peak flows on the Flambeau River are due to increased surface runoff from snowmelt, precipitation, or a combination of the two. Spring peak flows are primarily from snowmelt that occurs as the air temperature rises above freezing. Spring rains, such as occurred in 1965, augment the peak flow from snowmelt. Heavy precipitation in midsummer may not increase streamflow substantially because evapotranspiration is at a maximum and the rain replaces a soil moisture deficit (see Hydrologic Budget, sheet 1). Winter decline in streamflow does not follow decline in ground-water level during January and February because surface water is released from reservoirs to maintain uniform flow for hydroelectric power generation.

Ground and surface water are intimately and directly related in all phases of their movement within the basin. Both seasonal and long-term increases or decreases in ground-water levels, streamflow, and lake stages correspond. Similarly, natural or manmade changes in ground-water levels, streamflow, or lake stage cause corresponding changes in the others.

Over a long-term period, natural changes are in balance whereas manmade changes are variable and are not balanced. The quality of ground and surface water is also similar. However, surface-water quality is subject to greater variability because of overland runoff and manmade changes.



RELATION OF STREAMFLOW AND GROUND-WATER LEVEL TO CLIMATOLOGICAL ELEMENTS



RELATION OF LAKE STAGE AND GROUND-WATER LEVEL TO PRECIPITATION

Changes in stage of Beaver Dam Lake and in water levels in nearby wells correspond closely and are related to long-term changes in precipitation. These long-term changes are approximated by the cumulative departure of precipitation from normal. By contrast, the monthly precipitation record generally does not correlate with the trends of lake stage and ground-water level; however, high summer precipitation in 1957 stopped the downward decline in water level and caused a slight rise in lake stage.

The runoff rate of the Yellow River increases downstream to a point about 20 miles above its mouth. At that point it flows over a topographic high in the bedrock and into a narrow belt of outwash, which widens and deepens toward Cadott. The water table is below the stream in the outwash and the stream loses water.

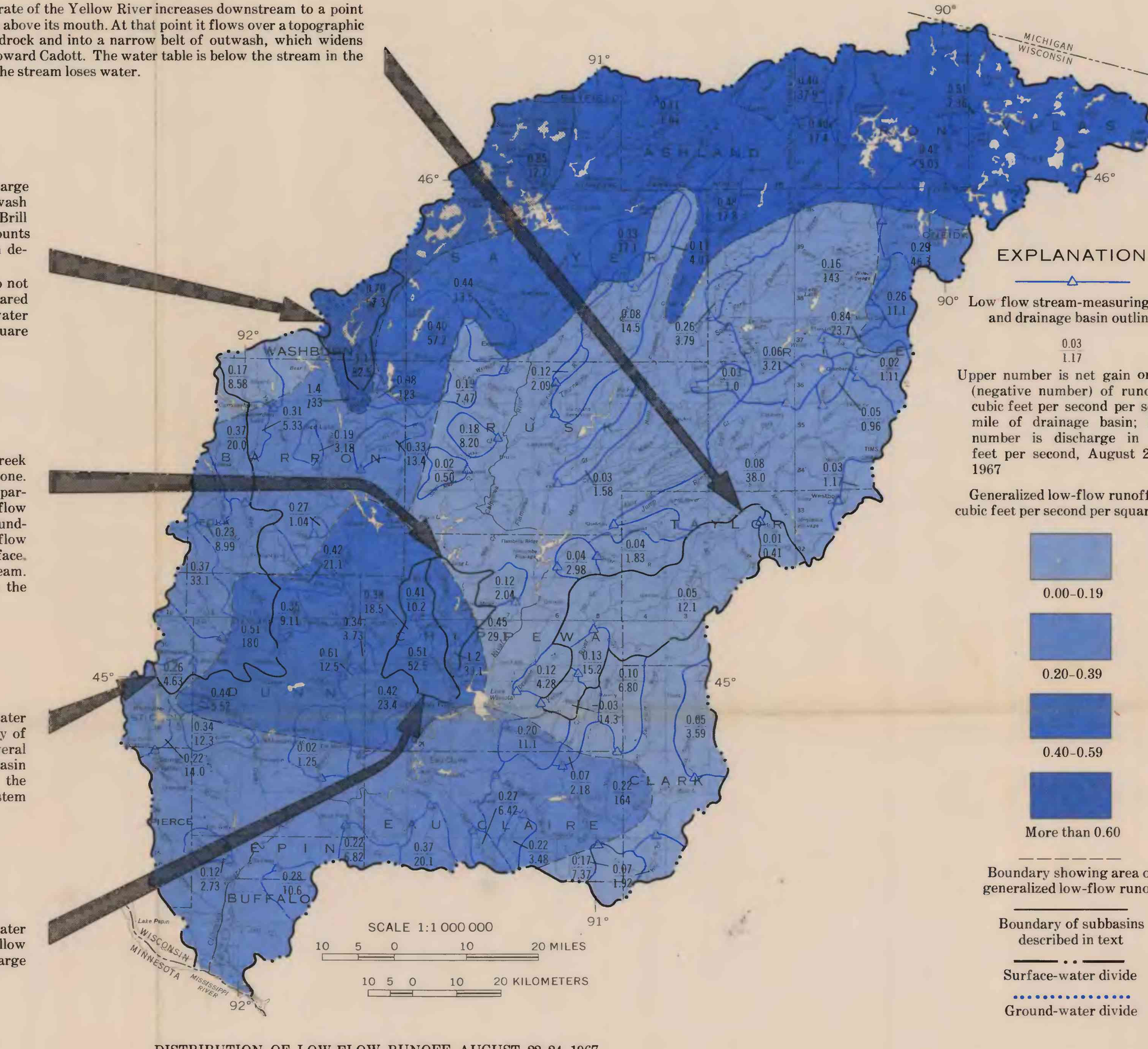
Very high low flow from the Brill River basin is due to large recharge to, and storage of, ground water in deposits of coarse-grained outwash and end moraine sediments. Runoff is greater from the lower Brill basin than from the upper basin. The lower basin stores larger amounts of ground water because of more extensive and thicker outwash deposits.

