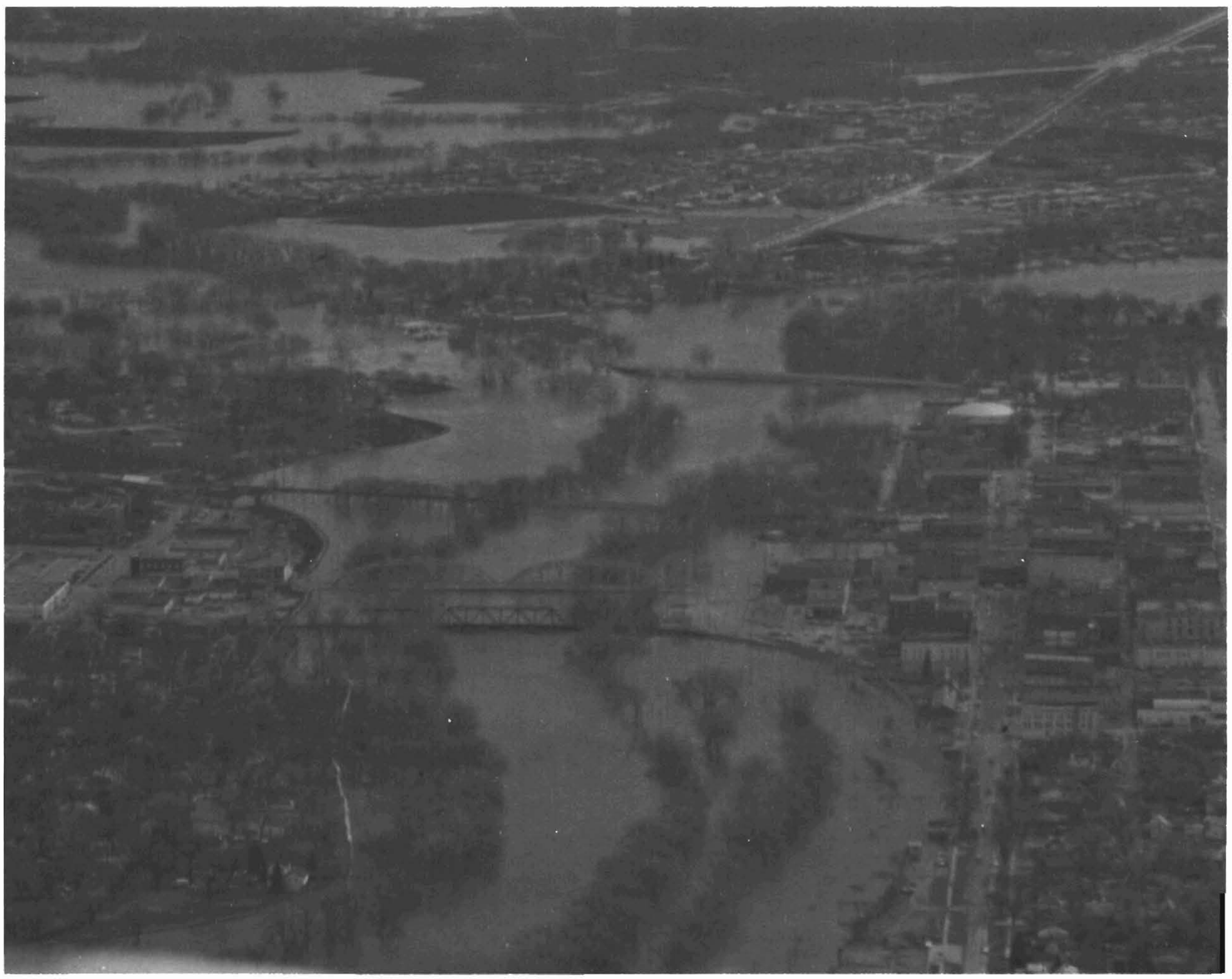
FLOODING IN THE GRAND FORKS–EAST GRAND FORKS AREA

by

Samuel S. Harrison and John P. Bluemle



Educational Series 12

North Dakota Geological Survey

Lee C. Gerhard, *State Geologist*

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NORTH DAKOTA GEOLOGICAL SURVEY

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PREFACE

Low-lying areas in Grand Forks-East Grand Forks are flooded moderately nearly every other year. Major floods affecting large areas of both cities have occurred, on the average, once in every six years. Since 1950, however, such severe flooding in the Red River Valley has occurred twice as often. Media coverage of recent floods shows that much of the general public and news media do not have a good understanding of the local flood problem. The recent Red River floods of 1975, 1978, and 1979 and the English Coulee flood of 1979 have shown that there is an unawareness of (1) the actual flood problem in Grand Forks-East Grand Forks and (2) the steps that have been taken or need to be taken to reduce flood losses.

This booklet concerning the flood problem was prepared to provide information not readily available to the public. An understanding of flood potential and flood hazards is important in land-use planning and for management decisions concerning flood-plain utilization. The booklet includes a history of flooding in Grand Forks-East Grand Forks and identifies those areas subject to future floods. The booklet does not, however, provide solutions to flood problems. It suggests the adoption of land-use controls for flood-plain development, reducing flood damage and flood-control effort.

The North Dakota Geological Survey published an earlier version of this booklet in 1968. However, recent severe floods have made it necessary to take a fresh view of the problem. Although some of the methods and terminology used in the booklet are necessarily technical, suffcient explanation is provided for the layman. Except where otherwise noted, photos are by John Bluemle.

The predictions of the frequency and extent of future flooding set forth in this booklet are based on records of past floods, a record less than a hundred years long. Because we are attempting to predict a natural phenomenon--one uncontrolled by man--these predictions can never be 100 percent accurate. The North Dakota Geological Survey and the writers, therefore, can accept no responsibility for any direct or indirect damages resulting from the failure of nature to comply with these purely statistical predictions.

Cartoon by Stuart McDonald. Published in the Grand Forks Herald.

THE FLOOD PROBLEM IN THE RED RIVER VALLEY

Floodwaters frequently inundate large areas of the Red River Valley during the spring snowmelt and occasionally after heavy summer rains. As a result, cropland, farmsteads, private residences, transportation facilities, and businesses are all subjected to heavy damage.

About 8 percent of the total area of Grand Forks-East Grand Forks is included in the nation's 100 million acres of flood plain--areas subject to periodic flooding (Hertzler, 1961). Throughout the early history of the two cities, floods were simply endured, with little organized effort being made to combat the muddy waters of the Red and Red Lake Rivers. As low-lying areas along the rivers have become more thickly settled, however, vast amounts of money have been spent on temporary and permanent flood-protection works and, when floods occur, on flood-damage repair and cleanup.

Flooding occurs most frequently in the Red River Valley in the spring, following the snowmelt, but it can be aggravated by rainfall that occurs with or immediately after the spring thaw. The usual type of flooding is associated with streambank overflow. Flooding also occurs when runoff from snowmelt or heavy rainfall is impounded along sections of land bounded by raised roadways where culverts and ditches are either plugged or of inadequate capacity to accomodate large, infrequent discharges. This type of flooding can submerge the roadway embankments, inundating section after section of farmland as it moves overland toward major stream channels and drainage ditches.

The northward flow of the Red River can be an important factor influencing the magnitude of the floods. Rising spring temperatures, which produce the snowmelt runoff, begin in the southern headwater portion of the basin and progress northward toward Canada. Flood peaks of local and tributary runoff, particularly in the southeastern part of the Red River Valley, often tend to coincide with the Red River main channel flood peak stage, increasing the volume of flooding. Furthermore, the spring floods can flow northward into channels still blocked by winter ice cover. The channel ice can act as a dam, causing backwater and local increases in river stages. However, if warmer temperatures arrive through the entire area at about the same time, the snow cover melts everywhere. This is more likely to happen when the spring thaw is late, as it was in 1979.

The flatness of the Red River Valley is an important factor influencing tributary floods. Outside the valley, high flows are normally confined within the deeply entrenched channels in the escarpment and beach ridge areas near the edge of the Red River Valley, causing little damage. However, the stream slopes become gentler and the channel capacities decrease in the flat valley areas. The floodwaters can escape the channels and move overland, inundating thousands of acres of farmland and even entire communities.

Snow and ice accumulate in the tributary stream channels, particularly at river bridges and constricted parts of the channel. These ice jams sometimes increase upstream levels, causing localized flooding. Standing and fallen trees, brush, and sediment deposited within the channel banks all tend to reduce the flow capacities of streams and ditches. Windblown soil from previous years may also have accumulated in stream valleys, ditches, and channels, further reducing flow-carrying capacities.

North of the Grand Forks-East Grand Forks area, the capacity of the main channel of the Red River is less than it is upstream at Grand Forks. Floodwater near Oslo can spread out over a vast area of the flat Red River Valley.

Sediment deposited during past floods has built natural levees up to 5 feet high along the main channel of the Red River and the lower reaches of some of its tributaries. During flood periods, the river surface may be well above ground levels behind the natural levees. If the natural levees are overtopped or circumvented, the land for several miles on either side of the river can be rapidly flooded.

The extensive tributary and main channel flood-plain area of the Red River is heavily occupied as a result of the regional agricultural economy. As a result, urban and rural residences and businesses and transportation facilities all suffer damage during

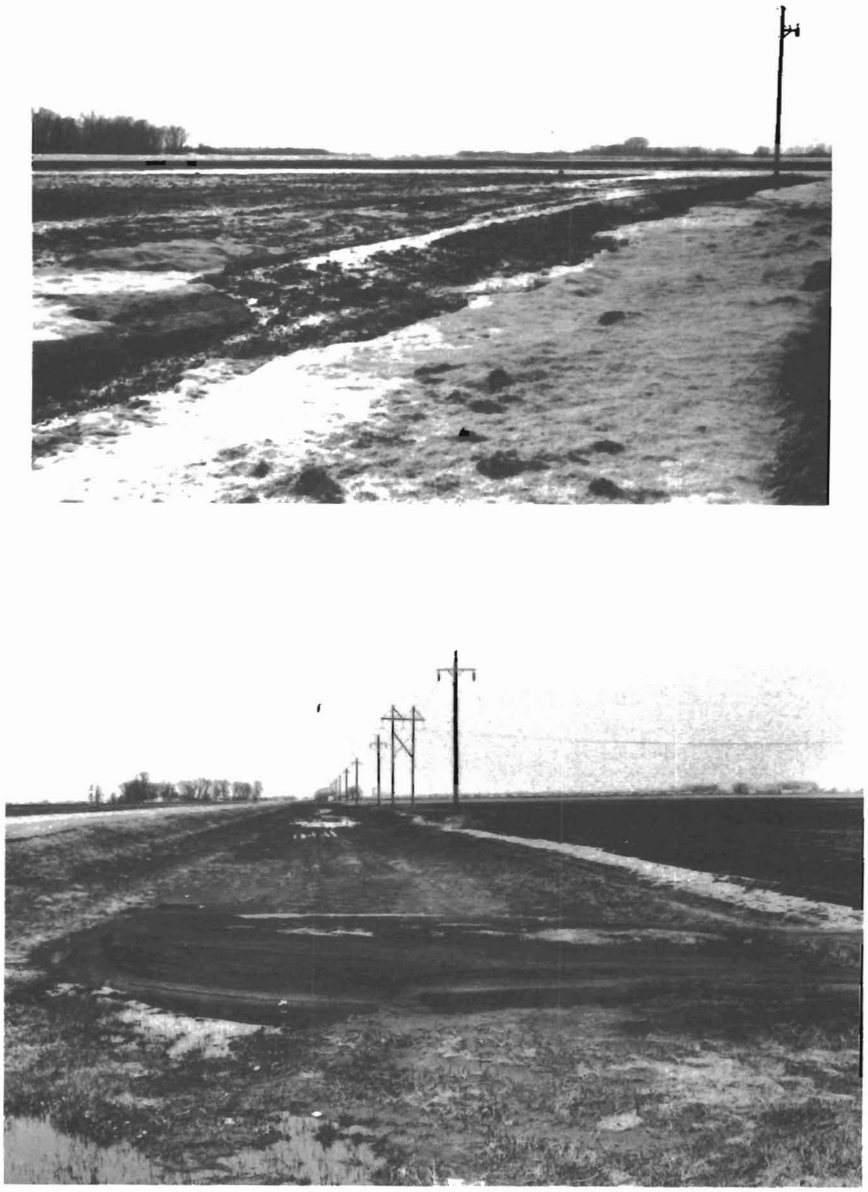


Figure 1. Two photos of runoff-damage to fields in the Grand Forks area. Perhaps the single most important money loss to agricultural land during spring floods is the damage to fields and loss of topsoil due to erosion by running water. Millions of tons of precious black soil are moved by the flowing water, although only a small fraction actually reaches the Red River. Here, a flow from a field (above) results in a small "delta" of black soil being deposited in the road ditch (below).

flooding. However, the brunt of the damage occurs in the approximately 600,000 acres of flood-plain farmland along either side of the Red River in North Dakota and Minnesota.

Damages from floods include both tangible and intangible losses. The tangible losses include: (1) agricultural damages (fig. 1), (2) water damage to structures, utilities, and transportation facilities, (3) cost of fighting the floods (figs. 2 and 3), (4) business losses, and (5) increased expenses for normal operations during floods. The monetary value of damages caused during several floods is listed

TABLE 1. Annual flood damage along the Red River

Flood	Urban	Agricultural	Transportation	Total
1950	$8,700,000	$ 15,900,000	$28,000,000	$52,500,000
1965	3,500,000	8,000,000	2,400,000	15,000,000
1966	3,300,000	9,700,000	1,300,000	14,000,000
1969	4,800,000	22,100,000	2,500,000	29,500,000
1975 (April)	800,000	8,000,000	NA	NA
1975 (July)	4,000,000	148,100,000	NA	NA
1978	800,000	5,300,000	500,000	6,600,000
1979	9,100,000	31,900,000	3,300,000	44,300,000

NA=Not Available

The dollar amounts listed in this table are not the same as those mentioned in the descriptions of each flood in the text. This is because they are keyed to the retail consumer price index (CPI) so that a more meaningful comparison can be made of damages attributed to each flood. Adjusting flood losses with the CPI attempts to measure the quantitative loss. The (money) loss of 1979 seems greater than the (money) loss of 1950 because of pure monetary inflation. A 1979 dollar does not buy what a 1950 dollar did so to compare losses in current terms would be to compare dissimilar units of measurement. Thus, for example, that total damage attributed to the 1950 flood was 33 million dollars (1950 dollars); the total damage caused by the 1979 flood was 91 million dollars (1979 dollars). In terms of constant (1967 dollars), the totals become 52.5 million for 1950 and 44.3 for 1979.

I am grateful to Dr. Scot Stradley, Professor of Economics, University of North Dakota, for his help in computing losses in terms of constant, 1967 dollars.

in table 1. Intangible losses, which cannot be measured in dollars, include: (1) loss of life and threat of loss of life, (2) human misery during the flood, (3) disruption of normal community activities, (4) potential health hazards from contaminated water and food supplies, and (5) flooding of sewage collection and treatment facilities.

Under the present limited flood protection philosophy in the Red River Valley, all tangible and intangible flood losses now sustained during floods will continue on an increased scale as the result of future floods. Changes in the type and extent of flood damages can only result from community renewal programs, land-use shifts, and changes in agricultural practices.

In rural areas, clearing of timber, intensive wetland drainage, fall tillage, conversion of grassland to cropland, drainage ditch construction, and construction of railroad and highway embankments and bridges have all contributed to the flooding problem. In urban areas, the amount of infiltration by precipitation and snowmelt has been decreased by paving extensive areas. The flooding problem has been compounded by development of flood-prone areas such as the English Coulee drainage. Finally, changes in land use in the headwaters area can increase erosion there and result in sedimentation in downstream areas.

River gaging data for the Red River prior to 1882, when a river gage was established at Grand Forks, are not available in the United States. However, early records maintained near Winnipeg, Manitoba, indicate that major floods occurred in 1824, 1825, 1826, 1851, 1852, and 1853. Some of these floods apparently exceeded by several feet the worst floods of this century.

Since the installation of the river gage at Grand Forks, floods exceeding 43 feet (which is a 10-year flood) have been recorded at least a dozen times. It is not unusual for several floods to occur in a single year at different points in the river basin and along the various tributaries. All of the 43-foot and higher floods of record (except the 1965 and the July 1975 floods)

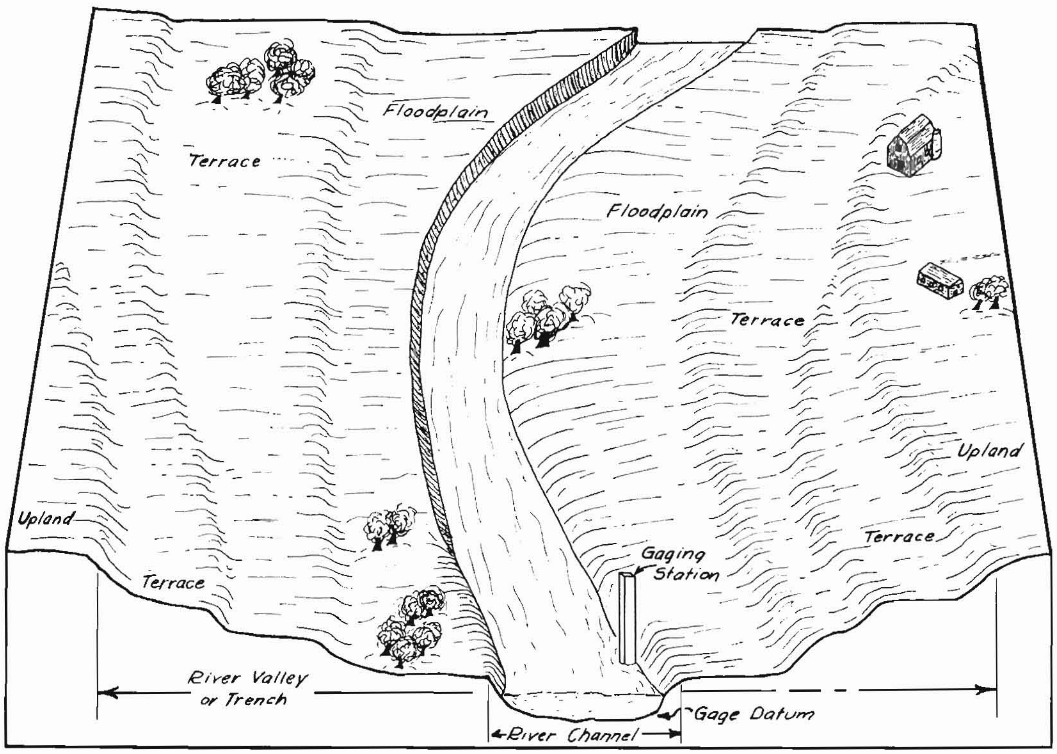


Figure 4. Diagram showing flood-plain features.

were caused by spring snowmelt. The greatest recorded floods in the United States part of the Red River Valley were those of 1897, 1950, 1978, and 1979. The July 1975 flood was particularly devastating because it occurred after crops were well on the way to maturity; a great deal of grain that had already been swathed was lost.

FLOOD TERMINOLOGY

Because the use of some semi-technical terminology is both unavoidable and desirable, a few general definitions are given here (fig. 4).

Backwater: A high water surface of a stream resulting from a downstream obstruction or high stages of an intersecting stream.

Discharge: The rate of flow of a river past a specific point, usually expressed as a number of cubic feet in a given time, for example, cubic feet per second. Sometimes expressed as gallons per second.

Flood: The exact definition of a flood varies somewhat, but for the purposes of this report, a river or stream is considered to be flooding if it overflows its banks and inundates the flat areas adjacent to the stream that are not normally covered by water and that are used or are usable by man. Floods have two essential characteristics: the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, ocean, lake, or other body of standing water.

Normally, a "flood" is defined as any temporary rise in streamflow or stage that results in significant adverse effects in the vicinity. Adverse effects may include damages from water overflowing land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels or on flood plains during flood, rise of groundwater with increased streamflow, and other problems. Water standing in fields prior to running off is not considered to be floodwater.

Flood Crest: The highest level that any particular flood attains at a given point along the river is referred to as the crest or peak of that flood.

Flood Plain or Floodplain: Again,

the definitions vary. In this booklet, a flood plain consists of the relatively flat land areas bordering a river or stream above the level of the banks. These areas, as the name implies, are periodically inundated and become part of the river channel during floods.

Bankfull Stage: The height of the water when it is level with the top of the natural banks of the river channel is referred to as bankfull stage. If water rises above bankfull stage, inundation of the flood plain begins.

Flood Stage: The height of the water at which flooding begins to occur is called flood stage (generally the same as bankfull stage).

Gage Reading: Floods in Grand Forks-East Grand Forks are referred to by numbers such as 44.6, 35.7, etc. These numbers represent the height of the river surface in feet above the reference datum or base of the U.S. Geological Survey gage. The base or datum of the Grand Forks gage is 778.35 feet above sea level; thus, the river surface during a 40.00-foot flood crest is 778.35 feet plus 40.00 feet or 818.35 feet above sea level at the gage. The surface of the river is from ½ to 2 feet higher than the gage reading at the south end of Grand Forks-East Grand Forks. The gage readings are roughly equal to the depth of the water in the main channel of the river.

Prior to October 1962, the river-level gage was housed in a concrete tower about 50 feet high located 500 feet downstream from the dam in Riverside Park on the left bank (Grand Forks side) of the river. The gage is presently located on the second floor of the old Grand Forks sewage disposal plant about ¼ mile north of the old site. The reference datum of the new gage is also 778.35 feet above sea level.

Hydrograph: A graph showing discharge against time at a given point, usually measured in cubic feet per second (cfs). The area under the curve indicates total volume of flow.

Intermediate Regional Flood: A flood having an average frequency of occurrence of about 100 years, although the flood may occur in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the general region of the watershed. There is a one percent chance an intermediate regional flood will occur in any given year.

Left Bank: The bank on the left side of a river, stream, or watercourse, looking downstream.

Right Bank: The bank on the right side of a river, stream, or watercourse, looking downstream.

Recurrence Interval: The recurrence interval of a flood is the average number of years separating floods of a given magnitude or greater. The recurrence-interval value is based on the flood record, which extends back to 1882 in Grand Forks-East Grand Forks. To understand how recurrence interval is computed, assume that a flood 40 feet high or higher has occurred 20 times in the past 100 years. We could expect, therefore, to have a flood at least this high on an average of once in 5 years; thus the recurrence interval of a 40-foot flood would be 5 years. Another way of expressing recurrence interval is to say that the chances of having a flood 40 feet or higher is one out of five or 1/5 or 20 percent for every year (using our assumed data). It is important to note, however, that the recurrence interval <u>does not</u> imply that if a 40-foot flood occurs this year, another of that magnitude will not occur for 5 years. Rather, over a period of 20 years, about four floods of this magnitude can be expected; when they will occur or how many years will separate them cannot be predicted.

Runoff: Runoff is that part of the total precipitation throughout the drainage basin which eventually reaches the river.

500-Year Flood: The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. A 500-year flood has a 1 in 500 chance of occurring in any given year.

