PHYSICAL DATA FOR LAND-USE PLANNING

CASS COUNTY, NORTH DAKOTA AND CLAY COUNTY, MINNESOTA

AN INVENTORY OF MINERAL, SOIL, AND WATER RESOURCES

By B. Michael Arndt and Stephen R. Moran

NORTH DAKOTA GEOLOGICAL SURVEY
REPORT OF INVESTIGATION 54

A compilation of available data on the surficial materials, mineral resources, and groundwater resources of Cass County, North Dakota and Clay County, Minnesota. Interpretive data regarding suitability of surface materials for general construction and three types of waste disposal facility are included.

This report was prepared by the North Dakota Geological Survey in cooperation with the Minnesota Geological Survey for the Fargo-Moorhead Metropolitan Council of Governments.

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This report on Physical Data for Planning is one of the items in the Council's 1973-74 Work Program and is designed to inventory and analyze the Soil and Water Resources in Cass and Clay Counties.

The report was prepared under the Council's sponsorship by Mr. B. M. Arndt and Dr. S. R. Moran of the North Dakota Geological Survey in Grand Forks, ND. The Council wishes to extend its appreciation and thanks for the excellent job these gentlemen have done in preparing this report.

The Fargo-Moorhead Metropolitan
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Moorhead, MN 56560

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The Area

Cass County is located in extreme eastern North Dakota and Clay County in northwestern Minnesota (map 1) about 140 miles south of the international border and 225 miles northwest of Minneapolis-St. Paul. The two counties have a combined area of 2825 sq. miles. In maximum dimension Cass County is 42 miles north-south by 44 miles east-west and Clay County about 30 miles east-west by 36 miles north-south. The Red River of the North, which separates the two counties, is the main stream in the region. Its principal tributaries in the two-county area include the Wild Rice, Sheyenne, and Maple Rivers in North Dakota and South Branch Wild Rice and Buffalo Rivers in Minnesota (map 1).

The eastern and western parts of the two-county area are rolling uplands that range in elevation from 1200 to 1500 feet. In the central part of the two-county area the land is a flat plain, the Red River Valley. This plain rises steadily to the east and west from an elevation of about 870 feet where the Red River leaves Cass County to about 1100 feet. This plain is 40 or 50 miles across.

Fargo and Moorhead are the only urban areas within the two-county area. Their combined population of 82,600 constitutes 69 percent of the total population of the two counties, 120,500. Other towns include West Fargo, Tower City, and Harwood in Cass County and Hawley, Glyndon, and Barnesville in Clay County.

The Report

This report has been prepared at the request of the director of the Fargo-Moorhead Metropolitan Council of Governments to serve as a physical data base for general land-use planning. The available information on land, mineral, and water resources in the two-county area has been synthesized to provide a readily available information source to aid in the decision-making process. Most of the basic data presented here has been derived from existing sources of information, but we have made some modifications as a result of our own field work. Because of the reconnaissance nature of most of the information available, this report is intended to serve only a general advisory function. The broad patterns of material distribution presented here are intended to serve as guidelines for generalized planning. More detailed work to refine boundaries and subdivide units will be required for detailed land-use decisions. The maps presented here are designed to be used only at the published scale. If they are enlarged, a false sense of accuracy will result.

The report contains two sections: "Basic Data" and "Interpretive Data for Planning." The first section contains a discussion of the materials that make up the surface of the two-county area, as well as the mineral resources, groundwater resources, potential for groundwater pollution, and agricultural resources of the entire area. A discussion of flood hazard in the Fargo-Moorhead urban area is also included in this first section. The second section is derived from the first section. It outlines the suitability of each of the earth materials in the area for general construction and for three types of waste disposal projects.

Topographic maps at a scale of 1:24,000 (1 inch to 2000 feet) and a contour interval of 5 or 10 feet are available for nearly all the area except for some areas in southeastern Clay County. Maps with a scale of 1:62,500 (1 inch to about 1 mile) and a contour interval of 10 to 20 feet are available in this area. These maps are available from the United States Geological Survey. Their use with this report is essential to evaluate the information contained here. Detailed soil maps of most of the area are available in the district offices of the Soil Conservation Service. These maps will be helpful in aiding the user who is concerned with detailed planning decisions in small areas. Wherever possible, the use of this report should be augmented by consultation with geologists, soil scientists, hydrologists, and engineers who are familiar with the properties of earth materials of the two-county area.

Use of Physical Data in Planning

Two types of land-use decisions are dealt with by decision makers. One is finding the optimum location for a given project or finding the optimum use for a single parcel of land; this has long been of concern to governments, companies, and individuals. The second involves the overall pattern of land use; only recently has this become of concern to governmental agencies. This second type of land-use decision is commonly categorized as "land-use planning."

As our population grows and land becomes scarce, people are more and more recognizing the interdependence of all the components of the total land-use picture. The use of an individual plat of land for a specific purpose influences all other land-use and planning decisions. If a parcel of land is used for a shopping center, for example, it cannot be used for another purpose; this seems self-evident, yet the implications of this fact have just recently been recognized. In many urban areas throughout the United States, including Bismarck, Minneapolis, and St. Paul, urban expansion has covered high-quality concrete aggregate, making it permanently unavailable. In some areas severe shortages of concrete aggregate have resulted, or costs have risen steeply because of the long haulage distance for alternative resources. This example shows that a single land-use decision by a small number of improperly informed individuals has resulted in a widespread impact on their community. Recognition of the interrelation of land uses has led to a concern for the development of information and procedures necessary to formulate land-use plans.

The key element in both types of land-use decisions is the information that is available to the decision maker. If the amount, kind, or quality of the information available is inadequate, he will be unable to make the appropriate judgments.

The information provided in this report is designed to serve as a basis for initial decisions on optimum land use. The information provided here will be combined with the other information and included in the ultimate plan. The physical environment limits the options presented by land availability, distance of travel, and other social, political, and economic aspects that have traditionally been part of the planning process.

BASIC DATA

Materials

The surface materials of Cass and Clay Counties have been separated into ten map units on the basis of their physical characteristics. The distribution of these ten material units is shown on map 2. The Cass County part of map 2 is a synthesis of geological maps by Klausing (1969) and Bluemle (in preparation), soil maps by Knobel, and others (1924), the North Dakota State Agricultural Experiment Station, (1963); and Omodt, and others (1966), and our own mapping of the central part of the Red River Valley. The Clay County part of the map is based largely on the soil maps by Nikiforoff, and others (1939) and Arneman, and others (1969). Units have been delineated on the basis of lithology without regard to origin or history.

Characteristics of Map Units

Unit 1—Till

Extensive areas of till in western Cass and eastern Clay Counties are mapped as unit 1. Till is a mixture of approximately equal parts of clay, silt, and sand that contains scattered pebbles, cobbles, and boulders. The upper few feet may be quite soft in some places, but within a few feet of the surface the till is hard and dense. The till generally has low permeability, but in places where it is excessively drained and dry much of the time, cracks increase its permeability.

The topography of unit 1 is generally flat (slope angles less than 3%) or undulating (slope angles range from 3% to 6%). In a few areas the topography is rolling (6% to 9% slopes) or hilly (slopes greater than 9%). The steeper slopes occur mostly on valley sides. Numerous small depressions that are less than ¼ mile across occur throughout the landscape where this unit is mapped. These depressions, which contain small temporary ponds, sloughs, and are floored by clay, have not been separated on the map because of their small size.

In most areas the till extends downward, essentially unchanged, for several tens of feet. In some places, sand, gravel, or clay underlie the till at shallow depths. There are no known large areas where these other materials occur within 5 feet of the surface.

Unit 2—Till and Boulders

This unit occurs in small areas in southeastern Clay County and on steep slopes along the South Branch Wild Rice River and Buffalo River. This unit consists of till that is covered with a surface veneer of large boulders. Except for the presence of the boulders the unit is the same as unit 1. Slopes are everywhere rolling or hilly (greater than 6%).

Unit 3—Clay and Silt

This map unit is the most extensive in the two-county area. It underlies the central part of the Red River Valley in eastern Cass County and western Clay County. The unit consists of clay in the central part of the Red River Valley and becomes siltier toward the edges. Silt also occurs along the major rivers (map 1). The isolated areas of the unit in western Cass County and eastern Clay County are generally silt, but clay is present in some places. Thin, flat, or slightly undulating bedding is commonly present in this unit. The clay and silt are soft, and water is commonly encountered within a few feet of the ground surface. The unit is characterized by very low permeability.

Topographically, unit 3 is flat to very gently undulating (slopes less than 3%), except where adjacent to some large streams short slopes exceed 10%.

Throughout most of its extent, this unit is very thick (approaching 100 feet in the Fargo-Moorhead area) and uniform in composition. Along the eastern and western edges of the Red River Valley and in the isolated occurrences of the unit east and west of the Red River Valley, till occurs within 10 feet of the surface. Sand may occur in places within 10 feet of the surface along the Maple, Buffalo, and South Branch Wild Rice Rivers.

Unit4—Clay and Silt over Sand

Unit 4 occurs in the central part of the Red River Valley as narrow linear belts overlying a network of buried river channels. The clay and silt that make up the upper part of the unit is the same as in unit 3. In places, especially between Moorhead and Glyndon, the upper part of unit 4 contains fine sand. Fine-grained to medium-grained sand underlies the clay and silt at depths ranging from 5 to 20 feet.

Generally, the topography of this unit is flat or very gently undulating. The surface is nearly everywhere slightly elevated above the surrounding areas.

Unit 5—Clay and Silt over Till

This unit occurs in a few small areas in west-central Cass County. It consists of a surface layer of clay and silt that is underlain by till within 5 feet of the surface. In some places, a layer of sand a few inches thick occurs at the interface between the clay and silt and the till. Both the clay and silt and till have low permeability, but the horizontal permeability of the intervening sand layer is high.

The topography of unit 5 is flat to gently undulating (slopes less than 3%).

Unit 6—Sand

Unit 6 is widespread throughout both counties. It consists of sand and gravelly sand that ranges in thickness from 5 feet to more than 50 feet. The unit includes material that ranges from fine-grained, well sorted sand to gravelly, coarse-grained sand. For this reason, its characteristics are variable. The permeability is high. Compressive strength is generally high. The water table is low beneath elevated areas and very near the surface in low areas.

