Minnesota Works Progress Administration: Writers Project Research Notes.

NATURAL RESOURCES OF MINNESOTA

(The Geographic Basis Of The State's Economic Life)

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Letter of Submittal

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To the Minnesota Resources Commission:

America's participation in the present war marked an end of one era and the beginning of another in the State's history as well as in the Nation's that will reach on into generations to come. "It is a different world". "It will never be the same again". "We cannot go back, but must go forward". These and many similar expressions are being voiced daily by our leaders. At this juncture it is a good time to appraise the natural resources of the State as they constitute not only the material basis for Minnesota's part in winning the war but also a richer and finer democracy afterward.

The material used in this survey is in each instance the latest authentic information available in 1941 from official sources which could be used on a comparative basis. It is a selection and condensation of a wealth of material from the standpoints of significance, pertinancy, and usefulness, both in the attack on problems of wartime conservation, and in the formulation of post war policies. Moreover, an effort has been made to bring into common focus many of the phases of the broad subject of natural resources that have not been previously treated in their relations to each other.

This publication is further designed to be a statistical and graphic compendium, with an explanatory text, of certain data which constitute the basic information for the best utilization and conservation of Minnesota's natural resources. The subject treated is one with which the well-being of the people of the State is intimately bound, yet to which, in the past, too little attention has been paid.

Respectfully submitted,

Introduction

The soils, climates, waters, minerals, forests, grass lands, and animals constitute Minnesota's principal natural resources. Conservation of these resources has been a problem of deep concern to some private citizens and government officials in Minnesota for many years. Interest in it increased with the difficult economic and social conditions of the 1930's. Most people then came to recognize the natural resources not as something apart, but as elements interwoven with conditions of industry, labor, finance, agriculture, income, recreation, and good citizenship. A growing awareness of the needs of the future developed, as did a realization of the fact that to waste and destroy natural resources instead of using them so as to conserve and increase them would result in impoverishment of the standard of living in the years ahead.

Conservation of natural resources must be based on an accurate "stock taking" and an appreciation of how they are being used. This volume is intended to be a non-technical presentation of the facts concerning the natural resources of Minnesota. Not only are the natural assets evaluated, but also the natural liabilities. The current condition of each of the resources is clarified where possible by a summary of how they have been used. Problems such as wasted forest land, destructive floods, distressing periods of low water, erosion, sedimentation, and depleted game do not arrive full grown. They originate in a small way on a multitude of farms and forest tracts.

The survey is organized on the premise that a thorough knowledge of the physical characteristics and basic wealth of the State is essential for an accurate understanding of the economic life of the State and the many problems confronting its people. An earnest effort has been made not only to present an inventory of the State's natural resources but to touch upon the relationships that these have to the general problem of improving the living conditions of Minnesota people now and in future years.

The tables and illustrations as well as the text seek to afford a readily usable summary of pertinent information on the physical and economic geography of Minnesota to the end that greater public understanding and appreciation may be had in the consideration of such concrete public undertakings as soil conservation, forestry, water control, recreation development, and mining regulation. It is hoped that the survey will be of service to many persons charged with that function, both state and local, and that it will possess a wide public interest. It is anticipated that it will furnish helpful information for use in secondary schools and colleges, adult classes, and study groups interested in the development of intelligent citizenship in Minnesota.

Land, water, forest and recreational resources may be so used as to remain permanent assets yielding a perpetual income to the people of Minnesota. On the other hand, they may be so used as to destroy them as sources of income. This is the choice of the people of this State. Therefore, the matters discussed in this report are not to be dismissed as the concern only of ~~the~~ technicians and government officials. Every citizen must understand and not only cease wasting the abundance created for him but play his part in recreating that part of the natural heritage which has been impaired. It is to help the citizen of Minnesota to understand and act, individually and together, that this report is made.

Harold Jorgenson
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Illustrations And Tabulations

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MINNESOTA'S GEOGRAPHIC RELATIONSHIPS

Geographic Location

The State of Minnesota lies near the geographic center of North America, between 43° 30' and 49° 24' north latitude and 59° 29' and 97° 15' west longitude and contains the sources of three great drainage systems - the Mississippi, the St. Lawrence, and the Nelson. ~~- which make~~ It is therefore it a hydrographic center of the continent. At its maximum length, it extends about 406 miles from north to south; ~~and~~ its maximum width, from east to west, is about 357 miles. In area Minnesota ranks 11th in size among the states, with a total of 84,068 square miles, of which approximately 4,059[1] represents water surface. The State has more water surface than any other state except Florida. The Most northerly projection of the United States is found in Minnesota.

Minnesota is bounded on the north by the Canadian provinces of Ontario and Manitoba, on the east by Wisconsin, on the south by Iowa, and on the west by South and North Dakota. Important natural features delineate much of its boundary. These include Lake of the Woods, Rainy Lake and Rainy River, a series of "Border Lakes", and Pigeon River on the North; Lake Superior and the St. Croix and Mississippi Rivers on the east; and Traverse and Big Stone Lakes and Red River on the west.

The effect of central location is a key to understanding Minnesota and its people. This becomes clearer as the idea of location is broadened to include the complex of significant relations which go with place such as climate and plant life at one end of the scale and population and economic

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[1] Excluding part of Lake Superior, 2,212 square miles

organization at the other. The historical development of Minnesota has been greatly affected by its geographical setting.

Physiographic Relations

The State for the most part occupies a portion of the great Central Lowlands Province ~~of United States~~ which gradually merges into the Great Plains not far to the west. The northeastern portion embraces a part of the southwestern extension of the Laurentian Plateau here known as Lake Superior Uplands (Figure -). The Superior Upland comprises an area of old crystalline rocks and of worn down mountain ranges, whereas the Central Lowlands is underlain by a series of nearly horizontal beds of sedimentary rocks.

Climatic Relations

Far from the tempering affect of the sea, Minnesota has extremes of climate. Major climatic features are hot summers, cold winters, relatively short growing season, preponderantly summer rainfall regime, swift changes in weather, and abundant sunshine. It is a wholesome climate that makes for vigorous and energetic people. Most crops common to the Temperature Zone may be grown, and crop failures are comparatively rare.

Figure - shows that the State, but for a relatively limited area in the northwest, receives on ~~an~~ the average more than twenty inches of precipitation a year. In periods of normal rainfall the State~~, with occassional years of exception,~~ lies east of the transitory zone of critical rainfall deficiency. To the west, rainfall variability becomes increasingly more important as ~~the basis of most of the~~ an agricultural risk~~s of the region.~~ Areas which are sub-humid in some years may be semi-arid or arid in others. Out of climatic variations from year to year, and from the successively wet ~~to~~ or dry stages of a cycle, stem a large share of the region's troubles. Minnesota's economic and social development has reflected the effects of changeable climate. Figure - indicates areas of greatest drought intensity from 1930 to 1936.

Vegetative Relations

In figure - may be seen areas in forest and prairie vegetation which climate has demarcated in this region. Coniferous forests grow in the northeastern third of the State and a belt of deciduous forest, varying in width from a few to over a hundred miles, spreads diagonally between them and the prairies of the south and west. Within the transition area of hardwoods are more or less extended fragments of both the prairie and the coniferous forests and within the coniferous forests are scattered stands of hardwood ~~forest~~. Early General Land Office surveys indicate that about 31,500,000 acres, or three-fifths of the State's area, was originally forested. Forests now occupy only 15,492,300 acres. ~~, or a little less than one-third of the area of the State.~~

Forests of Minnesota have been of prime importance, not only in the commercial development of the State, but also in relation to agriculture. Forest and prairie country have been mutually complementary in supplying the necessaries of life.

As figure - shows, grasslands of the region may be divided into the tall grass (prairie grassland) and short grass (plains grassland). Decreasing and uncertain precipitation determines the prairie-steppe boundary, which fairly well coincides with the line (isarithm) of 10 dry years in 20.[11] Tall grasses grow, in general, where soil moisture is distributed to a depth of two feet or more. Minnesota has long shared in supplying needs of the grassland economy to the west and in processing its agricultural products.

Soils Relations

Climate and vegetation are of greatest importance in determining the nature of zonal soil groups illustrated in figure -. Local conditions of relief, parent rock, living matter and climate are important in determing important subdivisions within these zonal groups. In the most humid upland

[11] Trewartha, G. T., "Climate and settlement of the subhumid lands," chapter in Climate and Man, U.S. Dept. Agric. Yearbook 1941, p. 171.

grassland areas are found the Prairie soils. They are dark brown in color, mildly acid, high in content of organic matter in the upper part of the soil body, and well supplied with elements necessary for growth of grasses and other herbaceous plants. The high natural fertility of these soils together with favorable climate in which they are found make them among the most productive in the world for grains and grasses.

The next zonal group of soils west of the Prairie soils is Chernozem, found in the most humid part of the drier region having soils with a calcium (lime) carbonate layer (horizon). Calcium and magnesium are brought up by the grasses and carbonated in the surface soil and the limited rainfall permits these carbonates to accumulate within reach of the roots of the grass cover because leaching is at a minimum. Luxuriant tall grasses constituting the natural vegetation produced black soils very high in organic matter content and very fertile for grasses and other herbaceous plants. These soils are well adapted to small grains, expecially wheat, and furnish the greater part of the country's breadstuffs. Although somewhat more fertile due to a higher content of mineral plant nutrients than Prairie soils, they are somewhat less productive, as the rainfall is lower and less dependable.

In the progressively drier climate in the western portion of the region vegetation is more sparse and consequently soils of the Brown group are thinner and lighter in color. The soils are rich in mineral plant nutrients, but rainfall is insufficient for dependable crop production. Brown soils are also used for wheat, but because climate is so hazardous the more rolling and less productive land is used for grazing, for which nutritious short grasses, when not overgrazed, provide excellent pasture. Plowing land in this area for grain has destroyed the native grass protection, and in recent years, has exposed the soil to severe wind erosion.

so that the processes of vegetable decay do not return these bases to the surface soil in sufficient quantity to prevent acidity.

Podzol soils, note from figures - and - , are found in the forested and more humid eastern and northern portions. There is sufficient moisture for the podzolization process to remove soluble elements, including the less soluble carbonates of calcium and magnesium, completely from the soil. Trees feed more lightly on mineral bases than do grasses, ~~and not sufficient amounts are thus returned by vegetation (decayed vegetation) to the surface soil to prevent it from becoming acid.~~ acidity. ~~Through a complex and obscure process~~ the soil layers near the surface become impoverished of organic matter and of other ~~those~~ elements ~~considered most~~ necessary for the nutrition of crop plants. An accumulation of the bases, principally iron and alumina takes place in a lower soil layer. Coniferous forests with a low content of bases in their leaves and twigs fostered the strongest development of Podzols. Podzol soils are not considered fertile though they are well adapted (and in a sense fertile) for growing the trees under which they developed. They contain low percentages of soluble plant foods; are chemically poor soils; and always test acid unless derived from calcareaus (limey) rocks. Ability of these soils to produce crops is rated as being moderately low.

Broadleaved deciduous forests in a more temperate climate return more bases to the surface of the ground and hence the Gray Brown Podzolic soils which developed there tend to be more fertile for plant crops than those of the Podzols. Their medium fertility together with very favorable climate for growth of a wide variety of plants has made the area admirably adapted to the development of a prosperous agriculture of the general farming type. Under good farming practices, including some fertilization and liming, Gray Brown Podzolic soils will produce as well or better than Chernozem soils.

The primary economic resource is land, especially agricultural land. With almost seven-eights of all American farm land which the National

Resources Planning Board tentatively rates as grade one, with more than half of grade two farm land, and with about a sixth of the farm land the Board calls third, fourth, and fifth rate this upper midland region is of all the country's great farming sectors the most richly endowed. Minnesota possesses 13.2 percent of the grade one agricultural land and 10.3 percent of the grade two farm land found in the North Central States.1/

1/ North Central States include the two U. S. Census Bureau divisions, East North Central States comprising Ohio, Indiana, Illinois, Michigan, and Wisconsin and the West North Central States embracing Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas.

While Minnesota ranks eleventh among the states in the Nation in land area, it rates second in the number of acres of excellent and good agricultural land, having 7.7 percent of all such acreage in the United States. Iowa ranks first with 10.5 percent. The percentage of total land area in farms ranges from 96.5 percent in Nebraska to 49.4 percent in Michigan. Minnesota has 63.7 percent of its land in farms.

Economic Geography

Geographic position of Minnesota as the western-most Great Lakes state, its geniture relation to the upper reaches of the Mississippi River, and its location in the path of a network of rail lines as they swing out from Chicago to cross the continent make the State the gateway to the northwest area of United States. While it lies in the heart of the country's richest agricultural area its position ties the State economically to the agricultural reserves west of it on the one hand and to the westwardly expanding manufacturing region of east central North America on the other.

Agricultural Geography

United States may be divided agriculturally into two parts, East and West, on the basis of prevalent use of land, whether for crops or for pasture (Figure -). The dividing line approximates the western boundary of the north central division in which Minnesota lies. Figure - shows the North Central States include seven agricultural regions or parts of regions defined on the basis of dominance of a certain crop or kind of farming which is the result largely of temperature, rainfall, and soil conditions. Within Minnesota are included the northwestern margin of the Corn Belt, a major part of Hay and Dairy Region, and in the extreme northwest a portion of the Forest and Hay Region.

The North Central States are virtually the granary and livestock feeding ground of the Nation. Figure - shows the concentration areas of staple food crops of the country. Nearly the entire hard spring wheat and hard winter wheat regions lie within these states. On an average forty-three percent of the country's wheat acreage harvested lies in the four most western states.[1/] North Dakota is the largest producer of spring wheat among the states, followed in order by Montana, South Dakota, Washington and Minnesota.[1/] Kansas has long been the leading producer of winter wheat.

About one-half of the corn of United States and one-third of the world's crop is produced in the Corn Belt. Nearly all is grown east of the line of 8 inches of summer rainfall and south of the line of 66° F. summer temperature. Note in figure - that except in western portion the Corn Belt stops where rich glaciated soils end. Iowa and Illinois lead in production with Nebraska, Missouri, Kansas and Minnesota following in order.[1/]

1/ Based on 10 year average, 1929-1938. Source: Crops and Markets, December 1939

The great oats belt of United States extends in a crescent from the Red River Valley to Ohio. Iowa and Minnesota are greatest producers. Distribution of the oat crop is largely in the northern portion of the Corn Belt and in areas just north and east of it. The crop is especially important in the dairy belt where more oats is grown than any other grain.

A dot on the barley and flax maps represent only one-fifth as much acreage as on maps of corn, wheat, and oats. Nearly half of the barley acreage of United States is cropped in Minnesota and North and South Dakota.[1] Minnesota is by far the foremost producer. Farmers raise barley in the Spring Wheat Region because it will grow in a short season, give high yields of grain per acre, resist drought and fit well into a rotation system. Since 1933, the acreage has increased considerably because of renewed demand for malting barley.

Major flax producing region of United States is situated in the Spring Wheat Region in western Minnesota, the Dakota, and eastern Montana (Figure -). This region produces approximately ninety-two percent of all the flaxseed grown in the country with Minnesota contributing nearly half of the total production.[1] The boundaries of the "Flax-Belt" are fixed primarily by the climatic factors of too much and too little rainfall on the east and west, respectively, and higher temperatures on the south.

Approximately half of the country's rye acreage lies in Minnesota and North and South Dakota. On an average nearly twice as much land is devoted to rye in North Dakota than in Minnesota, but since Minnesota realizes a greater yield per acre it produces about four-fifths as much as North Dakota.[1] The year 1937 set a record for rye production in Minnesota with

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[1] Based on 10 year average, 1929-1938. Source: Crops and Markets, December 1929.

over ten million bushels. In addition to its historic use as a bread crop, rye has been extensively utilized as a feed crop, especially during the recent series of drought years. Rye pasture has been found useful as a late - season pasture in the fall or else for early pasture in the spring.

Commercial potato production in United States is largest in a northern tier of states from North Dakota eastward. Statistics reveal that on an average Minnesota has the largest acreage of any of the late potato producing states but ranks sixth in production.1/ Great Lakes States have an important climatic advantage in production of this crop - the relatively cool summers which benefit potato production. The bulky nature of the crop favors its development near the most populated regions of the country.

Production of farm crops in Minnesota compared with national production should reflect the State's ranking position (second) in wealth of excellent and good soil. In 1939 Minnesota had a total acreage of land used for crops (harvested and failure) of 19,058,233 acres which was 5.5 percent of the total in United States. This placed Minnesota third among the states in this acreage, only outranked by Texas and Iowa. The following table reveals the significant place held by Minnesota's crop production in the national picture.

1/ Based on 10 year average, 1929-1938. Source: Crops and Markets, December 1929

Table 1. Minnesota's 1939 Crop, Production and Rank

Crop	Unit	Amount	Percentage of U. S.	Rank of State
Barley	Bushels	54,945,979	21.07	1
Rye.	Bushels	6,134,752	17.14	1
Flaxseed	Bushels	11,692,840	62.10	1
All hay 1/	Tons	6,130,000	7.20	1
Alfalfa hay.	Tons	2,235,109	8.71	1
Sweet clover seed 1/ . . .	Bushels	558,000	39.36	1
Spring Wheat	Bushels	17,695,005	10.67	2
Corn for silage.	Tons	4,500,590	13.83	2
Oats	Bushels	143,070,552	16.44	2
Alsike clover seed 1/. . .	Bushels	64,100	20.08	2
All tame hay 1/.	Tons	4,773,000	6.27	3
Corn for grain	Bushels	162,766,107	7.04	4
Alfalfa seed 1/.	Bushels	137,000	9.21	4
Buckwheat.	Bushels	212,946	3.81	5
Irish potatoes	Bushels	18,144,946	5.70	6
Timothy seed 1/.	Bushels	76,000	5.36	6
Red Clover seed 1/	Bushels	102,000	5.67	8
Soy beans for beans 1/ . .	Bushels	510,000	.56	9
All wheat.	Bushels	20,341,862	28.71	12

Source: - U. S. Census Report on Agriculture, 1940.
1/ Data from Crops and Markets, general crop report as of December 1939.

Figure - shows the distribution of dairy cattle. The dairy belt as shown in the map has more than half of the dairy cows of United States. Southern Wisconsin has the greatest number of milk cows per square mile, followed closely by southeastern Minnesota and northeastern Iowa. The concentration of dairying is limited on the north by swamps and woods in Minnesota and rugged and sandy land in Wisconsin and Michigan. On the south better soils and more favorable climate permit corn and wheat to take the place of hay. In the west low rainfall suits spring wheat better than the dairy industry. Diversification of agriculture has expanded the dairy belt in Minnesota and other North Central States.

In the dairy region hay makes up half of the acreage of all crops. Rainfall varying from slightly more than 20 inches in the west to fifty inches in the east serves to produce luxuriant pasture and excellent forage crops. In the dairy belt lives nearly half of the urban population of the Nation and about a third of the total population.

North Central States west of Minnesota include notable protrusions of the cattle and sheep grazing area of the Great Plains and in addition the Corn Belt has about one-third of the beef cattle of the country. The map showing the distribution of beef cattle also shows the chief meat consuming area in the United States (Figure -).

Nearly sixty percent of the hogs and pigs in United States are in the Corn Belt (Figure -). Swine production for the tremendous eastern meat market is more closely associated with corn and barley production than any other livestock industry, although in the northern edge of the Corn Belt the dairy industry carries swine production a little farther north than would corn alone.

The following table reveals the important place held by Minnesota's livestock and livestock products in the Nation's agricultural economy.

Table 2. Minnesota's Livestock and Livestock Products Inventory

	Unit	Year	Amount	Percent of U. S.	Rank
Cows milked	Head	1939	1,552,279	7.08	2
Cows and heifers (2yrs. & over for milk).	Head	Apr. 1, 1940	1,699,849	7.06	2
Horses and colts (over 3 mo. old)	Head	Apr. 1, 1940	627,394	6.22	3
Sows to farrow1/.	Head	Apr. 1, 1940	695,632	8.71	3
Turkey raised	Head	1939	2,508,830	8.98	3
All cattle and calves (over 3 mo. old)	Head	Apr. 1, 1940	3,090,394	5.09	4
Turkeys	Head	Apr. 1, 1940	288,177	6.61	4
Chickens raised	Head	1939	28,301,790	4.28	5
Hogs and pigs (over 4 mo. old)	Head	Apr. 1, 1940	1,667,041	4.90	6
Chickens (over 4 mo. old) .	Head	Apr. 1, 1940	16,988,877	5.03	11
Sheep and lambs (over 6 mo. old)	Head	Apr. 1, 1940	972,435	2.42	15
Butter2/.	Pounds	1939	297,325,000	16.88	1
Milk produced	Gallons	1939	866,590,376	7.53	2
Honey produced.	Pounds	1939	3,992,517	5.97	5
Eggs produced	Dozens	1939	119,414,866	4.99	6
Wool shorn.	Pounds	1939	6,340,825	2.19	14

Source: U. S. Census Report on Agriculture, 1940.

1/ Sows and gilts that farrowed since December 1, 1939 or to farrow before June 1, 1940.

2/ Data from Preliminary Report Dairy Products Manufactured, November 1940, U. S. Department of Agriculture.

Industrial Geography

Since the markets for agricultural products of all the crop and livestock producing areas and the source of their imports lie mainly to the east, the movement of traffic as influenced by the Great Lakes, both as a waterway and as a barrier, is principally between west and east. The Minneapolis - St. Paul area at the head of navigation of the Mississippi and at the meeting place of the Minnesota and Mississippi Valleys with their easy rail gradients, and Duluth at the head of the Great Lakes, serve as commercial foci for much of the

Central Northwest. Their strategic locations give them the office of middlemen between the industrial east and the agricultural west and a many sided commercial and cultural relationship.

In few of the major regions of the continent are commercial routes so highly concentrated at one point as are rail lines of this region at Minneapolis - St. Paul. 1/ From almost every part west and northwest of the Twin Cities main lines lead to this center; the only important exception being the focal point at Duluth and Superior.

Figure - illustrates the importance of marine commerce at Duluth and Superior and the rising importance of river freight traffic at St. Paul and Minneapolis. Completion of the Upper Mississippi System (April 1940) enables barges to travel over 4,000 miles on a nine-foot waterway from the Gulf to the Twin Cities and from the Twin Cities to Chicago and Pittsburg. Duluth, Minnesota's principal lake port, has harbor facilities accommodating the largest lake vessels and passenger and freight piers equipped with warehouses and equipment for handling ore, coal, grain, building materials, pulp wood and fish, as well as package freight and automobile carriers.

Principally at the three commercial centers, but predominantly in Minneapolis and St. Paul are concentrated the economic activities listed below. In connection with these functions, it should be noted that while industry is found in nearly every part of the State, in 1939 the proportion of the State's total value added by manufacture produced in the Minneapolis-St. Paul industrial area and Duluth was 70 percent.

- Terminal, transfer, and building and repair activities of the railroads, trucks and buses, and the ship and barge lines.

1/ Hartshorne, Richard, Geography of the Minneapolis-St. Paul area, in Schwartz, G. M., Geology of the Minneapolis-St. Paul metropolitan area, Minnesota Geological Survey Bulletin 27, p. 7, 1936.

- Commercial activities concerned with assembling agricultural products of the northwest for the tremendous eastern market shown in figure - and the distributing of manufactured products brought in from eastern manufacturing regions shown in figure - - grain elevators, stockyards, storage warehouses, wholesale firms, jobbing offices, mail order houses, etc.

- Initial and final processing of collected agricultural produce and extracted natural resources - meat packing, flour and other grain milling, malt liquors, creamery butter, paper and pulp, canning and preserving (all among the ten leading industries in 1939) - and the assemblage of materials brought in from heavy manufacturing centers in the east - agricultural implements, construction equipment, industrial apparatus, automobiles, etc.

- The manufacture of materials to supply the consumers needs of the locality and its tributary area - news printing, bakery products (both among the ten leading industries in 1939), foundaries, ice cream and ices, etc.

In terms of economic organization, agriculture is Minnesota's main support. The United States Census of 1940 indicated that about one-third (34 percent) of all gainfully employed in Minnesota (except on public emergency work) are engaged in agriculture, including owners, tenants, paid farm workers and family workers. In addition, agriculture gives employment in processing of products of the soil to approximately 30,000 persons in manufacturing plants of Minnesota. About two-thirds of the value of the raw materials used in manufacturing plants in 1935 was derived from agriculture.1/ Table 3 indicates the importance of

1/ Agricultural resources of Minnesota - 1940, p. 11, Minnesota Resources Commission.

agricultural products in Minnesota.

Table 3. Minnesota's Processing of Agricultural Products - 1939

	Value of Product	Percentage of U. S.	Rank of State
Butter	78,029,290	15.83	1
Linseed oil.	10,383,567	15.28	1
Poultry dressing and packing	15,479,986	11.19	2
Flour and grain mill products.	67,437,432	10.38	3
Meat packing	198,124,044	7.48	3
Malt	9,071,682	15.51	3
Canning and preserving	9,425,657	1.61	15

Source: U. S. Census Report on Manufactures, 1939; preliminary report.

Industry is generally regarded as secondary in Minnesota. Yet a study of production income in 1935 by the National Industrial Conference Board revealed that while 17.5 percent of production income of Minnesota came from agriculture 15.4 percent came from manufacturing and 16.9 percent from trade (agriculture is of greater importance than these figures indicate since agriculture did not have price parity with industry).

Industries most significant in the industrial life of the State are those based on natural resources. Where adequate natural resources still exist the industries dependent upon them are flourishing. Meat packing has shown a steady increase rising from less than 0.5 percent of the national total in 1879 to 8.4 percent in 1939. Minnesota's share of the Nation's post-prohibition production of malt liquors has generally risen since 1933. The State leads all others in the production of butter. An increasing share of America's canning and preserving is produced in Minnesota. The poultry dressing, cereal preparations, and the stone cutting, shaping and finishing industries have rapidly grown in importance in recent years. Flour and other grain mill products have declined as a result of a shift in land use from wheat to corn and the development of wheat fields in other regions.

When natural resources were depleted the dependent industries suffered. Minnesota barely holds its own in production of paper, paperboard, and wood pulp and in the planing mills industry. In other forest linked industries - paper boxes, furniture, lumber and timber products, and wood preserving - Minnesota's share in the Nation's production has long since declined. Decrease in employment in the lumber and timber products industry, planing mills industry and the furniture industry account for 40 percent of the State's loss in industrial employment since 1923.

Those industries that have developed special skills have tended to prosper. There are many such enterprises located in Minnesota but the only ones ranking among the first ten are printing and publishing of books, music, and job and the refrigeration industries.

Minerals constitute the second great natural resource of the region. The great iron ore resources of the United States are concentrated in the Lake Superior region of northern Minnesota, Wisconsin, and Michigan, especially Minnesota. Within this Lake Superior region approximately 85 percent of all the iron ore mined in the United States in recent years has been produced. Minnesota contributed 61 percent of the United States total in 1939. In Minnesota the iron ranges are the Cuyuna, Mesabi, Vermillion, and Gunflint, progressing from southwest to northeast.

In 1940 the total tonnage of ore shipped from Minnesota was 48,949,322 tons of which 45,667,677 tons were removed from the exceedingly rich and easily mined Mesabi Range alone. As the reserve tonnage of about one billion tons of high grade ore is used up, increasing attention will doubtless be given to utilization of the great remaining tonnage of lower grade ore. In the Mesabi range alone there are approximately 1.3 billion tons of class two ore for concentration and 57.2 billion tons of class three ore for concentration.

Minnesota was eighth largest producer of minerals in United States in 1937. Mineral products of the State representing the largest production and value are:- iron ore, manganiferous ore, stone, sand and gravel, and clay products. The total value of mine and quarry products in Minnesota in 1937 was $152,107,070.

Minnesota, unfortunately, has no coal, oil, or natural gas fields. Its location on excellent waterways close to great coal producing areas of the Nation, however, is an advantage of utmost importance. It is axiomatic that iron goes to meet coal. From iron mines of Minnesota tremendous tonnages of ore are easily and speedily loaded into great steamers and cheaply transported to blast furnaces at the lower end of the Great Lakes where coal is available. The same steamers can carry an equal amount of coal as return cargo to factories and homes of Minnesota. Thus an ideal two-way movement of vitally important commodities exists which should result in a very inexpensive movement of fuel and other materials and goods (Figure -).

Originally, Minnesota in common with states in northeastern United States, possessed vast forest areas. So rapidly were the forests cut in this broad belt, not only for lumber but also farmland, that the lumber industry of the United States in less than one hundred years has migrated from New England to its present stage in Pacific forests. Now the entire northeastern forest area produces less than one-fourth as much lumber as the Pacific area. Minnesota reached its production zenith in 1899 when it ranked as third highest producer in the country. In the less than 100 years since commercial lumbering began in the State, nearly all the old-growth timber has been cut and one-third of the forest area has been permanently cleared for agriculture. Minnesota now imports almost four-fifths of its lumber requirements with lumber from the Pacific region predominating in its lumber yards.

The lumber industry as it was once known is almost entirely gone and much of the land formerly occupied by forests remain unsuited to agricultural use. The cut-over region is a serious problem area, but at the same time it offers a great opportunity for rebuilding a vital natural resource and thereby improving the economic and social conditions of its residents. Successful experimental production of alpha cellulose from aspen (or popple) at a "pilot plant" being established at International Falls may pave the way for a future large scale commercial production based on a forest resource estimated at 7,000,000 acres with a cover of 4,250,000 cords of merchantable size aspen.

Natural conditions are not only favorable to reforestation but also development of important recreational utilization. The rise of the tourist industry in the forested North Country has been phenomenal. The number of intra-state and inter-state vacationists has steadily increased and "tourist business" now exceeds all others in the forest regions. In 1939 there were in operation in Minnesota 765 tourist courts and tourist camps having 5,056 cabins, a greater number than in any other state. Minnesota's great variety of scenic beauty, immense areas of forest and park, multitude of lakes and streams, enjoyable summer climate, abundant wild life and historic landmarks attracted a tourist public that expended over 152 million dollars in 1940. The tourist industry ranks fourth to agriculture, manufacturing and mining as a wealth producer in Minnesota.

For every person engaged in the creation of wealth in agriculture, forestry, fishing, mining, manufacture and mechanical industries, approximately one other person is engaged in trade, transportation, communication, and other service industries and occupations which serve people as they work, play and live.

The People

The important economic endowments of any area are both its physical resources and its people - intelligent, healthy, happy, and secure people. The energy of Minnesotans, their ingenuity in invention, their ability to cooperate, their facility for organization, their ideals of liberty and justice, and their courage and resourcefulness - these are Minnesota's greatest assets. These characteristics made possible the opening and development of the State and on them its future depends. Where ignorance and carelessness have created problems, it will be these qualities that will find their solution.

In the ninety years from 1850 to 1940 the population of Minnesota grew from 6,077[1]/ to 2,772,300. During those years the area received hosts of

1/ Territory of Minnesota covered an area larger than the present State.

immigrants accustomed to strenuous labor from other states mainly in the Ohio Valley and New England regions and from abroad, principally from Sweden, Norway, Germany, Finland, Canada, Poland, Austria and Denmark. While the population has continued to grow until the present time, the rate of growth has decreased in recent decades and indications are that Minnesota is approaching population stability. The proportion of old people is becoming larger and that of young people smaller.

The urban population comprised 49.8 percent of the total in 1940 compared with 49.0 percent in 1930. Between 1930 and 1940 Minnesota's urban places continued to grow faster than the rural areas. In this period, however, the urban areas grew more slowly than at any time since 1850, whereas the rural areas reversed their decline of the previous decade by showing an increase. There are three cities of 100,000 or more and fifteen cities of 10,000 or more in Minnesota, one (Fergus Falls) having reached this size since 1930. All but one of these cities increased between 1930 and 1940, Austin having the most rapid growth (49.1 percent). Eighty-three of the 87 counties gained population between 1930 and 1940 with Lake of the Woods realizing the most extensive growth (42.5 percent).

Minnesota ranks eighteenth in population number among the states of the Union. With a population of 34.9 per square mile Minnesota rates thirty-first in the Nation in density of population. Unfortunately, from the marketing standpoint, Minnesota lies away from the most densely populated belt in United States, although the center of population is gradually moving westward (Figure -). The decline in population in the last decade in the tier of states west of Minnesota is also commercially significant. Within Minnesota and within its tributary area in the Northwest, however, are to be found approximately ten million people whose needs are by no means met by the industries of their territory.

Illustrations And Tabulations

MINNESOTA'S GEOLOGIC FOUNDATIONS

"Every valley shall be exalted, and
every mountain and hill made low."
Isaiah

Present geologic features and resources of Minnesota are the effects of geologic agencies that have been operative in the past. Time and again they have built up the land and tore it down again. Water and land have taken turn as conquerors. Aeons before man appeared on the scene Minnesota was at various times a mass of bare rock, volcanic mountains, plains country, littoral of mud, coastal lowland, a meeting place of irresistible glaciers. Some day Nature will have worn away all the familiar features of Minnesota of today, but more years than man can count will pass before this happens.

Each layer of rock now exposed reveals something of the earth's history in this locality. Mainly from their character, their relative position, and the remains of life found in them have the principal events in the geologic development of Minnesota been made known. A member of the Minnesota Geological Survey has said, "Just as human history is divided upon the basis of ruling families and the events which took place while they were in power, so the geological history is divided upon the basis of animal dynasties and contemporaneous events."1/

1/ Thiel, G. A., and Dutton, C. E., The architectural, structural, and monumental stones of Minnesota: Minn. Geol. Survey Bull. 25, p. 22, 1935.

Not all of the various geologic periods are represented by rocks in Minnesota. The generalized columnar section of geologic formations in Minnesota, figure -, shows the rocks which exist in any part of Minnesota, their approximate thickness, time and life of the period of formation, and their principal characteristics. The map on the following page (Figure -) shows the distribution of the various rock formations either as outcrops or beneath a cover of soil and glacial drift. Not all of the rocks of various periods in the geologic development of Minnesota are represented in any one area because geologic events may affect only certain areas and because erosion which has gone on all through most of Minnesota's geologic history in places has removed these rocks.

Pre-Cambrian Time

A convenient starting point in Minnesota's geologic history is pre-Cambrian time. What is now Minnesota was then part of the old Archean continent, leveled by erosion to a rather flat plain. Monotony of this old erosion surface was relieved by occasional residual elevations, both hills and mountains. Rocks of this old continent were predominantly igneous or metamorphic in character, that is granite, gabbro, basalt, diabase, gneiss, slate, and quartzite; a structure common to the pre-Cambrian complex of many parts of the world. Figure - summarizes the major local events in the shaping of this old land mass which, now greatly modified through unequal uplift and stream and ice erosion, constitutes the Superior Upland (Figure -). First there was the Archean period, then the Algonkian in its development.

Archean

Oldest rocks were poured out as a series of lava flows both upon the land and under water. Some of this oldest known rock is now exposed; one of the most familiar exposures being Jasper Peak near Soudan and Ely in northern Minnesota. Toward the close of such activity sedimentary material accumulated locally to form the iron ore beds of the Vermilion range.

This era was closed by mountainous upheavals and intrusion of large masses of igneous rock. In the Minnesota Valley near Ortonville and Big Stone City and at Saganaga Lake in the extreme northeastern part of the State, granites and granite gneisses of the period now lie exposed. In the Minnesota River Valley district these rocks are quarried for building stone.

Algonkian

Agencies of erosion combined to wear away the heights and supply materials for the sedimentary beds present in the Vermilion range especially, but also in the Mesabi area. These conglomerate, slate and sandstone like layers were later heaved into mountainous folds, crumpled, and broken by large igneous intrusions exposed today on the Giants Range and in the region north of Vermilion Lake (Figure -). Following these volcanic disturbances eroded materials were deposited which resulted in formation of sandstone, iron formation, and shales. Subsequent intrusions of lava flow in the region metamorphosed the sandstones and shales by heat and pressure to form the quartzite and slate formations shown in figure - . Tremendous thicknesses of lava flows were poured out on the surface or interbedded in the flows or other rock formations in a broad belt extending at least from Taylors Falls through northwestern Wisconsin and northeastern Minnesota. Broad exposures extend all along the north shore of Lake Superior from Duluth to Grand Portage. After the lava flows were exuded molten material continued to work its way upward but at places huge masses failed to reach the surface and formed great intrusives now recognized as gabbro or diabase. Such are found inland from the north shore of Lake Superior, in the Cook-Angora area, and in central Minnesota (St. Cloud area). Duluth gabbro is the largest mass

of this material in the world. Note in figure - that the age of Hinckley sandstone and the Red Clastic series is questionable. Their ages are uncertain as they may be either the basal formation of the Cambrian (succeeding period) or enormously thick red and shaly sandstones formed in troughs between ridges of the igneous rocks of this period. Rocks of the Algonkian period furnish important building and monumental stones in the State.
To the pre-Cambrian epoch Minnesota is indebted for a portion of its famous building stones and for its enormous iron ore deposits.

Paleozoic Era

Cambrian

At the beginning of this period the volcanic activity and folding characterized by intense pressure that had gone on for aeons of time ceased and down to the present only moderate changes have affected the rocks. Upon the crystalline and metamorphic land mass which had thus envolved in pre-Cambrian time a great arm of the sea encroached from the south in late Cambrian time, extending at least to a point somewhat north of the Twin Cities. Materials for sandstones and shales first laid down as sediments in this sea were carried into it by streams running over the ancient land areas in the same way that streams do today. Upon entering the sea the streams dropped materials carried in suspension and formed mud, sand, and gravel deposits depending on size of the particles. Waves and currents reworked much of this sediment, smallest particles being carried farthest from the shore. Differences or variation in height of the land being eroded or variation in depth of the water where materials were deposited altered the texture of various layers or sediments deposited. As a result layers may change gradually in a horizontal direction and change rather sharply vertically. Where there was a piling up of sediments those beneath were compacted by pressure or cemented together by dissolved substances. Mud was changed to shale, sands to sandstone, calcareous deposits to limestone and dolomite, and gravel, where present, to conglomerates. Of Cambrian rocks, sandstone is most abundant and most conspicuous. Cambrian and later rocks may be easily recognized and in some of them abundant fossils may be found (Figure -).

Ordovician

No sharp break separates rocks of the Cambrian from the Ordovician period, but fossil remains for the two periods show notable differences. This indicates recession of the sea from the area for a considerable time interval. When ocean water returned, comparatively quiet seas prevailed that permitted sediments to be precipitated by chemical processes or algae and myriads of sea organisms, forming limestone or dolomite. This was followed by a period of deposition of dolomite after which the sea withdrew.

After an interval of elevation and possible erosion the sea returned again and the remarkably pure white St. Peter sandstone was deposited. It is composed almost entirely of white rounded quartz grains and is so little cemented that it may be crumbled with the hand.

Under gradually changing conditions a variety of materials were laid down. In the Platteville formation are included a series of somewhat shaly limestone beds containing an abundance of fossilized shells. Other changes in conditions resulted in the differentiation of Decorah shale, Galena shale and limestone, and Maquoketa limestone.

Devonian

Only a single formation represents the Devonian period in Minnesota, the granular and massive Cedar Valley limestone that caps hills in southeastern Minnesota. As remnants are not found elsewhere it may be inferred that land to the north had by now emerged from the sea.

Withdrawal of the sea due to a major uplift accompanying the folding of the Appalachian Mountains and smaller foldings of the Arbuckle, Wichita and Ouachita Mountains and other interior highlands brought the Paleozoic era to a close. Gradual elevation, however, brought the Minnesota region above sea level before neighboring areas on the south and east. During the Carboniferous period which followed the Devonian, when coal and oil bearing strata were formed elsewhere, Minnesota was a lowland area subject to slight erosion.

There are some indications that epicontinental seas covered an area far more extensive than that now occupied by sedimentary beds laid down in them. Since the general uplift at the end of Paleozoic time most of the area has been continuously subject to erosion which may have removed these soft rock beds over the Superior Upland areas. Since uplift was simultaneous and even over the entire area the layers are nearly horizontal and undeformed. The only formation utilized to any great extent for building stones at present is the usually thick bedded, gray, pink, or buff-colored Oneota dolomite quarried in the Mankato-Kasota area and at Winona. Because of its purity the St. Peter sandstone is used in glass-making by the Ford Motor Company at St. Paul. Note the progression of life as preserved in the rocks of the Paleozoic era as shown in figure - .

Mesozoic Era

During earlier periods of the Mesozoic era the Minnesota area was subjected to prolonged erosion. During Cretaceous time the sea made its final thrust upon the Minnesota region, this time from the west. Much of western Minnesota has estuarine beds consisting generally of unconsolidated sand and clay (Figure - shows distribution of Cretaceous shales).

This encroachment was of brief duration and marked the end of the State's marine history.

Cenozoic Era

Preceding the glacial activity that has given Minnesota's landscape its familiar characteristics, erosion was general and deep valleys were cut in the sedimentary rocks. The Mississippi drainage system had been established and valleys were eroded more deeply than now. With advent of the glacier those old valleys were filled, some of them to be re-established upon its retreat.

Illustrations And Tabulations

Manuscript Page Reference

SURFACE GEOLOGY

Surface features of Minnesota can be understood only by turning to the last chapter of its geologic history - the glacial period. Glaciation was not peculiar to Minnesota nor even to North America for great ice sheets spread over a large portion of northern Europe at about the same time. Glaciation did not consist of a single great ice invasion but of a series of invasions separated by lengthy interglacial periods. So long as the rate of accumulation of ice exceeded waste by melting and evaporation the ice sheet continued to advance. When waste exceeded the advance the margin melted back.