GEOLOGY AND TOPOGRAPHY

The Red River of the North is formed by the confluence of the Otter Tail and Bois de Sioux Rivers at the cities of Wahpeton, North Dakota, and Breckenridge, Minnesota. From this point, the Red River flows northward for a distance of about 296 miles to the

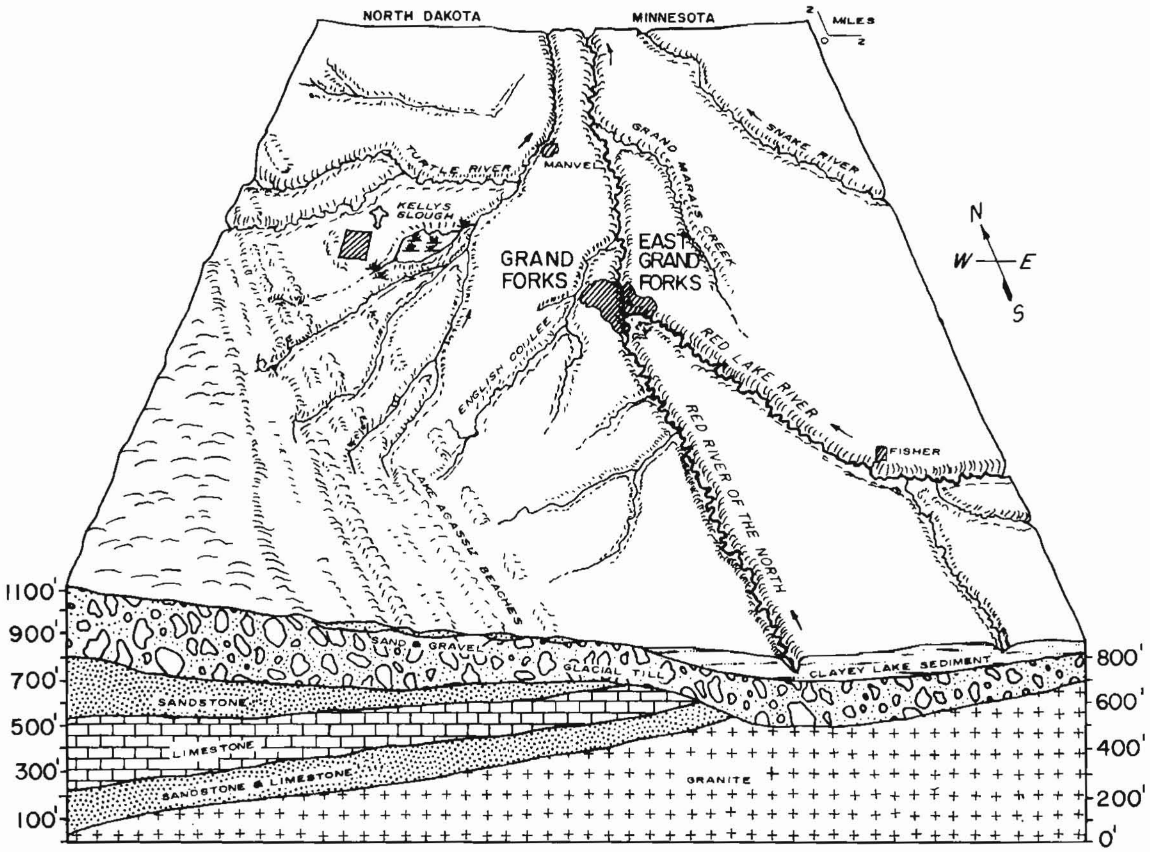


Figure 5. Physiographic map of Grand Forks-East Grand Forks area showing subsurface stratigraphy.

Grand Forks-East Grand Forks area and another 98 miles before reaching the international boundary. In Canada, the river continues northward through the city of Winnipeg to Lake Winnipeg, which is drained by the Nelson River to Hudson Bay.

Throughout its entire length, the Red River meanders along the exceptionally flat floor of the lake bed of the former glacial Lake Agassiz (fig. 5). Lake Agassiz drained about 9,000 years ago, when the last of the Great Ice Age glaciers melted in this area. When at its maximum extent, about 12,000 years ago, the water in glacial Lake Agassiz was over 200 feet deep in the Grand Forks-East Grand Forks vicinity and more than 100 feet of clay and silt was deposited on the lake bed (Bluemle, 1977). Solid bedrock lies at an elevation of about 500 feet above sea level in this area, or about 330 feet beneath the two-city area (Hansen and Kume, 1968). Along the margins of Lake Agassiz, wave action washed the glacial sediment and formed beaches and other nearshore deposits composed of gravel and sand. These deposits are especially prominent in this area near Arvilla and Emerado, North Dakota, and near Erskine, Minnesota. They serve as the only local source of sand for construction of "sandbag" dikes during floods.

The Red River flows along the axis of the gently northward sloping bed of the former lake. The gradient of the river averages about 0.5 feet in a mile, varying from about 1.3 feet in a mile in the Wahpeton-Breckenridge area to 0.2 feet in a mile at the Canadian boundary. At bankfull stage, the channel widths of the river vary from 200 to 500 feet and average depths range from 10 to 30 feet. At Grand Forks-East Grand Forks, the discharge at bankfull stage is about 32,000 cfs; to the north, in the Oslo area, the discharge is only about 23,000 cfs at

TABLE 2. Mean annual and monthly temperatures and precipitation for Grand Forks-East Grand Forks

	Temperature (°F)	Temperature (°C)	Precipitation (inches)	Precipitation (centimeters)
Annual	39.6	4.2	21.27	54.03
January	4.1	-15.5	0.64	1.63
February	9.0	-12.8	0.46	1.17
March	22.7	-5.2	0.90	2.29
April	41.4	5.2	1.52	3.86
May	54.2	12.3	2.36	6.00
June	64.1	17.9	4.04	10.26
July	69.7	21.0	3.24	8.23
August	68.1	20.1	3.10	7.87
September	66.9	19.4	2.43	6.17
October	46.3	8.0	1.09	2.76
November	27.4	-2.5	0.86	2.18
December	11.4	-11.5	0.63	1.60

bankfull stage.

CLIMATE

The Grand Forks-East Grand Forks area receives an average of 21.27 inches of precipitation annually (Bavendick, 1952), ranging from a low of less than half an inch in February to over four inches in June (table 2). More than three-quarters of the precipitation falls between April and September. The remaining quarter, or about five inches, accumulates throughout the winter as snowfall. Average winter snowfall totals 34.6 inches. As we shall see later, the melting of the winter snow cover in early spring is a major factor in causing floods in this area. An average monthly winter temperature (November through March) of 15°F results in the buildup of considerable thicknesses of ice on the rivers, which can also be an important factor in flooding.

HISTORY AND GENERAL ECONOMY OF THE AREA

The first settlers arrived in Grand Forks in 1870 (Robinson, 1966). They found the land bordering the river a natural place for settlement. The river provided an avenue of transportation, as well as water for themselves and for stock. The flood plain supported timber for fuel and building. Prior to 1900, considerable steamboat traffic served Grand Forks-East Grand Forks, but by 1920 the last of the steamers had disappeared, and transportation on the Red and Red Lake Rivers ceased.

The population of the two cities has increased steadily over the years. In 1975, Grand Forks had about 42,000 inhabitants and East Grand Forks about 8,500.

The Red River Valley is predominantly an agricultural area. Crops grown include wheat, small grains, sugar beets, sunflowers, and potatoes. Almost all local industries are dependent on agricultural production. They include beet and potato processing plants, retail outlets, repair shops, grain elevators, creameries, and other food-processing plants. Large manufacturing facilities are scattered throughout the Red River Valley, but the majority of them are located near or adjacent to the Red River itself.

Of the total land in the Red River Valley, approximately two-thirds is used as cropland (Souris, Red, Rainy River Basin Commission, 1972). About three million acres of forest land is located mostly in Minnesota along the eastern edge of the area drained by the Red Lake River. The forest land accounts for the second largest land use in the Red River Valley.

The flood-prone area of the Red River Valley includes about 600,000 acres. The major land use is agricultural, with cropland occupying 486,000 acres and pasture or rangeland, 60,000 acres. Other uses, such as woodlands, wildlife, and urban and built-up areas, occupy the remaining flood-prone acreage. Most of the cropland of the flood plain is used for small grain crops.

THE RED RIVER AND ITS DRAINAGE BASIN

The "Red River Valley," along which the Red River of the North flows, is not a true river valley, but rather the broad bed of former glacial Lake Agassiz. The lake bed, although very flat, slopes gently inward at about 3 to 10 feet per mile toward its axis along the North Dakota-Minnesota border. Tributaries such as the Sheyenne, Goose, Turtle, Red Lake, Forest, and Park Rivers flow northeast and northwest down the gentle slope of the lake bed to the Red River. Their gradients, controlled by the slope of the sides of the lake bed, are too gentle to permit much active erosion, and they have cut only shallow valleys. The north-south axis of the lake bed slopes about 3/4 foot per mile northward, giving the Red River a low gradient. The gradient is decreased even further by the intricate meanders or twisting of the channel. Between Grand Forks-East Grand Forks and Pembina, the river gradient is less than ½ foot in a mile. Like its tributaries, the Red River is unable to accomplish much erosion with this low gradient. In most places, the banks of the river are only about 25 feet below the surrounding upland.

The Red River at Grand Forks-East Grand Forks is about 200 feet wide and perhaps 8 to 10 feet deep during normal summer flow with banks about 30 feet above the bottom of the channel. Once water overflows the banks and spreads out on the flood plain, however, the river width increases rapidly. During severe floods, the river can be as much as several miles wide just north of the two-city area.

The velocity at which the river flows varies considerably with time and place, and depends on many factors. The velocity is generally highest during floods. The velocity varies from nearly zero along the sides and bottom to a maximum just beneath the surface of the water near the middle of the river. The average velocity of the Red River in Grand Forks-East Grand Forks during the summer is about 1 foot per second (2/3 mile per hour), whereas during floods it probably reaches speeds of 8 feet per second (5½ miles per hour). Compared to other rivers, this flow is relatively slow because of the gentle northward slope of the lake plain.

Flood damage along the Red River is seldom the result of the flow of water and its ice. Although the velocity may be high within the main channel of the river during floods, the velocity is generally low in the flooded reaches bordering the river where such flow damage is important.

The drainage basin of the Red River at Grand Forks-East Grand Forks includes all the land upstream from the two cities that contributes water to the river (fig. 6). Any water running off the land within this portion of the drainage basin (about 30,100 square miles) should flow into the Red River and pass through the two cities.

A one-inch rainfall throughout the basin produces about 70 billion cubic feet of water that could flow past Grand Forks-East Grand Forks (Harrison, 1968). Of the total 21 inches of annual precipitation in the drainage basin, only about 10 percent ever reaches the Red River. The remaining 90 percent is lost, mostly to evaporation and plant use (transpiration). Early spring rains, which often accompany flooding in this area, may produce a much higher percentage of runoff if the ground is frozen or saturated and unable to soak up moisture.

The volume of water that passes through the two cities has averaged about 60 billion cubic feet annually, or 2,432 cubic feet per second since 1882. However, since 1950, the average flow has been 3,094 cfs, apparently indicating a trend toward greater precipitation during the past 30 years than during the previous 67 years of record. A part of the increase could be caused by improved drainage resulting from man's activities. Of the total amount of water passing through the two cities, the Red Lake River contributes about 35 percent.

The Red River is a muddy river. Its muddiness, or turbidity, is caused by fine-grained sediment (silt and clay) being carried in suspension in the water. Measurements made during the summers of 1965 and 1966 show

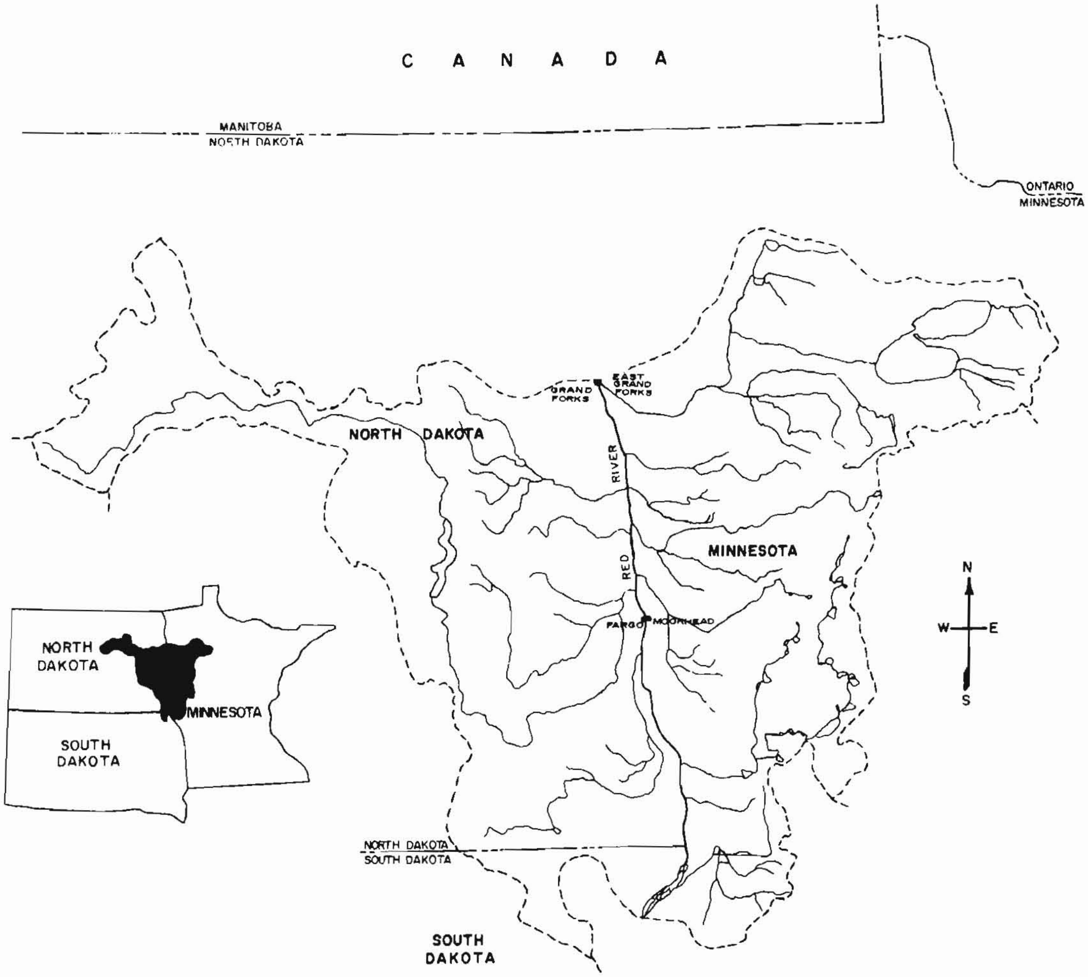


Figure 6. Drainage basin of the Red River at Grand Forks-East Grand Forks.

that the water in the Red River in this general area contains from 0.008 percent to 0.023 percent suspended sediment (80 to 230 parts per million) (Alan Cvancara, personal communication). If 0.015 percent (150 ppm) is an average value, then during a typical summer day more than 1,620 tons of suspended sediment (mud) pass through the two cities. During peak flows, when the river reaches heights of over 45 feet, more than 34,000 tons of sediment can pass between the two cities in a day. This is like 162 ten-ton-capacity trucks filled with mud traveling from south to north through Grand Forks each day during the summer! The unusually large amount of suspended sediment in the Red River is eroded from the clays and silts of the lake sediment of the valley.

Rapidly moving river water can carry more sediment. Upon reaching the still waters of Lake Winnipeg in Manitoba, the Red River abruptly slows down. The slower river current can no longer keep the sediment suspended so most of it settles to the bottom, forming the delta at the southern end of Lake Winnipeg. Much the same thing happens during floods. When the river water flows into flooded backwaters areas, the suspended sediment settles out of the slowed-down water, resulting in a coating of mud when the water recedes.

The river also carries dissolved salts in solution. The amount of dissolved material is measured periodically by the Water Resources Branch of the U.S. Geological Survey at the Grand Forks gaging station. These measurements show that during the 1962 water year (October 1, 1961 to September

30, 1962) an average of 4,650 tons of dissolved solids were carried through Grand Forks-East Grand Forks every day (U.S. Geological Survey, 1964).

Based on limited available data, water quality in the headwaters areas of the Red River is fair, except for areas immediately below towns and major discharge points such as feedlots. As the river flows toward the international boundary, the water quality is steadily degraded and appears to be significantly affected by the larger communities. Water entering the Red River, particularly from the North Dakota side of the valley, contains high mineral concentrations of dissolved solids, sulfates, and chlorides.

The water quality of the Red River is affected by variations in flows in the river and its tributaries. During winter, it is common to have low dissolved oxygen concentrations in the river water when aeration is restricted by the ice and snow cover. In the summer, nutrient-rich agricultural runoff, which consumes oxygen, combines with prolonged periods of low flow to occasionally produce low dissolved oxygen levels. Such conditions seriously affect surface water supplies of good water, periodically kill fish and other aquatic life, and impair aesthetic and recreational values of the river.

Total dissolved solids in the Red River at Grand Forks-East Grand Forks average 565 parts per million. The recommended maximum value for total dissolved solids in drinking water is 500 parts per million. Red River water commonly exceeds maximum levels of state water quality standards for both North Dakota and Minnesota for fecal coliform, turbidity, and total hardness (Souris, Red, Rainy River Basin Commission, 1972).

FACTORS AFFECTING FLOODING

Flooding in this area is the result of several factors. During the winter, snow accumulates over the entire drainage basin, more than 30,000 square miles of land upstream from Grand Forks. Much of the snow and ice is retained until spring, when it is released more or less suddenly by melting. The effect is as if the precipitation for several months fell within a few days time. As this water is carried out of the basin by the Red River, at least some flooding usually occurs. The magnitude of the flooding depends on the amount of moisture stored in the drainage basin, how fast it is released by melting, how much can be absorbed by the ground, and how much water is added by spring precipitation.

Many factors affect this accumulation-melting-flood relationship. The most important ones can be divided into two groups: "Constant" and "Variable." The factors are discussed in the order of their usual importance.

"Constant" Factors: Basin and Channel Characteristics

We have already discussed some of the hydrologic and physical characteristics of the Red River Valley. The gentle northward slope of the river results in low streamflow velocities. As a result, the area drains slowly, increasing the likelihood of flooding. Moreover, the flatness of the lake bed allows floodwater to spread out over a large area. The effects of the northerly flow direction of the Red River have already been described.

Obstructions such as bridge foundations restrict the flow of water by constricting the channel. They also greatly increase the likelihood of ice jams. Although dikes do, in many cases, prevent floodwaters from inundating lowlands along the river, they also tend to restrict the river to a narrow, artificial channel. The net result is a slight increase in the height of the river just upstream from the dikes as the water is forced through a relatively narrow neck in the channel during floods.

Artificial drainage ditches facilitate draining of valuable farmland, but they also result in faster and more complete transfer of rainfall and snowmelt to the river. Water that was once stored on the flatlands bordering the river is now poured into the river during the critical spring thaws.

The rural road system plays an important role in determining the manner in which meltwater runs off the land. In many places where culverts are too small to handle a large flow, water becomes dammed against the roads, forming lakes in the northeast corners of the sections (on the North Dakota side of the river; on the Minnesota side, lakes form in the northwest corners of the sections as the regional slope is northwestward). Water then pours over the roads, washing out bridges and stripping the gravel off the road surface or even washing out the roads (fig. 7).

The expansion of urban areas has resulted in a decrease in the area available for infiltration (seepage into the ground), and it has increased the speed with which an area can drain, as a result of streets and sewers.

"Variable" Factors: The Weather

It is the interplay of climatological factors from year to year that determines the magnitude of individual floods. Flooding can occur at any time of year that temperatures are generally above freezing, but in this area, flooding usually occurs in early spring (see fig. 8). The high concentration of floods in late March and April is caused by the sudden melting of snow and ice, which accumulated throughout the winter. Flooding can occur in the summer months after an especially heavy rainfall over a large portion of the drainage basin. Most of the "summer floods," however, do not reach the flood stage of 28 feet and have little direct effect on the two cities.

Since 1882, only two floods over 40 feet have occurred later than April. One of these occurred in 1950, as floodwaters were receding from the April crest of 43.9 feet. An early May blizzard forced the river back up to a second crest of 45.6 feet. The second major summer flood occurred in July 1975, following an extremely heavy rainfall in southeastern North Dakota in late June. The July 14 crest was 43.08 feet. The flooding season is dependent on the factors involving temperature and precipitation, which are discussed below.

1. Snow Accumulation. The history of flooding in the Red River Valley shows that nearly all large floods were preceded by unusually heavy winter snowfall (fig. 9) or late spring precipitation, or both. However, there are other factors besides the amount of winter snowfall affecting the magnitude of spring floods.

2. Thaw Rate. Following a winter of unusually heavy snowfall, the factor that is most important in determining whether or not a large flood will occur is the rate at which the snow melts. The shorter the melting period, the greater the flow of the river must be to carry the meltwater away. Cool days with temperatures in the low 30s and night temperatures below freezing allow for slow release of the meltwater. However, an unusually cool or late spring with temperatures remaining below freezing is likely to be followed by a sudden warming trend which causes a rapid release of moisture. Floods occurring after April 15 are apt to be more severe than are earlier floods.

3. Precipitation During Thaw. The amount and kind of precipitation which falls during the thawing period is also important. Any precipitation, even snow, increases the quantity of water that must be drained by the river. Moreover, a warm rain during the thawing period results in much faster melting of snow and ice on the ground than does warm air.

4. Timing of Crests. The drainage basin of the Red River at Grand Forks-East Grand Forks is divided between the Red Lake River to the east and the Red River south of Grand Forks. In fact, the Red Lake River can account for as much as 40 percent of the flow during a flood (table 3). The timing of the flood crest on each of these rivers is controlled by factors within their respective drainage basins. If the crests from both of them reach the two-city area at the same time, the flood hazard is considerably increased.

5. Condition of the Soil. If heavy rainfall occurred in the fall of the previous year, the soil within the drainage basin is saturated with moisture when it freezes. It is therefore able to soak up very little moisture from the spring thaw. A wet fall, then, contributes to spring flooding by increasing the percentage of early spring moisture that must be carried by the rivers.

Like saturated ground, a frozen soil is unable to soak up moisture, increasing the percentage of runoff into the rivers. The colder the winter, the greater the depth of frost penetration into the soil, the slower the ground will thaw in the spring, and the greater the amount of runoff to cause flooding. The coldness of the winter also affects the amount of snow remaining when the spring thaw arrives. In Grand Forks the average depth of frost penetration is 4.5 feet, but it can be as deep as 7 feet

Figure 7. Damage to rural roads south of Grand Forks. A small bridge at the northeast corner of a section was washed out when floodwater breached the road surface. The lower photo shows how the gravel has been washed off the road into the ditch north of the road.

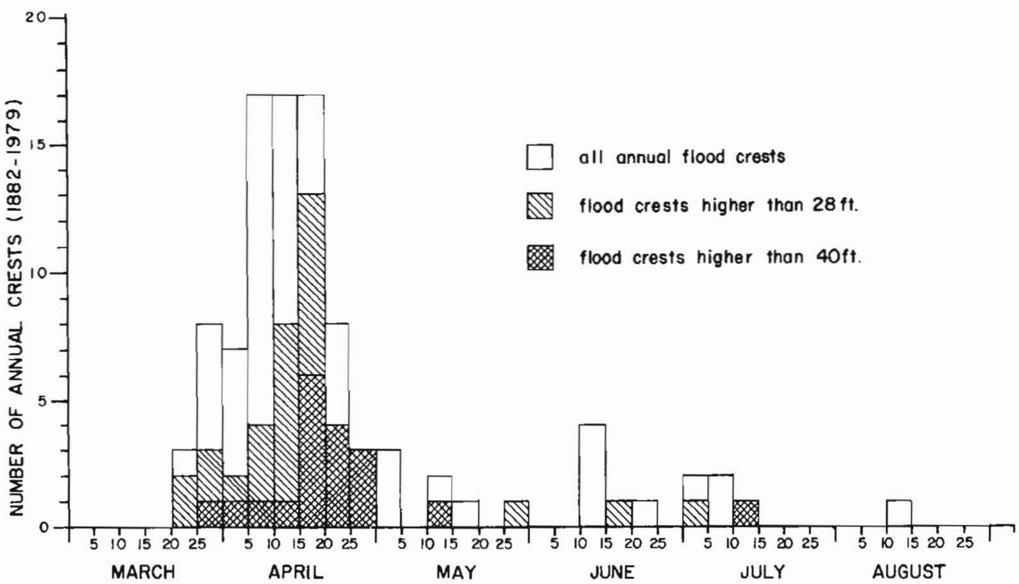


Figure 8. Time distribution of annual flood crests at Grand Forks-East Grand Forks.

(Jensen, 1974).

6. Ice Thickness. An unusually cold winter, especially if early winter snowfall is light, results in greater-than-average thickness of ice on the rivers. The thicker the ice, the longer it will remain on the river in the spring. Until the ice is cleared from the river, flow of floodwaters is impeded and threat of ice jamming remains.