The topography of unit 6 is highly varied. Slopes range from flat to greater than 10% on the edges of ridges, dunes, and along river banks. The sand occurs as flat to gently sloping areas, as narrow steep-sided ridges, and as sinuous, generally flat to locally hilly areas along rivers.

Unit 7—Sand over Clay and Silt

This unit occurs in a small area in northern Cass County. It consists of a layer of sand that overlies clay within 5 feet of the land surface. The surface of the unit is flat to undulating, with slopes less than 3%. The low permeability silt and clay within 5 feet of the surface makes unit 7 different from unit 6. The resulting change in permeability causes groundwater to be perched at the top of the clay and silt. The base of the sand is generally saturated.

Unit 8—Sand over Till

Unit 8 occurs in western Cass and eastern Clay Counties. Till occurs within 5 feet of the surface throughout most of the unit, but in some places the sand is more than 5 feet thick, and in other places the till occurs at the surface. Gravel and, in some places, boulders occur in the lower part of the sand. Like the previous unit, sand over clay and silt, the lower part of the sand is commonly saturated because of the decrease in permeability.

Unit 9—Gravel

This unit occurs in western Cass and eastern Clay Counties as narrow ridges and in southeastern Clay County as an area of irregular hilly terrain. The unit ranges from coarse gravel to gravelly sand. Slopes are generally rolling to hilly (greater than 6%). Permeability of the unit is very high, except in some places where till occurs at shallow depths or as inclusions within the unit. Till inclusions are most common in the hilly terrain of southeastern Clay County.

Unit 10—Peat

This unit occurs in depressional areas throughout eastern Clay County. It consists of organic sediment ranging from organic muck to peat. The material is wet, spongy, and has very low strength.

Mineral Resources

Gravel is the principal mineral resource in Cass and Clay Counties. Gravel occurs in unit 9 and in small, isolated areas in units 1, 2, and 6 that are less than ¼ mile across and are therefore too small to be shown on map 2. A large buried gravel deposit occurs as a north-south trending linear body, which ranges from 0.25 to 0.5 mile wide, about halfway between Moorhead and Glyndon. This deposit underlies part of unit 4.

Gravel for road surfacing is available throughout both counties, but it is more abundant in Clay County. Gravel for concrete aggregate is largely confined to Clay County. The abundance of shale pebbles in much of the gravel in Cass County makes it unsuitable for high-quality concrete aggregate.

Peat deposits of commercial quality may occur in Clay County. But the amount of peat is small even if quality were good enough to warrant use.

Groundwater Resources

Characteristics of Map Units

The known groundwater resources of Cass and Clay Counties are shown on map 3. Four map units are differentiated on the basis of the amount of water available, probability of finding water within the area designated, and the degree of certainty that the water supply will continue to produce at the desired rate once it has been developed. Information on aquifer characteristics, yields, and water quality has been obtained from Klausing (1968), Dennis and others (1949), and Maclay and others (1969).

Type I Aquifers

Type I aquifers, which are shown in dark green on map 3, consist of aquifers that are capable of producing large quantities of water and have a high probability of continuing to produce water for a long period of time regardless of climatic conditions. These aquifers possess a high degree of continuity, and wells drilled in them should produce water. The Page Aquifer, Hillsboro Aquifer, Sheyenne Delta Aquifer, West Fargo Aquifer, Moorhead Aquifer, and Fargo Aquifer are type I aquifers.

Page Aquifer.—The Page Aquifer is a buried sand and gravel deposit, the top of which is 10 to 80 feet below the land surface. It is located in northwestern Cass County. Water in this aquifer is very hard and contains much calcium bicarbonate. Total dissolved solids range between 270 and 850 parts per million (ppm), and the iron content averages 1.7 ppm.

At present the principal use of the Page Aquifer is as the municipal supply for the town of Page and for domestic wells in the surrounding area.

This aquifer has the greatest potential for development in Cass County (Klausing, 1968). Estimated storage of this aquifer is about 900,000 acre feet of water, and it has been estimated that properly spaced wells should be able to maintain pumping rates of 200 gallons per minute (gpm) for extended periods.

Hillsboro Aquifer.—The Hillsboro Aquifer is a coarse sand deposit that occurs at the surface and extends to 50 or 100 feet below the surface. It extends north from Cass into Traill County. In a few places gravel occurs in the lower part of the aquifer. Water quality changes with depth. Calcium bicarbonate is common near the surface. Calcium sulfate, sodium sulfate, or sodium bicarbonate are encountered at greater depths. Total dissolved solids range from 100 to 3120 ppm. The water is very hard and has a generally high iron content.

The aquifer is used only for farm and domestic wells. A properly developed well may yield as much as 500 gpm, adequate for municipal or industrial uses (Jensen and Klausing, 1971).

Sheyenne Delta Aquifer.—The Sheyenne Delta Aquifer is a surface aquifer that consists of two sand bodies separated by about 20 feet of silt. It is located in southern Cass County and extends into northern Richland County. In Cass County this aquifer is as much as 100 feet thick. Water from this aquifer contains abundant calcium and magnesium bicarbonate and is very hard. Total dissolved solids content is commonly more than 500 ppm. This water also has a high iron content, ranging between 0.3 and 7.2 ppm.

No large-scale development of this aquifer has been attempted. Small amounts of water are withdrawn by domestic and stock wells. The storage capacity of this aquifer has been estimated to be about 409,000 acre feet with potential well yields of 250 to 400 gpm. Because of the great extent and thickness of water-bearing sand, this aquifer is second only to the Page Aquifer for potential development (Klausing, 1968).

West Fargo Aquifer.—The West Fargo Aquifer is a buried sand and gravel deposit that contains some interbedded silt and clay. It ranges in thickness from 0 to 140 feet. The depth to the top of the aquifer ranges from 60 to 260 feet. It contains sodium chloride or sodium bicarbonate and is hard to very hard. Total dissolved solids range from 377 to 1562 ppm and average iron content is 0.57 ppm (Klausing, 1968).

The West Fargo Aquifer has been used primarily for industrial and municipal needs near South West Fargo. Consumption in 1965 was about 470 million gallons of water. Estimated storage of this aquifer is about 972,000 acre feet. Further development of this aquifer is possible. However, this aquifer is being slowly dewatered, so future production wells should be located to cause minimum drawdown.

Moorhead Aquifer.—The Moorhead Aquifer is a partly buried sand and gravel aquifer that, in places, is as much as 120 feet thick. Where it is buried, it is overlain by a few feet of silt and clay. Water from this aquifer contains calcium bicarbonate or calcium sulfate. It is very hard. Total dissolved solids concentration exceeds 500 ppm, and the iron content is greater than 0.5 ppm.

Prior to 1962, water from this aquifer was used to supply the city of Moorhead, but it is now only used for this purpose during periods of low flow in the Red River, which is the primary source for Moorhead's water. The water supply for the towns of Sabin and Glyndon and for some individual domestic and agricultural water users is from this aquifer. Capacity of this aquifer is sufficient for large-scale development. Individual wells may yield as much as 350 gpm under sustained pumping.

Fargo Aquifer.—The Fargo Aquifer is a buried sand and gravel aquifer that ranges in thickness from 0 to about 160 feet. The top of the aquifer is about 130 feet below the land surface. Water from this source is hard and contains much sodium bicarbonate. Measured concentration of total dissolved solids ranges between 750 and 1129 ppm. Iron concentration is about 0.4 ppm.

Storage in the aquifer has been estimated at about 86,000 acre-feet, and wells with yields of as much as 1000 gpm could be developed. However, such excessive pumping rates will result in considerable drawdown. Prior to 1956, water from this aquifer was used to supplement Fargo's municipal supply. Only the Cass-Clay Creamery uses it now. This aquifer has a high potential for future development both for domestic and industrial uses.

Type II Aquifers

Type II aquifers, which are shown in light green on map 3, consist of aquifers that will produce moderate amounts of water, are sensitive to short-term climatically controlled water-level fluctuations, or are uncertain water supplies because of internal variation or local absence. The Kragnes Aquifer, Ridges Aquifer, and Bantel Aquifer are type II aquifers.

Kragnes Aquifer.—The Kragnes Aquifer is a vaguely defined buried sand and gravel deposit that appears to be about 30 feet thick (Maclay and others, 1969). It is overlain by about 200 feet of till and clay. Water from this aquifer contains sodium bicarbonate and is hard. Total dissolved solids concentration generally exceeds 500 ppm. Iron content is generally above 0.5 ppm in the Moorhead area.

Presently, this aquifer supplies some industrial, domestic, and stock needs. The aquifer, in some places, has been pumped at a rate of 500 gpm. In order to evaluate its potential for future large-scale development, more subsurface investigation will be required.

Ridges Aquifer.—The Ridges Aquifer is made up of the Maple Ridge, Fargo Ridge, West Fargo Ridge, Sheyenne Ridge, and other unnamed related ridges. It is a series of buried channel deposits that contain sand and silt as much as 60 feet thick. Overlying this aquifer is as much as 20 feet of clay. No information on water quality from this aquifer system is available.

There has been no large-scale development of the Ridges Aquifer. Use has been limited to individual domestic and farm production.

The only pumping information from this aquifer is from relief wells used to partially dewater it during construction of railroad underpasses for I-94 and I-29. Water was produced at a rate of 70 gpm for an extended period of time.

Bantel Aquifer.—The Bantel Aquifer is a buried sand and gravel aquifer overlain by 5 to 40 feet of till. Water in this aquifer contains sodium sulfate and is very hard. Total dissolved solids concentration is about 1350 ppm with an iron content of about 0.36 ppm.

Present use of the Bantel Aquifer is limited to domestic and stock wells. The limited extent and thickness of this aquifer makes large-scale development unlikely (Klausing, 1968).

Type III Aquifers

Type III aquifers, which are shown in yellow on map 3, consist of aquifers that are capable of producing small amounts of water or large amounts of water for only short periods of time. These aquifers are generally quite sensitive to climatically controlled water-level fluctuations of short duration. Water is available only in certain places within the areas mapped because the aquifer material is thin or discontinuous. This unit includes the Tower City Aquifer and undifferentiated surface sand and gravel.

