The Flood Problem in Grand Forks -- East Grand Forks

What causes floods?

How often can floods be expected?

Will your property be flooded?

What is a "100-year flood?"

How can flood damage be reduced?

Are permanent dikes practical?

How are flood heights predicted?

North Dakota Geological Survey Miscellaneous Series 35

GRAND FORKS NORTH DAKOTA – 1968

The Flood Problem

in

Grand Forks--East Grand Forks

by

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illustrations by

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North Dakota Geological Survey Miscellaneous Series 35

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GRAND FORKS, NORTH DAKOTA

1968

Photo Acknowledgements

Cover Photo -- Aerial oblique view of Grand Forks - East Grand Forks looking south. East Grand Forks in foreground; Central and Riverside parks in center. River stage is about 42 1/2 feet. Photograph taken April 21, 1950, by the late Lee Evanson. Photo courtesy of Evanson Studio, Grand Forks.

Page 2 -- Cartoon by Stuart McDonald; published in the Grand Forks Herald.

Page 11 -- Downtown Grand Forks, March, 1966, blizzard. Photo by Colburn Hvidston, III.

Page 16 -- 1897 flood; view looking east from Sorlie Memorial Bridge in East Grand Forks. Photo owned by Charles Garvin, Grand Forks.

Page 21 -- April, 1966, flood in Grand Forks. Photo by Colburn Hvidston, III.

Preface

Low-lying areas in Grand Forks-East Grand Forks are flooded to some degree nearly every two years. Major floods affecting large areas of both cities have occurred on the average of once in every eight years. However, the recent floods of 1965 and 1966 have shown that the general public, and in some instances the press and other local news media, seems to be unaware of (1) the actual flood problem in Grand Forks-East Grand Forks and (2) what steps have been taken or might be taken to reduce flood losses.

In the past, information concerning the local flood problem has not been readily available to the general public. The purpose of this booklet, therefore, is to explain the local flood problem to the interested area residents. Although some of the methods and terminology used in this report are necessarily technical, sufficient explanation accompanies such technical jargon and procedures so as to make them understandable to the layman.

Predictions of the frequency and extent of future flooding as set forth in this booklet are based on the past flood record. Because this record is less than one hundred years long, and because we are attempting to predict a natural phenomena--as yet uncontrolled by man--it is unlikely that these predictions would be 100% accurate. The North Dakota Geological Survey and the writer, therefore, accept no responsibility for any direct or indirect damages resulting from the failure of Nature to comply with these predictions.

The Flood Problem

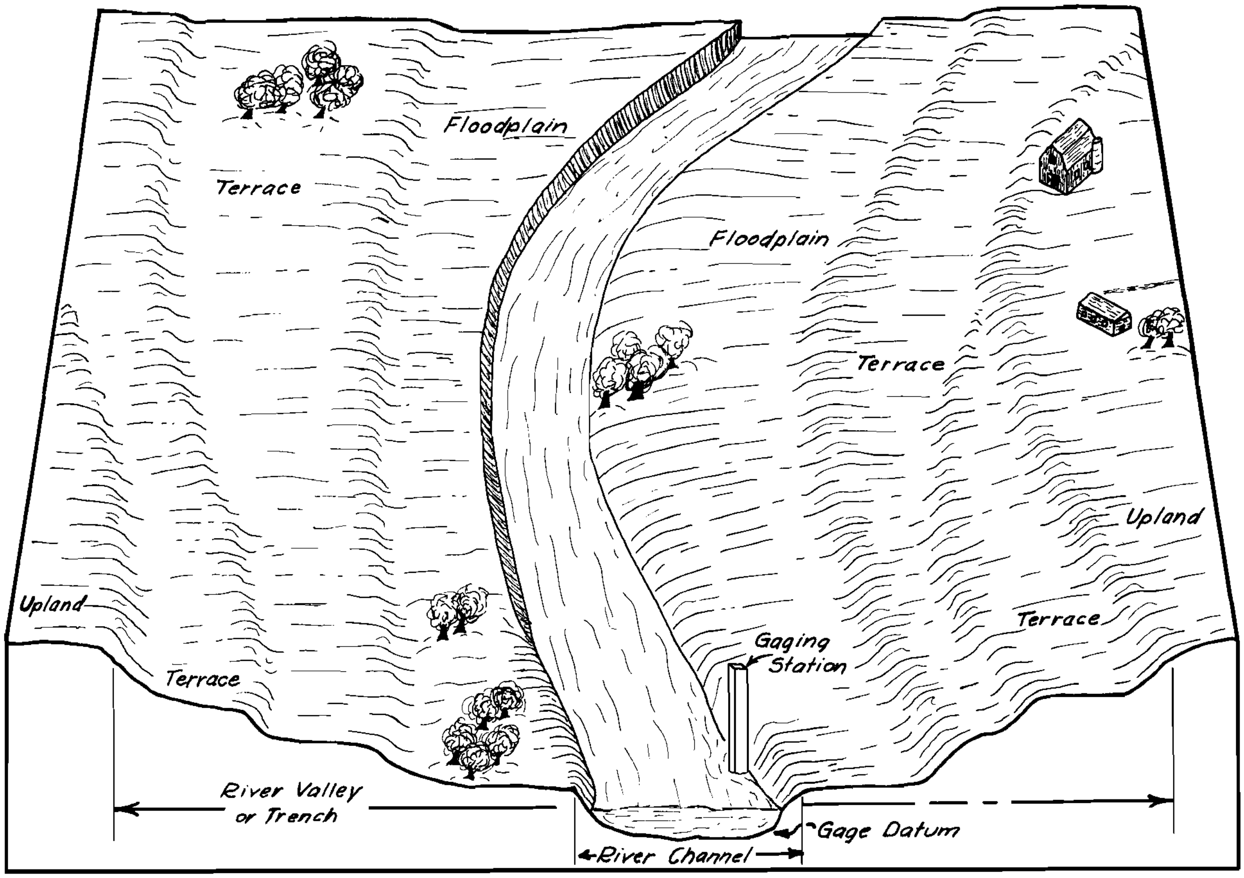
THE NATIONAL FLOOD PROBLEM

More than 100 million acres of land in the United States are subject to flooding. Although this area represents only slightly more than 5% of the total land area of the United States, it has been estimated that flood losses amount to over $955,000,000 annually (11)*. Nearly half of this flood-vulnerable land, or floodplain area, is protected to some degree by flood-prevention works constructed by the U.S. Corps of Engineers. Between 1918 and 1960 more than 5 billion dollars were spent on these works, yet flood losses grew steadily as floodplain use increased at the rate of 1.4% per year. At the present rate of increase in floodplain use and flood-protection construction, the potential flood costs will rise to 1 1/3 billion dollars per year by 1980. It is obvious, then, that with the cost of floods increasing at this rate the current flood-protection policies must be re-evaluated in the light of practical economics and the latest flood-loss-reduction practices.

*Numbers correspond to references listed in the back of the booklet.

THE LOCAL FLOOD PROBLEM

About 8% of the total area of Grand Forks-East Grand Forks is included in the nation's 100 million acres of floodplain. Throughout the early history of these 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 became more thickly settled, however, vast amounts of money were spent on flood-protection works. Due to emergency procedures such as diking, personal losses from flooding are usually not widespread in these cities. For the most part, the federal government has supplied the funds for this protection, which for the 1966 flood alone totaled over $1,000,000 for the two cities combined. Although much of the floodplain area in both cities, especially East Grand Forks, is now protected somewhat by dikes or levees, a flood similar to that of 1965 or 1966 would still necessitate considerable sandbagging, evacuation, and general inconvenience. Moreover, floodplain areas north and south of the present residential limits along the rivers will undoubtedly soon be developed as the cities continue to grow. These areas will also require costly flood-protection works unless steps are taken to develop them wisely with regard to potential flooding.



Flood Terminology

Because the use of some terminology is both unavoidable and desirable, a few general definitions are necessary before proceeding.

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.

FLOODPLAIN or FLOOD PLAIN: Again the definitions vary, but the simplest description states that a floodplain 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 occasionally inundated and become part of the river channel during floods. Often there are several of these flat floodplain areas along a single reach of the river, each becoming successively lower, like steps, as the river channel is approached. The higher, less frequently flooded floodplain levels are sometimes referred to as river <u>terraces</u>. For purposes of this report, all areas that are occasionally flooded will be considered as "floodplain," even though some may be technically "terraces."

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.

BANKFULL STAGE: The height of the water when it is level with the top of the banks of the river channel is referred to as bankfull stage. If water rises above bankfull stage, flooding occurs.

