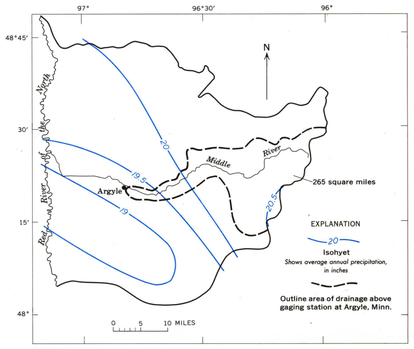
DEPARTMENT OF INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

HYDROLOGIC INVESTIGATIONS
ATLAS HA-201 (SHEET 3 OF 3)

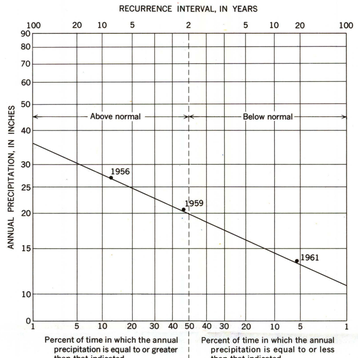
ESTIMATION OF WATER YIELD



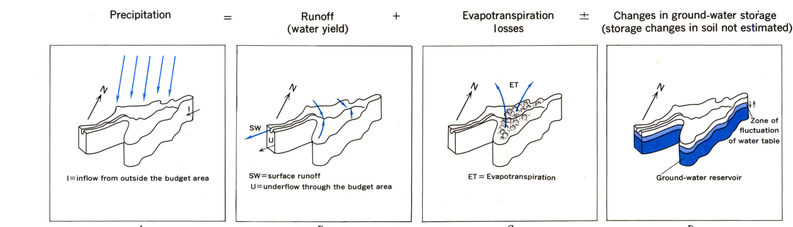
AVERAGE ANNUAL PRECIPITATION IN THE MIDDLE RIVER WATERSHED (1931–60)
Area of Middle River drainage above Argyle, Minnesota, used in the estimation of water yield

CLIMATIC SUMMARY.—*from Minnesota Division of Water, Bulletin 10.*

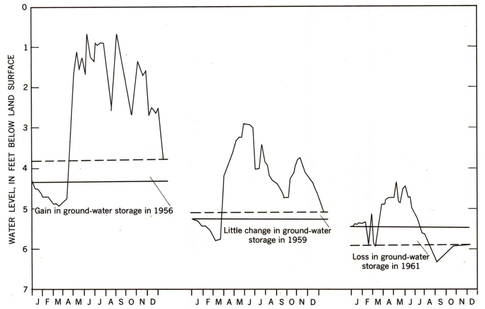
Station			Argyle	Angus 4 NNE	Hallock
Years of record			42	55	59
Temp °F		Maximum	107	108	109
		Mean annual	38.5	37.9	38.0
		Minimum	−43	−49	−51
Precipitation, in inches	Annual	Maximum year	28.25 1950	27.01 1941	30.92 1941
		Mean	19.06	18.73	20.07
		Minimum year	9.72 1936	7.81 1936	11.72 1952
		Snowfall	34.1	25.2	30.4
	Mean	Apr–Sept	14.54	14.50	15.15
		Oct–Mar	4.52	4.23	4.92
	Max. 24 hour		4.80 7–30–42	3.76 6–26–15	6.50 9–4–00



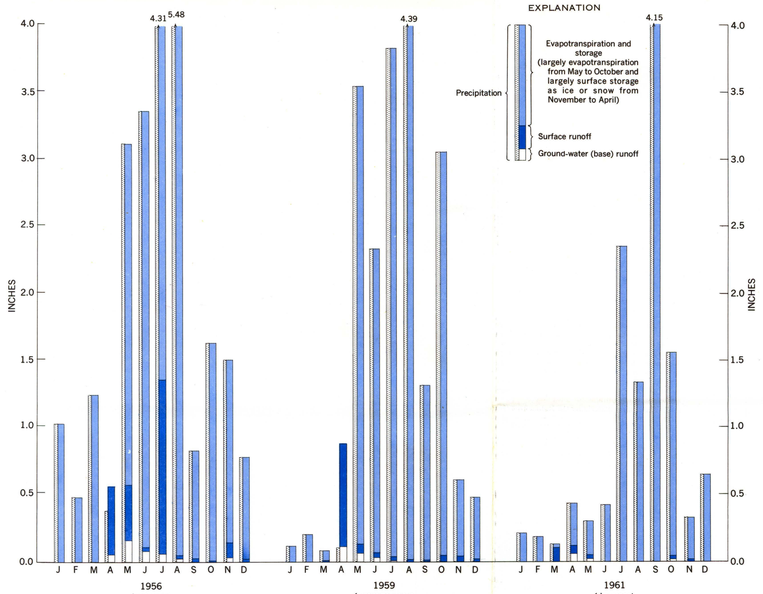
FREQUENCY DISTRIBUTION CURVE OF PRECIPITATION AT HALLOCK, MINNESOTA, —*Used to select years above and below average precipitation so that a comparison of estimated water yields could be made for a range of climatic conditions*