Tower City Aquifer.—The Tower City Aquifer is a surface sand and gravel deposit that is as much as 22 feet thick. Water from this aquifer contains calcium bicarbonate. The water is hard and has a total dissolved solids concentration of about 500 ppm.

The primary use of this aquifer is as the municipal water supply for Tower City. It could also support a few additional farm and stock wells but not enough water is present to permit further large-scale development. The amount of water in storage in this aquifer seems to be closely related to precipitation, so an extended period of drought would reduce the amount of water this aquifer can produce.

Undifferentiated Surface Sand and Gravel Aquifers.—The permeable materials at the surface in Cass and Clay Counties are thick enough in some places so that shallow wells may be developed in them. Yields from these deposits are generally adequate only for individual domestic or farm use. Pumping rates range from less than 1 gpm to several tens of gpm. Water quality is variable, but the water generally is hard. The amount of water available from these aquifers is closely dependent on recharge from precipitation. As a result, wells in these materials often dry up during extended periods of drought. Wells in these materials are also extremely easily polluted, and care must be taken to assure that water supplies derived from these aquifers remains safe from contamination.

Dakota Aquifer

The deepest aquifer present in Cass and Clay Counties, the Dakota Aquifer, underlies the area shown by the diagonal line pattern on map 3. Depth to this aquifer ranges from 300 feet in eastern Cass County to 700 feet in the western part of the county. The aquifer material consists largely of interbedded silt, shale, sand, and sandstone. The water from this unit contains sodium sulfate and is very hard. Sodium chloride is also present in some places and the water varies from soft to very hard. Total dissolved solids have been measured between 2680 and 4060 ppm.

The high degree of mineralization of the water from this source has limited its use mostly to watering stock. Where other water has not been easily available, it has also been used for domestic purposes.

Where desalinization is economically feasible, this aquifer can supply adequate quantities of water for municipal and industrial uses. Individual wells can be pumped at rates of 100 gpm for extended periods.

Groundwater Pollution

In this section, the aquifers are grouped on the basis of their susceptibility to surface pollution. Four classes of groundwater pollution susceptibility are shown on map 4.

Areas in which little to no danger of groundwater pollution exists are unmarked. This area includes several aquifers that are shown on map 3 but that are so deeply buried that pollution, except by improperly cased wells, is considered improbable.

Areas that are not themselves considered to be aquifers, but because of their high permeability and topographic position serve as conduits by which groundwater is recharged, are shown in yellow. This unit includes all areas of sand and gravel shown on map 2 that are not included on map 3 as aquifers. Improper disposal of wastes in these areas may result in groundwater pollution that will not be recognized until some time in the future.

Areas in which aquifer material, shown in map 3, occurs near the land surface but is overlain by a few feet to a few tens of feet of low-permeability till, clay or silt, are shown in light orange on map 4. The Page, Bantel, Ridges, and Moorhead Aquifers are included in this unit. Any surface disposal of wastes in these areas may result in pollution of the groundwater resource. In some areas, where the local direction of groundwater flow is away from the aquifer, well managed waste-disposal facilities may be possible. However, improper disposal of waste will nearly everywhere result in pollution.

Areas in which aquifer material shown in map 3 occurs at the land surface are shown in red on map 4. This unit includes the Sheyenne Delta, Tower City, Hillsboro, Moorhead, and Undifferentiated Surface Sand and Gravel Aquifers. In these areas, surface disposal of waste should be attempted only if absolutely unavoidable and then with extreme caution. Extensive engineering procedures will be needed to minimize the degree and rate of groundwater pollution.

Agricultural Resources

The agricultural resources of Cass and Clay Counties are very important to the economic health and growth of the area. The suitability of the soils for raising crops in a given area must be taken into account in planning for the use of that land. Map 5 is a map of the agricultural suitability of soils in the two-county area. Five units of agricultural quality are shown: excellent to good, good to medium, medium to fair, fair to poor, and poor to unsuitable (Patterson and others, 1968). *The General Soil Map of Cass County* (North Dakota State Agricultural Experiment Station, 1963) and reconnaissance soil map of Clay County (Nikiforoff, and others, 1939) were used to construct this map. The agricultural quality rating of each unit is based on the following criteria.

> The quality ratings for cropland assume dryland (nonirrigated) farming and are based principally on the estimated production of small grains, primarily hard red spring wheat; the area rating is weighted average for the various soils in an

area. Average or typical soil and crop management practices are assumed in the cropland ratings. It is assumed that drainage has been improved by the installation of road ditches and major drainage ditches in large areas of soils with some excess water problem, such as the Red River Valley, but that small, poorly drained depressions have not been drained. It also is assumed that cultivation is not prohibited by stones, trees and shrubs, gullies, etc. (Patterson and others, 1968, p. 3.)

Geologic Hazards—Flooding

Geologic hazards include all natural phenomena that present, merely by their existence, a hazard to all of the activities of man. Their operation does not require any action by man, but rather it requires only his presence in a certain place at a certain time. In many cases, a man's activities augment the effect or trigger the occurrence of the phemonenon, but they do not cause it to happen. The only geologic hazard that is considered important in the two-county area is flooding.

Historically, flooding has been a recurring problem in Cass and Clay Counties. Flooding hazards are greatest near the major streams and are most acute during early spring. The flatness of the land combined with the spring melt almost assures annual flooding. How serious the flooding will be in any given year depends mostly on how much snow accumulated in the drainage basins over the winter months and how rapidly the melting takes place.

Although flooding by the major streams has long been a problem, and documentation of flood damage has been extensive, little readily available information on floodwater distribution can be obtained. The U.S. Army Corps of Engineers (1972) has prepared a map showing flood-prone areas in urban Fargo-Moorhead. This map is reproduced here as figure 1 and shows those areas in the two cities that would be inundated by a flood that could occur once every 500 years on the average. The probability of this flood occurring in any given year is thus 1 in 500.

From the information that is readily available, compilation of this type of map for the entire two-county area would be a major project and is beyond the scope of this report.

INTERPRETIVE DATA FOR PLANNING

This section contains a series of four maps that show the suitability of the various earth materials for specific uses. These maps are directed at four types of land use in which physical constraints are most likely to affect planning decisions. The first map, map 6, is concerned with suitability for general construction. The remaining three maps deal with methods of waste disposal: sanitary landfills (map 7), sewage lagoons (map 8), and septic tanks (map 9).

General Construction Conditions

Earth materials have physical characteristics that affect their suitability as foundation materials. Sand and gravel, for example, can be expected to provide a more stable foundation than clay. Much of the task of the foundation engineer is to determine the distribution, thickness, and physical characteristics of the material at the site of a proposed structure so that the most appropriate design can be used. This information is determined by collecting samples from soil borings and having a battery of tests run on them in the laboratory.

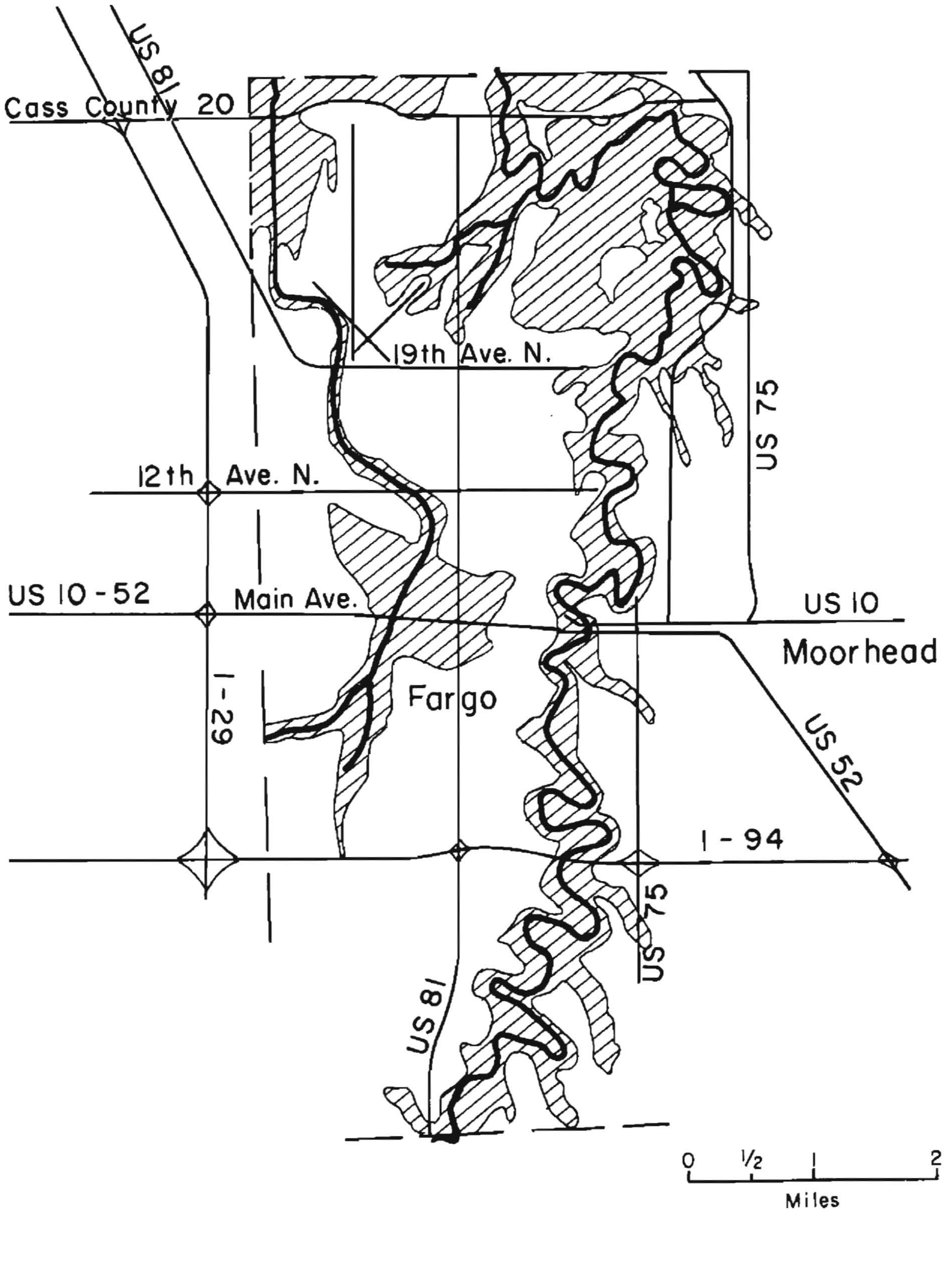


FIGURE 1. Map showing area in the Fargo-Moorhead urban area inundated by a flood having a recurrence interval of 500 years (U.S. Army Corps of Engineers, 1972).