Ice sheets which intruded upon Minnesota seem to have worked outward from three principal gathering grounds:- east of Hudson Bay (Labrador Ice Sheet), just west of Hudson Bay (Keewatin Ice Sheet), and southwest of Hudson Bay (Patrician Ice Sheet). Basis for establishing the several centers of dispersion is the radiating bearings of scratches (strias) left on rocks by the ice as it moved outward and the nature of transported material. All of Minnesota was covered by ice at some time, except for a narrow band in the extreme southeast (Figure -).

The earliest ice sheet, known as Nebraskan and sometimes referred to as pre-Kansan, came from central Canada and covered much of the State. It left deposits of dark gray till[1] now deeply weathered. Constituent

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[1] Heterogeneous material consisting of clay, sand, gravel, and boulders intermingled in any proportion, left at varying depth over the surface by the ice sheet as it melted from the area.

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pebbles are generally in an advanced stage of decay and even granite boulders are so highly disintegrated that they can be cut with a spade. Little is known about the distribution of this drift[2] as later ice sheets largely covered

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[2] Deposits of earth, sand, gravel, and boulders, transported by glaciers (glacial drift) or by running water emanating from glaciers (fluvio-glacial drift).

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or disturbed it. None is shown in figure - .

The second or Kansan stage of glaciation moved into Minnesota from the Keewatin center west of Hudson Bay and crossed the State from northwest to southeast. Drift it deposited is calcareous (limey) blue gray till, containing rocks derived mainly from limestone formations of southern Manitoba, together with Cretaceous shale from Minnesota and a liberal supply of crystalline boulders from Canada and Minnesota. This old gray drift apparently covers more of the State than any other. Deposits are found in the northwestern part of the State and nearly to the extreme southeastern part. A line marking the east edge of a definite sheet of till runs southward through eastern Wabasha, western Winona, and central Fillmore Counties. In figure - note the exposures in southwestern and southeastern parts of the State. It is found on the Mesabi range as far east as the mine pits at Hibbing and probably underlies later drift south of the range. Withdrawal of the Kansan ice sheet was followed by a long period of time known as the second or Yarmouth interglacial stage. Peat, muck, gumbotil, and loess deposits between Kansan and Illinoian drifts and the amount of erosion the Kansan drift suffered afford impressive evidence of the long duration of this interglacial stage.

During stage of glaciation known as Illinoian, ice moved southwestward from the Labrador center, across the west end of Lake Superior, and into most of Washington and Dakota Counties in eastern Minnesota (Figure -). Average thickness of this old red drift is scarcely 10 feet, but in Dakota County it is heaped up into a range of hills from 75 to 100 feet high that runs from Hampton southeastward nearly to Cannon River. Iowan drift, in the opinion of Frank Leverett, probably was deposited in this same glacial stage as the product of ice coming in from the region west of Hudson Bay.[1]

1/ Leverett, Frank, Quatermary geology of Minnesota and parts of adjacent states: U. S. Geol. Survey Professional Paper 161, p. 7.

This drift is now exposed in a band across southwestern Minnesota and neighboring parts of Iowa and South Dakota (Figure -). The interval of time between Illinoian and the next ice sheet, though shorter than the Yarmouth interglacial period, lasted about 70,000 years.[2] During interglacial stage

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2/ Leverett, Frank, Relative length of Pleistocene glacial and interglacial stages: Science, new ser., vol. 62, pp. 193-195, 1930.

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the main deposits of loess were laid down by wind.

In the Wisconsin ice stage or stages, ice sheets moved out from several centers in Canada, lobal ice fronts advancing and retreating at various times. Early in this stage, the ice sheet moved southwestward from the Labrador center but failed to reach Minnesota. In the midst of this Labrador ice movement when its highest part (center of dispersal) had shifted westward a movement began more directly southward into the Great Lakes region from the Patrician area southwest of Hudson Bay. Material deposited by the

Patrician, or mid-Wisconsin ice sheet, is mainly chocolate brown to red in color and is referred to as young red drift (Figure -). Drift of the Superior ice is thought to pertain to the Labrador part of the Laurentide ice sheet.

Still later in the Wisconsin glacial stage a vigorous ice movement set in from the Keewatin district which deposited young gray drift. A miner lobe of this ice sheet known as Grantsburg sublobe, passed north of Minneapolis and St. Paul, at a right angle from the general direction of movement from northwest to southeast and overlapped an extensive portion of young red drift by now freed from ice. In figure - note direction of movement of ice and the area of overlapping. Its drift is easily distinguished from red Wisconsin drift by the pale color and presence of limestone fragments from Manitoba. Another sublobe extended southeastward across the Mesabi range and spread out in the St. Louis and Upper Mississippi Basins. Here too, gray drift overlaps red drift for some distance.

As Wisconsin glaciation waned, when the Keewatin ice front had receded, there seems to have been renewed activity in the Patrician district with spreading of ice northward and westward to form the morainic system north of the Lake Superior Basin.

Great glacial lakes - When the Superior glacial lobe shrank within the Lake Superior Basin, water was ponded in front of it to such height the lake drained southward into the St. Croix River and thence into the Mississippi. Lake Superior was several hundred feet higher than at present and covered a much larger area (Figure -).

Upon retreat of the ice from the basin drained northward by the Red River, there also was a ponding of water in that basin. A large lake of an estimated 100,000 square miles known as Lake Agassiz was formed, which extended through northwestern Minnesota, eastern North Dakota, and northward over a very large area in Canada (Figure -). This great body of water drained southward via River Warren, in whose bed the Minnesota now flows. The great volume of water coursing down this outlet rapidly eroded the great valley and gorge that now seems so incongruous with the size of the present river.

The name Lake Aitkin is given to a body of water which for a time covered the low ground on the borders of the Mississippi in Aitkin County, with slight extensions northwestward into Itasca County and westward into Crow Wing County. Upon withdrawal of the St. Louis sublobe ponded waters accumulated at its southwest end and gradually extended with melting away of the ice. At the same time another lake, glacial Lake Upham (St. Louis), was formed in the basin south of the Mesabi range along the eastern border of the same receding ice lobe.

Illustrations And Tabulations

PHYSIOGRAPHY

Most of Minnesota is a part of the great Central Lowland province of middle United States which gradually merges into the Great Plains not far to the west. The northeastern triangle embraces part of the southwestern extension of the great Laurentian Upland or pre-Cambrian "Canadian Shield" of North America, here known as Superior Upland (Figure -). Geologically, the Superior Upland is an area of old crystalline and resistant rocks and worn down mountain ranges whereas the Central Lowland portion is underlain by nearly horizontal sedimentary beds of chiefly Cambrian, Ordovician and Cretaceous rocks. The sedimentary formations of the Central Lowland lap upon and end against the older and generally more elevated igneous and metamorphosed rocks of the Superior Upland.

Minnesota presents more variety in surface features than most North Central States, yet a great part of its surface is level or only gently undulating. Relief features, except in the Superior Upland and Driftless Area, consist mainly of glacial effects that were superimposed upon preglacial erosion surfaces and modified somewhat in all places by subsequent action of weathering agencies.

Territory within boundaries of Minnesota is naturally divided into six major regions designated as physiographic divisions, some of which contain subdivisions (Figure -). Each division is characterized by a relatively uniform geologic history, structural framework, and topographic (relief) character. The physiographic regions conform rather closely with the State's geologic foundations and glacial geology of which they are surface expressions (Figures - and -) and, in general, soils and vegetation also exhibit marked relationships to them.

Physiography is a principal factor along with climate in determining and delimiting natural regions of the State. Furthermore, each physical unit tends to condition a unity of interests of people within it. Its physical attributes influence not only the distribution, economic life, social activities, and numerical trend of the people, but to an undetermined extent, their very natures.

Superior Upland 1/

This is the roughest area in the State (Figure -). Through unequal uplift and differential stream and ice erosion this district has been greatly modified from its condition as a relatively level old erosion surface at the close of Paleozoic time. Most conspicuous relief is found in the "Sawtooth Range" and other prominent ridges that closely border Lake Superior and which ascend abruptly along a fault scarp from 500 to 900 feet above the lake. Rock ranges lying back from the shore, though more elevated than those fronting on the lake, seldom rise more than 200 or 300 feet above the swamps and lakes about them. High rock hills in central Cook County reach the highest elevations in the State. One group, Misquah Hills, largest and highest of the monadnocks, attains an altitude of 2,230 feet. Most prominent part of the Mesabi iron range in St. Louis County rises from 400 to 450 feet above the boulder strewn table-land surrounding it.

Superior Upland is an area of rough stony land with a generally thin covering of soil over the bedrock which shows in many places. The glacier removed the mantle rock of the region so completely in the north and northeast that the landscape chiefly displays extensive rock outcrops (Figure -). Morainic systems of the Patrician and Superior glacial lobes tend to be topographically conspicuous, numerous hills being 50 to 100 feet high with steep slopes difficult of cultivation.

1/ The boundary between the Superior and Moraine-Lake Districts is necessarily conventionalized. In part it is drawn arbitrarily to conform generally with the tentative boundary along the 93d meridian used by the United States Geological Survey. Nevin Fenneman in Physiography of Eastern United States considers that though a broad area (10,000 acres) northwest of the Hinckley sandstone belt (Cambrian ?) in Minnesota is underlain by thick and fairly homogeneous Upper Huronian sediments, mainly Virginia slate, only the eastern third belongs to the Superior Upland as the remainder is so deeply covered by glacial drift that the rock beneath exerts little affect on the topography. Even in the eastern part that is included, where there are occasional rock outcrops, surface features are mainly glacial. Between the Mesabi range and the Lake Agassiz Plain the boundary follows the 1400 foot contour.

The district everywhere exhibits most irregular drainage and is par excellence the lake and river region of United States.

Land Use - Forests which cover most of the area constitute the primary land use. Recreation and wildlife management while based upon exceptional resources, possibly need further introduction. Only small areas in valleys and on smooth slopes are cultivated as nearly all soils rate very low in productivity due to their stoniness and shallow depth. Great resources of iron ore are the main economic asset of the region. Land in metaliferous mining claims embraces over forty-two thousand acres. Nearly all of the 3,725,850 acre (gross area) Superior National Forest, including the purchase units, lies within this district. Land in federal and state reservations totals about 2,432,771 acres, comprising 1,826,477 in national forest, 501,178 in state forests, 73,987 in Indian reservations, 27,116 in federal recreational areas, and 4,013 in state parks.

Bedrock District - Includes tracts along the International Boundary where Patrician glaciers scoured the pre-Cambrian bedrock bare or but thinly strewed it with drift. The land is very broken with numerous rock knobs among which lakes and swamps abound in a most extraordinary drainage pattern.

Mesabi Range - Major topographic feature consists of an almost continuous ridge of granite called the Giants Range (Mesabi means giant in Chippewa Indian language) which extends northeast-southwest on the northwest side and parallel to the iron formation. Crest of the range in places extends broad and flat, in others both narrow and sharp. At its highest it rises 500 feet above the plateau on either side. The area is very thinly coated with bouldery drift in most places, although its south slope and the portion west from Chisholm bear a relatively heavy covering.

Lake Duluth Bed - Glacial lake bed extends as far west as Moose Lake. Where exposed it exhibits a smooth surface and a prevailing soil composed of heavy red clay containing few pebbles. On rugged north shore the soil consists largely of wave-washed till and gravelly and cobbly beach remnants. At its highest stages the lake reached 500 to 700 feet above the present surface of Lake Superior. Remnant shore lines show an increasing height toward the northeast as a result of unequal land adjustment after glaciation.

Moraine - Lake District

This region is mainly underlain by metamorphic and intrusive rocks of the pre-Cambrian complex, here less elevated than in the Superior Upland. Different altitudes in various parts and the general slopes are mainly determined by the broad swells and extensive valleys of preglacial topography. Surface features derive almost entirely from work of the great ice sheets which at successive times, and from different directions, overspread or encroached upon the region (Figure --).

Glacial deposits comprise an intricate system of usually strong hilly moraines with rolling to knolly surface associated with nearly level outwash plains of sand and gravel and gently undulating ground moraine. Moraines formed along the ice borders where they held their positions for a relatively long time and allowed materials they carried along to pile up in rudely concentric systems marking successive positions as the ice fronts halted and melted off from the region. Sands and gravels of outwash plains were distributed on the outer borders of moraines by waters released by melting ice. Ground moraine (till plain) was left as the ice borders melted back somewhat rapidly, thus forming few knolls and ridges. This division is separated from the glacial lake plain to the west and north by the Herman series of beaches which are generally well defined sandy ridges.

Thickness of drift generally ranges from 100 to 300 feet in depth but at places approaches 500 feet. Most of the extremely mixed soils developed from glacial drift and consist of stony loams, sandy loams, loams and sands interspersed with large and small peat bogs. In the eastern half of region the soils contain more stone than in the western part, especially those in areas of Patrician red drift. Predominent upland soils in northern part are gray or red loams and sandy loams. In southwestern part they comprise fertile dark colored heavy loams with variable textured subsoils. The southeastern section embraces extensive tracts of sandy surface soils with sand or gravel subsoils. Throughout the area large and small old lake plains with rich muck soils abound.

Drainage is not well established anywhere in this unit. About one-fourth of the area constitutes swamps. The drainage pattern consists primarily of large and small lakes, sloughs, and muskegs connected by rivers and creeks which appear to weave a network of water-ways. Notable among the lakes are Mille Lacs, Leech, and Winnibigoshish, second, third, and fourth largest lakes in Minnesota. Number of lakes in the region is destined to become much smaller **within** a century.

<u>Land Use</u> - Cut-over land represents most of the area, although a large proportion has been brought under cultivation. Most of original coniferous and hardwood forests have been cut and a large aggregate acreage classifies as idle deforested land. Restocking stands, the most prevalent forest size class, contain mainly aspen-birch, jack pine, spruce-balsam and spruce swamp cover types. Average inherent productivity of soils in the area ranges from fair to good, with extensive areas of poor and very poor soils included. The Soil Conservation Service suggests changes in land use to retire poorer land from cultivation and combat wind and water erosion which is serious in some places. About half of the land is tillable in the more agriculturally suitable southwestern portion where yields average high. Soils low in organic matter, nitrogen and water holding capacity handicap agriculture in the southeastern section. This is the dairying, livestock and potato district of Minnesota. Next to agriculture outdoor recreation ranks as the most important use. Iron ore mining claims on the Cuyuna range are of great economic importance and embrace almost seven thousand acres. Publicly owned lands in state and national reserves aggregates approximately 1,676,897 acres, including 620,391 in the Chippewa National Forest, 496,341 in state reforestation and flood control areas, 267,769 in state forest, 206,639 in Indian reservations, 35,834 in state parks, 34,581 in U. S. Biological Survey lands, and 15,343 in state game refuges and public hunting grounds.

<u>High Moraine Area</u> - Includes considerable area of large and thick moraines of calcareous till deposited on the relatively high, broad and hilly granite area in west-central Minnesota (Figure -). Elevations generally reach above 1400 feet with highest morainic hills attaining heights of over 1,700 feet. The Mississippi River begins at Lake Hernando de Soto which lies in an area ranging from 1500 to 1600 feet in elevation. Innumerable depressions left in the moraines gave origin to thousands of lakes, with the greatest number in Ottertail and Becker Counties. This is another famous Minnesota lake region, the southern portion known as Lake Park Region constituting one of the most interesting scenic areas of Minnesota.

Anoka Sand Plain - Embraces extensive pitted outwash plain deposited over a wide area in Anoka County and adjacent areas during retreat of the Grantsburg sub-lobe of late Wisconsin glaciation. Well-developed belts of dune sand exist but they occupy a relatively small percentage of the total area. Clayey Keewatin drift under the sand deposits serves to hold up the ground water table and add to the agricultural value of these lands. Wind erosion creates a serious problem on many cultivated fields.

Glacial Lake Basins - Includes lacustrine areas lying within the portions of the Mississippi and St. Louis River watersheds covered by the St. Louis ice lobe of the Keewatin ice sheet. The area comprises land flooded by glacial Lake St. Louis (Lake Upham) and glacial Lake Aitkin. Because the St. Louis River, flowing for most of its course through lowlands between the Mesabi iron range and ranges fronting on Lake Superior, in preglacial time probably emptied into the preglacial Mississippi, it seems justifiable to include the glacial lake basin formed in that watershed together with the area covered by glacial Lake Aitkin in one subdivision in the Moraine-Lake physiographic unit, rather than as a subdivision in the Superior Upland. Sand in this area probably marks the shallow-water margin of the lakes and silt the area of deeper water. The subdivision contains a large acreage in great and small muskeg swamps.

Lake Agassiz Plain

This district embracing 15,000 square miles of Minnesota is the most extensive nearly level land area in the state, because it was once the bed of glacial Lake Agassiz (Figures - and -). Red River Valley served as the axis of movement of the Keewatin ice sheet when it invaded Minnesota and upon its retreat ponding of Lake Agassiz took place. Beach ridges of the glacial lake rise high and dry above the lacustrine surface between them. They generally reach from 5 to 10 feet above the bordering plains, occasionally from 15 to 20 feet, and vary in width from a few rods to nearly one-half mile. This physiographic unit should be divided into two major subdivisions on the basis of drainage and lake deposition.

Red River Plain - Prairie land of the Red River Valley includes the three following soil divisions based on differences in soil parent material: (1) dark-colored fine-textured heavy soils developed on lake laid clays, (2) dark-colored medium textured soils developed on lake laid silty material, and (3) lighter-colored, loose and coarse-textured soils formed on lake laid sands and associated gravel ridges. Because of uniform topography much of the area lacks adequate natural drainage. The Red River is extremely sluggish and meanders in intricate curves.

Land Use - Soils of group 1 above produce mainly small grains with wheat the leading crop; group 2, potatoes, sugar beets, small grain and corn; and group 3, small grains (including mainly rye and barley), potatoes, alfalfa and other tame grasses. For decades this area has been famous as part of the spring wheat region. Increases in livestock and livestock products mark a trend toward diversification. Roughly 80 percent of the land lies in farms of which 60 percent classes as tillable. Inherent productivity of the soils is good, although a considerable acreage ranges from poor to fair. Wind erosion prevails throughout the region, and in localized areas causes serious damage on more sandy soils.

Lake Swamp - Intermixed glacial till, lake-washed till, lake deposits, and lake shore material underlie the area. Interspersed among the large and continuous muskeg swamps that cover over two-thirds of the district are many islands of loamy sand and long sinuous beach ridges. In many places burns have exposed the mineral soil beneath the peat layer which ranges from less than one to more than 20 feet in thickness in the swamp areas. Land near streams is better drained and much of it is cultivated.

Land Use - Principal land uses are forest, wildlife propagation, hay and pasture, and recreation. Greatest amount of agriculture of the seed, livestock, and dairy types is practiced in western portions of the area. Most soil types grade as loose, porous and of low inherent productivity. Approximately 2,568,210 acres lie within public reservations including 906,370 in state reforestation and flood control areas, 560,718 in state forests, 477,792 in state game refuges, 451,300 in Indian reservations, 100,977 in conservation development projects, 66,553 in U. S. Biological Survey reserves, and 4,500 in the Superior National Forest.

Till Prairie

Relief is almost wholly depositional and ranges from nearly level and undulating land in the west to rolling and hilly land in the east. Contours of the bedrock-surface influence the land forms at only a few places, though they control the general slope and altitude of the district. Steepest slopes occur along streams where occasional gullies are associated with erosion. During retreat of the Keewatin ice front, glacial Lake Minnesota for a time covered several hundred square miles in valleys of tributaries of the Minnesota River south of Mankato. The Minnesota River, former outlet of glacial Lake Agassiz, is entrenched approximately 200 feet below the present land surface in a trough extending from one-half to four miles wide. In general the glaciated land lies free of stone on or below the surface. Soils developed from calcareous till under a vegetative cover consisting chiefly of tall prairie grasses.

Land Use - Approximately 95 percent of the total area lies in farms, of which about three-fourths classes as tillable. Farmers use uncultivated acres for permanent hay, pasture and woodlots. Agriculturally the district is one of dairy, livestock, and grain farming, the latter to a more important degree in the western part. Corn occupies about one-third of the land, oats approximately one-fourth, and barley, wheat, flax and rye lesser proportions in the order named. Surface soils average deep, rich in organic matter and high in water-holding capacity. Outcroppings of quartzite in relatively large tracts in Rock and Pipestone Counties render some areas unfit for agriculture.

Young Till Prairie - Strong morainic systems in eastern portion include considerable coarse stony drift with gravelly knolls and ridges. Westward and southwestward more clayey till, with in place an extensive thin covering of silt, comes in gradually and gravelly and sandy deposits become more and more infrequent. Weak western moraines generally mark successive positions of the Keewatin ice border as it receded from the area by melting. In eastern part of the region some peat occurs in poorly drained depressions, part of which has been reclaimed for agricultural use. Elevation ranges from about 700 feet in the Minnesota Valley bottom to 1,200 feet a considerable distance north and south of the valley (Figure -).

Prairie Hills - Coteau des Prairies ("Hills of the Prairie"), a linear upland extending across southwestern Minnesota, owes its elevation to quartzite areas rising above the general level of the bordering Cretaceous formation and to strong morainic ridges which to some extent follow the crest. Although the greater part of the very thick glacial material on the Coteau was laid down in earlier stages of glaciation, moraines of the Keewatin ice sheet added materially since they are more numerous and larger here than elsewhere in southwestern Minnesota. This condition resulted from a looping back of the ice edge by the Coteau and the massing together of several moraines. The Coteau surface has an altitude of 1,700 to 1,900 feet or more along the highest part in Minnesota but the rise from surrounding prairies is so gradual that the elevation can scarcely be appreciated by one crossing over it (Figure -).

Old Till Prairie - This prairie land occupies the Coteau upland area of old gray drift of the Kansan ice sheet that was not covered by young gray drift of the later Wisconsin glaciation. Subdivision differs noticeably from younger till prairie to the north because the landscape exhibits submature to mature relief and greater degree of erosion. It differs also in the almost complete absence of morainic ridges. Much of the land has a deposit of loess over the till that generally reaches several feet in depth, or enough to form the soil and subsoil.

Old Moraine - Hill

This hilly upland of hard and soft rocks rises from 1,000 to 1,300 feet or more above sea level (Figure -). Except in driftless subdivision it is covered with old and much eroded gray drift and exhibits a much dissected phase in the eastern part and a rolling phase in the western part (Figure -). Glacial drift is very scanty in the eastern sections of the glaciated part of this unit in Wabasha, Olmsted, Fillmore, and western Winona and Houston Counties. Extreme eastern portions of the district in Winona and Houston Counties lie within the Driftless Area of the Upper Mississippi Valley.

Figure - shows extent of loessial deposits within this division. Loess rests in part on glacial drift deposits and in part on residuary clay and rock formations of the Driftless Area. In unglaciated area and in the thinly mantled (drift and loess) and stream dissected areas, rock ledges of limestone and sandstone outcrop along rugged and almost precipitous slopes of the valleys, often forming walls of considerable height.

Undulating to rolling plateau areas between valleys, including those in the Driftless Area, usually have several feet of residuary clay and also a coating of loess or wind-deposited silt loam covering the bedrock formations. Soils are predominantly friable and uniformly textured silt loams. Good drainage exists nearly everywhere, particularly in the eastern half, for almost every acre slopes toward some drainage course. Because of damaged vegetative cover, sloping land, and extremely erodible soil, sheet and gully erosion have become serious.

Land Use - About all the land that topography will permit lies under cultivation in this dairy, livestock and small grain area. Intensive dairying, largely on a butterfat basis, is mainly supplemented by swine. Wheat constitutes the major cash crop with potatoes, flax, barley, and oats following. Woodland is most prevalent along the rugged strip bordering the Mississippi where nearly one-third of the land area comprises wooded pasture. Inherent productivity of upland soils ranges from good to excellent, while that of the rough broken land grades very low. Diversification of products to which Minnesota farmers have turned is nowhere in greater evidence than in this district.

Driftless Area - Glacial sheets as they advanced and receded left one small area untouched - an area confined to eastern Houston and Winona Counties. Cut by tributary streams of the Mississippi the area is comparatively rugged. Silt loam (loess) extends down on the gentler slopes from the divides between streams, but leaves the steeper part of the slopes with rock exposed. Fine-textured unstratified loessial soils erode easily and erosion progresses rapidly from sheet to the gully stage.

Minneapolis - St. Paul Artesian Basin

General structure of rocks of the Twin City metropolitan area resembles a very flat basin or saucer-shaped depression slightly elongated in a northeast-southwest direction. Average dip of the beds on sides of the basin according to recent findings appears to be about 20 feet per mile.1/ Exposure of porous for-

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1/ Schwartz, George, M., The Geology of the Minneapolis-St. Paul metropolitan area: Bull. 27, Minnesota Geological Survey, p. 89, 1936.

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mations at the surface surrounding the structural depression or beneath the glacial drift permits water to seep into them and find its way toward the center for domestic and industrial use.

Moraines with rolling or pronounced hilly surface cover most of the district except in the northern portion where the Anoka Sand Plain extends into the basin. Lake Minnetonka and most of the other lakes resulted from irregular heaping up of rock debris by the glacier and disturbance of preglacial drainage systems. Materials in the moraines of this area were left by several ice invasions and have formed relatively deep, fertile and permeable soils (Figure -). Land extends generally free of stone both on and below the surface except on the young red drift left by the Patrician ice sheet.

Land Use - Mixed dairy and general farming typifies the agricultural use. Many truck farms and specialty farms frequent the Twin City metropolitan fringe. Some farms devote considerable acreage to potatoes. Over four-fifths of the land lies within farms, of which over 70 percent classes as tillable. Inherent productivity of soils grades from good to poor. Urban area aggregates over 108,000 acres.

Illustrations And Tabulations

CLIMATE OF MINNESOTA

Introduction

Minnesota's basic industries, agriculture, mining and quarrying, forestry, and recreation all closely reflect climatic conditions, and consequently the industries of conversion and exchange founded upon these industries are also affected. Climate conditions the distribution as well as the yield of agricultural crops and the general systems of farming. It sets the limits of distribution of vegetation types. Practical cessation of mining operations on the iron ranges and the industrial shift to logging and allied occupations in winter attests further to the rule of climate. It imparts a strong seasonality to Minnesota employment and affects very intimately the economic and cultural life of Minnesota through its influence on income and cost of living, particularly in northern portions.

Climatic differences, whether inter-state or intra-state vitally concern in a number of ways the summer commercial recreation industry. Effective conservation of natural resources of the State, particularly water and forest resources, depends to a notable extent upon understanding climatic conditions both "normal" and "abnormal". It is an element in the physical resources of the State which can scarcely be over-acknowledged.

Minnesota lies entirely within the climatic province described as "humid continental with short summers". Major climatic features are hot summers, cold winters, comparatively short growing season, late spring and early summer rainfall, swift changes in weather, and abundant sunshine. However, through comparison of statistical data compiled through weather observations over a long period of time it is possible to bring out certain definite differences of climatic regime within an area as large as Minnesota. Criteria for differentiation are principally diversity in amount and time of precipitation (various forms are rain, snow, hail, and sleet) and the temperature conditions.

Climatic Controls

Climate has been defined as continuous composite weather. Description of it must be predicated on a perspective of major controls of climate. Those affecting the State are:-

Latitude - Minnesota lies between 42° 30' and 49° 24' north latitude, a distance of 406 miles. Within this distance latitudinal difference alone will profoundly influence temperature and effectiveness of precipitation. Great annual range in solar radiation makes winters long and cold with but 8 to 9 hours of daily sunshine and the summers short but with 15 to 16 hours of daily sunshine (Figure -). On Minnesota's northern boundary daily sunshine lasts twice as long in July as in January.

Land and Water - Minnesota is remote from tempering influence of the sea and so has relatively great seasonal fluctuations of temperature. Mid-continent areas are prone to be productive of unstable air currents, frequent thunderstorms, and occasional destructive cyclones or tornadoes.

Great water areas of the Gulf of Mexico and the Atlantic Ocean, especially the Gulf, constitute initial sources of large quantities of water vapor which are carried into the Mississippi Valley in which Minnesota lies by the continental indraft of air during warmer months. To a minor extent the Great Lakes affords supplies of water vapor.

Affect of winds from great bodies of water is to equalize temperatures of lands near by and lengthen the crop-growing season. In the vicinity of Lake Superior, the great inland sea effects a more moderate winter climate than would otherwise obtain in that portion of Minnesota. Summer temperatures are likewise tempered and people from long distances inland are attracted to that section during hot summer months. Unnumbered smaller lakes scattered throughout the State exert material local influence in modulating the heat of summer and giving comfort to thousands of residents on their shores.

Relief - All Minnesota freely opens to the vast interior lowlands of Canada on the north and to the Gulf of Mexico on the south. During winter months cold air from the far north may easily sweep southward over Minnesota with no obstruction. The Mississippi Valley forms a wide trough up which moisture-laden southeast winds may pass to the north interior in which Minnesota lies.

Pressure Conditions - Mid-continental region embracing Minnesota tends to become much colder than the oceans and Gulf in winter and much warmer in summer. Result is that air pressure, on the whole, is higher in winter and lower in summer than over the water bodies. Because air moves down the pressure gradient from an area of high pressure to a region of low pressure, there is a general tendency for air during winter to flow toward the south and east, being replaced by the cooler and drier air from Canada. Upon moving southward the air becomes warmer and can hold more moisture, hence precipitation is least during winter. During summer the converse holds true. Pressure over interior regions is lower than over the water bodies and moisture laden winds in general blow into the area. Spring and fall months constitute transition periods in air pressure conditions.

Cyclonic Storms - Minnesota lies in the path of prevailing drift from the west of midlatitude air masses - low and high pressure areas. The more or less elliptical low pressure areas usually result from removal of air above due to heating and expansion. The broad atmospheric eddy (average diameter of 1000 miles) which sets in with its attendant weather phenomena is known as a cyclonic storm (not to be confused with cyclones). Winds in general blow toward and around the center in a counterclockwise direction. Toward east of center the winds generally blow in from southeast and are both warm and filled with moisture. As they come in contact with cooler air and are forced to rise as they approach the center of the cyclonic area they precipitate their moisture. Northwest winds to north and west of the cyclonic center bring cold dry air. High pressure areas that are built up and follow low pressure areas from west to east are known as anticyclones and usually bring clear and cooler weather.

As there is an average of almost two cyclonic storms each week with fair weather periods between, Minnesota has variable and rapidly changing weather. Cyclones are much more intense and move at higher speeds in winter than in summer because of greater contrast in temperatures of high and low latitudes during winter season. In summer the rainfall is produced [illegible] by convectional disturbances, usually of thunderstorm variety, and by the forcing up of warm gulf air over cooler polar air.

Temperature

Average annual temperature of Minnesota for the period 1891 to 1938 inclusive, is 41.6 degrees. Highest annual mean temperature, 46.9 degrees, occured in 1931, and the lowest, 37.7 degrees, in 1917. Departure from normal of the average temperature of any year may readily be determined in figure -.

Coldest month is January, which has a mean temperature of 9.2 degrees. The average for February reaches considerably higher, 12.5 degrees, but in many instances February has averaged colder than the preceeding January. July is the warmest month, with an average temperature of 70.0 degrees, although in a few years, the mean temperature for June or for August recorded higher than for July of the same year.

Temperature conditions may be generalized in terms of average temperatures for different seasons of the year, average length of growing season, and average dates of last killing frost in spring and first killing frost in fall. The maps depicting these climatic aspects are based upon reports of 74 weather stations all having over ten years of record up to 1938. Lines, or isotherms, are drawn through all points that have the same average temperature or the same average dates of first or last killing frost.

Temperature maps indicate temperature conditions which may be expected to prevail in any specific area of considerable extent in each of the four seasons of the year - spring, summer, fall, and winter (Figures - to -). From these it may be noted the temperature of the State presents great differences from one season to another and appreciable diversity both with relation to latitude and water.

In-so-far as altitude affects temperature the three widely separated sections of highest elevation, the northeast wedge, the southwest corner, and the section of large moraines around the source of the Mississippi, should have temperatures between two and three degrees lower than those areas approximating 900 to 1,000 feet in south central portion of Minnesota and along the Red River Valley. Pipestone, which lies along the Coteau at 1,710 feet, records an average temperature from 1.5 to 2.0 degrees lower than several stations below 1,000 feet at about the same latitude. The high moraine district has average temperatures from one to two degrees lower than stations approximately at the same latitude in less elevated Red River Valley.

Winter - Latitudinal and water controls apparent in annual averages, are most evident in averages for winter months and in winter season averages. Greatest differences in temperature exist during that period between northern and southern Minnesota. Lowest January averages recorded in the north are

0.5 degrees and 0.9 degrees for Hallock and Roseau, respectively. In the south the highest January averages exist at Faribault and St. Peter with 14.6 degrees (Table -). Figure - illustrates the rather steep temperature gradient between northern and southern parts of the State during winter. In general, the map shows that winter temperatures are lowest toward the northwest and in directions away from the lake. Lines of equal temperature all bend southward around localities of higher altitude such as the north-central high moraine area and in southeastern and southwestern Minnesota. January and February include the lowest temperatures of the year. Note in table -, the average temperaturesfor the coldest month on record for selected stationsand the lowest extremes. Table - gives stations and date of lowest temperatures recorded in Minnesota. Occassional periods during the winter when for several days temperatures hover around 20 degrees below or lower account for limited cultivation of fall sown crops. Duration and intensity of the cold depends upon strength of the Polar Continental high pressure air mass. Average monthly temperatures for weather stations recording temperatures show marked breaks between November and December and between February and March, setting off the three months as a definite period (Table -).

Spring - Spring is the period of transition. In March and April unstable atmospheric conditions prevail which involve sharp variations in temperature. Cyclonic storms begin to move more slowly and erratically as insulation increases. Except in the northeast third of the State a rapid rise in temperature occurs. Water of Lake Superior warms much more slowly than the land and this lowers temperatures of adjoining areas (Figure -). Duluth has an average temperature of 47.3 degrees in May while Moorhead in approximately the same latitude records 55.1 degrees. Melting of a compartively deep snow

MONTHLY AND ANNUAL MEAN TEMPERATURE AND MEAN DAILY RANGE IN DEGREES FAHRENHEIT

Station	Monthly and annual mean temperature to 1938, Inc.													Yrs.	Mean daily range			
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.	Rec.	Jan.	Apr.	July	Oct.
NORTHERN DIV.																		
Ada	4.2	7.5	22.9	42.1	54.0	63.7	68.6	66.1	57.0	43.8	26.1	10.8	38.9	42*	20.4*	24.3*	24.6*	24.1*
Ah-gwah-ching	6.5	11.4	25.7	41.3	53.5	63.9	68.7	65.7	57.4	45.1	28.6	13.6	40.1	31*	19.9*	21.4*	22.1*	19.0*
Angus	2.0	6.6	22.3	40.7	52.5	62.4	66.7	64.5	56.0	43.1	26.1	9.1	37.7	36*	21.2*	23.5*	26.2*	23.7*
Argyle	3.3	9.0	22.8	41.0	53.7	63.5	68.0	66.1	56.7	42.7	26.1	8.5	38.4	22	21.4	24.0	26.5	23.5
Baudette	2.2	7.3	21.0	39.4	52.0	62.0	66.9	64.1	55.4	42.4	26.0	10.0	37.4	28	22.2	25.2	26.1	20.9
Bemidji	5.4	9.1	22.5	41.7	54.4	63.9	68.5	66.7	56.3	45.5	27.9	13.9	39.6	20	21.0	24.4	25.6	20.2
Big Falls	3.8	13.8	33.2	39.6	52.5	63.8	69.0	68.2	56.1	49.1	23.4	11.8	40.4	8	25.6	23.4	27.1	23.9
Cloquet	6.8	11.4	23.5	39.3	50.6	60.2	65.7	63.1	54.9	43.3	28.3	13.7	38.4	28*	23.0*	25.5*	27.8*	21.6*
Crookston	3.7	7.4	22.3	41.8	54.0	64.5	69.0	66.2	57.0	44.1	26.5	11.8	39.0	50	19.5	21.7	21.8	20.5
Detroit Lakes	4.0	7.5	23.1	41.0	53.4	63.0	68.3	65.7	56.9	44.2	27.2	11.0	38.8	43	23.8	24.1	25.6	23.3
Duluth	7.9	11.4	23.7	37.0	47.3	57.2	63.9	62.6	55.1	44.1	30.0	15.9	38.0	68	17.3	15.9	18.7	14.4
Fosston	2.4	8.3	23.5	41.2	52.6	63.1	67.6	65.0	56.4	43.8	26.2	10.1	38.4	29	20.3	19.5	23.8	21.8
Grand Marais	14.6	17.1	24.9	36.7	44.6	52.6	59.4	62.0	54.5	43.2	31.4	18.7	38.3	22	20.0	17.2	23.2	17.4
Grand Rapids	5.0	11.3	24.0	39.5	52.3	62.0	67.4	64.2	55.3	43.0	27.4	11.4	38.6	24*	24.8*	25.9*	28.7*	21.9*
Hallock	0.5	4.6	20.2	40.4	52.9	62.7	66.8	64.8	55.6	42.9	25.3	7.9	37.0	40	22.3	23.9	26.8	22.8
Itasca State Park	3.3	9.1	21.8	40.1	51.8	61.4	66.1	63.0	54.9	42.4	27.8	11.9	37.8	26	25.9	25.9	27.3	26.1
Leech Lake Dam	5.1	8.4	22.2	40.0	51.7	62.5	67.1	63.8	55.7	43.4	26.8	12.3	38.2	51*	22.9*	24.6*	24.3*	21.3*
Meadowlands	6.6	10.0	23.3	39.4	50.6	61.0	66.0	62.5	54.5	42.9	27.9	12.5	38.1	28*	24.0*	24.8*	26.5*	21.1*
Moorhead	3.8	8.1	22.7	40.6	55.1	64.4	68.1	66.1	58.2	44.5	27.1	11.5	39.2	58	19.3	21.3	23.4	21.2
Park Rapids	3.8	7.6	22.5	40.1	52.6	63.1	68.0	64.7	55.7	43.0	26.3	11.9	38.3	48	22.8	23.0	25.1	21.5
Pine River Dam	5.2	8.7	22.9	40.6	52.6	63.5	68.5	65.4	57.1	44.4	28.0	13.5	39.2	52*	23.2*	24.7*	24.0*	21.7*
Pokegama Falls	3.9	7.4	21.6	39.3	51.2	61.4	66.0	63.2	54.6	42.6	26.3	11.2	37.4	51	25.6	25.9	26.5	23.2
Redby	3.5	9.6	22.3	40.2	52.8	63.4	68.2	65.3	57.5	44.1	27.4	12.2	38.9	33	22.1	23.3	22.1	20.4
Red Lake Falls	3.3	7.4	22.0	42.1	53.5	64.0	69.1	66.3	57.0	44.3	28.2	10.2	39.0	23*	22.1*	23.7*	23.9*	23.3*
Roseau	0.9	5.2	20.3	40.3	52.4	62.7	66.5	63.8	55.1	42.5	24.4	8.2	36.9	34	21.9	22.7	26.9	22.7
Sandy Lake Dam	6.5	9.9	23.5	40.3	52.2	62.3	67.2	64.5	56.3	44.3	28.0	13.3	39.0	46*	22.9*	23.9*	23.4*	20.1*
Two Harbors	12.6	15.0	26.1	39.0	48.1	56.8	64.0	63.9	56.5	45.6	31.7	18.7	39.8	45*	21.0*	19.4*	24.2*	18.8*
Virginia	5.7	9.8	23.0	39.9	51.6	61.7	66.2	63.3	55.1	42.9	26.2	11.6	38.1	45	21.6	24.5	27.0	21.3
Warroad	1.2	6.5	20.4	39.1	51.8	62.5	66.7	63.9	54.5	43.1	25.7	9.1	37.0	31	22.7	23.0	23.2	20.4
Winnibigoshish	5.0	8.7	22.5	40.1	52.7	63.2	68.0	64.8	56.6	44.0	27.1	12.7	38.8	51	22.0	24.0	22.8	19.5
SOUTHEASTERN DIV.																		
Albert Lea	12.7	16.9	30.3	46.1	57.8	67.2	72.6	70.0	61.7	48.9	32.8	19.3	44.7	50	17.4	20.4	22.3	20.4
Brainerd	7.3	10.4	24.5	42.1	54.2	62.8	68.5	65.6	56.5	44.9	29.7	13.8	40.0	34	20.5	21.9	23.2	20.7
Cambridge	9.1	12.2	27.8	43.4	57.9	67.6	72.0	69.1	60.0	46.2	27.9	15.8	42.4	11	20.2	21.0	27.3	22.3
Chaska	14.4	21.2	31.4	45.8	58.5	68.2	73.9	70.2	61.9	48.2	32.8	17.9	45.4	14	1/	1/	1/	1/
Collegeville	11.8	15.2	28.3	44.4	55.9	65.7	70.7	68.2	59.9	47.4	31.3	17.6	43.0	46*	19.2*	20.5*	21.4*	18.7*
Faribault	14.6	17.6	31.1	46.0	57.3	66.4	71.6	69.5	61.9	49.7	34.4	19.6	45.0	41	19.2	22.1	18.3	21.6
Farmington	12.2	15.2	28.9	45.5	56.4	66.4	71.0	68.8	60.4	47.8	31.6	18.4	43.6	49	20.1	23.0	24.6	22.0
Grand Meadow	12.0	15.6	28.9	44.8	56.0	66.3	71.3	68.6	60.4	47.6	31.8	18.4	43.5	52	18.3	22.8	25.0	22.8
Gull Lake Dam	6.9	12.8	25.5	41.8	53.8	64.0	68.9	66.2	57.8	45.6	29.7	14.4	40.6	28	1/	1/	1/	1/
Hinckley	8.8	11.9	27.1	42.6	53.0	63.8	68.5	64.9	58.1	44.4	32.1	16.4	41.0	18	1/	1/	1/	1/
Little Falls	9.7	13.6	26.9	43.0	54.2	64.8	70.2	67.4	58.8	46.2	31.4	15.3	41.8	29*	19.8*	22.5*	27.9*	23.6*
Maple Plain	11.3	14.4	29.1	45.4	57.3	67.3	72.0	69.4	60.9	48.4	31.7	17.5	43.7	41*	17.2*	22.6*	23.8*	20.3*
Milaca	9.2	12.8	27.0	42.4	54.2	63.8	69.0	66.4	57.8	46.0	30.5	14.8	41.2	36*	21.0*	24.1*	25.9*	22.3*
Minneapolis	12.7	15.9	29.6	46.4	57.7	67.5	72.3	69.9	61.4	48.9	32.4	19.6	44.5	48	16.8	18.8	19.5	17.6
Mora	9.2	13.8	27.7	43.3	54.1	64.3	69.2	66.6	58.4	45.8	31.2	16.1	41.6	34	21.2	24.1	26.0	22.2
Rochester	9.4	16.4	28.9	45.1	56.2	67.2	71.6	68.5	60.7	47.8	33.3	19.3	43.7	28	19.4	21.5	25.0	22.3
St. Cloud	9.8	13.4	27.4	44.3	56.3	65.7	71.2	68.2	59.4	48.7	30.2	16.8	42.6	62	20.8	19.9	23.9	21.0
St. Paul	12.6	15.8	29.1	45.6	57.9	67.1	72.1	69.4	61.3	48.6	32.5	19.0	44.2	66	17.3	19.1	19.8	17.6
St. Peter	14.6	17.6	31.9	47.4	58.2	68.1	72.4	70.4	62.4	50.0	33.9	20.0	45.6	44	20.6	23.2	25.4	22.2
Taylors Falls	11.7	15.5	29.1	45.5	56.6	66.2	71.1	68.5	61.0	48.4	33.6	18.4	43.8	33	24.3	24.5	26.0	23.4
Waseca	12.7	18.7	31.4	45.4	57.3	66.9	72.2	69.7	61.5	48.5	33.3	18.4	44.7	23*	20.6*	23.4*	24.5*	22.5*
Winnebago	14.2	17.8	31.3	46.5	58.0	67.2	72.3	70.3	61.7	49.7	33.7	19.9	45.2	43	18.3	22.6	23.8	22.6
Winona	14.1	18.9	32.3	47.7	59.6	68.8	73.4	70.4	62.5	49.6	35.1	21.5	46.2	43	18.0	20.6	22.2	20.2
SOUTHWESTERN DIV.																		
Alexandria	7.1	10.8	24.8	42.2	54.4	64.6	69.6	67.1	58.1	45.5	28.9	12.9	40.5	44	20.1	21.1	21.9	20.5
Artichoke Lake	12.0	18.0	30.1	44.0	56.3	65.9	71.4	69.2	60.6	47.0	30.8	15.6	43.4	22	19.7	23.1	24.7	22.7
Beardsley	11.6	14.4	28.3	45.2	56.7	65.8	71.1	69.2	60.2	48.0	31.1	16.9	43.2	40	22.5	25.6	28.1	27.4
Bird Island	11.4	15.1	29.0	45.4	56.9	66.2	71.4	68.8	60.7	48.1	31.4	17.4	43.5	49	20.0	23.1	23.0	23.3
Campbell	5.8	11.0	25.2	42.8	54.1	64.4	69.1	66.6	57.6	44.2	27.9	13.2	40.2	34	21.4	25.1	27.6	28.1
Canby	14.3	19.8	31.1	46.1	57.5	67.8	74.0	70.7	61.4	49.1	33.8	19.1	45.4	21	18.6	17.3	26.0	23.5
Fairmont	13.8	17.1	30.1	46.0	57.5	67.3	72.3	69.8	61.6	48.9	32.9	20.3	44.8	52	18.6	22.1	21.5	21.4
Fergus Falls	8.0	11.8	26.2	43.6	55.7	65.7	70.8	68.4	59.1	46.1	28.7	14.4	41.5	47	19.4	22.2	23.7	20.6
Long Prairie	6.8	9.5	25.4	43.1	54.6	64.6	68.7	66.5	58.3	44.9	28.5	14.4	40.4	25*	20.9*	24.8*	26.0*	21.9*
Milan	10.6	14.2	28.6	45.2	56.5	65.7	70.7	68.6	59.9	47.3	30.4	16.5	42.8	45*	22.2*	24.6*	27.6*	25.1*
Montevideo	11.9	15.4	28.9	45.6	57.1	66.9	71.6	69.2	61.3	48.4	32.0	17.8	43.8	48	18.3	22.8	24.4	23.2
Morris	8.3	12.5	26.9	44.5	55.9	66.0	70.6	68.1	59.4	46.5	29.5	15.7	42.0	53	19.8	22.9	23.8	22.6
New London	9.6	13.0	27.2	43.6	55.4	65.6	71.2	68.8	60.3	46.9	30.7	15.6	42.3	45	20.7	21.5	23.0	22.0
New Ulm	13.4	16.4	30.7	46.1	57.8	67.9	73.0	70.3	61.3	48.4	32.5	18.9	44.7	45	21.0	20.5	25.3	24.7
Pipestone	13.8	16.3	29.9	45.0	56.2	65.7	71.7	69.9	60.7	48.6	32.7	18.6	44.1	37	20.1	24.4	24.8	24.0
Redwood Falls	12.7	19.8	31.9	46.6	58.0	67.4	73.5	70.7	62.1	49.2	32.8	19.1	45.3	24*	19.7*	23.6*	24.1*	22.1*
Tracy	14.0	19.5	30.5	46.2	57.7	67.4	73.2	70.7	62.4	49.0	33.7	18.9	45.3	27	19.2	22.9	23.8	21.8
Wadena	5.6	12.6	25.5	40.4	52.8	63.0	67.3	65.8	57.8	44.0	29.3	13.0	39.8	20	22.5	23.2	35.5	22.2
Wheaton	9.7	16.7	28.8	44.5	55.3	65.6	71.8	69.3	60.2	46.9	31.2	14.7	42.9	23*	20.3*	24.1*	25.7*	23.9*
Willmar	11.1	14.9	27.5	44.3	56.1	65.6	71.0	68.3	59.5	46.5	29.3	15.7	42.5	32	19.0	21.2	23.8	21.5
Windom	12.1	16.6	31.7	44.9	56.0	65.0	71.7	70.2	61.5	48.2	35.3	18.8	44.3	12	20.9	22.6	25.2	25.8
Worthington	14.1	17.2	30.0	45.3	56.5	66.0	71.2	69.1	61.1	48.4	32.5	19.4	44.2	44	18.8	21.6	22.7	22.1