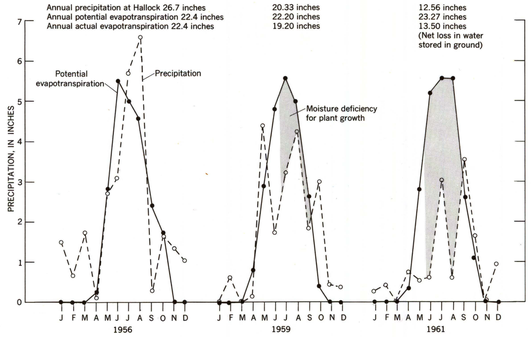
WATER YIELD IS DEPENDENT ON *A*, PRECIPITATION, *B*, SURFACE RUNOFF AND UNDERFLOW, *C*, EVAPOTRANSPIRATION, AND *D*, UNDERGROUND STORAGE



RELATIVE CHANGES IN GROUND-WATER STORAGE FOR 1956, 1959, AND 1961 ARE INDICATED BY DIFFERENCE IN WATER LEVELS BETWEEN THE BEGINNING AND END OF EACH YEAR.—*The water levels were measured in an observation well at Lake Bronson, Minnesota. Storage changes in the ground-water reservoir in the budget area are estimated to be less than those of the observation well because of the lower infiltration capacity of surficial deposits in the budget area*



WATER YIELD OCCURS LARGELY AS RUNOFF DURING SPRING AND EARLY SUMMER
Most precipitation is lost by evapotranspiration. Ground-water runoff is inadequate to sustain streamflow even during wet years



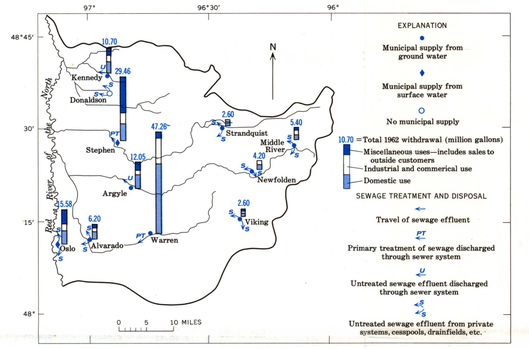
DURING YEARS OF AVERAGE AND BELOW AVERAGE PRECIPITATION THE ACTUAL EVAPOTRANSPIRATION CALCULATED BY USING THORNTHWAITE'S METHOD AGREES CLOSELY WITH VALUES COMPUTED BY RESIDUAL METHOD GIVEN IN THE SUMMARY BELOW

ANNUAL SUMMARY OF WATER BUDGET FOR MIDDLE RIVER DRAINAGE AREA ABOVE GAGING STATION AT ARGYLE (265 SQUARE MILES)

	Inches per square miles		
	1956	1959	1961
Annual precipitation (weighted average for budget area)	22.30	20.10	14.20
Runoff (direct)	2.20	1.00	0.20
Runoff (base flow)	0.66	0.28	0.14
Runoff (total)	2.86	1.28	0.34
Subsurface outflow	0.02	0.02	0.02
Evapotranspiration	19.22	18.80	13.94
Changes in storage	0.2	0.0	−0.1

Water yield for the budget area is approximately equal to surface runoff. The budget area is hydrologically representative of the entire watershed unit. Based on data from the budget area the estimated yield of the watershed unit is about 280,000 acre-feet for 1956, about 130,000 acre-feet for 1959, and about 29,000 acre-feet for 1961. Utilization of the entire water yield requires storage. If surface-water reservoirs are constructed, evaporation losses will increase and therefore water yield will decrease proportionately

WATER USE



WITHDRAWALS OF WATER FROM COMMUNITY SYSTEMS, 1962, AND SEWAGE TREATMENT AND DISPOSAL IN THE MIDDLE RIVER WATERSHED

WATER USE WITHIN THE MIDDLE RIVER WATERSHED
Gallons per day in 1962

Type of use	Ground water	Surface water	Total
Domestic and community	446,000	83,000	529,000
Industrial, commercial, and institutional	81,000	38,000	119,000
Agricultural	193,000	66,000	259,000
Totals	720,000	187,000	907,000