The information presented on map 6 carries the planning process a step farther. Commonly, other criteria are the sole basis for selecting the site of a structure, but the physical properties of the materials should be included as one of the general criteria in initial site selection. The specific site selected must still be studied in detail to determine the most appropriate design; the preliminary information is not a substitute for a site evaluation.

There are two principal advantages of using this approach. By initially selecting a site in which minimal foundation problems are expected, a project may be completed at a lower cost. Difficult construction conditions, if recognized in preliminary studies, may be bypassed by a highway at considerably less total expense even though the final alignment may be slightly longer. The second advantage is that the foundation requirements of two competing types of land use may differ, and a more beneficial use can be attained by taking this fact into consideration in the location of the projects.

The earth materials in Cass and Clay Counties have been grouped into four categories on the basis of suitability for general construction (map 6). By general construction we refer to the type of construction characteristic of the area. Apartment and office buildings of two to four stories or the large agricultural or industrial metal buildings that are common throughout the two-county area constitute the "design building." Slopes, excavations, and fills of the magnitude that would be associated with interstate highway construction through the two counties are the type considered. Bearing capacity, shear strength, compactability, permeability, slope stability, water-table depth, and the existence of special conditions, such as abundant, large boulders or quick conditions are included in the definitions of the four categories. The degree of uniformity of the material, both laterally and vertically, is also taken into account.

Areas rated as good for most construction, shown in dark green on map 6, are underlain by sand and gravel. These areas are characterized by high-bearing capacity and low compressibility. Internal drainage is good because of the high permeability. Because of the high permeability, no problems associated with high water-table conditions should be expected, except in depressions.

Areas rated as good to moderate, shown in light green on map 6, are underlain by till. High-bearing capacity is characteristic of these areas. Although the permeability is generally quite low, problems associated with high water-table conditions should be minor because of the high position of most of this unit. The presence of scattered boulders on top of and throughout the till may cause some problems during excavation, compaction, and pile driving. In some places, clay stringers or sand and gravel lenses will be intersected by excavations and borings. Water entering excavations because of the corresponding change in permeability may require pumping. Piping of sand and ensuing slope failure may also result.

Areas of moderate suitability for construction include those of sand over till, clay over till, and sand over clay (yellow on map 6). More extensive boring programs to assess and design for existing conditions are required in these areas because of the variable thickness of the overlying layer. In most areas, the discontinuity between the sand and the underlying till or clay is expected to have a significant effect on internal drainage. The lower part of the sand is generally saturated. Where clay overlies till, a thin layer of sand or gravel commonly occurs on the contact. This layer will bring water into excavations. Dewatering and slope stability problems may be expected where this condition exists.

Areas rated as poor for general construction are underlain by silt and clay, silt and clay over sand, or peat (red on map 6). These areas have generally low-bearing strength, high water content, high liquid limit, and a high plasticity index. Permeability is very low and generally high water-table conditions can be expected. These areas are often flooded, particularly near the major streams and rivers (map 1).

Included in the poor category are the buried river channels of unit 4 (map 2). These areas pose particular problems because the water in the buried saturated sand is under considerable pressure in many areas. The result is that quick conditions are commonly encountered, especially in the western part of Fargo. Sewer-trench excavations in this area often have wall-stability problems. In 1955, a grain elevator constructed in one of these areas on the west side of Fargo collapsed and was a total loss (Nordlund and Deere, 1970). Excavation for a grade separation at the intersection of Interstate 94 and the Burlington Northern Railroad (NP) southwest of Fargo encountered quick conditions and pile driving problems (Bell, 1968).

Suitability for Sanitary Landfills

The sanitary-landfill method of disposal of solid waste consists of daily burial of refuse, either beneath the ground in the trench method or above the ground in the area or ramp method. The base of the landfill should be sufficiently impermeable that fluids moving down through the landfill will not seep out. Sufficient low-permeability cover material should be available to permit burial of all the refuse placed in the landfill. If possible, the base of the landfill should be above the water table, so that leachate generation and pollution of groundwater is minimized and equipment does not become bogged down. As much as is possible, the materials in which the landfill is located should be easy to excavate and compact in both wet and very cold weather.

Water that comes into contact with the decomposing wastes in a landfill becomes highly mineralized by leaching soluble constituents of the refuse. This leachate lowers the quality of the groundwater because of the increase in total dissolved solids. More importantly, trace amounts of heavy metals, pesticides, hydrocarbons, pathological organisms, and other toxins may also move with the leachate and cause very dangerous pollution of groundwater. Seepage of leachate out onto the ground surface is also undesirable because of the potential for surface-water pollution and because of the unpleasant odor of the leachate. For these reasons, minimization of leachate generation and retention of any leachate that is generated are important.

To prevent leachate generation the refuse must be kept as dry as possible. The best way to keep the refuse dry is to locate the landfill so that its base is well above the water table and to keep a well compacted, low-permeability cover over the refuse. The cover material should be of relatively low permeability and easily compactible. Till, silt, and clay are generally satisfactory as cover material. Some clay is not good cover material. Although it has very low permeability, it is difficult to compact and tends to swell when wet. Sand and gravel are not impermeable enough to be satisfactory cover material.

Leachate can be kept within a landfill by locating the landfill in material that has very low permeability. Clay, silt, and till generally have low enough permeability if the topography is not so steep that the groundwater flow gradient is large. Leachate can also be kept in the landfill by locating the landfill where the groundwater flow is toward the site. Because flow is always toward the site no leachate can escape. This type of site may be the best way to handle solid waste in regions where the water table is everywhere close to the surface.

On the accompanying map, map 7, the surficial materials are rated on the basis of their suitability for sanitary-landfill disposal sites as good, good to moderate, moderate, moderate to poor, and poor. These ratings are based on permeability of the material, depth to water table, availability to low-permeability cover material and ease of excavation and compaction under various climatic extremes. Susceptibility to frequent flooding is also considered.

The areas designated as good are largely underlain by till (dark green on map 7). Permeability of the material is quite low. The till provides a good impermeable base, and is also good cover material. Workability is generally not a problem. Except in depressions, the water table is usually low enough that it will not intersect the base of the landfill.

Good to moderate areas are underlain by till with extensive boulders lying on or near the surface or overlain by clay (light green on map 7). The bouldery surface may cause difficulty in excavation. Clay is particularly difficult to work with when it is frozen. The contact between clay and till will also provide an avenue for leachate escape.

Those areas underlain primarily by clay are rated as areas of moderate suitability (yellow on map 7). Permeability of clay is very low, so seepage of leachate is minimized. The clay is also a very good low-permeability cover material. However, the high water content of the clay causes problems with both excavation and compaction, particularly in the winter, when the clay is subject to freezing. The water table is generally quite near the surface in these materials, so the base of the landfill will be beneath water in most places. Problems of equipment bogging down during certain periods will also be encountered.

Areas of moderate to poor suitability are either underlain by sand over till or sand over clay (light orange on map 7). The sand is thick enough in some places to permit leakage of leachate and is not adequate cover material. The contact between the sand and the underlying material may act as a conduit for leachate removal as well.

The areas of poor suitability (red on map 7) are largely underlain by sand. The floodplain areas along the major streams in the two counties are also rated as poor. Sand is highly permeable and is also a poor cover material. Areas along rivers are generally underlain by silt or clay, and though these earth materials would be suitable, the danger of surface water pollution posed by flooding must be considered.

In evaluating a site for a sanitary landfill, map 4 (Potential for Groundwater Pollution), should be used with map 7 to assess the significance of potential seepage of leachate. Two sites in which potential seepage of leachate is considered a problem would have different degrees of suitability if the one was located in an area of little to no danger of groundwater pollution and the other in an area of high danger of such pollution.

Suitability for Sewage Lagoons

A sewage lagoon is a shallow pond or lake that is used to hold sewage so that bacterial decomposition may take place. These lagoons are generally not less than 2 feet or greater than 5 feet deep. In evaluating a site for a sewage lagoon (or any lagoon for disposal of liquid wastes), factors including permeability of the underlying material, water-table position, flooding susceptibility and presence of organic soils (such as peat) must be taken into account.

It is important that a lagoon be located in material having low permeability so that leakage from the lagoon is minimized. Where the water table is near the surface, the probability that leakage from the lagoon will emerge at the surface as springs and seeps is increased. A lagoon should not be located where frequent flooding occurs. During flooding a lagoon may be flushed and cause contamination of surface water. Materials that contain considerable organic matter may be a two-fold problem for a sewage lagoon located on them. These materials generally have relatively high permeability, and from that standpoint alone, are not suitable because of the resulting leakage. Secondly, the presence of organic matter may modify the desired biological action in the lagoon. Sewage lagoons should be located in relatively flat areas of low relief. Where surface relief is high, possible surface and groundwater drainage gradients may cause the lagoon to leak.

The surface materials in Cass and Clay Counties are classified on the basis of suitability for a sewage lagoon site on map 8. The units delineated are good, good to moderate, moderate to poor, and poor. The permeability of the materials is the principal property used to create this classification. The other considerations listed above were given lesser importance. For example, water-table position is not particularly significant because in those areas where it is high, the sediments are the least permeable.

The areas delineated as good on map 8 (dark green) are underlain by clay. Permeability is very low, and the surface is flat. The water table may be fairly high during some times of the year, although groundwater flow rates are extremely slow. Flooding may be a problem along river and stream valleys.

The areas defined as good to moderate (light green on map 8) are underlain mostly by till. In some places the till is overlain by clay or is covered with a relatively heavy concentration of boulders. The till itself is generally of relatively low permeability, but in some places sand and gravel lenses at shallow depths provide avenues for rapid leakage of sewage. Where clay is present over the till, commonly a path for leakage occurs at the contact of the two materials. Boulders overlying the till not only provide difficult working conditions, but if they are extensive enough, leakage may occur around them. It would be particularly difficult to build proper embankments around the lagoons on this surface.