In the upper Brill basin the ground- and surface-water basins do not coincide. The ground-water basin is 68 square miles in area compared with 82 for the surface-water basin. Runoff from the ground-water basin is 0.84 cfs per square mile compared with 0.70 cfs per square mile from the surface-water basin.

Ground-water runoff is moderately high in the upper O'Neil Creek basin where the stream flows on a wide outwash plain over sandstone. The overall water-table gradient on the plain is very low, mainly parallel with the stream (see water-table map), and the ground-water flow component toward the stream is small. In the lower basin ground-water runoff is very high because of a constriction of outwash for recharge caused by a topographic high on the Precambrian bedrock surface. This constriction forces ground water to the surface into the stream. The water table dips steeply beneath the creek downstream from the bedrock high, and the lower 2 miles probably is a losing reach.

The headwaters of the Hay River basin have a lower ground-water runoff rate than the lower parts of the basin. The low permeability of moraines restricts recharge and ground-water movement in several local parts of the headwater areas. In the lower part of the basin ground water is readily recharged and released to streams by the underlying sandstone and highly permeable outwash in the main-stem valley.

The Duncan Creek basin has a moderately high rate of ground-water runoff. Thin, sandy ground moraine and permeable outwash allow good recharge to the underlying sandstone which provides large ground-water storage.



EXPLANATION

Low flow stream-measuring site and drainage basin outline

Upper number is net gain or loss (negative number) of runoff in cubic feet per second per square mile of drainage basin; lower number is discharge in cubic feet per second, August 22-24, 1967

Generalized low-flow runoff, in cubic feet per second per square mile

0.00-0.19

0.20-0.39

0.40-0.59

More than 0.60

Boundary showing area of generalized low-flow runoff

Boundary of subbasins described in text

Surface-water divide

Ground-water divide

DISTRIBUTION OF LOW-FLOW RUNOFF, AUGUST 22-24, 1967

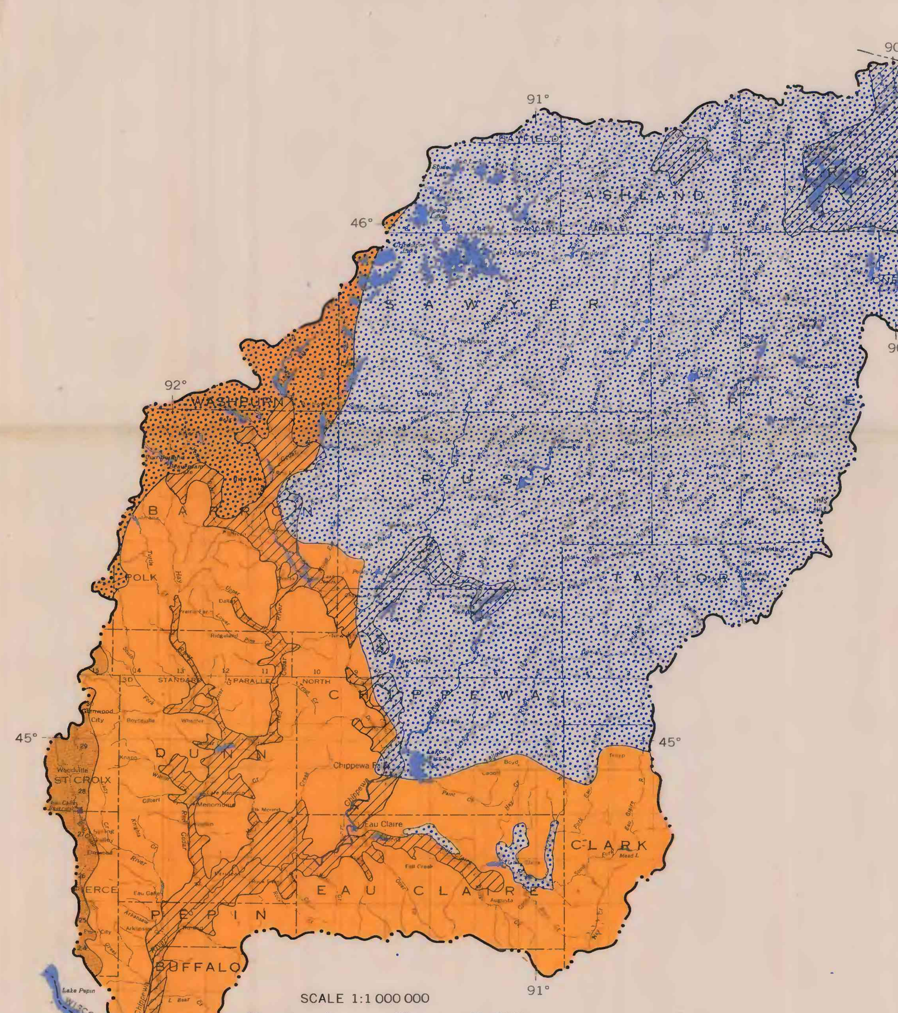
Low-flow discharge of streams in the basin differs greatly among subbasins and consists mainly of ground-water runoff. The generalized patterns on the map show low-flow runoff based on discharge measurements made during August 22-24, 1967. Discharges at gaging stations on main rivers were not used to generalize low-flow runoff because of the effects of surface storage and diversity of subbasins. Low-flow discharge is reduced to discharge per unit basin area (cfs per square mile) to compare the contributions of the many subbasins of different size.

