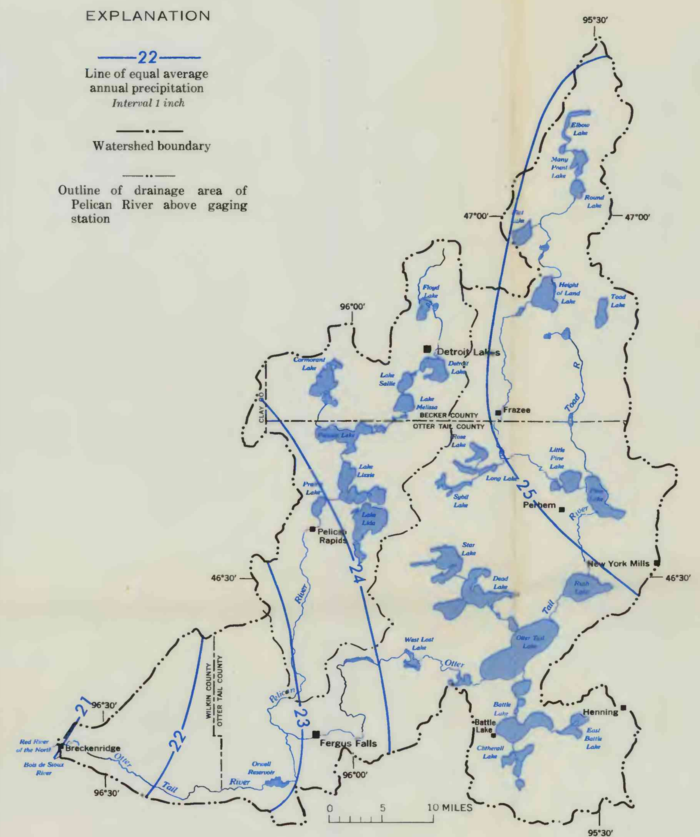
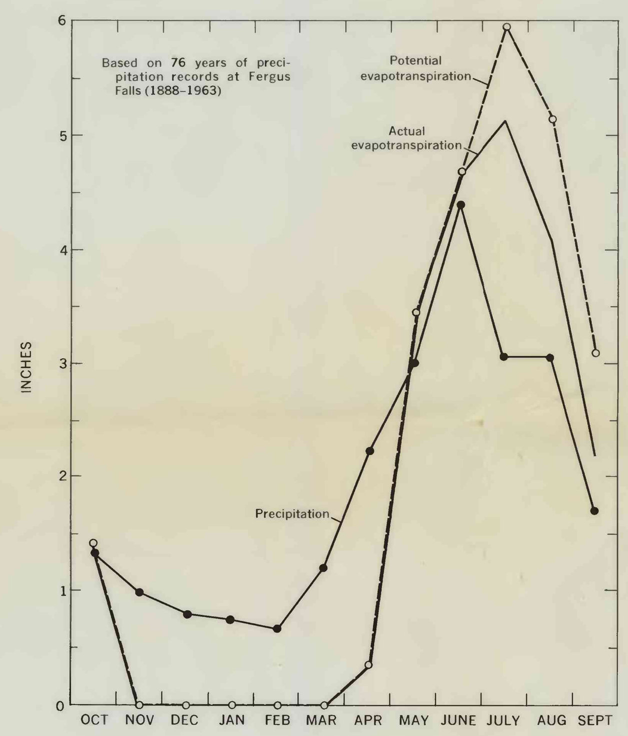
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS AND MINERALS