The areas considered moderate to poor (light orange on map 8) are underlain by clay that overlies sand at shallow depths. In some places pore-water pressure in the sand is quite high. As a result, the strong upward component of groundwater flow will produce quick conditions during construction. In places where the pore-water pressure is not so high, seepage from the lagoon into the sand will cause groundwater pollution.

Those areas delineated as poor for sewage lagoon suitability include sand, gravel, and peat (red on map 8). Here, the permeability is so high that it would take extensive engineering to provide a suitable lagoon. The areas underlain by peat have additional limitations as noted above.

In evaluating a site for a lagoon disposal facility, map 4 (Potential for Groundwater Pollution), should be used with map 8 to assess the significance of potential leakage from the lagoon. Two sites in which potential leakage from the lagoon is considered a problem would have different degrees of suitability if one was located in an area of little to no danger of groundwater pollution and the other in an area of high danger of such pollution.

Suitability for Septic Systems

Septic tanks and their accompanying filter fields are a principal method of sewage disposal in private homes in much of Cass and Clay Counties. The septic tank acts as a vessel in which harmful contaminants are neutralized. After the biological-decay processes have ceased, the aqueous solution is passed through a drain-tile field where the solids are filtered out and the water is removed by seepage.

In evaluating the suitability of earth materials for proper operation of a septic system the permeability of the material is of major importance. If the permeability is too low, adequate filtration may not occur. The effect might be the same as the sewer backing up in a home that is on a municipal-sewage system. If the permeability is too high, filtration will be too rapid, and proper neutralization in the septic tank cannot take place. High permeability also increases the danger of pollution of groundwater.

Septic tanks should be located so that they are not subject to flooding. Spring flooding may result in periods of as much as several weeks during which water stands on the flat land in the central part of the two-county area. At the base of steep slopes in the eastern and western parts of the two-county area, short term flooding conditions occur at times of exceptionally heavy precipitation. In sloping areas, septic-system filter fields should be located, as much as possible, so that surface runoff does not drain into the field, but rather flows away from it.

Position of the water table is important, particularly where it is subject to seasonal fluctuations. Ideally, the water table should be well below the septic system so that effluent drainage is away from the system rather than towards the system.

In defining the categories of suitability for septic disposal shown on map 9, permeability of the sediments is the controlling factor. Water-table position is only a peripheral consideration, because, in most cases in Cass and Clay Counties, where the permeability is high the water table is low, and vice versa. At the scale of mapping used in this report, consideration of slope was not feasible. Slope should be included by using map 9 in conjunction with a topographic map and field inspection of each specific site under consideration. Flooding was not included because flood data is only available for the major streams in the two-county area, and at the scale of the map used in this report, would have little or no effect on the derived suitability ratings.

The surficial materials in Cass and Clay Counties were rated on the basis of their suitability for septic-tank systems as poor, moderate to poor, moderate, good to moderate, and good (map 9).

Those areas designated as poor are underlain by clay of very low permeability (red on map 9). Generally, in these materials the water table is also high. Very large drain-tile fields would be a necessity for adequate drainage of a septic system.

The areas of clay underlain by sand or till are designated as moderate to poor (light orange map 9). Here also the permeability of the clay is very low. However, in some places the clay overlying the sand may be thin enough so that drainage may take place into the sand. The till is generally of somewhat higher permeability than the clay and should provide better drainage than through clay alone.

Areas designated as moderate are underlain largely by till (yellow on map 9). Permeability of this material is adequate with a properly designed drain-tile field. The water table is low enough in most areas so that it will not affect proper operation of the system. The terrain in these areas may have locally high relief, so slope should be considered.

Sand overlying clay or till is designated as areas of good to moderate suitability (light green on map 9). The sand has very good permeability and is almost an ideal type of material for the filtering action necessary for proper drainage. These areas are not designated as good because the sand is of variable thickness, and till may be encountered at shallow depths.

The areas underlain by sand and gravel are designated as good (green on map 9) for septic-tank systems. In these areas, individual systems may be relatively closely spaced and still provide adequate operation. However, in some places, gravel may be overly permeable; that is, drainage would be too rapid. Also, in the very coarse material proper filtration may not occur. Steps should be taken to avoid actual placement in a gravel body.

In evaluating a site for a septic system, map 4 (Potential for Groundwater Pollution) should be used with map 9 to assess the pollution potential of the septic system. Special care should be taken to determine whether wells in the immediate area of the proposed septic system are producing from the same permeable material in which disposal is proposed.

REFERENCES CITED

Arneman, H. F., Erickson, R. A., Harmes, G. F., Hanson, L. D., Rust, R. H., and Wright, H. E. Jr., 1969, Minnesota soil atlas: Brainerd sheet: University of Minnesota, Agricultural Experiment Station, Misc. Report 90-1969, 34 p.

Bell, G. L., 1968, Engineering geology of interstate highway 94 underpass at Northern Pacific Railway, Fargo, North Dakota, *in*, Kiersch, G. A. (ed.), Engineering geology case histories, number 6: Geological Society of America, p. 49-53.

Dennis, P. E., Akin, P. D., and Worts, G. F. Jr., 1949, Geology and ground-water resources of parts of Cass and Clay Counties, North Dakota and Minnesota: North Dakota State Water Conservation Commission, Ground-Water Studies, No. 10, 177 p.

Jensen, H. M., and Klausing, R. L., 1971, Geology and groundwater resources of Traill County, North Dakota, Groundwater resources: North Dakota Geological Survey, Bull. 49, Part 3, and North Dakota State Water Commission, County Ground Water Studies 10, 40 p.

Klausing, R. L., 1968a, Geology and groundwater resources of Cass County, North Dakota, Geology: North Dakota Geological Survey, Bull. 47, Part I, and North Dakota State Water Commission, County Ground Water Studies 8, 39 p.

Klausing, R. L., 1968b, Geology and groundwater resources of Cass County, North Dakota, Hydrology: North Dakota Geological Survey Bull. 47, Part 3, and North Dakota State Water Commission, County Ground Water Studies 8, 77 p.

Knoble, E. W., Peightal, M. F., and Chapman, J. E., 1924, Soil survey of Cass County, North Dakota: U.S. Dept. of Agriculture Bull. 29, ser. 1924, 80 p.

Maclay, R. W., Bidwell, L. E., and Winter, T. C., 1969, Water resources of the Buffalo River watershed west-central Minnesota: U.S. Geological Survey, Hydrologic Investigations Atlas, HA-307.

Nikiforoff, C. C., Hasty, A. H., Swenson, G. A., Gray, A. L., Fieger, E. A., Hill, Sam, Newman, H. C., Mattson, C. H., Hide, J. C., and Kneen, Eric, 1939, Soil Survey (reconnaissance). The Red River Valley area, Minnesota: U.S. Dept. of Agriculture, Bureau of Chemistry and Soils, ser. 1933, no. 25, Washington.

Nordlund, R. L., and Deere, D. U., 1970, Collapse of Fargo grain elevator: Journal Soil Mechanics and Foundations Division, American Society of Civil Engineers, v. 96, no. SM2, Proc. Paper 7172, p. 585-607.

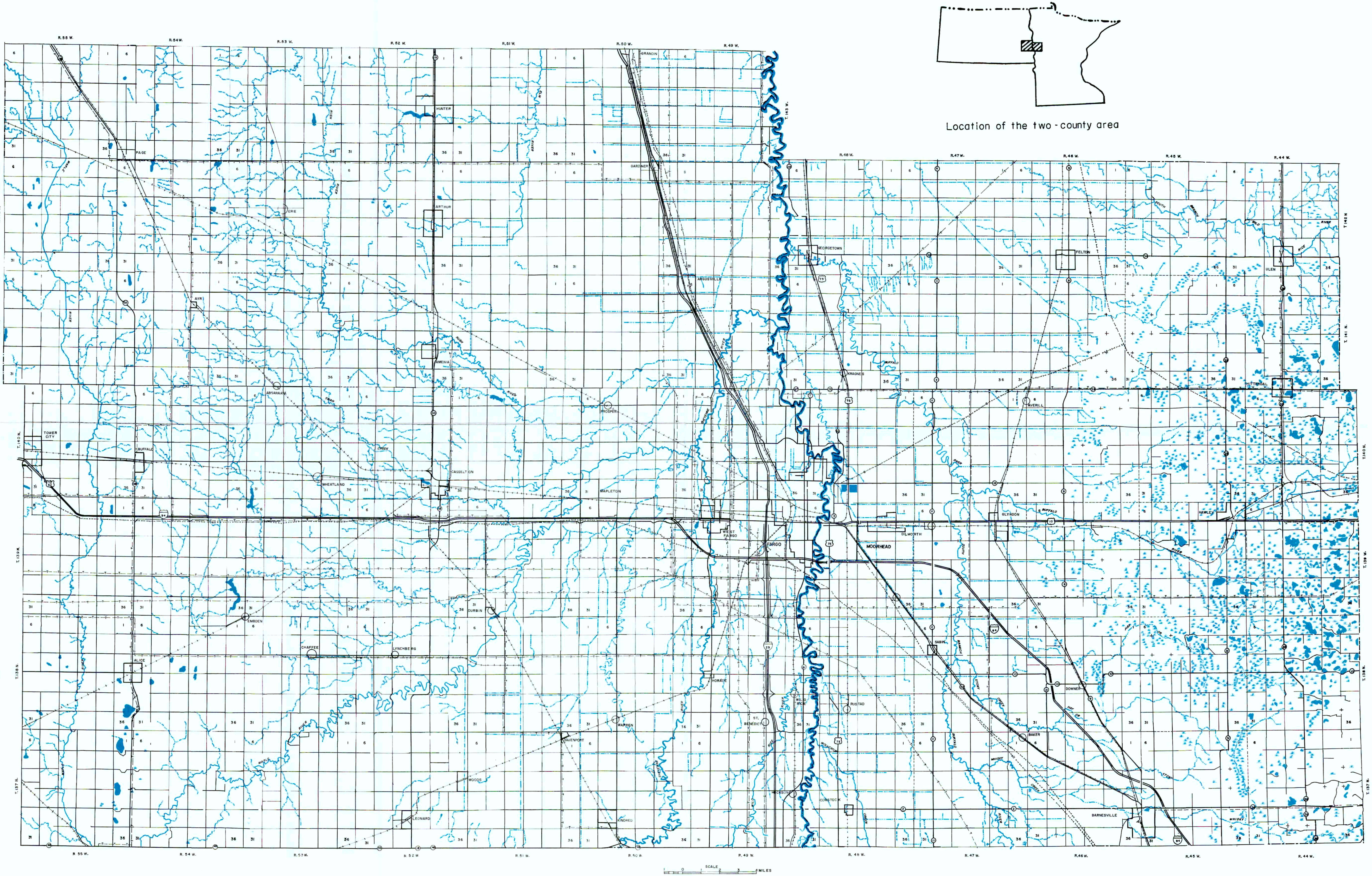
North Dakota State University Agricultural Experiment Station, 1963, General soil map Cass County: Fargo, North Dakota.