* Data compiled to 1930 only.
1/ Data not available in Climatic Summary of 1930.
Source: Compiled from Climatological Data, U. S. Weather Bureau

TEMPERATURE DATA FOR SELECTED STATIONS

Selected Stations	County	Elevation	Years of Record	Annual Mean Temp.	Average Annual Maximum	Average Annual Minimum	Maximum Average Monthly	Month	Minimum Average Monthly	Month	Average Temp. Warmest Month	Month	Year	Average Temp. Coldest Month	Month	Year	Absolute Maximum	Month	Year	Absolute Minimum	Month	Year
Grand Meadow	Mower	1338	53	43.5	54.8	33.4	84.1	July	2.8	Jan.	79.4	July	1901	-4.1	Jan.	1912	107	May	1934	-39	Jan.	1887
Minneapolis	Hennepin	839	49	44.5	63.0	36.1	82.8	July	5.1	Jan.	81.4	July	1936	-2.7	Jan.	1912	108	July	1936	-34	Jan.	1936
Fergus Falls	Otter Tail	1210	48	41.5	52.2	31.2	83.2	July	-1.9	Jan.	80.4	July	1936	-8.4	Feb.	1936	110	July	1936	-42	Feb.	1936
Moorhead	Clay	904	58	39.2	50.3	29.2	81.2	July	-5.2	Jan.	80.2	July	1936	-9.3	Jan.	1887	114	July	1936	-48	Jan.	1887
Worthington	Nobles	1593	45	44.2	54.8	34.0	83.2	July	4.9	Jan.	80.7	July	1936	-2.0	Jan.	1912	110	July	1936	-37	Feb.	1899
Duluth	St. Louis	1128	64	38.0	47.3	30.6	74.8	July	0.2	Jan.	70.2	Aug.	1930	-7.2	Jan.	1912	106	July	1936	-41	Jan.	1885
Hallock	Kittson	815	40	37.0	48.9	25.3	78.6	July	-10.9	Jan.	78.0	July	1936	-14.4	Feb.	1936	109	July	1936	-51	Feb.	1914
Winnibigoshish	Itasca	1315	52	38.8	49.9	28.2	80.0	July	-6.1	Jan.	75.2	July	1916	-10.0	Jan.	1912	103	July	1901	-49	Feb.	1933
Collegeville 1/	Stearns	1242	47	43.0	52.8	33.1	81.3	July	1.8	Jan.	75.0	July	1894	-2.5	Jan.	1912	106	July	1936	-39	Jan.	1936

Note: Data compiled to 1938, inclusive
1/ Collegeville data computed to and including 1930 only, as no data is available for subsequent years. Revisions to 1938 would show only negligible change.
Source: Compiled from Climatological Data, U. S. Weather Bureau

STATIONS WITH HIGHEST AND LOWEST TEMPERATURES RECORDED IN MINNESOTA

Station	County	Years of Record	Elevation Feet	Highest Temperature	Date	Station	County	Years of Record	Elevation Feet	Lowest Temperature	Date
Moorhead	Clay	58	904	114	July 6, 1936	Leech Lake Dam	Cass	51	1,301	-59	February 9, 1899
Beardsley	Big Stone	40	1,090	114	July 29, 1917	Pokegama Falls	Itasca	51	1,280	-59	February 16, 1903
Milan	Chippewa	45	955	113	July 21, 1934	Warroad	Roseau	31	1,069	-55	February 8, 1933
Wheaton	Traverse	23	1,018	113	July 16, 1936	Detroit Lakes	Becker	43	1,364	-53	February 9, 1899
Wadena	Wadena	20	1,350	112	July 10, 1936	Big Falls	Koochiching	8	1,220	-53	February 8, 1933
Maple Plain	Hennepin	41	1,023	112	May 31, 1934	Ada	Norman	42	906	-53	February 15, 1936
Ada	Norman	42	906	111	July 6, 1936[1]	Pine River Dam	Crow Wing	52	1,251	-53	January 12, 1912
Campbell	Wilkin	34	975	111	July 10, 1936	Bagley	Clearwater	12	1,438	-52	January 11, 1912
Canby	Yellow Medicine	21	1,243	111	July 12, 1936	Little Fork	Koochiching	6	1,175	-52	January 7, 1912
New Ulm	Brown	45	791	111	July 14, 1936	Sandy Lake Dam	Aitkin	46	1,234	-52	January 31, 1899
Fosston	Polk	29	1,289	110	July 8, 1936	Roseau	Roseau	34	1,040	-52	February 11, 1914
Red Lake Falls	Red Lake	23	1,001	110	July 12, 1936	Grand Rapids	Itasca	24	1,281	-51	January 26, 1927
New London	Kandiyohi	45	1,215	110	July 20, 1901	Hallock	Kittson	40	815	-51	February 11, 1914
Fergus Falls	Otter Tail	47	1,210	110	July 6, 1936	Park Rapids	Hubbard	48	1,426	-51	February 9, 1899
Redwood Falls	Redwood	24	1,050	110	July 13, 1936[1]	Itasca State Park	Clearwater	26	1,500	-51	February 8, 1933
Worthington	Nobles	44	1,593	110	July 17, 1936	Crookston	Polk	50	888	-51	February 15, 1936
Farmington	Dakota	49	902	110	July 14, 1936						

Note: Data compiled to 1938, inclusive.
1 Other dates are in other months also.
Source: Compiled from Climatological Data, U. S. Weather Bureau

layer and the prevalence of heavier forest cover retards the rise north and west of the lake. Comparisons of average temperatures for stations within this area and western prairie stations attest to this condition (Table -). Effect of higher elevation may be seen in figure -.

Summer - Examination of table - reveals that July represents the warmest month everywhere in Minnesota. It is pertinent to note that in summer months interior stations north of Lake Superior experience higher average monthly summer temperatures than do stations near the lake. Further, the daily range of temperatures averages smaller along the lake than at inland stations, due to lower daily maximums and higher daily minimums but temperature varies more from day to day, due to frequent onshore winds (Table -).

The Lake Superior region has become increasingly popular in summer months as a resort area not only for residents of the State, but for people throughout central United States. Low summer temperatures together with exceptional recreation resources make most of northern Minnesota attractive as a summer vacation land not only to residents south of Minnesota but within the State as well. With occassional "hot waves", there is a virtual exodus to northern centers, particularly in northeastern Minnesota. Table - gives the stations with the highest temperatures recorded in Minnesota.

Cool weather sometimes comes with the passing of weak summer cyclones in July and August. Such occurrences afford welcome interruption, particularly in the southern division of the State, to rather continuous summer heat in those months. Figure - graphs the average summer temperature distribution.

Fall - In the fall, lowering temperatures enable the continental air mass to steadily build up, without however, rapidly moving cyclones and sudden changes which characterize the spring transition period. Cold air moving in from the north results in dry clear weather commonly known as "Indian Summer". There is enough solar insolation to create warm days but the nights turn cool. In the fall Lake Superior cools more slowly than surrounding land; hence the isotherms turn northward near the lake (Figure -). Average monthly temperatures show marked breaks between October and November.

Frost-Free Season

Probably no other factor in the study of climate from the standpoint of agriculture should be given more consideration than length of growing season. This is the key to actual knowledge regarding possibilities of success or failure in production of crops in various parts of the State. As seen from tables -, -, and -, frosts have occured in some parts of Minnesota every month of the year and not uncommonly in most of Minnesota in the latter half of May and before the middle of September. Damagingly low temperatures, however, except in northern portions, may not be expected during June, July and August. As shown by figure -, nearly the entire State has an average expectancy of 110 or more frost-free days. Most elevated sections of the State may expect shorter periods as brought out in figure - . Nearness to Lake Superior materially affects length of the growing season. The longest season, 160 days, obtains along the Mississippi River in Wabasha and Winona Counties as shown in figure - and very probably along the lowlands of the valley both farther north and south. The Minneapolis-St. Paul area also enjoys 160 days or more. Shortest season, of 100 days or less, extends in a broad loop mainly north of the iron ranges. Note the bars comparing length of growing season for north to south stations, in eastern, central and western portions of the State. Table - registers average date of last killing frost in spring and first in autumn and average length of growing season for selected stations in Minnesota.

DATE OF LAST KILLING FROST IN SPRING IN MINNESOTA
SELECTED STATIONS TO 1938, INCLUSIVE

Station	County	Elevation Feet	Years of Record	April						May						June						July		
				1-5	6-10	11-15	16-20	21-25	26-30	1-5	6-10	11-15	16-20	21-25	26-30	M 31-J 4	5-9	10-14	15-19	20-24	25-29	J 30-J 4	5-9	10-14
				Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent
NORTHERN DIVISION																								
Ada	Norman	906	42						4.7	2.3	7.1	9.5	16.7	21.4	7.1	9.5	19.0	2.3						
Ah-gwah-ching	Cass	1,336	31					3.2	3.2	12.9	19.3	22.5	9.7	16.1	3.2	3.2		3.2			3.2			
Angus	Polk	870	37						2.7		8.1	5.4	18.9	13.5	10.8	10.8	16.2	8.1	5.4					
Baudette	Lake of Woods	1,084	29						3.5		3.5	13.7	13.7	27.5	3.5	6.9	13.7	10.3	3.5					
Bemidji	Beltrami	1,400	22							9.1	9.1	9.1	9.1	18.1	18.1	9.1	9.1	9.1						
Crookston	Polk	88	49				2.0		6.1	6.1	12.2	16.3	14.3	18.3	12.2	4.1	8.1							
Detroit Lakes	Becker	1,364	42						4.7	2.3	7.1	7.1	21.4	9.5	11.9	7.1	11.9	9.5	7.1					
Duluth	St. Louis	1,133	66		1.5		7.5	6.1	13.1	16.8	13.6	13.6	15.1	6.1	4.5		1.5	1.5						
Grand Marais	Cook	606	23							8.7	8.7	21.7	8.7	13.0	21.7	8.7	4.3	4.3						
Hallock	Kittson	815	40						2.5		10.0		12.5	15.0	10.0	12.5	22.5	10.0	5.0					
International Falls	Koochiching	1,112	21						4.7		4.7	9.5	14.3	4.7	23.8	9.5	4.7	9.5	4.7	4.7				4.7
Leech Lake Dam	Cass	1,301	41						2.4		7.3	9.7	26.8	17.1	9.7	7.3	9.7	7.3	2.4					
Meadowlands	St. Louis	1,259	30							3.3		6.7		16.7	16.7	13.3	16.7	6.7	6.7	6.7	6.7			
Moorhead	Clay	935	58				6.9	3.5	6.9	17.2	10.3	13.7	17.2	8.6	6.9	5.1	3.5							
Park Rapids	Hubbard	1,426	47						2.1	4.2	19.1	17.0	19.1	17.0	8.5	4.3	6.3				2.1			
Pokegama Falls	Itasca	1,280	52							1.9	7.7	1.9	7.7	13.5	7.7	17.3	19.2	9.6	3.9	7.7		1.9		
Redby	Beltrami	1,158	32							6.3	9.3	18.7	9.3	31.3	6.3	9.3	6.3	3.1						
Red Lake Falls	Red Lake	1,001	22							13.6		9.1	22.7	22.7		18.1	13.6							
Roseau	Roseau	1,040	35						2.9			11.4	11.4	11.4	5.7	20.0	17.1	5.7	8.6	5.7				
Sandy Lake Dam	Aitkin	1,324	46					2.1	2.1	4.3	13.0	6.5	10.9	21.7	10.9	10.9	8.7	4.3		2.1	2.1			
Tower	St. Louis	1,357	17							5.9		11.7	11.7		11.7	17.7	5.9	23.5			11.7			
Two Harbors	Lake	614	45					4.4	6.7	8.9	4.4	28.9	8.9	15.6	8.9	4.4	4.4	2.2	2.2					
Virginia	St. Louis	1,465	45						2.2		4.4	8.9	11.1	17.8	20.0	6.7	15.6	4.4	6.7	2.2				
Winnibigoshish Dam	Itasca	1,315	41						2.4	7.3	14.6	14.6	31.7	9.8	12.2	4.8		2.4						
SOUTHWESTERN DIVISION																								
Alexandria	Douglas	1,391	43					2.3	7.0	23.3	18.6	20.3	11.6	9.3	4.7	2.3								
Beardsley	Grant	1,090	41					2.4	2.4	2.4	17.1	14.6	12.2	12.2	9.8	4.8	14.6	4.8	2.4					
Bird Island	Renville	1,039	47		2.1			10.6	11.6	21.3	10.6	14.9	12.7	8.5	2.1	2.1	4.3							
Canby	Yellow Medicine	1,243	16						18.8	18.8	6.3	18.8	6.3	31.3										
Fairmont	Martin	1,240	52	1.9		1.9	3.9	11.5	28.1	19.2	5.8	9.6	11.5	5.8	1.9	3.9								
Fergus Falls	Otter Tail	1,210	45					6.7	15.6	13.3	13.3	20.0	8.9	15.6	2.2		4.4							
Long Prairie	Todd	1,299	25					8.0		4.0	28.0	20.0	12.0	8.0	4.4	4.0	8.0		4.0					
Lynd	Lyon	1,175	30					6.7	6.7	13.3	23.3	10.0	13.3	16.7	3.3		6.7							
Milan	Chippewa	955	45				2.2	2.2	6.7	11.1	17.8	11.1	17.8	17.8	4.4	2.2	6.7							
Montevideo	Chippewa	900	48					8.3	18.8	22.9	12.5	10.4	14.6	8.3	2.1		2.1							
Moorhead	Clay	935	57				7.0	3.5	7.0	17.5	8.7	14.0	17.5	8.8	7.0	5.3	3.5							
Morris	Stevens	1,170	54					3.7	7.4	13.0	18.5	13.0	22.2	5.6	3.7	9.3	3.7							
New London	Kandiyohi	1,215	46			2.2		8.7	15.2	21.7	10.9	17.4	10.9	8.7		2.2	2.2							
New Ulm	Brown	791	45	2.2				13.3	20.0	17.8	6.7	8.0	8.9	13.3	4.4		2.2	2.2						
Pipestone	Pipestone	1,710	37				2.7		10.8	16.2	10.8	21.6	13.5	13.5	2.7		5.4			2.7				
Redwood Falls	Redwood	1,050	24					16.7	20.8	25.0	16.7	4.2	8.3		4.2		4.2							
Wadena	Wadena	1,350	19						5.3	5.3	21.1	5.3	10.5	15.8	5.3	15.8	15.8							
Wheaton	Traverse	1,018	23						8.7	8.7	17.4	21.7	21.7	13.0	4.4		4.4							
Willmar	Kandiyohi	1,133	34			2.9		11.8	14.7	20.6	5.8	17.7	11.8	11.8			2.9							
Worthington	Nobles	1,593	43				2.3	11.6	9.3	18.6	9.3	18.6	14.0	11.7	2.3		2.3							
SOUTHEASTERN DIVISION																								
Collegeville	Stearns	1,242	46			4.4		6.5	10.9	19.6	13.0	17.4	13.0	8.7	4.4		2.2							
Farmington	Dakota	902	46					4.4	15.2	17.4	10.2	17.4	15.2	13.0	2.2		4.4							
Grand Meadow	Mower	1,338	53			1.9		5.7	9.4	22.6	3.8	18.9	18.9	7.6	7.6		3.8							
Minneapolis	Hennepin	918	48	2.1	10.4	4.2	10.4	12.5	27.1	16.7	6.3	4.2	6.3											
Mora	Kanabec	1,001	34						5.8	14.7	2.9	29.4	14.7	11.8	8.8	5.8	5.8							
Pine River Dam	Crow Wing	1,251	52					3.9	3.9	3.9	7.7	19.2	17.3	11.5	11.5	9.6	3.9	1.9	3.9			1.9		
St. Paul	Ramsey	703	63	3.2	12.7	7.9	12.7	15.9	19.1	11.1	4.8	6.4	4.8	1.6										
St. Peter	Nicollet	825	46				2.2	8.7	13.0	17.4	8.7	21.7	13.0	4.4	8.7					2.2				
Taylors Falls	Chisago	759	31						9.7	16.1	6.5	25.8	16.1	12.9	6.5									
Winnebago	Faribault	1,100	44					15.9	22.7	15.9	9.1	13.6	11.4	4.5	4.5	2.3								
Winona	Winona	700	39	2.6	10.3		2.6	18.0	15.4	14.4	15.4	10.3	5.1	5.1										

Note: When frost was not recorded the last temperature of 32° or lower was used.
Source: Compiled from Climatological Data, U. S. Weather Bureau.

LENGTH OF GROWING SEASON IN MINNESOTA

SELECTED STATIONS

Station	Elevation	Years of Record	Average Date of Last Killing Frost in Spring	Average Date of First Killing Frost in Autumn	Average Length of Growing Season (Days)	Latest Date of Killing Frost in Spring	Earliest Date of Killing Frost in Autumn
SOUTHEASTERN DIVISION							
Collegeville	1242	46	May 8	Sept. 29	143	June 7	Aug. 12
Farmington	902	46	May 11	Sept. 29	141	June 6	Sept. 9
Grand Meadow	1338	53	May 11	Sept. 28	140	June 8	Sept. 10
Minneapolis	918	48	Apr. 28	Oct. 12	169	May 20	Sept. 13
Mora	1001	34	May 17	Sept. 22	130	June 9	Aug. 27
Pine River Dam	1251	52	May 21	Sept. 29	121	June 30	Aug. 26
St. Paul	837	62	Apr. 25	Oct. 9	166	May 23	Sept. 18
St. Peter	825	46	May 10	Sept. 29	142	June 22	Sept. 10
Taylors Falls	759	31	May 14	Sept. 29	137	June 9	Sept. 10
Winnebago	1000	44	May 6	Oct. 3	150	May 31	Sept. 8
Winona	700	40	Apr. 30	Oct. 6	159	May 25	Sept. 10
Zumbrota	917	36	May 13	Sept. 27	137	June 9	Aug. 30
SOUTHWESTERN DIVISION							
Alexandria	1391	43	May 11	Sept. 29	140	May 31	Sept. 10
Artichoke Lake	1075	22	May 12	Sept. 26	136	May 29	Sept. 4
Beardsley	1090	44	May 21	Sept. 19	120	June 15	Aug. 30
Bird Island	1039	49	May 10	Sept. 29	141	June 7	Aug. 24
Campbell	975	39	May 16	Sept. 19	125	June 9	Aug. 22
Canby	1243	23	May 11	Sept. 30	141	May 24	Aug. 24
Fairmont	1240	44	May 5	Oct. 4	151	May 31	Sept. 11
Fergus Falls	1210	38	May 10	Sept. 23	135	June 7	Sept. 5
Milan	955	46	May 15	Sept. 24	131	June 9	Aug. 30
Montevideo	900	48	May 8	Sept. 29	143	June 7	Sept. 12
Moorhead	935	58	May 12	Sept. 25	135	June 8	Aug. 25
Morris	1170	53	May 14	Sept. 26	134	June 7	Aug. 30
New London	1215	33	May 8	Oct. 1	145	June 6	Sept. 12
New Ulm	791	47	May 8	Sept. 30	144	June 10	Sept. 8
Pipestone	1710	39	May 13	Sept. 26	135	June 21	Aug. 11
Redwood Falls	1050	26	May 8	Oct. 5	149	June 5	Sept. 18
Tracy	1403	28	May 7	Oct. 3	148	May 24	Aug. 25
Wadena	1350	23	May 26	Sept. 23	119	June 7	Aug. 28
Wheaton	1018	25	May 14	Sept. 25	133	June 9	Aug. 30
Willmar	1133	33	May 7	Sept. 25	140	June 7	Sept. 4
Worthington	1593	45	May 8	Oct. 1	145	June 6	Sept. 7
NORTHERN DIVISION							
Ada	906	42	May 23	Sept. 19	118	June 14	Aug. 22
Ah-gwah-ching	1336	31	May 16	Sept. 29	135	June 29	Sept. 9
Angus	870	37	May 27	Sept. 13	108	June 18	Aug. 20
Argyle	845	22	May 25	Sept. 19	116	June 15	Aug. 25
Baudette	1084	29	May 26	Sept. 17	113	June 15	Aug. 26
Bemidji	1400	22	May 24	Sept. 16	114	June 13	Aug. 22
Cass Lake	1323	22	May 23	Sept. 20	119	June 14	Aug. 24
Crookston	888	49	May 18	Sept. 24	128	June 7	Sept. 6
Detroit Lakes	1364	42	May 25	Sept. 19	116	June 18	Aug. 23
Duluth	1133	66	May 8	Oct. 4	148	June 14	Sept. 10
Fosston	1289	28	May 24	Sept. 16	114	June 26	Aug. 13
Grand Marais	606	23	May 21	Oct. 3	134	June 13	Sept. 9
Grand Rapids	1281	24	May 26	Sept. 14	110	June 20	Aug. 20
Hallock	815	40	May 29	Sept. 17	110	June 18	Aug. 24
Itasca State Park	1500	28	June 4	Sept. 11	98	June 18	Aug. 16
Leech Lake Dam	1301	41	May 24	Sept. 14	112	June 15	Aug. 13
Mahnomen	1213	22	May 29	Sept. 17	110	June 14	Aug. 23
Meadowlands	1259	30	June 2	Sept. 9	98	June 27	July 18
Park Rapids	1426	47	May 19	Sept. 20	123	June 25	Aug. 25
Pokegama Falls	1280	44	June 1	Sept. 11	101	June 30	Aug. 2
Redby	1158	33	May 21	Sept. 24	125	June 13	Aug. 28
Red Lake Falls	1001	24	May 23	Sept. 19	118	June 9	Aug. 25
Roseau	1040	35	May 31	Sept. 11	102	June 22	July 18
Sandy Lake Dam	1234	46	May 23	Sept. 19	118	June 28	Aug. 24
Thief River Falls	1137	27	May 25	Sept. 17	114	June 18	Aug. 26
Tower	1375	20	May 31	Sept. 9	100	June 25	Aug. 15
Two Harbors	614	45	May 17	Sept. 29	134	June 17	Sept. 7
Virginia	1465	45	May 27	Sept. 15	110	June 23	Aug. 16
Warroad	1069	30	May 25	Sept. 17	114	June 27	Aug. 25
Winnibigoshish Dam	1315	41	May 18	Sept. 23	127	June 11	Aug. 17

Note: When frost was not recorded the last or first temperature of 32° or lower was used. Data compiled to 1938, incl.
Source: Compiled from Climatological Data, U. S. Weather Bureau.

Using average dates for last killing frost in spring and first killing frost in autumn for a large number of places in Minnesota, figures -, -, and - were constructed to show average beginning and ending of crop growth and to determine the average length of growing season. Lengthening of the season near Lake Superior occurs both in spring and in fall, but particularly in the fall. The lake tends to retard growth of plants in spring until damage of frost is over, and wards off early frost in the fall.

To supplement the maps showing average dates of last killing frost of spring and first of autumn, charts are given at the bottom of each which show for selected stations the deviation of frost occurence from the average - the number of frost occurrences by the number of days before or after the average occurrence. To further indicate distribution of killing frosts in spring and autumn and to bring out the likelihood of occurrence in a given period, percentages of occurrence for most stations in Minnesota are presented in tables - and -. In table - are given the latest date of killing frost in spring and earliest date of killing frost in autumn for a considerable number of stations in Minnesota.

Precipitation

Year in and year out, Minnesota's people are most concerned about the precipitation factor in climate for even moderate deviations within the annual cycle have important consequences. If early summer rains do not come until late in the season, corn and other grain crops sown in April or May sprout too late to become a good money crop. Continuous dry weather during July and August results in extreme evaporation with wilting, and consequently a small crop yield. Drought over some of Minnesota is occassionally desolating. If the season happens to be excessively moist and humid, rust may ravage grains and rot despoil tuber crops. Little precipitation in fall or early spring increases the hazard of forest fires, while excessive precipitation promotes floods and erosion. Hail comes with a frequency unknown in most other regions in the United States and in five minutes may beat a promising crop into the dirt. These are precipitation aspects of the weather which climatic averages inadequately express and which occasionally occur. Happily, precipitation deviations of this nature seldom prevail beyond safe limits and a failure of all the important crops is very rare, even over a small portion of the State.

Annual Precipitation - Annual normal precipitation of the State as a whole for a period of 48 years, 1891 to 1938 inclusive, is 25.15 inches. The geographic distribution of average annual precipitation in Minnesota is shown in figure -, which is based on reports from 86 stations, all but two of which have more than 10 years of record. The point may be emphasized that amounts shown do not mean that every year these quantities of precipitation may be expected. In some years these amounts will be considerably exceeded while in others the amount will be significantly less. Further, relative distribution shown on the map will vary from year to year. Note distribution of departures from normal for selected stations at the bottom of the map. The map is a picture of what the annual average precipitation will be over a long period of years. It shows the following primary facts relating to distribution of annual precipitation.

1. Normal yearly rainfall in Minnesota ranges from slightly less than 20 inches in the northwest to slightly over 32 inches in the southeast. If this amount of rainfall could be depended upon each year, crop production would be secure.

2. Annual rainfall increases from west to east. Precipitation is about one-fourth to one-third greater along the eastern boundary of the State than along the western boundary.

3. Lines of equal annual precipitation (isohyetal lines) tend to run irregularly in a southwest - northeast direction.

4. Area of least rainfall is in the northwest, but there a slower rate of evaporation and transpiration makes precipitation effectiveness somewhat greater than in more southerly portions of the State.

5. Highest areas of eastern Minnesota, the Old Moraine - Hill area and the Superior Upland receive most rains.

6. Major regions of the State divided on the basis of precipitation strikingly conform with natural regions previously described in section on physiography.

Seasonal Distribution - Of more importance than total precipitation is its distribution during the year. Average annual and monthly precipitation for stations in Minnesota are given in table -. From this it may be seen that two-thirds of the rainfall occurs during the period from May 1 to September 30. Figure - illustrates average distribution of precipitation during the growing season. Distribution of the amount of rainfall available in that period is an important factor for most crops in the State, because the proper amount of water in the soil at the critical period of development of the plant is necessary to produce a large crop. Table - shows that June is the wettest month with an average rainfall of 4.01 inches and July next with 3.29 inches. The early summer maximum is, of course, ideal for agricultural purposes. All but two of the stations given have over ten years of record and have been adjusted to a 35 year normal.

The Red River Valley definitely receives least precipitation of any area in the State during the growing season. As most of the summer rain falls in showers of local character the result is that within short distances moisture differences may be considerable in the same season. Greatest rainfall in one month for any station in the State was 16.5 inches at Alexandria in August, 1900 (Table -). Again note from the map the influence of topography on lines of equal precipitation. Mean precipitation and temperature for the growing season are given in table - for 86 stations in Minnesota.