CLIMATE AND WATER USE

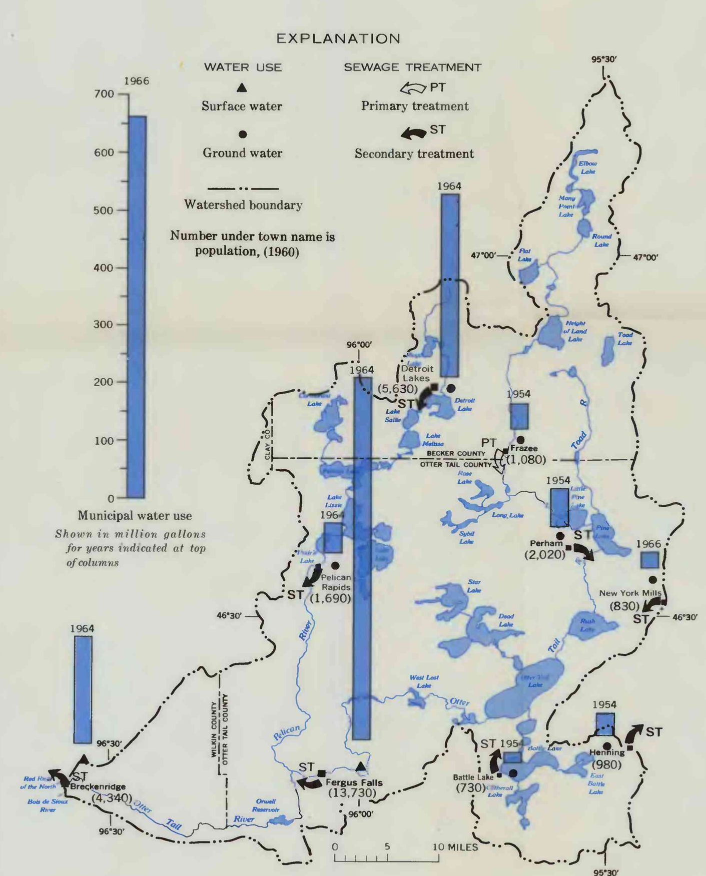


AVERAGE ANNUAL PRECIPITATION RANGES FROM 21 INCHES NEAR BRECKENRIDGE TO MORE THAN 25 INCHES IN THE NORTHEAST PART OF THE WATERSHED.—*The area is characterized by a continental climate which has cold winters and warm to hot summers, scanty winter precipitation, and normally sufficient summer rainfall for crops. The rainfall during the summer months occurs largely as thunderstorms. Annual average snowfall is slightly more than 40 inches per year.*

About 24 inches annual precipitation occurs in the Pelican River drainage area which was used in the estimation of water yield.

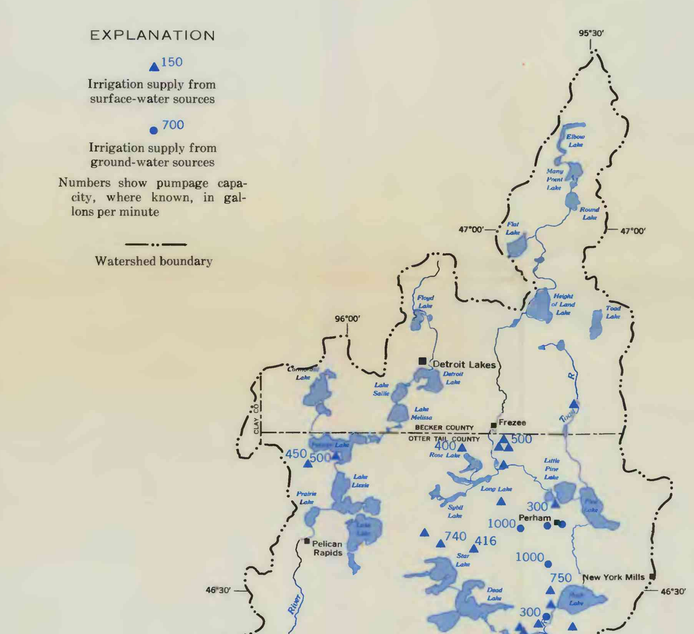


ACTUAL EVAPOTRANSPIRATION APPROXIMATES POTENTIAL EVAPOTRANSPIRATION FOR ALL MONTHS OF THE YEAR, ON AN AVERAGE, EXCEPT JULY, AUGUST, AND SEPTEMBER WHEN IT IS ONE HALF TO ONE INCH LESS PER MONTH.—*Actual evapotranspiration is greater than precipitation from May through October. This estimation of potential and actual evapotranspiration was computed by the method described by Thornthwaite and Mather (1957), which is based on the monthly precipitation, mean temperature for the month, and an average capacity for moisture storage in soils, estimated for this watershed to be 6 inches.*



THE LARGEST SINGLE USER OF WATER IN THE WATERSHED, FERGUS FALLS, OBTAINS ITS WATER FROM THE OTTER TAIL RIVER.—*However, most communities obtain their water from underground sources because ground water is the most economical source and requires less treatment.*

All municipalities with sewage systems have sewage treatment facilities.



IRRIGATION IS PRACTICED LARGELY IN THE SANDY OUTWASH PLAIN IN THE SOUTHEASTERN PART OF THE WATERSHED.—*Most of the water is obtained from surface sources. Irrigators report pumpage capacities ranging from about 200 to 2,000 gallons per minute. Irrigation is largely supplemental and pumpage varies considerably from year to year.*

PHYSICAL SETTING AND SUMMARY

EXPLANATION

Till (moraine)
Clay-silt loam, sandy and contains some gravel and boulders. The till is generally sandier in the eastern part of the watershed. The topography ranges from gently rolling to steep. Slopes are well drained, but there are numerous closed depressions—often containing a marsh or lake. Water erosion is moderate in most flat or rolling cultivated areas where contour plowing is practiced. Locally, deep erosional gullies occur on steep slopes where the natural tree cover is removed and the land is cultivated

Till (lake-washed)
Clay-loam, silty and sandy, containing some gravel and boulders. The area is flat and natural drainage is poor; however, drainage ditches remove some of the storm runoff. The area is largely cultivated for small grains

