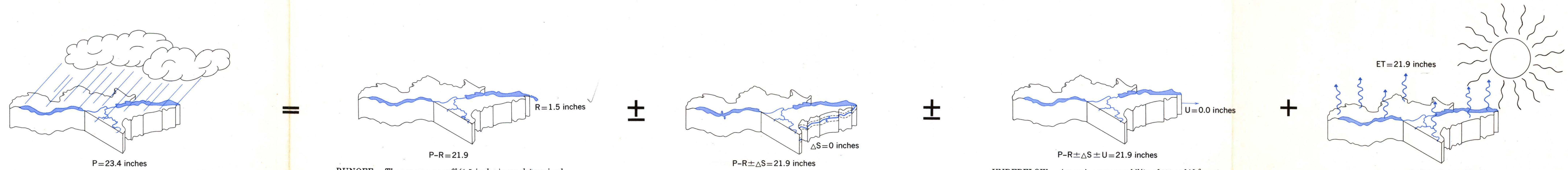
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS

23.4
1.5
21.9
Runoff
Evap.

THE WATER CYCLE



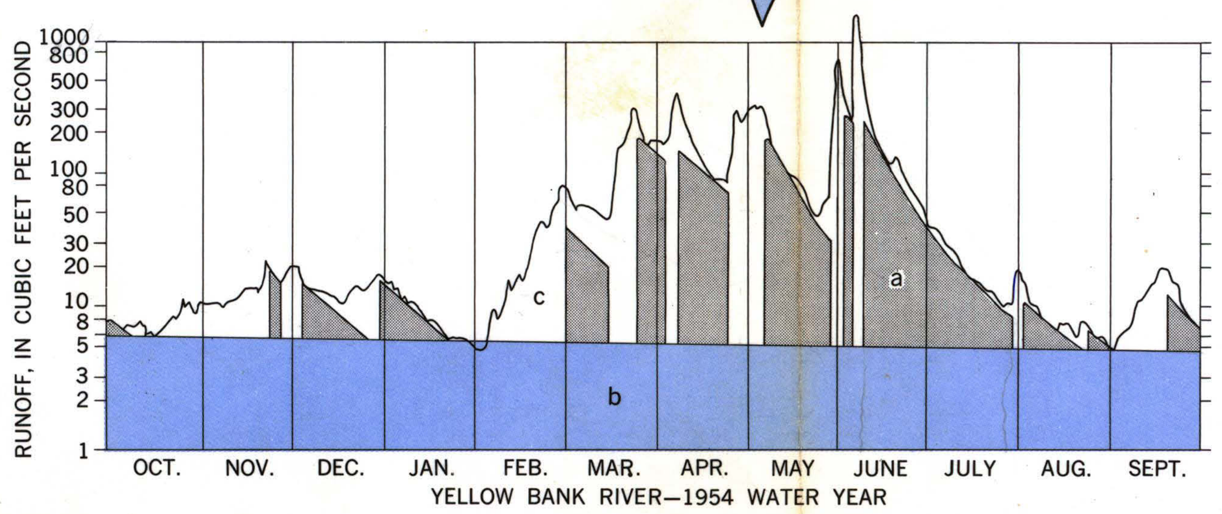
PRECIPITATION.—*The average annual precipitation (23.4 inches) for the 18-year period (1945–62) was determined by arithmetic mean using 6 weather bureau stations*

RUNOFF.—*The average runoff (1.5 inches) was determined by subtracting all stream flow originating outside of the watershed from the flow of the Minnesota River at Lac qui Parle*

CHANGE IN STORAGE.—*For the 18-year period it is assumed that gains in ground- and surface-water storage were balanced by losses. (Change=0)*

UNDERFLOW.—*Assuming a permeability of 100 gpd/ft², and a saturated thickness of 50 feet, the underflow at the basin outlet is negligible in relation to other quantities (Underflow=0)*

EVAPOTRANSPIRATION.—*The average evapotranspiration, obtained from the equation, is 21.9 inches*