Summary of Factors Affecting Flooding

From the above discussions, it can be seen that the optimum flood conditions for the Red River are: (1) an unusually wet fall, (2) an unusually cold winter, (3) unusually heavy winter snow accumulation, (4) an unusually late, cool spring followed by a sudden warming trend, and (5) widespread, heavy, warm rainfall during the thawing period. No one of these factors alone can cause a large flood. It is the interplay of all of them that determines just how large each spring flood will be.

FLOOD HISTORY OF GRAND FORKS-EAST GRAND FORKS

Pre-1882 Era

Information concerning floods in this part of the Red River Valley prior to 1882 is meager. David Dale Owen, traveling north on the Red River in 1848, noted that "Below the mouth of the Red Fork (Red Lake River). . .is found evidence of the power of ice in this river (Red River of the North) during the winter season. Fifteen, eighteen, and even twenty feet above the level of the river, in July, we observed the trees on the brink of the river, either barked or deeply cut into, and even entirely severed across" (Owen, 1852). The barking of trees, which he noted, was probably caused by blocks of ice floating in the floodwaters during spring breakup floods.

During 1853, no farming was done in the Red River Valley in the vicinity of Pembina because of the floods of the past three years (1851, 1852, and 1853). The 1852 flood is estimated to have reached a height more than 52 feet above our present Grand Forks gage datum, which is higher than any subsequent flood recorded in this area (U.S. Geological Survey, 1952). The worst floods known along the Red River occurred in 1824, 1825, and 1826. In 1826, the water rose to a height of 66 feet above the modern datum level near Pembina (the 1979 flood reached 53.7 feet), drowning out all the land. This flood was attributed to heavy winter snowfall, a cold winter, and rapid melting of snow and ice in April. Floodwaters did not recede until late July in 1826, and even the

Figure 9. Two common scenes in Grand Forks during the 1978-79 winter. Over 50 inches of snow fell between November 10 and early April. Almost all of this snow melted in the space of a few days. Photos by Lee Gerhard.

TABLE 3. Contribution of various tributary drainage areas to the Red River at Grand Forks-East Grand Forks (Adapted from U.S. Army Corps of Engineers, 1978)

Tributary	Drainage Area (percentage)	Annual Flow Volume (percentage)	Percentage of Total Flood Volume Contributed at Grand Forks-East Grand Forks for several selected floods				
			1948	1950	1965	1966	1969
North Dakota	41.2	15.8					
Wild Rice	6.9	2.9	1	2	3	3	12
Sheyenne	20.8	9.4	17	13	10	12	11
Elm	2.1	0.3	3	3	2	2	2
Goose	4.9	2.3	7	6	6	5	5
Minor Tributaries	6.5	0.9	7	7	0	3	2
Minnesota	58.8	84.2					
Bois de Sioux*	8.8	5.2	6	4	10	6	13
Otter Tail	8.1	12.0	5	3	5	6	6
Buffalo	5	5.2	3	4	6	7	6
Wild Rice-Marsh	8.3	13.4	4	6	12	12	9
Sandhill	2	2.7	3	3	4	4	3
Red Lake	20.6	44.2	32	38	40	36	27
Minor tributaries	6	1.5	12	11	2	4	4

*Includes 195, 360, and 1,533 square miles located in North Dakota, South Dakota, Minnesota, respectively.

bison disappeared from the Pembina area.

1897: The Highest Flood on Record

Grand Forks was settled about 1870. By 1882, a river-level gage had been installed near the Northern Pacific railroad bridge and accurate records of subsequent floods have been kept. The highest of the recorded floods in Grand Forks-East Grand Forks occurred in 1897, when water rose to a height of 50.2 feet above our present gage datum (fig. 10).

Several severe blizzards during the winter of 1896-1897 produced a heavy snow accumulation with drifts as deep as 20 to 30 feet, which nearly covered many houses. Warm weather came suddenly the following spring, and snowmelt water rushed into the rivers. The swift breakup produced ice jams, which increased flood stages. In the resulting flood, much of Grand Forks and East Grand Forks was inundated (fig. 11), many livestock were lost, and small buildings were washed from their foundations.

During the 1897 flood, a strip of country 30 miles wide and 150 miles long was inundated (Bavendick, 1952). Railway and vehicular bridges connecting the two cities were badly damaged and nearly lost. Four locomotives had to be placed on the Great Northern railroad bridge to keep it from being washed completely away. About 25 city blocks of cedar-block paving were damaged in Grand Forks, and in East Grand Forks business had to be suspended in all but a half dozen places. Water there was three feet higher than in 1882 when a steamboat landed on Third Street (Bavendick, 1952). Boats of all kinds were in great demand and many were hurriedly constructed during the flood. Steamboats carried provisions to stranded valley farmers; one of Grand Forks' two steamers was sunk on such a mission.

1950: Two Crests, One Flood

The 1950 flood is the sixth highest on record in Grand Forks-East Grand Forks, cresting at 45.61 feet above gage datum (fig. 12). Losses through-

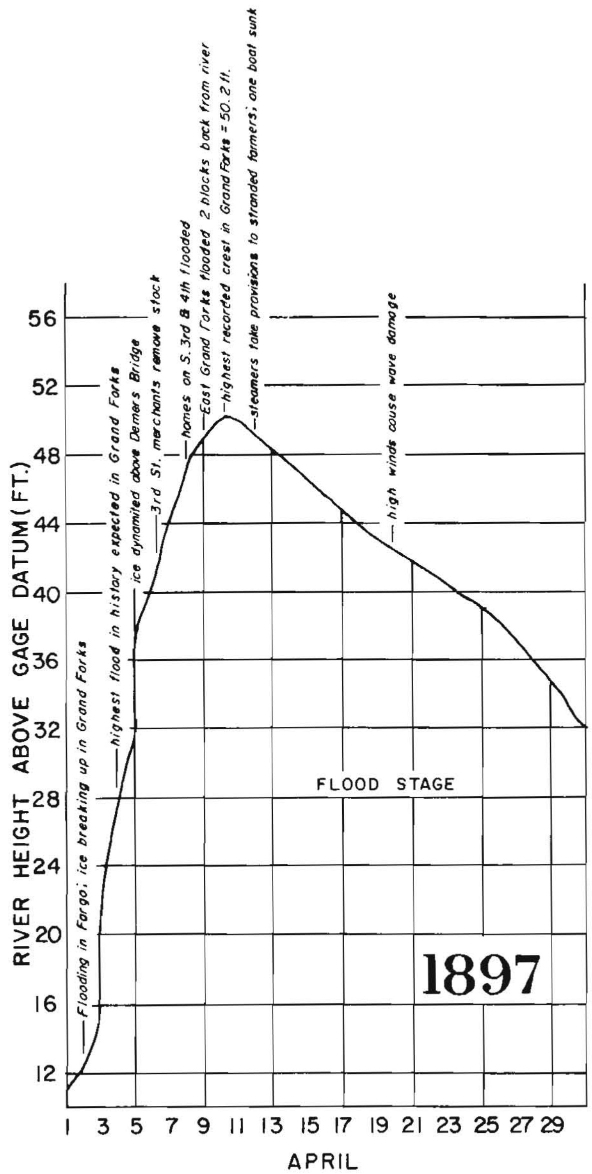


Figure 10. Hydrograph of the 1897 flood.

out the valley were estimated at $33,000,000 (about 52 million 1967 dollars). This flood was preceded by unusually heavy winter snowfall, later-than-normal spring melting, and heavy spring precipitation (Bavendick, 1952). In places, the valley was flooded to widths of 30 miles (fig. 13). In Grand Forks, 275 families had to be evacuated. Just as the first crest of the flood was receding in early May, heavy rain once again swelled the river, making this the longest duration flood on record in this area. Due to the prolonged flood, a critical livestock-feed shortage developed through the Red River Valley.

1965: Little Time to Prepare

In 1965, during the second week of April, the Red River began a sudden rise, peaking at 44.9 feet on April 17. The 1965 flood was triggered by heavy, widespread rainfall on deeply frozen soil. Damage was especially high in East Grand Forks, despite construction of an emergency dike consisting of

Figure 11. 1897 flood; view east from Sorlie Memorial Bridge in East Grand Forks. Photo owned by Charles Garvin, Grand Forks.

over 400,000 sandbags. More than 400 civilians, students, and airmen were needed to maintain and watch these dikes, which cost an estimated $182,000. In Grand Forks, the cost of dike construction, cleanup, and sewer repair totaled $26,000. Both cities were reimbursed for these losses by the Federal Office of Emergency Planning. Damages to all urban areas along the Red River during the 1965 flood amounted to over $3,000,000. Total flood damages in the Red River Valley were about 14 million dollars (1967 dollars).

1966: Spring Blizzard

Following the blizzard of March 3, 4, and 5, 1966, which dumped more than two feet of snow throughout the area (Grand Forks received about 31 inches) a prediction for a 48½- to 51-foot crest was issued by the Weather Bureau. Dike construction began immediately in both cities in anticipation of the near record-making crest. Cool weather caused slow melting, however, thus reducing the predicted flood threat to about 47 feet by the time dikes were completed. An eventual crest of 45.6 feet on April 4th (fig. 14) marked the third highest flood recorded in Grand Forks-East Grand Forks to that time and the second severe flood in two years. Although it was only about a half foot higher than the 1965 flood, the cost of flood protection and damage was about 20 times as great as in the preceding year. Reasons for this are probably (1) the crest was originally predicted to be as high as 51 feet, which necessitated building much higher temporary dikes than those of 1965 at far greater cost; (2) some existing dikes had to be made higher to accommodate the higher crest prediction; and (3) the slow rise of the floodwaters permitted much more extensive diking than in the previous year, again at greatly increased cost. Reimbursement to Grand Forks by the Office of Emergency Planning for dike construction, cleanup, and sewer damage amounted to $555,907. Similar payments to East Grand Forks totaled over $500,000.

1969: A New Record for the 20th Century

Heavy snowfall from October through February, during the winter

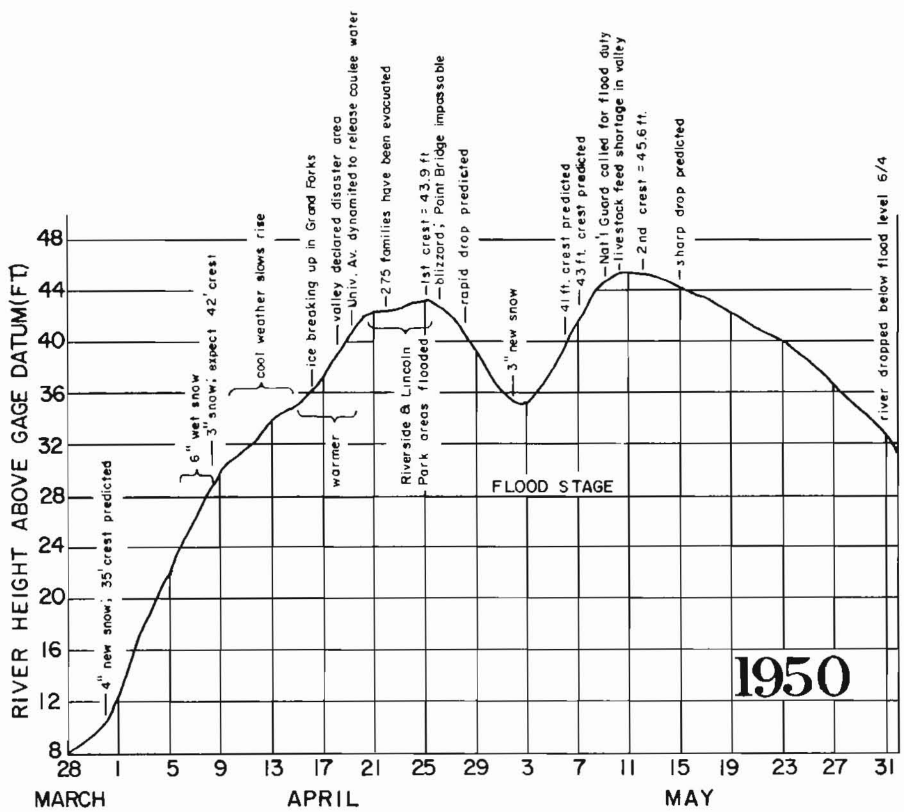


Figure 12. Hydrograph of the 1950 flood.

of 1968-1969, resulted in far greater than normal snow water content ranging from three to seven inches as of March 21, 1969. The heavy snow cover began to melt in late March, but it stopped melting during the first week of April when cold weather moved in. The resumption of melting during the second week of April was accompanied by widespread rainfall of one to two inches. The resulting runoff produced the record flood of the century to that time on the Red River and along most of its tributaries as far downstream as Grand Forks. During the 1969 flood, approximately 790,000 acres of farmland were flooded in North Dakota and Minnesota. Total damages throughout the Red River Valley were calculated at nearly 30 million dollars, of which 22 million were agricultural (values in terms of 1967 dollars).

1975: Two Separate Floods

In 1975, Grand Forks-East Grand Forks experienced both spring and summer floods. The April flood resulted from snowmelt and the July flood occurred as a result of rainfall ranging from 10 to 22 inches falling on already saturated soils during the period from June 28 to 30 (the 22-inch rainfall figure was recorded at Leonard, North Dakota). The July flood was far more disastrous than the April flood as thousands of acres of small grains and specialty crops were inundated, with crop losses running to several millions of dollars. Stagnant waters remaining after the flood subsided promoted mosquito infestations with the associated health hazard of infectious encephalitis. At least two deaths were directly attributed to the disease.

The spring flood of 1975 occurred during middle to late April (crest on April 23 at 43.30 feet). Several small communities in low-lying areas were flooded, and some of the larger cities suffered relatively high property damages. Urban damages throughout the Red River Valley were estimated at

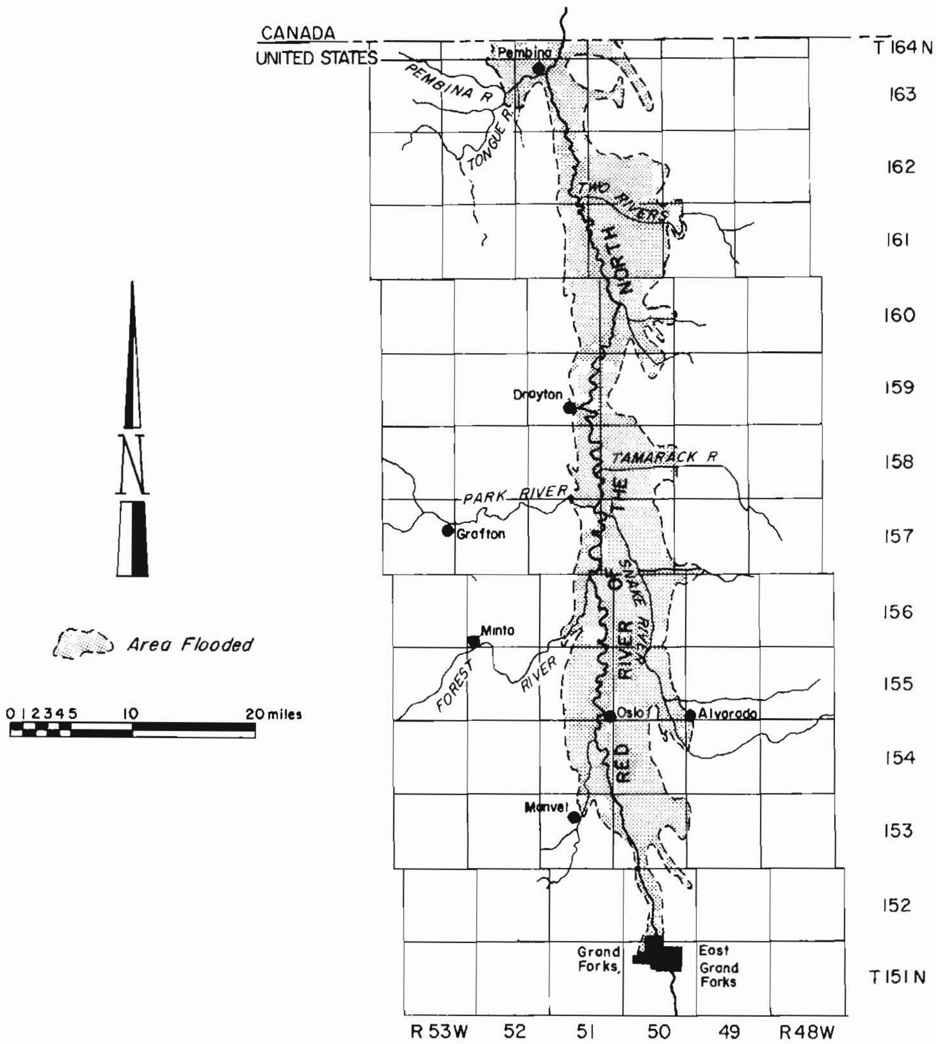


Figure 13. Flooded area between Grand Forks-East Grand Forks and the Canadian boundary during the 1950 flood.

approximately $1,300,000 ($800,000 in terms of 1967 dollars). North of Grand Forks-East Grand Forks, floodwaters overflowed agricultural areas, inundating flood-plain areas up to 10 miles wide where normal bank-to-bank widths are only 75 to 100 feet. The total flooded area was estimated at approximately 240,600 acres. The 1975 spring flood caused about $12,900,000 of rural damage. In addition to crop losses, many farmsteads were completely surrounded by floodwater, and some secondary roads became impassable.

The July flood occurred from June 28 through July 15, cresting in Grand Forks-East Grand Forks at 43.08 feet on July 14. It began without warning, the result of the heavy rains mentioned earlier. Several small towns on tributaries to the Red River suffered heavy flooding and high property losses. The total area inundated in the Red River Valley by floodwaters from both overbank and overland flooding during the July flood was estimated at 2,028,000 acres. Red River Valley area urban and rural damages were calculated at approximately $6,400,000 and $238,800,000, respectively ($4,000,000 and $148,100,000-1967 dollars). Of the rural damages, approximately 2 percent were to transportation facilities, 53

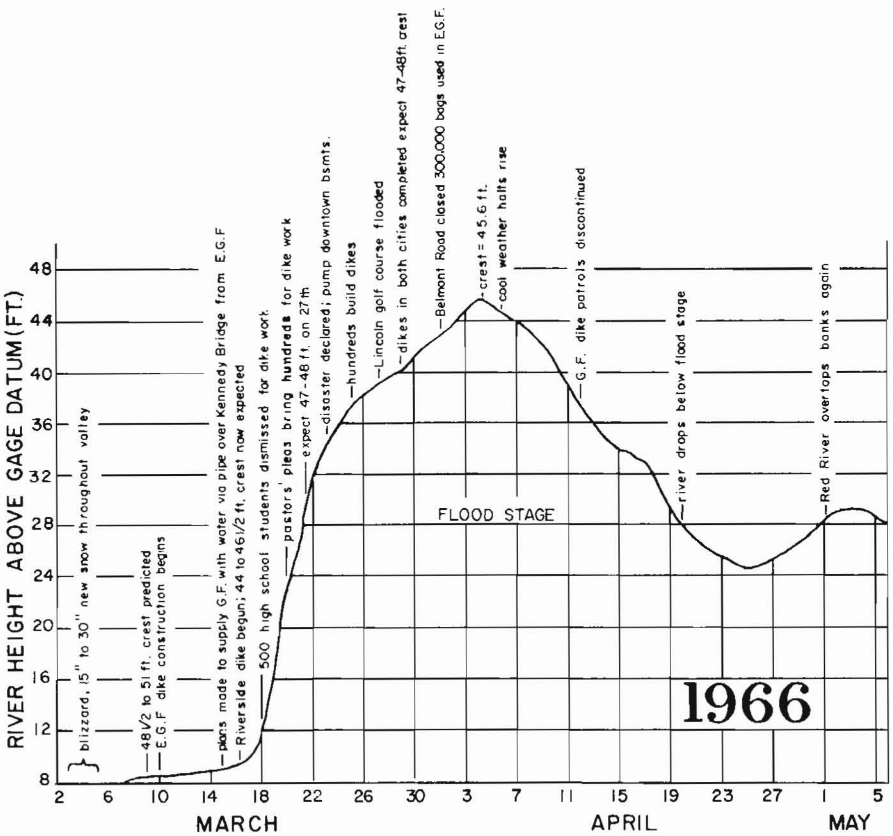


Figure 14. Hydrograph of the 1966 flood.

percent to crops, and 45 percent to farmstead properties such as buildings, machinery, and stored grains.

1978: Time to Prepare

Data on snowfall amounts, water content, soil temperature, and associated information collected during the winter of 1977-1978 led the National Weather Service to issue an initial flood outlook in mid-February indicating potentially serious flooding along the entire Red River and several of its major tributaries. This advance forecast gave federal, state, and local officials time to make emergency preparations before the flood, which spanned the period from March 24 to April 18. Several tributaries of the Red River were subject to flooding, and moderate flooding occurred along the Red River from Wahpeton-Breckenridge northward to Grand Forks. In the Grand Forks-East Grand Forks area, however, the flood was the highest of the century to that time (45.73 feet) and downstream at Oslo, Minnesota, the 1978 flood levels on the Red River were the highest ever recorded. North of Grand Forks-East Grand Forks, floodwaters spread out five miles wide, inundating farmland, roads, and rural homes. The agricultural levees on the Minnesota side were generally effective, and North Dakota levees were either breached, overtopped, or outflanked by floodwaters from the Red River tributaries on the North Dakota side. In the Red River drainage basin, a total of 553,000 acres of land was flooded. The 1978 spring snowmelt flood caused about $13,000,000 ($6,600,000-1967 dollars) in damages. Approximately 80 percent of this was sustained by the agricultural segment of the economy. The flood also claimed two lives. Advance planning, accurate forecasting, and emergency protective measures helped to minimize flood losses in the urban areas.

1979: The Worst Yet

The April 1979 flood is still a subject of considerable controversy as this analysis is written. Charges of inaccurate predictions by the National Weather Service; charges that drainage of wetlands and farm drainage ditches aggravated flood conditions; the unexpected flood by the English Coulee in Grand Forks--all of these and other considerations make it difficult to present an accurate "instant analysis" of a flood only recently subsided.

The soil throughout the Red River drainage area was reported to be low in subsurface moisture prior to the first snowfall in November 1978. This condition would normally have helped to minimize flooding. However, several factors combined to more than offset this single favorable factor. The winter of 1978-79 was unusually long and unremitting, with above-normal snowfall and a very late thaw. Winter unofficially arrived on November 10, with snow and cold. Except for a few days in mid-December, temperatures were below freezing continually for about five months. The Grand Forks-East Grand Forks area received about 54 inches of snow, about 20 inches more than normal, during the winter. This was equivalent to about 5 inches of water in the snowpack when the melt began during the second week of April, about a month later than usual. Virtually all of the snow that fell through the winter was still on the ground when the spring thaw arrived. The base of the snowpack had been transformed into a layer of ice several inches thick. Finally, nearly two inches of rain accompanied the mid-April thaw and very little sunshine was available during the thaw to help evaporate snow and runoff.

When temperatures rose suddenly into the 50s and 60s on April 16, the snow cover melted rapidly. Apparently, much of the water from the melting snow flowed over the frozen ground and over the basal icepack so rapidly that almost none of it was absorbed by the supposedly dry subsoil. Furthermore, the very rapid melt immediately saturated the uppermost fraction of an inch of topsoil wherever ice was not present. This resulted in swelling of the clay-rich soil, forming an essentially impermeable seal at the top of the soil zone. The meltwater flowed off over the sealed soil surface instead of replenishing the subsoil moisture supply. Had the melting been only slightly less rapid, the swelling of the surficial clay layer would have been much less effective in forming a seal. It would have dissociated and broken down, allowing a far greater percentage of the water to penetrate the soil zone. The soil did become saturated in areas where the runoff water accumulated, against the south and west sides of roads in the northeast corners of nearly all sections.

The April 1979 flood was characterized by an extremely rapid rise of the Red River (fig. 15). The crest of 48.81 feet came on April 26. Many farmsteads and communities--Warren, Minnesota, and Emerado, North Dakota, for example--were inundated by "flash" floods of runoff water from nearby fields, not by the river itself. In Grand Forks, the rapid runoff caused a severe flood on the English Coulee, a situation few people anticipated (for a separate analysis of the English Coulee flood, see app. 3).