Sand and gravel (ice-contact)
Sandy loams to gravelly sandy loams. Sandy till may occur locally within this area. The topography is generally moderately rolling to steep. The soils are well drained and have low capacity for moisture storage causing a moderate to severe drought hazard. The area is not intensively cultivated in the rolling and steep areas

Sand and gravel mixed with till (ice-contact)
Sandy loams, gravelly sandy loams and clay-silt loams. Clay-silt loams formed on till are interspersed throughout the area so that soil types vary within short distances

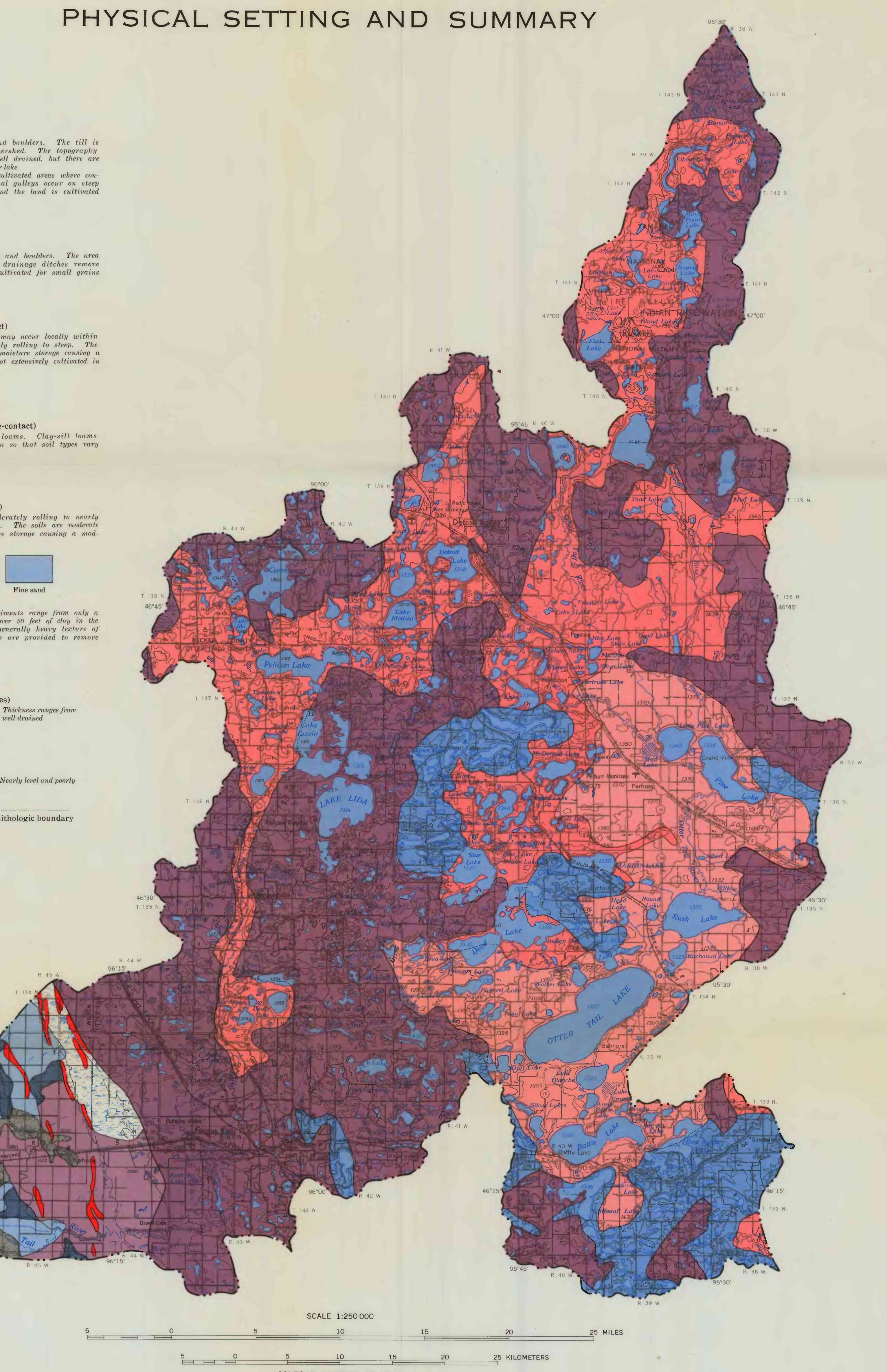
Sand and gravel (outwash)
Sandy loam and loamy sand. Topography is moderately rolling to nearly level, but is relatively steep near lakes and streams. The soils are moderate to well drained and have low to moderate capacity for moisture storage causing a moderate to severe drought hazard during dry-weather periods