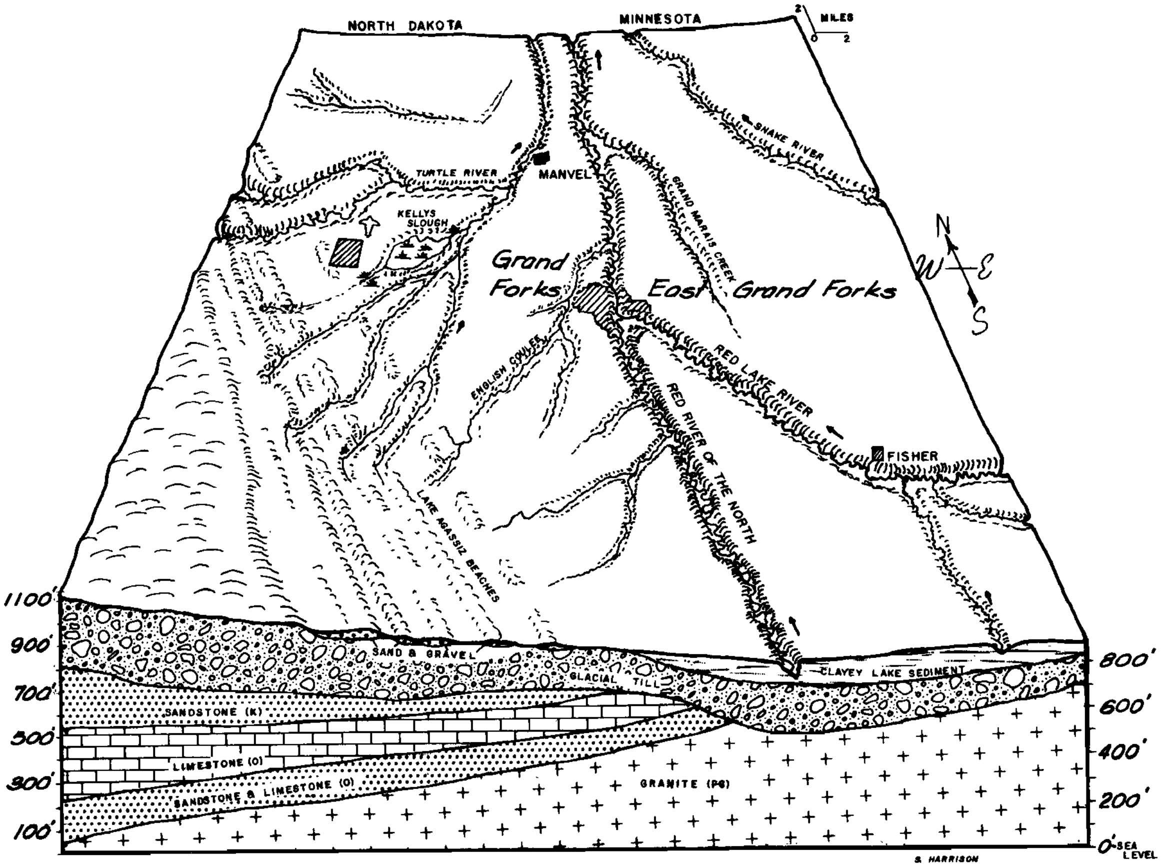
FLOOD STAGE: The height of the water at which flooding begins to occur is called flood stage (generally the same as bankfull stage).

GAGE READING: Floods in Grand Forks-East Grand Forks are referred to as 44.6 feet, 35.7 feet, etc. This number represents the height of the river surface 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 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 1/2 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 500 feet downstream from the dam in Riverside Park on the Grand Forks side of the river. The gage is presently located in the old Grand Forks sewage disposal plant about 1/4 mile north of the old site. The reference datum of the new gage is also 778.35 feet above sea level.

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 ten times in the past 80 years. We could expect, therefore, to have a flood at least this high on an average of once in 8 years; thus the recurrence interval of a 40-foot flood would be 8 years. Another way of expressing recurrence interval is that the chances of having a flood 40 feet high or higher is one out of eight or 1/8 for every year (using our assumed data). It is very important to note, however, that the recurrence interval <u>does</u> <u>not</u> imply that if a 40-foot flood occurs this year, another of that magnitude will not occur for 8 years. Rather, over a period of 32 years about four floods of this magnitude can be expected; when they will occur or how many years will separate them is not known.

RUNOFF: Runoff is that part of the total precipitation throughout the drainage basin which eventually reaches the river, either by flow over the land surface or groundwater flow.



PHYSIOGRAPHIC MAP OF GRAND FORKS – EAST GRAND FORKS AREA SHOWING SUBSURFACE STRATIGRAPHY

Geology-Climate-History

The Red River Valley is about 50 miles wide at the latitude of Grand Forks-East Grand Forks. The "Red River Valley," however, is not a true river valley; it is actually the bed of former glacial Lake Agassiz. This lake 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 Lake Agassiz was over 200 feet deep in the vicinity of these two cities and more than 100 feet of clay and silt was deposited on the lake bed. Solid bedrock (mostly granite) lies at an elevation of about 500 feet above sea level in this area, or about 330 feet beneath Grand Forks (8). Along the margins of the former lake, wave action washed the glacial till and formed beaches and other near-shore deposits composed of sand and gravel. These deposits are especially prominent in this area near Arvilla and Emerado, North Dakota, and Erskine, Minnesota, and incidentally, serve as the only local source of sand for construction and for "sandbag" dikes. The Red River of the North presently flows along the axis of the gently northward tilting bed of former Lake Agassiz. This "valley," or lake bed, is about 50 miles wide, whereas the actual trench cut by the river is on the order of 1/2 mile wide.

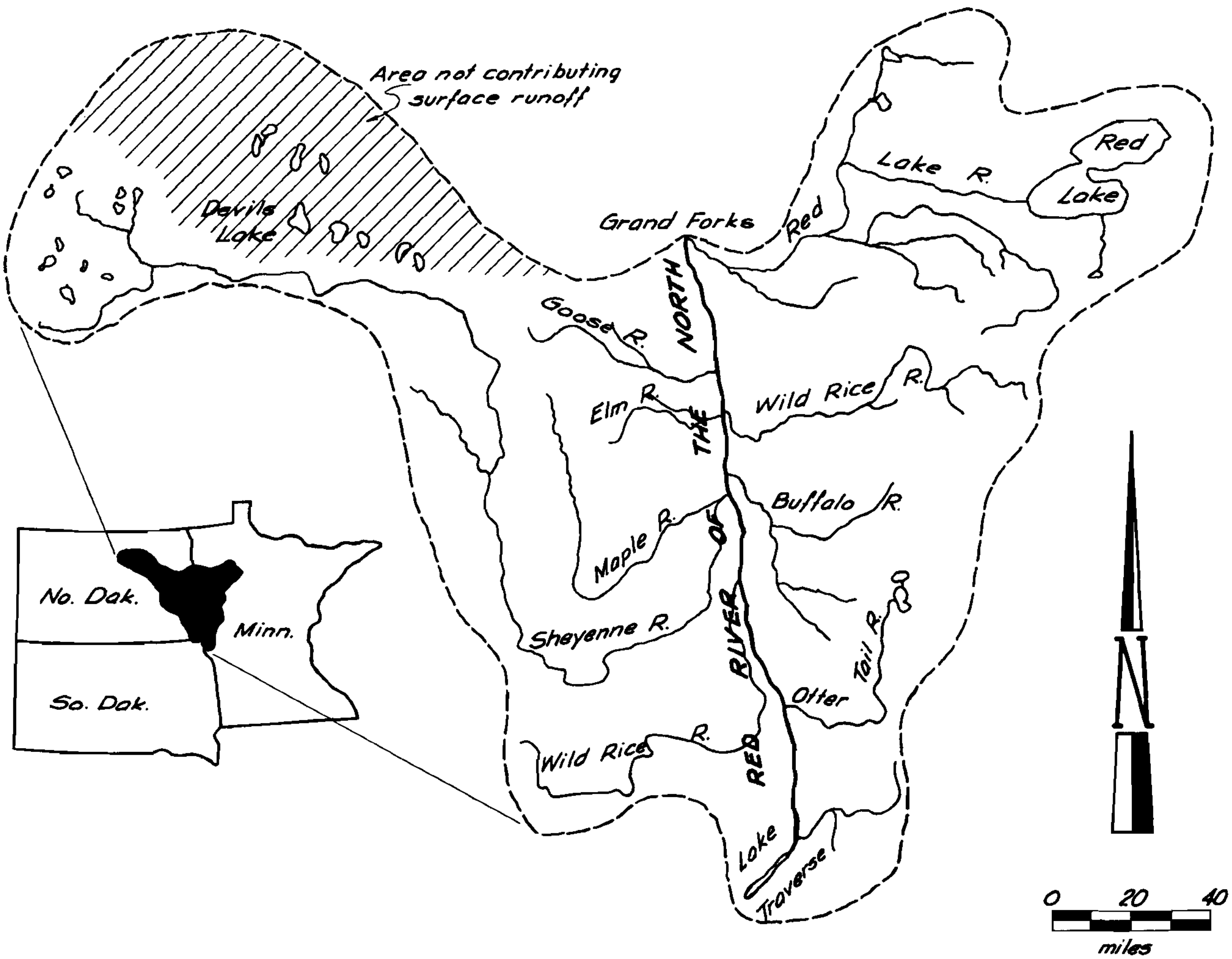
CLIMATE

The Grand Forks-East Grand Forks area receives an average of 19.80 inches of precipitation per year, ranging from as much as 21.88 inches in 1925 to as little as 6.08 inches in 1936. Of this precipitation, more than three-fourths falls between April and September. The remaining one-fourth, or about 4 inches, accumulates throughout the winter as snowfall (average winter snowfall totals 34.6 inches). As we shall see later, the melting of this snow in early spring is a major factor in causing floods in this area. An average monthly winter temperature (November through March) of 14.7°F results in the build-up of considerable thicknesses of ice on the rivers, which is also an important factor in flooding.

SETTLERS ARRIVE IN 1870

The first settlers arrived in Grand Forks in 1870(13). They found the land bordering the river a natural place for settlement because there one could find timber for fuel and building, water for himself and stock, and the river itself provided an avenue of transportation. Prior to 1900 there was considerable steamboat travel through Grand Forks-East Grand Forks, but by 1920 the last of the steamers had disappeared, and transportation on the Red and Red Lake rivers in this area was practically non-existent.

The population of the cities has increased steadily. In 1960 Grand Forks contained 30,000 inhabitants and East Grand Forks claimed about 7,500. Projected populations for the two cities are 50,000 and 12,000, respectively, by 1980 (7).



DRAINAGE BASIN OF THE RED RIVER AT GRAND FORKS

Hydrologic Setting

As previously mentioned, the "Red River Valley," along which the Red River flows, is actually the bed of former glacial Lake Agassiz. The lake bed, although generally described as "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 down the gentle slope of this 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; as a result, they have accomplished little erosion of the lake bed and for the most part have cut only shallow valleys across it. The north-south axis of the lake bed drops about 3/4 foot per mile northward. This, in turn, gives the Red River a low gradient. The gradient is decreased even further by the intricate meanders (wanderings of the channel) so that between Grand Forks and Pembina the river gradient is less than 1/2 foot per mile. Like its tributaries, the Red River is unable to accomplish much erosion with this low gradient and thus has not carved a very large valley. In most places the banks of the river are only about 25 feet below the surrounding upland.

THE RED RIVER AND ITS DRAINAGE BASIN

The Red River at 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 floodplain, however, the river width increases rapidly to as much as several miles just north of the city during severe floods.