Differences in ground-water runoff are due largely to differences in subsurface storage and permeability, which depend on variations in rock types, but also are due to differences in soils, precipitation, evapotranspiration, surface relief, and the retention of water in lakes, marshes, and reservoirs. Ground-water runoff is greatest in areas of thick, permeable glacial deposits, such as outwash and end moraine along the northwestern and northern parts of the basin. In these areas, recharge is high, surface runoff is low, and ground-water storage is large. The converse is true in areas of thin ground moraine over crystalline bedrock, such as the east-central part of the basin. Runoff is intermediate from the area of sedimentary rocks, but low runoff and losing stream reaches may occur in valleys filled with permeable outwash deposits. Evapotranspiration from areas of swamps reduces low flow.

GROUND WATER

Large supplies of good quality water are available from the ground-water reservoir in parts of the Chippewa River basin. Almost 1 trillion gallons of water are discharged to streams and wells each year; this is about 4 million gallons for each person in the basin. Aquifers throughout the basin serve dual functions: they provide water to wells and springs, and they furnish a perennial base of streamflow and lake stage by seepage and spring discharge.

Ground water is expected to continue its role in meeting domestic, agricultural, municipal, and industrial needs in the basin because it is readily available in quantities adequate to meet needs in areas of present and future use. Major areas of heavy pumpage are Eau Claire, Chippewa Falls, Menomonie, Rice Lake, and Barron. In general, ground-water development is small and scattered throughout the remainder of the basin. Detailed ground-water studies will be needed to guide resource development, especially in present and anticipated pumpage centers.



EXPLANATION

SAND AND GRAVEL AQUIFER

Surficial outwash deposits

Maximum reported well yield—2400 gallons per minute; average high-capacity well yield—985 gallons per minute

Undelineated buried and ice-contact deposits

Domestic and stock well yields—5 to 15 gallons per minute; locally wells may yield 100 to 200 gallons per minute

SANDSTONE AQUIFER

Sandstone

Maximum reported well yield—1400 gallons per minute; average high-capacity well yield—375 gallons per minute

Dolomite

Domestic and stock well yields—10 to 30 gallons per minute. Large yields must be obtained from underlying sandstone

Surface-water divide

GROUND-WATER AVAILABILITY

Ground water in the basin is obtained from the sand and gravel aquifer and the sandstone aquifer. The sand and gravel aquifer is the only source of ground water in the northern two-thirds of the basin, whereas both the sandstone and the sand and gravel aquifers are good sources of ground water in the southern one-third. Minor amounts of water are obtained from poorly sorted drift and from Precambrian crystalline bedrock. Crystalline rocks are generally impermeable and their surface is the lower limit of the ground-water reservoir. The areas of ground-water availability are delineated on the basis of well records, rock types, and soil types (Hole and others, 1968).

SAND AND GRAVEL AQUIFER

Surficial outwash deposits.—Deposits of surficial sand and gravel are primarily outwash that fill preglacial valleys in the southern one-third of the basin and outwash plains and ice-contact deposits in the northern part. Much of the outwash in preglacial bedrock valleys is thicker in major valleys than in tributaries.

The deposits are highly permeable and yield large quantities of water to wells. About 80 percent of the high-capacity wells, yielding 70 gpm (gallons per minute) or more, in surficial sand and gravel are between 70 and 130 feet in depth. The median specific capacity of these wells is 28 gpm per foot of drawdown, and the specific capacity of 25 percent of them is 63 or above. These sand and gravel deposits, which supply the water for the cities of Eau Claire and Chippewa Falls and most of the irrigation water, have the greatest potential for supplying water for additional development in the basin.