Clay — Silt — Fine sand
(Lake Agassiz sediments)
Clay to loamy fine sand underlain by till. The sediments range from only a few feet of sand in the eastern part of the area to over 50 feet of clay in the western part. The nearly level topography and generally heavy texture of the soils causes poor natural drainage. Ditches are provided to remove storm runoff. Most of the area is cultivated

Sand and gravel (beach ridges)
Loamy sand to gravelly sandy loam underlain by till. Thickness ranges from a few feet to more than 15 feet. The soils are well drained

Peat
Generally only a few feet thick and underlain by till. Poorly drained and poorly drained. Springs are common

Physiographic boundary
Lithologic boundary
Watershed boundary



Base from U.S. Geological Survey, 1:250 000 series: Grand Forks, 1952; Fargo, 1953–64; Bemidji, 1954–65; and Brainerd 1953–65

THE OTTER TAIL RIVER WATERSHED INCLUDES THREE GENERAL PHYSIOGRAPHIC AREAS—A MORAINE AND ICE-CONTACT AREA, AN OUTWASH PLAIN, AND THE PLAIN OF GLACIAL LAKE AGASSIZ

The moraine and ice-contact area is a fairly rugged complex of hills characterized by local relief of several hundred feet in some areas, particularly in the extreme north and southeastern parts of the watershed. The outwash plain is fairly flat to rolling and the Glacial Lake Agassiz plain is extremely flat.

The watershed has an area of about 1,920 square miles and includes parts of Becker, Otter Tail, Wilkin, and Clearwater Counties. The population of the area is about 55,500; 32,600 urban and 22,900 rural. The economy is largely agricultural. Grain farming is dominant, but dairying is important.

The extremely large number of lakes in the area provides a basis for a large recreation-based economy.

SUMMARY OF WATER RESOURCES

Purpose	Consideration	Surface water: Otter Tail and Pelican Rivers	Surface water: Large lakes	Surface water: Small lakes and minor streams	Ground water: Sand lenses within till	Ground water: Sand and gravel (ice-contact and outwash)
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity 1. Minimum sustained flow of 1 cfs or 450 gpm. Quality 1. Total dissolved-solids content less than 500 ppm. 2. Iron concentration less than 0.3 ppm. 3. Hardness less than 180 ppm.	Generally adequate flow in Otter Tail River. Additional storage possible. Favorable location—largest cities and industries located near rivers. Total dissolved solids less than 500 ppm. Iron content less than 0.3 ppm. — Additional storage needed for Pelican River during droughts. At low flow, water is very hard. Treatment necessary.	Adequate for most uses. Additional storage possible. Good surface- and ground-water inflow. Total dissolved solids less than 500 ppm. Iron content generally less than 0.3 ppm. — Water is generally very hard. Treatment necessary.	Some are adequate if storage facilities are developed. Wide areal distribution. Total dissolved solids less than 500 ppm. Iron content generally less than 0.3 ppm. — Some dry up during severe droughts. Water is generally very hard. Treatment necessary.	Some sand and gravel lenses within the till will yield 450 gpm to several wells. Total dissolved-solids content varies, but is generally less than 500 ppm. — Test drilling is usually required to find sand lenses that will yield several hundred gpm to individual wells. Lenses generally do not have large areal extent. Iron concentration is usually greater than 0.3 ppm. Hardness is usually greater than 180 ppm.	Potential yield to individual wells several hundred gpm at many places. Large areal extent. Total dissolved-solids content generally less than 500 ppm. — Iron and hardness concentration is greater than recommended limits.
Rural domestic and stock supply	For an adequate farm supply, needs are: Quantity 1. About 5 gpm or more. Quality 1. Total dissolved-solids content less than 1,000 ppm.	Adequate flow. Suitable quality. — Available only to riparian lands. No flow on lower Pelican River during severe cold winter following season of low flow. Treatment necessary for domestic use.	Adequate supply. Suitable quality. — Available only to riparian lands. Treatment necessary for domestic use.	Most are adequate for stock. Suitable quality. — Available only to riparian lands. Some dry up during droughts. Treatment necessary for domestic use.	Sand lenses that will yield more than 5 gpm to individual wells can be found at most places in the area. Total dissolved-solids content is rarely greater than 1,000 ppm. — Sand lenses usually have small areal extent. Iron content and hardness are high for domestic use.	Adequate yields. Large areal extent. Total dissolved-solids content less than 1,000 ppm. — Iron and hardness concentration is greater than recommended limits.
Irrigation supply	For an average farm, needs are: Quantity 1. Minimum flow of 2 cfs during growing season or wells yielding 250 gpm or more. Quality 1. Total dissolved-solids content less than 2,000 ppm. 2. Percent sodium less than 70. 3. Boron content less than 3 ppm.	Adequate flow. Additional storage possible. Suitable quality. — Restricted to riparian lands.	Adequate supply during years of normal wetness. Additional storage possible. Suitable quality. — Restricted to riparian lands. High evaporation losses.	Some are adequate for small acreage during years of normal wetness with development of storage facilities. Suitable quality. — Restricted to riparian lands. Limited inflow. High evaporation losses.	Some sand and gravel lenses will yield over 100 gpm to individual wells. Suitable quality. — Test drilling is usually required to find lenses that will yield over 100 gpm to individual wells. Lenses usually do not have large areal extent.	Potential yield to individual wells several hundred gpm at many places. Large areal extent. Suitable quality.
Hunting and fishing	Adequate access to hunting and fishing areas. Adequate cover for wildlife habitat is provided by: 1. Wetlands—potholes or lakes surrounded by marsh areas. 2. Streams which have woodland and marsh areas along banks. Adequate depth and quality of water for fish in lakes and streams.	Public access at many sites. Good migratory waterfowl resting and feeding areas. Some game refuges. Good fishing conditions. Excellent habitat along banks. Suitable quality. — Occasional high water.	Public access at many sites. Excellent migratory waterfowl nesting, resting, and feeding areas. Excellent fishing conditions. Favorable habitat in marsh areas and along shores. Suitable quality. — Occasional change in stage.	Public access at some sites. Good migratory waterfowl nesting, resting, and feeding areas. Some game refuges. Many are suitable for fishing and hunting. Wide areal distribution. Suitable quality. — Occasional high water. Shallow. Some dry up during droughts.		
Other recreation	Adequate access to lakes and streams. Availability of areas suitable for water sports. Available resorts and lake cottages. Aesthetic considerations: 1. Absence of odors. 2. Sightliness. 3. Attractive physical setting. 4. Absence of pollution.	Public access at some sites. Suitable for canoeing and boating. Favorable location with respect to population. Aesthetic considerations generally good. Suitable quality. — Occasional high water.	Public access and many sites suitable for canoeing, boating, and other water sports. Many lakeshore resorts and cottages. Favorable location with respect to population. Aesthetic values generally good. Generally suitable quality. — Occasional change in stage.	Public access at some sites. Many small lakes suitable for canoeing, boating, and other water sports. Wide areal distribution. Generally suitable quality. — Occasional high water. Shallow. Some go dry during droughts. Many small lakes poor for swimming at certain times of the year because of algal blooms.		