NORMAL MONTHLY AND ANNUAL PRECIPITATION IN INCHES

Station	County	Elevation Feet	Years of Record	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Maximum Monthly Rainfall Recorded	Month	Year
Minnesota				0.8	0.7	1.4	2.1	3.2	4.0	3.3	3.2	2.9	1.8	1.2	0.8	25.2			
NORTHERN DIVISION																			
Ada	Norman	906	46	0.4	0.5	0.7	1.7	2.8	3.7	3.0	2.8	2.2	1.5	0.8	0.6	20.6	8.2	June	1925
Ah-gwah-ching	Cass	1336	32	0.7	0.6	1.1	1.6	2.6	4.3	3.3	3.6	2.8	1.7	1.1	0.7	24.1	11.9	June	1914
Angus	Polk	870	37	0.4	0.5	0.6	1.5	2.4	3.4	3.0	2.7	2.1	1.4	0.7	0.5	19.1	9.9	June	1925
Argyle	Marshall	845	26	0.6	0.6	1.0	1.6	2.4	3.6	3.4	2.6	2.3	1.4	0.8	0.8	21.1	7.3	July	1937
Bagley	Clearwater	1446	13	0.6	0.5	1.0	1.4	2.9	3.9	3.9	2.9	2.7	1.4	0.8	0.8	22.8	9.1	June	1915
Baudette	Lake of Woods	1084	30	0.6	0.5	0.8	1.2	2.4	3.1	3.3	2.8	2.5	2.0	1.1	0.7	20.9	12.5	July	1937
Bemidji	Beltrami	1373	38	0.6	0.6	1.0	1.6	2.6	3.8	3.4	3.4	3.0	1.7	1.0	0.9	23.7	11.0	June	1915
Cass Lake	Cass	1323	33	0.5	0.6	0.8	1.5	2.9	3.8	3.2	3.5	3.1	1.9	1.1	0.6	23.4	11.4	June	1915
Cloquet	Carlton	1265	28	1.0	0.9	1.2	1.7	3.1	4.1	3.8	3.6	3.3	2.3	1.5	1.0	27.3	7.0	July	1924
Crookston	Polk	888	50	0.5	0.6	0.8	1.6	2.8	3.4	3.1	2.7	2.2	1.5	0.7	0.7	20.6	9.7	June	1895
Detroit Lakes	Becker	1364	44	0.6	0.7	0.8	1.8	3.3	4.1	3.7	3.7	2.7	1.9	0.9	0.7	24.7	10.9	June	1915
Duluth	St. Louis	1128	68	1.0	1.1	1.5	2.1	3.3	3.9	3.8	3.2	3.3	2.3	1.5	1.2	27.9	11.5	Sept.	1881
Fosston	Polk	1289	30	0.4	0.6	1.0	1.3	2.6	3.7	2.9	2.8	2.5	1.5	0.9	0.7	20.8	13.4	July	1909
Gonvick	Clearwater	1454	18	0.5	0.6	0.8	1.2	2.2	3.3	3.5	3.2	2.3	1.4	1.0	0.7	20.5	7.5	July	1937
Grand Marais	Cook	606	37	1.2	1.1	1.7	1.3	2.2	3.1	3.5	2.8	3.4	2.2	1.5	0.9	24.9	11.9	Aug.	1900
Grand Rapids	Itasca	1281	24	0.6	0.8	0.9	1.5	2.5	4.0	3.4	3.5	2.9	2.2	1.4	0.9	24.5	7.8	June	1915
Hallock	Kittson	815	40	0.5	0.6	0.9	1.3	2.4	3.5	2.9	2.7	2.6	1.5	0.8	0.6	20.2	15.3	Sept.	1900
Itasca State Pk.	Clearwater	1500	28	0.7	0.6	0.9	1.8	3.0	4.0	3.0	3.9	2.5	2.0	1.0	0.8	24.0	8.2	June	1915
Leech Lake Dam	Cass	1301	52	0.7	0.6	1.1	1.6	3.0	3.9	3.5	4.0	2.9	2.0	1.2	0.8	28.0	11.6	June	1915
Mahnomen	Mahnomen	1213	27	0.3	0.3	0.7	1.5	2.8	2.9	3.4	3.0	2.4	1.6	0.9	0.5	20.2	14.4	July	1909
Meadowlands	St. Louis	1259	34	0.7	0.7	0.9	1.3	2.7	3.9	3.3	3.5	3.3	1.9	1.1	0.7	23.9	9.0	June	1920
Moorhead	Clay	904	58	0.7	0.7	1.0	2.2	2.9	4.1	3.4	2.9	2.2	1.7	0.9	0.7	23.3	8.0	July	1897
Orr	St. Louis	1309	13	0.7	0.6	1.0	1.5	2.3	4.0	4.1	3.4	2.9	2.3	1.5	0.8	25.1	7.6	Aug.	1928
Park Rapids	Hubbard	1426	49	0.6	0.7	1.0	1.8	3.0	4.1	3.5	3.7	2.7	1.9	1.1	0.7	24.7	10.2	July	1897
Pigeon R. Bridge	Cook	950	15	1.1	1.0	1.6	2.1	2.1	4.2	3.2	3.0	5.1	3.8	2.9	1.2	31.3	10.5	Sept.	1933
Pine River Dam	Crow Wing	1251	52	0.5	0.6	1.0	1.9	3.3	4.5	3.6	3.6	3.0	2.3	1.1	0.6	26.0	12.6	June	1914
Pokegama Falls	Itasca	1280	52	0.5	0.5	1.0	1.7	2.9	3.9	3.5	3.5	3.0	2.0	1.2	0.6	24.1	9.9	Aug.	1900
Redby	Beltrami	1158	35	0.6	0.6	0.8	1.3	2.4	4.2	3.2	2.8	2.7	1.6	1.0	0.7	21.8	10.5	June	1914
Red Lake Falls	Red Lake	1001	26	0.6	0.7	0.9	1.7	2.8	3.6	3.3	3.1	2.1	1.7	0.8	0.9	22.0	9.1	June	1925
Roseau	Roseau	1040	36	0.6	0.5	1.0	1.3	2.3	3.2	3.3	2.9	2.6	1.5	0.9	0.6	20.3	9.1	July	1919
Sandy Lake Dam	Aitkin	1234	47	0.6	0.5	1.0	1.6	3.1	4.0	3.7	3.6	3.0	2.0	1.2	0.6	24.8	13.4	July	1897
Tower	St. Louis	1375	24	0.9	0.8	1.3	1.7	3.2	4.5	4.0	3.9	3.9	2.3	1.5	0.8	28.6	11.2	Nov.	1926
Two Harbors	Lake	614	45	0.6	0.7	1.0	1.6	3.0	3.9	3.6	3.3	3.8	2.2	1.6	0.8	26.1	10.0	July	1897
Virginia	St. Louis	1445	46	0.7	0.7	1.1	1.5	2.8	4.1	3.8	3.6	3.7	2.2	1.3	1.0	26.5	10.1	Aug.	1900
Warroad	Roseau	1069	33	0.5	0.5	1.0	1.2	2.3	3.6	3.6	2.6	2.7	1.6	1.0	0.6	21.2	9.9	July	1919
Winnibigoshish	Itasca	1315	52	0.6	0.6	1.0	1.6	2.9	3.9	3.5	3.9	3.0	1.9	1.2	0.7	24.7	12.7	June	1915
SOUTHWESTERN DIVISION																			
Alexandria	Douglas	1391	53	0.5	0.5	0.9	1.6	3.2	3.8	3.4	3.4	2.4	1.7	0.9	0.5	22.9	16.5	Aug.	1900
Artichoke Lake	Big Stone	1075	22	0.3	0.3	0.8	1.9	3.3	3.7	3.3	2.8	2.1	1.5	0.9	0.4	21.1	9.0	June	1920
Beardsley	Big Stone	1090	46	0.7	0.6	1.1	2.2	3.0	3.9	3.3	3.2	2.0	1.5	0.6	0.5	22.6	11.6	Aug.	1899
Bird Island	Renville	1039	50	0.6	0.6	1.1	1.8	3.1	4.4	3.0	3.4	2.9	1.8	1.1	0.6	24.5	9.8	Sept.	1900
Campbell	Wilkin	975	54	0.6	0.8	1.0	2.0	2.9	3.8	3.2	3.0	2.6	1.8	0.9	0.7	23.1	8.5	June	1925
Canby	Yellow Med.	1243	24	0.7	1.1	0.8	2.1	3.5	3.9	2.9	3.5	3.3	1.4	0.9	0.5	23.7	10.1	June	1919
Fairmont	Martin	1187	52	0.8	1.0	1.4	2.2	4.1	4.3	3.6	3.7	3.6	1.9	1.5	0.9	29.0	10.2	May	1903
Fergus Falls	Otter Tail	1210	52	0.8	0.8	1.0	1.9	3.0	4.2	3.5	3.0	2.7	1.7	1.0	0.8	27.9	10.2	June	1923
Long Prairie	Todd	1299	27	0.5	0.5	1.0	1.8	3.0	4.3	3.4	3.1	2.7	1.9	1.1	0.5	23.8	11.6	Aug.	1900
Milan	Chippewa	955	46	0.9	0.8	1.0	1.9	3.0	3.8	3.1	3.1	2.5	1.6	1.0	0.9	23.6	8.8	June	1920
Montevideo	Chippewa	900	50	0.7	0.7	1.1	2.0	3.1	4.0	3.0	3.2	2.8	1.7	1.2	0.7	24.1	9.4	June	1925
Morris	Stevens	1170	54	0.8	0.7	1.0	2.0	3.2	4.0	3.6	3.0	2.4	1.6	1.0	0.7	23.9	11.7	Aug.	1899
New London	Kandiyohi	1215	46	0.5	0.5	0.8	1.5	2.8	3.9	3.6	3.0	2.8	1.7	1.0	0.5	22.6	10.3	Apr.	1896
New Ulm	Brown	791	61	1.1	1.1	1.6	2.2	3.6	4.7	3.7	3.6	3.6	2.2	1.3	0.9	29.4	11.2	June	1925
Pipestone	Pipestone	1710	43	0.5	0.6	0.8	1.8	3.2	4.0	2.8	3.5	3.0	1.7	0.9	0.5	23.4	10.6	Aug.	1902
Redwood Falls	Redwood	1050	42	0.7	0.9	1.3	1.9	2.9	4.5	3.0	3.0	2.9	1.7	1.2	1.1	25.0	13.1	June	1890
Tracy	Lyon	1403	32	0.6	0.6	1.0	1.6	3.1	4.0	2.8	3.3	2.8	2.0	1.0	0.5	23.2	9.5	June	1919
Wadena	Wadena	1350	25	0.5	0.6	0.9	1.4	3.2	4.4	3.8	3.4	2.9	1.7	0.8	0.5	24.1	9.1	June	1920
Wheaton	Traverse	1018	25	0.4	0.6	0.9	1.9	2.7	3.5	2.8	2.7	1.9	1.5	0.8	0.4	20.3	10.5	June	1914
Willmar	Kandiyohi	1133	33	0.5	0.9	1.3	1.8	3.0	4.1	3.2	3.6	3.1	1.8	1.0	0.7	24.8	9.8	Aug.	1926
Windom	Cottonwood	1356	22	0.8	0.8	1.0	2.7	4.5	4.2	3.6	3.6	2.8	1.6	1.1	0.6	27.3	11.1	June	1914
Worthington	Nobles	1593	48	0.6	0.8	1.3	2.1	3.9	4.3	3.4	3.8	3.5	1.7	1.2	0.6	27.1	12.7	May	1903
SOUTHEASTERN DIVISION																			
Albert Lea	Freeborn	1229	50	0.8	0.9	1.2	2.4	4.2	4.6	3.5	3.7	4.0	2.1	1.5	1.0	29.8	10.1	June	1914
Brainerd	Crow Wing	1215	38	0.5	0.9	1.1	1.8	3.3	4.4	3.4	3.6	2.8	2.2	1.1	0.6	25.5	9.7	Aug.	1899
Chaska	Carver	726	8	0.8	0.7	1.3	1.6	2.9	4.2	3.1	2.9	3.9	2.1	1.4	0.8	25.6	8.6	May	1937
Collegeville	Stearns	1242	47	0.6	0.6	1.0	1.6	2.9	3.8	3.4	3.0	2.8	1.7	1.1	0.6	23.1	15.2	July	1913
Faribault	Rice	1003	46	0.6	0.7	1.0	1.9	3.2	4.4	3.4	3.4	3.5	2.1	1.1	0.6	25.8	11.2	Aug.	1924
Farmington	Dakota	902	51	1.0	0.9	1.4	2.1	3.2	3.8	3.3	3.3	3.3	2.4	1.4	0.9	26.9	10.6	Aug.	1924
Fort Ripley	Crow Wing	1136	41	0.4	0.5	0.7	1.5	2.7	3.7	3.2	3.3	2.5	1.9	1.1	0.5	21.8	8.1	June	1914
Grand Meadow	Mower	1338	53	1.0	1.0	1.7	2.5	4.3	4.8	3.6	3.5	3.8	2.4	1.6	1.2	31.5	14.5	June	1914
Gull Lake Dam	Cass	1215	8	0.4	0.6	1.0	1.9	3.6	4.5	3.7	3.8	2.8	2.4	1.2	0.6	26.3	7.4	July	1937
Hinckley	Pine	1054	9	0.6	0.6	0.8	2.0	3.6	3.9	3.5	3.5	3.3	1.9	1.5	1.0	26.1	7.7	Aug.	1909
Little Falls	Morrison	1115	32	0.8	0.8	1.1	1.8	3.4	3.6	3.5	3.6	2.8	2.3	1.4	0.8	25.7	10.6	Sept.	1926
Mankato	Blue Earth	773	43	0.7	0.7	1.2	2.2	3.6	4.8	3.4	3.9	3.9	2.3	1.4	0.8	28.8	11.2	June	1908
Maple Plain	Hennepin	1023	49	1.1	1.2	1.7	2.1	3.5	4.5	3.6	3.7	3.6	2.5	1.6	1.1	30.2	10.5	Aug.	1924
Milaca	Mille Lacs	1072	40	0.5	0.6	1.0	1.8	3.4	4.0	3.6	3.6	3.4	2.4	1.1	0.6	26.0	11.4	July	1903
Minneapolis	Hennepin	839	77	0.9	1.0	1.4	2.2	3.7	4.2	3.7	3.1	3.1	2.1	1.3	1.0	27.7	11.9	July	1892
Mora	Kanabec	1001	35	0.9	0.8	1.2	1.9	3.4	4.1	3.6	3.1	3.3	2.1	1.6	0.7	26.5	7.7	June	1915
Reads	Wabasha	681	48	0.7	0.7	1.2	2.1	3.8	4.6	3.4	3.6	4.2	2.5	1.5	0.9	29.0	11.8	Aug.	1928
Red Wing	Goodhue	680	54	1.0	1.1	1.4	2.1	3.6	4.6	3.4	3.4	3.9	2.5	1.6	0.9	29.5	11.7	Sept.	1903
Rochester	Olmsted	991	24	1.1	0.8	1.3	2.7	4.0	4.6	2.8	3.3	3.0	2.1	1.6	0.9	28.2	12.0	June	1914
St. Cloud (near)	Sherburne	1020	49	0.7	0.7	1.1	1.9	3.4	4.4	3.6	3.4	3.4	2.2	1.2	0.5	26.4	12.8	July	1897
St. Paul (Airpt.)	Ramsey	703	101	0.9	0.9	1.4	2.4	3.3	4.1	3.6	3.0	3.1	2.2	1.3	1.1	27.2	11.7	June	1874
St. Peter	Nicollet	825	51	0.9	0.7	1.1	2.0	3.4	4.7	3.4	3.5	3.6	2.2	1.3	0.7	27.5	12.1	June	1908
Taylors Falls(nr.)	Chisago	759	33	0.6	0.6	1.0	1.8	3.5	4.5	3.7	3.4	4.1	2.7	1.4	0.6	27.8	10.9	June	1914
Waseca	Waseca	1153	25	0.8	1.0	1.4	2.3	4.1	4.6	3.9	4.4	3.5	2.2	1.3	0.7	29.8	11.9	Aug.	1924
Winnebago	Faribault	1100	45	0.8	0.9	1.3	2.3	4.0	4.6	3.6	3.5	3.6	2.0	1.4	0.8	28.6	13.9	June	1899
Winona	Winona	700	49	1.0	1.0	1.6	2.3	4.1	4.7	3.7	3.6	3.8	2.5	1.6	1.1	31.0	14.1	June	1914

Note: Data compiled to 1938 inclusive.
Source: Compiled from Climatological Data, U. S. Weather Bureau.

MEAN TEMPERATURE AND PRECIPITATION FOR GROWING SEASON

Station	County	Elevation	Years of Record	Mean Temperature	Total Normal Precipitation
NORTHERN DIVISION					
Ada	Norman	906	43	61.9	14.52
Ah-gwah-ching	Cass	1,336	31	61.8	16.64
Angus	Polk	870	36	60.4	13.55
Argyle	Marshall	845	23	61.6	14.39
Bagley	Clearwater	1,446	13	1/	16.21
Baudette	Lake of the Woods	1,084	28	60.1	14.03
Bemidji	Beltrami	1,373	35	61.9	16.24
Cass Lake	Cass	1,323	32	1/	16.39
Cloquet	Carlton	1,265	28	58.9	17.81
Crookston	Polk	888	49	62.1	14.18
Detroit Lakes	Becker	1,364	43	61.5	17.44
Duluth	St. Louis	1,128	68	57.2	17.41
Fosston	Polk	1,289	29	60.9	14.48
Gonvick (near)	Clearwater	1,454	17	1/	14.39
Grand Marais	Cook	606	30	54.6	14.99
Grand Rapids	Itasca	1,281	24	60.2	16.22
Hallock	Kittson	815	40	60.6	14.05
Itasca State Park	Clearwater	1,500	27	59.4	16.31
Leech Lake Dam	Cass	1,301	52	60.2	17.27
Mahnomen	Mahnomen	1,213	22	1/	14.44
Meadowlands	St. Louis	1,259	29	58.9	16.62
Moorhead	Clay	904	58	62.4	15.48
Orr	St. Louis	1,309	13	1/	16.61
Park Rapids	Hubbard	1,426	49	60.8	16.96
Pigeon River Bridge	Cook	950	14	1/	17.67
Pine River Dam	Crow Wing	1,251	52	61.4	18.07
Pokegema Falls	Itasca	1,280	52	59.3	16.80
Redby	Beltrami	1,158	33	61.4	15.27
Red Lake Falls	Red Lake	1,001	23	61.9	14.85
Roseau	Roseau	1,040	34	60.1	14.12
Sandy Lake Dam	Aitkin	1,234	46	60.5	17.36
Tower	St. Louis	1,375	22	1/	19.45
Two Harbors	Lake	614	45	57.9	17.49
Virginia	St. Louis	1,445	45	59.6	18.01
Warroad	Roseau	1,069	31	59.9	14.89
Winnibigoshish	Itasca	1,315	52	61.1	17.24
SOUTHWESTERN DIVISION					
Alexandria	Douglas	1,391	52	62.8	16.26
Artichoke Lake	Big Stone	1,075	22	64.9	15.15
Beardsley	Big Stone	1,090	42	64.6	15.43
Bird Island	Renville	1,039	49	64.8	16.81
Campbell	Wilkin	975	46	62.4	15.40
Canby	Yellow Medicine	1,243	21	66.3	17.14
Fairmont	Martin	1,187	52	65.7	19.32
Fergus Falls	Otter Tail	1,210	51	63.9	16.35
Long Prairie	Todd	1,299	26	62.5	16.48
Milan	Chippewa	955	45	64.3	15.49
Montevideo	Chippewa	900	49	65.2	16.07
Morris	Stevens	1,170	53	64.0	16.24
New London	Mandiyohi	1,215	45	64.3	16.08
New Ulm	Brown	791	59	66.1	19.04
Pipestone	Pipestone	1,710	39	64.8	16.55
Redwood Falls	Redwood	1,050	38	66.3	16.23
Tracy	Lyon	1,403	30	66.3	16.03
Wadena	Wadena	1,350	21	61.3	17.69
Wheaton	Traverse	1,018	24	64.4	13.74
Willmar	Kandiyohi	1,133	32	64.1	17.03
Windom	Cottonwood	1,356	15	61.4	18.66
Worthington	Nobles	1,593	47	64.8	18.92
SOUTHEASTERN DIVISION					
Albert Lea	Freeborn	1,229	48	65.9	19.92
Brainerd	Crow Wing	1,215	34	61.5	17.43
Cambridge	Isanti	1,000	12	65.3	1/
Chaska	Carver	726	14	66.5	16.92
Collegeville	Stearns	1,242	46	64.1	15.88
Faribault	Rice	1,003	42	65.3	17.80
Farmington	Dakota	902	50	64.6	16.81
Fort Ripley	Crow Wing	1,136	59	1/	15.39
Grand Meadow	Mower	1,338	53	64.5	20.10
Gull Kake Dam	Cass	1,215	28	62.1	18.33
Hinckley	Pine	1,054	18	61.7	17.74
Little Falls	Morrison	1,115	29	63.1	16.83
Mankato	Blue Earth	773	41	1/	19.52
Maple Plain	Hennepin	1,023	44	65.4	18.83
Milaca	Mille Lacs	1,072	36	62.2	17.96
Minneapolis	Hennepin	832	48	65.8	17.87
Mora	Kanabec	1,001	34	62.5	17.32
Reads	Wabasha	681	48	1/	19.55
Red Wing	Goodhue	680	54	1/	18.79
Rochester	Olmsted	991	28	64.8	17.62
St. Cloud	Sherburne	1,020	62	64.2	18.11
St. Paul	Ramsey	703	66	65.6	17.06
St. Peter	Nicollet	825	49	66.3	18.62
Taylors Falls	Chisago	759	33	64.7	19.08
Waseca	Waseca	1,153	24	65.5	20.37
Winnebago	Faribault	1,100	44	65.9	19.18
Winona	Winona	700	46	66.9	19.84
Zumbrota	Goodhue	971	43	65.0	1/

Note: Growing season duration used is from May 1 to September 30. Data compiled to 1938, inclusive.
1/ Climatic factor not recorded.
Source: Compiled from Climatological Data, U. S. Weather Bureau

Figure - reveals the distribution of rainfall by months for areas within Minnesota. These are all adjusted to a uniform 35 year period, 1898 to 1932, except for Orr which is for 13 years of record. It will be seen that everywhere except at Orr and Grand Marais the maximum precipitation occurs during June. At those two stations (in that area) maximum rainfall is delayed until July by less rapidly rising temperature, for reasons already explained, and hence less convectional overturning causing summer rainstorms, and because during that time more rain is caused by warm prairie air being forced up over a wedge of cool air lying over the Lake Superior Basin. Note that in eastern stations the rainfall is generally more uniform during summer months than in northwestern stations, perhaps due to the influence of the lake and the open Mississippi Valley to the Gulf.

Study of reliability and recurrence of specific amounts of precipitation is vitally important to a more secure agriculture and scientific conservation of water resources in Minnesota. Table - gives the frequencies for selected stations and brings out significant differences between contrasted sections of the State. Frequencies of small amounts of rainfall during the summer months for the western stations should be noted particularly, and contrasted with eastern and central stations. It has been shown that the western boundary of Minnesota lies a short distance east (60 to 100 miles) of the line of 10 semiarid years in 20, and for the most part the eastern boundary is west of the line of 1 dry year in 20.1/

1/ Russell, Richard Joel, Dry Climates of the United States. II Frequency of dry and desert years, 1901-20, Calif. Univ. Pubs., Geog. 5 : 245-274.

Cyclical Variation Of Climate

F From the material thus far presented it appears obvious that important deviations within the annual cycle are characteristic and not exceptional and that these deviations occur from a favorable normal. Most important effects of climatic variability are those on crops. They affect not only current yields but also relate to the extent of planting in following years. Were it possible to anticipate these climatic departures farmers could adjust their cropping plans accordingly. Some authorities believe that measurements of

PRECIPITATION DATA OF SELECTED STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Crookston 1890 to 1938, Elevation 888 Feet.													
Years with less than ½ inch	28	25	22	5	2	0	0	2	5	11	23	29	
Years with ½ to 1 inch	14	16	10	9	3	2	3	5	4	9	14	9	
Years with 1 to 1½ inch	3	4	9	10	7	5	5	8	11	9	5	4	
Years with 1½ to 2 inches	4	2	4	13	3	6	4	5	8	4	4	5	
Years with 2 to 2½ inches	0	2	3	4	6	6	10	7	9	8	2	1	
Years with 2½ to 3 inches	0	0	1	3	8	6	7	3	5	5	1	0	
Years with 3 to 4 inches	0	0	0	1	9	12	8	12	3	2	0	0	
Years with 4 to 6 inches	0	0	0	4	9	7	9	5	3	1	0	0	
Years with 6 to 8 inches	0	0	0	0	1	3	1	2	1	0	0	0	
Years with 8 to 10 inches	0	0	0	0	1	2	2	0	0	0	0	0	
Years with 10 inches and over	0	0	0	0	0	0	0	0	0	0	0	0	
Years with less than 1 inch	42	41	32	14	5	2	3	7	9	20	37	38	
Years with less than 2 inches	49	47	45	37	15	13	12	20	28	33	46	47	
Years with less than 3 inches	49	49	49	44	29	25	29	30	42	46	49	48	
Years of Record	49	49	49	49	49	49	49	49	49	49	49	49	
Average Precipitation	0.53	0.55	0.81	1.63	2.81	3.35	3.07	2.74	2.21	1.53	0.72	0.68	20.63
Brainerd 1889 to 1938, Elevation 1,215 Feet.													
Years with less than ½ inch	16	18	11	1	2	0	1	1	0	3	10	16	
Years with ½ to 1 inch	14	8	10	7	2	1	1	2	3	8	9	9	
Years with 1 to 1½ inch	2	5	6	6	4	1	3	5	6	4	6	7	
Years with 1½ to 2 inches	0	1	2	7	4	3	3	6	6	6	4	2	
Years with 2 to 2½ inches	1	0	3	8	6	6	3	1	5	3	1	1	
Years with 2½ to 3 inches	0	1	2	4	2	1	4	3	2	7	2	0	
Years with 3 to 4 inches	0	0	0	0	4	10	9	6	9	3	2	0	
Years with 4 to 6 inches	0	1	0	1	7	6	9	6	3	1	0	0	
Years with 6 to 8 inches	0	0	0	0	2	5	1	3	0	0	0	0	
Years with 8 to 10 inches	0	0	0	0	1	1	0	1	0	0	0	0	
Years with 10 inches and over	0	0	0	0	0	0	0	0	0	0	0	0	
Years with less than 1 inch	30	26	21	8	4	1	2	3	3	11	19	25	
Years with less than 2 inches	32	32	29	21	12	5	8	14	15	21	29	34	
Years with less than 3 inches	32	33	34	33	20	12	15	18	22	31	32	35	
Years of Record	33	34	34	34	34	34	34	34	34	34	34	35	
Average Precipitation	0.47	0.86	1.08	1.81	3.30	4.37	3.39	3.59	2.78	2.15	1.14	0.57	25.51
Milan 1894 to 1938, Elevation 955 Feet.													
Years with less than ½ inch	16	14	12	3	2	0	2	1	1	8	13	18	
Years with ½ to 1 inch	14	17	7	1	2	3	1	2	10	10	17	12	
Years with 1 to 1½ inch	9	9	13	13	5	1	5	4	3	8	5	10	
Years with 1½ to 2 inches	3	3	9	3	7	8	6	8	9	7	4	2	
Years with 2 to 2½ inches	0	0	2	13	5	7	9	5	6	4	2	1	
Years with 2½ to 3 inches	1	2	1	6	8	4	6	4	3	4	2	1	
Years with 3 to 4 inches	1	0	0	2	5	5	5	11	6	2	1	1	
Years with 4 to 6 inches	1	0	1	3	9	11	10	6	6	2	1	0	
Years with 6 to 8 inches	0	0	0	1	2	4	1	3	1	0	0	0	
Years with 8 to 10 inches	0	0	0	0	0	2	0	1	0	0	0	0	
Years with 10 inches and over	0	0	0	0	0	0	0	0	0	0	0	0	
Years with less than 1 inch	30	31	19	4	4	3	3	3	11	18	30	30	
Years with less than 2 inches	42	43	41	20	16	12	14	15	23	33	39	42	
Years with less than 3 inches	43	45	44	39	29	23	29	24	32	41	43	44	
Years of Record	45	45	45	45	45	45	45	45	45	45	45	45	
Average Precipitation	0.89	0.80	1.03	1.94	2.99	3.78	3.13	3.11	2.48	1.61	0.99	0.85	23.60
Virginia 1894 to 1938, Elevation 1,465 Feet.													
Years with less than ½ inch	16	17	9	4	2	1	0	0	1	3	7	9	
Years with ½ to 1 inch	15	19	10	9	1	1	0	1	1	6	10	14	
Years with 1 to 1½ inch	8	7	15	9	5	1	3	6	4	7	8	15	
Years with 1½ to 2 inches	3	1	8	10	6	4	6	2	3	3	8	3	
Years with 2 to 2½ inches	1	0	0	4	5	3	5	4	4	7	5	1	
Years with 2½ to 3 inches	1	0	0	4	6	7	3	7	5	7	3	3	
Years with 3 to 4 inches	1	1	3	3	8	10	10	10	11	8	3	0	
Years with 4 to 6 inches	0	0	0	2	9	11	12	11	13	4	0	0	
Years with 6 to 8 inches	0	0	0	0	3	5	3	2	2	0	0	0	
Years with 8 to 10 inches	0	0	0	0	0	2	3	1	0	0	0	0	
Years with 10 inches and over	0	0	0	0	0	0	0	1	1	0	0	0	
Years with less than 1 inch	31	36	19	13	3	2	0	1	2	9	17	23	
Years with less than 2 inches	42	44	42	32	14	7	9	9	9	19	33	41	
Years with less than 3 inches	44	44	42	40	25	17	17	20	18	33	41	45	
Years of Record	45	45	45	45	45	45	45	45	45	45	45	45	
Average Precipitation	0.74	0.69	1.11	1.50	2.80	4.05	3.84	3.61	3.71	2.19	1.32	0.98	26.54
Grand Meadow 1866 to 1938, Elevation 1,338 Feet.													
Years with less than ½ inch	12	15	5	1	0	1	0	0	0	3	13	12	
Years with ½ to 1 inch	17	17	9	2	0	1	6	0	4	4	10	15	
Years with 1 to 1½ inch	11	11	9	8	4	2	4	5	2	6	8	12	
Years with 1½ to 2 inches	7	6	11	10	4	4	1	10	4	13	9	10	
Years with 2 to 2½ inches	4	1	8	8	8	3	4	13	5	9	4	0	
Years with 2½ to 3 inches	1	2	8	6	4	4	5	2	6	7	3	0	
Years with 3 to 4 inches	0	1	2	10	8	10	14	7	9	5	3	4	
Years with 4 to 6 inches	1	0	1	7	12	12	13	10	14	4	2	0	
Years with 6 to 8 inches	0	0	0	1	7	11	5	2	7	1	1	0	
Years with 8 to 10 inches	0	0	0	0	5	1	1	2	2	1	0	0	
Years with 10 inches and over	0	0	0	0	1	4	0	2	0	0	0	0	
Years with less than 1 inch	29	32	14	3	0	2	6	0	4	7	23	27	
Years with less than 2 inches	41	49	34	21	8	8	11	15	10	26	40	49	
Years with less than 3 inches	52	52	50	35	20	15	20	30	21	42	47	49	
Years of Record	53	53	53	53	53	53	53	53	53	53	53	53	
Average Precipitation	1.04	0.99	1.70	2.53	4.33	4.83	3.62	3.51	3.81	2.38	1.57	1.18	31.40

Note: Data compiled to 1938, inclusive.
Source: Compiled from Climatological Data, U. S. Weather Bureau.

moisture content of the soil at seeding time can be employed as a practicable guide for cropping plans.[1]

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[1] Unpublished memorandum, F. E. Clements

There exists not only variation within the annual cycle from year to year but also irregular minor cycles of several years and major cycles of many years duration. These assume especial significance in a marginal climate such as Minnesota's. Figure - graphs precipitation and temperature departures for Minnesota from 1891 to date. It indicates annual variations and the tendency for similar deviations to form aggregates which have a cyclical recurrence. Variations or cycles appear even more evident in charts in the chapter on water (pages - to -) which were drafted from ten year moving averages for specific stations and regional composites. The period from 1932 through 1936 comprises the years of most severe drought conditions. Note the increase in precipitation in 1937 and 1938 for nearly all stations. Northeastern Minnesota suffered least in the drouth extending from 1929 through 1936.

If shifts in climatic conditions could be predicted, adjustments could be made and natural risk involved in agricultural operations would be reduced very materially. Successful development of long-range forecasts was a goal set by President Roosevelt when in 1936 he appointed F. W. Reichelderfer, one of the Navy's outstanding meteorologists, as chief of the Weather Bureau. Such forecasting promises much not only to Minnesota farmers, but power companies, recreation interests, commodity traders, government officials, etc.,

Sunshine, Wind, and Number Of Rainy Days

Figure - shows the sky conditions for the years 1891 to 1938 in terms of percentage of days clear, partly cloudly, and cloudy for Minnesota. The average number of clear days totals 150, partly cloudy 106 days, and cloudy

109 days; or 41% of the year is clear, 29% partly cloudy, and 30% cloudy. Note the trends in sky conditions and number of rainy days in contrast to the major tendencies in precipitation and temperature.

Greater amount of cloudiness in winter months along with fewer hours of sunshine (Figure -) obviously results in far less sunshine during that period. It should be noted, however, that periods of clear crisp weather typify northern interior winters. Clearest weather prevails during the summer months of June, July, and August and during fall months of September and October. Reduction of partly cloudy days together with a continuance of clear days of summer normally attends fall weather of Minnesota. Area about Lake Superior has the smallest percentage of possible sunshine in Minnesota, 54% compared with 59% at Minneapolis and Moorhead in 1938.

Winds are not pronounced in Minnesota, averaging 8.7 miles per hour at Collegeville, 8.8 at Moorhead, 10.8 at Minneapolis, and 12.5 at Duluth. Table - gives seasonal and annual prevailing directions for a large group of stations in Minnesota. Prevailing wind for the State as a whole is northwest, except in summer months and early fall when the wind blows chiefly from a southerly sector, mainly southwest.

Table - also gives the number of rainy days and inches of snowfall, both seasonally and annually. Smallest number of rainy days per year is 55.5 at Redby in Beltrami County and the largest 123 days at Duluth. Snowfall averages from 22.4 inches to 59.1 inches in Minnesota. It averages lightest in the southwest portion of the State and heaviest in the northeastern section. Figure - shows the hours of sunrise, sunset, darkness, daylight, and twilight at Minneapolis and St. Paul and other locations on approximately the same meridian.

AVERAGE NUMBER OF RAINY DAYS, INCHES OF SNOWFALL, AND PREVAILING DIRECTION OF WIND

Station	Record Of Years to 1938		Winter			Spring			Summer		Fall			Annual		
	Rainy Days	Snow Fall	Rainy Days	Snow Fall	Prevailing Wind	Rainy Days	Snow Fall	Prevailing Wind	Rainy Days	Prevailing Wind	Rainy Days	Snow Fall	Prevailing Wind	Rainy Days	Snow Fall	Prevailing Wind
NORTHERN DIVISION																
Ada	41	34	11.4	17.3	nw.	18.4	7.8	nw.	25.4	s.	16.1	4.4	nw.	71.1	29.8*	nw.
Ah-gwah-ching	30	30	15.7	20.3	n.	20.0	8.7	w.	26.2	s.	21.1	4.9	w.	83.0	35.9	n.
Angus	36	35	14.7	13.7	n.	21.6	5.9	n.	28.0	n.	18.1	3.7	n.	82.4	24.2	n.
Baudette	28	28	19.3	29.6	nw.	22.4	13.1	nw.	29.5	nw.	25.4	12.5	nw.	96.6	55.1	nw.
Bemidji	35	28	14.3	25.1	nw.	20.2	12.0	nw.	27.3	se.	19.3	7.7	nw.	80.9	43.7	nw.
Crookston	50	27	13.5	20.2	nw.	19.5	9.0	s.	25.9	s.	15.9	5.8	nw.	74.8	34.8	nw.
Detroit Lakes	42	40	11.6	20.9	nw.	20.2	9.6	nw.	26.3	nw.	16.5	6.7	nw.	74.7	37.3*	se.
Duluth	68	55	29.8*	30.5*	nw.	30.9	15.9	ne.	35.4	ne.	30.0	8.0*	nw.	123.0*	54.4*	ne.
Grand Marais	24	21	16.4*	40.9*	sw.	20.3	15.4	ne.	24.9	ne.	23.2	8.7	ne.	84.8*	64.3*	ne.
Hallock	39	37	14.2	16.7	s.	19.0	6.9	n.	29.1	s.	17.7	5.6	s.	79.9	29.2	s.
International Falls	22	17	16.0	29.2	nw.	17.0	10.5	nw.	27.0	sw.	19.0	8.6	nw.	79.0	48.3	nw.
Leech Lake Dam	51	47	18.5	28.3	nw.	24.5	13.3	nw.	28.7	nw.	22.4	9.0	nw.	94.0	50.6	nw.
Meadowlands	28	26	13.2	23.9	nw.	18.4	12.1*	se.	24.1	sw.	17.1	7.0	nw.	72.0	41.5*	nw.
Moorhead	58	54	25.0	21.6	s.	27.8	10.9	n.	30.4	s.	22.6	7.2	s.	105.8	39.7	s.
Park Rapids	48	48	21.6	21.6	nw.	27.3	13.7	nw.	32.5	nw.	25.9	8.3*	nw.	107.3	43.4*	nw.
Pokegama Falls	51	51	17.9	25.0*	nw.	24.4	12.7	nw.	29.5	nw.	22.6	8.6	nw.	94.5	46.4*	nw.
Redby	33	32	9.2	22.5	w.	13.5	7.9	w.	19.4	w.	12.4	7.6	s.	55.5*	38.4	w.
Red Lake Falls	23	22	16.9	25.8	nw.	19.0	10.3	nw.	23.4	nw.	16.7	9.3	nw.	77.0	46.1	nw.
Roseau	34	33	12.2	18.5	nw.	20.1	9.2	nw.	29.4	nw.	19.8	7.5	nw.	81.4	35.2	nw.
Sandy Lake Dam	46	45	16.3*	27.6	nw.	21.9	12.9	nw.	26.6	se.	20.9	7.3	se-w.	85.8	47.8	nw.
Tower	20	19	17.0*	29.5	nw.	22.6	14.9	w.	31.6	w.	28.2	10.8	nw.	99.3*	55.3	nw.
Two Harbors	45	44	17.6	33.2*	nw.	21.5	13.4	ne.	28.1	ne.	23.4	5.9	nw.	90.6*	52.4*	ne.
Virginia	45	44	20.4	27.0	nw.	22.5	15.5	nw.	30.4	sw.	25.2	10.6	nw.	98.5	52.9	nw.
Winnibigoshish Dam	51	51	17.9	27.7	nw.	23.7	12.4	nw.	29.0	se.	22.6	8.8	nw.	93.2	48.8	nw.
SOUTHWESTERN DIVISION																
Alexandria	44	44	12.1	17.2	nw.	20.7	11.1	nw.	23.4	nw.	16.1	3.9	nw.	72.6	32.1	nw.
Beardsley	40	37	12.2	18.3	nw.	19.7	9.5	nw.	25.3	se.	14.8	4.2	nw.	71.9	31.3	nw.
Bird Island	49	49	13.8*	18.3	nw.	24.1	9.9	nw.	23.6	se.	18.3	4.4	se.	79.9*	32.7	se.
Canby	17	17	10.8	14.1	nw.	19.4	12.5	nw.	20.2	s.	14.1	5.0	nw.	68.6	38.3	nw.
Fairmont	52	52	13.9	22.9	nw.	23.8	11.2	nw.	24.1	se.	18.5	5.2	nw.	80.1	39.1	nw.
Fergus Falls	47	47	31.0*	33.4	nw.	30.4	11.1	se.	32.1	se.	26.4	7.0	nw.	119.9*	41.5	nw.
Long Prairie	25	25	10.6	15.8	nw.	21.8	11.6	se.	24.6	nw.	15.6	3.8	nw.	72.6	31.1*	nw.
Lynd	29	29	10.0	21.5	nw.	19.0	10.7	nw.	24.0	sw.	14.0	4.0	nw.	67.0	36.2	nw
Milan	45	45	12.7	23.5	nw.	21.8	9.8	se.	25.7	se.	15.6	4.0	nw.	75.7	36.9	nw.
Montevideo	48	48	13.0	20.0	nw.	23.1	10.1	se.	25.9	se.	17.8	4.5	se.	79.8	34.8	se.
Morris	53	53	12.2	19.5	nw.	21.0	10.0	s.	26.5	s.	16.6	4.8	nw.	76.4	34.2	nw.
New London	45	45	10.8	16.8	nw.	17.4	8.3	nw.	21.8	se.	15.8	4.2	nw.	65.9	29.3	nw.
New Ulm	45	45	16.4*	25.8*	nw.	26.1	10.9	s.	28.4	s.	20.8	3.6	nw.	91.8*	40.2*	s.
Pipestone	35	35	9.8	14.2	nw.	21.2	6.4	nw.	25.6	sw.	16.2	2.3	nw.	72.8	22.4	nw.
Redwood Falls	25	23	14.4*	25.8	nw.	22.2	11.3	nw.	24.3	nw.	17.2	4.1	nw.	78.0*	41.8	nw.
Wadena	21	21	14.6	20.5	nw.	17.6	9.3	nw	24.2	sw.	17.6	6.7	nw.	72.6	37.3	nw.
Wheaton	23	23	14.4	17.3	nw.	22.3	7.2	nw.	26.3	s.	17.3	10.0	n.	80.4	34.7	n.
Willmar	32	32	12.3	19.6	nw.	20.0	9.2	nw.	22.4	s.	15.1	5.3	nw.	69.7	34.1	nw.
Worthington	44	44	11.3	18.3	nw.	24.3	9.8	nw.	25.9	se.	17.0	3.7	nw.	78.5	31.6	nw.
SOUTHEASTERN DIVISION																
Collegeville	46	46	14.3*	21.1	nw.	28.3	9.6	nw.	28.7	nw.	21.8	4.3	nw.	93.1*	35.0	nw.
Farmington	49	50	16.0	25.6	nw.	23.3	13.6	nw.	24.5*	s.	18.8	5.5	nw.	82.7*	44.9	nw.
Grand Meadow	52	52	17.2	25.8	nw.	26.3	11.5	nw.	26.1	sw.	22.3	5.4	nw.	91.9	42.6	nw.
Minneapolis	48	48	23.3	25.0	nw.	29.8	12.0	nw.	29.4	s.	25.0	4.6	s.	107.6	41.7	nw.
Mora	35	35	19.5	22.7	nw.	25.7	10.7	e.	29.6	w.	26.5	6.5	nw.	101.3	39.6	nw.
Pine River Dam	52	52	15.3	23.9	nw.	21.7	10.7	e.	26.4	nw.	17.7	6.9	nw.	81.2	41.4	nw.
St. Paul	66	53	25.0*	24.1*	nw.	31.3	12.2	nw.	30.1	se.	25.9	5.0	se.	112.8*	41.5	nw.
St. Peter	44	44	13.0	19.8	nw.	20.8	8.2	n.	27.1	s.	15.8	3.1	s.	76.5	31.0	s.
Taylors Falls	31	28	15.2	25.6	n.	21.9	10.1	s.	26.4	s.	22.7	3.6	s.	86.2	39.6	s.
Winnebago	44	43	12.5	20.5	nw.	23.5	8.9	nw.	26.8	se.	19.0	3.2	nw.	81.7	32.4	nw.
Winona	43	43	19.2	24.9*	w.	27.0*	8.6	nw.	27.5*	nw.	24.2*	4.0*	w.	98.1*	37.3*	e.

* Partly Interpolated.

Note: Data Compiled to 1938, inclusive.

Source: Compiled from Climatological Data, U. S. Weather Bureau.

Navitation

Table - gives the date of opening and closing of navigation at Duluth from 1871 to 1938 and for St. Paul the date of ice break-up and ice formation from 1895 to 1938.

NAVIGATION SEASON AT DULUTH

Year	Local Navigation		Interlake Navigation		Year	Local Navigation		Interlake Navigation	
	Opening	Closing	Opening	Closing		Opening	Closing	Opening	Closing
1938	April 12	Dec. 8	April 13	Dec. 7	1904	May 8	*Jan. 11	May 12	Dec. 14
1937	April 14	Dec. 11	April 13	Dec. 7	1903	March 26	*Jan. 12	April 11	Dec. 11
1936	April 27	Dec. 12	May 1	Dec. 8	1902	March 12	*Feb. 8	March 30	Dec. 18
1935	April 1	Dec. 16	April 19	Dec. 9	1901	April 16	*Feb. 7	April 26	Dec. 16
1934	April 18	Dec. 10	May 1	Dec. 10	1900	April 18	*Feb. 9	April 22	Dec. 13
1933	April 16	Dec. 9	April 20	Dec. 9	1899	April 29	*Jan. 26	April 29	Dec. 19
1932	March 31	Dec. 6	April 21	Dec. 6	1898	March 19	Dec. 23	April 10	Dec. 12
1931	March 18	Dec. 12	April 7	Dec. 12	1897	April 15	*Feb. 4	April 17	Dec. 13
1930	April 9	Dec. 6	April 27	Dec. 6	1896	April 12	Dec. 18	April 21	Dec. 11
1929	April 12	Dec. 14	April 15	Dec. 11	1895	April 11	*Jan. 29	April 27	Dec. 12
1928	April 9	Dec. 27	May 1	Dec. 12	1894	April 16	Dec. 26	April 18	Dec. 7
1927	March 30	Dec. 16	April 14	Dec. 14	1893	May 9	Dec. 10	May 9	Dec. 8
1926	April 20	Dec. 21	May 2	Dec. 12	1892	April 20	Dec. 26	April 20	Dec. 5
1925	April 10	Dec. 29	April 14	Dec. 15	1891	April 30	*Feb. 13	April 30	Dec. 7
1924	April 10	Dec. 13	April 22	Dec. 16	1890	April 2	*Feb. 2	April 16	Dec. 8
1923	April 22	*Jan. 8	May 5	Dec. 11	1889	April 11	*Jan. 12	April 11	Dec. 4
1922	April 7	*Jan. 11	April 21	Dec. 13	1888	April 21	*Jan. 17	May 11	Dec. 4
1921	March 30	*Jan. 22	April 11	Dec. 12	1887	May 4	Dec. 29	May 4	Dec. 2
1920	April 4	*Jan. 20	April 21	Dec. 13	1886	May 6	Dec. 30	May 6	Dec. 4
1919	March 23	*Jan. 3	April 11	Dec. 7	1885	April 27	*Jan. 10	May 14	Nov. 29
1918	April 7	*Feb. 5	April 26	Dec. 12	1884	May 1	*Jan. 1	May 1	Dec. 10
1917	April 30	*Jan. 8	May 1	Dec. 15	1883	April 9	*Jan. 3	May 9	Dec. 11
1916	April 13	*Jan. 25	April 22	Dec. 18	1882	April 15	Dec. 30	May 15	Dec. 3
1915	April 10	*Jan. 25	April 17	Dec. 17	1881	May 8	Dec. 16	May 8	Dec. 5
1914	March 14	*Jan. 24	April 21	Dec. 11	1880	May 1	Dec. 17	May 1	Nov. 15
1913	April 17	*Feb. 9	April 17	Dec. 14	1879	April 17	Dec. 12	May 2	Dec. 3
1912	April 16	*Jan. 22	April 25	Dec. 15	1878	March 23	*Jan. 2	April 8	Dec. 3
1911	March 1	*Jan. 9	April 18	Dec. 9	1877	April 25	Dec. 17	May 2	Nov. 30
1910	March 20	*Jan. 30	April 9	Dec. 9	1876	May 2	Dec. 19	May 8	Nov. 26
1909	April 8	*Feb. 14	April 17	Dec. 22	1875	May 12	Dec. 12	May 12	Dec. 2
1908	April 8	*Feb. 4	April 26	Dec. 10	1874	May 2	Dec. 11	May 12	Dec. 2
1907	April 1	*Jan. 27	April 16	Dec. 12	1873	May 10	Dec. 30	May 5	Nov. 18
1906	April 7	*Jan. 20	April 13	Dec. 21	1872	March 9	Nov. 24	May 11	Nov. 26
1905	March 30	*Feb. 28	April 8	Dec. 18	1871	April 5	Dec. 6	May 8	Nov. 29

Source: Statistical Report of Marine Commerce of Duluth, Minnesota and Superior, Wisconsin.
* Closing was in calendar year following that of opening.