The velocity at which the river is flowing varies considerably with time and place, and depends on many factors. As with most streams, velocity is generally highest during floods. The velocity is not uniform throughout the channel; it varies from nearly zero along the sides and bottom to a maximum just beneath the surface of the water at about the middle of the river. The average velocity of the Red River in 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 (5 1/2 miles per hour). Compared with rivers in other areas, however, this is relatively slow, primarily because of the gentle northward slope of the lake plain or "valley."

Flood damage along the Red River is seldom the result of the impact of floodwater or ice. Although the velocity may reach a considerable magnitude within the main channel of the river during floods, the velocity is generally low in the flooded reaches bordering the river where damage might occur.

The drainage basin of the Red River at Grand Forks includes all the land upstream from Grand Forks that contributes surface water to the river, either directly to the Red River or indirectly via its tributaries. Ideally, any water running off the land within this portion of the drainage basin (about 30,000 square miles) will eventually flow into the Red River and pass through the two cities.

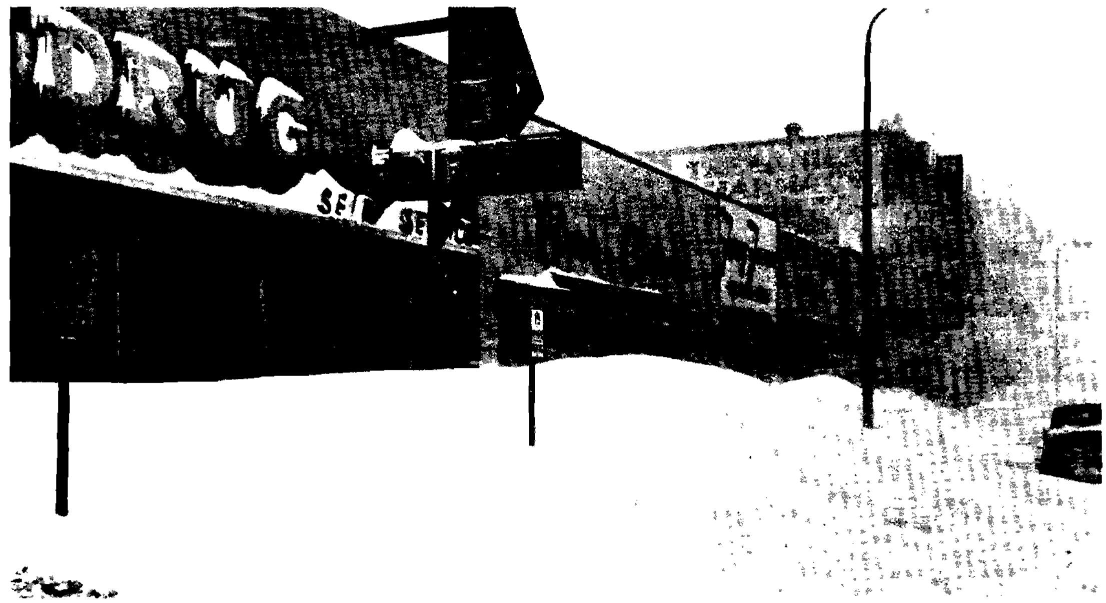
A 1-inch rainfall throughout the basin should therefore result in about 70 billion cubic feet of water that must pass through the river at this point. In reality, only 1 to 2 inches, or 10%, of the total 20 inches of annual precipitation in this basin ever reaches the Red River, the remaining 90% being lost primarily to evaporation and plant use (transpiration). Early spring rains, however, which often accompany flooding in this area, may produce a much higher percentage of runoff if the ground is frozen and therefore unable to soak up moisture.

The volume of water that passes through Grand Forks averages about 60 billion cubic feet annually or 2300 cubic feet per second. Of this amount, the Red Lake River contributes about one-half (2).

Upon seeing the Red River one is immediately aware of its muddy appearance. This muddiness, or turbidity, is caused by fine-grained sediment (mud) being carried in suspension in the water. Measurements made during the summers of 1965 and 1966 show that the water in the Red River in this general area contains from 0.008% to 0.023% suspended sediment (80 to 230 ppm) (3). Using 0.015% (150 ppm) as an average value, calculations show that during a typical summer day more than 1,620 tons of suspended sediment (mud) pass through Grand Forks-East Grand Forks, and during peak flows, when the river reaches heights of over 45 feet, more than 34,000 tons of sediment would pass between the two cities per day. This estimated volume of mud transport can perhaps be better envisioned if one imagines 162 ten-ton-capacity trucks filled with mud traveling from south to north through Grand Forks each day during the summer! The reason for the unusually large amount of suspended sediment in the Red River is probably that nearly all the land over which the water in the river flows before reaching Grand Forks is composed of fine-grained sediment. This is especially true along the central axis of the valley where the Red and its tributaries flow across clays and silts that were deposited in former glacial Lake Agassiz.

What eventually happens to all this suspended sediment? Upon reaching the still waters of Lake Winnipeg in Manitoba, the Red River is abruptly slowed down. Having decreased its velocity, the river current is no longer strong enough to keep the sediment suspended and consequently most of it settles to the bottom, forming a delta at the southern end of Lake Winnipeg.

In addition to the suspended sediment, the river is carrying dissolved salts in solution. The amount of dissolved material being transported by the river 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 every day (16).



Factors Affecting Flooding

Although flooding in this area is the result of numerous factors, the basic problem is this: During the winter, snow accumulates over the entire drainage basin, which encompasses more than 30,000 square miles of land. Some of this moisture is lost during the winter by sublimation, a process whereby snow and ice are released directly into the atmosphere without passing through a liquid stage. Much of the snow and ice is retained until spring, however, when it is released more or less suddenly by melting. In effect, it 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, flooding usually occurs to some degree. In general, the magnitude of the flooding is dependent upon the amount of moisture stored in the drainage basin and how fast it is released by melting.

Obviously there are many factors which affect this accumulation-melting-flood relationship. Some of the more important factors have been divided into two groups and are discussed below, although some factors have undoubtedly been overlooked or have not yet been recognized as being important. It is difficult, and sometimes impossible, to determine the relative importance of these factors, but the order in which they are discussed indicates their approximate rank <u>within</u> the two groups below.

"CONSTANT" FACTORS: BASIN AND CHANNEL CHARACTERISTICS

1. GRADIENT: As mentioned previously, the gentle northward slope of the bed of former glacial Lake Agassiz limits the gradient of the Red River to less than 1/2 foot per mile. Because the velocity of the river is controlled largely by the gradient, the Red River is unable to attain high velocities and thus drains the basin rather slowly. This increases the likelihood of flooding. Moreover, the flatness of the lake bed allows flood water to spread over a large area of the Red River Valley.

2. DIRECTION OF FLOW: The Red River is somewhat unusual in that it flows northward. Spring melting and runoff occur first in the southern or headward reaches of the basin. However, as this ice and water flows northward it frequently encounters unthawed portions of the river. These ice-covered reaches retard the flow of the river and often result in ice jams.

3. CHANNEL OBSTRUCTIONS AND DIKES: Bridges built across the Red River and its tributaries during the past 100 years increase the flood hazard somewhat. Not only does the bridge foundation restrict the flow of water by constricting the channel, but it greatly increases the likelihood of ice jams. It is therefore sometimes necessary to place draglines and other heavy equipment on the upstream side of bridges during floods to break up the oncoming ice before it jams.

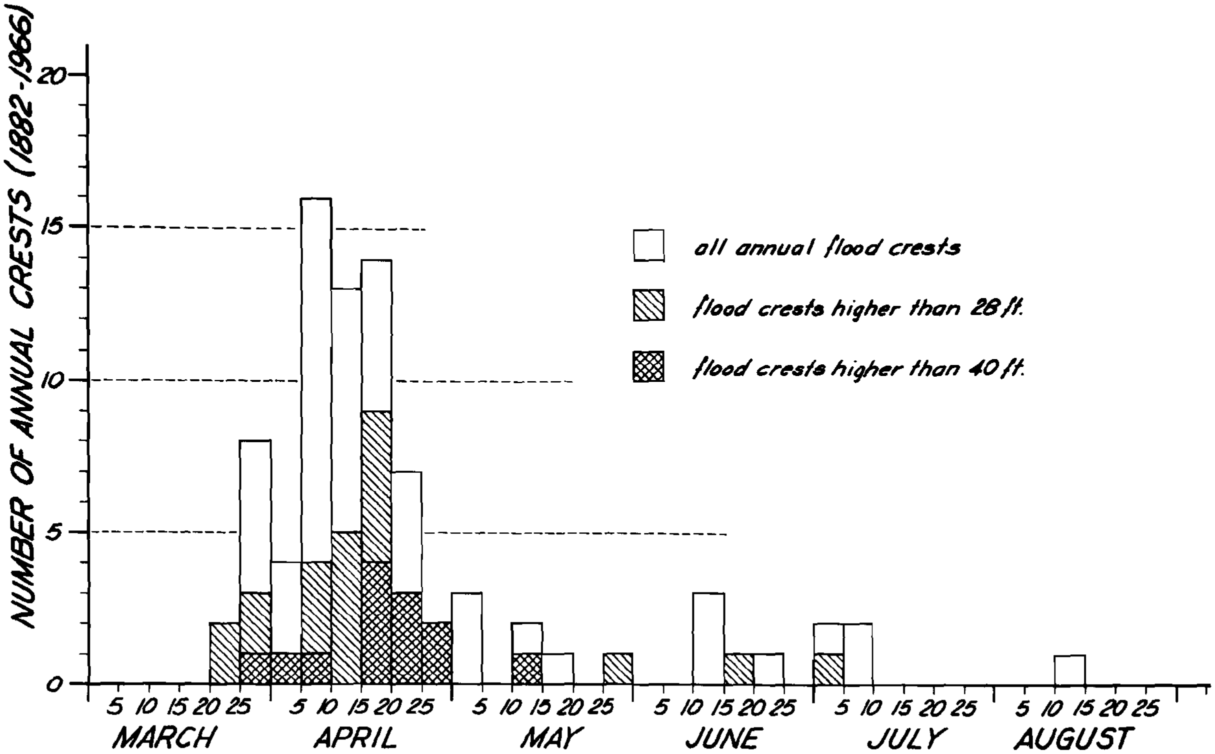
Although dikes do, in many cases, prevent floodwaters from inundating lowlands along the river, they also tend to restrict the river to a narrow artificial channel. The net result is a slight increase in the height of the river just upstream from the dikes as the water is forced through a relatively narrow neck in the channel during floods.