Undelineated buried and ice-contact deposits.—Buried sand and gravel deposits are beneath or included in ground and end moraine of the northeastern two-thirds of the basin. The ground moraine is locally thin or absent over bedrock highs. The thickest buried sand and gravel deposits, which are in preglacial bedrock valleys, are similar to the deposits in the lower valley of the Chippewa River. The size and continuity of these buried aquifers usually are indiscernible without detailed exploratory studies. The area of glacial drift shown on the map contains some deposits of ice-contact sand and gravel that are not delineated because of lack of data.

Adequate domestic wells with yields of 5 to 15 gpm are finished in buried lenses of sand or gravel, which are often less than 5 feet thick, at depths from about 20 to 200 feet. Most wells, however, are less than 100 feet deep.

Most municipalities in the northeastern half of the basin obtain their water from buried deposits. Some could increase their supplies by exploration outside their corporate limits; however, exploration commonly is restricted to the immediate vicinity of the municipality to avoid the costs of a long pipeline and transmission of the water.

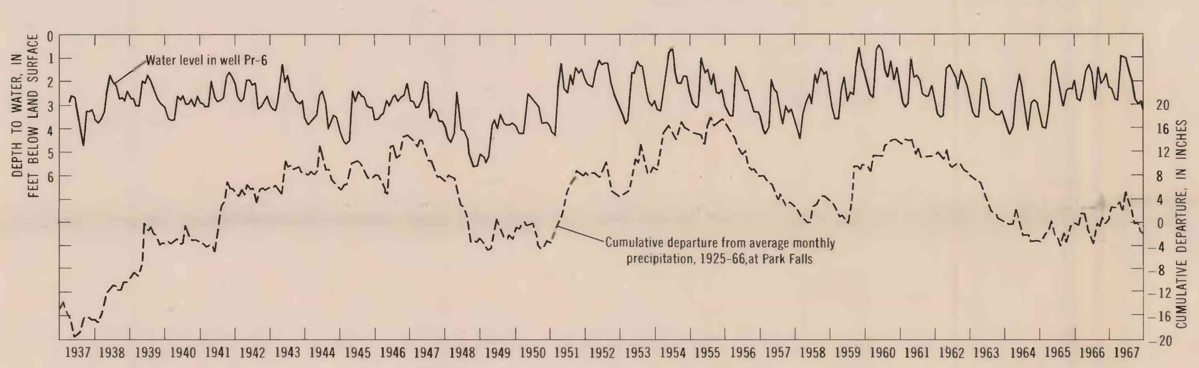
SANDSTONE AQUIFER

This aquifer, the most important throughout the State, consists of the saturated parts of the St. Peter Sandstone, the Prairie du Chien Group, and the sandstone formations of Cambrian age (see Bedrock Geology, sheet 1). The latter compose the bulk of the aquifer, and dolomitic rock of the Prairie du Chien Group forms the remainder. Very little St. Peter Sandstone occurs in the basin and it is not saturated.

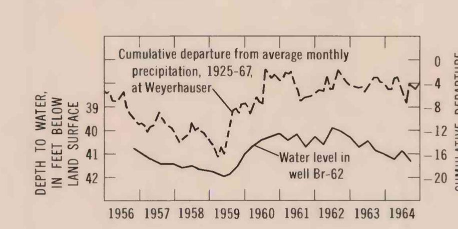
Sandstone.—In the southern third of the basin, the sandstone aquifer provides reliable supplies for municipal, industrial, public, domestic, stock, and irrigation uses. Although the sandstone is thick in northern Barron County, it is not used because the overlying drift is very thick and yields adequate domestic supplies. In the vicinity of the Chippewa-Clark County boundary, municipal supplies are marginal because the sandstone is thin or absent over Precambrian crystalline rock and the glacial drift, which is also thin, is mainly clayey till.

Because consolidated sandstone is less permeable than unconsolidated sand and gravel, high-capacity sandstone wells must penetrate more saturated aquifer than drift wells to obtain comparable yields. About 85 percent of the high-capacity wells are 100 to 475 feet deep, and the median depth is 230 feet. The median specific capacity of high-capacity wells in the sandstone is 7.5 gpm per foot of drawdown, and the specific capacity of 25 percent of these wells is 14 or above.

Dolomite.—The dolomite is a minor water source along the extreme western edge of the basin. It overlies the sandstone, forms the upland surface, and usually is exposed on the valley walls. The saturated zone is thin and the water table is deep, but adequate well yields are obtained for domestic and stock uses. The few high-capacity wells that penetrate the dolomite produce mainly from the underlying sandstone.



The water level in this water-table well, which is 13 feet deep in Pleistocene sand and gravel, responds rapidly to recharge by precipitation. The hydrograph shows a close relationship to cumulative departure of precipitation. During a period of below normal precipitation, 1947-48, ground-water levels declined to a record low in the winter of 1948. Other periods of drought in 1956-57 and 1962-64 caused similar declines in ground-water level. These declines did not seriously deplete ground water in storage as indicated by the maximum range in fluctuation of only 5 feet. The change in depth to water in this well is used as an index of soil moisture by State foresters.