EXPLANATION

Good — Fair — Poor
Overall evaluation for purposes and considerations indicated

Adequate flow. Additional storage possible. Suitable quality. — Advantages
Restricted to riparian lands. — Disadvantages

CONCLUSIONS

1. Ground water in the deeper part of the ground-water reservoir, regionally, moves westward from the ground-water divide in the central part of watershed to the lake plain drained by the Red River of the North. Locally, ground water moves toward depressions and valleys within the uplands.
2. Large amounts of water are available from sand and gravel deposits along the Otter Tail River. Yields of more than 1,000 gallons per minute may be developed in some places.
3. At most places in the watershed, ground water has low sodium hazard and medium salinity hazard. These waters are suitable for irrigation on most soils.
4. Ground water in the watershed generally is very hard, having a hardness greater than 200 parts per million.
5. Annual runoff from the Pelican River drainage area ranges from less than 0.6 inch to more than 3.7 and averages about 1.9 inch. Most of the runoff occurs during spring and summer. Annual runoff is largely determined by precipitation and seasonal temperature during the spring and summer.
6. The Otter Tail River, Pelican River, major tributaries, and many lakes provide an abundance of water of good quality for most uses if storage and transmission facilities were constructed. Average annual evaporation of about 2.1 cubic feet per second per square mile of lake or reservoir surface must be considered in design of storage reservoir or other aspects of water management.
7. The runoff from the headwaters region is more than twice that from the lake plain area.
8. The natural streamflow of the Otter Tail River above Fergus Falls is more uniform than the Pelican River because it has greater storage in lakes, swamps, and permeable outwash deposits. However, the 200 days of no flow on the Pelican River near Fergus Falls since 1943 occurred during the severe winters (1946, 1949, 1950), as the result of freezeup.
9. Length of streamflow records prevent the defining of the frequency of recurrence of low flows such as occurred during the drought of the 1930's.
10. Generally, the most uniform daily discharge occurs just prior to spring breakup and, in contrast, the least uniform occurs during the summer.
11. The large ground-water reservoir and many lakes and swamps are effective in reducing peak flows, the maximum stages have mostly been caused by ice jams. Streams in the lake region in the upper part of the watershed seldom overflow their banks.
12. Lakes and streams in the Otter Tail area are among the most heavily used in the upper midwest because of the many recreational facilities.
13. Lakes in the watershed are classified by their geologic and geomorphic setting into three types: 1. Lakes in very hilly glacial moraine underlain by till, 2. Lakes in ice-contact or outwash areas underlain by sand and gravel, and 3. Lakes in gently rolling glacial moraine underlain by till.
14. The Otter Tail River above Orwell Dam is very favorable for canoeing most summers, although the large lakes on the Otter Tail can be dangerous because of sudden high waves caused by sudden thunderstorms. Wildlife and varying vegetation and physical settings along the stream add to enjoyable canoeing.