Flooding in 1979 was severe in parts of Grand Forks that have not often been greatly affected by past Red River floods. Parts of Walnut and Chestnut Streets at 15th Avenue South were flooded (figs. 16 through 22) when a lift station failed. Water backed up across South Forks Road near Schroeder School, flooding parts of the Terrace Drive area, the President's Park Trailer Court, and the Sleepy Hollow area.

The 1979 Red River flood resulted in damages of $91,000,000 (about 44 million 1967 dollars) in North Dakota and Minnesota. Damages to city of Grand Forks property were estimated at $1.2 million ($580,000 1967 dollars). It drove an estimated 7,500 people from their homes in North Dakota alone; 6,000 North Dakota residences were damaged by the flood (no Minnesota figures are available as this is written). Five million sandbags were used in the two cities during the flood and costs of fighting the flood totaled over two million dollars (all the dollar figures given here are preliminary estimates). Reimbursement to Grand Forks by the federal government for costs of repair and flood-fighting efforts have amounted to approximately $1,300,000 as this report is written.

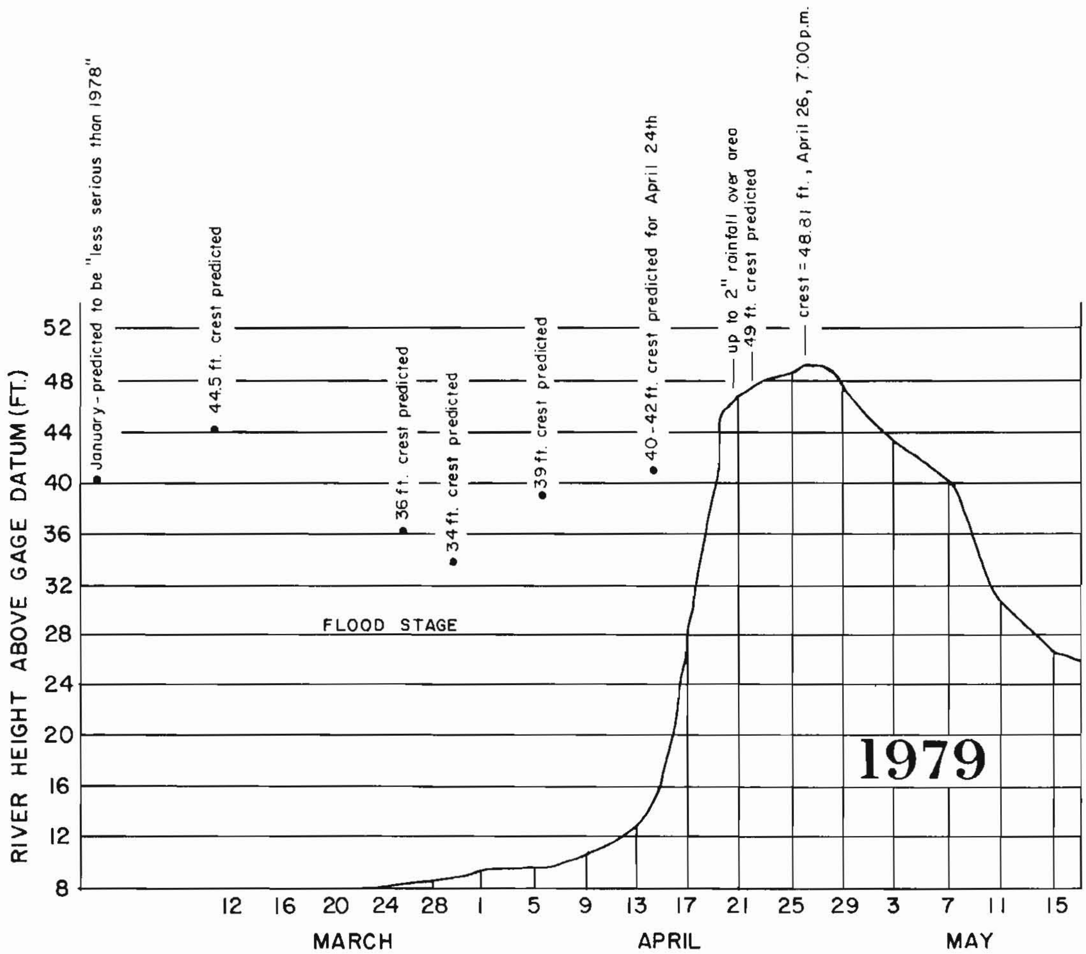


Figure 15. Hydrograph of the 1979 flood.

Similar payments to East Grand Forks total about $1,000,000.

THE LOCAL FLOOD HAZARD

Although the Red River officially reaches flood stage at a gage reading of 28 feet, little damage is done in Grand Forks-East Grand Forks until a river height of 35 feet is surpassed. At crests above 40 feet, damage is considerable, necessitating sandbagging and evacuation of some residential areas. This involves considerable expense to the community, the federal government, and a few unfortunate individuals. It is important, therefore, to know how often floods of a certain magnitude can be expected, how fast the floodwaters will rise, what areas will be flooded and for how long, and what effects future floods will have on public transportation and utilities. These problems will be discussed in the following pages.

Magnitude of Past Floods

The magnitude of the peak annual floods from 1882 to 1979 is shown on page 28 (fig. 23; also see apps. 1A and 1B,). The twelve worst floods are summarized on table 4. The highest known flood in this area, which occurred in 1852, crested at about 51 feet above gage datum. Although Grand Forks-East Grand Forks was not yet settled at that time, the height of this flood has been interpreted from historic records (U.S. Geological Survey, 1952).

Figure 2. Riverside Park area showing sandbag dike. The expense of building massive sandbag dikes can be staggering. This dike (picture taken after the water receded) is near Riverside Pool, which was permanently closed as a result of damages sustained during the 1979 flood. Over 5 million sandbags were used in Grand Forks-East Grand Forks in fighting the 1979 flood.

Figure 3. Riverside Park area showing dike cleanup. The cost of cleaning up after a flood is also considerable. Volunteer labor generally "dries up" as soon as the crest is reached. This dike is in the Riverside Park area.

Figure 16. Belmont Road near Lincoln Park Golf Course (1500 Block) during the 1979 flood. View to the north. Photo by Lee Gerhard.

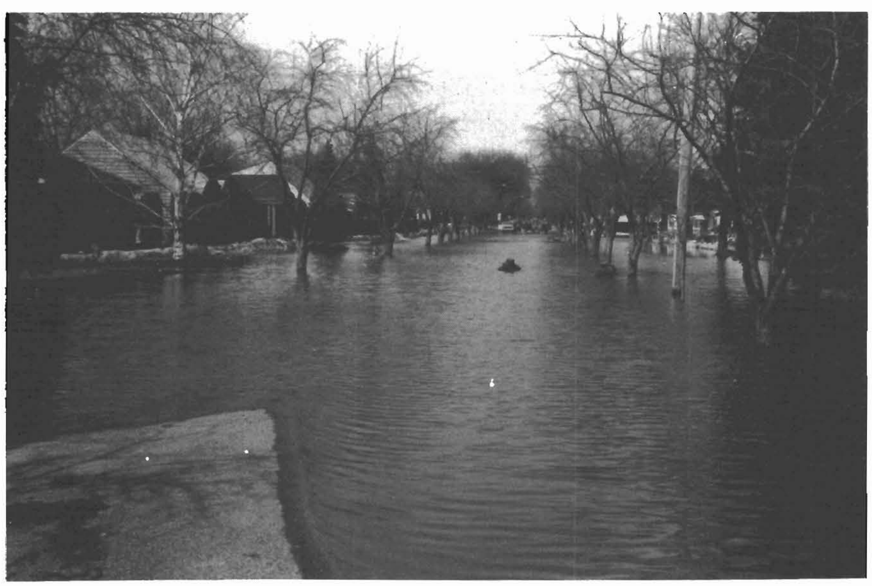


Figure 17. Walnut Street at 15th Avenue South during the 1979 flood. Photo by Lee Gerhard.

Figure 18. Belmont Road at the 1300 Block. View south, during the 1979 flood.

Figure 19. Flooded area of the Lincoln Park Golf Course during the 1979 flood.

Figure 20. An air view of the Riverside Drive area during the 1979 flood. Four homes were heavily damaged there during the 1979 flood when a dike gave way. The expense of protecting these homes from nearly every flood has been a point of considerable controversy. Photo by Lee Clayton.

Figure 21. A flooded area along Terrace Drive in southern Grand Forks during the 1979 flood. This area and others, such as the homes flooded by the English Coulee near the United Hospital, are examples of recent housing developments in areas that might have been more logically left in their original condition--cattail sloughs. Photo by Lee Gerhard.

Figure 22. Downtown Grand Forks (lower left) and East Grand Forks at a 49-foot river level (April 26, 1979). Both ends of the DeMers Avenue Bridge are submerged. Photo by Lee Clayton.

The graph (page 28) indicates that the magnitude of floods is somewhat cyclic. Periods of lower-than-average flooding occurred during the late 1880s, about 1900, 1911, middle 1920s, middle 1930s, and early 1960s. These lows probably correspond to periods of less precipitation, especially the low-flood period of the 1930s. The peaks of the high-flood cycles are separated by periods ranging from 10 to 30 years, though the common interval is about 12 years. These flood cycles probably reflect similar cycles in the average annual precipitation, the ultimate control of which might be the shifting of the high-altitude jet stream, sunspots, or other poorly understood phenomena.

Rate of Rise of Floodwater

The rate at which the river rises during flooding is dependent upon the flood factors discussed previously. The rate of rise of the Red River at Grand Forks-East Grand Forks during past floods is shown on figure 24.

The rate of rise generally decreases as the river height increases. This is due to the rapid spreading of the river over the flood plain once its banks are overtopped. As a result of this widening of the channel, a greater volume of water is needed to increase the river height from 25 to 30 feet than from 20 to 25 feet. The relationship can easily be seen on the discharge-river height curve for the

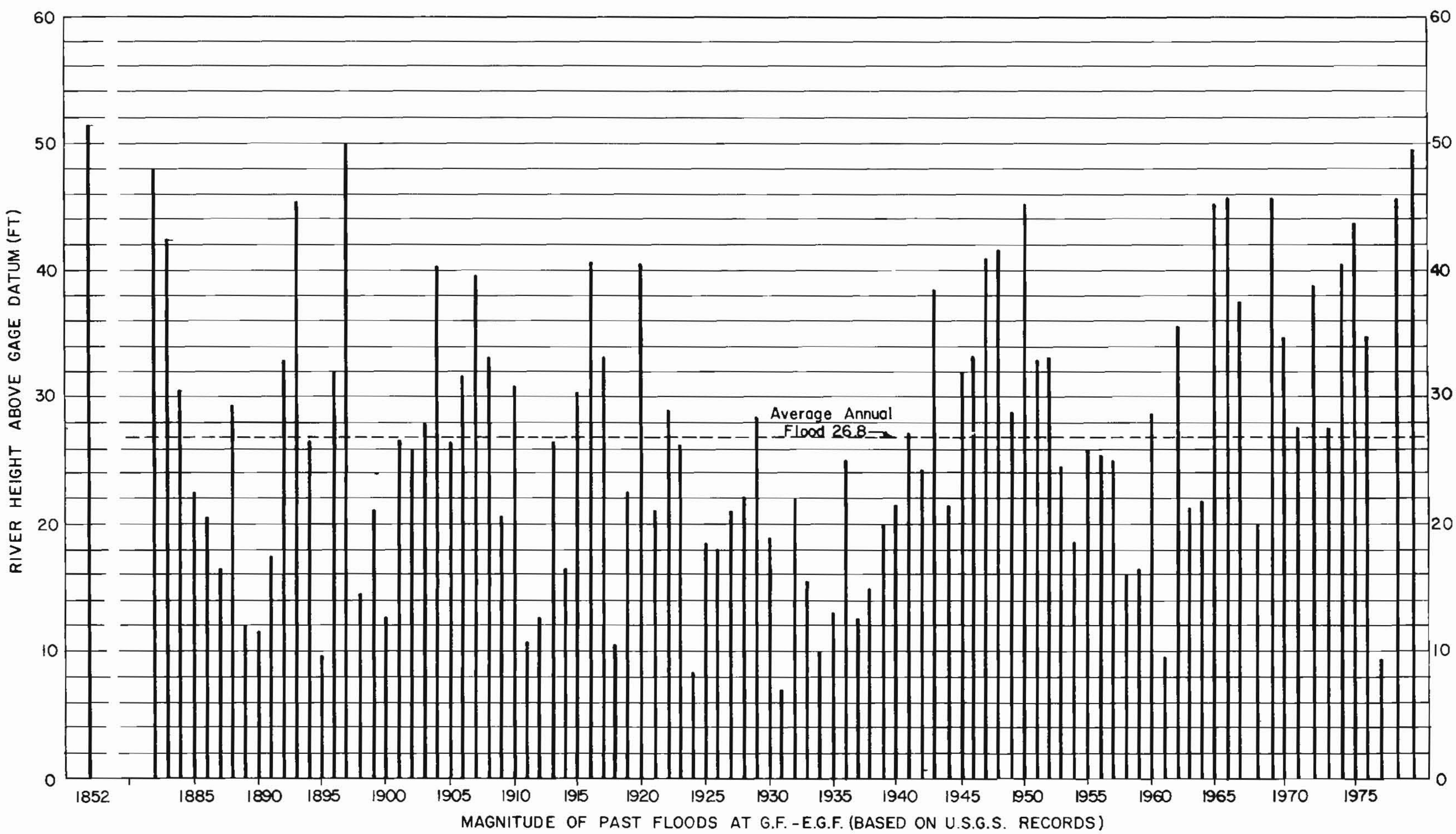


Figure 23. Magnitude of past floods at Grand Forks-East Grand Forks (based on U.S.G.S. records).

TABLE 4. Historic floods (since 1882--when gage was installed)

RANK	HEIGHT	YEAR	PEAK DISCHARGE[a] cubic feet/second (cfs)
1	50.2	1897	100,000[b]
2	48.81	1979	82,000
3	46.3	1882	68,000
4	45.73	1978	54,200
5	45.69	1969	53,500
6	45.61	1950 (May)	54,000
7	45.55	1966	55,000
8	44.92	1965	52,000
9	43.8	1893	53,300
10	43.8	1950 (April)	43,800
11	43.3	1975 (April)	42,600
12	43.08	1975 (July)	42,700

[a]Cubic feet per second (cfs) is a measure of the rate of flow past a specific point within a given time period (one cfs for a duration of one day would amount to water one foot deep over two acres of land). The floodwaters from the April 26, 1979 flow had a discharge of 82,000 cfs at Grand Forks-East Grand Forks. The floodwaters for just that day would have covered 164,000 acres to a depth of 1 foot (or a single section--640 acres--of land to a depth of 250 feet).

[b]The peak discharge figure for April 10, 1897, is simply an estimate based on known discharge figures for the 1979 flood. The 1897 flood was previously estimated at 80,000 cfs, but this was based on known discharge figures for the 1950 flood as no discharge figures were calculated at the time of the 1897 flood. Similarly, the 1882 discharge figure is an estimate.

The 50.2 gage reading for the 1897 flood is probably correct. All eyewitness accounts attest to a higher level for the river in 1897 than in 1979. For example, farmers living east of Buxton report that the river extended nearly three miles farther west over farmland in 1897 than during the 1979 flood. This is just about what would be expected if the river level were a foot higher.

Red River at Grand Forks-East Grand Forks (fig. 25).

According to the discharge-river height curve, a discharge of 3,000 cubic feet per second is needed to raise the river from 20 to 25 feet, whereas 4,500 cubic feet per second are required to raise it from 25 to 30 feet. To raise the river from 45 to 50 feet would require an increase of about 50,000 cubic feet per second (at 45 feet, flow is 52,000 cfs; at 50 feet it is about 100,000 cfs). Note that the slope of the curve is much more gentle above the 28-foot height than below it. The 28-foot height corresponds to flood stage--the height at which water begins to overflow the banks of the river and greatly increases the width of the channel; at this height, the river is flowing at 32,000 cfs. This same relationship is verified by the graph (fig. 26) showing the increase in width of the Red River at Riverside Park as the water rises.

In some areas of the United States, especially the arid portions, flash floods are a hazard. In these

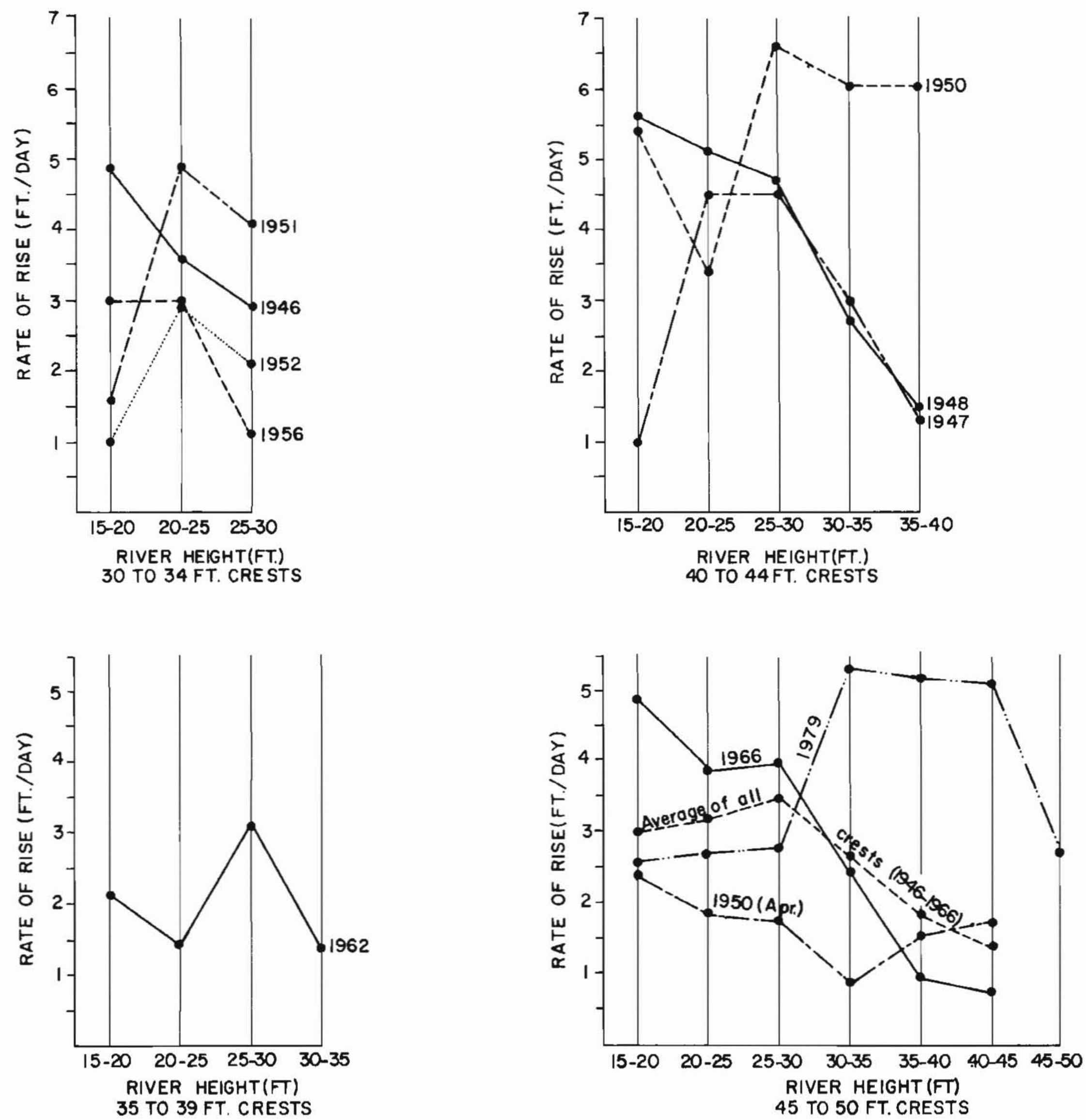


Figure 24. Rate of rise of river during floods of various heights.

areas, the length of time between the river's flood stage and its flood crest is usually short, perhaps only a few hours. In the Red River Valley, however, flash floods are not usually a problem, except on smaller streams. Overland flows resulting from rapid melting of snow cover or from heavy rainfall can result in flood situations such as those in several small towns and rural areas during the 1979 melt. The rapid rise on the English Coulee in south Grand Forks is probably the nearest thing to a "flash flood" likely in this area.

Usually, several days elapse between the time the Red River tops its banks and reaches its crest. This is especially true of the larger floods, those over 40 feet. The flood-to-peak time interval for several of the larger floods in the two-city area has ranged from 6 to 17 days; in 1979 it was nine days.

Flood Frequency

One useful relationship that can be

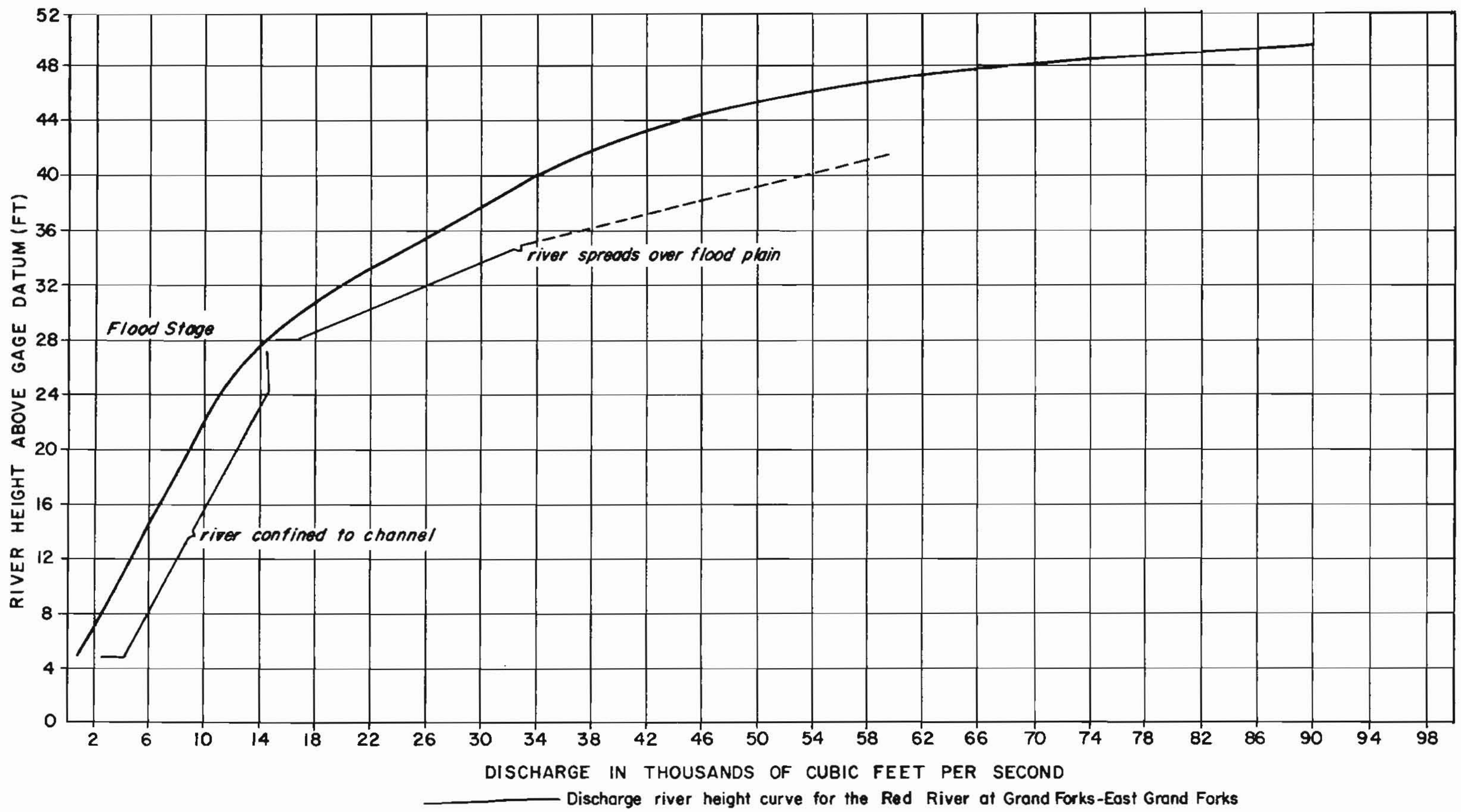


Figure 25. Discharge river height curve for the Red River at Grand Forks-East Grand Forks.