The hydrograph of this water-table well in glacial outwash shows a long-term decline in the ground-water level in 1956-58 due to small recharge from below-normal precipitation. Recovery of the water level in 1959-60 resulted from recharge during a period of above-normal precipitation.

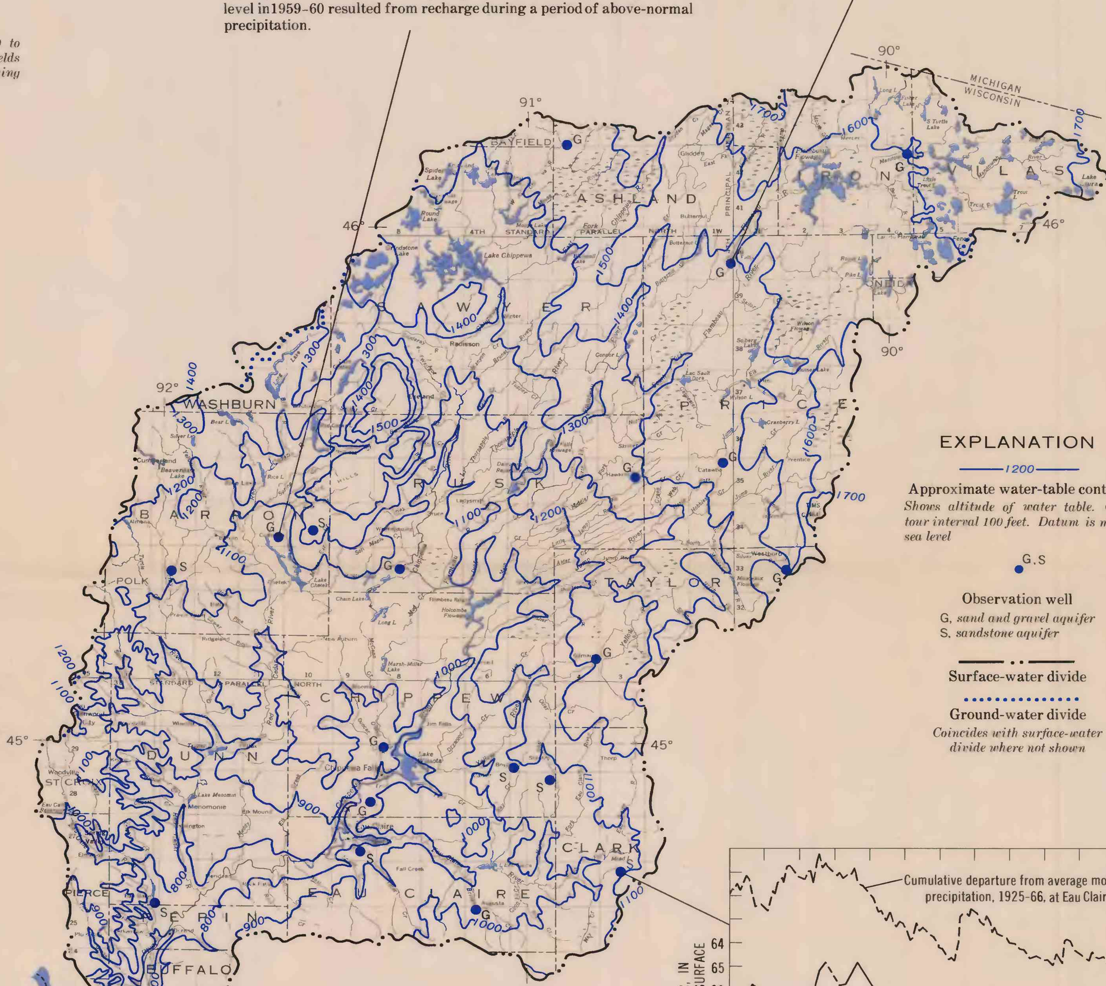
Ground water underlies the entire basin and moves constantly to areas of discharge—streams, lakes, wetlands, springs, and wells. The top of the saturated zone of ground water at atmospheric pressure is called the water table. It has a shape similar to the land surface, and contours on the water table indicate its slope. Ground water moves along this slope generally perpendicular to the water-table contours and conforms regionally to the direction of surface runoff. The distance that ground water in the basin travels to a discharge area is generally less than 4 miles.

The ground-water divide coincides closely with the surface-water divide except in a few areas, mainly along the western edge of the basin. The largest difference between the ground-water and the surface-water divides is in Washburn County where the ground-water divide is within the surface-water basin. Ground water in the intervening area moves out of the Chippewa River basin to the St. Croix River basin. Where the divides are not coincident, the ground-water divide of the Chippewa River basin is mainly inside the surface-water basin, but the ground-water basin is only about 20 square miles smaller than the surface-water basin. A very small net loss of ground-water underflow occurs (see Hydrologic Budget, sheet 1).

The water table in the basin generally is within a few tens of feet of the land surface. It is commonly most shallow near surface-water bodies and in areas of thin glacial drift over Precambrian bedrock, and it is deeper below hills, especially in the southwest where topographic relief is great. Maximum water-table depths of 200 to 300 feet occur below hills in the area of the basin boundary in Pepin and Pierce Counties.