SUMMARY OF WATER RESOURCES

	Source of water	Lake Plain area		Shoreline area		Till Upland	
		Availability	Quality	Availability	Quality	Availability	Quality
Surface water	Red River of the North	Source of industrial municipal, and irrigation supplies.	Variable—Relatively low total dissolved solids during high flow. Suitable for municipal and industrial uses.				
	Streams tributary to the Red River of the North	Generally no flow from July to April. Undependable source for municipal supply. Lack of natural storage sites.	Fair quality during high flow.	No flow at nearly all times between August and April. Source of small municipal supplies are available from the Tamarac and Middle Rivers if storage reservoirs are constructed at a few natural sites.	Fair quality at low flow, however, very hard. Relatively low total dissolved solids during high flow.	No flow or flows less than 1 cfs at nearly all times during late summer and winter months.	Good quality. Low in chloride. Hard water at low flow. Relatively low total dissolved solids during high flow.
Ground water	Lake clays	Yields very little water to large diameter wells.	Unsuitable for domestic use at most places because of high chloride content.	Not a source of water.		Not a source of water.	
	Beach deposits	Not present		Large continuous ridges yield moderate quantities of water.	Water is low in chloride, but is very hard.	Large continuous ridges yield moderate quantities of water.	Water is low in chloride, but is very hard.
	Surficial channel deposits	Not present		Areas A and B: Area A: Yields of 50 gpm could be obtained. Area B: Yields of 1000 gpm could be obtained.	Water is very hard in both aquifers, but is low in chloride, in most places.	Not present	
	Buried channel deposits	Not present		Areas $C-_{1,2,3}$: Areas $C-_1$ and $_2$: Yields of more than 20 gpm could be obtained. Area $C-_3$: Yields of 200 gpm could be obtained (large yields near Warren.)	Water is very hard and is relatively low in chloride (less than 500 gpm).	Not present	
	Sand bed within till	Area F: Most wells flow 1 to 2 gpm, some could be pumped at 50 gpm.	Unsuitable for domestic use at most places because of high chloride content.	Area C–4. Yields of up to several hundred gpm could probably be obtained.	Water is very hard, but is low in chloride.	Areas D and E: Area D: Yields of 50 to 150 gpm could probably be obtained. Area E: Yields of up to 40 gpm.	Water in both aquifers is very hard and low in chloride.
	Stratified sedimentary rocks	Yields unknown, but most wells flow and probably yield moderate quantities of water.	Extremely poor quality due to high chloride content.	Present in about half of the area. Yields unknown, but most wells flow and probably yield moderate quantities of water.	Extremely poor quality due to high chloride content.	Not present	

EXPLANATION

Surface water	Ground water	Quality
Good (suitable for municipalities, industries)	Good (greater than 100 gpm)	Good
Fair (suitable for small municipalities, provided storage available)	Fair (30–100 gpm)	Fair
Poor (undependable for municipalities)	Poor (less than 30 gpm)	Poor

CONCLUSIONS

1. Small to moderate supplies of ground water for domestic use, dairying, creameries, and small municipalities are available at most places in the Till Upland and eastern part of the Shoreline area. Small to inadequate supplies of ground water for domestic purposes occur throughout most of the Lake Plain and western part of the Shoreline area. Water from most wells in the Lake Plain contains high dissolved solids and is not suitable for most domestic purposes.
2. The aquifer underlying the Halma area (Halma-Lake Bronson) is the largest source of ground water in the Middle River Watershed Unit. Wells having yields of 1,000 gpm or more could be developed in thicker parts of the aquifer. The quality of this water is suitable for irrigation of potatoes and sugar beets on well drained land.
3. Ground-water supplies for the small communities in the watershed are adequate for present rate of use. Additional amounts of ground water could be developed at communities by drilling additional wells at properly spaced intervals within the mapped aquifers.
4. Potential yield from all ground-water source is small compared to surface water, but ground water is important for small local supplies.
5. The Tamarac and Middle Rivers are potential sources of water for moderate amounts of industrial, agricultural, and municipal uses. The development of water from these intermittent streams requires adequate storage. Storage potential is available for small reservoirs, but large storage capacities are limited by reservoir sites and high evaporation losses.
6. Red River of the North is potentially the largest source of water for the Middle River Watershed Unit.
7. Estimated annual water yield of the Middle River Watershed Unit ranges from about 280,000 acre-feet to about 29,000 depending upon climatic conditions.
8. This report was based on a reconnaissance to determine areal availability and give a general appraisal of water resources in the Middle River Watershed Unit. Detailed studies are still needed to solve local water problems of supply, use, and management.

ACKNOWLEDGMENTS

This study was done under the direct supervision of Minnesota Council of the Water Resources Division of the U.S. Geological Survey, R. F. Brown, Chairman, D. B. Anderson, and D. M. Culbertson, district chiefs respectively, of the Ground, Surface, and Quality of Water Branches of the U.S. Geological Survey.

We express our appreciation to the many well owners and well drillers in the area for their generous help in supplying information and basic data for this study.

REFERENCES

Erskine, H. M., 1962, Frequency of low flows Red River of the North, North Dakota-Minnesota: North Dakota State Water Conservation Commission, mimeographed report, 18 p.

Minnesota Division of Waters, 1959, Hydrologic atlas of Minnesota: Minnesota Div. of Waters, Bull. 10, 182 p.

Prior, C. H., and Hess, J. H., 1961 Floods in Minnesota Magnitude and Frequency: Minnesota Div. of Water, Bull. 12, 142 p.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65018

WATER RESOURCES OF THE MIDDLE RIVER WATERSHED, NORTHWESTERN MINNESOTA

By
R. W. Maclay, T. C. Winter, and G. M. Pike

1965

For sale by U. S. Geological Survey, price $1.50 per set