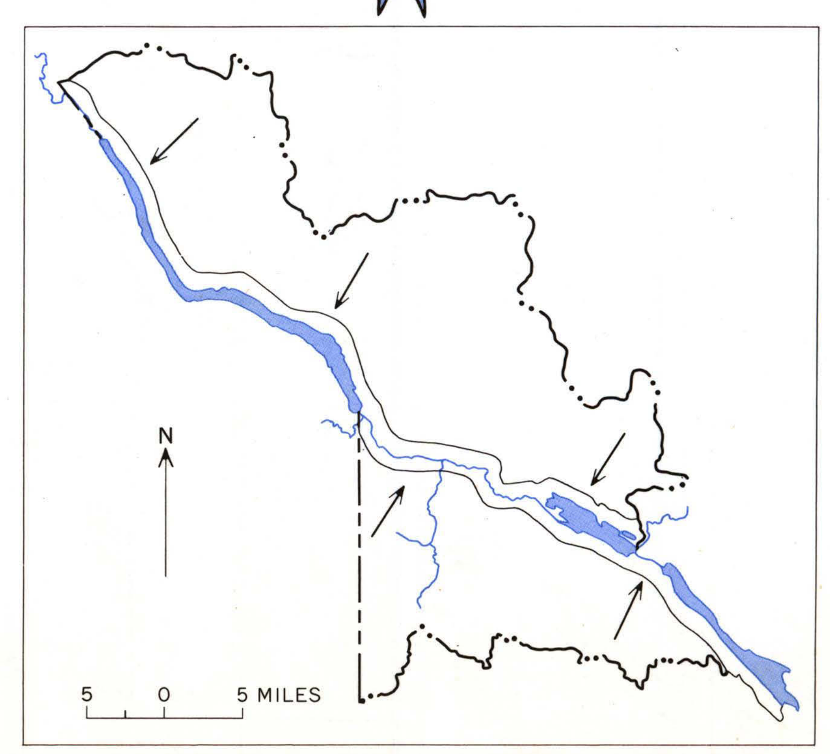
RUNOFF OF A STREAM IS DERIVED FROM WATER IN STORAGE AND FROM DIRECT OVERLAND RUNOFF OF PRECIPITATION.—*In the above figure, runoff components were estimated for the Yellow Bank River using Kunkle's (1962) hydrograph separation method.*

a — *37% of the total stream-flow is contributed from the area adjacent to the stream channel—about 10% of the total area of the watershed. This 37% consists of (1) water stored on the flood plain, (2) water that entered the ground-water reservoir from the stream, remained for a period of a few days to a few weeks, and gradually discharged back into the stream, and (3) a small amount of water added to the ground-water reservoir from precipitation on the flood plain (Flashy, varies with river stage).*