The water table is not static, but fluctuates with changes in recharge and discharge. The three hydrographs illustrated are characteristic of these fluctuations. Five or more years of water-level records are available from the 19 observation wells located on the map. Hydrographs are published for 15 of the wells (Devaul, 1967).

Wells in local areas in the southern part of the basin have artesian water levels (at greater than atmospheric pressure). This pressure is produced in an aquifer by less permeable overlying strata that confine the flow of ground water derived from a recharge area of higher elevation. Weidman and Schultz (1915) reported flowing artesian wells in sandstone at Menomonie in the Red Cedar River valley and at Durand and nearby Meridean in the Chippewa River valley, and in valley fill along Arkansaw Creek. Artesian heads were low, and few of these wells had a large flow. The pressure has declined by as much as 50 percent because of pumpage, unchecked flow and leaky well casings. Most wells in use now must be pumped and many wells have been abandoned and plugged.



EXPLANATION

Approximate water-table contour

Shows altitude of water table. Contour interval 100 feet. Datum is mean sea level

Observation well

G, *sand and gravel aquifer*

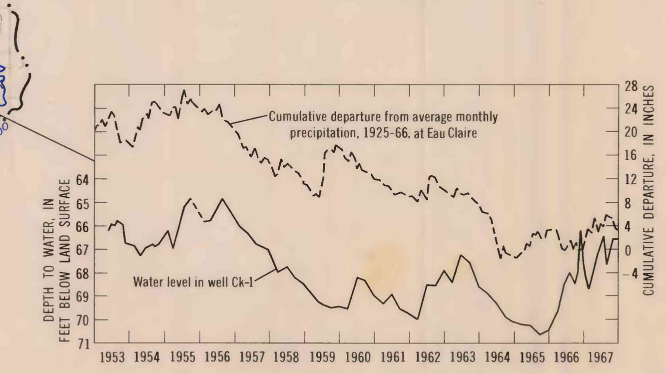
S, *sandstone aquifer*

Surface-water divide

Ground-water divide

Coincides with surface-water divide where not shown

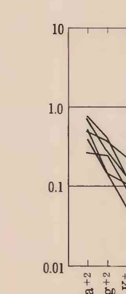
WATER TABLE AND OBSERVATION-WELL NETWORK



The water level in this artesian well, 150 feet deep in sandstone, has a delayed response to recharge from precipitation as shown by comparison with cumulative departure of precipitation. This delay of several months to a year may be due to slow downward movement of water through the overlying material before the aquifer is recharged.

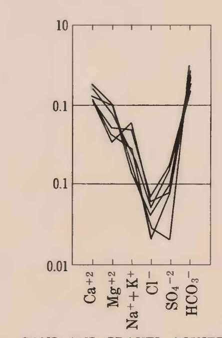
GROUND—WATER QUALITY

Ground water in the Chippewa River basin is generally of very good quality and is usable for most purposes. Regional differences in the quality of ground water are due to the composition, solubility and surface area of the particles of soil and rock through which the water moves, and to the length of time the water is in contact with these materials. Minor water-use problems are caused by hardness and locally by high iron concentrations. About 40 percent of the ground water sampled has hardness greater than 120 mg/l (milligrams per liter) and 15 percent has hardness greater than 180 mg/l and needs softening for many uses.



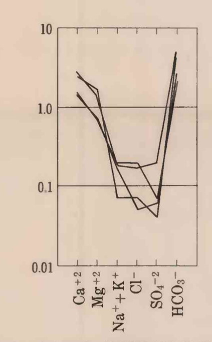
SANDSTONE AQUIFER, GENERALLY OVERLAIN BY THICK OUTWASH SAND AND GRAVEL

This water from sandstone overlain by permeable outwash is very low in mineralization. The water is similar in quality to water in the outwash because recharge is rapid to the sandstone through the outwash.



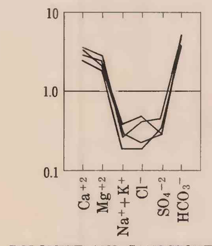
SAND AND GRAVEL AQUIFER

This water in the drift has moderately high mineralization composed mainly of Ca^{+2}, Mg^{+2}, and HCO_3^- derived from calcareous ground moraine. Three wells show slight base exchange of Na^+ and K^+ for Ca^{+2} and Mg^{+2}, which is common where water rich in Ca^{+2} and Mg^{+2} comes in contact with clay minerals in the glacial till.



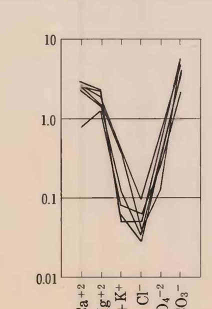
SANDSTONE AQUIFER, GENERALLY OVERLAIN BY THICK DRIFT WITH LITTLE SAND AND GRAVEL

Water from these deep wells in sandstone has more Ca^{+2}, Mg^{+2}, and HCO_3^- than water from shallower sandstone wells to the east. SO_4^{-2} is low, but amounts vary, as do Na^+, K^+, and Cl^-.