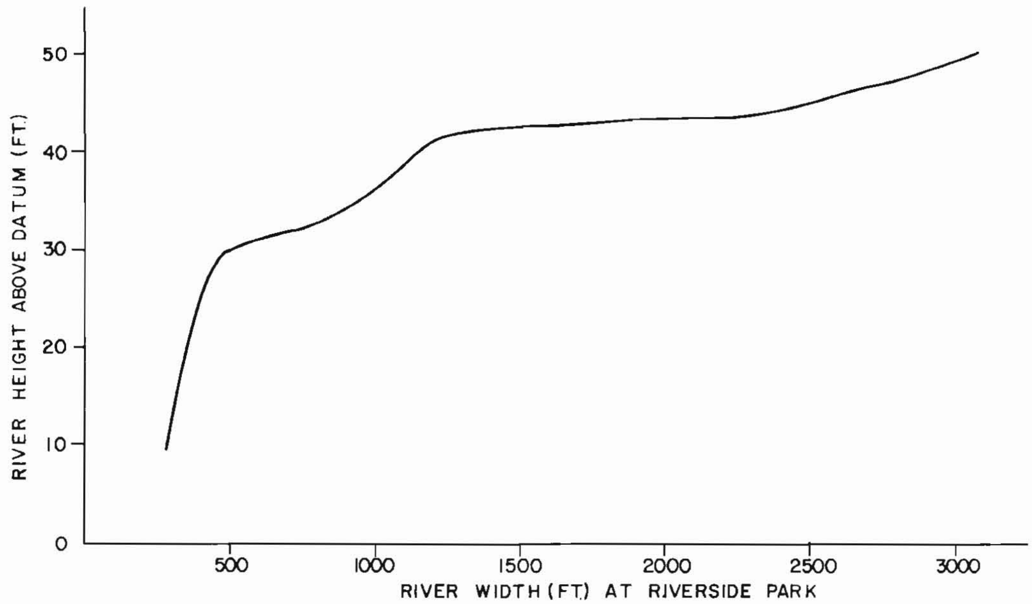


Figure 26. River width at various heights at Riverside Park.

derived from flood records is that of flood magnitude (height or volume of flow) to flood frequency (Dalrymple, 1960). The rank and height of each flood since 1882 is shown on appendix 1B. A flood-frequency graph (fig. 27), based on rank and recurrence interval of all known floods was derived from these records.

The flood-frequency curve (fig. 27) shows that a crest above flood stage can be expected to occur, on the average, about every 2½ years. Floods of less than 40 feet, however, do little damage in this area. A flood 40 feet high or higher can be expected to occur on the average about one year out of seven. This does not mean that seven years must separate each of these floods, but that over a 70-year period, about 10 floods of this magnitude or greater may be expected.

The flood-frequency graph (fig. 27) is an approximation, based on the rank and recurrence interval of known floods since 1882. Recurrence interval is calculated using the U.S. Geological Survey formula: years of record + 1 divided by rank of flood equals recurrence interval. The Grand Forks-East Grand Forks flood record goes back 98 years; so, for example, the 1979 flood, which is the second highest-ranking flood, has a recurrence interval of (98+1) 2=49.5 or approximately 50 years. Therefore, it falls at the 50-year point on the curve. Similarly, a 43-foot flood should have a recurrence interval of about 10 years according to the graph. We see that the 10th-ranking flood, in 1975, crested at 43.30 and the recurrence interval for that flood can be calculated: (98+1) 10=9.9.

Graphs like the one shown on figure 27 have some interest, but they should not be taken too seriously. It is especially important to keep in mind that the recurrence interval is merely a statistical curiosity that has no bearing whatsoever on what may happen during any given year.

The chance of a flood over 45 feet high occurring in any one year is about 1 in 18. These floods, such as the flood of 1979, cost hundreds of thousands of dollars for flood protection and damage in Grand Forks-East Grand Forks.

A flood 50 feet high or higher can be expected about every 70 years; or, the chance that it will occur in any given year is about 1 in 70. A flood of this magnitude has not occurred in Grand Forks since 1897. The recurrence interval of floods more than 50 feet high can only be estimated.

Estimating future floods is a chancy undertaking, at best. The highest flood that might be expected

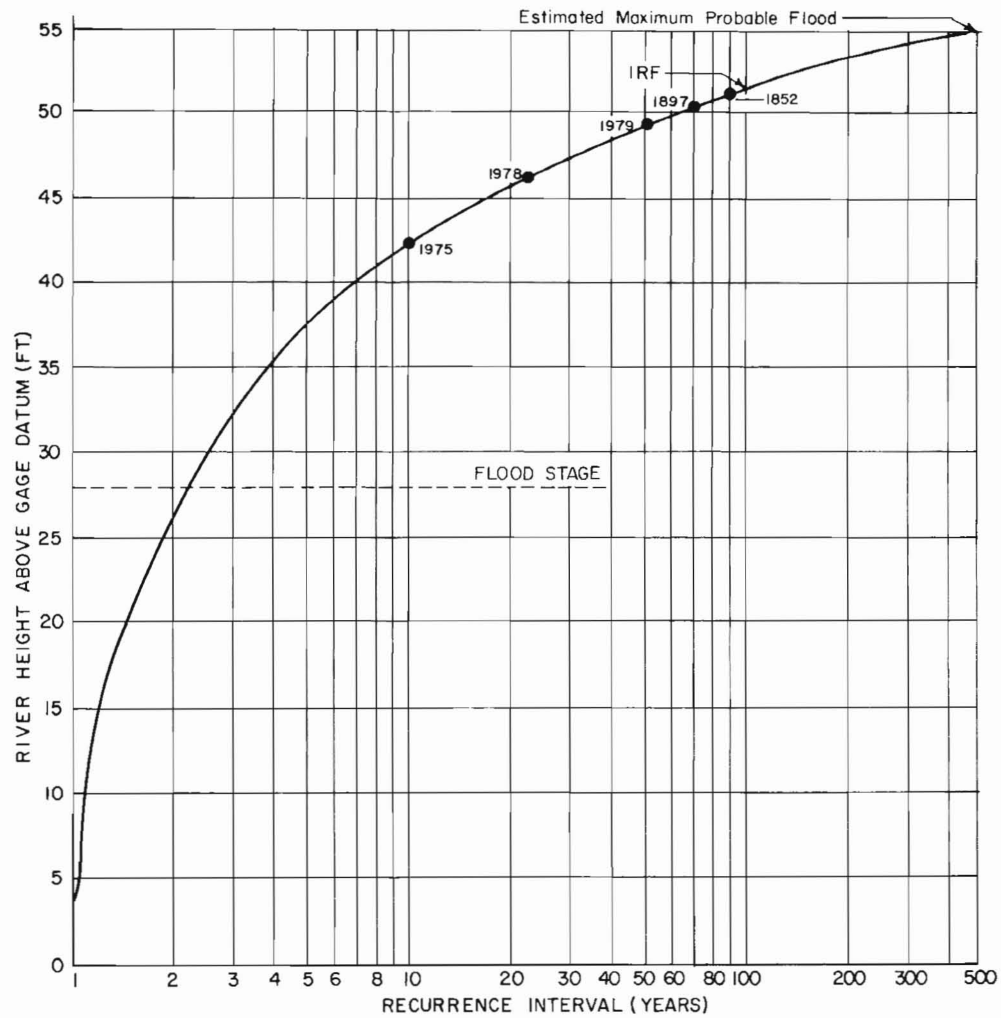


Figure 27. Flood frequency graph for the Red River at Grand Forks-East Grand Forks.

once every hundred years on the average is defined as the Intermediate Regional Flood (IRF), although such a flood could occur any year; it has a 1 percent chance of occurring in any given year. The peak flow and height of this flood have been developed from statistical analyses of streamflow and precipitation records, as well as runoff characteristics for the river and its tributaries. The Intermediate Regional Flood is one with a discharge of about 117,000 cfs and a gage reading of 51.4 feet (table 5).

The 500-year flood represents a reasonable upper limit of expected flooding in the Grand Forks-East Grand Forks area. It can be defined as the major flood that can be expected to occur once in 500 years on the average, although it could occur in any year. It would occur as a result of the combination of the most severe meteorological and hydrological conditions considered to be reasonably possible in the Red River of the North drainage basin. In other words, it is the volume of flow that would be expected, assuming all flood-producing factors are at their worst. The estimate of this flood is expressed as a river discharge of 146,800 cfs (table 5). The discharge-river height curve (fig. 25) was extended mathematically to give a rough estimate of the height of the maximum probable (500-year) flood--about 55 feet above gage level.

While frequency can be statistically

TABLE 5. Maximum discharge and elevation comparisons (theoretical predictions)

Flood at Grand Forks-East Grand Forks	Discharge (cfs)	Elevation (ft)	River Reading (ft)
500-year flood	146,800	833.4	55.0
Intermediate Regional Flood (100-year flood)	117,000	829.8	51.4
1979 flood	82,500	827.5	48.81

The figures above are those calculated by the North Dakota Geological Survey. The U.S. Geological Survey calculates that a regional flood would have a discharge of only 89,000 cfs, an elevation of 829.2, and a river reading of 50.8. In view of the fact that a river reading of 48.81 (1979 flood) is equivalent to a flow of 82,500 cfs, the USGS flow and river reading figures seem to be somewhat out of step with one another.

defined for each flood of the past and, within limits, projected for the future, it should be emphasized that the period of record for the Red River of the North at Grand Forks-East Grand Forks is relatively so short (98 years), that it is difficult to accurately assign a frequency figure for a large flood that has not yet been experienced. Thus, the frequency derived for a 500-year flood reflects the best judgment of hydrologists who are familiar with the area and with its hydrological and meteorological characteristics. It must be regarded as approximate and should be used with caution in connection with any planning of flood plain use. Floods larger than the 500-year flood can occur in any year, although the combination of factors necessary to produce such large flows would be extremely rare. Flood-frequency estimates assume present climatic and land-use conditions. Climatic conditions can shift substantially within periods of time less than 500 years.

Effects of Flooding

Some of the effects of both past and hypothetical floods are listed on table 6. These effects were determined from historical records and from the flood-extent map (in pocket in back) and will be discussed later. Only the more important effects are listed, with emphasis being given to the relationship of flood heights to transportation, public utilities, large residential areas, and flood-protection dikes. The city of East Grand Forks has prepared a flood-fighting manual documenting the effects of the 1979 flood at various flood levels and indicating what should be expected at a given level. The city of Grand Forks has no such plan at the present time.

Table 6 shows that relatively little damage is done by floods less than 40 feet high, which occur, on the average, during one year in seven. At a river height of about 40 feet, many downtown merchants experience basement seepage and find it necessary to use sump pumps, and in some instances, to remove their stock.

At a river height of about 42 feet, most of Riverside, Central, and Lincoln Parks are inundated and several residences require protection in the form of sandbag dikes. At about 45 feet, the Minnesota Point bridge becomes flooded (fig. 28). The DeMers Avenue (Sorlie) Bridge becomes impassable when the water reaches 48 feet (fig. 22). Also, at this height, the river is level with the top of the permanent East Grand Forks dikes.

All railroad bridges become impassable at river heights over 50 feet, though this has happened only once since 1882. Residences protected by the Lincoln Park dike would theoretically be safe until the river surpasses a height of from 52 to 53 feet. At a river height of 55 feet, the estimated maximum probable height the river could reach in this area (the so-called "500-year flood"), the greater part of both cities would be inundated by shallow water unless drastic emergency

TABLE 6. Effects of various flood heights on residential and business areas, public utilities, and transportation

Recurrence Interval	Gage Reading	Elevation	Effects
	0.0	778.4	Gage datum
2½	28.0	806.4	Flood stage--Red River begins to overflow banks
4	34.0	812.4	Water over roof of Red River water pump house
7	40.5	818.9	Seepage in business district basements
10	42.0	820.4	Riverside, Central, and most of Lincoln Parks flooded in Grand Forks
18	45.0	823.4	Belmont Road at 15th Ave. requires diking to protect homes
40	47.0	825.4	Several homes in Riverside Park area flooded if not protected--water up to the intersection of N. 3rd and 5th Ave. N. in Grand Forks--some homes on Elm Ave. and Woodland Ave. in Central Park area require protection
45	48.0	826.4	DeMers Ave. Bridge impassable--water reaches top of East Grand Forks dikes--much of the Point in East Grand Forks flooded--parts of downtown Grand Forks flooded
70	51.2	829.6	All railroad bridges impassable--this is the estimated height of the 1852 flood
150?	53.6	832.0	Water reaches top of Lincoln Park dike
500?	55.0	833.4	This is the estimated maximum probable flood for the two-city area--the greater part of both cities would be covered by shallow water

sandbagging was undertaken.

Extent of Floods

A generalized picture of the extent of floodwaters in Grand Forks-East Grand Forks is shown on the flood-extent map (in pocket in back). The extent of floods having a recurrence interval of 10 and 100 years is shown along with the estimated extent of the maximum probable flood. Areas that would be inundated by each of these hypothetical floods were determined by tracing the elevation of each flood, beginning at the Riverside Park gaging station and working upstream. An increase in river height of about one foot was allowed between the gage site and the south end of Grand Forks. The exact gradient of the river in this area during floods varies somewhat with each flood. The value used by the Grand Forks City Engineers is about ½ foot per mile. Synchronous measurements of water level made during the 1966 flood indicate a drop in the river surface of about 2 feet between the south end of East Grand Forks and the old gaging station at Riverside Park (Floan, written communication). Therefore, the gradient of approximately 1 foot that was used in delineating the flood extent on the map is probably somewhat conservative.

The 10-year flood (43 feet high), shown by the darkest shade of blue color band on the map, is well above the banks of the rivers and spreads over the flood plain producing a river width ranging from about 600 feet near DeMers Avenue to about 2,300 feet in the vicinity of the Lincoln Park Golf Course. The constriction of the river near DeMers Avenue probably causes a steeper gradient during floods than is normal and hence tends to increase the height of the river upstream from that point. Dikes, such as those located at Lincoln Park and throughout East Grand Forks, have the same effect.

Figure 28. Minnesota Point, East Grand Forks. The end of the Minnesota Point Bridge and nearly all of the roadway of the Red Lake River Bridge were submerged during the April 1979 flood. The river level shown here is approximately 49 feet. Photo by Lee Clayton.

The additional extent of a 30-year flood (47 feet) is not shown on the flood-extent map. Except in Lincoln Park and the residential area lying north of DeMers Avenue in East Grand Forks (now protected by dikes), the additional area flooded by a 30-year flood is only a few hundred feet wide, indicating little spreading of the water beyond the 10-year level. This suggests that in most places the water, in rising from 43 to 47 feet, is impinging on a relatively steep valley wall, which borders the flood plain.

The additional large areas inundated by the Intermediate Regional Flood (the 100-year flood--51.4 feet) are in the vicinity of 15th Avenue South and Belmont Road, Central Park, downtown Grand Forks, River Heights, the area near Schroeder Jr. High School, the Minnesota Point area of East Grand Forks, and the general area just north of the two cities. These areas are shown in medium blue on the flood-extent map. With the exception of the 15th Avenue South and Belmont Road areas, most of this zone lies at or below the confluence of the two rivers, indicating a broader flood plain downtown.

The maximum probable flood (500-year flood), estimated at approximately 55 feet above gage datum, would likely cover most of both cities with shallow water (areas shown in light blue on the flood-extent map). Only areas lying above 833 feet on the north end of town and above 835 feet on the south end would escape inundation. Few areas are this high, however. Most of the upland along the river in this area lies between 832 and 833 feet above sea level.

Two profiles, one drawn through Riverside Park and the other through Central Park, are shown on figure 29. The location of these profiles is shown on the map by lines A-A' and B-B'. The extent of inundation in these areas is indicated for gage readings of 30, 45, 51.4 (Intermediate Regional Flood) and 55 (500-year flood) feet.

It should be apparent that, when the river is "artificially" confined by the construction of permanent or temporary dikes, the size of the channel is diminished (fig. 30). For this reason, dikes tend to raise the river level, both upstream from the dikes and at the point the dikes are built. They also tend to increase the flow velocity of the river, tending to increase its destructiveness.

Obviously, temporary dikes are necessary to protect already-developed areas, but they will always be an expensive, stop-gap measure in areas that would be better left undeveloped, except as parks, etc., to flood without interference and undue expense and damage.

The approximate levels that the 100-year (51.4 ft.) and 500-year (55 ft.) floods might be expected to reach at various locations in Grand Forks and East Grand Forks are shown on the following series of photographs (figs. 31 to 42). These levels are theoretical and they disregard the effects of diking. Generally, however, it should be possible to successfully protect most of the areas shown from the 100-year flood.

FLOOD FORECASTING

Forecasts of flood crests allow time for precautions to be taken to reduce flood damage. The prediction of flood crests for the Red and Red Lake Rivers involves evaluation of all the flood-producing factors discussed earlier. These include: (1) slope, size, and shape of the drainage basin, (2) condition of the soil, depth of frost, and ice thickness on the river, and (3) snow accumulation, spring precipitation, and time and rate of spring thaw. Past flood records are used to develop the predictions.

For the Grand Forks-East Grand Forks area, official outlooks and flood predictions are issued by the National Weather Service River Center in Kansas City. An "outlook" is based on actual conditions existing prior to the spring runoff; a "forecast" is an attempt to predict a specific crest and crest date based on actual conditions of melting and precipitation. The computer modeling technique used by the Weather Service to project floods is based on a variety of factors and conditions, but it assumes "normal" weather conditions between the time the prediction is made and the projected crest date. Forecasts are updated if "normal" conditions do not occur. Specific factors used in the predictions are: (1) amount of moisture in the soil at time of freezing, (2) water content of snow cover before spring runoff, (3) amount and type of precipitation during spring runoff, (4) temperature pattern during spring runoff, (5) depth of frost, and (6) ice in stream under a northerly flow.

Soil moisture, water content of snow, and frost depth can be measured accurately throughout the drainage basin well in advance of the flood. Precipitation and temperature pattern during the spring runoff, however, can only be predicted by extended weather forecasts. By considering a range of possible temperature and precipitation conditions during the spring runoff, a range of expected flood crests can be made several days or weeks in advance of the flood. For instance, in 1966, following the March blizzard, a prediction was made for a 48- to 51-foot crest more than one month before the actual crest occurred. This advance warning provided ample time for extensive protective measures to be taken. After the advance prediction was made, the range of the expected crest heights was decreased every few days as temperature and precipitation fluctuated.

On the other hand, in 1979, flood-crest predictions were erratic due to changing weather conditions and the unusually late thaw. The National Weather Service issued its first "outlook" in January of 1979. At that time, they expected flooding to be less serious than in 1978. In early March, the Weather Service predicted a crest of 44½ feet, assuming normal tempera-

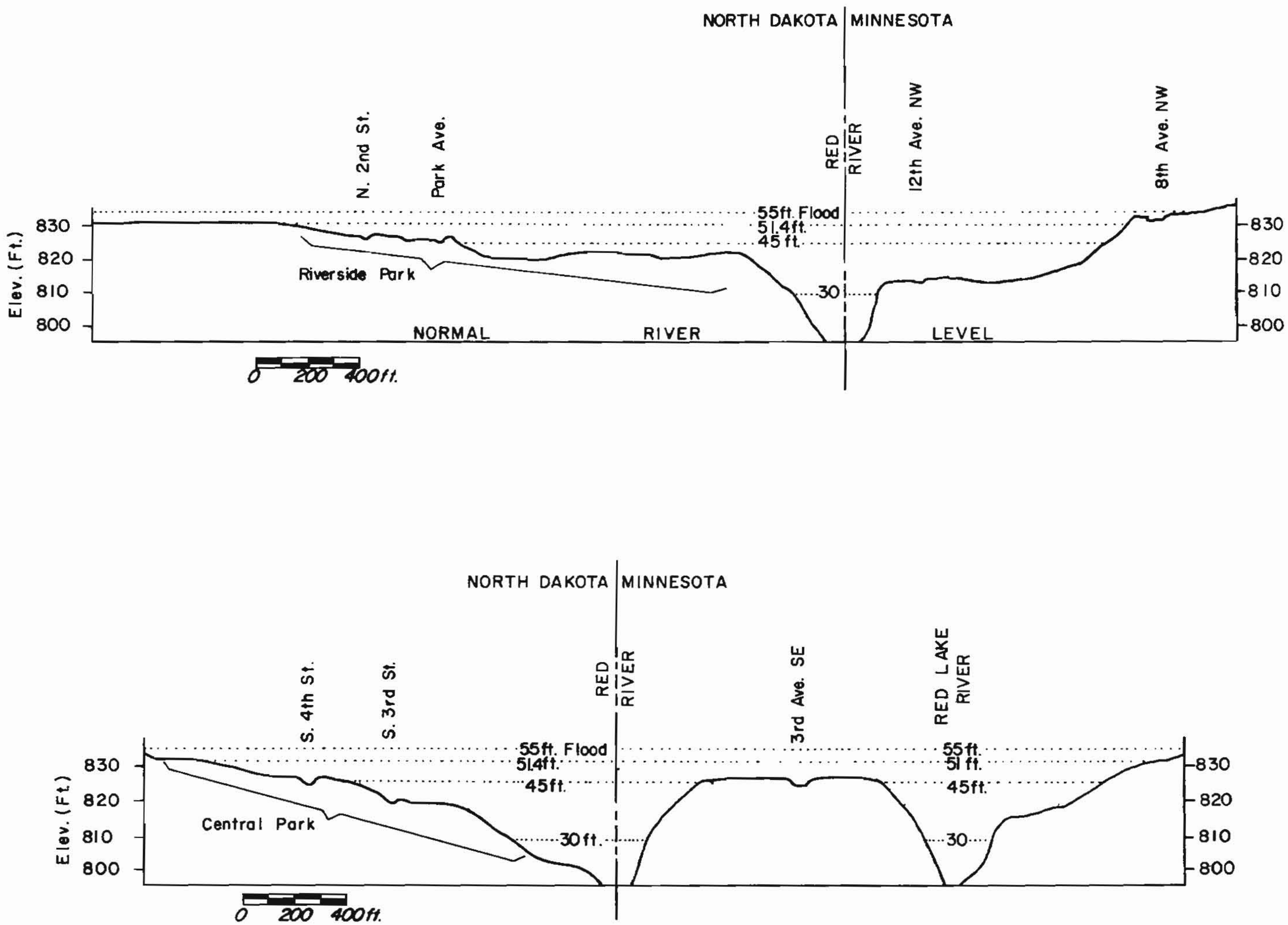


Figure 29. Profiles of the flood-hazard areas in the Riverside Park vicinity (A-A', above) and in the Central Park vicinity (B-B', below), both in Grand Forks.

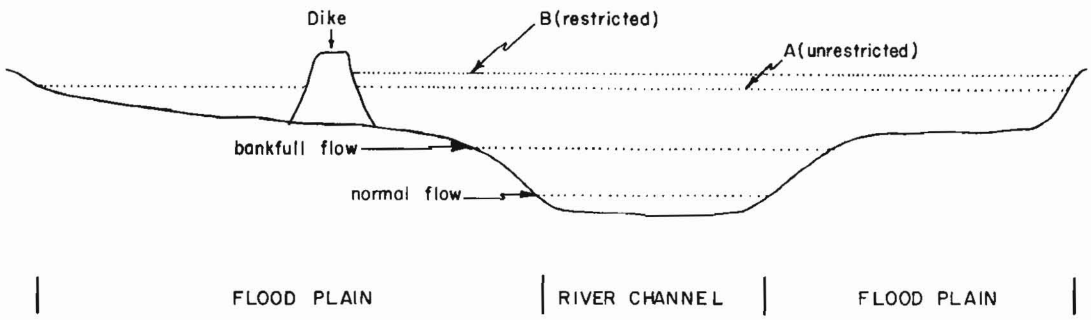


Figure 30. Diagram showing the effects of diking. This diagram shows that, without a dike, the river will flow at the level marked A (unrestricted). If a dike is built, that water which would have flooded the land protected by the dike is forced to flow within the dike. Most of this water contributes to raising the river to a new, higher level, B (restricted), although some of it helps to increase the river's velocity and some adds to flooding additional land upstream from the diked area.

tures and precipitation. On March 25, the prediction was revised downward to 36 feet and on April 1 it was revised downward again to 34 feet.