4. DRAINAGE DITCHES: Artificial drainage ditches facilitate draining of valuable farm land, but also result in faster and more complete transfer of rainfall and snowmelt to the river. Water that was once stored on the flats bordering the river is now poured into the river during the critical spring thaws.

"VARIABLE" FACTORS: THE WEATHER

It is the interplay of climatological factors from year to year that determines the magnitude of individual floods.

1. TIME OF FLOOD: Flooding can occur any time of year that temperatures are generally above freezing. In this area, however, flooding typically occurs in early spring, as shown in the following graph:



TIME DISTRIBUTION OF ANNUAL FLOOD CRESTS AT G.F.

The reason for the high concentration of floods in late March and April is obviously that snow and ice which accumulated throughout the winter are at that time more or less suddenly released by melting. Flooding can occur in the summer months in response to especially heavy rainfall over a large portion of the drainage basin. These "summer" floods, however, seldom reach the flood stage of 28 feet and inflict little if any damage in Grand Forks-East Grand Forks. Since 1882, only one flood over 40 feet high has occurred later than April. This 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 season of flooding cannot, of course, be considered as an independent variable because it is in turn dependent on the factors involving temperature and precipitation which are discussed below.

2. SNOW ACCUMULATION: The history of flooding in the Red River Valley shows that nearly all large floods were preceded by unusually heavy winter snowfall or late spring blizzards (such as in 1966) or both. In a few cases, however, winters with heavy snowfall have been followed by relatively small floods, and vice versa. It is apparent, therefore, that there are other factors besides the amount of winter snowfall which affect the magnitude of spring floods.

3. 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 is melted. Naturally, the shorter the time during which snow and ice stored in the drainage basin is melted and released, the greater the flow of the river must be to carry the meltwater off. Cool days with temperatures in the low 30's and night temperatures below freezing allow for slow release of the meltwater. However, an unusually cool spring with temperatures remaining below freezing is likely to be followed by a sudden warming trend which causes a rapid release of moisture. This is probably the primary reason that floods occurring after April 15 are apt to be more severe than earlier floods (see previous graph).

4. 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.

5. TIMING OF CRESTS: The drainage basin of the Red River at Grand Forks-East Grand Forks is divided primarily between the Red Lake River to the east and the Red River south of Grand Forks. 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 Grand Forks-East Grand Forks at the same time, the flood hazard is considerably increased.

6. CONDITION OF SOIL: If heavy rainfall is experienced in the fall of the year, the soil within the drainage basin is saturated with moisture when it freezes. It is therefore able to soak up very little moisture upon thawing in the spring. A wet fall, then, contributes to spring flooding by increasing the percentage of early spring moisture that must be carried by the rivers.

Also important is whether or not the ground is still frozen when spring snowmelt occurs. If frozen, the soil is again unable to soak up moisture or permit infiltration and thus increases the percentage or runoff into the rivers. Therefore, it might be expected that the colder the winter, the greater the depth of frost penetration into the soil, the slower the ground will thaw in the spring, and thus the greater the amount of runoff which causes flooding. In addition, the coldness of the winter probably has some influence on the amount of snow that will be retained (and stored) on the ground until the spring thaw.

7. ICE THICKNESS: The coldness of the winter affects flooding in still another way. An unusually cold winter, especially if early winter snowfall is light, results in a greater-than-average thickness of ice on the rivers. Obviously, the thicker the ice, the longer it will take to melt it in the spring. Until the ice is cleared from the river, flow of floodwaters is impeded and the threat of ice jamming is present.

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 followed by an early spring blizzard
4. An unusually late, cool spring followed by a sudden warming trend
5. Widespread, heavy, warm rainfall during the thawing period

No one of these factors alone, however, can guarantee 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

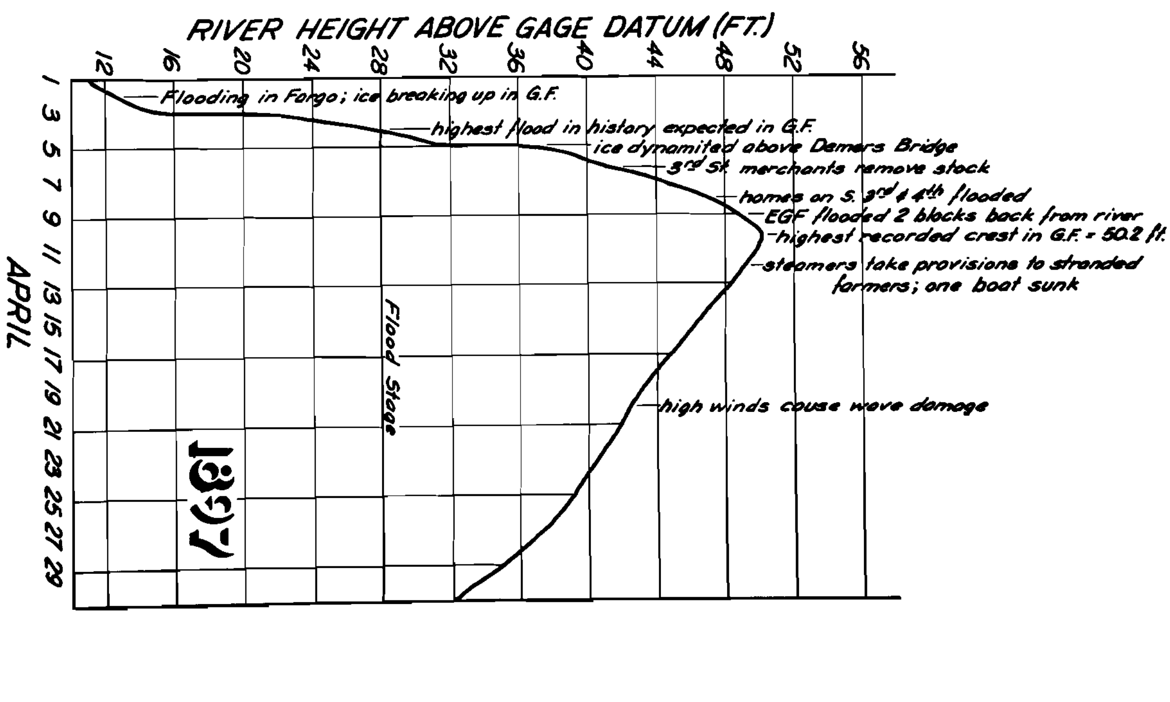
PRE-1882 ERA

Information concerning floods in this part of the Red River Valley prior to 1882 is meager. David Dale Owen (12), 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) 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." The barking of trees which he noted was probably caused by blocks of ice floating in the flood waters during spring breakup floods.

During 1853 no farming was done in the Red River Valley in the vicinity of Pembina on account of the annual 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 gage datum (15), which is higher than any subsequent flood in this area. Supposedly, however, the heaviest floods known in this area occurred in 1824, 1825, and 1826. In 1826 the water rose to a height of 66 feet near Pembina, 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. Flood waters did not recede until late July in 1826 and even the bison disappeared from the Pembina area!

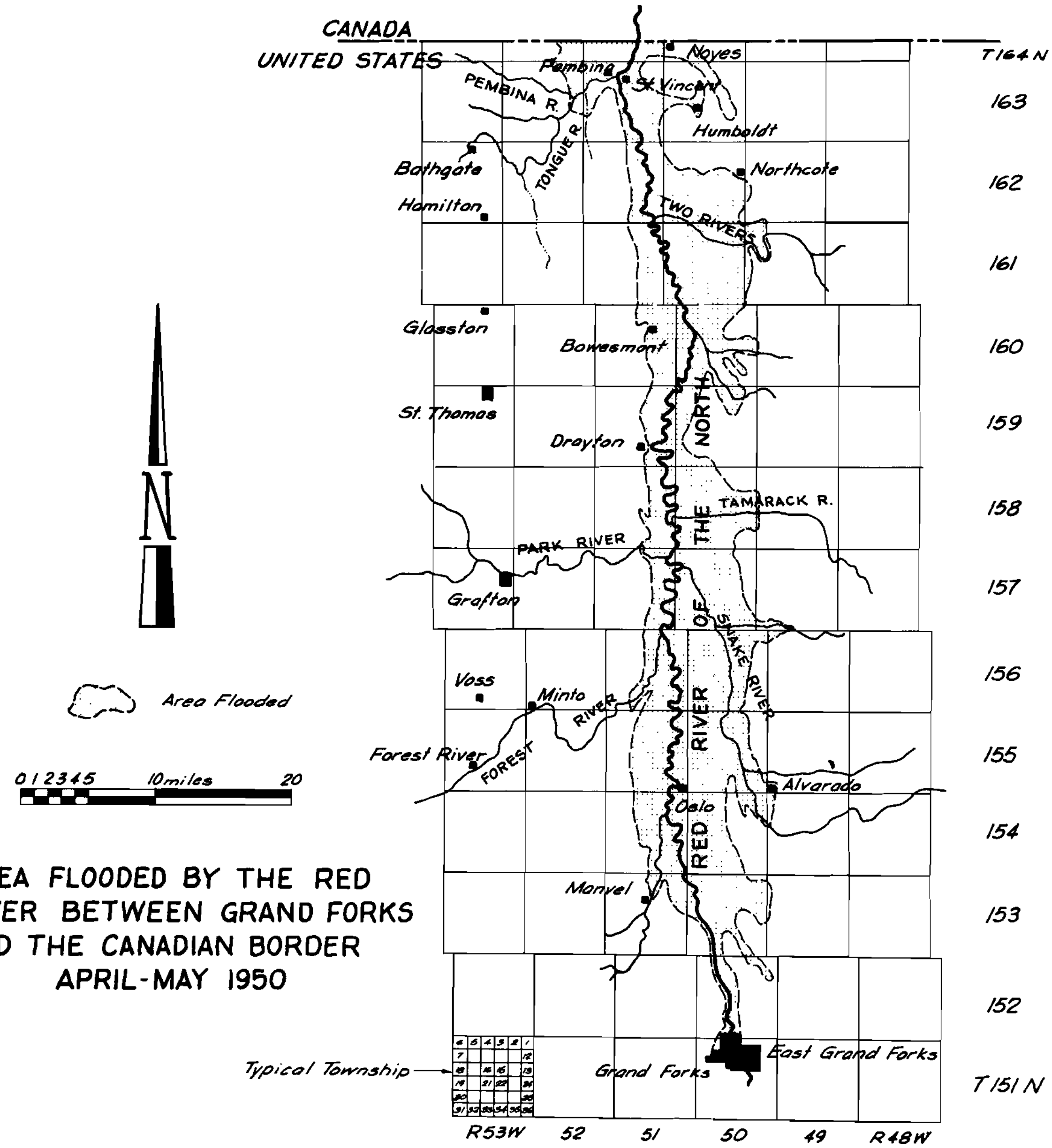
1897: THE HIGHEST FLOOD ON RECORD

Grand Forks was settled about 1870 and by 1882 a river-level gage had been installed near the Northern Pacific railroad bridge so that 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. During this flood a strip of country 30 miles wide and 150 miles long was inundated (1). 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 was 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 (1)! 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.