ACKNOWLEDGMENT

We wish to thank the well owners and well drillers in the area for their cooperation in providing data for this study.

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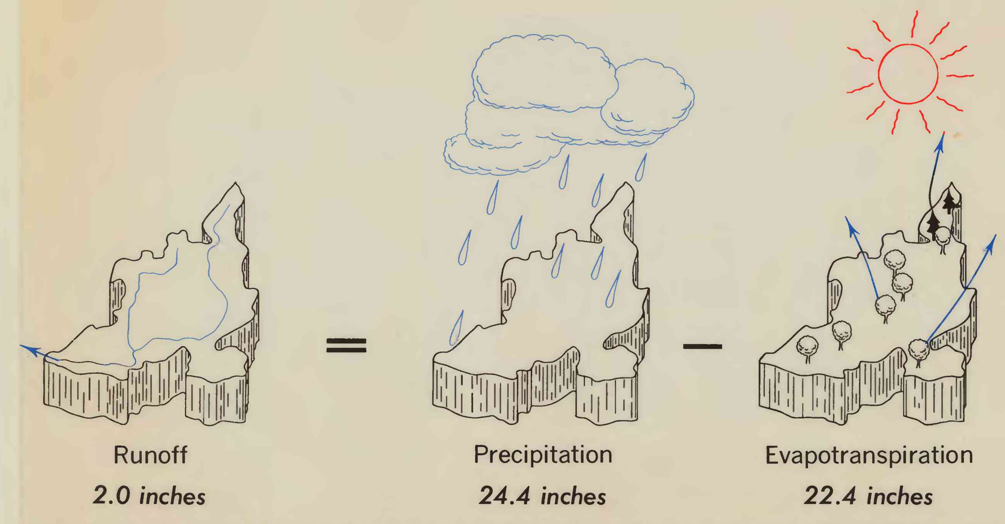
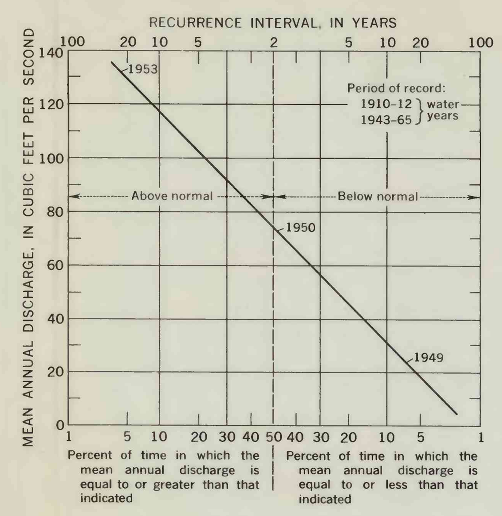
WATER YIELD



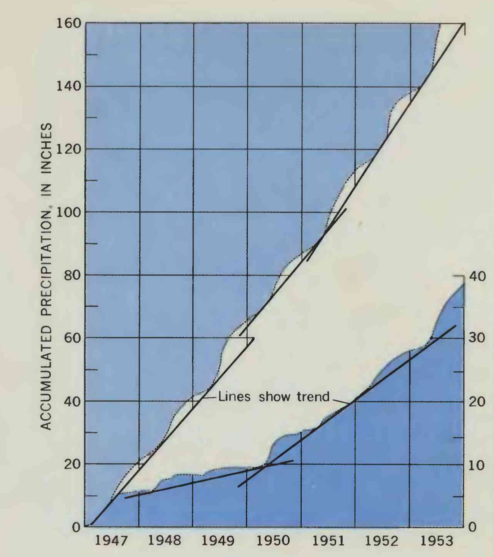
MOST OF THE WATER THAT FALLS AS PRECIPITATION IS RETURNED TO THE ATMOSPHERE BY EVAPOTRANSPIRATION

The remainder, which is available for man's use, either runs off as streamflow or seeps down to the ground-water reservoir. Water from the ground-water reservoir reappears as surface-water runoff during periods of baseflow. Long-term changes in storage in the ground-water reservoir are negligible. The figures shown are a long term average (21 years) and considerable variation occurs from year to year. As an example of the variation, a comparison was made of the precipitation-temperature-runoff relationships for three individual years on the Pelican River in the basin above the gaging station near Fergus Falls.