However, on April 6, the Weather Service predicted a 39-foot crest on the Red River at Grand Forks-East Grand Forks. Then, on April 13, the Weather Service predicted a 40- to 42-foot crest on April 24. A week later, on April 22, the Weather Service predicted a 49-foot crest for April 23 (by that time the river was already over 48 feet).

A diagram illustrating the accuracy of National Weather Service flood-crest predictions (fig. 43) shows the erratic nature of the 1979 predictions. Ideally, the "prediction curve" should be a relatively smooth line predicting fairly accurately, quite early, and approaching the correct crest as the crest date is neared. However, changing conditions, such as the prolonged cold or additional precipitation, may result in drastic, periodic revisions in the forecasts.

FLOOD DAMAGE REDUCTION

The solution to the flood problem is not simply to remove all structures from the flood plains and prohibit any future development (fig. 44). There are many definite advantages for developing (occupying) the flood plains, despite the flood hazard (Murphy, 1958). The problem, however, is that once individuals have developed the flood plain they subject the local community to considerable financial loss. If the individuals bore the entire flood-damage loss themselves, flood-plain development would be of little concern to the government--except as a moral responsibility to the individual who suffers due to his disregard of the flood hazard. Rarely, however, does the individual accept the full responsibility. Governmental units usually bear the expense of flood fighting, evacuation, damage to private property, and repair of public utilities. Heavy public investment often must therefore follow private investment on flood plains. These developed areas are a potential permanent drain on the economy of cities. Intelligent planning and regulating of development in these flood-plain areas is imperative, therefore, if damage from flooding is to be reduced.

Possible Means of Reducing Flood Loss

The following methods are usually employed to reduce flood losses (Murphy, 1958).

1. Engineering works: levees, reservoirs, channel enlargement and straightening, and channel bypasses. This is usually thought of as the best solution to flood problems. Experience has shown, however, that such protection is usually economically impractical.
2. Regulation of development: not necessarily prohibiting development, but defining the type of land use of the flood plain.
3. Adjustments in structures:

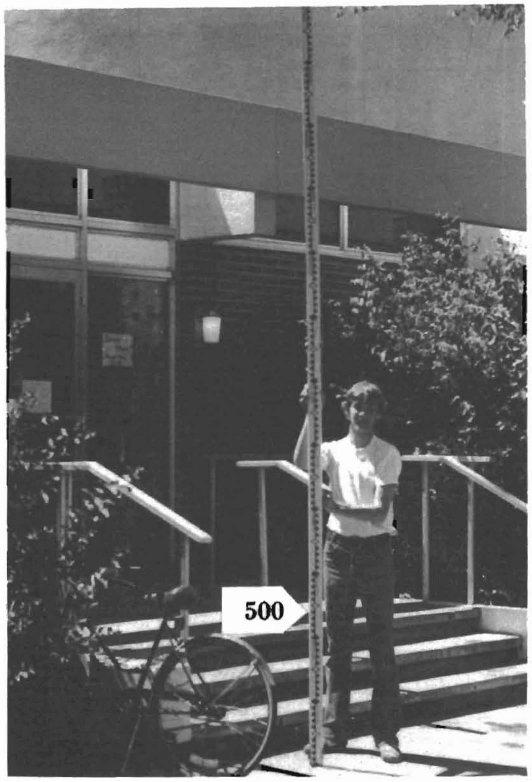


Figure 31. Expected level of the 500-year flood at the East Grand Forks Public Library-City Hall complex. The 100-year flood should not cause serious problems at this point.

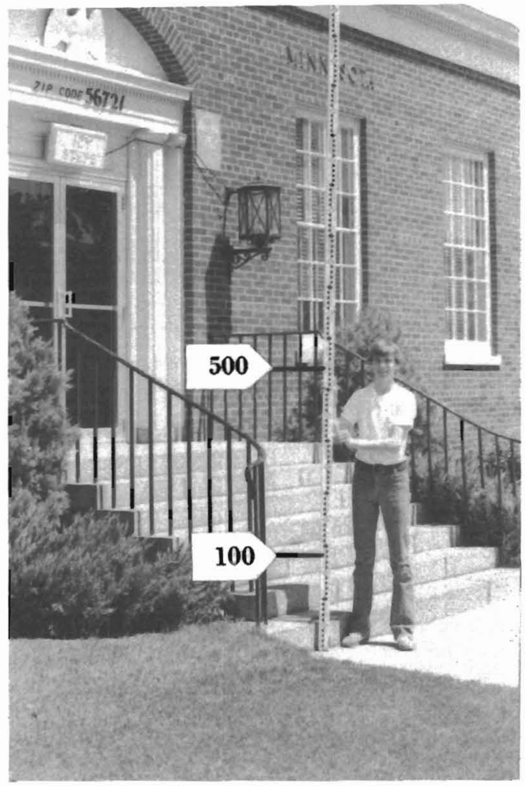


Figure 32. Future flood heights at the East Grand Forks Post Office. Dikes should protect the Post Office from a 100-year flood.

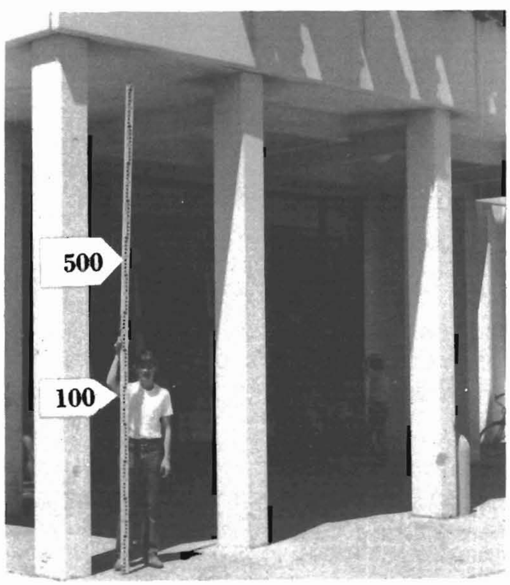


Figure 33. Future flood heights at the Holiday Mall in East Grand Forks. Dikes should protect Holiday Mall from a 100-year flood.

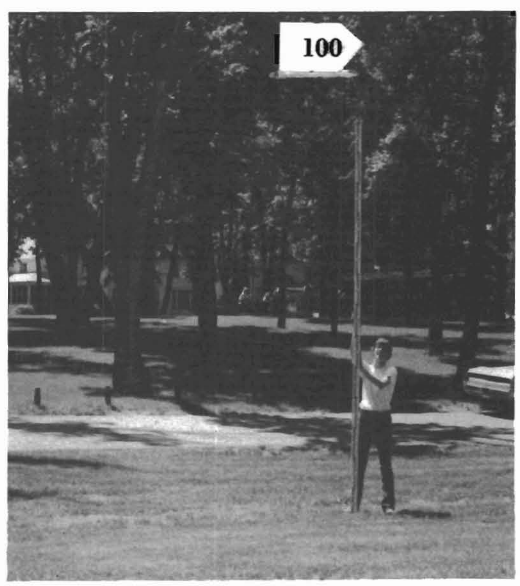


Figure 34. A 100-year flood in Sherlock Park in East Grand Forks is about 3 feet above the top of the rod. A 500-year level is off the photo.

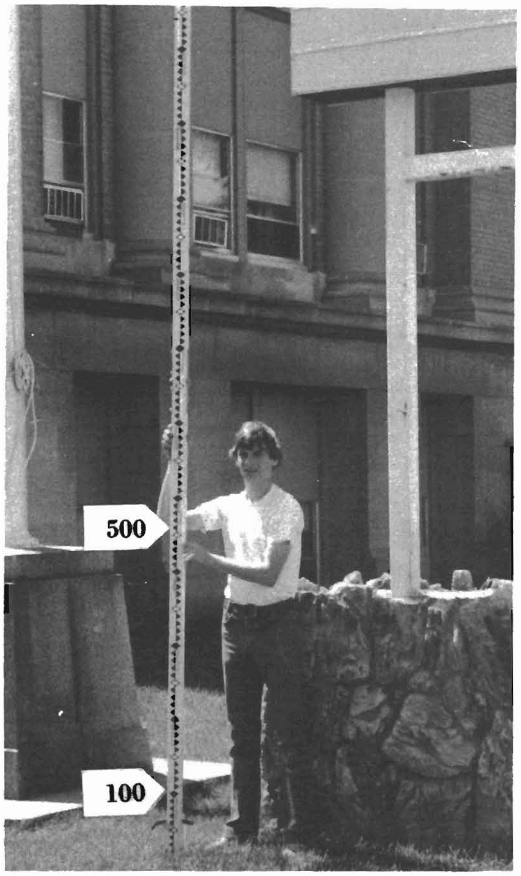


Figure 35. Expected level of the 500-year flood at Central High School in Grand Forks. The 100-year flood should not cause serious problems at this point, aside from possible sewer damage.

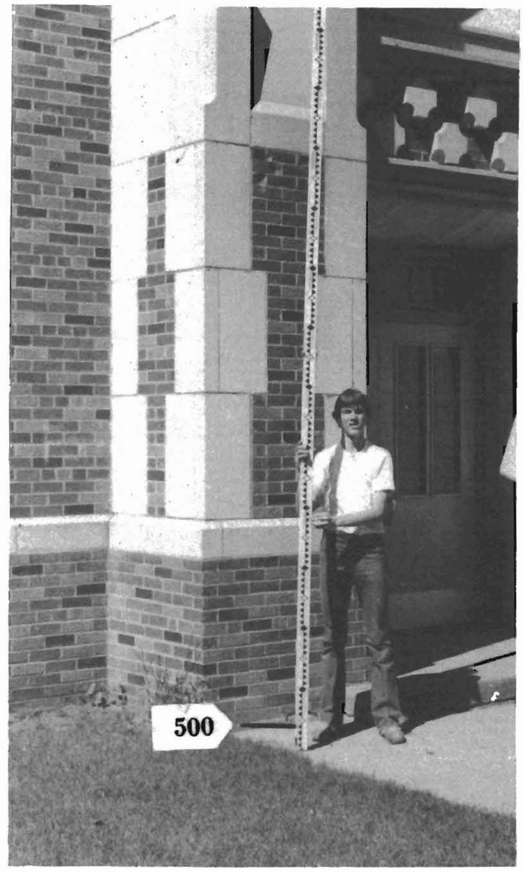


Figure 36. Expected level of the 500-year flood at South Junior High School in Grand Forks. The 100-year flood should not cause serious problems at this point.

including landfill, changing the design and layout of buildings, elevating equipment, water-proofing structures, etc. This is generally referred to as flood-proofing.

4. Emergency measures: temporary evacuation of flooded areas and rescheduling of services, transport routes, etc.

5. Loss protection: flood insurance may sometimes be available from the federal government to distribute losses.

Only after careful study of the problem can the best, most economical solution for reducing flood losses be found. In most instances, a combination of the above methods is applied.

Existing Flood Protection

Permanent flood protection in both cities consists entirely of flood levees, locally referred to as dikes. In 1958, the U.S. Army Corps of Engineers constructed a dike in the Lincoln Park area of Grand Forks consisting of 5,160 feet of earthen levee and 770 feet of concrete floodwall, as well as associated interior drainage works (fig. 45). The top of this dike is at an elevation of 832.0 feet at the north, or downstream end, and 832.5 feet at the upstream end. This dike should provide adequate protection from floods up to about 52 to 53 feet above gage datum, which is about the level of the Intermediate Regional Flood. The area behind the Lincoln Park dike is protected from back-flooding through storm sewers by an emergency pumping system. The total cost of the Lincoln Park dike, including construction, relocation of homes, and land purchases, amounted to $1,307,000, of which $940,000 was paid by the federal government.

Emergency levee works constructed

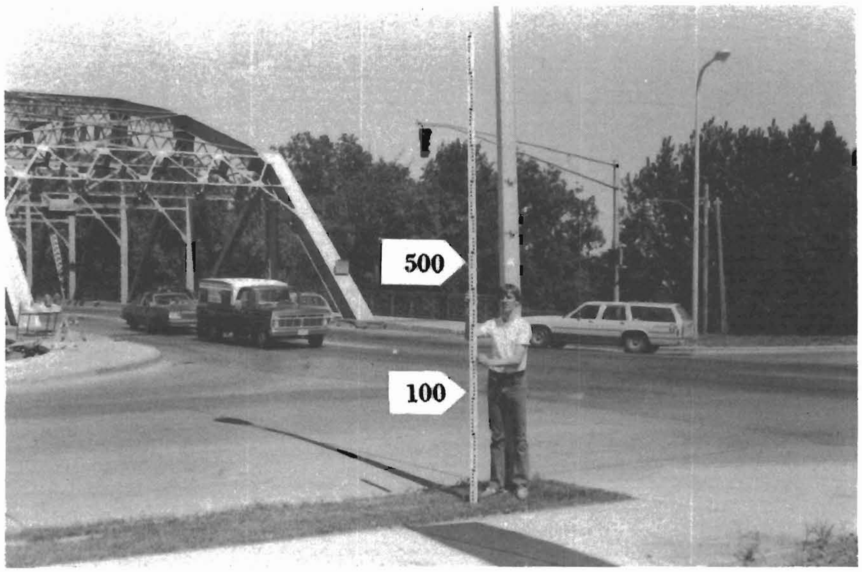


Figure 37. Future flood heights at the Grand Forks end of the Sorlie Bridge on DeMers Avenue.

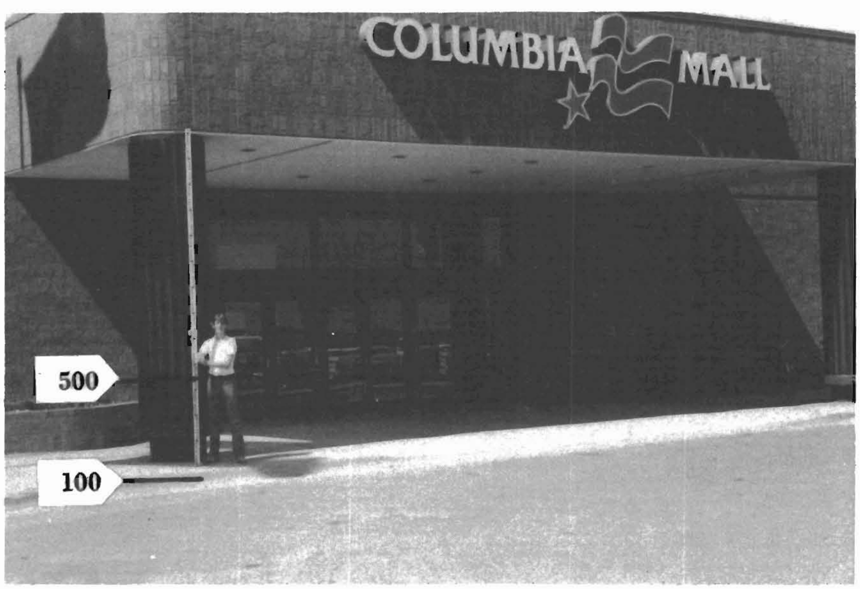


Figure 38. Future flood heights at the Columbia Mall in Grand Forks. The levels shown here correspond to readings on the Red River. English Coulee flooding is not taken into account.

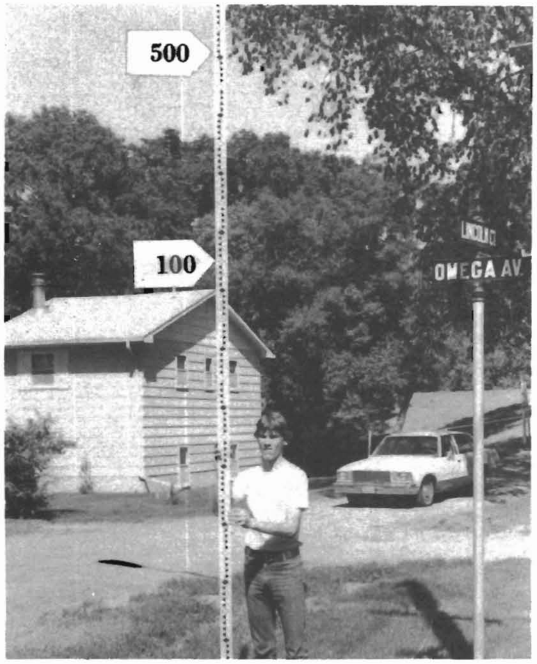


Figure 39. Expected flood heights at the corner of Omega Avenue and Lincoln Court in Grand Forks. This area is protected by a dike and it should be possible to withstand a 100-year flood. It is doubtful that the area could be protected during a 500-year flood.

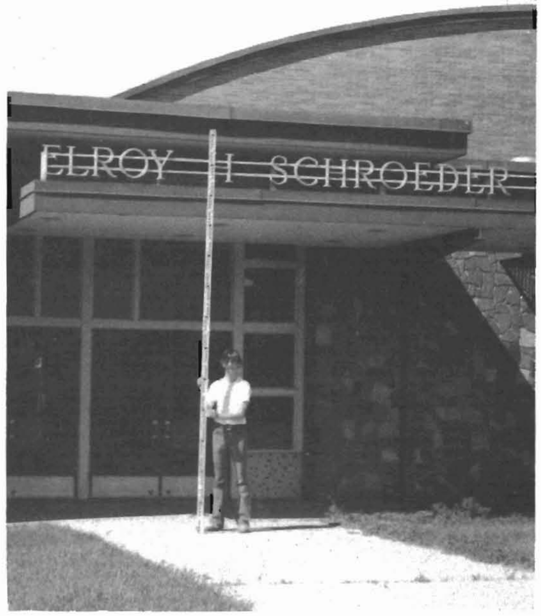


Figure 40. A 500-year flood would reach a level about 2½ feet below the base of the stadia rod shown here at Schroeder Junior High School in Grand Forks. However, extensive flooding would occur nearby.

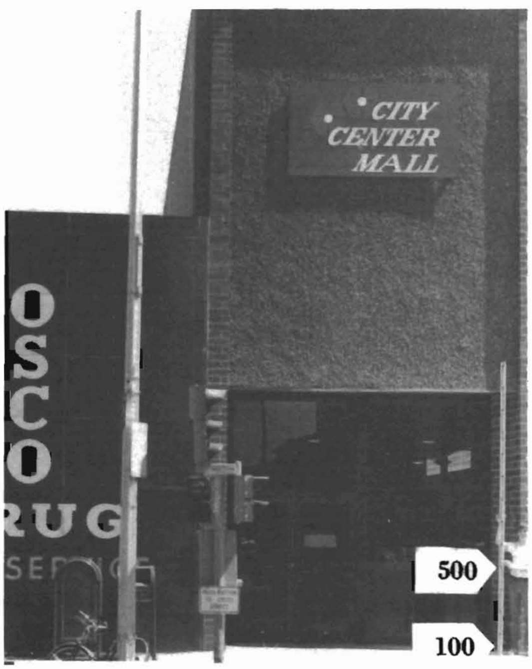


Figure 41. Expected levels of the 100-year and 500-year floods at the north entrance to the City Center Mall.

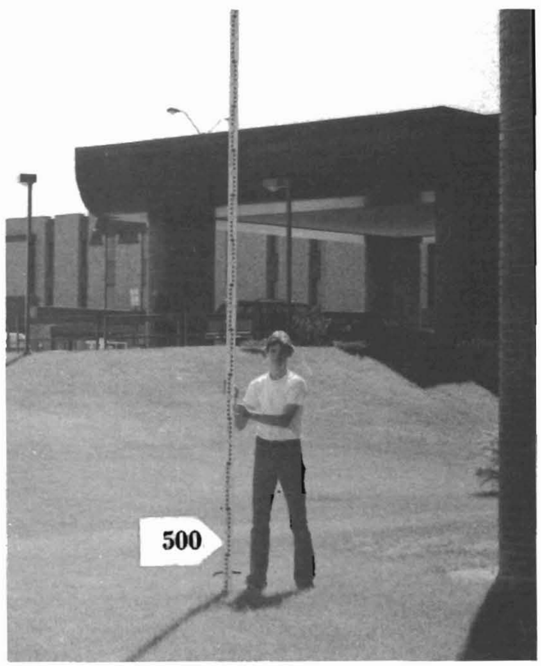


Figure 42. Expected level of the 500-year flood at the United Hospital in Grand Forks. This level corresponds to readings on the Red River. English Coulee flooding is not taken into account.

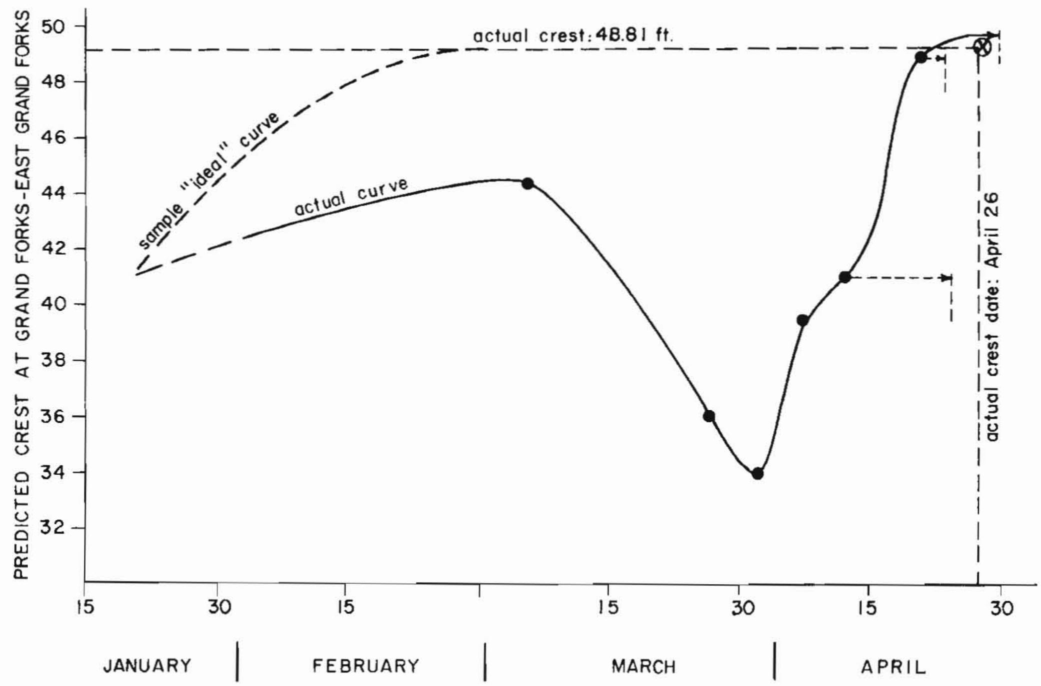


Figure 43. Flood-crest prediction accuracy during the time preceding the 1979 spring flood. The black circles represent the level predicted at various times.

during the 1975 flood remain at two locations in Grand Forks. A 1,500-foot-long earthen levee protects the Central Park area, and a 2,800-foot-long earthen levee plus a 650-foot-long wood plank floodwall protect the Riverside Park area. This levee was overtopped during the 1979 flood.

Permanent dikes in East Grand Forks also total about 1½ miles in length (about 8,000 feet). Most of these dikes were constructed during 1966 in the few weeks prior to the flood. As they were built as emergency dikes, most of the construction was covered by reimbursements from the Federal Office of Emergency Planning. Had they been constructed of the conventional sandbags, rather than clay, they probably would not have been suitable as permanent dikes. These dikes were constructed to withstand floods from 47 to 48 feet high (Floan, written communication). This level was topped in 1979 and the dikes had to be raised with sandbags.

Detailed plans were prepared by the Corps of Engineers in 1975 for additional dikes in East Grand Forks, but construction was not begun at that time because the city was unable to provide the assurances of local cooperation.

Oslo, Minnesota, downstream from Grand Forks-East Grand Forks, has an earthen levee 14,700 feet long as well as associated interior drainage works. The Corps of Engineers has also constructed a 14,600-foot earthen levee and a 1,000-foot reinforced-concrete floodwall for flood protection at Pembina, North Dakota, near the Canadian boundary.