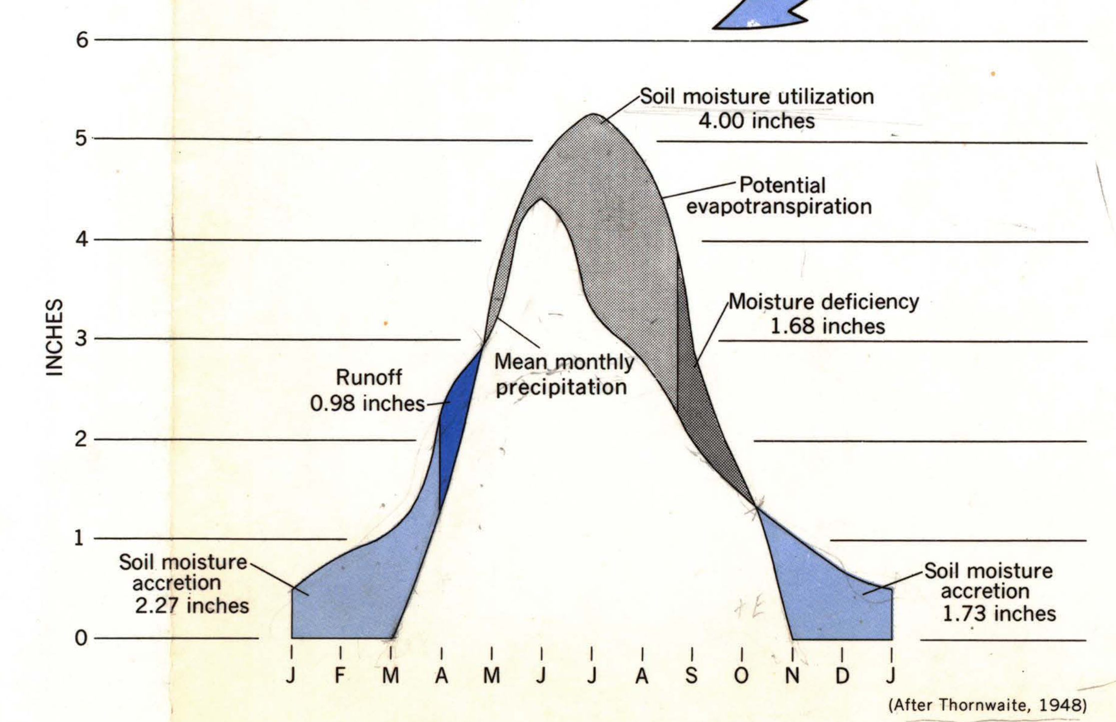
b — *7% of the total streamflow (basin storage discharge) is contributed from the area away from the stream channel—about 90% of the total area of the watershed. This 7% consists of water added to the ground-water reservoir from precipitation on the watershed area beyond the flood plain (Fairly constant, affected only by long-term climatic changes).*

c — *56% of the total streamflow is contributed from overland runoff (Flashy, varies with precipitation and season).*

For the same year and method, an analysis of the Whetstone River hydrograph showed, a=41%; b=11%; and c=48% of the total flow



THE DISCHARGE FROM BASIN STORAGE WAS CALCULATED, USING DARCY'S LAW, TO BE 7 PERCENT OF THE TOTAL RUNOFF.—*The cross-sectional area was selected about 1 mile from the river to avoid contributions from bank storage and rapid recharge from the more permeable valley deposits.*



EVAPOTRANSPIRATION DURING THE YEAR FOR THE BIG STONE LAKE WATERSHED FOR 1945–62 WAS COMPUTED BY THORNWAITE'S (1948) METHOD.—*The diagram shows some departure between the calculated runoff and measured runoff for the watershed. Meyer's (1944) method allows the following breakdown of evapotranspiration for the watershed. Evapotranspiration from land=56%; evapotranspiration from water=11%; transpiration=33%.*

CONCLUSIONS

GROUND WATER

1. Ground water in the watershed is from three principal aquifers.
   a. Near-surface sand and gravel aquifers are spotty throughout the watershed, but have the highest well yields. These aquifers, which are commonly exposed at the surface, receive high recharge but are more easily contaminated. The water is hard and commonly high in iron.
   b. Buried sand and gravel aquifers are present throughout most of the watershed. Well yields are low to moderate; the water is hard, and is commonly high in iron.
   c. Most of the wells in Cretaceous aquifers are in the northwest and southwest parts of the watershed. Yields are small to moderate. Most of the water is relatively soft and low in iron, but high in chloride, sulfate, sodium, and boron.
2. More ground water is available than is presently being pumped (1.4 mgd), or than is presently being discharged to surface water (3.5 mgd). Water can be salvaged from evapotranspiration losses by lowering the water table where it is near the land surface. However, lowering of the water table may result in changes in vegetation and wildlife habitat.