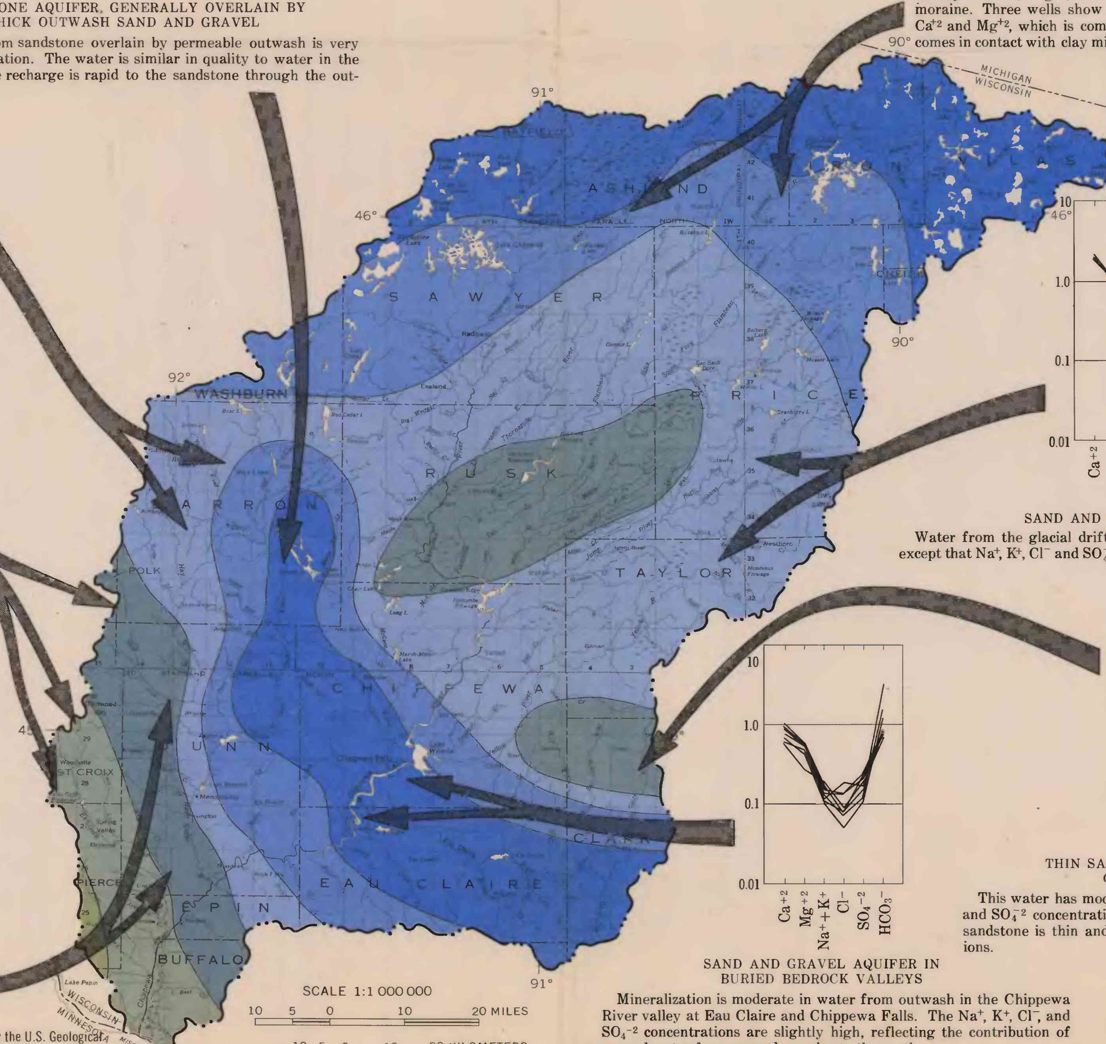
DOLOMITE AND SANDSTONE OF THE SANDSTONE AQUIFER

Water from the dolomite is highly mineralized and has the highest concentrations of Mg^{+2} and Ca^{+2} in the basin. Concentrations of all constituents generally are higher than elsewhere in the basin.



SANDSTONE AQUIFER NEAR DOLOMITE CAP ROCK

The high mineralization and Mg^{+2} to Ca^{+2} ratio of this water from deep sandstone wells indicates the influence of dolomite on the water quality in the sandstone.



REGIONAL QUALITY OF GROUND WATER

SAND AND GRAVEL AQUIFER

Water from the glacial drift is very similar to that to the north, except that Na^+, K^+, Cl^- and SO_4^{-2} are slightly higher.

THIN SANDSTONE AQUIFER OVERLYING CRYSTALLINE BEDROCK

This water has moderately high mineralization. The Na^+, K^+, Cl^-, and SO_4^{-2} concentrations are higher than in most of the basin. The sandstone is thin and is overlain by clayey till, the source of these ions.