Discussion of Future Flood-Loss Reduction

The 1979 Red River and English Coulee floods excited a great deal of controversy. The Grand Forks Herald, in May 1979, solicited suggestions for dealing with both the Red River and English Coulee flooding problems. Several people responded by suggesting dams, reservoirs, and additional, higher dikes to retain water during flooding situations. Dredging and channelization were proposed by some readers and others suggested that farmer-built dikes should be removed. It was suggested that the tributaries be shut off and one person proposed

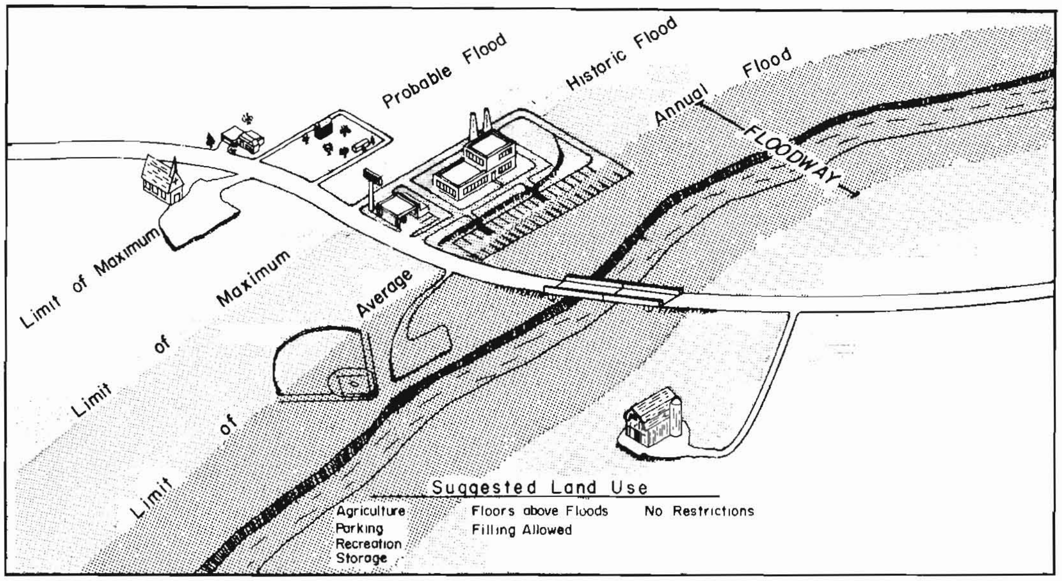


Figure 44. Proposed land-use categories for areas flooded at various river levels.

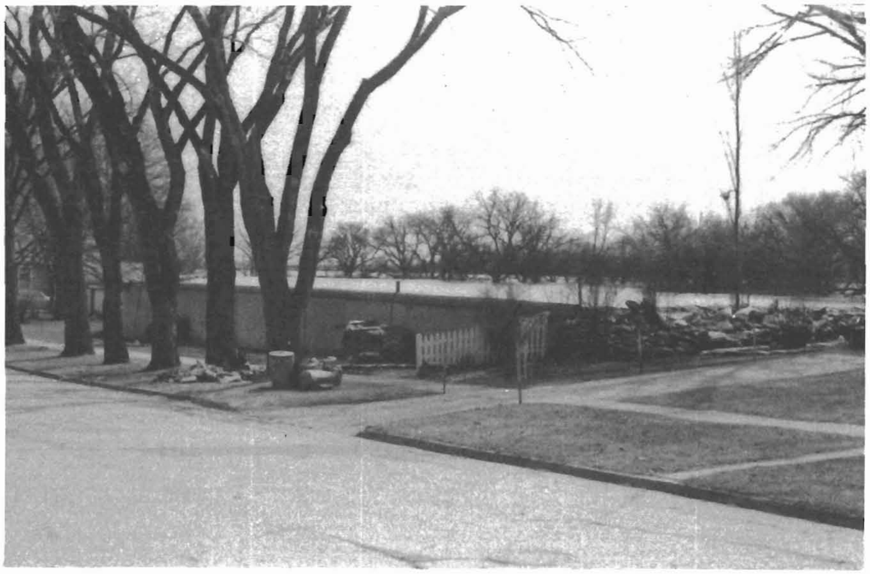
that the Red River be made to flow south instead of north.

Shelterbelts to collect snow and retard runoff were proposed by one reader. Another person suggested: "Take 100 feet from each side of the river and landscape the sides to channel a much larger waterway." A reader from Pisek offered what may be the most insightful suggestion: "The only way to get on top of this flood thing is to start controlling the snowmelt and water runoff at the upper reaches of any tributary--any river, stream, creek, coulee, drainage ditch, etc., that empties into the Red River. It will be necessary to have some means of controlling or regulating the flow of water in and from any and all of these, all up and down the Red River Valley, to benefit the entire area. Channelization. . .would definitely be the wrong way to go. It would only magnify the present problems. Building or raising dikes--while it may be the first thing to come to mind, especially during a crash effort in an emergency--is not the answer, except in a very few isolated cases. It would be rather impractical to try to dike tributaries very far back."

Clearly, no single solution will solve all of the flooding problems. Conservation measures such as shelterbelts and plantings to retain moisture are certainly steps in the right direction. Dikes are obviously with us to stay, although they can never be an ideal solution.

Grand Forks and East Grand Forks were built along the river because of the advantages of the location--the availability of river transportation, woodlands on the flood plain for construction and fuel, and a ready source of water. These advantages have evolved into disadvantages--problems in maintaining an orderly pattern of growth given the constraints of the river and railroad and a repeated flooding problem. It is too late to move the cities and the already-developed residential areas on the flood plain, which probably should have been left to the river. The Central Park, Riverside, Lincoln Park, and Griggs Park areas, the north end of East Grand Forks and other flood-prone areas aren't likely to be vacated. Additional flood-prone areas, such as the Terrace Drive area, Sleepy Hollow, and southwest Grand Forks continue to be developed. It is, perhaps, an unfortunate fact that, even given the benefit of sound planning advice, nearly all city governments tend to "cave in" to pressure from interests that stand to profit from ill-advised development.

The feasibility of additional flood-control projects in Grand Forks-East Grand Forks has been studied by the St. Paul District of the U.S. Army Corps of Engineers (see app. 2). The



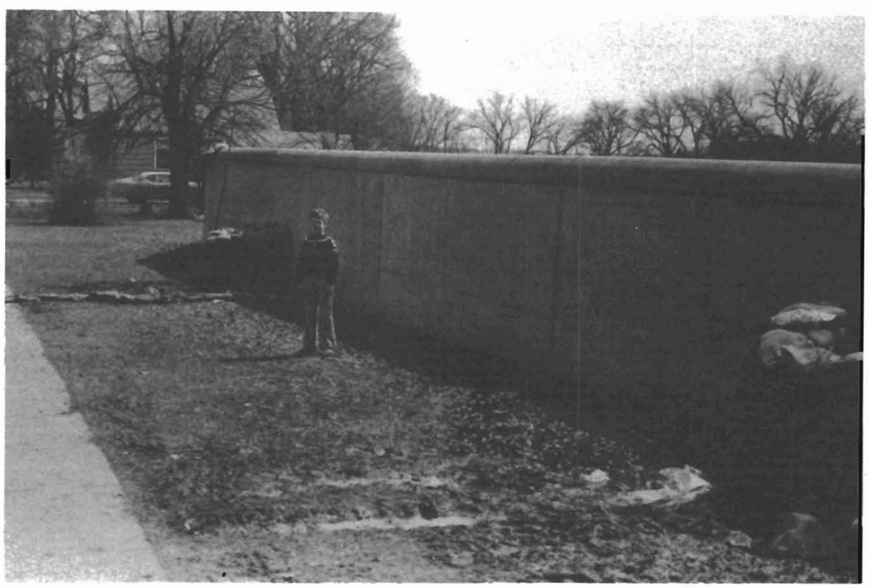


Figure 45. Two views of the south end of the Lincoln Park dike in Grand Forks during the 1979 flood. This dike includes 770 feet of concrete floodwall and 5,160 feet of earthen levee. It protects the Lincoln Drive area against a flood of 52 to 53 feet.

Corps offered a flood-protection plan to the residents of low-lying areas in the Riverside Park area in 1967 which provided that the federal government would bear the cost of moving the houses and provide a foundation or basement equal to that at the original site. Local interests would have been required to furnish all lands, easements, and rights-of-way for relocating the houses. The area formerly occupied by the relocated homes would have been added to the already-existing parks. Although some of the landowners were in favor of the proposal, the acceptance was not unanimous, so the plan could not be carried out. In addition, some of the residents of these areas stated they would no longer permit the construction of emergency dikes on their property.

In the opinion of the writers of this report, the best approach to alleviating the flooding problem in Grand Forks-East Grand Forks consists of the adoption of strict, informed, land-use controls for flood-plain development to reduce flood damage and flood-control effort. Areas that suffer repeated, severe flooding should be vacated to the river. The great initial expense of relocating homes and businesses would eventually be offset by reduced costs in combating future floods. The additional width returned to the river would help to lower future crests and the city would benefit from the newly created parkland.

It is unfortunate that the slough flooded by the English Coulee in 1979 (the United Hospital area) was ever developed (for a separate discussion of the 1979 English Coulee flood, see app. 3). Probably one way to guard against future flooding of this area would be to divert the English Coulee around the west side of Grand Forks, perhaps along Interstate Highway 29. Another partial solution would be a holding dam in the upper reaches of the drainage. However, either of these projects should be undertaken only after careful study and attention to the possible effects on related areas. Such projects would undoubtedly draw strong objections from affected landowners.

Similarly, a dam built at the Red River across the small drainage that backed into the South Forks Road area near Schroeder Jr. High School during the 1979 flood might help to control flooding in that area.

It might be possible to raise Belmont Road in the 15th Avenue South area to serve as a dike, protecting areas west of there; but again, it is likely that strong objections would be voiced to such a project.

In summary, we want to stress that the flood problem in Grand Forks-East Grand Forks has not been caused entirely as a result of man's actions. Diking, road construction, increased sediment in the river channel from farmed land all may affect the flood situation in various ways, but regardless of what man has done to the land or what he may do to alleviate the problem, whenever the weather refuses to cooperate, it produces a flood. As we pointed out early in this booklet, our highest recorded flood is still the 1897 one when the land was in virtually virgin condition. Unofficial accounts of several nineteenth-century floods higher than any we've experienced this century are probably accurate; absolutely no responsibility can be assigned to man for these floods. We will continue to have severe floods and there is no reason to believe we've seen the last or the worst of the Red River. Our best recourse is to try to minimize the damage and then "get out of the way" when floods happen.

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APPENDIX 1A

ANNUAL FLOOD OF THE RED RIVER AT GRAND FORKS-EAST GRAND FORKS-- HIGHEST LEVEL REACHED DURING EACH YEAR

APPENDIX 1B

RANK, HEIGHT, AND RECURRENCE INTERVAL OF FLOODS IN GRAND FORKS-EAST GRAND FORKS

APPENDIX 1A
ANNUAL FLOOD OF THE RED RIVER AT GRAND FORKS-EAST GRAND FORKS-- HIGHEST LEVEL REACHED DURING EACH YEAR

Year	Level	Year	Level	Year	Level	Year	Level
1882	46.3	1907	39.95	1932	22.07	1956	25.50
1883	40.5	1908	32.8	1933	15.18	1957	24.67
1884	31.1	1909	18.8	1934	10.02	1958	16.03
1885	23.1	1910	30.7	1935	13.07	1959	16.10
1886	20.6	1911	10.7	1936	25.0	1960	28.88
1887	16.3	1912	12.73	1937	11.57	1961	9.75
1888	29.5	1913	26.3	1938	15.49	1962	35.45
1889	12.0	1914	17.5	1939	20.13	1963	21.23
1890	10.6	1915	30.8	1940	21.8	1964	22.71
1891	17.7	1916	39.3	1941	27.86	1965	44.92
1892	33.4	1917	33.9	1942	24.10	1966	45.55
1893	43.8	1918	11.3	1943	38.16	1967	37.50
1894	26.9	1919	23.2	1944	19.79	1968	20.03
1895	9.9	1920	41.0	1945	32.0	1969	45.69
1896	32.0	1921	20.9	1946	33.23	1970	34.30
1897	50.2	1922	28.72	1947	40.71	1971	27.86
1898	15.0	1923	26.6	1948	41.68	1972	38.5
1899	20.9	1924	8.2	1949	29.11	1973	27.32
1900	13.2	1925	19.0	1950	45.61	1974	40.25
1901	26.3	1926	18.1	1951	33.52	1975	43.30
1902	26.0	1927	21.7	1952	33.60	1976	34.58
1903	28.0	1928	21.8	1953	24.63	1977	8.71
1904	40.65	1929	28.3	1954	18.63	1978	45.73
1905	26.11	1930	18.9	1955	26.17	1979	48.81
1906	36.0	1931	6.48				

APPENDIX 1B
RANK, HEIGHT, AND RECURRENCE INTERVAL OF FLOODS IN GRAND FORKS-EAST GRAND FORKS

Rank	Height	Year	Interval
1	50.2	1897	100
2	48.81	1979	50
3	46.3	1882	35
4	45.73	1978	25
5	45.69	1969	20
6	45.61	1950	17
7	45.55	1966	14
8	44.92	1965	12
9	43.8	1893	11
10	43.30	1975	10
11	41.68	1948	9
12	41.0	1920	8
13	40.71	1947	8
14	40.65	1904	7
15	40.5	1883	7
16	40.25	1974	6
17	39.95	1907	6
18	39.3	1916	6
19	38.5	1972	5
20	38.16	1943	5
21	37.50	1967	5
22	36.0	1906	5
23	35.45	1962	4
24	34.58	1976	4
25	34.30	1970	4
26	33.9	1917	4
27	33.60	1952	4
28	33.52	1951	4
29	33.4	1892	3
30	33.23	1946	3
31	32.8	1908	3
32	32.0	1896	3
33	32.0	1945	3
34	31.1	1884	3
35	30.8	1915	3
36	30.7	1910	3
37	29.5	1888	3
38	29.11	1949	3
39	28.88	1960	3
40	28.72	1922	3
41	28.3	1929	2
42	28.0	1903	2
43	27.86	1941	2
44	27.86	1971	2
45	27.32	1973	2
46	26.9	1894	2
47	26.6	1923	2
48	26.3	1901	2
49	26.3	1913	2

Rank	Height	Year	Interval
50	26.17	1955	2
51	26.11	1905	2
52	26.0	1902	2
53	25.50	1956	2
54	25.0	1936	2
55	24.67	1957	2
56	24.63	1953	2
57	24.10	1942	2
58	23.2	1919	2
59	23.1	1885	2
60	22.71	1964	2
61	22.07	1932	2
62	21.8	1928	2
63	21.8	1940	2
64	21.7	1927	2
65	21.23	1963	2
66	20.9	1899	2
67	20.9	1921	1
68	20.6	1886	1
69	20.13	1939	1
70	20.03	1968	1
71	19.79	1944	1
72	19.0	1925	1
73	18.9	1930	1
74	18.8	1909	1
75	18.63	1954	1
76	18.1	1926	1
77	17.7	1891	1
78	17.5	1914	1
79	16.3	1887	1
80	16.10	1959	1
81	16.03	1958	1
82	15.49	1938	1
83	15.18	1933	1
84	15.0	1898	1
85	13.2	1900	1
86	13.07	1935	1
87	12.73	1912	1
88	12.0	1889	1
89	11.57	1937	1
90	11.3	1918	1
91	10.7	1911	1
92	10.6	1890	1
93	10.02	1934	1
94	9.9	1895	1
95	8.75	1961	1
96	8.71	1977	1
97	8.2	1924	1
98	6.48	1931	1

$$\text{Recurrence Interval} = \frac{\text{years of record} + 1}{\text{rank of flood}}$$

APPENDIX 2

STUDIES AND PROJECTS

APPENDIX 2A

COMPLETED PROJECTS AND REPORTS

APPENDIX 2B

SUMMARY OF ONGOING STUDIES OR PROJECTS IN THE RED RIVER OF THE NORTH BASIN

APPENDIX 2
STUDIES AND PROJECTS

Since 1930, many reports dealing with various aspects of the flooding problem along the Red River have been prepared by assorted federal, state, local, and private agencies. In addition, several projects and studies now under way in the Red River drainage basin have been undertaken in response to requests from concerned local, state, and federal agencies. Summaries of completed projects and projects underway are given in the following tables. The information in these tables was obtained from the U.S. Army Corps of Engineers (1978).

APPENDIX 2A
COMPLETED PROJECTS AND REPORTS

Reports by federal and state agencies concerning general and specific water resource problems and identifying certain plans and programs for solving the diverse water problems in the Red River of the North Basin include:

(1) Report on the Red River of the North Drainage Basin, Interstate Committee of the Planning Boards of Minnesota, North Dakota, and South Dakota with federal assistance and in cooperation with the National Resources Committee, 1 December 1936.

(2) Report on the Comprehensive Water Plan Proposed in the Report of the Interstate Committee on the Red River of the North Drainage Basin, Corps of Engineers, 2 July 1937. Prepared at the request of the Works Progress Administration.

(3) Report on Stream Pollution, North Dakota Department of Health and the State of North Dakota Planning Board, 1 August 1937.

(4) Report on Red River of the North Drainage Basin, Works Progress Administration, 30 June 1939.

(5) Red River of the North Research Investigation, North Dakota Department of Health, 1938-1941.

(6) Report on Red River of the North Basin, House Document 185, 81st Congress, 1st Session (Corps of Engineers), 24 September 1947.

(7) Plan of Study for the Red River of the North Basin for Flood Control and Related Purposes, Corps of Engineers, April 1977.

Reports recommending a project involving regulation of Red Lakes and channel improvement on Red Lake and Clearwater Rivers for flood control and improvement of low flows include:

(1) Report on Red Lake River and Tributaries Including Clearwater River, Minnesota, House Document 345, 78th Congress, 1st Session (Corps of Engineers), 19 June 1943.

(2) Red Lake Watershed District Overall Plan, Board of Managers of Red Lake Watershed District, 30 September 1970.

(3) Draft Red Lake River Subbasin, Minnesota, Feasibility Study for Flood Control and Related Purposes, Corps of Engineers, March 1977.

The following reports were prepared on the Grand Forks-East Grand Forks urban area.

(1) Grand Forks-East Grand Forks Urban Water Resources Plan of Study, Corps of Engineers, September 1976.

(2) Grand Forks-East Grand Forks Urban Water Resources Study, Draft Background Information, Plan Formulation, Flood Control, Water Supply and Wastewater Reports, Corps of Engineers, February 1978.

Technical reports by the U.S. Geological Survey, North Dakota State Water Commission, and Public Health Service relating to groundwater, geology, water supply, and water quality of the area include:

(1) North Dakota Groundwater Studies No. 28, Minto-Forest River Area, Walsh County, U.S. Geological Survey, 1961.

(2) Water Supply and Water Quality Control Study, Red River Basin, Public Health Service, July 1965.

(3) Interim North Dakota State Water Resources Development Plan, Appendices A-E, North Dakota State Water Commission, December 1968.

(4) Minnesota Water and Related Land Resources--First Assessment, Minnesota State Planning Agency, June 1970.

(5) North Dakota Geological Survey Bulletin 53, Parts I-III, North Dakota Geological Survey, 1968-70.

(6) North Dakota Geological Survey Bulletin 57, Parts I-III, North Dakota Geological Survey, 1971-72.

(7) United States Geological Survey Water Supply Papers and Annual Surface Water Records, U.S. Geological Survey, Department of the Interior.

Corps of Engineers section 205 detailed project reports for flood control include:

(1) Red River of the North at Oslo, Minnesota, 28 February 1972. This report recommended construction of a levee encircling Oslo. The project is completed.

(2) Red River of the North at Pembina, North Dakota, September 1971. The report recommended construction of a combination levee and floodwall encircling the city. This project is completed.

(3) Red River of the North at Grand Forks, North Dakota. A levee and floodwall flood control project was constructed in Grand Forks in 1958.

(4) Lower Branch Rush River, North Dakota. Construction of a channel improvement project was completed in 1974.

(5) Souris-Red-Rainy River Basins Comprehensive Study, Souris-Red-Rainy River Basins Commission, 1972. The report presented alternative framework programs for development of the water and related land resources of the Souris-Red-Rainy region and a proposed program for selected subbasins of the Red River of the North Basin.

Reports prepared by the U.S. Geological Survey, Corps of Engineers, Soil Conservation Service, and States of North Dakota and Minnesota concerning delineation and evaluation of the 1-percent chance (100-year) flood at various points in the Red River of the North Basin, include:

(1) Flood Plain Information, Red River, Grand Forks, North Dakota, and East Grand Forks, Minnesota, Corps of Engineers, November 1971.

(2) Flood Plain Information, Red River, Fargo, North Dakota, and Moorhead, Minnesota, Corps of Engineers, April 1974.

APPENDIX 2B
SUMMARY OF ONGOING STUDIES OR PROJECTS IN THE RED RIVER OF THE NORTH BASIN

Source: Souris-Red-Rainy River Basins Comprehensive Study

Name	Location	Lead Agency Responsible	Authority	Description	Status as of Sept. 1978
Twin Valley Lake	West-central Minnesota	Corps of Engineers	Flood Control Act of 1970	A reservoir for flood control, recreation, and fish and wildlife enhancement on the Wild Rice River, Minnesota.	Preconstruction planning will be completed in 1979.
Kindred Lake	East-central North Dakota	Corps of Engineers	Flood Control Act of 1970	A review of water resource problems and potential solutions in the Sheyenne River Basin, including the authorized multiple-purpose reservoir on the Sheyenne River.	Preconstruction planning is scheduled for completion in 1982.
Park River* at Grafton	Northeastern North Dakota	Corps of Engineers	1976 Water Resources Development Act	A local flood protection project consisting of a levee and bypass channel on the Park River at Grafton.	Preconstruction planning is unfunded.
Roseau* River	Northwestern Minnesota	Corps of Engineers	Flood Control Act of 1965	A flood damage reduction project consisting of channel improvement and associated features in Roseau County and Canada.	Construction is estimated to be completed in FY 1983.
Wild Rice River-South Branch and Felton Ditch	West-central Minnesota	Corps of Engineers	Flood Control Act of 1968	A flood protection project consisting of channel improvements and levees and associated features along the Wild Rice River-South Branch and Felton Ditch.	Construction is estimated to be completed in FY 1981.
Pembilier* Dam and Lake	Northeastern North Dakota	Corps of Engineers	1976 Water Resources Development Act	A multiple-purpose reservoir for flood control, water supply, and recreation on the Pembina River, North Dakota.	Preconstruction planning is scheduled for completion in 1981.

*Studies or projects indicated by asterisks are on drainage areas north of Grand Forks-East Grand Forks. These will not directly affect the two-city area.

APPENDIX 2B--Continued
SUMMARY OF ONGOING STUDIES OR PROJECTS IN THE RED RIVER OF THE NORTH BASIN

Name	Location	Lead Agency Responsible	Authority	Description	Status as of Sept. 1978
Grand Forks-East Grand Forks	West-central Minnesota and east-central North Dakota	Corps of Engineers	Red River of the North general	Study of flood damage, water supply, water quality and wastewater problems and solutions for the urban area.	The study is scheduled for completion in 1980.
Red River Basin hydrologic model	Red River Basin	Corps of Engineers	Red River of the North	A mathematical model using all available water resources data for the Red River Basin.	Portions of the basin area are modeled with the entire model scheduled for completion in 1979.
Goose River Subbasin	East-central North Dakota	Corps of Engineers	Red River of the North general	Study of the flood damage and related water resource problems and potential solutions in the Goose River Basin.	The study is scheduled for completion in 1980.
Red River Basin water supply analysis	Red River Basin	Corps of Engineers	Red River of the North general (in cooperation with all Red River studies)	This analysis focuses on the capability of the Red River of the North main stem and tributaries to serve as a water supply source. Included is an investigation of current and projected minimum surface water withdrawal requests for municipal, industrial, and other uses. A computer-based program is being used to update basic studies conducted in 1972 and examine additional parameters concerning needs.	The study is scheduled for completion in 1979.
Red River main stem	Red River of the North	Corps of Engineers	Red River of the North general	A detailed study to investigate the feasibility of providing flood damage reduction along the main stem of the Red River.	The study is scheduled for completion in 1981.