Omodt, H. W., Shroer, F. W., and Redmond, C. R., 1966, Soil survey of tri-county area, North Dakota: U.S. Department of Agriculture, Soil Conservation Service, Washington, 94 p.

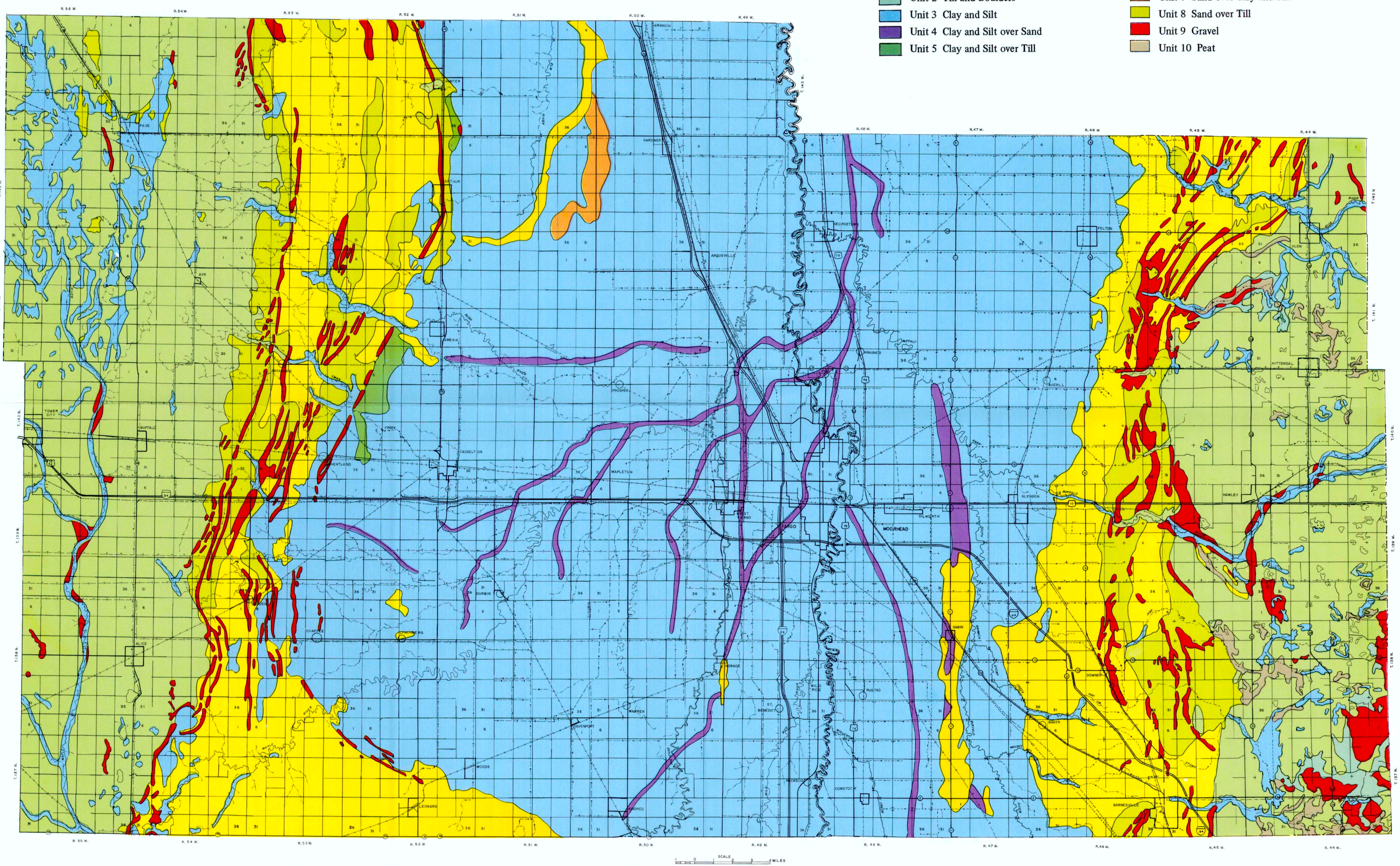
Patterson, D. D., Johnsgard, G. A., Sweeney, M. D., and Omodt, H. W., 1968, Soil survey report. County general soil maps, North Dakota: North Dakota State University Agricultural Experiment Station, Bull. 473, 150 p.

U.S. Army Corps of Engineers, 1972, Flood plain information, Red River of the North, Fargo, North Dakota, Moorhead, Minnesota: Dept. of the Army, St. Paul District Corps of Engineers, St. Paul, Minnesota, 41 p.

MAP 1 SURFACE WATER IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA



MAP 2 SURFACE MATERIALS OF CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA



EXPLANATION

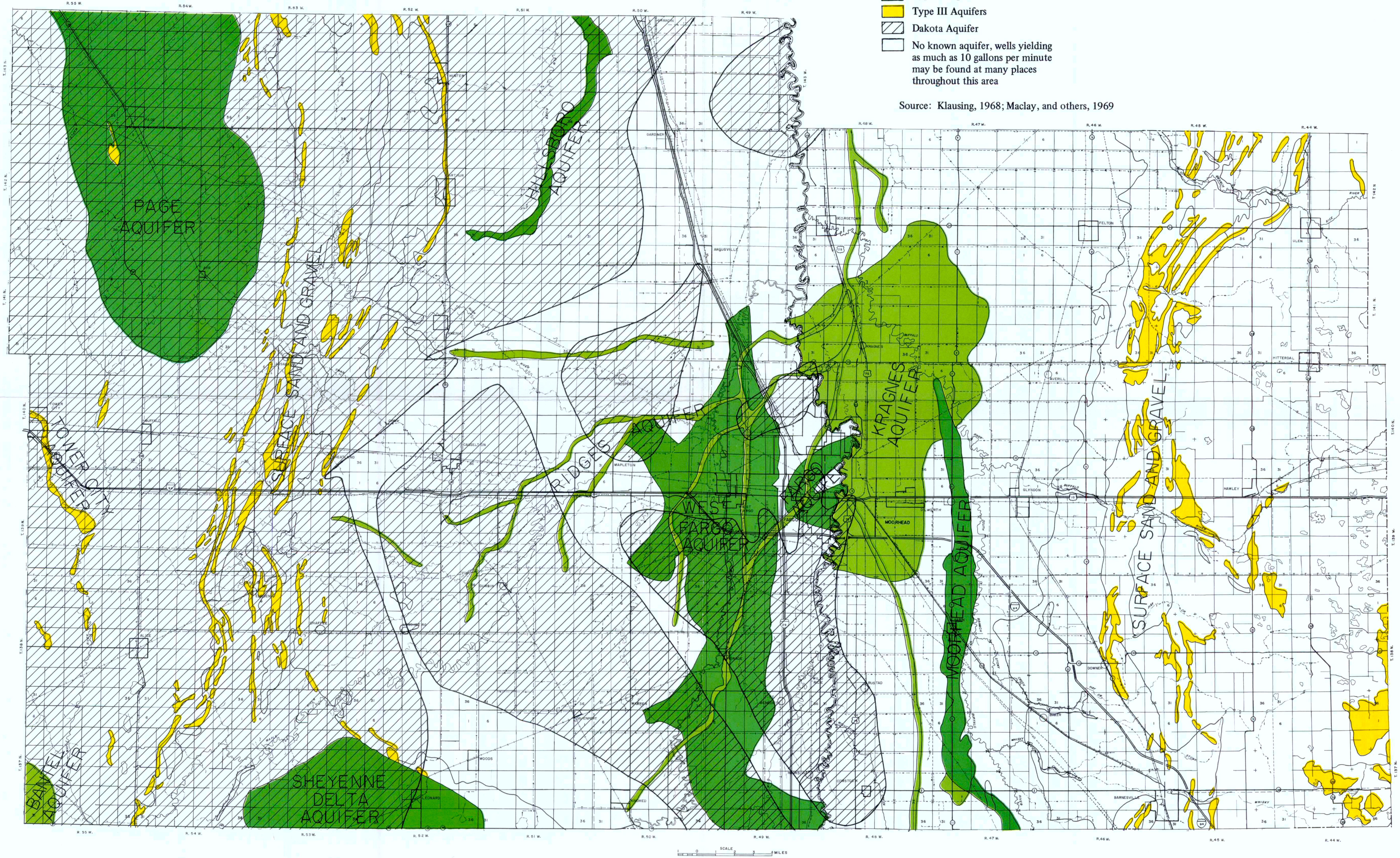
- Unit 1 Till
- Unit 2 Till and Boulders
- Unit 3 Clay and Silt
- Unit 4 Clay and Silt over Sand
- Unit 5 Clay and Silt over Till
- Unit 6 Sand
- Unit 7 Sand over Clay and Silt
- Unit 8 Sand over Till
- Unit 9 Gravel
- Unit 10 Peat

MAP 3 GROUNDWATER RESOURCES OF CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA

EXPLANATION

- Type I Aquifers
- Type II Aquifers
- Type III Aquifers
- Dakota Aquifer
- No known aquifer, wells yielding as much as 10 gallons per minute may be found at many places throughout this area