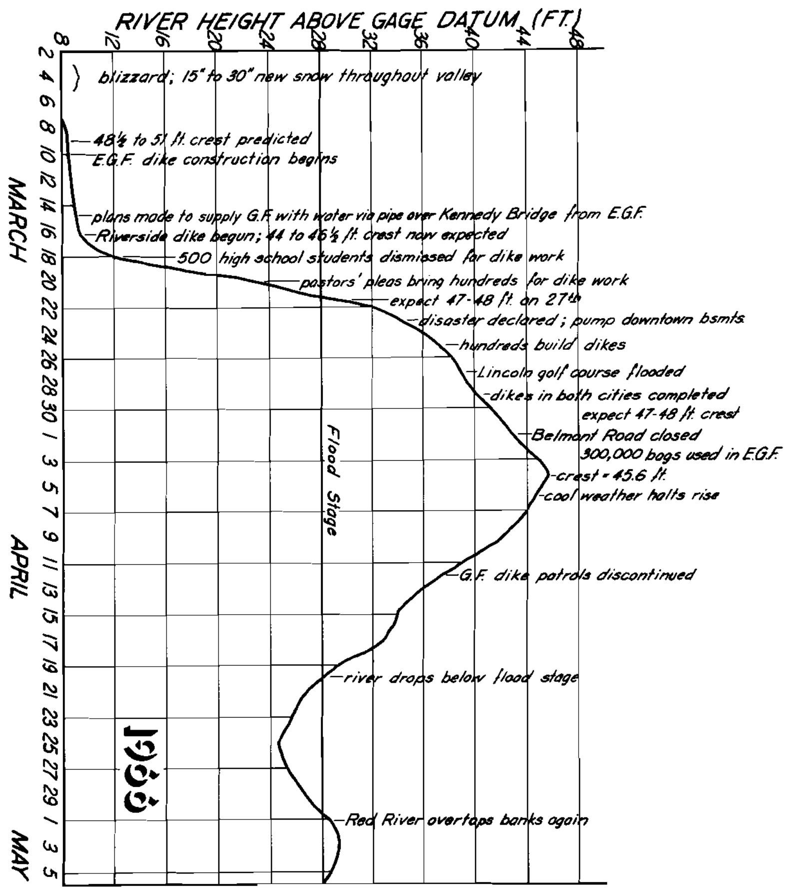


1950: THE FOURTH HIGHEST

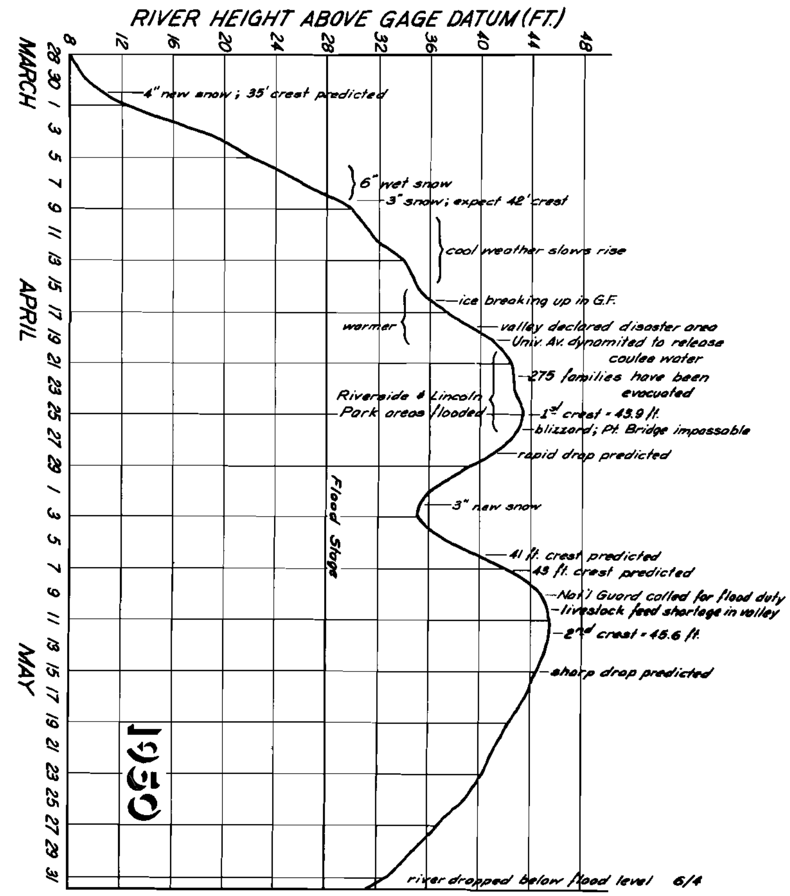
The 1950 flood is the fourth highest on record in Grand Forks-East Grand Forks, cresting at 45.61 feet above gage datum. Losses throughout the valley were estimated at $33,000,000. As usual, this flood was preceded by unusually heavy winter snowfall, later-than-normal spring melting, and heavy spring precipitation (1). In places the valley was flooded to widths of 30 miles (15) (see map below). In Grand Forks, 275 families had to be evacuated. Just as the first crest of the flood was receding in early May, heavy rains once again swelled the river, making this the longest duration flood on record in this area. Due to the unusual duration of the flood, a critical livestock-feed shortage developed throughout the valley.



AREA FLOODED BY THE RED RIVER BETWEEN GRAND FORKS AND THE CANADIAN BORDER APRIL-MAY 1950



RIVER HEIGHT ABOVE GAGE DATUM (FT.)
8 12 16 20 24 28 32 36 40 44 48
MARCH
APRIL
MAY
blizzard; 15" to 30" new snow throughout valley
48½ to 51 ft. crest predicted
E.G.F. dike construction begins
plans made to supply G.F. with water via pipe over Kennedy Bridge from E.G.F.
Riverside dike begun; 44 to 46½ ft. crest now expected
500 high school students dismissed for dike work
pastors' pleas bring hundreds for dike work
expect 47-48 ft. on 27th
disaster declared; pump downtown bsmts.
hundreds build dikes
Lincoln golf course flooded
dikes in both cities completed
expect 47-48 ft. crest
Belmont Road closed
300,000 bags used in E.G.F.
crest = 45.6 ft.
cool weather halts rise
G.F. dike patrols discontinued
river drops below flood stage
Red River overtops banks again
Flood Stage



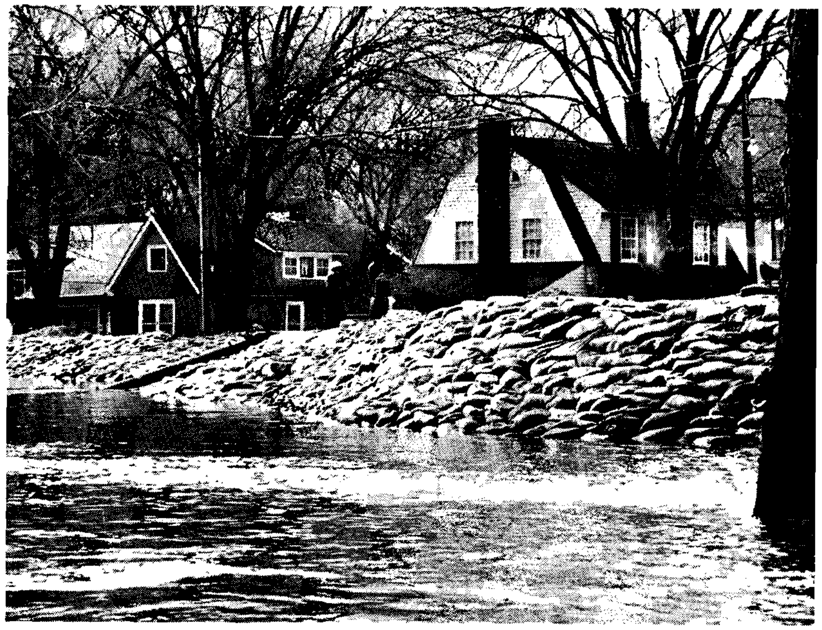
RIVER HEIGHT ABOVE GAGE DATUM (FT.)
8 12 16 20 24 28 32 36 40 44 48
MARCH
APRIL
MAY
4" new snow; 35' crest predicted
6" wet snow
3" snow; expect 42' crest
cool weather slows rise
ice breaking up in G.F.
warmer
valley declared disaster area
Univ. Av. dynamited to release coulee water
275 families have been evacuated
Riverside & Lincoln Park areas flooded
1st crest = 43.9 ft.
blizzard; Pt. Bridge impassable
rapid drop predicted
3" new snow
41 ft. crest predicted
43 ft. crest predicted
Nat'l Guard called for flood duty
livestock feed shortage in valley
2nd crest = 45.6 ft.
sharp drop predicted
river dropped below flood level 6/4
Flood Stage
1950

1965: LITTLE TIME TO PREPARE

In 1965, during the second week of April, waters suddenly began to rise, peaking at 44.9 feet on April 17. Damage was especially high in East Grand Forks despite construction of an emergency dike consisting of 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 and cleanup and sewer repair totaled $26,000. Both cities were reimbursed for these losses by the Federal Office of Emergency Planning.