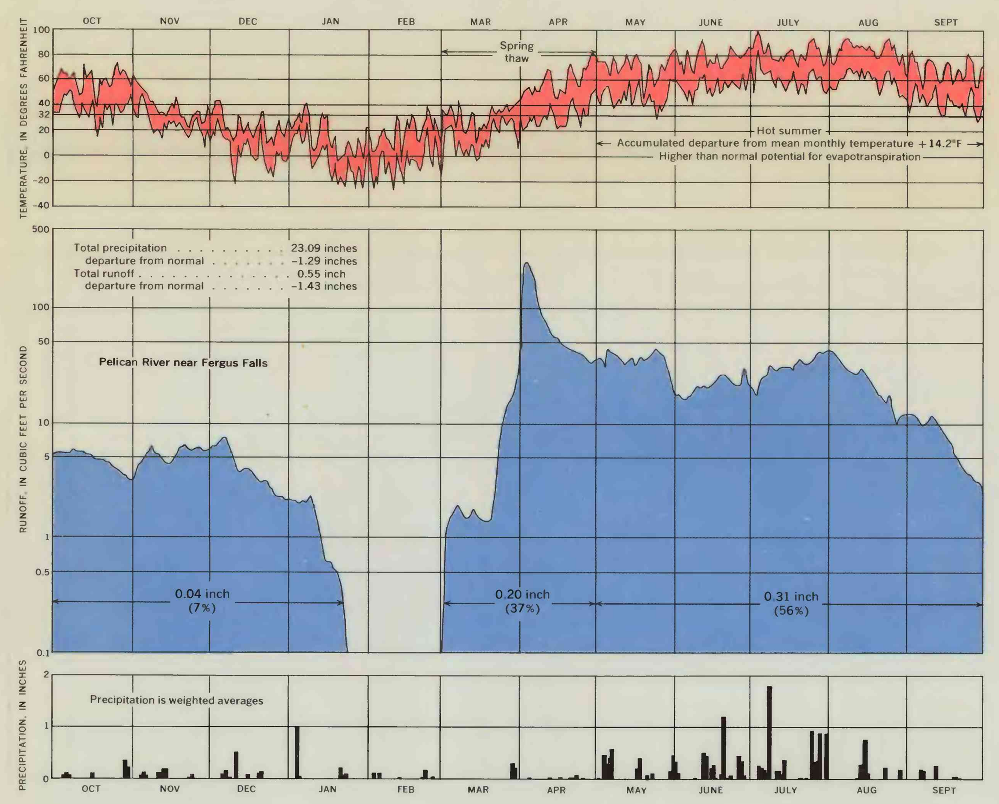


FREQUENCY DISTRIBUTION OF MEAN ANNUAL DISCHARGE OF PELICAN RIVER SHOWS THAT DISCHARGE OF ABOUT 70 CUBIC FEET PER SECOND MAY BE EXPECTED TO OCCUR ON AN AVERAGE OF ABOUT ONCE IN 2 YEARS.—*A high mean annual discharge of about 130 cubic feet per second and low mean annual discharge of 20 cubic feet per second may be expected to occur on an average of once in 20 years.*

The years shown on the graph were selected to estimate water yield for a wide range of discharge.