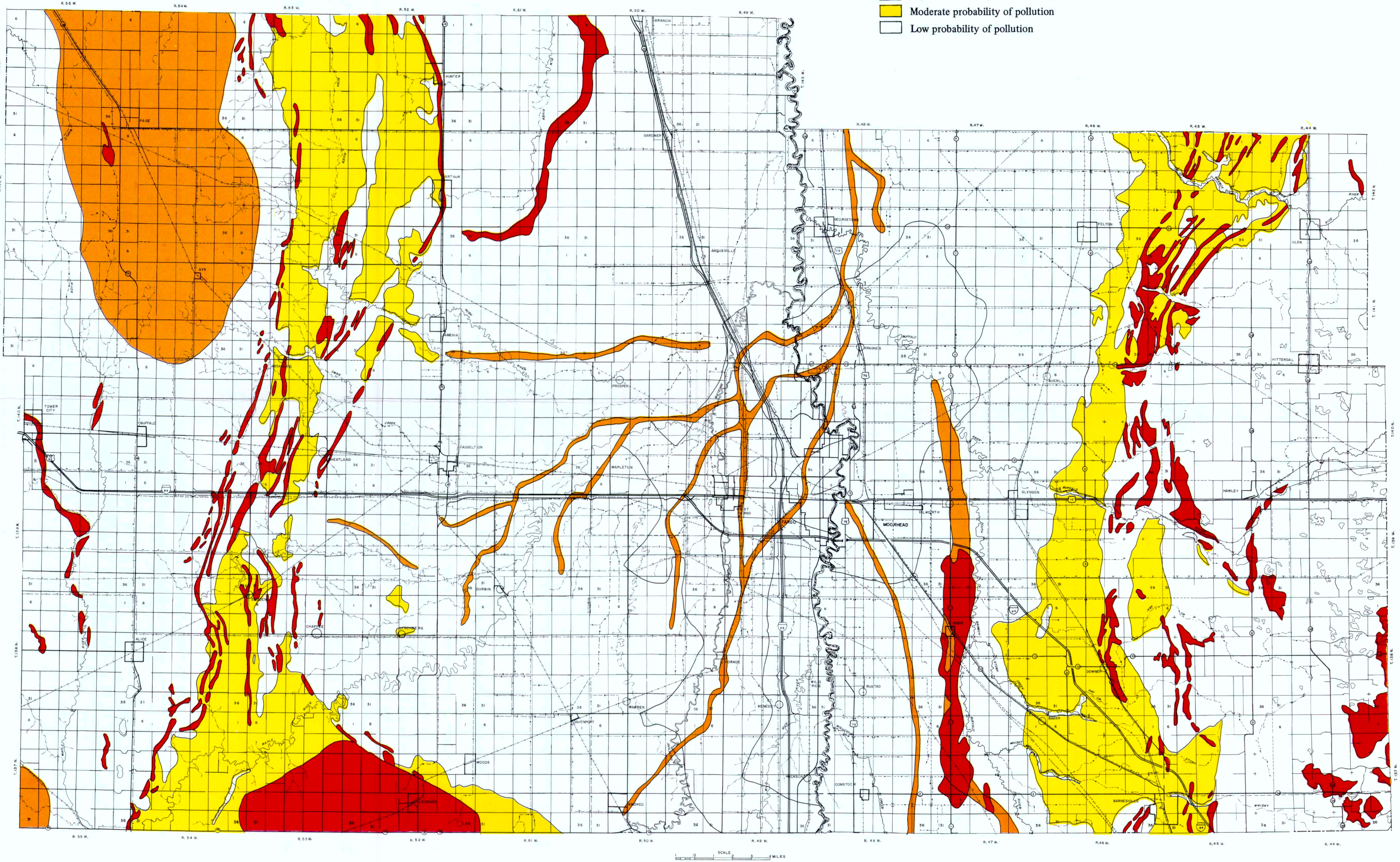
Source: Klausing, 1968; Maclay, and others, 1969



MAP 4 POTENTIAL FOR POLLUTION OF GROUNDWATER IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA

EXPLANATION

- High probability of pollution
- High to moderate probability of pollution
- Moderate probability of pollution
- Low probability of pollution

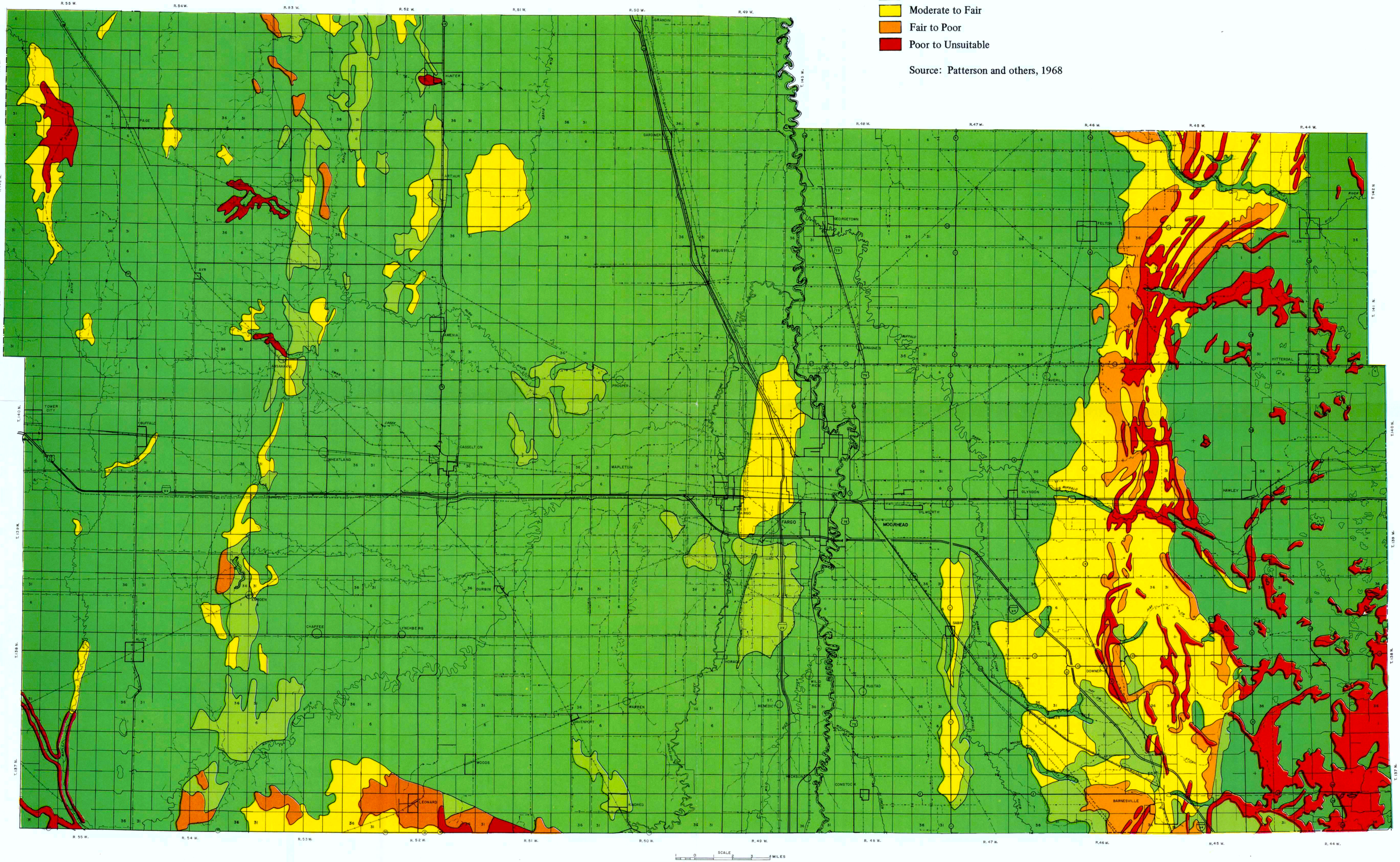


MAP 5 AGRICULTURAL SUITABILITY OF SOILS IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA

EXPLANATION

- Excellent to Good
- Good to Moderate
- Moderate to Fair
- Fair to Poor
- Poor to Unsuitable