1966: THIRD HIGHEST SINCE 1882

Following the blizzard of March 3, 4, and 5, 1966, which dumped more than 2 feet of snow on this area, a prediction for a 48 1/2 to 51-foot crest was issued by the Weather Bureau. Dike construction began immediately in both cities in anticipation of the 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 marked the third highest flood in history and the second big flood in two years. Although only about 1/2 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 much higher dikes than those of 1965, (2) some existing dikes had to be made higher to accommodate the higher crest prediction, and (3) the slow rise of the flood waters permitted much more extensive diking than in the previous year. 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.



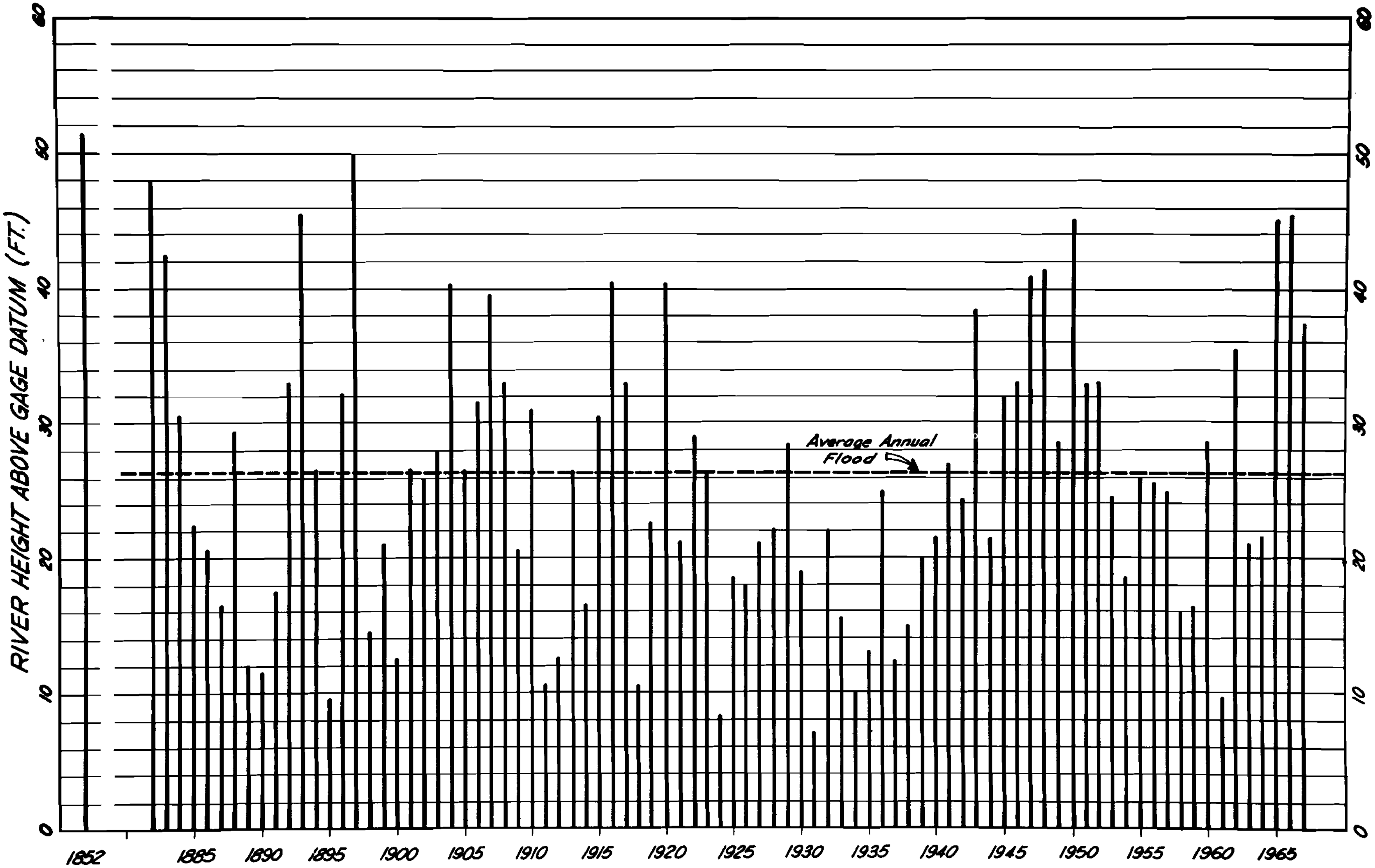
The Local Flood Hazard

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 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 1967 is shown on page 22 (see also the table on page 42). 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 were not yet settled at that time, the height of this flood has been interpreted from historic records (15).

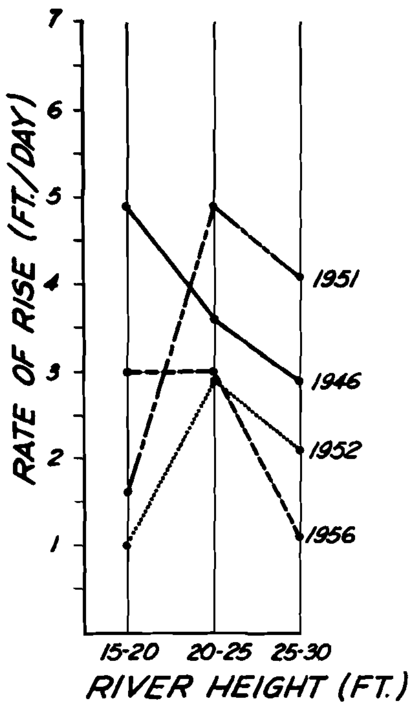
The graph (page 22) indicates that the magnitude of floods is somewhat cyclic. Periods of lower-than-average flooding occurred during the late 1880's, about 1900, 1911, middle 1920's, middle 1930's, and early 1960's. These lows probably correspond to periods of less precipitation, especially



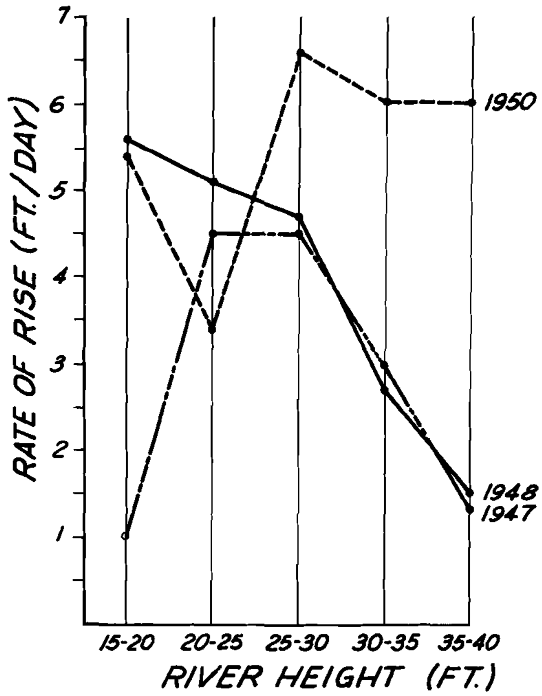
MAGNITUDE OF PAST FLOODS AT G.F.-E.G.F. (BASED ON U.S.G.S. RECORDS) the low-flood period of the 1930's. The peaks of the high-flood cycles are separated by periods ranging from 10 to 30 years, though the common interval is about 12 years. These flood cycles probably reflect similar cycles in the average 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 FLOOD WATER

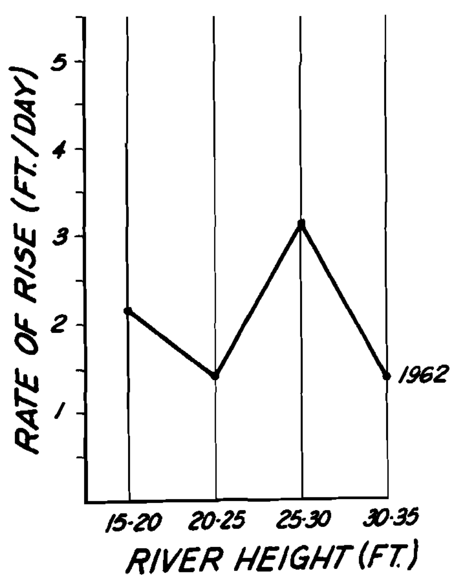
The rate at which the river rises during flooding is dependent upon the flood factors discussed previously. The rate of rise of the Red River at Grand Forks during past floods is shown below.