NAVIGATION SEASON AT ST. PAUL PORT

Year	Ice Break-up	Ice Formation	Year	Ice Break-up	Ice Formation
1938	March 31	November 28	1916	March 18	December 14
1937	April 12	November 23	1915	February 22	December 27
1936	April 3	November 23	1914	March 9	December 13
1935	March 2	November 22	1913	March 10	December 20
1934	March 2	December 7	1912	March 22	-
1933	February 23	-	1911	March 3	November 12
1932	March 15	December 7	1910	March 7	November 28
1931	January 21	-	1909	March 15	December 6
1930	January 21	November 28	1908	March 15	December 2
1929	March 3	December 1	1907	March 22	December 11
1928	February 27	-	1906	April 1	December 7
1927	February 1	December 8	1905	March 6	November 29
1926	February 15	November 10	1904	March 27	December 12
1925	January 27	December 26	1903	March 14	December 10
1924	February 15	December 19	1902	March 9	December 4
1923	March 20	-	1901	March 24	December 4
1922	March 4	December 11	1900	April 1	December 25
1921	January 22	December 21	1899	April 7	December 13
1920	March 14	December 18	1898	March 7	November 23
1919	March 10	December 2	1897	March 19	November 28
1918	March 3	-	1896	March 9	November 28
1917	March 22	December 5	1895	March 21	November 28

Source: Annual Report of Chief Engineer, U. S. Army, part 2, 1939.

LAND POLICIES AND LAND CLASSIFICATION

Acquisition of Area

All lands now included in the State of Minnesota did not become the property of the United States at the same time, nor was it all conveyed in the same manner or by the same nation. Before summarizing how it was acquired, it should be noted that except for a few square miles purchased for military purposes in 1805, all titles to land were subject to the right of occupancy of the Sioux and Chippewa Indians until the various Indian cessions, the first of which was negotiated in 1837.

Meager knowledge of geography was accountable for (some of the conflicting boundaries of the early claims established as a result of exploration, conquest, and grant.) Virginia Colony, chartered in 1609, first claimed the country which later became Minnesota ~~as part of her territory~~. Nevertheless, in 1671, at Sault Ste. Marie, St. Lusson ceremoniously claimed for France all interior North America. The Massachusetts Colony Charter issued in 1691 included in its territorial claim part of southern Minnesota.

The century long French regime of exploration and fur trading, lasted until 1762, when all rights west of the Mississippi were ceded to Spain, and 1763, in which year all lands east of that river were relinquished to England. In 1774, northeastern Minnesota became a part of the Province of Quebec under the Quebec Act. At the close of the American Revolution, title to the border-lakes country and the land east of the Mississippi was acquired by the newly created government of the United States, Virginia and Massachusetts relinquishing their colonial claims. The expanse west of the Mississippi, retroceded to France in 1780, came under American sovereignty in 1803 as a part of the Louisiana Purchase.

The Ordinance of 1787, in creating the Northwest Territory, included that portion of Minnesota east of the Mississippi which then belonged to the United States. At various times/ thereafter, the Minnesota area, in whole or in part, formed a part of the Territories of Indiana, Louisiana, Illinois, Missouri, Michigan, Iowa, and Wisconsin. Minnesota was formally organized as a separate territory July 1, 1849, and on May 11, 1858, it was admitted to the Union as a State. Now, with subsequent boundary disputes settled, the State has a total area of 53,803,520 acres, of which 51,205,760 acres is land and 2,597,760 acres water. 1/

1/ Approximate land area reported by U. S. Census Bureau in 1940. Measurements involved geodetic values and planimeter readings, and the latest and most authentic maps to be secured from public and private sources.

Disposition of Federal Public Domain

As a result of a liberal federal land policy, the entire public domain in Minnesota except for 31,160 acres of public land still unallotted and unreserved and 3,837,985 acres now in public reservations, passed into the hands of the State, and of private corporations and individuals. 2/

2/ An undetermined acreage of the public domain now in public reservations owned by the U. S. Government has been obtained by repurchase, following earlier conveyance to private or state ownership.

Chief methods of disposal are summarized graphically in figure --. It reveals that approximately 28,161,859 acres, or 55.0 percent of the public domain, was disposed of by pre-emption, homestead, Indian allotment, public sale and through various forms of scrip; 8, 505,750 acres, or 16.6 percent, by grants to the State in aid of common schools, the university, agricultural colleges, charitable institutions, and for internal improvements; 8,315,000 acres, or 16.2 percent, by donations to the State for aid to railroads; and 2,354,000 acres, or 4.6 percent, by deed directly to the Northern Pacific.

Disposition of State Public Domain

Through federal land grants, the State became the owner of 16,820,750 acres (Figure-). Congress placed few restrictions on the administration of these, except to specify the use to which the lands or proceeds might be devoted. Almost half, or 8,315,000 acres, a larger area than any other state received for that purpose, was conveyed to the railroads. In addition, the State deeded 2,858,583 acres to railroads from the 4,777,224-acre swamp land grant. The Cannon River Manufacturers Association also received lands from the swamp land grant (24,190 acres), as did the Madelia and Sioux Falls Wagon Road (4,683 acres) and the County Commissioners of McLeod County (4,684 acres). Educational grants aggregated 5,114,377 acres in Minnesota, if the 1,882,333 acres of swamp lands not disposed of to railroads and others and the salt spring grant of 46,080 acres are included, a greater area than received by most other states. Lands received in aid of internal improvements aggregated 496,492 acres. The legislature of 1881 authorized the use of money received from the sale of internal improvement lands for the payment of bonds defaulted by early railroad companies.

Most of the land obtained by virtue of the several land grants has been sold or otherwise disposed of. Of the original state domain, 3,100,038 acres remain under the jurisdiction of the State Department of Conservation and 5,751 acres under control of the regents of the University of Minnesota. 1/

1/ In 1873 the 46,080 acres of salt spring lands were transferred to the control of the University of Minnesota regents to be sold in such manner as they might direct.

Figure - illustrates the disposition of the state public domain. Revenue derived from the sale of trust fund lands is placed in a permanent trust fund, the principal of which must be held intact, but income from investments is used for public shcools, the university, state teachers colleges, and charitable and correctional institutions.

Present Land Ownership and Use

Present ownership status of land in Minnesota, by counties, is set out in table-as far as is practicable from available records. Almost a fifth, 18.3 percent, of the area of the State is held in public ownership, the remainder being the property of individuals and corporations. The State owns 5,500,949 acres, or 58.7 percent of the publicly owned land. 1/ The Federal Government owns 3,869,145 acres, or 41.3 percent. These lands, for the most part, are of low agricultural grade. They are located principally in northern cut-over counties, 72.1 percent of the acreage being in ten counties: St. Louis, Koochiching, Beltrami, Lake, Roseau, Cook, Aitkin, Cass, Itasca, and Lake of the Woods.

Of the federal lands, national forests account for 61.9 percent, Indian reservations 21.5 percent, Farm Credit Administration lands 8.9 percent 2/, Biological Survey lands 3.0 percent, conservation areas 2.6 percent, and the combined acreage of unappropriated and unreserved lands, recreational areas and military reservations 2.1 percent. Of the state-owned land, 50.1 percent is trust fund acreage. About 17.6 percent represents road and highways, 12.2 percent water and flood control lands and reforestation areas, 9.1 percent game refuges and public hunting grounds, 2.0 percent acquired state forest lands 1/, 0.8 percent state parks, 0.4 percent state institutions, and 7.8 percent miscellaneous state lands. (Table)

1/ At the time of this writing efforts are being made to turn a 978 acre tract of sand dune land in Sherburne County into a state forest.

2/ It is worthy of note that although the 343,758 acres of farm lands owned outright or subject to redemption by the Federal Land Bank of St. Paul and the Federal Farm Mortgage Corporation in Minnesota are classified with the federally owned lands, they distinctly differ in that they are subject to real estate taxes in the same way as private lands. Furthermore, the Federal Land Bank is owned jointly by the United States government and by local national farm loan associations.

LAND CLASSIFICATION AND LAND OWNERSHIP IN MINNESOTA

County	Land Area	Acres of Privately Owned Lands								
		All Farm Lands 2/				Approximate Farm Land Privately Owned	Metal-iferous Mining Claims	Railroad Right-of-way	Urban Area	Patented Unclassi-fied
		Cropland	Plowable Pasture	Woodland	All Other Farm Lands					
	Acres1/	Acres3/	Acres4/	Acres5/	Acres6/	Acres7/	Acres8/	Acres9/	Acres10/	Acres11/
Aitkin	1,167,360	93,895	26,505	96,276	2,642	291,710		2,781		435,925
Anoka	272,000	100,357	21,707	32,427	1,565	198,074		895	3,653	38,920
Becker	841,600	255,441	53,399	86,699	3,136	494,154		1,476	1,200	225,223
Beltrami	1,610,880	92,025	13,256	132,975	2,496	306,221		1,433	5,760	449,765
Benton	259,560	141,065	6,329	22,426	1,592	236,294		737	1,664	3,087
Big Stone	326,400	233,990	26,553	2,860	1,104	292,294		1,194		1,519*
Blue Earth	473,600	325,326	38,832	22,615	2,966	457,603		2,116	4,320	3,798*
Brown	392,320	273,422	28,236	9,495	2,021	371,527		1,341	5,543	3,428
Carlton	550,400	70,240	16,548	42,212	2,477	216,596		3,587	2,120	269,000
Carver	229,120	129,541	17,816	27,748	1,983	218,105		1,347		1,557
Cass	1,313,920	101,595	9,635	112,395	2,481	316,665		2,883		449,228
Chippewa	372,480	282,131	26,519	4,083	1,711	353,947		1,341	1,120	2,480*
Chisago	268,160	112,080	20,466	45,415	2,011	224,250		708		21,594
Clay	672,000	478,158	60,644	16,631	2,024	594,308		3,462	2,660	44,125
Clearwater	643,200	91,091	9,273	85,746	1,759	260,509		681		182,164
Cook	897,920	2,577	557	7,036	150	13,232		-		180,358
Cottonwood	409,600	306,069	31,997	3,702	1,935	399,836		938	1,037	3,643*
Crow Wing	639,360	77,392	18,183	77,222	2,010	234,757	6,916	3,017	5,869	348,615
Dakota	365,440	223,121	38,202	17,268	2,254	332,476		2,493	7,778	5,338
Dodge	278,400	176,367	47,011	6,077	1,762	269,236		715		413*
Douglas	407,680	232,056	28,155	27,414	2,657	381,329		1,262	1,651	6,934
Faribault	456,320	351,998	48,742	10,062	2,458	446,891		1,596	820	4,804*
Fillmore	549,760	287,881	73,004	57,729	3,001	516,473		1,225		11,075
Freeborne	449,280	289,730	54,753	12,489	2,906	437,104		1,912	1,312	2,686*
Goodhue	485,120	277,316	53,317	29,961	2,983	458,493		2,307	4,627	237*
Grant	356,480	250,639	28,203	4,670	1,348	325,021		1,728		10,856
Hennepin	361,600	147,966	36,681	16,694	4,022	247,990		4,948	65,005	26,453
Houston	361,600	129,468	31,449	93,335	1,800	328,640		1,282		6,020
Hubbard	596,480	74,186	31,351	57,928	1,400	192,680		1,102	1,280	301,288
Isanti	282,880	124,900	21,347	31,411	1,938	221,844		358		29,055
Itasca	1,704,320	64,655	13,654	125,378	2,955	262,881	11,953	2,361	1,000	943,353
Jackson	446,720	331,287	39,446	4,077	2,233	438,361		1,018	640	4,789*
Kanabec	336,000	74,276	9,361	33,486	1,721	196,408		397		114,400
Kandiyohi	527,360	328,290	37,691	15,078	2,569	466,089		1,677	1,720	24,380
Kittson	719,360	361,713	30,365	28,552	1,429	507,141		1,491		148,852
Koochiching	2,008,560	49,087	10,212	74,513	1,196	171,240		1,939	1,024	848,690
Lac qui Parle	494,720	371,985	24,240	3,964	2,064	464,951		810		4,566*
Lake	1,364,480	6,346	2,673	13,257	402	26,126	202	3,413	2,000	512,089
Lake Of Woods	837,120	52,714	6,718	24,567	1,032	152,079		465		385,128
LeSueur	292,240	167,539	23,455	13,344	2,052	273,632		1,397		735*
Lincoln	345,600	246,985	30,820	2,098	1,520	309,876		886		8,642
Lyon	456,320	341,869	28,386	3,219	1,936	436,531		2,137	1,960	4,666
McLeod	318,720	211,497	26,601	15,479	2,470	303,697		1,230	1,440	3,597
Mahnomen	367,360	99,234	15,968	31,326	961	183,668		369		83,154
Marshall	1,152,000	534,062	62,506	76,125	2,817	800,232		2,399		32,449
Martin	452,480	344,164	47,758	4,294	2,493	448,651		1,706	1,335	10,355*
Meeker	396,800	252,656	26,644	15,493	2,448	364,366		813	1,680	11,058
Mille Lacs	363,520	92,154	29,346	22,435	1,971	203,861		747		129,918
Morrison	727,040	252,245	27,658	61,819	3,335	499,199		1,856	1,200	185,458
Mower	449,920	296,777	76,701	7,689	2,511	437,614		2,172	2,060	4,504*
Murray	455,120	331,709	38,837	3,302	2,045	436,181		1,086		3,904
Nicollet	293,760	184,566	17,227	11,835	1,475	267,874		540	1,862	16,384
Nobles	455,680	344,121	40,594	1,701	2,158	447,071		1,421	1,182	6,276*
Norman	566,400	398,287	49,708	23,523	1,958	521,766		1,233		15,424
Olmsted	419,200	233,738	54,981	25,481	2,401	394,128		1,235	1,664	4,911
Otter Tail	1,280,000	650,896	92,114	136,715	6,892	1,131,566		3,813	4,701	72,614
Pennington	398,080	190,194	29,951	40,108	1,337	325,949		696	1,300	36,705
Pine	903,680	156,065	37,551	88,541	3,516	366,036		2,557		437,848
Pipestone	296,960	214,596	35,601	831	1,261	284,507		1,607	980	1,205*
Polk	1,287,680	792,859	88,064	67,247	4,210	1,101,228		4,668	3,125	112,184
Pope	435,840	270,510	37,486	9,093	1,840	378,046		1,315	1,408	20,943
Ramsey	102,400	22,689	8,883	3,256	854	42,939		3,195	36,052	15,967
Red Lake	276,480	150,495	19,473	17,969	956	243,283		873		15,857
Redwood	559,360	430,240	47,300	6,545	2,592	542,140		1,853	1,280	109*
Renville	627,200	471,862	49,065	12,560	3,057	606,289		1,196		958
Rice	316,800	184,273	29,606	13,699	2,318	300,074		1,492	7,040	3,785*
Rock	310,400	225,140	17,767	667	1,348	299,330		1,219	1,177	227*
Roseau	1,072,640	298,279	38,061	104,754	2,299	563,124		1,123		62,567
St. Louis	4,019,840	157,793	49,195	199,214	7,617	572,750	30,265	13,244	65,038	2,044,934
Scott	225,280	120,097	13,094	20,200	1,561	209,075		934		6,872
Sherburne	280,320	125,665	19,448	35,730	1,146	226,045		889	889	30,807
Sibley	371,840	249,891	37,997	10,405	2,266	366,661		580		5,306*
Stearns	867,840	490,444	59,366	50,050	4,533	803,301		3,164	2,860	21,625
Steele	272,000	177,142	35,944	8,574	1,912	266,991		956	5,056	8,526*
Stevens	364,800	277,470	34,556	2,267	1,303	347,219		1,034	1,152	3,677*
Swift	478,080	347,091	40,252	4,529	1,826	433,202		1,480	512	11,052
Todd	606,080	259,503	20,814	59,874	3,660	502,518		2,261	240	56,825
Traverse	366,080	287,495	27,570	2,398	1,059	336,375		653		10,390
Wabasha	333,440	169,156	38,880	48,750	1,638	309,105		648	2,200	1,177*
Wadena	343,040	113,724	18,533	44,979	1,551	238,134		1,065	2,560	72,325
Waseca	265,600	180,012	27,638	8,433	1,658	263,281		789	1,245	6,871*
Washington	249,600	128,463	25,170	25,639	1,782	215,255		2,073	2,082	13,361
Watonwan	277,120	204,498	22,924	3,894	1,443	270,017		1,259	340	2,127*
Wilkin	481,280	358,156	35,996	2,549	1,218	423,659		1,563	1,121	22,701
Winona	398,720	173,881	50,747	65,071	1,937	365,519		1,481	5,262	1,993*
Wright	439,440	228,716	82,997	31,789	3,702	393,911		1,304		9,561
Yellow Medicine	485,120	363,374	38,163	5,641	2,179	463,356		972		3,258*
Other										5,751*
Minnesota	51,205,760	20,135,203	2,840,821	2,931,805	190,964	31,844,314	49,336	152,515	285,406	9,504,095

Note: Acreages shown for the various ownership groups are not all comparable as to time (See the footnote for each). 1/ Approximate land area reported by the U. S. Census Bureau after remeasurement for the 1940 census. 2/ Acreage designated under "all farm land" includes all land in farms (publicly owned as well as private) as determined by the U. S. Census of Agriculture of April 1, 1940 (approximate acreage privately owned is given in another column). 3/ Includes acreages classed as cropland harvested, crop failure, and cropland lying idle or in summer fallow in accordance with the use made of the land in 1939. 4/ Land used only for pasture in 1939 which could have been used for crops without additional clearing, draining or irrigating. 5/ All farm wood lots or timber tracts, natural or planted, and cut-over land with young growth, which has or will have value as wood or timber. 6/ Includes pasture land other than plowable and woodland pasture, all wasteland, house yards, barn yards, feed lots, lanes, roads, etc. 7/ The approximate acreage in privately owned farms differs from the acreage in all farms as given by the U. S. Census. The acreage is obtained by deducting the acreage held by the Rural Credit Administration as of June 30, 1940 (included under miscellaneous state lands) and the Farm Credit Administration as of December 31, 1940 from all land in farms. The comparatively small aggregate farm acreage held in connection with various types of governmental institutions and other public agencies should also be deducted, but the data is not available. 8/ Compiled from the Minnesota Mining Directory, 1940. For Crow Wing County in 1939 the metalliferous mining claims include 1447 acres active, 5,080 acres inactive, and 389 acres exhausted; in Itasca County 5,121 acres active, 6,512 acres inactive, and 320 acres exhausted; in Lake County 202 acres inactive; and in St. Louis County 5,612 active, 19,893 acres inactive, and 4,760 exhausted. 9/ Determined from Railroad and Warehouse Commission records - valuation maps, station plats, Interstate Commerce Commission Order no. 7, and Commission ledgers or reports - as of June 30, 1940. 10/ Estimated in response to questionaires sent to municipalities of 2,500 or more population (Census definition of urban area). In the few instances where no reply was received planimeter readings were used. 11/ Includes mainly private timber holdings (8,227,500 acres, excluding farm woodlots, were reported in July 1937) and land in rural communities (under 2,500 population). In addition, the lands shown here include, in most counties, small acreages, mostly private, not otherwise accounted for. Owing to inaccuracies in surveys and errors from other sources, the combined areas of patented (classified) and non-patented lands (state and federal), in counties indicated thus (*), exceeds the total area. Acreages indicated for those counties must be deducted to reach the total shown for this column.

Of the privately owned lands, by far the largest proportion, approximately 31,844,314 acres, or 78 percent, is held in farms (Table -). 1/ Urban areas, railroad rights-of-way, and mining properties occupy smaller proportions of the total land area. Of the unclassified patented land, over 8 million acres consist of large and small private timber holdings in northern cut-over counties. 2/ Though shown as privately owned, about half this forest land has in fact been tax forfeited for several years. Though it is legally state property, much of the forfeited land is really under the control of county officials who are permitted to sell at their discretion. The remainder of the unclassified privately-owned land consists in the main of rural community areas.

1/ Note that the acreage in privately owned farms (31,844,314 acres) differs from the acreage in all farms (32,606,962 acres) in table -. The approximate acreage in privately owned farms is obtained by deducting the acreage held by the Rural Credit Administration and the Farm Credit Administration from the land acreage in farms as determined by the U. S. Census of Agriculture as of April 1, 1940.

2/ The Lakes States Forest Experiment Station forest survey revealed that approximately 8,227,500 acres of the forest land was held in large private and miscellaneous small private timber holdings as of July 1, 1937.

LAND OWNERSHIP AND CLASSIFICATION IN MINNESOTA - Continued

County	National Forest Lands	Indian Reservations and Lands	Biological Survey Lands	Military Reservations	Recreational Areas	Unappropriated and Unreserved	Farm Credit Administration	Conservation Areas	Total Government Owned Lands
	Federal Owned Lands								
	Acres 20/	Acres 21/	Acres 22/	Acres 23/	Acres 24/	Acres 25/	Acres 26/	Acres 27/	
Aitkin	-	-	11,152	2,520	-	680	1,686	-	16,038
Anoka	-	-	-	-	-	-	8,190	-	8,190
Becker	-	23,936	23,429	-	-	-	8,740	-	56,105
Beltrami	132,822	299,705	-	6	-	3,502	556	4,148	440,739
Benton	-	-	-	-	-	-	8,460	-	8,460
Big Stone	-	-	-	-	-	-	17,460	-	17,460
Blue Earth	-	-	-	-	-	-	347	-	347
Brown	-	-	-	-	-	-	472	-	472
Carlton	-	15,985	-	-	-	-	1,905	-	17,890
Carver	-	-	-	-	-	-	649	-	649
Cass	300,077	60,705	-	362	-	680	2,743	-	364,567
Chippewa	-	-	-	-	-	-	2,502	-	2,502
Chisago	-	-	-	3	-	-	7,676	-	7,679
Clay	-	-	-	-	-	-	4,939	-	4,939
Clearwater	-	124,380	-	-	-	160	2,478	-	127,018
Cook	526,299	38,113	-	-	-	-	239	-	564,651
Cottonwood	-	-	240	-	-	-	-	-	240
Crow Wing	-	-	-	1,668	-	-	1,814	-	3,482
Dakota	-	-	-	813	-	-	4,216	-	5,029
Dodge	-	-	-	-	-	-	1,063	-	1,063
Douglas	-	-	-	-	-	-	2,650	-	2,650
Faribault	-	-	-	-	-	-	155	-	155
Fillmore	-	-	-	-	-	-	6,394	-	6,394
Freeborn	-	-	-	-	-	-	693	-	693
Goodhue	-	507	-	4,652	-	-	1,538	-	6,697
Grant	-	-	-	-	-	-	4,159	-	4,159
Hennepin	-	-	-	2,173	-	-	2,251	-	4,424
Houston	-	-	12,902	1,508	-	-	2,569	-	16,979
Hubbard	-	-	-	63	-	-	5,212	-	5,275
Isanti	-	-	-	-	-	-	15,071	-	15,071
Itasca	130,426	9,560	-	264	-	2,000	510	-	142,760
Jackson	-	-	-	-	-	-	-	-	-
Kanabec	-	-	-	-	-	-	5,266	-	5,266
Kandiyohi	-	-	-	-	-	40	13,995	-	14,035
Kittson	-	-	-	-	-	-	-	-	-
Koochiching	932	84,192	-	-	-	17,397	480	19,572	122,573
Lac qui Parle	-	-	-	-	-	-	7,495	-	7,495
Lake	645,651	-	-	-	-	-	-	-	645,651
Lake Of Woods	-	95,509	-	-	-	-	-	48,507	144,016
Le Sueur	-	-	-	-	-	-	505	-	505
Lincoln	-	-	-	-	-	-	11,685	-	11,685
Lyon	-	-	-	-	-	-	2,419	-	2,419
McLeod	-	-	-	-	-	-	625	-	625
Mahnomen	-	48,693	-	-	-	-	1,828	-	50,521
Marshall	-	-	60,216	-	-	-	2,997	-	63,213
Martin	-	-	-	-	-	-	-	-	-
Meeker	-	-	-	-	-	-	7,597	-	7,597
Mille Lacs	-	2,080	-	-	-	-	3,393	-	5,473
Morrison	-	-	-	-	-	-	4,619	-	4,619
Mower	-	-	-	-	-	-	1,560	-	1,560
Murray	-	-	-	-	-	-	527	-	527
Nicollet	-	-	-	-	-	-	-	-	-
Nobles	-	-	-	-	-	-	253	-	253
Norman	-	-	-	-	-	-	2,762	-	2,762
Olmsted	-	-	-	-	-	-	4,658	-	4,658
Otter Tail	-	-	-	-	-	-	11,050	-	11,050
Pennington	-	-	-	-	-	-	960	-	960
Pine	-	-	-	-	27,116	240	10,289	-	37,645
Pipestone	-	1,035	-	-	116	-	1,916	-	3,067
Polk	-	-	-	-	-	-	4,483	-	4,483
Pope	-	-	-	-	-	-	17,064	-	17,064
Ramsey	-	-	-	-	-	-	60	-	60
Red Lake	-	-	-	-	-	-	480	-	480
Redwood	-	-	-	-	-	-	160	-	160
Renville	-	-	-	-	-	-	1,880	-	1,880
Rice	-	-	-	-	-	-	1,569	-	1,569
Rock	-	-	-	-	-	-	877	-	877
Roseau	-	-	-	-	-	-	160	28,750	28,910
St. Louis	658,095	24,920	-	-	-	6,461	825	-	690,301
Scott	-	-	-	-	-	-	1,237	-	1,237
Sherburne	-	-	-	9	-	-	6,508	-	6,517
Sibley	-	-	-	-	-	-	80	-	80
Stearns	-	-	-	2	-	-	8,549	-	8,551
Steele	-	-	-	-	-	-	320	-	320
Stevens	-	-	-	-	-	-	6,734	-	6,734
Swift	-	-	-	-	-	-	11,029	-	11,029
Todd	-	-	-	-	-	-	16,123	-	16,123
Traverse	-	-	-	-	-	-	7,681	-	7,681
Wabasha	-	160	1,025	4,910	-	-	4,781	-	10,876
Wadena	-	-	-	-	-	-	4,393	-	4,393
Waseca	-	-	-	-	-	-	-	-	-
Washington	-	-	-	580	-	-	3,569	-	4,149
Watonwan	-	-	-	-	-	-	-	-	[illegible]
Wilkin	-	-	-	-	-	-	13,275	-	13,275
Winona	-	-	8,236	4,083	-	-	3,511	-	15,830
Wright	-	-	-	-	-	-	8,387	-	8,387
Yellow Medicine	-	1,420	-	-	-	-	5,807	-	7,227
Other	-	-	-	-	-	-	-	-	-
Minnesota	2,394,302	830,900	117,200	23,616	27,232	31,160	343,758	100,977	3,869,145

20/ Includes acreage in Superior National Forest and purchase units (1,830,977 acres) and Chippewa National Forest (563,325 acres) as compiled by U. S. Forest Service in May 1940. Federal land includes 70,008 of Indian allotments within Chippewa National Forest. 21/ Includes tribal lands, trust allotments, lands recently purchased for the benefit of Indians, lands ceded back from the Public Domain, and lands in individual ownership supervised or administered by the Indian Service, as reported by the U. S. Indian Service as of September 1939. 22/ Reported by U. S. Fish and Wildlife Service as of December 30, 1940. 23/ Reported by U. S. Engineers Office, St. Paul, Minnesota as of July 1939. 24/ Includes 27,116 acres in the St. Croix Federal Recreational Area and 116 acres in Pipestone National Monuments as reported by the National Park Service as of June 30, 1940. 25/ Land in public domain reported by the General Land Office, Washington, D. C. as of June 30, 1939. 26/ Acreage in farms owned outright or subject to redemption by the Federal Land Bank of St. Paul and the Federal Farm Mortgage Corporation as reported on December 31, 1940. Date includes a certain number of farms for which the year of redemption has not yet expired. 27/ Includes acreage in Beltrami and Pine Island Development Projects owned by the federal government and leased to the Minnesota State Department of Conservation for a period of 50 years.

LAND CLASSIFICATION AND LAND OWNERSHIP IN MINNESOTA - Continued

County	State Owned Lands: Trust Fund Lands 12/ Unsold	Trust Fund Lands 12/ Forfeited Or Reverted	Acquired Lands for State Forests	Game and Fish Lands	Water and Flood Control and Reforestation Lands	State Parks	Roads and Highway	State Institution	Misc. State Lands	All State Owned Lands
	Acres	Acres	Acres 13/	Acres 14/	Acres 15/	Acres 16/	Acres 17/	Acres 18/	Acres 19/	Acres
Aitkin	10,579	127,393	-	-	258,460	-	9,126	-	15,348	420,906
Anoka	-	667	-	9,349	-	-	6,513	733	5,006	22,268
Becker	6,013	14,143	1,450	132	-	2,708	17,774	-	21,242	63,462
Beltrami	22,068	41,885	-	316,740	-	206	16,418	-	9,645	406,962
Benton	-	320	-	-	-	-	7,142	-	856	8,318
Big Stone	-	656	-	-	6,024	40	8,257	-	1,994	16,971
Blue Earth	-	80	-	-	-	110	12,688	-	124	13,002
Brown	-	-	-	-	-	878	8,666	-	565	10,109
Carlton	3,295	17,759	-	-	-	3,375	8,296	4,907	3,575	41,207
Carver	-	-	-	-	-	-	7,255	-	207	7,462
Cass	84,566	59,413	956	-	-	-	17,238	881	17,523	180,577
Chippewa	-	5	-	2	4,550	12	9,228	-	2,253	16,050
Chisago	-	-	-	916	-	154	6,721	-	6,138	13,929
Clay	-	3,722	-	-	-	280	6,640	-	11,864	22,506
Clearwater	11,020	14,808	1,802	4,440	-	24,171	9,792	-	6,795	72,828
Cook	131,446	412	3,003	-	-	-	3,477	-	1,341	139,679
Cottonwood	-	-	-	1,600	-	-	9,378	-	214	11,192
Crow Wing	3,419	17,799	-	85	-	-	9,160	-	6,831	37,294
Dakota	151	281	-	-	-	-	9,638	749	1,507	12,326
Dodge	-	360	-	-	-	-	6,504	-	935	7,799
Douglas	120	119	-	-	-	404	8,035	-	5,176	13,854
Faribault	-	-	-	-	-	-	11,456	-	206	11,662
Fillmore	-	-	-	41	-	-	13,414	-	1,140	14,595
Freeborn	-	84	-	-	-	-	10,699	-	82	10,865
Goodhue	-	380	-	-	-	-	11,979	560	314	13,233
Grant	-	80	-	-	122	-	9,854	-	4,660	14,716
Hennepin	-	-	-	-	-	-	12,280	368	132	12,780
Houston	-	894	-	-	-	325	6,895	-	565	8,679
Hubbard	7,626	27,790	33,795	-	-	4,937	10,305	-	10,402	94,855
Isanti	80	564	-	-	-	-	6,717	359	8,832	16,552
Itasca	207,337	95,180	9,014	-	-	2,121	22,466	454	4,040	340,612
Jackson	-	-	-	-	-	-	11,484	-	6	11,490
Kanabec	240	4,202	-	-	-	-	6,534	-	8,553	19,529
Kandiyohi	-	795	-	679	-	379	12,384	706	2,516	17,459
Kittson	3,327	36,396	-	-	-	712	15,198	-	6,243	61,876
Koochiching	775,418	69,345	160	-	-	-	10,673	-	1,498	857,094
Lac qui Parle	-	39	-	-	8,336	284	12,478	-	4,893	26,030
Lake	167,678	1,774	540	-	-	638	4,135	-	234	174,999
Lake Of Woods	-	-	34	145,285	-	-	8,918	-	1,195	155,432
Le Sueur	80	-	-	124	-	-	7,287	-	-	7,491
Lincoln	-	200	-	-	-	-	8,556	-	5,755	14,511
Lyon	-	-	-	-	-	470	5,680	-	2,457	8,607
McLeod	-	-	-	-	-	-	7,987	-	144	8,131
Mahnomen	8,461	1,206	2,150	1	22,380	285	5,117	-	10,333	49,648
Marshall	2,640	42,520	-	15,772	131,897	-	26,335	-	34,258	253,707
Martin	-	-	-	-	-	-	11,063	-	80	11,143
Meeker	-	-	-	-	-	-	9,351	-	1,935	11,286
Mille Lacs	40	11,464	-	-	-	130	9,130	-	2,757	23,521
Morrison	560	7,684	-	-	-	110	17,551	-	8,804	34,709
Mower	-	10	-	-	-	50	10,958	-	-	11,018
Murray	-	-	-	91	-	185	11,141	-	5	11,422
Nicollet	-	-	-	-	-	216	6,019	865	-	7,100
Nobles	-	40	-	-	-	-	11,989	-	-	12,029
Norman	-	2,839	-	-	-	-	12,723	-	9,653	25,215
Olmsted	-	-	-	-	-	105	10,469	1,360	670	12,604
Otter Tail	291	3,800	-	-	-	82	33,677	1,076	17,330	56,256
Pennington	120	4,698	-	-	-	-	9,422	-	18,229	32,469
Pine	-	27,650	-	-	-	1	17,236	-	14,707	59,594
Pipestone	-	-	-	-	-	227	7,687	-	10	7,924
Polk	80	12,347	-	-	-	-	23,151	916	25,498	61,992
Pope	160	719	-	203	-	-	10,263	-	5,719	17,064
Ramsey	-	-	-	77	-	-	3,015	947	148	4,187
Red Lake	-	4,750	-	-	-	6	6,304	-	6,927	17,987
Redwood	-	480	-	-	-	185	13,137	-	234	14,036
Renville	-	286	-	-	-	85	15,387	-	1,120	16,878
Rice	-	40	-	-	-	-	8,720	1,622	28	10,410
Rock	-	-	-	-	-	195	7,825	-	4	8,024
Roseau	29,456	112,030	-	-	239,200	-	18,857	-	17,373	416,916
St. Louis	393,512	97,179	54,371	-	-	-	51,319	-	1,927	598,308
Scott	40	-	-	-	-	-	5,239	167	1,716	7,162
Sherburne	338	1,539	-	-	-	-	6,498	-	7,098	15,473
Sibley	-	120	-	-	-	-	9,024	-	681	9,825
Stearns	80	1,225	-	-	-	-	21,310	1,569	4,155	28,339
Steele	-	-	-	-	-	180	6,249	329	445	7,203
Stevens	-	120	-	-	-	364	8,515	824	2,515	12,338
Swift	80	201	-	-	2,314	199	9,751	-	8,260	20,805
Todd	1,051	3,906	-	-	-	-	14,661	-	8,495	28,113
Traverse	-	240	-	-	-	1	8,871	-	1,869	10,981
Wabasha	-	10	-	-	-	-	7,452	-	4,326	11,788
Wadena	40	7,027	-	-	-	-	6,746	-	10,760	24,573
Waseca	-	80	-	-	-	-	6,319	597	160	7,156
Washington	-	-	-	-	-	-	8,475	1,000	4,208	13,683
Watonwan	-	130	-	133	-	-	6,604	-	264	7,131
Wilkin	-	3,924	-	-	-	-	12,892	-	2,145	18,961
Winona	244	1,021	-	-	-	1,055	8,111	-	2,190	12,621
Wright	-	60	-	-	-	-	15,104	-	1,113	16,277
Yellow Medicine	-	-	-	2,394	-	1	12,629	-	2,399	17,423
Other	-	-	-	-	-	-	-	-	5,751	5,751
Minnesota	1,871,656	886,890	107,275	498,064	673,283	45,866	967,621	20,989	429,305	5,500,949

12/ Acreage of Trust Fund Lands as of June 30, 1940. Compiled from Biennial Statistical Report, Department of Conservation, June 30, 1940 and supplementary date from Division of Lands and Minerals. 13/ Acquired land only as reported by the Division of State Forests as of January 1, 1940. 14/ Includes acres owned by State in game refuges, public hunting grounds, game farms (Madelia 133 acres, Carlos Avery acreage included in game refuge), permanent and seasonal hatcheries, and fish rearing pounds as reported by Division of Game and Fish and as compiled from State Auditor's records. 15/ Includes acres owned by State (S.E.R.A.) in Lac qui Parle and Whetstone water control projects administered by Division of Drainage and Waters as reported in report on Lac qui Parle by Division of Drainage and Waters, June 30, 1940; and acres in flood control and reforestation areas as authorized by various county ditch bond relief acts (Chap. 407, Laws of 1931; Chap. 312, Laws of 1937; Chap. 402, Laws of 1933) and reported by Division of Lands and Minerals as of June 30, 1940. 16/ Includes acreage in state parks, state memorial parks, state recreational reserves, state waysides, and state monuments as reported by Division of State Parks on June 30, 1940. 17/ Includes estimated acreage in trunk highways (127,447 acres), state aid roads (118,605 acres), township aid roads (539,381 acres), and county aid roads (182,187 acres) as reported by State Highway Department on December 1, 1939. 18/ Includes 13,331 acres in state institutions, 23 acres in State Capital and Historical Library grounds, 253 acres in State Fair Grounds, 138 acres in University of Minnesota grounds, 649 acres in University Farm, and 6,596 acres in University Experimental Stations as of June 30, 1940. 19/ Includes 418,890 acres in farms held by the Department of Rural Credit (real estate and sheriff's certificates) as of December 31, 1940, and 4,664 acres of material lands held by the State Highway Department and 5,751 acres (undistributed by counties) of the original salt spring land grant controlled by the regents of the University of Minnesota as of June 30, 1940.