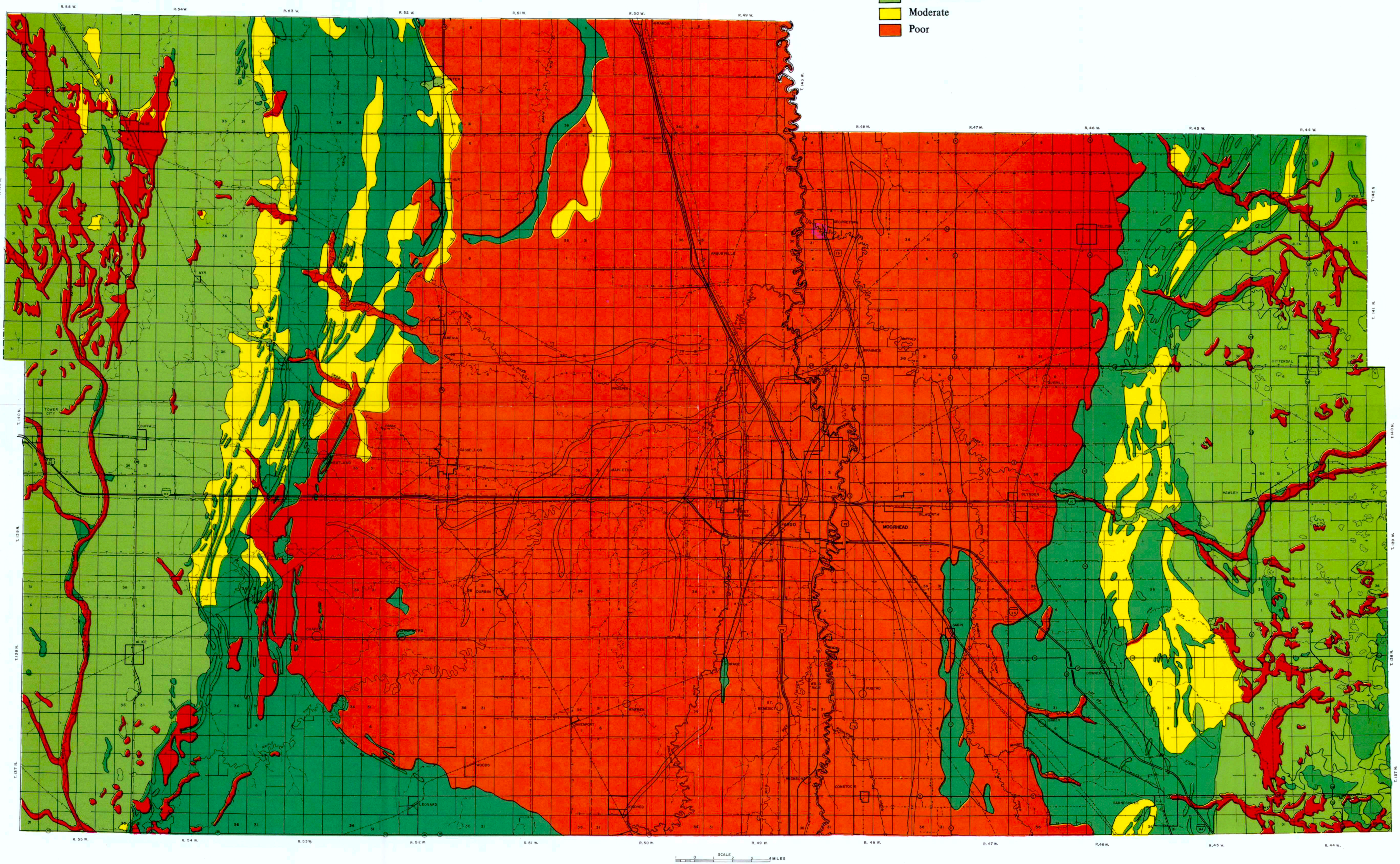
Source: Patterson and others, 1968



MAP 6 GENERAL CONSTRUCTION CONDITIONS IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA

EXPLANATION

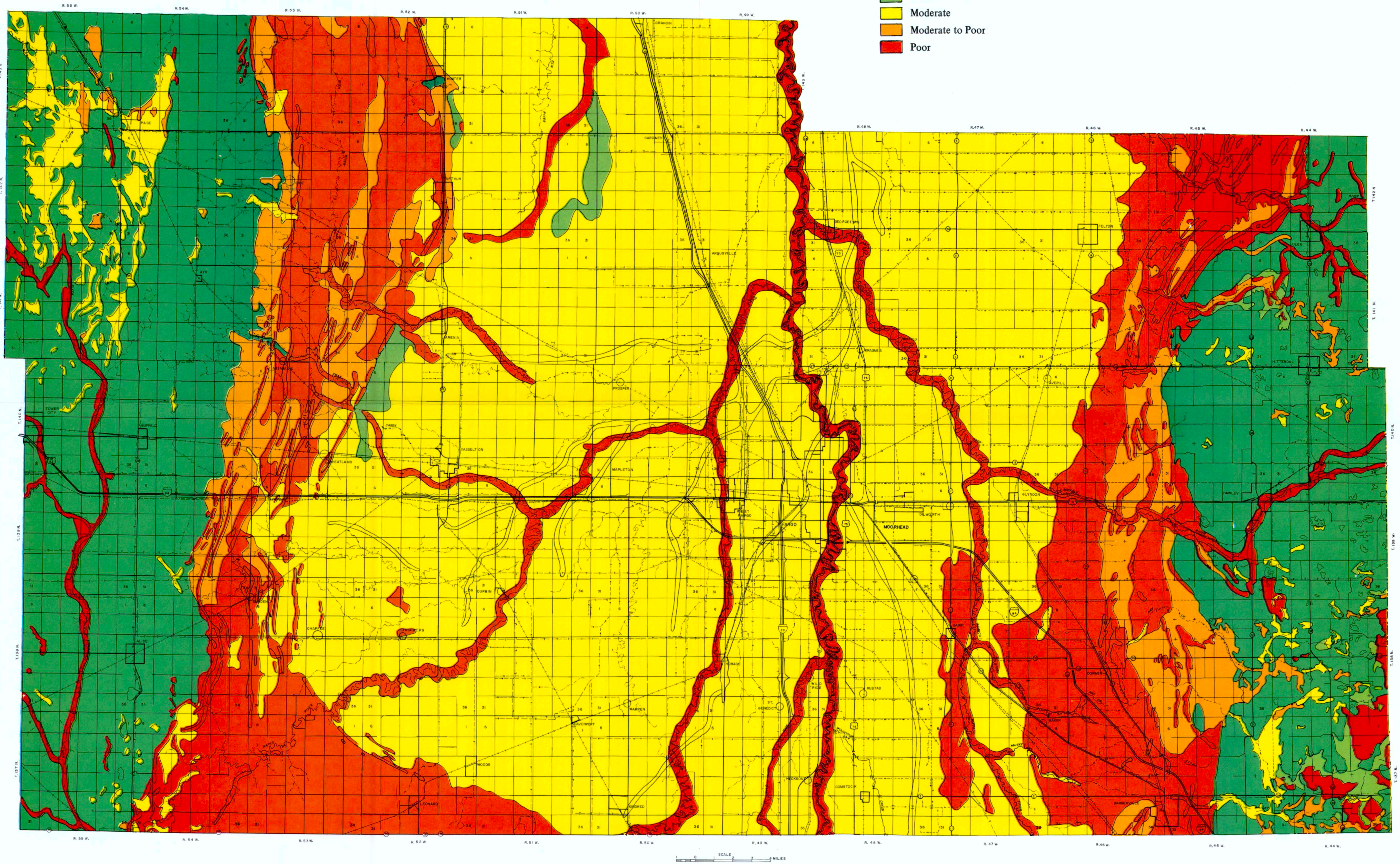
- Good
- Good to Moderate
- Moderate
- Poor



MAP 7 SUITABILITY OF AREAS IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA, FOR SANITARY LANDFILLS

EXPLANATION

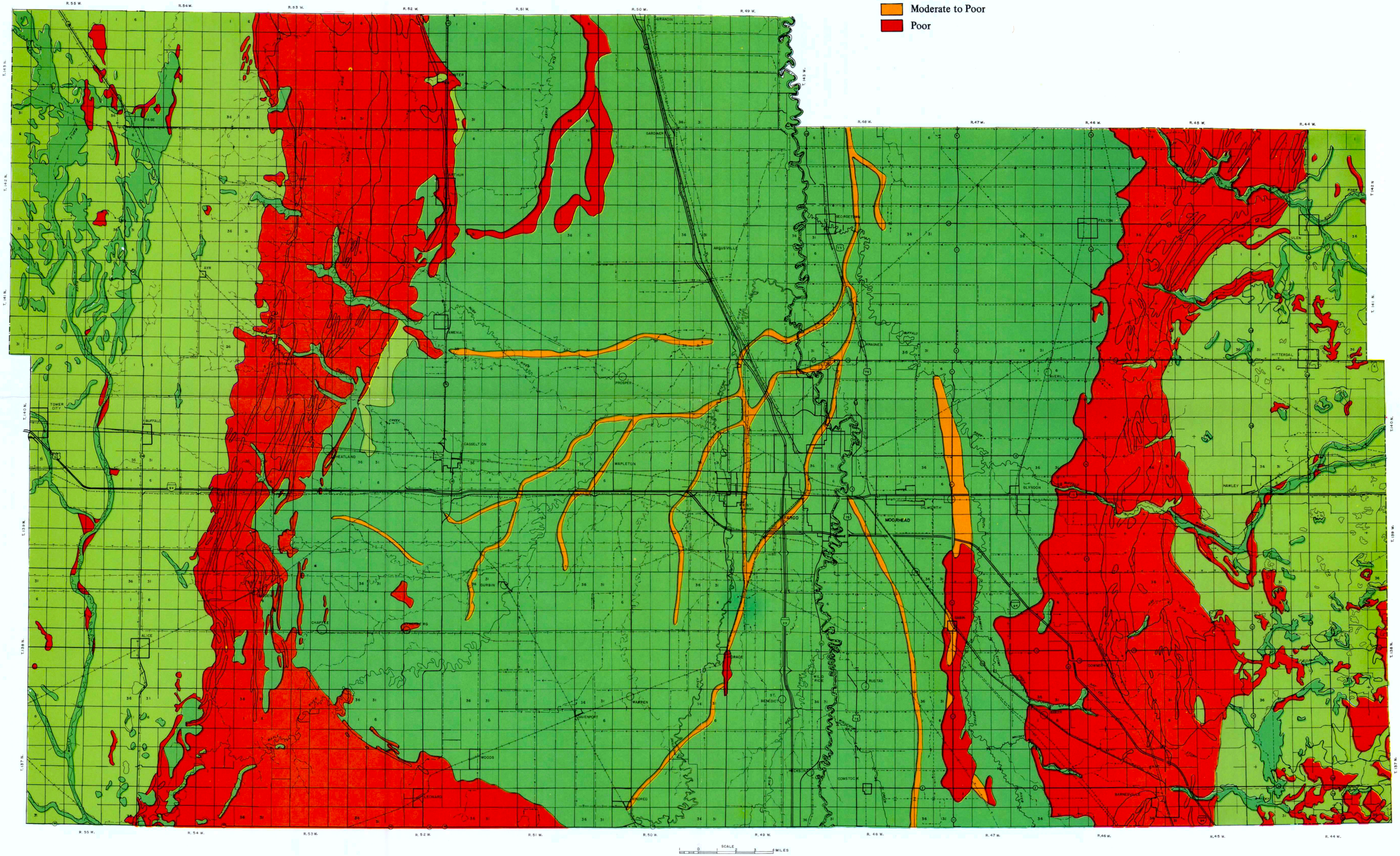
- Good
- Good to Moderate
- Moderate
- Moderate to Poor
- Poor



MAP 8 SUITABILITY OF AREAS IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA, FOR SEWAGE LAGOONS

EXPLANATION

- Good
- Good to Moderate
- Moderate to Poor
- Poor



MAP 9 SUITABILITY OF AREAS IN CASS COUNTY, NORTH DAKOTA, AND CLAY COUNTY, MINNESOTA, FOR SEPTIC SYSTEMS

EXPLANATION

- Good
- Good to Moderate
- Moderate
- Moderate to Poor
- Poor