Aquifer	Estimated discharge to surface water (Million gallons per day)[1]	Estimated discharge to wells (mgd)[1]	Additional amount that could probably be developed by wells (mgd)[2]	Estimate of discharge to surface water (gpd/sq. mile)[1]	Estimated discharge to wells (gpd/sq. mile)[1]	Additional amount that could probably be developed by wells (gpd/sq. mile)[2]
Near-surface sand and gravel	3.5	0.9	over 4	50,000	13,000	over 60,000
Buried sand and gravel	negligible	0.4	over 12	negligible	600	over 15,000
Cretaceous sandstone	negligible	0.1	over 4	negligible	300	over 10,000

[1] These figures are probably accurate to within 50 percent

[2] These estimates are based on scanty information and should be considered only relative. They are much less reliable than figures on present discharge.

SUMMARY OF WATER RESOURCES IN THE BIG STONE LAKE WATERSHED

Use \ Source	Minnesota River and major tributaries	Reservoirs- Lac qui Parle Marsh Lake Big Stone Lake	Small lakes and minor streams	Near-surface sand and gravel	Buried sand and gravel	Cretaceous sandstone
Municipal and industrial supply	Favorable location Adequate flow with development of storage facilities ——— Storage necessary Treatment necessary No flow in droughts Flood damage	Favorable location Adequate storage capacity for present demand Adequate inflow Enlargement possible ——— Treatment necessary Limited usable storage capacity without further development	Wide distribution ——— Limited capacity Limited inflow Many dry up in droughts Treatment necessary	Several favorable locations High well yields Rapid recharge ——— Limited distribution	Wide distribution ——— Limited recharge Low to moderate well yields	Fair distribution ——— Quality often unsuitable Low well yields
Rural-domestic and stock supply	Adequate for stock ——— Restricted areal distribution Treatment necessary for domestic use No flow during droughts	Adequate storage capacity Adequate inflow ——— Restricted areal distribution Treatment necessary for domestic use	Wide distribution ——— Treatment necessary for domestic use Many dry up Limited inflow	Adequate well yields ——— Restricted areal distribution	Wide distribution Adequate well yields ———	Fair distribution Adequate well yields "Soft" water preferred by some ——— Quality may be undesirable May be better water at a shallower depth
Irrigation supply	Adequate flow with development of storage facilities ——— Storage required Low flow during irrigation season Restricted areal distribution	Adequate storage capacity Adequate inflow Enlargement possible ——— Restricted areal distribution Limited usable storage capacity without further development	Wide distribution ——— Limited storage capacity Limited inflow Many dry up during irrigation season	High well yields Rapid recharge ——— Restricted areal distribution Soil formed on aquifer may be too permeable to irrigate	Wide distribution ——— Limited recharge Low to moderate yields	Fair distribution ——— Limited recharge Low yields Quality often unsuitable
Recreation	Favorable location Suitable for fishing and hunting ——— Variation in flow	Adequate area and depth Favorable for hunting and watersports Camping sites at parks Enlargement possible ———	Wide distribution Favorable for water-sports on a few lakes Hunting areas on many lakes and swamps ——— Shallow Many dry up during droughts			
Fish and wildlife habitat	Suitable for wildlife along banks ——— Variable streamflow	Marsh areas suitable for wildlife habitat Conservation pools maintained ——— Floods	Scattered marsh areas Excellent for wildlite habitat ——— Shallow Many dry up			

EXPLANATION

Color—indicates relative worth of source over entire watershed

Good

Fair

Poor

SURFACE WATER

1. Natural streamflow has similar characteristics throughout the watershed.
2. All the major streams have little natural surface storage; they cease to flow during droughts, and they flood as the result of rapid snowmelt, ice jams, and excessive precipitation.
3. The mean annual evaporation from the three reservoirs is 89 cfs, and in comparison, is 70 percent of the average flow of the Minnesota River near Odessa.
4. Many of the small lakes and minor streams go dry and are of little importance for water supply.
5. The lakes, swamps, reservoirs, and streams are suitable for wildlife habitat, water sports, recreation areas, and hunting lands.
6. Surface water, although hard, is generally of good quality for most uses.

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