LAND CLASSIFICATION AND LAND OWNERSHIP IN MINNESOTA

County	Land Area	Acres of Privately Owned Lands								
		All Farm Lands 2/				Approximate Farm Land Privately Owned	Metal-iferous Mining Claims	Railroad Right-of-way	Urban Area	Patented Unclassi-fied
		Cropland	Plowable Pasture	Woodland	All Other Farm Lands					
	Acres1/	Acres3/	Acres4/	Acres5/	Acres6/	Acres7/	Acres8/	Acres9/	Acres10/	Acres11/
Aitkin	1,157,360	93,895	26,505	96,276	2,642	291,710		2,781		435,925
Anoka	272,000	100,857	21,707	32,427	1,565	198,074		895	3,653	38,920
Becker	841,600	255,441	53,399	86,699	3,136	494,134		1,476	1,200	225,223
Beltrami	1,610,880	92,025	13,256	132,973	2,496	306,221		1,433	5,760	449,765
Benton	258,560	141,065	6,329	22,426	1,592	236,294		737	1,664	3,087
Big Stone	326,400	233,990	26,553	2,860	1,104	292,294		1,194		1,519*
Blue Earth	473,600	323,326	38,832	22,615	2,966	457,603		2,116	4,320	3,768*
Brown	392,320	273,422	28,236	9,495	2,021	371,527		1,241	5,543	3,428
Carlton	550,400	70,240	16,548	42,212	2,477	216,596		3,587	2,120	269,000
Carver	229,120	129,541	17,816	27,748	1,983	218,105		1,347		1,557
Cass	1,313,920	101,595	9,635	112,395	2,481	316,665		2,883		449,228
Chippewa	372,480	282,131	26,519	4,083	1,711	353,947		1,341	1,120	2,480*
Chisago	268,160	112,080	20,466	45,415	2,011	224,250		708		21,584
Clay	672,000	478,158	60,644	16,631	2,024	594,308		3,462	2,660	44,125
Clearwater	643,200	91,091	9,273	85,746	1,759	260,509		681		182,164
Cook	897,920	2,577	557	7,036	150	13,232		-		180,358
Cottonwood	409,600	306,069	31,997	3,702	1,935	399,836		938	1,037	3,643*
Crow Wing	639,360	77,392	18,183	77,222	2,010	234,767	6,916	3,017	5,869	348,615
Dakota	365,440	223,121	38,202	17,268	2,254	332,476		2,493	7,778	5,338
Dodge	278,400	176,367	47,011	6,077	1,762	269,236		715		413*
Douglas	407,680	232,056	28,155	27,414	2,657	381,329		1,262	1,651	6,934
Faribault	456,320	331,998	48,742	10,062	2,458	446,891		1,596	820	4,804*
Fillmore	549,760	287,881	73,004	57,729	3,001	516,473		1,223		11,075
Freeborne	449,280	289,730	54,753	12,489	2,906	437,184		1,312	1,312	2,686*
Goodhue	485,120	277,316	53,317	29,961	2,933	458,493		2,307	4,627	237*
Grant	356,480	250,639	28,203	4,670	1,348	325,021		1,728		10,856
Hennepin	361,600	147,966	36,681	16,694	4,022	247,990		4,948	65,005	26,453
Houston	361,600	129,468	31,449	93,335	1,800	328,640		1,282		6,020
Hubbard	596,480	74,186	31,351	57,928	1,400	192,680		1,102	1,280	301,288
Isanti	282,880	124,900	21,347	31,411	1,938	221,844		358		29,055
Itasca	1,704,320	64,655	13,654	125,378	2,955	262,281	11,953	2,361	1,000	943,353
Jackson	446,720	331,287	39,446	4,077	2,233	438,361		1,018	640	4,789*
Kanabec	336,000	74,276	9,361	33,486	1,721	196,408		397		114,400
Kandiyohi	527,360	328,290	37,691	15,078	2,569	468,089		1,677	1,720	24,380
Kittson	719,360	361,713	30,355	28,552	1,428	507,141		1,491		148,852
Koochiching	2,002,560	49,087	10,212	74,513	1,196	171,240		1,939	1,024	848,690
Lac qui Parle	494,720	371,985	24,240	3,964	2,064	464,951		810		4,566*
Lake	1,364,480	6,346	2,673	13,257	402	26,126	202	3,413	2,000	512,089
Lake Of Woods	837,120	52,714	6,718	24,567	1,032	152,079		465		385,128
LeSueur	282,240	167,539	23,455	18,344	2,052	273,632		1,397		785*
Lincoln	345,600	246,985	30,820	2,098	1,520	309,876		886		8,642
Lyon	456,320	341,869	28,386	3,219	1,936	436,531		2,137	1,960	4,666
McLeod	318,720	211,497	26,601	15,479	2,470	303,697		1,230	1,440	3,597
Mahnomen	367,360	99,284	15,968	21,326	961	183,668		369		83,154
Marshall	1,152,000	534,062	62,506	76,125	2,617	800,232		2,399		32,449
Martin	452,480	344,164	47,758	4,294	2,493	448,651		1,706	1,335	10,355*
Meeker	396,800	252,656	26,644	15,493	2,448	364,366		813	1,680	11,058
Mille Lacs	363,520	92,154	29,346	22,435	1,971	203,861		747		129,918
Morrison	727,040	252,245	27,858	61,819	3,335	499,199		1,855	1,200	185,458
Mower	449,920	296,777	76,701	7,689	2,511	437,614		2,172	2,060	4,504*
Murray	453,120	331,709	38,837	3,302	2,045	436,181		1,086		5,904
Nicollet	293,760	184,566	17,227	11,835	1,475	267,874		540	1,862	16,384
Nobles	455,680	344,121	40,594	1,701	2,158	447,071		1,421	1,182	6,276*
Norman	566,400	398,287	49,708	23,323	1,958	521,766		1,233		15,424
Olmsted	419,200	233,738	54,981	25,481	2,401	394,128		1,235	1,664	4,911
Otter Tail	1,280,000	650,896	92,114	136,715	6,892	1,131,566		3,813	4,701	72,614
Pennington	398,080	190,194	29,951	40,108	1,337	325,949		696	1,300	36,706
Pine	903,680	136,065	37,551	58,541	3,316	366,036		2,557		437,848
Pipestone	296,960	214,596	35,601	831	1,261	284,587		1,607	980	1,205*
Polk	1,287,680	792,859	88,064	67,247	4,210	1,101,228		4,668	3,125	112,184
Pope	435,840	270,510	37,486	9,093	1,840	378,046		1,315	1,408	20,943
Ramsey	102,400	22,689	8,583	3,256	854	42,939		3,195	36,052	15,967
Red Lake	276,480	150,495	19,478	17,969	956	243,283		873		13,857
Redwood	559,360	430,240	47,300	6,545	2,592	542,140		1,853	1,280	109*
Renville	627,200	471,862	49,055	12,560	3,057	606,289		1,195		958
Rice	316,800	184,273	29,306	13,699	2,318	300,074		1,492	7,040	3,785*
Rock	310,400	225,140	17,767	667	1,348	299,330		1,219	1,177	227*
Roseau	1,072,640	298,279	38,061	104,754	2,299	563,124		1,123		62,567
St. Louis	4,019,840	157,793	49,195	199,214	7,617	572,750	30,265	18,244	65,038	2,044,934
Scott	225,280	120,097	13,094	20,200	1,561	209,075		934		6,872
Sherburne	280,320	125,665	19,448	35,730	1,146	226,045		889	589	30,807
Sibley	371,840	249,891	37,997	10,405	2,266	366,661		580		5,308*
Stearns	867,840	490,444	59,366	50,050	4,533	803,301		3,164	2,860	21,625
Steele	272,000	177,142	35,944	8,574	1,912	266,991		956	5,056	8,526*
Stevens	364,800	277,470	34,556	2,267	1,303	347,219		1,034	1,152	3,677*
Swift	478,080	347,091	40,262	4,529	1,826	433,202		1,480	512	11,052
Todd	606,080	259,508	20,814	59,874	3,660	502,518		2,261	240	56,825
Traverse	366,080	287,495	27,570	2,398	1,059	336,375		653		10,390
Wabasha	333,440	169,156	38,830	48,750	1,638	309,105		648	2,200	1,177*
Wadena	343,040	113,724	18,533	44,979	1,551	238,124		1,065	2,560	72,325
Waseca	265,600	180,012	27,638	8,433	1,658	263,281		789	1,245	6,871*
Washington	249,600	128,463	25,170	25,639	1,782	215,252		2,073	2,082	12,361
Watonwan	277,120	204,498	22,924	3,894	1,443	270,017		1,259	840	2,127*
Wilkin	481,280	358,156	35,996	2,549	1,218	423,659		1,563	1,121	22,701
Winona	398,720	173,881	50,747	65,071	1,937	365,519		1,481	5,262	1,993*
Wright	429,440	228,716	22,997	31,789	3,702	393,911		1,304		9,561
Yellow Medicine	485,120	363,374	38,163	5,641	2,179	463,356		972		3,858*
Other										5,751*
Minnesota	51,205,760	20,133,203	2,840,821	2,931,805	190,964	31,844,314	49,336	152,515	285,406	9,504,095

Note: Acreages shown for the various ownership groups are not all comparable as to time (See the footnote for each). 1/ Approximate land area reported by the U. S. Census Bureau after remeasurement for the 1940 census. 2/ Acreage designated under "all farm land" includes all land in farms (publicly owned as well as private) as determined by the U. S. Census of Agriculture of April 1, 1940 (approximate acreage privately owned is given in another column). 3/ Includes acreages classed as cropland harvested, crop failure, and cropland lying idle or in summer fallow in accordance with the use made of the land in 1939. 4/ Land used only for pasture in 1939 which could have been used for crops without additional clearing, draining or irrigating. 5/ All farm wood lots or timber tracts, natural or planted, and cut-over land with young growth, which has or will have value as wood or timber. 6/ Includes pasture land other than plowable and woodland pasture, all wasteland, house yards, barn yards, feed lots, lanes, roads, etc. 7/ The approximate acreage in privately owned farms differs from the acreage in all farms as given by the U. S. Census. The acreage is obtained by deducting the acreage held by the Rural Credit Administration as of June 30, 1940 (included under miscellaneous state lands) and the Farm Credit Administration as of December 31, 1940 from all land in farms. The comparatively small aggregate farm acreage held in connection with various types of governmental institutions and other public agencies should also be deducted, but the data is not available. 8/ Compiled from the Minnesota Mining Directory, 1940. For Crow Wing County in 1939 the metalliferous mining claims include 1447 acres active, 5,080 acres inactive, and 389 acres exhausted; in Itasca County 5,121 acres active, 6,512 acres inactive, and 320 acres exhausted; in Lake County 202 acres inactive; and in St. Louis County 5,612 acres active, 19,893 acres inactive, and 4,760 exhausted. 9/ Determined from Railroad and Warehouse Commission records - valuation maps, station plats, Interstate Commerce Commission Order no. 7, and Commission ledgers or reports - as of June 30, 1940. 10/ Estimated in response to questionaires sent to municipalities of 2,500 or more population (Census definition of urban area). In the few instances where no reply was received planimeter readings were used. 11/ Includes mainly private timber holdings (8,227,500 acres, excluding farm woodlots, were reported in July 1937) and land in rural communities (under 2,500 population). In addition, the lands shown here include, in most counties, small acreages, mostly private, not otherwise accounted for. Owing to inaccuracies in surveys and errors from other sources, the combined areas of patented (classified) and non-patented lands (state and federal), in counties indicated thus (*), exceeds the total area. Acreages indicated for those counties must be deducted to reach the total shown for this column.

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County	Federal Owned Lands								
	National Forest Lands	Indian Reservations and Lands	Biological Survey Lands	Military Reservations	Recreational Areas	Unappropriated and Unreserved	Farm Credit Administration	Conservation Areas	Total Government Owned Lands
	Acres 20/	Acres 21/	Acres 22/	Acres 23/	Acres 24/	Acres 25/	Acres 26/	Acres 27/	
Aitkin	-	-	11,152	2,520	-	680	1,686	-	16,038
Anoka	-	-	-	-	-	-	8,190	-	8,190
Becker	-	23,936	23,429	-	-	-	8,740	-	56,105
Beltrami	132,822	299,705	-	6	-	3,502	556	4,148	440,739
Benton	-	-	-	-	-	-	8,460	-	8,460
Big Stone	-	-	-	-	-	-	17,460	-	17,460
Blue Earth	-	-	-	-	-	-	347	-	347
Brown	-	-	-	-	-	-	472	-	472
Carlton	-	15,985	-	-	-	-	1,905	-	17,890
Carver	-	-	-	-	-	-	649	-	649
Cass	300,077	60,705	-	362	-	680	2,743	-	364,567
Chippewa	-	-	-	-	-	-	2,502	-	2,502
Chisago	-	-	-	3	-	-	7,676	-	7,679
Clay	-	-	-	-	-	-	4,939	-	4,939
Clearwater	-	124,380	-	-	-	160	2,478	-	127,018
Cook	526,299	38,113	-	-	-	-	239	-	564,651
Cottonwood	-	-	240	-	-	-	-	-	240
Crow Wing	-	-	-	1,668	-	-	1,814	-	3,482
Dakota	-	-	-	813	-	-	4,216	-	5,029
Dodge	-	-	-	-	-	-	1,063	-	1,063
Douglas	-	-	-	-	-	-	2,650	-	2,650
Faribault	-	-	-	-	-	-	155	-	155
Fillmore	-	-	-	-	-	-	6,394	-	6,394
Freeborn	-	-	-	-	-	-	693	-	693
Goodhue	-	507	-	4,652	-	-	1,538	-	6,697
Grant	-	-	-	-	-	-	4,159	-	4,159
Hennepin	-	-	-	2,173	-	-	2,251	-	4,424
Houston	-	-	12,902	1,508	-	-	2,569	-	16,979
Hubbard	-	-	-	63	-	-	5,212	-	5,275
Isanti	-	-	-	-	-	-	15,071	-	15,071
Itasca	130,426	9,560	-	264	-	2,000	510	-	142,760
Jackson	-	-	-	-	-	-	-	-	-
Kanabec	-	-	-	-	-	-	5,266	-	5,266
Kandiyohi	-	-	-	-	-	40	13,995	-	14,035
Kittson	-	-	-	-	-	-	-	-	-
Koochiching	932	84,192	-	-	-	17,397	480	19,572	122,573
Lac qui Parle	-	-	-	-	-	-	7,495	-	7,495
Lake	645,651	-	-	-	-	-	-	-	645,651
Lake Of Woods	-	95,509	-	-	-	-	-	48,507	144,016
Le Sueur	-	-	-	-	-	-	505	-	505
Lincoln	-	-	-	-	-	-	11,685	-	11,685
Lyon	-	-	-	-	-	-	2,419	-	2,419
McLeod	-	-	-	-	-	-	625	-	625
Mahnomen	-	48,693	-	-	-	-	1,828	-	50,521
Marshall	-	-	60,216	-	-	-	2,997	-	63,213
Martin	-	-	-	-	-	-	-	-	-
Meeker	-	-	-	-	-	-	7,597	-	7,597
Mille Lacs	-	2,080	-	-	-	-	3,393	-	5,473
Morrison	-	-	-	-	-	-	4,619	-	4,619
Mower	-	-	-	-	-	-	1,560	-	1,560
Murray	-	-	-	-	-	-	527	-	527
Nicollet	-	-	-	-	-	-	-	-	-
Nobles	-	-	-	-	-	-	253	-	253
Norman	-	-	-	-	-	-	2,762	-	2,762
Olmsted	-	-	-	-	-	-	4,658	-	4,658
Otter Tail	-	-	-	-	-	-	11,050	-	11,050
Pennington	-	-	-	-	-	-	960	-	960
Pine	-	-	-	-	27,116	240	10,289	-	37,645
Pipestone	-	1,035	-	-	116	-	1,916	-	3,067
Polk	-	-	-	-	-	-	4,483	-	4,483
Pope	-	-	-	-	-	-	17,064	-	17,064
Ramsey	-	-	-	-	-	-	60	-	60
Red Lake	-	-	-	-	-	-	480	-	480
Redwood	-	-	-	-	-	-	160	-	160
Renville	-	-	-	-	-	-	1,880	-	1,880
Rice	-	-	-	-	-	-	1,567	-	1,569
Rock	-	-	-	-	-	-	877	-	877
Roseau	-	-	-	-	-	-	160	28,750	28,910
St. Louis	658,095	24,920	-	-	-	6,461	825	-	690,301
Scott	-	-	-	-	-	-	1,237	-	1,237
Sherburne	-	-	-	9	-	-	6,508	-	6,517
Sibley	-	-	-	-	-	-	80	-	80
Stearns	-	-	-	2	-	-	8,549	-	8,551
Steele	-	-	-	-	-	-	320	-	320
Stevens	-	-	-	-	-	-	6,734	-	6,734
Swift	-	-	-	-	-	-	11,029	-	11,029
Todd	-	-	-	-	-	-	16,123	-	16,123
Traverse	-	-	-	-	-	-	7,681	-	7,681
Wabasha	-	180	1,025	4,910	-	-	4,731	-	10,876
Wadena	-	-	-	-	-	-	4,393	-	4,393
Waseca	-	-	-	-	-	-	-	-	-
Washington	-	-	-	580	-	-	3,569	-	4,149
Watonwan	-	-	-	-	-	-	-	-	-
Wilkin	-	-	-	-	-	-	13,275	-	13,275
Winona	-	-	8,236	4,083	-	-	3,511	-	15,830
Wright	-	-	-	-	-	-	8,387	-	8,387
Yellow Medicine	-	1,420	-	-	-	-	5,807	-	7,227
Other	-	-	-	-	-	-	-	-	-
Minnesota	2,394,302	830,900	117,200	(?) 23,616	27,232	31,160	343,758	100,977	3,869,145

20/ Includes acreage in Superior National Forest and purchase units (1,830,977 acres) and Chippewa National Forest (563,325 acres) as compiled by U. S. Forest Service in May 1940. Federal land includes 70,008 of Indian allotments within Chippewa National Forest. 21/ Includes tribal lands, trust allotments, lands recently purchased for the benefit of Indians, lands ceded back from the Public Domain, and lands in individual ownership supervised or administered by the Indian Service, as reported by the U. S. Indian Service as of September 1939. 22/ Reported by U. S. Fish and Wildlife Service as of December 30, 1940. 23/ Reported by U. S. Engineers Office, St. Paul, Minnesota as of July 1939. 24/ Includes 27,116 acres in the St. Croix Federal Recreational Area and 116 acres in Pipestone National Monuments as reported by the National Park Service as of June 30, 1940. 25/ Land in public domain reported by the General Land Office, Washington, D. C. as of June 30, 1939. 26/ Acreage in farms owned outright or subject to redemption by the Federal Land Bank of St. Paul and the Federal Farm Mortgage Corporation as reported on December 31, 1940. Date includes a certain number of farms for which the year of redemption has not yet expired. 27/ Includes acreage in Beltrami and Pine Island Development Projects owned by the federal government and leased to the Minnesota State Department of Conservation for a period of 50 years.

LAND CLASSIFICATION AND LAND OWNERSHIP IN MINNESOTA - Continued

County	State Owned Lands: Trust Fund Lands 12/: Unsold	Trust Fund Lands 12/: Forfeited Or Reverted	Acquired Lands for State Forests	Game and Fish Lands	Water and Flood Control and Reforestation Lands	State Parks	Roads and Highways	State Institutions	Misc. State Lands	All State Owned Lands
	Acres	Acres	Acres 13/	Acres 14/	Acres 15/	Acres 16/	Acres 17/	Acres 18/	Acres 19/	Acres
Aitkin	10,579	127,393	-	-	258,460	-	9,126	-	15,348	420,906
Anoka	-	667	-	9,349	-	-	6,513	733	5,006	22,268
Becker	6,013	14,143	1,450	132	-	2,708	17,774	-	21,242	63,462
Beltrami	22,068	41,885	-	316,740	-	206	16,418	-	9,645	406,962
Benton	-	320	-	-	-	-	7,142	-	856	8,318
Big Stone	-	656	-	-	6,024	40	8,257	-	1,994	16,971
Blue Earth	-	80	-	-	-	110	12,688	-	124	13,002
Brown	-	-	-	-	-	878	8,666	-	565	10,109
Carlton	3,295	17,759	-	-	-	3,375	8,296	4,907	3,575	41,207
Carver	-	-	-	-	-	-	7,255	-	207	7,462
Cass	84,566	59,413	956	-	-	-	17,238	881	17,523	180,577
Chippewa	-	5	-	2	4,550	12	9,228	-	2,253	16,050
Chisago	-	-	-	916	-	154	6,721	-	6,138	13,929
Clay	-	3,722	-	-	-	280	6,640	-	11,864	22,506
Clearwater	11,020	14,808	1,802	4,440	-	24,171	9,792	-	6,795	72,828
Cook	131,446	412	3,003	-	-	-	3,477	-	1,341	139,679
Cottonwood	-	-	-	1,600	-	-	9,378	-	214	11,192
Crow Wing	3,419	17,799	-	85	-	-	9,160	-	6,831	37,294
Dakota	151	281	-	-	-	-	9,638	749	1,507	12,326
Dodge	-	360	-	-	-	-	6,504	-	935	7,799
Douglas	120	119	-	-	-	404	8,035	-	5,176	13,854
Faribault	-	-	-	-	-	-	11,456	-	206	11,662
Fillmore	-	-	-	41	-	-	13,414	-	1,140	14,595
Freeborn	-	84	-	-	-	-	10,699	-	82	10,865
Goodhue	-	380	-	-	-	-	11,979	560	314	13,233
Grant	-	80	-	-	122	-	9,854	-	4,660	14,716
Hennepin	-	-	-	-	-	-	12,280	368	132	12,780
Houston	-	894	-	-	-	325	6,895	-	565	8,679
Hubbard	7,626	27,790	33,795	-	-	4,937	10,305	-	10,402	94,855
Isanti	80	564	-	-	-	-	6,717	359	8,832	16,552
Itasca	207,337	95,180	9,014	-	-	2,121	22,466	454	4,040	340,612
Jackson	-	-	-	-	-	-	11,484	-	6	11,490
Kanabec	240	4,202	-	-	-	-	6,534	-	8,553	19,529
Kandiyohi	-	795	-	679	-	379	12,384	706	2,516	17,459
Kittson	3,327	36,396	-	-	-	712	15,198	-	6,243	61,876
Koochiching	775,418	69,345	160	-	-	-	10,673	-	1,498	857,094
Lac qui Parle	-	39	-	-	8,336	284	12,478	-	4,893	26,030
Lake	167,678	1,774	540	-	-	638	4,135	-	234	174,999
Lake Of Woods	-	-	34	145,285	-	-	8,918	-	1,195	155,432
Le Sueur	80	-	-	124	-	-	7,287	-	-	7,491
Lincoln	-	200	-	-	-	-	8,556	-	5,755	14,511
Lyon	-	-	-	-	-	470	5,680	-	2,457	8,607
McLeod	-	-	-	-	-	-	7,987	-	144	8,131
Mahnomen	8,461	1,206	2,150	1	22,380	2,150	5,117	-	10,333	49,648
Marshall	2,640	42,520	-	15,772	131,897	-	26,335	-	34,258	253,707
Martin	-	-	-	-	-	-	11,063	-	80	11,143
Meeker	-	-	-	-	-	-	9,351	-	1,935	11,286
Mille Lacs	40	11,464	-	-	-	130	9,130	-	2,757	23,521
Morrison	560	7,684	-	-	-	110	17,551	-	8,804	34,709
Mower	-	10	-	-	-	50	10,958	-	-	11,018
Murray	-	-	-	91	-	185	11,141	-	5	11,422
Nicollet	-	-	-	-	-	216	6,019	865	-	7,100
Nobles	-	40	-	-	-	-	11,989	-	-	12,029
Norman	-	2,839	-	-	-	-	12,723	-	9,653	25,215
Olmsted	-	-	-	-	-	105	10,469	1,360	670	12,604
Otter Tail	291	3,800	-	-	-	82	33,677	1,076	17,330	56,256
Pennington	120	4,698	-	-	-	-	9,422	-	18,229	32,469
Pine	-	27,650	-	-	-	1	17,236	-	14,707	59,594
Pipestone	-	-	-	-	-	227	7,687	-	10	7,924
Polk	80	12,347	-	-	-	-	23,151	916	25,498	61,992
Pope	160	719	-	205	-	-	10,263	-	5,719	17,064
Ramsey	-	-	-	77	-	-	3,015	947	148	4,187
Red Lake	-	4,750	-	-	-	6	6,304	-	6,927	17,987
Redwood	-	480	-	-	-	185	13,137	-	234	14,036
Renville	-	286	-	-	-	85	15,387	-	1,120	16,878
Rice	-	40	-	-	-	-	8,720	1,622	28	10,410
Rock	-	-	-	-	-	195	7,825	-	4	8,024
Roseau	29,456	112,030	-	-	239,200	-	18,857	-	17,373	416,916
St. Louis	393,512	97,179	54,371	-	-	-	51,319	-	1,927	598,308
Scott	40	-	-	-	-	-	5,239	167	1,716	7,162
Sherburne	338	1,539	- T	-	-	-	6,498	-	7,098	15,473
Sibley	-	120	-	-	-	-	9,024	-	681	9,825
Stearns	80	1,225	-	-	-	-	21,310	1,569	4,155	28,339
Steele	-	-	-	-	-	180	6,249	329	445	7,203
Stevens	-	120	-	-	-	364	8,515	824	2,515	12,338
Swift	80	201	-	-	2,314	199	9,751	-	8,260	20,805
Todd	1,051	3,906	-	-	-	-	14,661	-	8,495	28,113
Traverse	-	240	-	-	-	1	8,871	-	1,869	10,981
Wabasha	-	10	-	-	-	-	7,452	-	4,326	11,788
Wadena	40	7,027	-	-	-	-	6,746	-	10,760	24,573
Waseca	-	80	-	-	-	-	6,319	597	160	7,156
Washington	-	-	-	-	-	-	8,475	1,000	4,208	13,683
Watonwan	-	130	-	133	-	-	6,604	-	264	7,131
Wilkin	-	3,924	-	-	-	-	12,892	-	2,145	18,961
Winona	244	1,021	-	-	-	1,055	8,111	-	2,190	12,621
Wright	-	60	-	-	-	-	15,104	-	1,113	16,277
Yellow Medicine	-	-	-	2,394	-	1	12,629	-	2,399	17,423
Other	-	-	-	-	-	-	-	-	5,751	5,751
Minnesota	1,871,656	886,890	107,275	498,064	673,283	45,866	967,621	20,989	429,305	5,500,949

12/ Acreage of Trust Fund Lands as of June 30, 1940. Compiled from Biennial Statistical Report, Department of Conservation, June 30, 1940 and supplementary date from Division of Lands and Minerals. 13/ Acquired land only as reported by the Division of State Forests as of January 1, 1940. 14/ Includes acres owned by State in game refuges, public hunting grounds, game farms (Madelia 133 acres, Carlos Avery acreage included in game refuge), permanent and seasonal hatcheries, and fish rearing pounds as reported by Division of Game and Fish and as compiled from State Auditor's records. 15/ Includes acres owned by State (S.E.R.A.) in Lac qui Parle and Whetstone water control projects administered by Division of Drainage and Waters as reported in report on Lac qui Parle by Division of Drainage and Waters, June 30, 1940; and acres in flood control and reforestation areas as authorized by various county ditch bond relief acts (Chap. 407, Laws of 1931; Chap. 312, Laws of 1937; Chap. 402, Laws of 1933) and reported by Division of Lands and Minerals as of June 30, 1940. 16/ Includes acreage in state parks, state memorial parks, state recreational reserves, state waysides, and state monuments as reported by Division of State Parks on June 30, 1940. 17/ Includes estimated acreage in trunk highways (127,447 acres), state aid roads (118,605 acres), township aid roads (539,381 acres), and county aid roads (182,187 acres) as reported by State Highway Department on December 1, 1939. 18/ Includes 13,331 acres in state institutions, 23 acres in State Capital and Historical Library grounds, 253 acres in State Fair Grounds, 138 acres in University of Minnesota grounds, 649 acres in University Farm, and 6,596 acres in University Experimental Stations as of June 30, 1940. 19/ Includes 418,890 acres in farms held by the Department of Rural Credit (real estate and sheriff's certificates) as of December 31, 1940, and 4,664 acres of material lands held by the State Highway Department and 5,751 acres (undistributed by counties) of the original salt spring land grant controlled by the regents of the University of Minnesota as of June 30, 1940.

T Efforts are being made to turn a 978 acre tract of sand dune land in Sherburne County into a state forest.

THE USE AND CONTROL OF WATER

"We are but tenants and transients on the earth.
Let us hand down our heritage not only unimpaired
but enriched to those who come after us".
Mississippi Valley Committee

Because water is so abundant and commonplace in Minnesota, it is not always accorded the high regard it deserves among the natural resources of the State. A constant supply of water is a critical necessity in the home for drinking, cooking, bathing and washing. Fertile soils of Minnesota become unproductive when there is insufficient moisture. Many industries which in total use more water than all private homes of the State together, suffer interrupted production when supplies diminish or fail, It provides cheap transportation and in a State without native coal or oil as sources of energy it has particular value for production of power. Minnesota's fourth largest business, the tourist industry, is founded primarily upon the State's lakes and streams. People who live in more arid regions of the country know better how to appreciate to the full this resource with which Minnesota is so plentifully endowed.

Planning For Water Use

To adopt available and potential water resources to the best use and convenience of man requires consideration also of land utilization. Land and water go together, and people cannot reach a permanently high level of well-being unless they make wise use of both of them. Problems of water control as well as land use should be of as much concern to merchants, manufactures, and bankers as they are to those who toil directly upon the land or gain their living from the water, for Nature's gifts are the basis of all phases of economic life.

The actual task of so using and controlling water as to achieve the highest possible quality of human living calls, therefore, for planning on a very broad scale. Planners must be able to view in their proper relationships the problems of water supply, sewage disposal, flood control, erosion and siltation, drainage, hydroelectric power, and irrigation, and to integrate them all in a comprehensive water and land resources program. Such planning is necessary if wholly beneficial results are to be realized from even a single extensive project, for water does not serve any one isolated community alone, it is used over and over again in various ways by a succession of communities as it moves down the basin.

A water project should not be built to serve one single purpose if it can advantageously be made to serve several. Nor should a project be undertaken in one locality without due regard for its affect on the water needs of other localities. Unified treatment of water and land problems in each drainage basin is essential. Many things that ought to be done to establish the best use and control of water are little things - things each citizen and each small community can do - things little in themselves but vital and far-reaching in their combined results. Every citizen, therefore, needs to understand water problems and to play his part in their solution.

Minnesota is one of a few States which until recent years has shown little interest in the conservation and regulation of public waters. "Like Topsy", a former Commissioner of Conservation has said, "the State's policy with reference to its water has 'just growed', without training and without much care as to the part this resource might be made to play in the ultimate future development of the State". 1/ No doubt Minnesota's physiographic position as a headwater State

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1/ Report of the Commissioner of the Department of Conservation: Annual Report 1938 and Fourth Biennial Report for the Biennium Ending June 30, 1938, January 1, 1939.

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had much to do with this early indifference. The ordinary problems of upriver diversion, pollution and misuse outside the State's jurisdiction seldom arose.

The recent drought, especially in the summers of 1934 and 1936, did more than anything else to make Minnesotans "water-minded." The lowering of lakes reduced property values by many millions. Lower river levels menaced the health and welfare of a number of communities. Western and northwestern sections were actually threatened with a water famine.

In response to statewide demands, the Legislature in 1937 enacted Minnesota's first constructive water regulatory act. The Laws of 1937, Chapter 468, made it the duty of the Commissioner of Conservation to devise and develop a general water resources program for the State. In compliance with this act, the Division of Drainage and Waters in the Department of Conservation has gone as far as is possible, with presently available information and funds, to inaugurate a comprehensive program for the orderly development of the State's surface and underground waters. The general policy of the Department of Conservation is the control and distribution of the State's water resources so as to make them serve as many uses as possible, observant of the relative rights of all interests affected, before they flow beyond the State's boundaries. Such a broad objective should include:- retardation of accelerated run-off, restoration and stabilization of lake, pond, and marsh levels, control of stream flow, regulation of drainage and ground water use, correction of surface and ground water pollution, and quality improvement of domestic and industrial supplies.

In the Red River Valley, the first attempt is now being made to treat jointly, with North and South Dakota, the problems of the conservation, pollution, and flood control in accordance with a commonly accepted water program for the entire basin. After many years without such a plan, the Interstate Committee of the Red River of the North Drainage Basin in August 1937 submitted to the National Resources Committee a report on economic conditions in the basin, its assets and deficiencies in water resources, and the research and construction needed to correct the deficiencies. This report may result in better coordination of water control efforts in that area.

Inadequacy of Existing Data

Sound solution of all water problems requires adequate and unbiased factual data. Water conservation measures in the past have been hampered by lack of such information. Substantial losses in the State have resulted from incomplete knowledge of the behavior of water falling as rain or snow, flowing in streams, or percolating into the ground. Actual experience with crop losses, floods, erosion, siltation, receding lake levels, and similar damage suggests that many millions may have been wasted through failure to make comparatively small but needed expenditures to obtain necessary information.

The accumulation of factual data should be a continuous process. Short time investigations will not suffice to establish with certainty the maximum, minimum, and normal for any particular water factor at any given place. The collection of data, it may be said, will never really be completed.

Statistical information on water does more than merely to insure the better design and construction of new projects and prevent overdevelopment and under-development of available supply; it also promotes the successful operation of completed structures and the proper division of water among its rightful users. To meet this need, the Division of Drainage and Waters of the Minnesota Department of Conservation, the Minnesota Resources Commission, the U. S. Weather Bureau, U. S. Geological Survey, U. S. Army Engineers, and other public and private agencies have been collecting water resources data for many years. Much remains yet to be done.

The General Problem.

In general, the principal problems of control and use of water in a drainage basin are occasioned by extreme variations of stream flow. The flow of a stream is determined by a great number of natural and man-made circumstances, many of which are themselves in a state of constant change. Dominant natural influences are the amount and distribution of rainfall and the nature and condition of the soil on which it falls, the state of the vegetative cover, and the temperature, humidity and motion of the atmosphere. With flow governed by such unstable phenomena, it is naturally very irregular, but Man has accentuated this variability by disturbing the natural harmony of forces that exists in every basin as by cutting forests, draining lakes and swamps, and plowing up the vegetative cover. Axe and plow did most to upset Nature's balance between sun, air, water, soil, and vegetation.

If it is borne in mind that use and control of water should begin with elimination of critical variations of stream flow or with amelioration of their effects the remedial measures for problems of water supply, sewage disposal, stream pollution, flood control, navigation, hydro-electric power, soil erosion, siltation, water recreation, and conservation of aquatic wild life will be more apparent.

Illustrations And Tabulations

PHYSICAL BASIS OF USE AND CONTROL OF WATER

"To know the limitations of rainfall and how our run-off waters behave under varying conditions of climate, cover, and topography, and having acquired this knowledge, to apply it with wisdom in making them serve present and future needs most effectively - to aim to make our waters our servant and not our master - is water conservation."

Minnesota Department of Conservation 1/

Precipitation

Within Minnesota's borders the normal rainfall varies from 20 inches in the northwest to 32 inches in the extreme southeast (Figure -). This places the State, except for a relatively limited area in the southeast, in the 20-to 30-inch rainfall belt just to the east of the zone of critical rainfall variability (Figure -). If this amount of rainfall could be depended upon each year, crop production would be secure and the whole water problem much less acute. Unfortunately, Minnesota's normal annual rainfall of 25.15 inches (based on arithmetical averages of annual means of all stations to 1938) may be widely departed from in individual years (Figure -). During the years from 1891 to 1938, it varied from a mean low of 14.77 inches in 1910 to a mean high of 32.67 inches in 1905. Furthermore, rainfall received in any given year may be excessive in a certain part of the State and deficient in another.

Annual precipitation in western Minnesota is not only least in absolute amount, but it is also subject to more frequent variations of vital consequence than in eastern Minnesota. For instance, at Hallock, where normal annual rainfall is 20.15 inches, a deviation of five inches, or about 25 percent below normal, is much more serious than in the wetter eastern part of the State. At Minneapolis, with 27.66 inches normal annual rainfall, a 5-inch variation below normal represents less than 20 percent and still leaves more than 20 inches. In western Minnesota,

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1/ Outline of a proposed water conservation and utilization plan, p. 9, Department of Conservation, State of Minnesota, October 1932.

moreover, a 5-inch deviation above normal is more likely to result in excess moisture problems than in eastern Minnesota because of the soil, topography and vegetation conditions.

Cyclical Variation

Marked variations occur not only from year to year but also in irregular cycles lasting several years and in major cycles of many years duration. Figure - indicates a pronounced decrease in annual precipitation in recent years, except 1937 and 1938, and suggests a major cyclical tendency. Variations or cycles are even more evident in figure - which shows 10-year moving averages of precipitation for St. Paul since 1846. Both charts show an apparent slow increase of mean annual precipitation up to about 1905 or 1909 and a definite downward trend from those years to 1936, with the average for the eight years 1929-1936 dropping lower than for any previous like span of years. A very similar cycle, according to the St. Paul chart, extended over approximately the same number of years in the last half of the nineteenth century. Three periods of comparatively scanty rainfall are revealed, and two intermediate periods of more abundant precipitation. It should not be inferred from this chart that rainfall oscillations tend to be of equal magnitude or duration.

Whether the downward trend after 1905 - 1909 is part of a long time cycle or whether it represents a result of man made changes in surface conditions is a subject on which there is considerable disagreement. Perhaps the best opinion leans toward a fusion of these two ideas. Were it possible to foresee shifts in climatic conditions it would permit corresponding adjustments in husbandry and use of available water supplies. Most experts believe this is not yet practical -

> "Apparently there is no cyclical recurrence of rainfall conditions which can be reduced to a simple mathematical expression that would permit forecast through extrapolation. Evidence derived from tree rings, lake levels, etc., indicates that in the Great Plains the period from 1825 to 1865 was a long drought with occasional wet years. *** On the basis of that experience we may assume that the

present drought might be prolonged for 20 or more years. Since rainfall averages now stand far below the normal, it is safe to forecast an increase throughout the drought area, but we have no reason to expect it immediately nor to regard the occurrence of a single wet year as the conclusion of the drought. Until further advance is made in the field of accurate long-range weather forecasts, there is no way of anticipating climatic variations.1/

1/ Thornthwaite, C. W., The great plains, in Goodrich, Carter, and others, Migration and economic opportunity, p. 219, Univ. of Penn. Press, 1936.

Periods of either high or low precipitation occur simultaneously over large areas. In Water Supply Paper 772, Studies of Relations of Rainfall and Run-Off in the United States, charts and tables show annual and seasonal changes in precipitation by geographic areas from 1870 to 1934.2/ From this study, the averages

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2/ Hoyt, W. G., and others, Study of relations of rainfall and run-off in the United States: U. S. Geological Survey Water-Supply Paper 772, 1936.

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of progressive 10-year averages for a number of long-time stations3/ in the West

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3/ Includes St. Paul, Minnesota; Muscatine and Farmersburg, Iowa; Blair and North Platte, Nebraska; Yorktown and Huron, South Dakota; and Devils Lake and Garison, North Dakota.

North Central States were plotted for both annual and seasonal values from 1880 to 1934 (Figure -). Note similarity of this regional chart to that for St. Paul. Table - shows the data by seasons for this area (group of stations). Ten-year progressive averages indicate that the average winter precipitation for the last 32 years of record was less than that for the first 32 years, and that the maximum 10-year period ended in 1897 while the minimum period ended in 1934. Statistics for the growing season (May to August) show that average summer precipitation during the last 32 years of record was less than that for the first 32 years, that the maximum 10-year period ended in 1908-09 and the minimum period in 1934, and that the percentage of decrease from one 32-year period to the other is less than for winter precipitation. Changes in fall precipitation are the exact reverse of winter

CHANGES IN SEASONAL PRECIPITATION IN WEST NORTH CENTRAL STATES

Average (inches)			Ratio last 32 years to first 32 years (percent)	Average for 10 years ending 1934 (inches)	Ratio last 10 years (percent)		Maximum 10 year period		Minimum 10 year period		Ratio last 10 years to minimum 10 years (percent)
1871-1934	1871-1902	1903-1934			Long-time average	To last 32 years	Inches	Date of ending	Inches	Date of ending	
Precipitation, December to April, 1871 - 1934											
5.98	6.29	5.68	90	5.22	87	92	6.92	1897	5.22	1934	100
Precipitation, May to August, 1871 - 1934											
13.10	13.29	12.90	97	11.15	85	86	15.16	1908-9	11.15	1934	100
Precipitation, September to November 1871 - 1934											
5.24	5.02	5.46	109	5.90	113	108	5.90	1934	4.04	1897	146

Source: Hoyt, W. G. and others, Study of relations of rainfall and run-off in the United States: U. S. Geological Survey Water-Supply Paper 772, pages 44, 46, and 47 and summer trends - the average for the last 32 years has been above that for the first 32 years and there is now an upward trend.

Seasonal Distribution

Distribution of precipitation by months for areas within Minnesota is illustrated in figure -. It should be noted that for all stations except Orr and Grand Marais maximum rainfall occurs during June. In those areas the maximum is delayed by the slower rise of temperature, and hence less of the convectional overturning that causes summer rainstorms, until July. On the average the State (based on arithmetical averages of monthly means of all stations) receives about 55% of its precipitation during the growing season months of May, June, July, August; 23% in the fall months of September, October and November for water-table replenishment; and 22% during the storage period, December through April.

Snow - The amount and distribution of snowfall is an important factor affecting water use and control. Snow reduces the winter run-off by storing precipitation to be released in the spring of the year. Spring freshets are caused in part by the sudden release of water when the snow melts too quickly. To obtain a more practicable basis for forecasting stream flow, the Corps of Engineers of the U. S. Army in 1935 proposed to set up and maintain seven snow survey courses in Minnesota. Unfortunately, the project was not completed.

Snow measurements along these courses would have served several major purposes. In the first place, forecasts of run-off would promote more effective operation of Federal water control projects. Flood forecasting would be more effective, and power companies and other water using organizations would benefit from the closer estimates of probable water supply.

Precipitation And Temperature

The study referred to above also presents graphs and tables showing annual and seasonal changes in temperature by regions. Figure - shows the means of 10-year progressive averages for seven stations1/ in the West North Central area.

1/ Includes North Platte, Nebraska; Dubuque, Iowa; La Crosse, Wisconsin; Duluth and Moorhead, Minnesota; Rapid City, South Dakota; and Bismark, North Dakota

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It indicates rather conclusively that there has been an increase in temperature at least since the 1890's. Regarding temperature changes the report on the basis of data up to 1934 concludes: "It also seems reasonably certain that the increased temperature may have operated with the decreased precipitation to create, in certain sections of the country, a condition that is increasingly unfavorable to the maintenance of water supplies, both in surface streams and in the ground. This condition is especially acute in the upper Mississippi Valley and the Red River Valley, where, as will be shown later, the average annual losses through evaporation and transpiration so nearly equal the average annual precipitation that any change which would tend to increase the losses would materially affect the amount of water available for steam flow and for replenishment of soil moisture and ground water."2/

2/ Op. cit. p. 57-58.

Disposition of Rainfall

Water is a resource which always replaces itself. In this it differs from forests, grasslands, and soils, and is even more unlike minerals, which once extracted and used cannot be restored. It is well to recognize this general fact, however, "The quantity of water with which mankind is concerned must always remain substantially the same, but its occurrence and distribution over the surface of the earth is continually changing." 3/

3/ Meyer, Adolph F., Elements of Hydrology, p. 5, 1917.

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p. 7.

This sheet is <u>not</u> completed

Few figures to be added on

The Hydrologic Cycle

Disposition of the varying amount of precipitation which falls on Minnesota depends, as elsewhere, upon the natural circulation of waters between the earth's surface and the atmosphere. This circulation, called "The Hydrologic Cycle", is pictured in figure -, showing how sun, air, water, soil, and vegetation form Nature's balance. Arrows pointing down show how moisture is supplied to the earth, while the arrows going up show moisture returning into the air. An understanding of the hydrologic cycle is important since it is possible to regulate and control the circulation of water. Factors of the hydrologic cycle that Man can manipulate most readily are the infiltration, absorption, and evapo-transpiration processes - the last through his control of the plant cover.1/ It must not be overlooked that

1/ Influence of vegetation and watershed treatments on run-off, silting, and stream flow, U. S. Dept. of Agri., Forest Service and Soil Conservation Service, Misc. Pub. 397, p. 4, 1940.

modification of any portion of the hydrologic cycle may influence another part. The great cycle turns about as follows in Minnesota:-

Precipitation - Some precipitation is evaporated in the atmosphere during its fall and hence is called ineffective precipitation (Figure -). Applying the weighted average effective precipitation of   inches of the State it is evident that Minnesota normally receives approximately   acre feet of water or an average depth of   feet of water over each acre of surface, each year.2/

2/ Weighted average is used rather than the simple arithmetical average of observed precipitation in Minnesota because Weather Bureau Stations are much more closely spaced in certain parts of the State than in others.

Of the precipitation which reaches the earth, some is intercepted by vegetation, some runs off over the surface, some percolates into the ground, and some evaporates or is transpired by plants (Figure -). Some water takes a long time to complete the cycle, some only a short while.