SAND AND GRAVEL AQUIFER IN BURIED BEDROCK VALLEYS

Mineralization is moderate in water from outwash in the Chippewa River valley at Eau Claire and Chippewa Falls. The Na^+, K^+, Cl^-, and SO_4^{-2} concentrations are slightly high, reflecting the contribution of ground water from ground moraine to the north.

EXPLANATION

Concentration of dissolved solids, in milligrams per liter

Less than 100

100-150

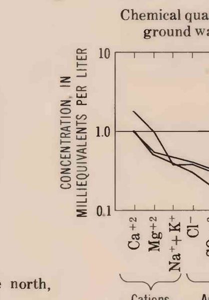
150-200

200-250

250-300

More than 300

Chemical quality of ground water



Surface-water divide

Dissolved solids, indicative of hardness, vary considerably throughout the basin. The main constituents of the water are calcium, magnesium, and bicarbonate, which are derived primarily from limestone and dolomite (magnesium limestone) and glacial drift containing these rocks.

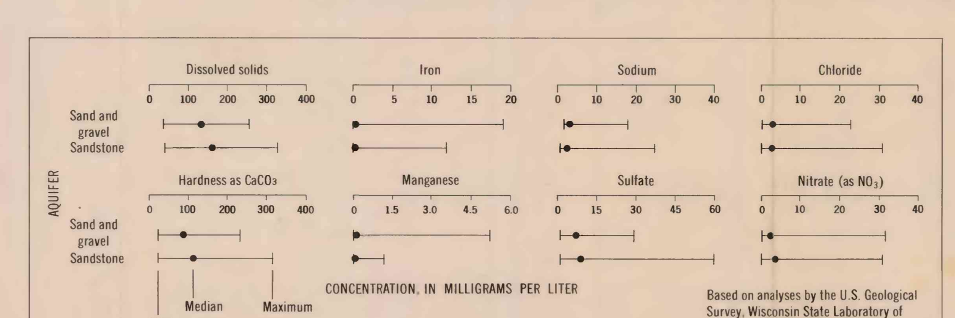
The highest concentration of dissolved solids in ground water in the basin is in the uplands along the southwestern basin boundary. Ground water in the sandstone is highly mineralized by infiltration of recharge through the overlying dolomite. The deep water table in this area causes long transit times for recharge infiltrating to the saturated zone.

The concentration of dissolved solids is high in the central part of the basin, an area of calcareous ground moraine. Ground water dissolves much material from the fine sediments because they retard water movement and have a large surface area.

The lowest concentrations of dissolved solids and hardness in ground water are in a broad, 20- to 30-mile wide belt in the northern part of the basin and in a 15- to 30-mile wide area in the southern and eastern parts. These areas are primarily outwash sand and gravel where rapid ground-water movement through the coarse-grained sediments results in low dissolved solids.

The ground water in the outwash above the sandstone in the Chippewa and Red Cedar valleys is low in dissolved solids content; however, the values are not used on the map because of their localized nature.

Regional differences in ground-water quality are shown by the eight graphs, which contain representative analyses from many areas of the basin. Mineralization of the water is largely from the following ions: calcium (Ca^{+2}), magnesium (Mg^{+2}), and bicarbonate (HCO_3^-). The remaining ions shown, sodium (Na^+), potassium (K^+), chloride (Cl^-), and sulfate (SO_4^{-2}), are much lower in concentration and generally are more variable in occurrence within areas.



QUALITY OF WATER BY AQUIFER

The overall quality of ground water in the basin is excellent, as indicated by the low median concentrations of these chemical constituents and physical properties of the water. The chemical quality of water from the glacial drift and the sandstone is very similar. Water from the sandstone is slightly more mineralized and slightly harder than water from the drift; however, hardness is only a minor problem because it can be reduced readily by softening. Maximum iron and manganese concentrations are greater in the drift than in the sandstone.

High concentration of iron or manganese is the most common ground-water quality problem. The presence of objectionable quantities of iron and manganese generally is unpredictable, and water from wells close together may have large differences in concentrations of these constituents. Drinking water standards of the U.S. Public Health Service (1962) suggest maximum allowable concentrations of 0.3 mg/l of iron and 0.05 mg/l of manganese. The standards are based on the levels that may produce objectionable taste and stains. Although median concentrations of these constituents in the basin are far less than the standards, some local supplies contain iron in quantities that greatly exceed the standards. Eau Claire is an example where treatment is necessary to reduce the concentrations of iron and manganese in the municipal supply.

The concentration of nitrate in ground water of the basin generally is low. The higher concentrations, above about 10 mg/l, probably are not from natural sources but may be from contamination by organic wastes. The drinking water standards recommend that nitrate content be less than 45 mg/l because of the association of nitrate with the occurrence of methemoglobinemia in infants.

All analyses show low concentrations of sodium, chloride and sulfate. The maximum concentrations being 25, 30, and 60 mg/l, respectively. The maximum concentration of sulfate is from a well in a very shaly sandstone at Elk Mound in eastern Dunn County.

Base from U.S. Geological Survey
1:500 000, 1968

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972—W70138

WATER RESOURCES OF WISCONSIN—CHIPPEWA RIVER BASIN

By
H. L. Young and S. M. Hindall

1972