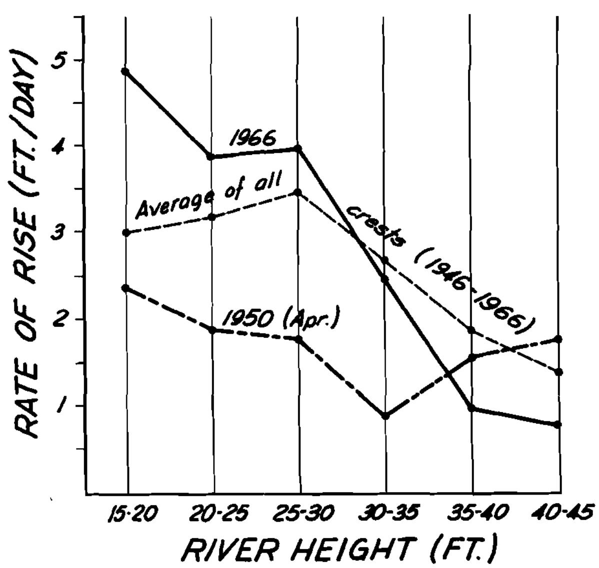
30 TO 34 FT. CRESTS



40 TO 44 FT. CRESTS

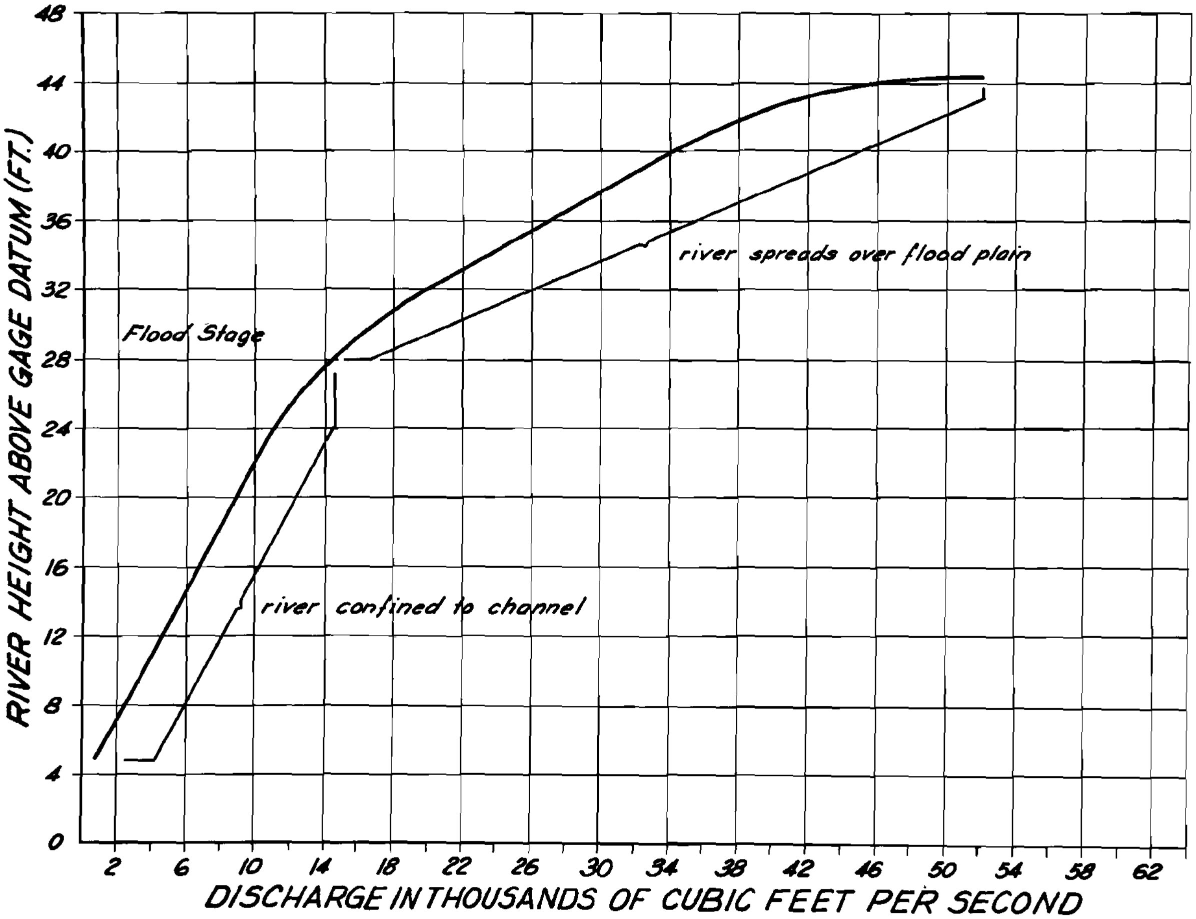


35 TO 39 FT. CRESTS



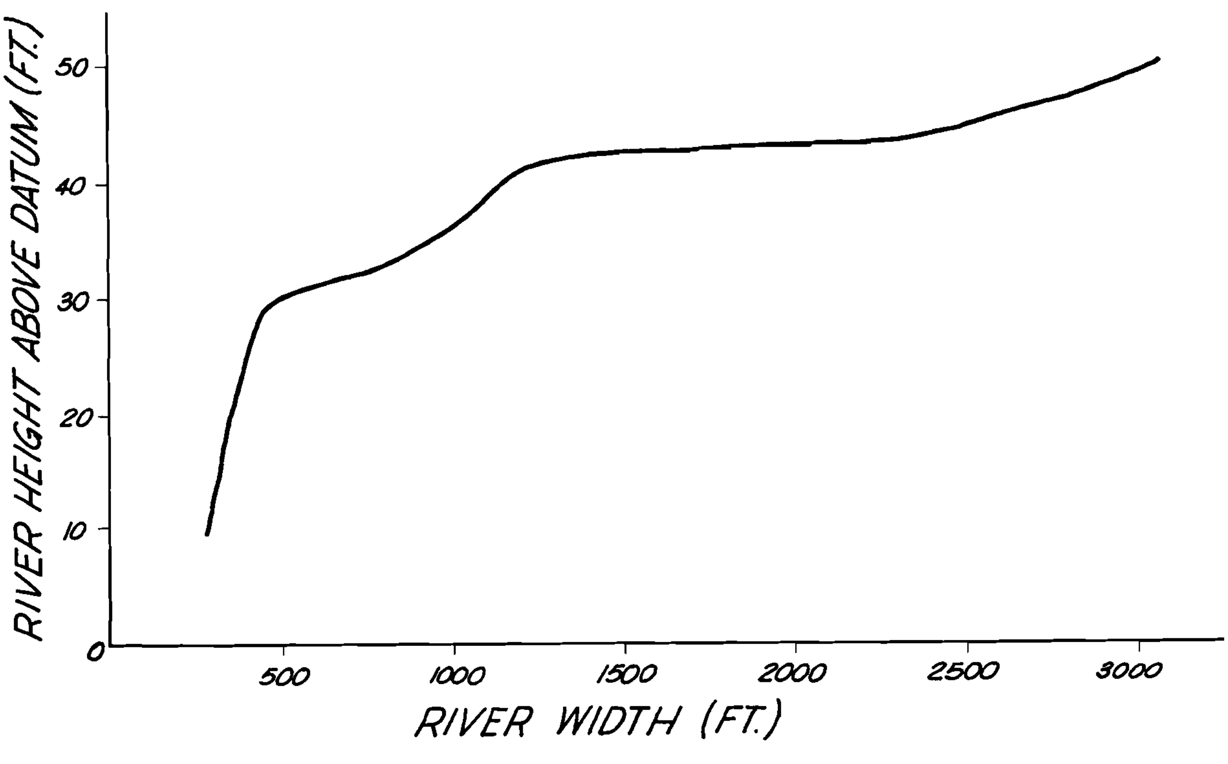
45 TO 49 FT. CRESTS

It is evident that the rate of rise generally decreases as the river height increases. This is due to the rapid spreading of the river over the floodplain 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 following discharge-river height curve for the Red River at Grand Forks.



DISCHARGE RIVER HEIGHT CURVE FOR THE RED RIVER AT GRAND FORKS

According to the discharge-river height curve, a discharge of 3000 cubic feet per second is needed to raise the river from 20 to 25 feet, whereas 4500 cubic feet per second are required to raise it from 25 to 30 feet. 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 increase the width of the channel. This same relationship is verified by the graph below, which shows 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 areas, the length of time that elapses between the river's flood stage and its flood crest is usually short, perhaps only a few hours. In this area, however, flash floods are not a problem. Several days usually elapse once the river has overtopped its banks before it reaches its peak or crest, especially in the case of the larger floods (over 40 feet). The flood-to-peak interval for several of the larger floods in this area has ranged from 6 to 17 days.

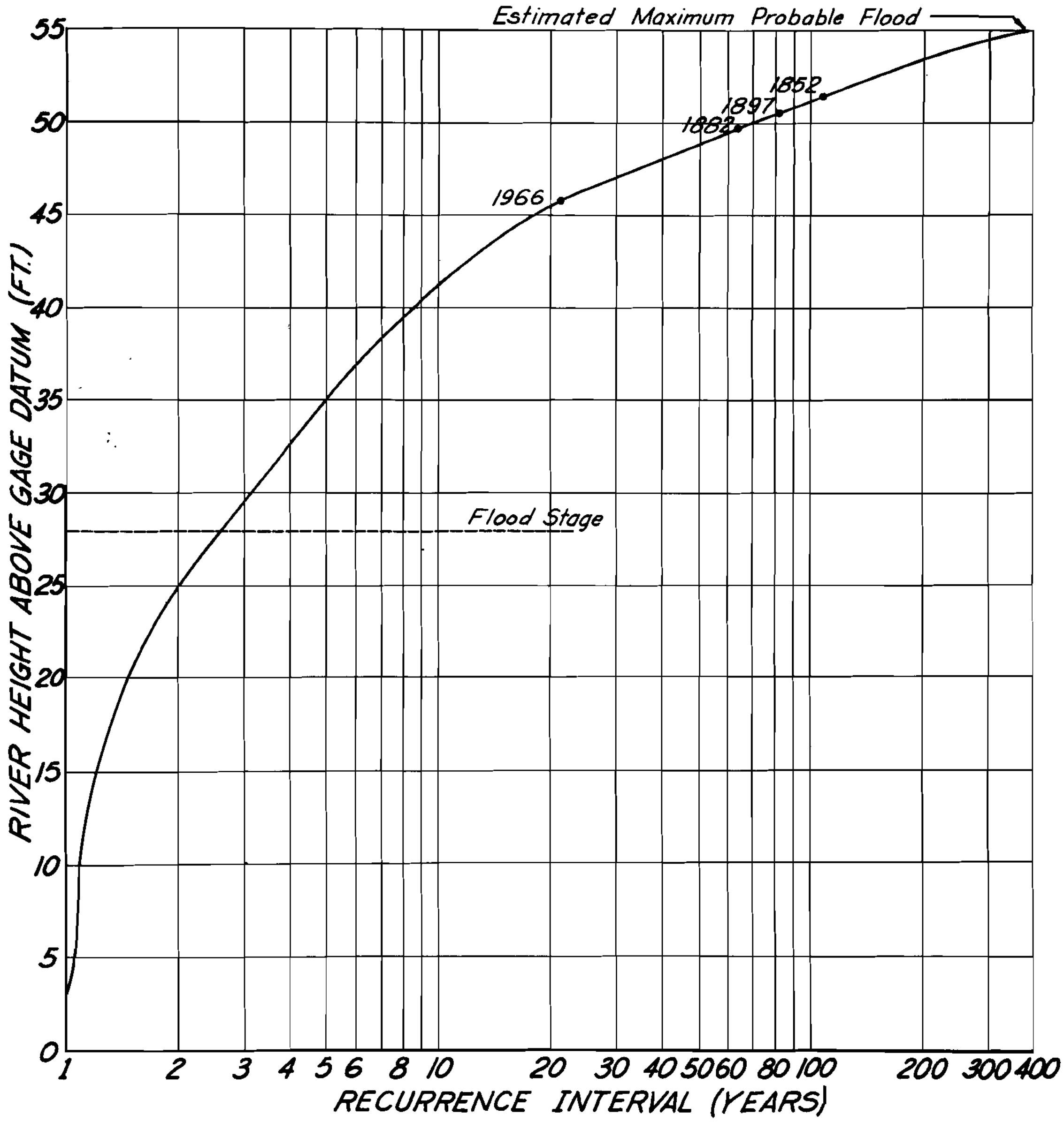
FLOOD FREQUENCY

One of the most useful relationships that can be derived from flood records is that of flood magnitude, or height, to flood frequency. The frequency, or recurrence interval, of each flood since 1882 is shown on page 42 (in back of booklet). The resulting flood-frequency graph, based on the rank and recurrence interval of all these floods, appears on page 27. Data for floods occurring after 1882 was obtained from gage records; the height of the 1852 flood has been interpreted from historic records (15).