Interception - Some precipitation is intercepted by vegetation, from which most of it evaporates back into the atmosphere. Naturally, the more vegetation and foliage there is, the greater the losses by interception. It has been reported that summer rains amounting to as much as one-half inch or more may be almost completely intercepted and evaporated by heavy foliage.1/ Studies by the U. S. Forest Service show

1/ Saville, Thorndike, Basic principles of water behavior, in Headwaters control and use, p. 3, Trans. Upstream Engineering Conference in Washington, 1936.

that from 12 to 40 percent of the summer rainfall on forests is lost by interception and evaporation, depending upon the kind of timber stand.2/

2/ Watershed and other related influences, U. S. Dept. of Agriculture, Forest Service, S. Doc. 12, Separate 5, 72nd Congress, 1935.

Surface Run-off - When the rate of precipitation exceeds the speed at which water may percolate into the soil - surface run-off occurs. This water is shed off at once over the surface of the ground into creeks, rivers and lakes and from there ultimately into the oceans (Figure -). Stream flow also results from subsurface run-off, which passes through the ground before reaching the surface streams. It is axiomatic that if the greater part of the precipitation runs off the surface of a watershed the resulting stream flow will be erratic and irregular and any flow of consequence will be of short duration. Little opportunity will be afforded for replenishment of ground-water reserves and floods and erosion may result.

The following tabulation for the Red River watershed and major subdivisions of the Mississippi watershed above Koekuk, Iowa, within Minnesota, records the estimated mean annual surface run-off as expressed in inches, percent of the total run-off, and percentage of precipitation. Figures in general are based on a five-year annual average for the period noted and were obtained by subtracting from the total stream flow the estimated ground-water run-off.3/

3/ Ground-water run-off was estimated from study of the plotted hydrographs of stream flows. Methods used and the results are discussed in Study of relations of rainfall and run-off in the United States by W. G. Hoyt and others, U. S. Geol. Survey Water-Supply Paper 772, 1936.

Average Annual Surface and Ground Water Run-off

Watershed	Precipitation	Surface Run-off			Ground Water Run-off		
		Inches	Percent of Total Run-off	Percent of Precipitation	Inches	Percent Total Run-off	Percent of Precipitation Minus Surface Run-off
Red River above Grand Forks, N. Dak. (1928-1932)	18.53	0.35	59.3	1.9	0.24	40.7	1.3
Mississippi River above Keokuk, Iowa (1928-1932)	28.64	3.36	56.2	11.7	2.62	43.8	10.4
Minnesota River above Mankato, Minn. (1930-1932*)	22.22	0.42	61.0	1.9	0.27	39.0	1.2
Zumbro River above Zumbro Falls, Minn. (1931-1932*)	26.35	1.70	48.8	6.5	1.78	51.2	7.2
Root River above Houston, Minn. (1931-1932*)	27.98	2.42	44.6	8.6	3.00	55.4	11.7
St. Croix River above Rush City, Minn. (1928-1932*)	25.32	3.76	51.7	14.8	3.51	48.3	16.3

* Years ending September 30.

Source: Hoyt, W. G., and others, Study of relations of rainfall and run-off in the United States: U. S. Geological Survey Water-Supply Paper 772, pages 120-121.

Applying the percentages of total run-off given in the above table for the Red River watershed above Grand Forks and the Mississippi River watershed above Keokuk to the average annual run-offs for the periods of record (1882-1934, Red River; 1878-1934, Mississippi River) the following close approximations of disposition of the precipitation by surface run-off are obtained.

	Percent of Total Run-off		Average Annual Run-off		Approximate Annual Surface Run-off
Red River - - - -	59.3	x	1.25	=	.74 inches
Mississippi - - -	56.2	x	6.98	=	3.92 inches

Any decrease of surface run-off means of necessity, providing the precipitation remains the same, a corresponding increase in the amount of water that enters the soil to be disposed of the transpiration, evaporation, or ground water flow. Conversely, any action that ensues in an increase in the amount of rain entering the soil as infiltration results of necessity in a decrease of surface run-off.

Several benefitsmay result from control of surface run-off, according to Robert Horton, director of the Horton Hydrological Laboratory;1/

1. Reduction in soil erosion and gullying of the soil, with consequent reduction in silt transport of rivers and the sedimentation of reservoirs.

2. Increase in the soil moisture available for vegetation.

3. Increase of the ground water storage, either through raising of ground water levels or their equalization, thus providing an increase of ground water flow of streams and better sustained ground water levels for domestic or other uses and for the supply of such types of vegetation as depend in part upon the water table.

4. Decrease in flood intensity in ordinary floods, although there may be little if any decrease in maximum flood intensities. There will, however, be a substantial decrease in the frequency of occurrence of floods.

5. General betterment in the regularity or regimen of streams, particularly headwater streams and first order tributaries, providing perennial flow where only ephemeral flow previously existed.

1/ Horton, R. E., Surface run-off control, in Headwaters control and use, p. 18, Trans. Upstream Engineering Conference, 1936.

These are the objectives of surface run-off control and they all come under the head of conservation of water resources. Surface run-off control can be accomplished mainly through operations on the soil surface which make running water walk or creep and permeate the soil. Vegetation is Man's strongest ally in bringing about maximum usefulness instead of dissipation of precipitation.

ADAPTATION OF BOTH CROPS AND CROPPING PRACTICES TO THE PURPOSE OF CONSERVATION HELPS TO CONTROL SURFACE RUN-OFF. Strip cropping - soil-laden water from the strip of clean-tilled crops, such as corn, that offers little resistance to water run-off is stayed and filtered of its load in the strip of close-growing crop such as oats. Contour plowing - furrows that follow the contour of the slope dam up and hold the rainfall on the land until it has time to sink into the earth. Terracing - cropland dams across the face of cultivated fields break the downhill flow of rain water, helps it soak into the soil, and leads the surplus into safe channels. Crop rotating - proper rotation increases the absorbency of soils and in addition makes them more fertile and workable.

WELL MANAGED GRASSLANDS VERY EFFECTIVELY HELP IN THE CONTROL OF SURFACE RUN-OFF. Regulated grazing - moving stock from one pasture to another gives grass a chance to keep in good condition. Grassed drainageways - waterways and terrace outlets covered with grass conduct excess rainfall slowly and harmlessly downhill to drainage streams.

IMPEDING SURFACE RUN-OFF IN MANY PLACES REQUIRES EXTENSIVE USE OF TREES. Planting trees - on steep slopes and badly gutted soils, trees will stay the flow of running water and hold the soil in place. Saving forests - when Nature's cover of trees is destroyed by wasteful logging, destructive fires, or harmful insects, little remains to hold back the surface water or the absorbent top-soil.

Absorption And Infiltration

The proportion of normal precipitation retained in the ground cannot be accurately estimated, for absorption and infiltration vary greatly with temperature, previous water content of soil, and numerous conditions determining the character of the soil and rock beneath. Of that which seeps into the ground, a part is used by vegetation and then given off to the atmosphere, a part returns to the ground surface through capillary action1/ and evaporation, a part

1/ Phenomena by which the surface of a liquid where it is in contact with a solid (as in a tube) is elevated or depressed. Elevation of liquids in capillary tubes and the action of blotting paper and wicks are examples of capillarity.

appears later in streams as run-off that passed through underground strata, and a part becomes deep seepage perhaps to appear in other watersheds or as water in deep wells, lakes, or the oceans (Figure -).

Table - presents estimates of mean annual run-off from underground drains. for the Red River watershed above Grand Forks and major subdivisions of the Mississippi River watershed above Keokuk. This is called ground water run-off and is expressed in inches, percent of total run-off and percentage of precipitation.

Such estimates are subject to error. To the extent that estimates of ground water run-off are too large, estimates of surface run-off are too small. Discussion about ground water run-off in Water Supply Paper 772 points out, "These estimates are rough approximations of the amount of infiltration that eventually reaches stream channels. They represent on an annual basis that part of the stream flow which is dependable, as compared with erratic and often destructive surface run-off."2/

2/ Op. cit. p. 245.

Applying the percentages of total run-off given in the above table for the Red River watershed above Grand Forks and the Mississippi River watershed above Keokuk to the average annual run-off for the periods of record (1882-1934, Red River; 1878-1934, Mississippi River) the following close approximations of disposition of precipitation by ground water run-off are obtained:

	Percent of Total Run-off		Average Annual Run-off		Approximate Annual Surface Run-off
Red River - - - - - -	40.7	x	1.25	=	.51 inches
Mississippi River - -	43.8	x	6.98	=	3.06 inches

Generally, ground water leakage into brooks and streams and rivers occurs along porous strata. Most persons are surprised to learn how large a proportion of the total run-off of streams is derived from ground water. For watersheds as given in table - this varies from 39 percent for the Minnesota River above Mankato to over 55 percent for Root River above Houston, Minnesota. It may run a great deal more in the case of streams that run through deep, sandy, glacial deposits, such as occur in large areas in Minnesota.

Maintenance of underground water storage is of vital importance. Even in better watered sections, rainfall during the growing season seldom suffices for production of a full crop, so that generally the productivity of Minnesota is essentially dependent upon water stored in soil and subsoil and underlying rocks within root-draft of growing plants. Moreover, states a Bureau of Soils bulletin, "This store is the chief source of springs and streams where animals drink; it is the supply for wells whence men take the water required for domestic uses; and it is the reservoir which holds storm waters and equalizes the flow of brooks and rivers."1/

1/ Wells and subsoil waters, U. S. Dept. of Agriculture, Bureau of Soils, Bull. 92, p. 8, 1913.

"It is, as we shall discover," writes H. S. Person, "Largely by acts which decrease absorption and infiltration, and ground water store, and which accelerate run-off, that Man has seriously disturbed natural arrangements and harmed himself."1/

1/ Person, H. S., Little Waters: A study of headwaters streams and other little waters, their use and relations to the land; Soil Conservation Service - Resettlement Administration - Rural Electrification Administration, Revised Edition, p. 8, 1936.

Evaporation And Transpiration

The atmosphere heated by the sun takes up water from the earth's surface in two ways - by evaporation from oceans, lakes, rivers, land, and vegetation and by transpiration from leaves of vegetation (Figure -). Evaporation and transpiration, as roughly measured by precipitation minus run-off over the period of record, averages about 20 inches (20.91 inches precipitation - 1.25 inches run-off = 19.67 inches) for the Red River watershed and 23 inches (29.51 inches precipitation - 6.98 inches run-off = 22.53 inches) for the Mississippi River watershed, according to Water Supply Paper 772.

In its relation to agriculture, evaporation is probably as important as either precipitation or temperature. Loss of soil moisture by evaporation assumes especial significance in western parts of the State because of the comparatively narrow margin between crop success and failure. Even with its important bearing on agriculture, and on drainage and impounding of water, quantitative data on evaporation exist for only a few scattered stations, and even the available records are useful only to a limited extent, because they were obtained for different periods and by different methods.

Transpiration is one of the basic functions in the life processes of plants. Plants take up water from the soil through roots, utilize it in producing growth and maintaining life, and then discharge it through pores into the atmosphere as water vapor. The amount of precipitation thus returned to the atmosphere varies greatly with temperature, humidity, and wind velocity, and with the character of the vegetation and soil. A given area of conifers will transpire the equivalent of from 3 inches (pines) to 8.5 inches (spruce) of the precipitation, hardwoods from 5 inches (oaks) to 10 inches (beech).1/

1/ From unpublished manuscript by Aaron Raber, Water relations of trees with special reference to the economic species of the North Temperate Zone; U. S. Department of Agriculture, Forest Service.

In normal years most of the rainfall received in the growing season returns to the atmosphere through direct surface evaporation and transpiration. During summers of subnormal rainfall the ground water table2/ of Minnesota is lowered,

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2/ Upper level of the ground water storage zone is called the "water table".

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especially in the areas of greater deficiency, because the rate of evaporation and transpiration of moisture from the ground and surface of plants exceeds infiltration.

Figure - taken from Water Supply Paper 772 shows the ten-year progressive averages of precipitation minus run-off at Grand Forks; thesemay be taken as the approximate amounts of water required for transpiration and evaporation there, assuming no progressive change in ground water storage over the period. If, for a rough consideration, the average is given the value of 20 inches, it is clear that whenever annual rainfall is less than that amount (a) agriculture is seriously affected, and (b) vegetation will take up precipitation in such an amount that low-water stream flow will be reduced to extremely low values.3/

3/ Report on regional planning, part V - Red River of the North, National Resources Committee, p. 9, August 1937.

Draft upon ground water reserves during subnormal rainfall years causes a rapid recession in stream flow and, if prolonged over a period of dry years, results in the dying of old mature trees, drying up of wells, lowering of lake levels, and acute danger to domestic water supplies from pollution. These facts suggest the great importance of making every practical provision for water conservation and storage in years of plentiful rainfall.

The situation is perhaps clearer when expressed in another way. If the average annual precipitation is taken as 22 inches (Figure -) and evaporation and transpiration placed at 20 inches, it is obvious that under those average conditions less than 2 inches of water remains for conservation. The National Resources Committee has reported that, "For the seven years, 1929 to 1935, the average run-off at Grand Forks was only 0.36 inches. This represents an extremely small amount of water available for storage and stream regulation."1/ But a total rainfall of 28 inches,

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1/ Op. cit. Idem., p. 41.

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say, in one year, produces at least 8 inches for conservation. Thus, roughly, a one-third increase in precipitation there will multiply the waters which become available to maintain lakes, streams and sub-surface supplies about three times.

Summary

In general summary, in Minnesota (Figure -), Nature uses from 19 to 26 inches of the 20 to 32 inches of precipitation to meet the demands for deep seepage, evaporation from land and water areas, and transpiration of plants. Minnesota streams and lakes and swamp storage, depending upon rainfall conditions, dispose of from 1 to 6 inches.

As shown, the run-off for any given area is roughly proportional to the amount of precipitation. The extent of correlation between trends of annual rainfall, temperature conditions, and run-off may be seen by examining figures - and -, already shown, and figure - which shows ten-year progressive averages of annual run-off in inches for the Red River at Grand Forks and the Mississippi at Keokuk, Iowa over almost the last half century. Progressive averages of gage heights of Lake Superior were also plotted in figure - . On relations between rainfall and run-off, Water Supply Paper 772 concludes, "On the basis of the long-time averages it appears that in the Red River Basin a change of one inch in rainfall is reflected by a change of about 0.3 inches in run-off. * * *. In the Mississippi River Basin a change of one inch in rainfall is reflected by a change of about 0.5 inches in run-off."1/ While

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1/ Hoyt, W. C., and others, Study of relations of rainfall and run-off in the United States: U. S. Geol. Survey Water-Supply Paper 772, p. 100, 1936.

Man has as yet little or no control over precipitation or temperature, his activities exert an ever increasing influence on the process of water run-off.

Surface Waters

Study of a map of Minnesota shows the State contains the headwaters of three of the continent's major drainage systems, all flowing to the Atlantic side but by three widely divergent courses. Part of the drainage of Minnesota leads to the Gulf of Mexico (Mississippi River System), part to the Gulf of St. Lawrence (Great Lakes - St. Lawrence River System), and part to Hudson Bay (Nelson River System). The Gulf of Mexico receives about 57 percent of the drainage, the St. Lawrence less than 9 percent, and Hudson Bay fully 34 percent.2/

2/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent states: U. S. Geol. Survey Prof. Paper 161, p. 9, 1932.

Practically no water enters or materially augments the water supplies of Minnesota from any outside drainage area except as to streams entering the St. Croix and the Mississippi from Wisconsin on the eastern boundary of the State and streams entering the Red River from North and South Dakota on the west.

Major Drainage Systems

The poorly defined divide between the St. Lawrence and Nelson drainage systems follows the prominent Mesabi iron range and then on to the northeast along the top of a relatively flat, forested, morainic plateau, dotted with many lakes. Between the divide and Lake Superior the generally rough topography is dissected by many streams which descend in cascades to Lake Superior. In Cook and Lake Counties are streams which drop 900 feet within a few miles. Pigeon River descends 1,050 feet, over a series of falls and rapids, from its source to the level of Lake Superior (602 feet); 700 feet of this descent takes place in the last 20 miles. St. Louis River flows for most of its course through a level swampy tableland between the Mesabi iron range and the escarpment fronting on Lake Superior, finally to plunge 555 feet in 12 miles from a point below Cloquet to Allouez Bay.

The Divide between the Mississippi and Nelson drainage systems trends irregularly from the southern boundary of Traverse County on the southwest in a northerly and northeasterly direction along the large moraines of calcareous till in Ottertail, Becker, Clearwater and southern Beltrami Counties; and then easterly in Itasca County to the iron range divide. Most streams emptying into the Red River of the North, tributary of the Nelson, have moderately high but irregular gradients in their upper reaches, but after reaching the level glacial Lake Agassiz plain their gradients greatly decrease. In hilly moraines bordering the lake plain, innumerable small depressions were left, giving origin to thousands of lakes with the greater number in Ottertail, Becker and Itasca Counties. Few lakes occur in the lake plain and most of these are large, notably Lake Traverse, Lake of the Woods, and Upper and Lower Red Lake. On the most poorly drained parts of the Lake Agassiz bed, extensive peat bogs developed in Roseau, Lake of the Woods, Koochiching, and northern Beltrami Counties. In general drainage is in a youthful stage of development, being featured by numerous lakes and swamps and drainage courses that are poorly organized and irregular.

The upper part of Mississippi River follows a circuitous route with a descent from an altitude of about 1,475 feet at Lake Itasca, near its source, to about 620 feet at the Minnesota-Iowa line. The gradient varies considerably in the post-glacial course above the Twin Cities. From the source in Lake Hernando de Soto to the outlet of Lake Winnibigoshish, a distance of about 50 miles, a fall of somewhat over 150 feet takes place. From there to Brainard, a distance of 250 miles, the gradient is low, with a total fall of approximately 125 feet, or an average fall of about six inches per mile. * * *. The character of the river then changes abruptly and in the 150 miles between Brainard and the Twin Cities, the river falls from about 1,175 feet above sea level to 700 feet.1/ In the re-excavated pre-glacial valley below the junction of the Minnesota River to the state line, which is about 175 miles, there is a total fall of approximately 80 feet.

The Mississippi headwaters area has strong belts of morain interspersed in more rolling ground moraine or flat sandy and gravelly outwash material. Basins as well as knolls conspicuously emphasize the glaciated topography. Lakes abound throughout the area. Mille Lacs, Leech, and Winnibigoshish Lakes, three of the largest lakes Minnesota, are located in higher parts of the basin at elevations between 1,250 and 1,300 feet above sea level. The Mississippi itself flows through a series of these larger lakes, including Bemidji, Cass, and Winnibigoshish. Drainage lines are not yet thoroughly developed in this area.

The Minnesota River, principal tributary to the Mississippi in Minnesota, has a length of about 400 miles. It flows through rolling till prairie country in a very broad valley that was cut mainly by drainage from glacial Lake Agassiz. It has only a 300 foot gradient over its entire course. Lakes are far less numerous

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1/ From the Report of the Committee on Water Resources to the Minnesota State Planning Board, p. 5, Oct. 1934.

in the Minnesota watershed though marshes occur frequently, especially near rivers. The valley of the Minnesota River generally runs about 200 feet below the surrounding ground level with bluffs lining the gorge from Granite Falls to its mouth.

The drainage area of the Mississippi River in the southeastern corner of Minnesota comprises a bowed up highland covered with old moraine with a youthful, much-dissected, loess-mantled phase in the eastern part and a rolling phase in the western part, except for a narrow belt in the extreme southeast which escaped glaciation and is therefore called the Driftless Area. Along the Mississippi and it tributaties, rather narrow V-shaped valleys open from the edge of the water for varying distances until they attain the higher ground of the plateau back of the bluffs. A great deal of the upland lies above the 1,000-foot elevation. The bluffs are badly gullied and eroded and drainage lines throughout the area are well established.

Annual Run-off

Relatively, the stream flows are low in western Minnesota and high in eastern sections as a result of the distribution of precipitation and vegetation and differences in physiography. The approximate mean annual run-off for principal rivers and selected tributaries in Minnesota, compiled from the best data available, are tabulated in table -. Table - lists discharge recording stations in Minnesota and their years of record.

Comparison of the average annual discharges at and near Anoka with the averages at St. Paul for the same periods of record (1906-1913 and 1932-1938) reveals that the Mississippi headwaters contributed 64 percent and 70 percent, respectively, of the total run-offs of the Mississippi River at St. Paul just below its confluence with the Minnesota River, although the Minnesota drains an area approximately four-fifths as large as the Mississippi headwaters. The proportion of the run-off at St. Paul comprising upper Mississippi drainage runs considerably greater in dry years and less in wet years. During especially dry years the Mississippi headwaters provide almost the entire minimum flow at St. Paul.

SUMMARY OF DISCHARGE DATA OF PRINCIPAL RIVERS AND SELECTED TRIBUTARIES TO 1939

River	Station	Drainage Area Square Miles	Years of Record	Maximum Discharge Calendar Day Cu. Ft. Per. Sec.	Maximum Gage Height Feet	Annual Run-off		
						Maximum Cu. Ft. Per. Sec.	Minimum Cu. Ft. Per. Sec.	Average Cu. Ft. Per. Sec.
Red River Basin								
Red River	Grand Forks, North Dakota	25,500	38	32,920	50.2	5,580	244.0	1,777
Red River	Fargo, North Dakota	6,420	38	7,720	23.6	805	17.5	262
Red River	Near Fergus Falls	1,800	2	-	8.66	-	-	-
Roseau River	Caribou	1,650	12	3,160	12.8	683	120.	301
Roseau River	Ross	1,030	11	2,290	14.64	259	28.9	141
Two Rivers, South Branch	Hallock	776	6	1,830	17.44	79	30.5	55
Red Lake River	Crookston	5,320	38	14,400	21.5	1,970	83.6	680
Red Lake River	Thief River Falls	3,430	21	7,040	15.0	1,330	133.	506
Red Lake River	Red Lake	1,950	6	273	5.80	68.2	5.55	20
Clearwater River	Red Lake Falls	1,310	9	3,990	6.95	470	127.	260
Thief River	Near Thief River Falls	1,010	25	4,080	14.5	344	2.64	96
Wild Rice River	Twin Valley	805	18	2,200	20.0	337	53.1	133
Ottertail River	Near Fergus Falls	1,310	10	1,075	4.20	377	140.	224
Ottertail River (Head of Red River)	Near Fergus Falls	1,300	4	982	3.0	466	356.	415
Bois des Sioux River	Near Tenney	1,460	20	390	5.68	1/	1/	1/
Mustinka River	Above Wheaton	776	15	2,240	14.7	57.9	.19	15
Minnesota River Basin								
Minnesota River	Mankato	14,600	36	43,800	21.20	5,670	136.	1,731
Minnesota River	Montevideo	6,300	30	22,000	18.85	1,880	4.43	424
Minnesota River	Odessa	1,560	4	850	11.60	-	-	43
Blue Earth River	Rapidan Mills	2,260	2	13,100	11.50	-	-	-
Chippewa River	Near Watson	1,850	17	9,700	17.86	138.	20.9	60
Cottonwood River	New Ulm	1,190	13	4,490	16.15	279.	54.8	137
Pomme de Terre River	Near Appleton	960	8	700	6.42	49.2	25.8	37
Lac qui Parle River	Lac qui Parle	838	13	2,020	11.14	51.9	10.2	45
Redwood River	Redwood Falls	703	15	1,260	4.84	92.9	18.7	48
Yellow Medicine River	Near Granite Falls	540	8	2,170	6.62	123.	9.47	66
Rainy River Basin								
Rainy River	International Falls	14,600	11	37,300	15.21	13,900	4,610	8,174
Basswood River	Near Winton	1,920	8	7,950	4.38	1,547	778	1,086
Little Fork River	Little Fork	1,620	20	19,300	37.00	1,730	308	846
Big Fork River	Big Falls	1,520	15	11,500	15.12	926	92.6	476
Kawishiwi River	Near Winton	1,300	27	8,010	2/	1,340	241	809
Vermilion River (below Lake Vermilion)	Tower	530	18	2,290	3.96	520	178	281

SUMMARY OF DISCHARGE DATA OF PRINCIPAL RIVERS AND SELECTED TRIBUTARIES TO 1939 - Continued.

River	Station	Drainage Area Square Miles	Years of Record	Maximum Discharge Calendar Day Cu. Ft. Per. Sec.	Maximum Gage Height Feet	Annual Run-off Maximum Cu. Ft. Per. Sec.	Annual Run-off Minimum Cu. Ft. Per. Sec.	Annual Run-off Average Cu. Ft. Per. Sec.
Upper Mississippi River Basin								
Mississippi River	St. Paul	36,800	52	80.800	18.00	20,600	1,935	8,518
Mississippi River	Near Anoka	19,100	8	35,400	11.92	5,886	1,603	3,239
Mississippi River	Anoka	17,100	9	44,300	10.40	13,400	3,290	6,911
Mississippi River	Elk River	14,500	24	31,300	11.31	9,920	1,454	4,087
Mississippi River	Near Royalton	11,600	15	19,200	-	3,840	1,213	2,410
Mississippi River	Near Ft. Ripley	10,700	3	8,700	8.92	-	-	-
Mississippi River (below Sandy River)	Libby	5,060	9	2,000	15.43	1,409	505	853
Mississippi River (above Sandy River)	Libby	4,560	26	9,572	3/ 27.2	3,564	1,180	2,188
Rum River	Near Anoka	1,430	3	7,560	21.3	-	-	-
Rum River	Near St. Francis	1,360	10	5,440	8.80	529	66.1	255
Rum River	Cambridge	1,160	6	4,900	16.2	383	160	255
Crow River	Near Dayton	2,540	1	11,000	13.9	-	-	-
Crow River	Rockford	2,520	17	10,400	15.9	1,690	64.5	499
South Fork of Crow River	Near Rockford	1,160	4	2,650	8.60	-	-	-
Elk River	Near Big Lake	615	15	4,970	9.8	485	88	233
Sauk River	Near St. Cloud	815	15	1,690	8.95	210	51.0	126
Platte River	Royalton	338	9	1,380	6.36	-	-	-
Crow Wing River	Pillager	3,230	6	6,920	11.0	838	539.	736
Crow Wing River	Motley	2,140	8	9,440	13.2	1,430	366.	1,007
Crow Wing River	Nimrod	1,010	14	2,000	7.1	-	-	-
Long Prairie River	Near Motley	973	11	4,280	15.0	571	54	290
Lower Mississippi River Basin								
Mississippi River	Prescott, Wisconsin	45,000	11	59,700	13.04	13,800	4,367	8,752
Mississippi River	Winona	59,200	11	94,900	12.83	26,810	9,742	17,360
Root River	Near Houston	1,280	19	25,000	15.34	847	442	641
North Branch Root River	Near Lanesboro	647	8	10,500	13.00	416	260	324
Zumbro River	Zumbro Falls	1,120	19	18,300	26.26	617	170	436
South Branch Zumbro River	Near Zumbro Falls	821	7	7,940	10.91	507	246	379
Cannon River	Welch	1,290	15	10,500	12.04	467	137	312
St. Croix River Basin								
St. Croix River	Near St. Croix Falls, Wis.	5,930	29	35,800	4/	6,040	1,754	3,151
St. Croix River	Near Rush City, Minn.	5,120	16	27,500	13.90	4,380	1,599	2,715
St. Croix River	Swiss, Wisconsin	1,550	25	8,220	6.73	1,730	843	1,146
Snake River	Pine City	915	5	7,240	-	944	343	548
Snake River	Mora	422	5	3,600	16.7	209	87.2	132
Kettle River	Sandstone	825	10	10,600	7.70	945	231	632
Iowa - Cedar Rivers Basin								
Cedar River	Near Austin	425	6	5,230	14.4	167	100	126
Des Moines - Skunk Rivers Basin								
West Fork Des Moines River	Jackson	1,160	5	1,690	10.0	-	-	-
Heron Lake Outlet	Near Heron Lake	492	9	1,660	8.53	198	26.5	81

1/ No flow during the entire climatic year 1924-1925.
2/ No gage heights, a power plant record.
3/ Gage height maximum and minimum are from period 1925 to date. Prior to 1925 records not available.
4/ Data not available.
\- Ommission in record.
Source: Water Supply Papers, U. S. Geological Survey.

DISCHARGE RECORDING STATIONS IN MINNESOTA BY RIVER BASINS
PERIOD OF RECORD THROUGH 1939

Station	County	River	Years Duration	Years Of Record
RED RIVER BASIN				
Detroit Lakes	Becker	Ottertail	3	1937-1939
Fergus Falls (head of Red R.)	Otter Tail	Ottertail	5	1913-1917
Fergus Falls (near)	Otter Tail	Ottertail	10	1904-1913
Fergus Falls (below Pelican R.)	Otter Tail	Ottertail	10	1930-1939
Breckenridge	Wilkin	Ottertail	2	1931-1932
Fergus Falls (near)	Otter Tail	Red	2	1909-1910
Fargo (North Dakota)1/	Cass	Red	39	1901-1939
Grand Forks (North Dakota)1/	Grand Forks	Red	39	1901-1939
Pembina (North Dakota)1/	Pembina	Red	1	1901
Emerson (Manitoba)1/		Red	12	1902, 1929-1939
Fergus Falls (near)	Otter Tail	Pelican	4	1909-1912
Wheaton (above)	Traverse	Mustinka	16	1917, 1919-1924, 1931-1939
Wheaton (near)	Traverse	Mustinka	1	1916
Dilworth	Clay	Buffalo	9	1931-1939
Twin Valley	Norman	Wild Rice	19	1909-1917, 1930-1939
Waskish (head of Red Lake R.)	Beltrami	Red Lake*	4	1930-1933
Redby	Beltrami	Red Lake*	3	1930-1932
Red Lake (near)	Beltrami	Red Lake*	7	1933-1939
Red Lake (near)	Beltrami	Red Lake	7	1933-1939
Goodridge (at High Landing)	Pennington	Red Lake	10	1930-1939
Kratka	Pennington	Red Lake	2	1929-1930
Thief River Falls	Pennington	Red Lake	21	1909-1918, 1920-1930
Crookston	Polk	Red Lake	39	1901-1939
Middle River (near Thief R.)	Marshall	Thief Lake*	8	1932-1939
Thief River Falls (near)	Pennington	Thief	26	1909-1917, 1920-1921, 1922-1924, 1928-1939
Red Lake Falls	Red Lake	Clearwater	9	1909-1917
Pelan (head of Two R., S. Fork)	Roseau	Two	10	1928-1937
Bronson (South Fork)	Kittson	Two	12	1928-1939
Hallock	Kittson	Two	6	1911-1914, 1929-1930
Hallock (Middle Fork)	Kittson	Two	9	1931-1939
Lancaster (North Fork)	Kittson	Two	10	1929-1938
Lancaster (near)	Kittson	State Ditch #85	10	1929-1938
Malung	Roseau	Roseau	12	1928-1939
Roseau	Roseau	Roseau	1	1939
Ross	Roseau	Roseau	12	1928-1939
Badger (near)	Roseau	Roseau	12	1928-1939
Haug (near)	Roseau	Roseau	8	1932-1939
Caribou	Roseau	Roseau	12	1917, 1920-1930
Caribou (below cut-off ditch)	Roseau	Roseau	11	1929-1939
Caribou (at Int. Boundary)	Roseau	Roseau	7	1933-1939
Malung (South Fork)	Roseau	Roseau	16	1911-1914, 1928-1939
Pine Creek (near)	Roseau	Pine Creek	12	1928-1939
Badger (near)	Roseau	Badger Creek	10	1929-1938
Bagley (near)	Clearwater	Rice Lake*	5	1935-1939
Leonard (near)	Clearwater	Clearwater Lake*	6	1934-1939
Leonard	Clearwater	Clearwater	6	1934-1939
Plummer	Red Lake	Clearwater	1	1939
Red Lake Falls	Red Lake	Clearwater	6	1934-1939
Sprague	Polk	Mud Creek	12	1928-1939
MINNESOTA RIVER BASIN				
Ortonville	Big Stone	Minnesota	3	1937-1939
Odessa (near)	Big Stone	Minnesota	5	1909-1913
Montevideo (near)	Chippewa	Minnesota	31	1909-1939
Judson	Blue Earth	Minnesota	2	1938-1939
Mankato (near)	Blue Earth	Minnesota	37	1903-1939
Carver (near)	Carver	Minnesota	6	1934-1939
Odessa (near)	Big Stone	Yellow Bank	1	1939
Appleton (near)	Swift	Pomme de Terre	9	1931-1939
Lac qui Parle	Lac qui Parle	Lac qui Parle	14	1910-1914, 1931-1939
Watson (near)	Chippewa	Chippewa	15	1909-1917, 1931-1936
Granite Falls (near)	Yellow Medicine	Yellow Medicine	9	1931-1939
Redwood Falls (near)	Redwood	Redwood	16	1909-1914, 1930-1939
New Ulm, (near)	Brown	Cottonwood	14	1909-1913, 1931-1939
Rapidan Mills	Blue Earth	Blue Earth	2	1909-1910
Rapidan (near)	Blue Earth	Blue Earth	1	1939
Milan (near)	Chippewa	Chippewa	3	1937-1939
Rapidan (near)	Blue Earth	Le Sueur	1	1939
Mayer (near)	Carver	S. Fork of Crow	6	1934-1939
RAINY RIVER BASIN				
Ranier (head of Rainy R.)	Koochiching	Rainy Lake*	8	1910-1917
International Falls	Koochiching	Rainy	11	1907-1917
Birchdale (near)	Koochiching	Rainy	2	1933-1934
Manitou Rapids	Koochiching	Rainy	6	1934-1939
Winton (near)	St. Louis	Basswood	7	1933-1939
Winton (near)	St. Louis	Kawishiwi	28	1905-1907, 1912-1919, 1923-1939
Ely (near)	St. Louis	Burntside Lake*	3	1933-1935
Tower (below Lake Vermilion)	St. Louis	Vermilion	14	1911-1917, 1933-1939
Little Fork	Koochiching	Little Fork	16	1909-1917, 1933-1939
Big Falls	Koochiching	Big Fork	11	1909-1912, 1933-1939
Laurel	Koochiching	Big Fork	1	1939
Loman	Koochiching	Black River	1	1909

(Continued)

DISCHARGE RECORDING STATIONS IN MINNESOTA BY RIVER BASINS--Continued
PERIOD OF RECORD THROUGH 1939

Station	County	River	Years Duration	Years Of Record
LAKE SUPERIOR BASIN				
Beaver Bay (near)	Lake	Baptism	12	1928-1939
International Bridge	Cook	Pigeon	19	1921-1939
Lutsen	Cook	Poplar	12	1928-1939
UPPER MISSISSIPPI BASIN				
Lake Itasca (Mississippi R.)	Clearwater	Lake Itasca*	7	1933-1939
Libby (above Sandy River)	Aitkin	Mississippi	26	1895-1915, 1925-1928, 1929
Libby (below Sandy River)	Aitkin	Mississippi	10	1930-1939
Aitkin	Aitkin	Mississippi	3	1929-1931
Fort Ripley (near)	Crow Wing	Mississippi	3	1909-1910, 1929
Royalton (near)	Morrison	Mississippi	16	1924-1939
Sartell	Benton	Mississippi	1	1929
Sauk Rapids (near)	Benton	Mississippi	4	1903-1906
Elk River	Sherburne	Mississippi	25	1915-1939
Anoka	Anoka	Mississippi	9	1905-1913
Anoka (near)	Anoka	Mississippi	9	1931-1939
St. Paul	Ramsey	Mississippi	53	1887-1939
Federal Dam	Cass	Leech Lake	1	1929
Grand Rapids	Itasca	Prairie	1	1909
Palisade	Aitkin	Willow	1	1929
Pine River (below reservoir)	Cass	Pine River	23	1895-1916, 1929
Nimrod	Wadena	Crow Wing	15	1910-1914, 1930-1939
Motley	Morrison	Crow Wing	8	1909, 1913-1917, 1930-1931
Pillager	Cass	Crow Wing	6	1903, 1909-1913
Dorset (near)	Hubbard	Little Sand Lake*	10	1930-1939
Gull Lake (reservoir)	Cass	Gull	1	1929
Motley (near)	Morrison	Long Prairie	11	1909-1917, 1930-1931
Fort Ripley (near)	Crow Wing	Nokaysippi	1	1929
Royalton	Morrison	Platte	8	1929-1936
St. Cloud (near)	Stearns	Sauk	16	1909-1913, 1929-1939
St. Francis River (above)	Sherburne	Elk	1	1929
Big Lake (near)	Sherburne	Elk	16	1911-1917, 1931-1939
Rockford (near)	Wright	Crow	2	1909-1910
Rockford	Wright	Crow	20	1909-1917, 1929-1939
Dayton	Anoka	Crow	1	1906
Rockford (near) (South Fork)	Wright	Crow	4	1909-1912
Wealthwood (head of Rum River)	Aitkin	Mille Lacs Lake*	7	1933-1939
Onamia	Mille Lacs	Rum	4	1909-1912
Cambridge	Isanti	Rum	6	1909-1914
St. Francis	Anoka	Rum	1	1903
St. Francis (near)	Anoka	Rum	11	1929-1939
Anoka (near)	Anoka	Rum	3	1905-1916, 1909
Swan River (near)	Itasca	Swan	1	1929
Sandy Lake (below)	St. Louis	Sandy	24	1893-1916
LOWER MISSISSIPPI BASIN				
Prescott (Wisconsin)2/	Pierce	Mississippi	12	1928-1939
Winona	Winona	Mississippi	12	1928-1939
La Crosse (Wisconsin)2/	La Crosse	Mississippi	11	1929-1939
Welch	Goodhue	Cannon	16	1909-1914, 1930-1939
Zumbro Falls	Wabasha	Zumbro	20	1909-1917, 1929-1939
Thielman	Wabasha	Zumbro	4	1936-1939
Zumbro Falls	Wabasha	S. Branch Zumbro	7	1911-1917
Houston (near, below S. Fork)	Houston	Root	2	1938-1939
Houston (near)	Houston	Root	20	1909-1917, 1929-1939
Hokah	Houston	Root	1	1939
Lanesboro	Fillmore	N. Root	8	1910-1917
Lanesboro	Fillmore	S. Root	1	1939
Beaver	Winona	Whitewater	4	1936-1939
Elba (near)	Winona	N. Whitewater	1	1939
Altura (near)	Winona	Whitewater	1	1939
Beaver	Winona	Beaver Creek	1	1939
Winona	Winona	Gilmore Creek	1	1939
ST. CROIX BASIN				
Swiss (Wisconsin)	Burnett	St. Croix	20	1914-1933
Grantsburg (near) (Wisconsin)2/	Burnett	St. Croix	17	1923-1939
Rush City (near)	Chisago	St. Croix	17	1923-1939
St. Croix Falls (near) (Wis.)2/	Polk	St. Croix	30	1910-1939
Sandstone (near)	Pine	Kettle	10	1908-1917
Mora	Kanabec	Snake	5	1909-1913
Pine City (near)	Pine	Snake	5	1913-1917
DES MOINES - SKUNK RIVERS BASIN				
Jackson (near)	Jackson	Des Moines	10	1930-1932
Jackson	Jackson	Des Moines	5	1909-1913
Heron Lake	Jackson	Heron Lake Outlet*	10	1930-1939
Ceylon (Des Moines R.)	Martin	Tuttle Lake*	10	1930-1939
IOWA - CEDAR RIVERS BASIN				
Austin	Mower	Cedar	6	1909-1914

* Station located on lake.
1/ Selected North Dakota stations on main stem and one Manotoba station.
2/ Selected Wisconsin stations on main stem.

Seasonal Run-off

Total run-off during the year is of little importance to most human activities, as compared with the seasonal regimen. This follows more or less the seasonal distribution of rainfall, although, as was learned in the discussion of the hydrologic cycle, no simple relationship exists between the two. Figure -, which shows the graphs of daily flow of a number of rivers in Minnesota, illustrates the markedly seasonal run-off. The need for storage to equalize stream flow is especially evident in figures -b and -d. Figure -c indicates a distribution of flow that is erratic, ranging from flashy flood peaks to extremely low stages. Great fluctuations depreciate stream value for water power production and other uses. Distinctly seasonal distributions appear in figures -a, -e, and -f, but here there are more equalized flows throughout the year, caused by the greater ground-water flow from a thicker and more porous glacial moraine and greater surface-water storage in lakes.

Ground Water

Next to soil, ground water is most important to the success of agriculture, for it has a direct relation to the value and use of farm land. In times of drought, the flow of surface streams depends upon subsurface water supplies. Virtually the entire population of Minnesota, except in the larger cities, depends on ground water for domestic use and water for stock. In 1940 about 93 percent of the public water supply systems in the State derived from ground- water sources.

Since availability of ground water is closely connected with the geologic structure of the State frequent reference should be made in the ensuing discussion to maps showing the geologic foundations and surface geology of Minnesota (Figures - and -). Brief general description of various geologic formations are given in figure -.

Table - summarizes for general consideration the geologic relationships of underground waters in Minnesota. The various formations can be broadly divided into (a) loose unconsolidated surface deposits, chiefly glacial drift, which cover almost the entire State to various depths; (b) "soft rocks", many of which are water-bearing and which range from Cretaceous to Cambrian in age; and (c) "hard rocks" of pre-Cambrian age which contain little water. Figure - shows the areas where hard and soft rocks occur.

Soft Rocks

In broad outline, the area of "soft rocks" comprises the southern third of Minnesota. The division includes 45 counties extending from the northern boundary of Big Stone, Swift, Kandiyohi, Meeker, Wright, Anoka, and Washington Counties to the Iowa line. Outside the cities of St. Paul and Minneapolis, about 95 percent of the public water supply and practically all the agricultural supply is derived from underground waters.1/

1/ Status of information on ground waters in North Dakota, South Dakota and Minnesota, Report of Sub-committee on Underground Waters of the Upper Mississippi Drainage Basin Committee "A", National Resources Planning Board, p. 29, March 1940.