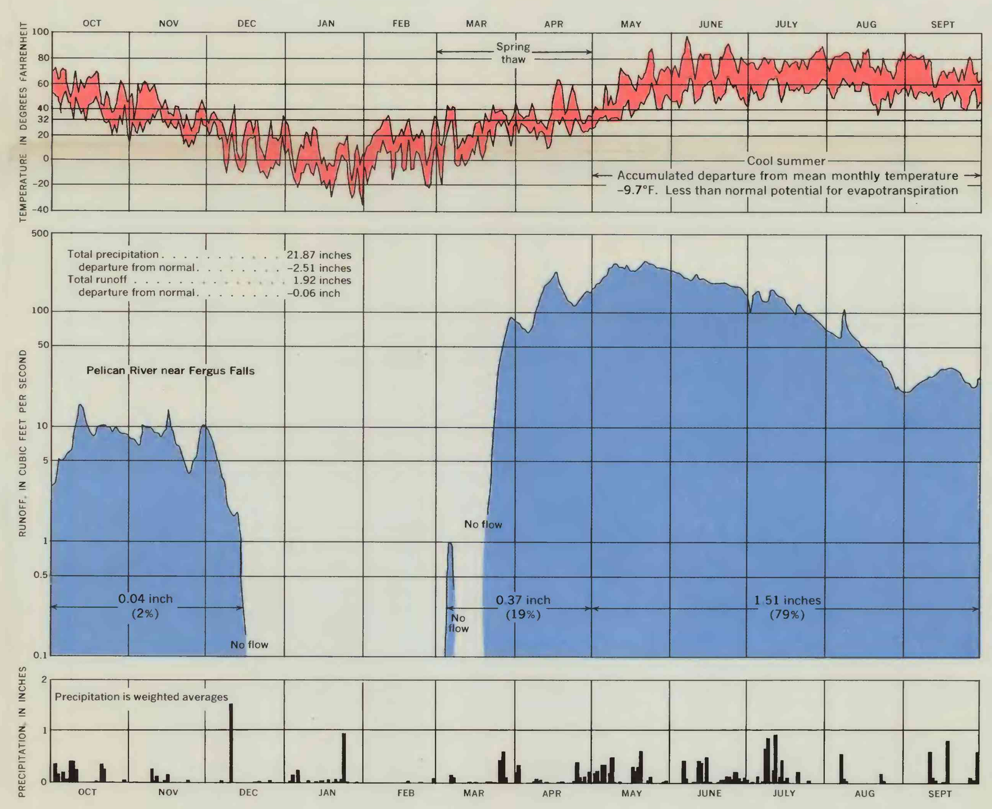


LESS THAN NORMAL PRECIPITATION IN THE PELICAN RIVER BASIN DURING 1947 AND 1948 IS REFLECTED IN BELOW NORMAL RUNOFF FOR 1949.—*Increased precipitation during 1949 resulted in a slight increase of stream runoff in 1950. A moderate increase in precipitation from 1950 to 1953 caused a substantial increase in runoff.*



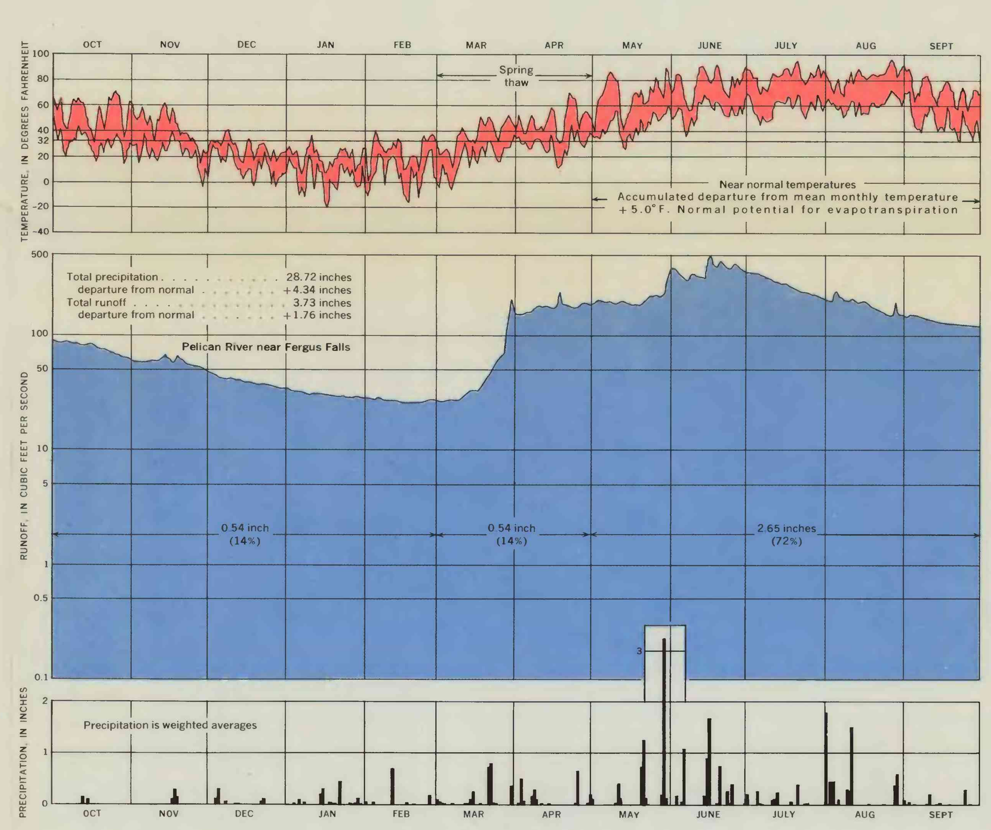
RUNOFF IN WATER YEAR 1949 WAS BELOW NORMAL

Although the precipitation during the growing season was greater than normal, runoff was less than normal because of high evapotranspiration losses due to high temperatures. Precipitation, which was less than normal in 1947 and 1948, was not adequate to maintain normal lake levels and ground-water storage. The depleted ground-water reservoir was inadequate to maintain streamflow during the winter when seeps and springs were frozen.



RUNOFF IN WATER YEAR 1950 WAS NEAR NORMAL

Precipitation during the growing season was less than normal but evapotranspiration was considerably less than normal due to relatively low temperatures during this time. Less than normal runoff during the non-growing season reflects the relatively low storage of water within the watershed.



RUNOFF IN WATER YEAR 1953 WAS ABOVE NORMAL

Precipitation during the growing season was much above normal and evapotranspiration losses were about normal; consequently, more water was available for runoff. Water stored within the watershed increased during 1951 and 1952 which resulted in a higher rate of baseflow throughout the year.

WATER RESOURCES OF THE OTTER TAIL RIVER WATERSHED, WEST-CENTRAL MINNESOTA

By
T. C. Winter, L. E. Bieda, and R. W. Maclay

1969