APPENDIX 2B--Continued
SUMMARY OF ONGOING STUDIES OR PROJECTS IN THE RED RIVER OF THE NORTH BASIN

Name	Location	Lead Agency Responsible	Authority	Description	Status as of Sept. 1978
Halstad	Red River of the North at Halstad, Minnesota	Corps of Engineers	Section 205 of the 1948 Flood Control Act	A detailed project study to determine the feasibility of reducing flood damages at Halstad.	Initiation of detailed study is awaiting receipt of funds.
Enderlin	East-central North Dakota	Corps of Engineers	Section 205 of the 1948 Flood Control Act	A detailed study of the flood problems and potential solutions along the Maple River at Enderlin, North Dakota.	Study is scheduled for completion in 1979.
Flood insurance or flood hazard studies	Crookston Hallock Kittson County Roseau Norman County Roseau County Warroad Wilkin County Grand Forks-East Grand Forks Minto Forest River Mayville Hillsboro Valley City Fargo-Moorhead	U.S. Department of Housing and Urban Development with contracts awarded to various agencies	National Flood Insurance Act of 1968, as amended (FIA)	An investigation of the existence and severity of flood hazards at each location to aid in the administration of the FIA and the Disaster Protection Act of 1973.	All contracts have been awarded and studies are in progress. Some draft reports have been prepared. The studies for Hillsboro and East Grand Forks have been completed.

APPENDIX 2B--Continued

SUMMARY OF ONGOING STUDIES OR PROJECTS IN THE RED RIVER OF THE NORTH BASIN

Name	Location	Lead Agency Responsible	Authority	Description	Status as of Sept. 1978
Soil Conservation Service studies (Minnesota)	Snake-Middle River Subbasin	Soil Conservation Service	Public Law 566	Studies for watershed protection and flood control	
	Melgard-Swift Coulee				Applications approved.
	Middle River				Applications approved.
	Snake River				Applications approved.
	Angus-Oslo				Applications approved.
	Red Lake River Subbasin	Soil Conservation Service	Public Law 566	Studies for watershed protection and flood control	
	Burnham Creek				Authorized for planning.
	Badger Creek				Applications approved.
	Roseau River Subbasin	Soil Conservation Service	Public Law 566	Studies for watershed protection and flood control	
	Badger-Skunk				Applications approved.
	Red River main stem	Soil Conservation Service	Public Law 566	Studies for watershed protection and flood control	
	Norman-Polk				Under construction.
	Comstock Coulee				Applications approved.
	Buffalo River Subbasin	Soil Conservation Service	Public Law 566	Studies for watershed protection and flood control	
	South of Hawley				

APPENDIX 3

THE 1979 ENGLISH COULEE FLOOD

APPENDIX 3
THE 1979
ENGLISH COULEE FLOOD

The English Coulee is an intermittent stream that enters Grand Forks from the southwest, flows through the University of North Dakota campus, and joins the Red River about a mile north of the State Mill and Elevator (fig. 46). Before the Grand Forks area was settled, the English Coulee drainage basin included about 110 square miles southwest of Grand Forks. The English Coulee, along with other natural drainage ways in this area, trends generally northeastward or east-northeastward. However, several drainage ditches that have been dug, coupled with changes in the drainage pattern that have resulted from the construction of roads, have altered the shape and characteristics of the original English Coulee drainage basin in several ways.

South of Grand Forks, the drainage ditch (Drain #4) that follows the section line road eastward from Merrifield, cuts off a natural drainage that would (if the ditch hadn't been constructed) flow northeastward into the English Coulee. The runoff from an area of approximately 30 square miles is thereby carried past the south edge of Grand Forks directly eastward through the drainage ditch to Cole Creek, which then flows about a quarter of a mile to the Red River. The net result of this drain should be to diminish the total runoff to the English Coulee.

South Forks Road (formerly 32nd Avenue South) borders the south edge of Grand Forks, west of South Washington Street. Prior to 1978, this road served as a dike, diverting north-flowing water eastward, away from the English Coulee and toward the Red River. With the construction of the Columbia Mall in 1978, the road was widened and lowered several feet so that it no longer acts as a dike.

West of Grand Forks, the English Coulee has been channelized from a point in section 15, T151N, R51W (Brenna Township) eastward to section 8, T151N, R50W (Grand Forks Township). This drainage channel (Drain #9) parallels the westward extension of 17th Avenue South. The natural route of the English Coulee prior to the channelization was along a more northerly course through the Ray Richards Golf Course and, in fact, during periods of high water, much of the English Coulee runoff still follows this route. The main overall effect of this channelization has been to divert most of the flow of the English Coulee to a slightly more southerly route; however, the same total flow results (with or without channelization) at the point where the English Coulee passes beneath the railroad tracks south of the University (point "A" on fig. 46).

Farther west, the drain that follows the south side of U.S. Highway 2 intercepts (in section 3, T151N, R51W; Brenna Township) a small, unnamed northeast-trending coulee that would, if left undisturbed, continue generally eastward along a slightly more northerly route (dashed line on fig. 46), eventually entering the English Coulee north of the Grand Forks fairgrounds. As a result of the drainage ditch that has been constructed, this drainage enters the English Coulee about a half mile farther south than it otherwise would.

Given a situation of heavy, rapid runoff, Fresh Water Coulee, located mainly in T151N, R52W (Oakville Township) will spill eastward through a natural spillway in section 13, T151N, R52W and section 18, T151N, R51W into the unnamed coulee described above. Heavy runoff can also result in overland flows from areas that would normally drain through Salt Water Coulee, which passes through Emerado and joins Fresh Water Coulee just west of the Grand Forks International Airport, north of U.S. Highway 2 (section 30, T152N, R51W; Rye Township).

It does not seem likely that the building of drainage ditches channelizing the flows of the English Coulee and other streams to the west of Grand Forks was the main reason for the anomalously high flows into southwestern areas of Grand Forks during the April 1979 flood. However, it is possible that the overall section line road system acted as a barrier to the northeastward flow to such an extent that large flows of water were diverted far enough east so that they entered the English Coulee drainage basin. The road system, particularly U.S. Highway 2 and other east-west section line roads, tends to divert water eastward, away from natural drainages that would normally (if the roads, ditches, etc. did not exist) flow northeastward past

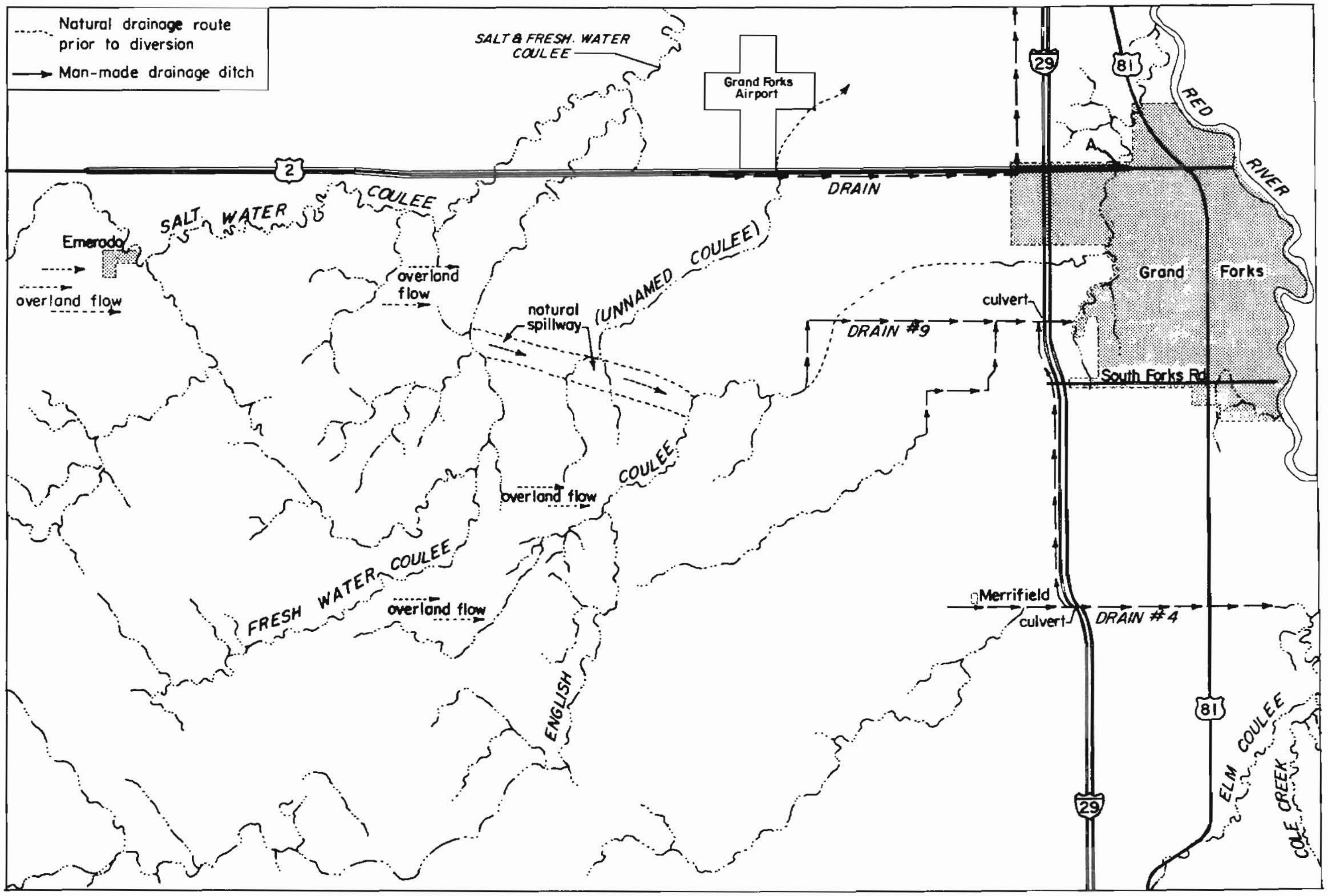


Figure 46. Map of the Grand Forks area showing English Coulee drainage. Saltwater and Freshwater Coulees are also shown as are some of the areas of overland runoff during the 1979 spring flood. The dashed line on the English Coulee shows its route prior to diversion by Drain 9. Point A is the culvert beneath the railroad tracks south of the University of North Dakota.

Figure 47. Culverts beneath the Burlington Northern Railroad tracks at the south edge of the University of North Dakota campus. Each culvert has a cross-sectional end area of 130 square feet (6.5x10 feet). A culvert system this size can handle a maximum flow of approximately 1,875 cu ft/sec before water starts backing up.

the city. The additional drainage area diverted into the English Coulee drainage basin can amount to as much as 100 square miles, although not all of the runoff from this additional area can ever actually spill over into the English Coulee drainage basin; most of the water in the drainage basin west of the English Coulee Basin flows to the Red River along the natural drainage. The percentage of runoff from the additional 100-square-mile area that might enter the English Coulee drainage would depend on the capacity of the natural drainage to handle the runoff. High runoff amounts would result in greater percentages of the runoff entering the English Coulee system. It should be noted that virtually none of the east-west roads diverting the above-mentioned drainage eastward into the English Coulee system have large enough or sufficient numbers of culverts to allow all the runoff water to flow along its natural drainage route during a high-water situation.

The route of the northward flow of the English Coulee, once it reaches Grand Forks, is through culverts and beneath bridges that carry it past obstructions such as the railroad tracks, University Avenue, Sixth Avenue North, U.S. Highway 2, and other points. This flow, once it reaches a certain volume, is greatly impeded by these obstructions. The culverts and bridges that have been provided for the flow of the English Coulee through the city of Grand Forks are not sufficiently large to allow unimpeded flow of the increased volume of water during flooding, although they are sufficient for normal runoff.

The State Soil Conservation Service measured the peak flow on the English Coulee west of Grand Forks (four miles south of the International Airport) at about 3,000 cfs. This flow was rated at something greater than a 100-year flood (a 100-year flood on the English Coulee at that point would have a flow calculated at about 2,600 cfs). The drainage received considerable additional runoff downstream from that point, however, and the total flow in Grand Forks probably exceeded 5,000 cfs (personal communication, Jerry Spaeth, hydrologist with the State Soil Conservation Service).

The single most important obstruction to the flow of the English Coulee through Grand Forks during the April 1979 flood was the culvert system beneath the railroad tracks at the south edge of the University of North Dakota campus (fig. 47). The two concrete culverts at that point measure about 6.5x10 feet each. These two culverts are large enough to allow an unimpeded flow of approximately 1,800 cubic feet of water per second; that is, up to a stream flow of about 1,800 cfs, the railroad tracks would not cause much damming effect. However, during the flood, the flow on the Coulee was so great that water backed up south of the railroad tracks to such an extent that the resulting hydraulic head was sufficient to force about 3,500 cubic feet of water a second through the culverts.

Theoretically, a 22-foot diameter culvert would have allowed the English Coulee to flow beneath the railroad tracks without backing up (a 22-foot culvert is approximately equivalent to eight 8-foot culverts; the existing system is equivalent to two 8-foot culverts. Of course, the English Coulee stream channel itself is not large enough to handle the flow through Grand Forks during a 100-year flood, and regardless of the size of the culverts and bridges provided, once a volume of water approaching the amount involved in the 1979 flood reaches the city, flooding is inevitable. It should also be pointed out that the area north of the railroad tracks would have experienced much more serious flooding if the culvert beneath the railroad tracks had been larger.

The three main reasons for the flooding by the English Coulee in southwest Grand Forks during the 1979 flood were the presence of the rural road system, which diverted water eastward; the insufficient size of the culverts in the city, which retarded the flow of the water from the flooded area; and the overland water flows from the south, which prior to the reconstruction of South Forks Road, would have been diverted away from the English Coulee.

A fourth point should be mentioned. Like all streams flowing over the glacial Lake Agassiz plain, the English Coulee occupies a shallow valley that is generally no more than 5 or 10 feet lower than the surrounding plain. Most of this area in Grand Forks was a cattail slough or marsh prior to the residential and commercial development during the mid and late 1970s. Much of this area was filled in during the course of construction.

This area would have been flooded during the April 1979 English Coulee flood regardless of whether it had been developed, but the damage to a cattail slough would likely have been somewhat less than it was to the houses that have been built in the slough. The area should not have been developed. Without some kind of corrective measures, serious flooding will eventually occur along the English Coulee again.

It is not within the scope of this report to examine potential engineering projects that could remedy the flood situation along the English Coulee. As this is written, several proposals are already being considered to alleviate future flooding along the English Coulee in Grand Forks. Possible remedies might involve a major diversion to reroute the English Coulee west of Grand Forks or the construction of a dry dam to provide a holding reservoir in the upper reaches of the coulee drainage basin or the construction of a series of small dikes between the English Coulee drainage basin and drainage farther west that overflowed into the English Coulee system. Perhaps a combination of all of these or other remedies might eventually be undertaken. However, any remedial diversions or other flood-prevention measures that might be taken may disrupt other areas in ways that should be carefully studied before they are undertaken.

APPENDIX 4

MAP OF THE REGIONAL FLOODPLAIN IN THE
GRAND FORKS-EAST GRAND FORKS AREA

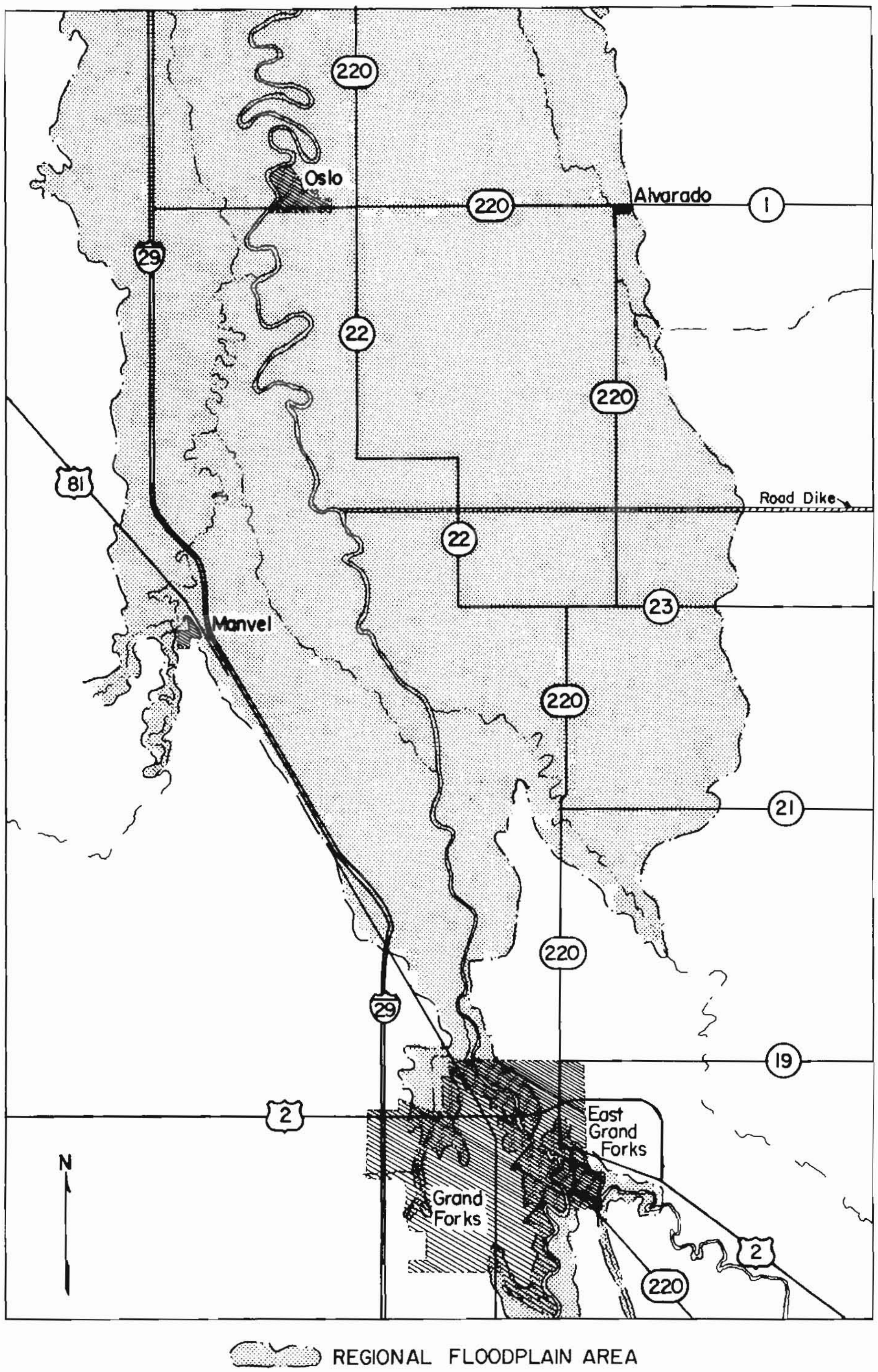
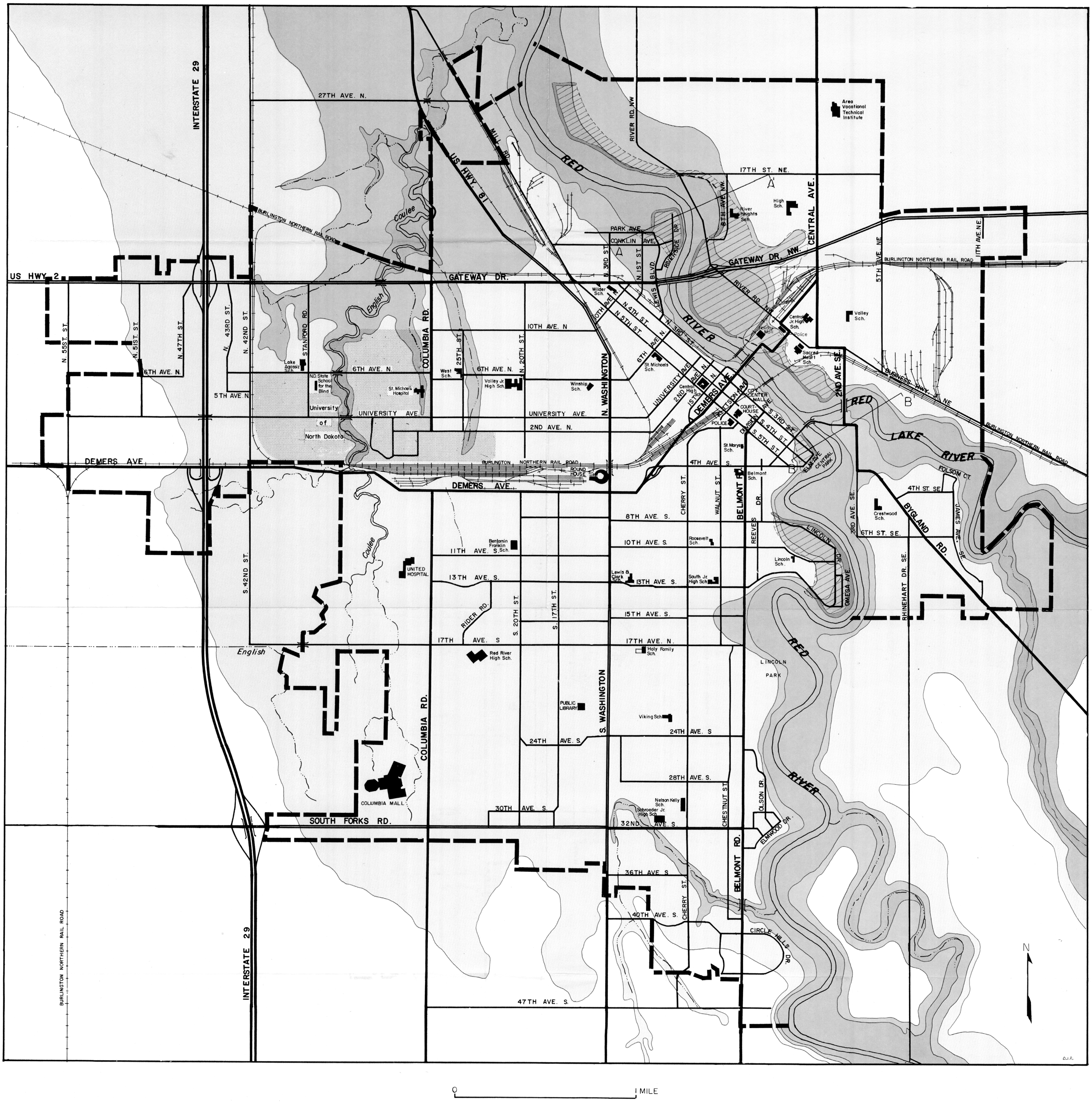


Figure 48. Map showing that the flood plain of the Red River is much broader downstream from Grand Forks-East Grand Forks than it is in the two cities. Floodwaters near Oslo can spread out over a vast area, nearly 15 miles wide during an Intermediate Regional Flood (100-year flood).

EDUCATIONAL SERIES 12

APPROXIMATE FLOOD-EXTENT MAP
Grand Forks—East Grand Forks

NORTH DAKOTA GEOLOGICAL SURVEY
Lee C. Gerhard, State Geologist



EXPLANATION

- Approximate extent of 10-year flood (43.5 ft. river level; 822 feet elevation)
- Approximate extent of 100-year flood (51.4 ft. river level; 830 feet elevation)
- Approximate extent of 500-year flood (55 ft. river level; 833.5 feet elevation)
- Dikes
- Areas protected by dikes

The extent of flooding shown on this map disregards the effect of dikes. Dikes shown on the map protect the Lincoln Park area in Grand Forks to about a 53-foot flood and the Central Park area to a 48-foot flood. Permanent dikes in East Grand Forks are designed to withstand floods up to about 48 feet.

This is an approximate map. Detailed land surveys would be required to determine the precise effect of any given flood level at any given point. This map is based on the best available aerial photography and U.S. Geological Survey topographic data, which is supplied at a five-foot contour interval. Detailed land surveys were not undertaken during the compilation of this map.