GEOLOGIC-WATER RELATIONSHIPS

Formation	Feet Thickness	Formation Description	Yield	Quality
SURFICIAL				
Pleistocene (drift)	to 600	Till, sand, gravel	Variable	Variable
BED ROCK-SOFT				
Cretaceous	to 500	Shale, sandstone	Variable	Some hard, some soft alkali
Devonian	to 300	Limestone, shale	Variable	Hard
Ordovician				
(Maquoketa)	75 - 300	Shale, dolomite	None	--------
(Galena, Decorah, Platteville, etc.)	200-510	Dolomite, limestone	Variable	Hard
(St. Peter)	to 500	Sandstone	Large	Medium hard
(Prairie du Chien)	to 700	Dolomite, sandstone	Large	Hard
Includes Oneota, New Richmond, and Shakopee				
Cambrian				
(Jordan)	to 200	Sandstone	Large	Medium hard
(St. Lawrence)	100-350	Dolomite, silty	Small	Hard
(Franconia)	70-150	Sandstone, fine, dol.	Moderate	Medium hard
(Dresbach)	30-200	Sandstone, white	Large	Medium hard
(Mt. Simon)	to 1000	Sandstone	Very large	Soft to hard
Age unknown				
(Red Clastics)	to 2250	Sandstone, shale, red	Small	Salty
BED ROCK-HARD				
Huronian	to 7000	Quartzite, slate, etc.	Small	Soft
Igneous and metamorphic	- - - -	Granite, gneiss, etc.	Very small	Soft

Adapted from geologic section of Illinois, Iowa, Minnesota, and Wisconsin showing water bearing quality of formations, compiled by F. T. Thwaites in Unpublished Report on Ground Water Resources of Mississippi Basin in Illinois, Iowa, Minnesota and Wisconsin, of the National Resources Board, 1934.

The "soft rock" area may be divided into eastern and western sections on the basis of underlying geologic formations. In the eastern part, or the area roughly extending from the Mississippi River to a line running approximately north and south through Mankato, the surface deposits are underlaid with sedimentary bedrock - sandstone, limestone, dolomites, and shales. All of these hold more or less water near their outcrop, but at depths of more than a few hundred feet, shales, limestones, and dolomites are not important water producers.1/ Coarser grained sandstones yield

1/ Thwaites, F. T., Unpublished report on ground water resources of Mississippi Basin in Illinois, Iowa, Minnesota, and Wisconsin, National Resources Board, p. 7, 1934.

some water as far down as they have been penetrated by drill. In the western division, surface deposits are generally underlaid with granites, quartzites, sandstones, limestones, and shales, but there are extensive areas in which granite is present at relatively shallow depths and covered with thick, residual clays. The clays (Cretaceous shales in figure -) which are derived from granite are relatively impervious to ground water and in areas where they are present, ground water in appreciable quantity is present only in surface deposits. In parts of the area sandstone formations yield adequate supplies of water, while in other parts the yield is small.2/

2/ Idem, p. 31.

Minneapolis - St. Paul Area - The general structure of rocks of the Twin City Metropolitan Area is like a very flat basin or saucer shaped depression slightly elongated in a northeast-southwest direction - artesian basin (Figure -). The average dip of beds at the sides of the basin appears to be about 20 feet per mile, while the strata at the bottom are decidedly flat. Exposure of formations on the sides, at the surface, or beneath the glacial drift permits water to seep into porous sandstone and find its way toward the basin center where it is estimated it supplies over six hundred artesian wells in the Metropolitan Area. Artesian wells may be flowing or non-flowing, depending upon pressure and upon depth of the well above the saturated strata. The Minnesota Geological Survey reports that the majority of artesian wells do not flow in the Minneapolis - St. Paul area.

Both cities obtain their public supplies from the Mississippi River, although in St. Paul the river water may at times be augmented by a small amount of ground water. During recent years many concerns have resorted to use of ground water for industrial purposes and for air conditioning, and the present rate of increase in number or wells for such purposes affords reason for grave concern over the future of the supply. The estimated aggregate consumption by industries, most of it drawn from the Jordan sandstone, is about 47 million gallons daily on a year-round basis, with summer consumption estimated as averaging about 56 million gallons daily.1/

1/ Op. cit., National Resources Planning Board, 1940, p. 32.

This unusually heavy draft on the Jordan sandstone has resulted in a lowering of the water level at a rate estimated in 1937 to be at least one foot per year.2/

2/ Fifth report of the Minneapolis-St. Paul Sanitary District for the year 1937, Appendix C.

With an increasing demand for water for air conditioning, the annual draft may increase even more within the next few years. Professor G. M. Schwartz of the Minnesota Geological Survey regards the demands now being made on Jordan sandstone waters as very heavy in view of the relatively restricted area of exposure in which water may enter to supply the basin (approximately 400 square miles).

Hard Rocks

The "hard rocks" section roughly includes the northern two-thirds of Minnesota. The portion which extends to the eastward from the western boundaries of Koochiching, Itasca, Crow Wing, Benton, and Sherburne Counties and a line drawn through Cass and

Morrison Counties is for the most part underlaid with crystalline rocks of igneous origin and by highly metamorphosed sediments in which water in appreciable quantity is rarely present.1/ Water is commonly obtained from the overlying glacial drift

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1/ Op. cit., National Resources Planning Board, 1940, p. 32.

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or from surface-water supplies. The western division, which embraces about the northwestern one-third of the State, is underlaid with sandstones, clays, and crystalline rocks to depths ranging to several hundred feet. In a report by the National Resources Planning Board conditions were summarized as follows, "In general the yield of water from these deposits is adequate for agricultural supplies but much of that present in the Red River Valley is of very poor quality. In this division as in the southwestern subdivision, underlying rocks are extensively covered with thick residual clays which are relatively impervious to water. In such areas ground water is present only in surface deposits."2/

2/ Op. cit., National Resources Planning Board, 1940, p. 32.

Surficial Deposits

Geologic foundation rocks almost everywhere lie under a heavy mantle of glacial drift deposited either directly by glacial ice (till) or by waters released by melting (sand, gravel, and clay). A relatively thin layer of fine textured material (loess) was laid down by wind in extreme southwestern Minnesota and in a rather broad belt in southeastern Minnesota (Figure -). Surficial deposits vary widely in water bearing capacity. In general, glacial drift furnishes abundant water wherever it contains porous gravel and sandy lenses below the water table and relatively little where it is clayey. Fortunately, sand and gravel deposits are prevalent in many localities, particularly in regions of firm rocks where the glacial drift is stony. Sandy and gravelly outwash deposits are very important sources of water supply, especially in pre-glacial valleys. Where the glacial drift is thin or composed mainly of clay, penetration into underlying rock usually is necessary to obtain sufficient supplies of water. The same necessity prevails in areas of loessial deposits, although if they are underlaid with impervious till they may contain water during humid seasons. Silts and clays laid down in glacial lakes contain considerable water, but pores are so small that the water yield is too slow to make good wells.

In the Red River Valley, water is obtained from shallow wells in the beach and delta deposits of glacial Lake Agassiz, from drill wells in the lacustrine clays and silts, and less commonly from tubular and artesian wells in the drift and sedimentary bedrock. A water geologist of the National Resources Planning Board described the shortcomings of such water supplies: "The shallow sand and gravel waters are usually good though scanty, the waters of clayey deposits 'alkaline', and the deeper artesians saline. The shallow waters have been greatly depleted by drought and artesians by waste. 1/

1/ Simpson, H. E., The ground water resources of the United States, p. 5, 1934 (manuscript report in file of National Resources Board).

Conservation

Although ground water is even more important than surface water over much of Minnesota, its conservation heretofore has largely been neglected. Unnecessary depletion and contamination needs to be stopped, and wherever practicable, principles of equitable appropriation and beneficial use should be applied. The best utilization of ground water requires certain basic data not now available. The National Resources Planning Board, in its report 2/ of March 1940, recommends that

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2/ Op. cit., National Resources Planning Board, 1940, pp. 4-5.

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a program of research be undertaken in the State to include:

1. Study of the St. Paul-Minneapolis metropolitan area to determine the safe yield of the water-bearing formations which would include a study of the consumption of ground water, precipitation, permeability of aquifers, intake facilities, chemical quality, pollution, and feasibility of utilizing uncontaminated waste water for additional purposes or for ground-water recharge.

2. Observation, for State as a whole, of fluctuations of water levels and artesian pressures and a study of the effect of land drainage, different methods of cropping, and regulation of lake levels on ground waters.

3. Study in the northwest area of Minnesota of the economic feasibility of further development of surface water supplies to supplement or replace present unsatisfactory ground water supplies.

4. Investigation to ascertain the effect of improper well construction on leakage and pollution with recommendations for minimum specifications of well construction.

Depletion of underground waters is a complex problem. It is affected by such factors as farming methods, artificial drainage, deforestation, and climatic change. Some hydrologists estimate that Minnesota's water table has declined 10 to 20 feet in the past twenty to thirty years (Figure -). Examining these estimates, the National Resources Planning Board points out that they do not rest upon accurate periodic observations and that considering the great variability in fluctuations of the water table and artesian head found in some other parts of the United States, it is unwise to draw any conclusions as to whether there is any definite trend in ground water levels.1/

1/ Op. cit., National Resources Planning Board, 1940, pp. 33-34.

There is rather widespread popular belief that ground water supplies in Minnesota are seriously endangered by certain developments of recent years. Among the menaces cited are the cultivation of lands that formerly supported growths of grass or timber, the drainage of swamp lands, and wasteful use of underground supplies. Some geologists and engineers have shared in this alarm, others have not. The water table it is agreed, will be permanently lowered if infiltration has been decreased or transpiration or evaporation increased through changes in type or amount of vegetative cover. The effect of these changes upon the ground water supply will remain a moot question until further study is made of the intricate relations involved in the hydrologic cycle. The Report of the Mississippi Valley Committe holds that in the border zone (which includes western Minnesota) between the semi-arid and humid regions, the change from grass to crop appears to have reduced infiltration and increased transpiration to such an extent as to diminish the supply of water available to maintain the water table.1/

1/ Report of the Mississippi Valley Committee of the Public Works Administration, p. 117, 1934.

The belief that the present low water table is a temporary condition, due to a cyclical reduction in rainfall, finds some substantiation in recent records of water table fluctuations in drought areas of the Mississippi Valley. They show, for instance, that the water table made a marked recovery in 1935, after the drought of 1934, and that although part of the recovery was subsequently lost (1936) the water levels in observation wells in at least parts of the region were higher on September 1, 1936, than they were in September 1934.2/ This viewpoint perhaps should be

2/ Data in unpublished records in files of U. S. Geological Survey, Washington, D. C.

qualified as to Minnesota, where widespread artificial drainage may have permanently disturbed the natural balance. That some relation exists between precipitation totals and the fluctuations in ground water levels there can be no doubt, expecially when a deficiency in precipitation continues over a long period. There is, however, essentially no basic information in regard to the nature of fluctuations of the water table in Minnesota or the factors that produce them.

In certain non-drought areas the water table has been seriously lowered and artesian pressures in underground reservoirs reduced by heavy withdrawals of ground water for municipal and commercial uses. In parts of southeastern Minnesota it seems quite evident that the draft on water-bearing beds exceeds their natural capacity to yield water without eventual depletion. The only apparent way to prevent permanent overdraft is to reduce the pumpage from aquifers by supplementing or replacing sub-surface sources.

Recession of lake levels in recent years within and surrounding the Minneapolis-St. Paul metropolitan area, including those of such bodies of water as Bald Eagle and White Bear Lake in Ramsey County and Lake Minnetonka in Hennepin County and possibly even the Chisago chain of lakes in Chisago county, was very likely due in part at least to overdrafts upon underground supplies of the artesian basin. The gradual lowering of artesian levels, in itself a sufficient cause for concern, has been particularly disturbing in recent years in view of the limited surface water at times available in rivers during periods of peak demand.

Many experiments are being conducted throughout the county to find whether it is possible to increase the supply of ground water in storage by: (1) Control and increase of direct infiltration from rainfall by methods involved in the processes of soil conservation such as contour plowing and fall plowing. (2) Constructing check dams to hold flood water for a time and give it an opportunity to sink underground. (3) Spreading flood water on selected areas where conditions are favorable for rapid infiltration. (4) Introduction of flood water into wells, marshes, peat bogs, and lakes.

Quality Of Water

The purest natural form of water is rain. As soon as it falls on the earth, however, it begins to accumulate impurities. Any increase in the volume of impurities as a result of human activities is known as pollution. Fortunately, impurities in limited amount do not usually render water harmful for domestic or industrial use, nor are they even unpleasant to the taste. Water which is suitable for drinking (potable waters) may not be satisfactory for domestic uses, or for manufacturing and steam generation. Information about the quality of water supplies is of utmost importance to the location of many industrial plants and to individual homeseekers. Chief impurities in water are:

Calcium And Magnesium

Water containing over 60 parts per million of calcium and magnesium sulphates and carbonates classifies as hard. If it has more than 120 parts per million it is inferior for domestic use and unsatisfactory for most manufacturing purposes. Hard water requires more soap to produce a lather and deposits of mineral salts form when it is heated or evaporated. In areas of high calcium and magnesium content, artificial softening is needed, as well as special steam boiler equipment to prevent boiler scale. Figure - shows the geographic distribution of ground water according to hardness. Of the 403 communities for which analyses for hardness are available, 360 have surface or ground water supplies with 120 parts per million or over (includes treated water supplies) and 306 have supplies with an excess of 200 parts per million. Surface waters of Minnesota, except in the northern and northeastern sections, generally contain more than 120 parts per million.

Iron And Manganese

In numerous places in Minnesota both iron and mangenese are dissolved in water in sufficient quantity to be objectionable. Three-tenths of one part of either per million may affect the taste and even stain the porcelain of plumbing fixtures. A great many Minnesota cities and villages have water supplies carrying excessive quantities of iron. Of 365 cities and villages for which analyses for iron are available, the public water supply in 217 cases carries more than five-tenths of one part per million and in 153 cases more than one part per million. Figure - shows the reported analyses of iron content in public water supplies in Minnesota.

Of 230 cities and villages for which analyses for manganese are available, 23 have water supplies with more than five-tenths of one part per million, or enough to cause accumulation in water pipes. Excessive manganese in water is exceedingly troublesome in laundry work and is particularly deleterious in manufacturing operations which involve a pulping process.

Suspended Matter

All rivers contain varying amounts of organic or inorganic suspended matter, since the primary geological functions of rivers are erosion and transportation of sediment. Underground waters usually contain a higher ratio of soluble to suspended matter than surface waters. Public supplies served to customers are generally free from noticable suspended matter (also called turbidity).

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WATER USE AND CONTINGENT PROBLEMS

"Men and Nature must work hand in hand. The throwing out of balance of the resources of nature throws out of balance also the lives of men"
Franklin D. Roosevelt

Floods

Floods occur ordinarily when water derived from run-off and underground sources spreads beyond the constraining banks of stream channels. A flood may therefore be defined as relatively large amounts of water temporarily out of place. The usual cause of a flood is rapid and excessive run-off from heavy precipitation. Other causes of floods, primary or contributory, may be dam failures, ice or timber obstructions, and gales along the shores of large bodies of water. In a river, the first few feet of rise above flood stage occasions little damage to life or property. It is when the volume of flow greatly exceeds the carrying capacity of a stream bed, that a flood becomes a rampaging agent of destruction.

Minnesota, as a headwater state, does not often experience floods of disastrous proportions. The problem is nevertheless an essential element in the States program of water control, for losses from stream overflow are frequent and, in the aggregate, important. Much of the damage, moreover, is economically preventable. Records of flood damage are too fragmentary to permit full and accurate analysis, and losses about which nothing is ever said or recorded aggregates many thousands of dollars annually. Data which indicate areas and extent of flooding cannot be obtained in sufficiently comprehensive form either, to allow an exact picture of conditions.

Damage from floods appears to be on the increase, due to the progressive weakening of natural reservoirs which level out the run-off peak. Forests have been cut, swamp lands drained, grasslands cultivated, soil absorbency decreased. Worse still, silt from eroded land has accumulated in river beds to make excess flow increasingly unmanageable. Man is largely to blame for this and he persists for economic reasons in living in areas, such as on the flood plains of rivers, which are particularly subject to floods.

Floods in Minnesota may be classified under two general types: (1) those caused by excessive run-off resulting from a combination of frozen ground that prevents sink in, heavy rainfall and/or melting of large accumulations of snow (snow retarded in melting by a heavy forest cover is often carried off by April rains and thereby contributes materially to flood flows), and usually occurring in early spring (last of March and in April); and (2) those caused by excessive rainfall occurring coincident with the late spring and early summer rainfall maximum (last of May and in June). Heavy rains of the cloudburst type, however, may cause considerable flood damage in limited areas at any time during the summer.

Floods in early spring constitute normal natural events in rivers which flow through fairly well defined valleys. If climatic conditions do not favor extremes in run-off, or if ice jams do not form in the rivers, those floods are usually not destructive and may even be helpful, promoting as they do the storage of water in natural and artificial reservoirs for use later in the season. The following brief accounts of damaging spring floods for recent years are excerpts from "Climatological Data", a monthly publication of the U. S. Weather Bureau.

1939 Floods occurred in tributary streams below Hastings Dam. Lowlands in southeastern counties were inundated with damage estimated at $25,000. At Anoka the Rum River overflowed its banks causing some damage.

1938 During April, heavy rains caused flood damage at Brainerd and vicinity estimated at $27,000. Damages in Aitkin County were placed at $12,100 and in vicinity of Hastings and Jordan at $157,135. April and May rains caused a number of streams in north central and southeastern counties to overflow their banks. Crop losses confined principally to meadows and lowlands amounted to $55,000. Major damage was to highways along the rivers or those crossing lowlands and is placed at $1,000,000.

1937 Rapid melting of snows in southeastern Minnesota caused minor flood damage in Houston County. Flood damage in April to tangible property in extreme southwestern counties was estimated at $30,000.

1936 Rapid melting of a deep snow layer in southern Minnesota resulted in a number of rivers and creeks overflowing their banks. Vast areas of lowlands were inundated with damage estimated at $39,100. Melting snows in April caused considerable additional flood damage at Ada and vicinity.

1934 In April considerable damage from floods occurred in extreme southeastern counties bordering on the Mississippi River.

Generally more serious in Minnesota, because crops by then are subject to damage, are the late spring or summer floods which follow heavy and recurring downpours. In nearly every case of this kind damage occurs either in the more narrow and steep-sided valleys or in exceptionally flat valleys where a comparatively small rise of the river results in the inundation of surrounding areas. Floods of the steep-sided valley type, known as "gully washers," are typical in tributaries of the Mississippi in southeastern Minnesota. The more extensive shallow-valley type occurs at times in watersheds of the Red River and the Minnesota and along the upper Mississippi where it drains expanses of glacial outwash or glacial lake beds. The following brief accounts of damaging late spring or summer floods for recent years are also excerpts from "Climatological Data", monthly publication of the U. S. Weather Bureau.

1937 Excessive rains at Chaska in May caused flood damage estimated at $145,000. Flood damage in June was estimated at $19,000 in extreme south central counties. Damages from floods caused mostly by heavy rains in July, resulted in a loss estimated at over $2,000,000 in Lake of the Woods, Pennington, Roseau, Beltrami, Marshall, Red Lake, and Clearwater Counties.

1936 Heavy rains in May caused small flood damage near Aitkin.

1935 Heavy thunderstorms in May in the vicinity of Bird Island and Belle Plaine caused flood damage estimated at $33,500. During August unusually heavy rains occurring in the vicinity of Le Sueur, Owatonna, southern Big Stone County, and southern Stearns County caused flood damages to property and growing crops estimated at $228,500.

1934 Heavy rainfalls in September occasioned a rapid rise in rivers with some overflowing their banks. Flood damage in September estimated at over $12,740.

1933 During May excessive rainfall accompanied a severe wind and hail storm at Princeton, Mille Lacs County which flooded basements and low places and caused some washouts. Unusually heavy rains in September in the extreme southwestern counties caused several small rivers to overflow their banks. The flood damage principally in Rock, Nobles, Pipestone, and Murray Counties was estimated at $116,000, mostly to tangible property.

Data given above show that damaging floods occur almost every year. To indicate flood frequencies of various magnitude, histograms of flood frequencies for the Mississippi, Minnesota, Red, Red Lake and St. Croix Rivers were graphed (Figure -) from flood records in a recent Water Supply Paper.1/ In analyzing and

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1/ Jarvis, C. S., and others, Floods in the United States; U. S. Geol. Survey Water Supply Paper 771, 1936.

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interpreting flood records for this report the U. S. Geological Survey decided that the daily (average) flood peaks above some selected base afforded the most practicable and useful basis of recording flood data.2/ The base discharge, or the lower limit for selection of flood discharges, ordinarily comprised the minimum annual flood.3/ Where the minimum annual flood proved unsatisfactory for a base discharge, all annual floods (maximum) for the period of record based on both the calendar year and the record year (October to September) were recorded.

2/ Flood data may be collected on the basis either of maximum daily average discharge or of momentary peak discharge for each flood rise, but in practice the former is generally used, because of its uniform availability. Ordinarily, the item of record is the average discharge for a 24-hour period, generally taken as a calendar day, midnight to midnight.

3/ Annual flood is the maximum daily average flow occurring during 12 consecutive months. The year extends from October 1 to September 30.

Flood analysis requires the study of all the records available on the particular stream in question. If no scientific data are available, the mistake should not be made of using the discharge history of a neighboring drainage course as an absolute guide. Each river presents its own problems, and the treatment accorded a nearby stream or system may or may not be applicable. Physical conditions affecting floods in any watershed are precipitation characteristics, run-off features, topography, river orientation, drainage basin shape, soil and rock conditions, depression storage, vegetation, and physiography. The primary determinant, however, is the intensity, duration, and extent of flood producing rains. Figures -, -, -, -, -, -, -, and - show some of the water control factors for the various drainage basins in Minnesota. Figure - shows the areas of most serious local floods. The map indicates location only, not the extent of the areas affected.

The only serious flood problem along the Mississippi above St. Paul exists near Aitkin where channel capacity is insufficient to carry maximum flow. The area damaged may range from 2,500 acres at a 10-foot flood stage to 30,000 acres if the flood reaches the highest stage of 17 feet. Such flooding occurs about once in three years. Plans for flood correction at this point as devised by the Engineer Corps, United States Army, require an estimated expenditure of $1,000,000 which is not considered economically justifiable.1/ The reforestation program of the State Division of Forestry

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1/ Unpublished reports concerning drainage basins within Minnesota or Minnesota region, National Resources Committee, 1936. Manuscript on file at Minnesota Resources Commission.

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in Aitkin County has as one objective the reduction of flood flows by retarding surface run-off in the vicinity.

Tributary streams of the Mississippi below St. Paul, being rather flashy in character due to steep slopes, narrow valleys, and scarcity of natural or artificial storage, inflict periodic flood damage to crop lands, urban property, railways and highways. The ratio of length to width of the areas damaged by floods in this locality makes flood correction by levee and channel straightening very expensive. It may be possible at some future time to establish an economically sound system of flood control through storage, as part of a multi-purpose flow correction program.

The frequency of damaging floods in the Minnesota River Valley is slightly more than one in three years. As far back as 1909, the Federal Government and the State made surveys and investigations for control of floods and improvement of navigation on the Minnesota by construction of a dam at the foot of Lac Qui Parle Lake. Three great floods in 1919 spurred public interest and a comprehensive flood control plan was devised, but efforts to carry out the project under State laws failed. The same plans, somewhat modified in the light of knowledge gained during the drouth years, were used in construction of the present project under the Works Progress Administration.

The plan of operation involves diversion of the Chippewa and Lac Qui Parle Rivers, in combination with a system of water conservation and flood control in the Marsh Lake and Lac Qui Parle reservoirs. All land needed for the project (about 23,000 acres costing the State approximately $700,000) have been acquired, and all the hydraulic structures, such as dams, control weirs, diversion channels, and dikes are built, but because several smaller essential units have never been completed, the vast project remains inoperative. Until funds can be made available to complete these units, particularly the raising of the Great Northern Railway tracks where they cross the pool west of Appleton, the project cannot operate, and the money already invested will fail to produce the beneficial results originally in view.1/

1/ For additional data concerning the Lac Qui Parle Project the reader is referred to the Status Report on the Lac Qui Parle Flood Control Project, Division of Drainage and Waters, Minnesota Department of Conservation, March 1, 1940.

Diversion works have been completed on the Whetstone River. Originally this stream emptied into Big Stone Lake, but long ago it was diverted to join the Minnesota just below the Lake. Flash floods in the new course made it necessary to turn the stream back into its old channel. As the State allotted no money to buy flowage rights on Big Stone Lake or on the Minnesota River below the Lake the entire project is now virtually ineffective. Conflicting interests of farmers, resort owners, and recreation interests along lakes and rivers must here be compromised with the water interests of the valley below, if the project is to accomplish its original purpose of flood correction through regulated storage.

The Lake Traverse-Bois de Sioux flood control and water conservation project now under construction by the Corps of Engineers, U. S. Army, will effectively reduce most flood stages along the Bois de Sioux and alleviate flood conditions on the Red River below Fargo. In 1892, a Minneapolis Swedish newspaper first suggested construction of a dam on Lake Traverse to store and control spring floods. Not until 1941, almost a half century later, was the White Rock dam, a main unit of the Tri-State project, finally built across the valley in the area originally suggested by the newspaper. It is estimated the reservoir created by White Rock dam and control structure which extends 14,400 feet will cover 23,000 acres of land. Other units of the project are the Reservation dam and control at the north end of Lake Traverse proper, the Browns Valley levee, and the Bois de Sioux River channel improvement. Now under consideration by the War Department is a proposal to divert the excess waters of the Little Minnesota River, normally emptying into Big Stone Lake, to the Lake Traverse reservoir.

A Red Lake River improvement project has long been urged by local interests and by the Division of Drainage and Waters of the Minnesota Department of Conservation. An appreciable part of the cost of regulating stream flow would be offset by the benefits of flood alleviation. The project was approved for investigation and report in the Federal Flood Control Act of 1939. A report by the Corps of Engineers, U. S. Army, is now under preparation.

A proposed Roseau flood control project, also investigated under the 1938 act, was not approved on the ground that the cost would exceed the benefits to be derived. The Division of Drainage and Waters is preparing to appeal from these findings and to request that the project be referred back to the Corps of Engineers for further study.1/

1/ Report of the Commissioner of the Department of Conservation: Statistical report for biennium ending June 30, 1940, p. 39, December 1940.

Existing flood control works are widely scattered throughout the various basins in Minnesota. They vary greatly in nature and in the degree of protection given (Figure -, -, -, -, -, -, -, and -). In most instances protective works are the result of coordinated plans covering an entire river basin. In early years, however, there was a good deal of hap-hazard development, with little regard for a unified system of control and use of water. Floods may always be controlled, but the benefits derivable do not always justify the cost.

Floods may be controlled through retarding or storage basins, diversion channels, stream channel improvements, and by the construction of levees and embankments. Measures to retard surface run-off are also important. The logical and proper method of control is to limit the quantity of water reaching the stream to the discharge capacity of its channel. This is accomplished by means of natural retardation or storage basins. The most effective protection is generally secured not through any single method, but by a combination of several.

WATER SUPPLY AND SANITATION

The Supply*

Hygienic living requires an abundant supply of good, clean water. "To be satisfactory for drinking, culinary, and other purposes", the Division of Sanitation of the Minnesota Department of Health asserts, "water should be incapable of causing discomfort or disease, and should be clear, free or practically free from odor or color, pleasant to the taste, and devoid of toxic salts or an excessive amount of dissolved mineral substances".1/

1/ Small water supplies and sewerage systems, Minnesota Department of Health, Division of Sanitation, 1938.

Because water may become a vector in transmission of typhus and other waterborne disease, maintenance of safe water supplies has for a great many years claimed the attention of public health authorities. In 1908, a typhoid epidemic involving a public water supply, was responsible for 511 cases and 35 deaths, and it is estimated that this epidemic alone cost the community in which it occurred about $350,000.2/

2/ Report of the Committee on Public Health to the Minnesota State Planning Board, November 1934.

* The statistical data on public water supplies in Minnesota were compiled in 1940 and related to the population conditions of 1930 since the census of population of 1940 had not been completed. Current conditions are insufficiently different to warrant the expenditures required to re-compile and re-illustrate this information.

Figure - shows the decline in typhoid fever rate in Minnesota. Supervision of water supplies was largely responsible for the dramatic decrease in typhoid fever up to 1915. Since then only a few minor outbreaks have been traceable to contaminated water. Unsafe water is still in use, however, especially in smaller municipalities, in institutions, and on farms, although Minnesota ranks above the average State in this regard.

Figures -, -, -, -, -, -, -, and -, indicate the source of supply for all incorporated municipalities having water-works, and the manner of treatment as of January 1940. Table - recapitulates this information with respect to percentage of population served by public water supplies. Table - shows the relation of source and treatment of water supplies to size of community. It should be noted that all population figures given are from the U. S. Census Reports on Population for 1930.

Approximately three-fifths of the total population of Minnesota is served by community water systems, according to data obtained from the Division of Sanitation of the State Department of Health. There are 444 water-works, serving 452 communities with central supply and distribution facilities. Private utility companies own only 12 of the 444 water-works and supply less than 2 percent of the population served. Two of the water-works are jointly owned, private companies supplying the water under contract through community-owned systems.

Systems depending upon ground water as a source of supply number 413 and those depending upon surface supplies from lakes and streams only 27. Four others use both surface and ground water. Municipalities depending upon ground water number 413 while surface supplies from lakes and streams serve 35. The latter include the largest cities and contain about 60 percent of the population of all of Minnesota's municipalities, or 36 percent of the entire population of the State. In addition there are four communities with a total population of 8,469 depending both on surface and ground waters.

PUBLIC WATER SUPPLIES IN MINNESOTA, JANUARY 1940[1]

Classification	Incorporated Municipalities		Incorporated Municipalities Having Public Water Supplies				Incorporated Municipalities Not Having Public Water Supplies			
	Number	Population	Number	Percent of Total Number	Population	Percent of Total Population	Number	Percent of Total Number	Population	Percent of Total Population
Urban										
Cities over 100,000	3	837,425	3	100	837,425	100	-	-	-	-
Cities of 20,000 to 100,000	3	62,471	3	100	62,471	100	-	-	-	-
Cities of 10,000 to 20,000	8	97,109	8	100	97,109	100	-	-	-	-
Cities of 5,000 to 10,000	18	123,500	18	100	123,500	100	-	-	-	-
Cities and towns of 2,500 to 5,000	41	137,111	41	100	137,111	100	-	-	-	-
Rural										
Places of 1,000 to 2,500	93	135,139	90	96.77	130,604	96.64	3	3.23	4,535	3.36
Places of 500 to 1,000	143	99,466	135	94.41	94.611	95.12	8	5.59	4,855	4.88
Places under 500	419	105,742	148	35.32	47,288	44.72	271	64.68	58,454	55.28
Total all incorporated municipalities	728	1,597,963	446	61.26	1,530,119	95.75	282	38.74	67,844	4.25

1 Does not include six unincorporated municipalities which have public water supplies.
Source: Compiled from data obtained from Division of Sanitation, Minnesota Department of Health.
Note: Population statistics are from the Census of Population, 1930.

SOURCE AND TREATMENT OF COMMUNITY WATER SUPPLIES IN MINNESOTA, JANUARY 1940[1]

Source	Urban					Rural			Total
	Cities Over 100,000	Cities of 20,000 to 100,000	Cities of 10,000 to 20,000	Cities of 5,000 to 10,000	Cities and Towns of 2,500 to 5,000	Places of 1,000 to 2,500	Places of 500 to 1,000	Places Under 500	
Municipalities Having Wells									
Treatment									
Number	-	-	5	4	5	11	5	4	34
Population	-	-	62,057	29,733	16,996	19,399	3,530	1,552	133,267
No Treatment									
Number	-	2	3	6	26	69	118	138	362
Population	-	41,471	35,052	41,074	86,017	95,576	82,270	43,829	425,389
Municipalities Having Surface Water Supplies									
Treatment									
Number	3	1	-	7	7	3	7	3	31
Population	837,425	21,000	-	45,520	25,618	5,127	5,627	1,044	941,361
No Treatment									
Number	-	-	-	-	-	1	1	1	3
Population	-	-	-	-	-	1,801	514	214	2,529
Municipalities Having Springs or Infiltration									
Treatment									
Number	-	-	-	-	1	-	1	-	2
Population	-	-	-	-	2,552	-	618	-	3,170
No Treatment									
Number	-	-	-	-	-	4	2	1	7
Population	-	-	-	-	-	6,160	1,296	291	7,747
Municipalities Having Both Wells and Springs									
Treatment									
Number	-	-	-	-	-	-	-	-	-
Population	-	-	-	-	-	-	-	-	-
No Treatment									
Number	-	-	-	1	-	-	1	1	3
Population	-	-	-	7,173	-	-	756	358	8,287
Municipalities Having Surface Water and Wells									
Treatment									
Number	-	-	-	-	2	1	-	-	3
Population	-	-	-	-	5,928	1,386	-	-	7,314
No Treatment									
Number	-	-	-	-	-	-	-	-	-
Population	-	-	-	-	-	-	-	-	-
Municipalities Having Wells not Treated and Surface Water Treated									
Number	-	-	-	-	-	1	-	-	1
Population	-	-	-	-	-	1,155	-	-	1,155
Municipalities Not Having Public Water Supply Systems									
Number	-	-	-	-	-	3	8	271	282
Population	-	-	-	-	-	4,535	4,855	58,454	67,844
All Incorporated Municipalities									
Number	3	3	8	18	41	93	143	419	728
Population	837,425	62,471	97,109	123,500	137,111	135,139	99,466	105,742	1,597,963

1 Does not include six unincorporated municipalities which have public water supplies. Five depend on ground water supplies and one on surface water.

Note: Population statistics are from the Census of Population; 1930.

Source: Compiled from data obtained from Division of Sanitation, Minnesota Department of Health.

Table - reveals further that the water used by 71 percent of the 1,530,119 people living in incorporated municipalities with public and private water systems is treated for protection of health or improvement of quality, or both. Figure - shows the percent of the municipal population living in incorporated communities of various size classifications having public water supplies and the percent having treated water supplies. Chlorination is practiced at only 44 plants of the 444 now in operation. Filtration facilities exist in 39 plants, but none are of the slow sand type.

According to table -, three of the 93 incorporated municipalities with a population greater than one thousand have no central water supplies, while of the 143 towns with populations between five hundred and one thousand, 135, or nearly 95 percent, are served with central water supplies. Of the 419 communities below five hundred, 148, or about 35 percent, have central water supplies. Study of figure - reveals an apparent need for additional treatment plants.

It is estimated that in rural and outlying urban districts of Minnesota there are about 200,000 private water supply systems. The water in nearly all these cases is obtained from underground sources, generally free from contamination. Certain principles of location, construction, and operation must be adhered to, however, in order to prevent pollution or contamination.

Investigation of water supplies by the State Department of Health in cooperation with local officials is constantly reducing the number of unsatisfactory installations and improving their operation. About half of the 452 cities and villages, in January 1940, had supplies that met the rigid standards of the State Department of Health. Since the water in most of the large municipalities in the State meets these demands, satisfactory water supplies are now available to more than 80 percent of the residents of cities and villages and to the large number of people who travel about and visit them.1/

1/ Op. cit., Minnesota State Planning Board, p. 50.

Sewage Disposal[1]

Essential though water is to life of all kinds, it can also be the agent of death and disease. If polluted by dirt, filth, sewage or industrial waste and subsequently untreated, it is dangerous for drinking and even for bathing. Not only does water pollution endanger public health; it also lowers real estate values, with consequent reduction in tax revenues. St. Paul and Minneapolis alone suffered about $2,000,000 in reduced property values from this cause before the Twin City sewage disposal plant was installed. Furthermore, pollution may ruin present and potential recreational areas, kill fish and water fowl, and destroy natural beauty, thus driving the well-to-do farther and farther into primitive areas in search of playgrounds, while at the same time depriving poorer families of access to safe and adequate water recreation facilities. Minnesota's recreation loss through pollution runs into hundreds of thousands of dollars.

Figures -, -, -, -, -, -, -, and - reveal the location of municipalities served with sewage treatment plants as of January 1940. It will be noted that several maps show municipalities with plants under construction. Figure - illustrates the growth of municipal sewage treatment in Minnesota. Especially noteworthy is the increase in sewage disposal during recent years.

Figure - shows the percent of population living in municipalities which have sanitary sewers and sewage treatment plants. The population statistics used here

[1] The statistical data on sewage disposal in Minnesota were compiled in 1940 and related to the population conditions of 1930 since the census of population of 1940 had not been completed. Current conditions are insufficiently different to warrant the expenditures required to re-compile and re-illustrate this information.

are also from the U. S. Census Reports on Population for 1930. Practically all of the municipalities in Minnesota with a population of 1,000 or more have comprehensive sewer systems, as have many of even the smaller towns. In sewage treatment, municipalities with a population from 5,000 to 10,000 have not kept pace with the smaller communities in the 1,000-5,000 class. This condition can probably be ascribed to the location of larger municipalities on main inland streams where year-around water is available for dilution; moreover, disposal systems in the larger communities date back to a time when little thought was given to sewage treatment.

Of the 728 incorporated municipalities in the State only 200 have any sort of sewage treatment (January 1940).1/ Approximately 80 percent of the total population in the 728 communities, however, is serviced by these treatment plants (Table -). There are also 28 institutional sewage treatment systems. Of the 200 municipal treatment plants, 108 have been installed since 1927, when more intensive investigation of stream and lake pollution problems began. During the same period, major improvements were made on 14 other plants. In 1939, 41 of the 108 municipal sewage treatment plants were constructed or the beginnings made on their erection, and plans and specifications were approved by the State Board of Health on 9 other plants. Especially significant are the improvements of the last few years because they include sewage treatment for some of the largest municipalities in the State, including Minneapolis, St. Paul, and Duluth.

1/ Total includes municipalities with sewage treatment plants under construction.

INCORPORATED PLACES IN MINNESOTA HAVING SANITARY SEWERS AND SEWAGE TREATMENT PLANTS BY POPULATION GROUPS

Classification	Incorporated Municipalities		Having Sanitary Sewers			Without Sanitary Sewers			Treating Sewage			
	No.	Population	No.	Population	Percent of Total Population	No.	Population	Percent of Total Population	No.	Population	Percent of Total Population	Percent of Population Having Sanitary Sewers
Urban												
Cities over 100,000	3	837,425	3	837,425	100.00	-	-	-	3	837,425	100.00	100.00
Cities of 20,000 to 100,000	3	62,471	3	62,471	100.00	-	-	-	3	62,471	100.00	100.00
Cities of 10,000 to 20,000	8	97,109	8	97,109	100.00	-	-	-	6	70,304	72.40	72.40
Cities of 5,000 to 10,000	18	123,500	18	123,500	100.00	-	-	-	10	70,151	56.80	56.80
Cities and Towns, 2,500 to 5,000	41	137,111	39	129,057	94.13	2	8,054	5.87	30	97,375	71.02	75.45
Rural												
Places of 1,000 to 2,500	93	135,139	88	127,951	94.68	5	7,188	5.32	59	84,904	62.83	66.36
Places of 500 to 1,000	143	99,466	101	73,709	74.13	42	25,727	25.87	66	48,688	48.95	66.03
Places under 500	419	105,742	46	16,258	15.38	373	89,484	84.62	23	8,437	7.98	51.89
Total	728	1,597,963	306	1,467,510	91.84	422	130,453	8.16	200	1,279,755	80.09	87.21

Note: Includes municipalities with sewage treatment plants under construction as of January 1, 1940.
Source: Compiled from Reports of Minnesota Department of Health, Division of Sanitation.

Pollution

Pollution of lakes and streams may occur from either natural or artificial causes. Natural pollution may result from objectionable organic or inorganic material washed in by run-off from forest and agricultural lands. Artificial pollution is the result mainly of sewage from cities and villages, chemical solutions and waste from industrial plants or mines, and filthy surface drainage from densely settled land. Wells and underground waters may be polluted by cesspools and barnyards, and unprotected well openings and springs tainted by surface wash and by cattle. Some industrial wastes are from 10 to 100 times stronger than domestic sewage in their ability to deplete oxygen in a lake or stream.1/

1/ Whittaker, H. A., Lake and stream pollution, The Conservation Volunteer, vol. 1, no. 5, pp. 29-32, February 1941.

Fortunately, water will purify itself if not polluted beyond the capacity of free oxygen in the water to oxidize wastes and change them into harmless compounds. There is a limit, however, to the amount of filth that can be naturally disposed of even by a large and swift stream. Furthermore, it is possible so to contaminate waters as to render the most elaborate processes of water treatment ineffective. Obviously, therefore, definite restrictions must be imposed to safeguard the public against defilement of water. Involved in this are such matters as the ascertainment of the source, quantity and quality of sewage and wastes, determination of the damage done to lakes and streams, equitable distribution of abatement costs among beneficiaries, regulation of stream flow, and adoption of protective legislation.

The menace of pollution became really alarming in the recent drouth years, when reduced stream flow literally converted some rivers into open sewers. In the Red River Valley, the problem began years before the intensified drouth conditions of the 1930's. Throughout the subnormal rainfall period of the 1920's, the general decrease