The flood-frequency curve shows that a crest above flood stage can be expected to occur, on the average, about every 2 2/3 years. Floods 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 eight. This does not mean that seven years must separate each of these floods, but that over an 80-year period, about 10 floods of this magnitude or greater can be expected.

The chance of a flood over 45 feet high occurring in any one year is about 1 in 20. These floods, such as the flood of 1966, 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 80 years, or, the chance that it will occur in any given year is about 1 in 80. 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. This is especially true for the maximum probable flood, which is shown at a height of about 55 feet and at a recurrence interval of about 300+ years. A flood of this magnitude is not known to have occurred here. However, the U.S. Army Corps of Engineers has estimated the worst probable flood for this area by computing the volume of flow assuming that all flood-producing factors are at their worst. Their estimate of this flood is expressed as a river discharge of 146,800 cubic feet per second (15). The discharge-river height curve was extended to give a rough estimate of the height of the maximum probable flood--about 55 feet. The recurrence interval was likewise estimated by extending the flood-frequency graph to a height of 55 feet.



FLOOD FREQUENCY GRAPH FOR THE RED RIVER AT G.F.

EFFECTS OF FLOODING

Some of the effects of both past and hypothetical floods are listed on the following page. These effects were determined from historical records and from the flood-extent map (in pocket in back) to 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 table (page 29) shows that relatively little damage is done by floods less than 40 feet high, which occur, on the average, during one year in eight. 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 47 feet the Grand Forks water plant becomes inoperative, necessitating the laying of an emergency water line across Kennedy Bridge from the East Grand Forks water plant. DeMers Avenue bridge becomes impassable when the water reaches 48 feet. Also, at this height the river is level with the top of the East Grand Forks dikes. The Northern States Power plant in Grand Forks has to be shut down at 49 feet.

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 greater part of both cities would be inundated by shallow water.

EXTENT OF FLOODS

Although some of the details of the areas and utilities affected by flooding have been discussed above, a more generalized picture of the extent of flood waters 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, 30, 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 1/2 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 (6). Therefore, the gradient of approximately 1 foot that was used in delineating the flood extent on the map is probably somewhat conservative.

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
2.6 yrs.	28.0	806.4	flood stage - Red River begins to overflow banks
4.6	34.0	812.4	water over roof of Red River water pump house
5.6	36.0	814.4	seepage in basement of NSP power house
9.0	40.5	818.9	seepage in business district basements
9.5	41.0	819.4	water works needs protection
10.8	42.0	820.4	sandbags needed for NSP power plant - Riverside, Central and most of Lincoln parks flooded in Grand Forks - homes on N. 4th St. just south of River Heights in East Grand Forks require diking
18.0	45.0	823.4	Belmont Road at 17th requires diking to protect homes
30.0	47.0	825.4	Grand Forks water plant becomes inoperative - 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
40.0	48.0	826.4	DeMers Avenue bridge impassable - water reaches top of East Grand Forks dikes - much of the Point in East Grand Forks flooded - downtown Grand Forks flooded
60.0	49.0	827.4	NSP power plant in Grand Forks inoperative
114	51.2	829.6	all railroad bridges impassable - this is the estimated height of the 1852 flood, the largest known in this area
200?	53.6	832.0	water reaches top of Lincoln Park dike
300+?	55.0	833.4	this is the estimated maximum probable flood for this area - the greater part of both cities would be covered by shallow water

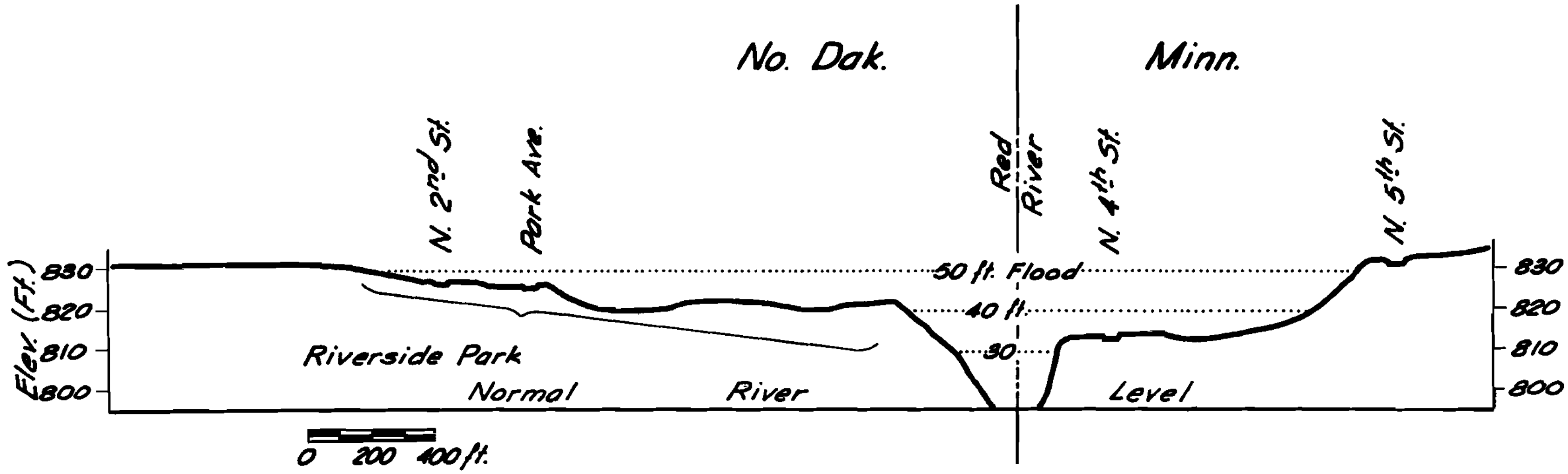
The 10-year flood (42 feet high), shown by the dark blue color band on the map, is well above the banks of the rivers and spreads over the floodplain producing a river width ranging from about 600 feet near DeMers Avenue to about 2300 feet in the vicinity of the Lincoln Park golf course. The constriction 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.

The extent of the 30-year flood (47.5 feet) is shown on the map by the medium blue color band. Except in Lincoln Park and the residential area lying north of DeMers Avenue in East Grand Forks (now protected by dikes), this band 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 42 to 47 1/2 feet, is impinging on a relatively steep valley wall which borders the floodplain.

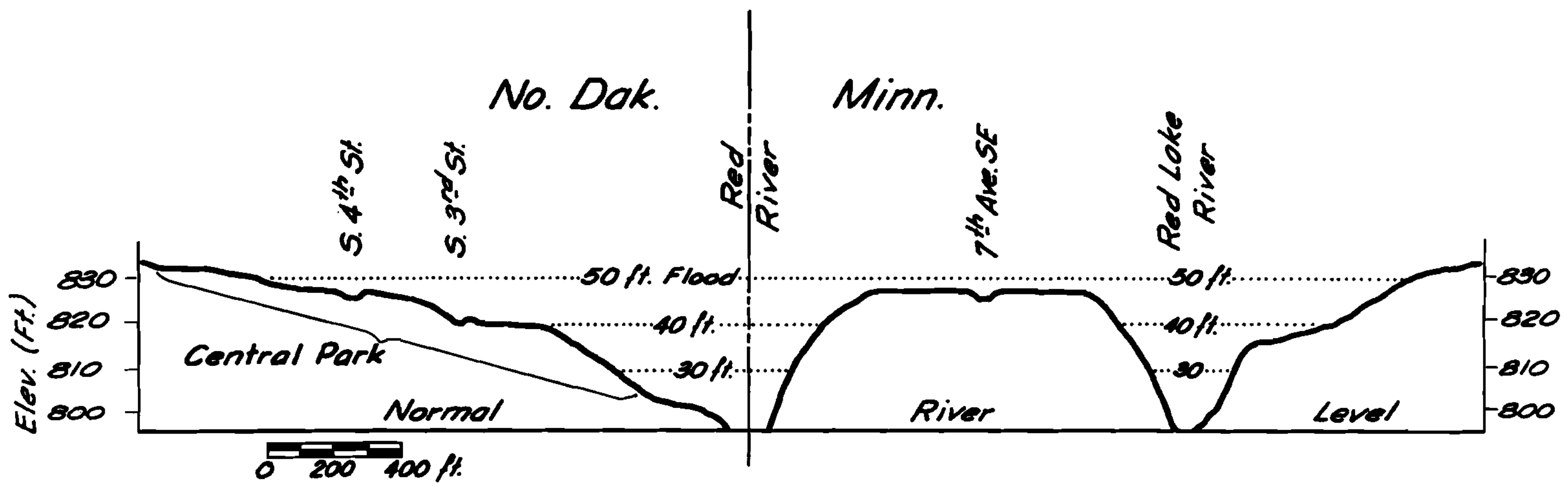
The additional large areas inundated by the 100-year flood (51 feet high) are in the vicinity of 17th Avenue South and Belmont Road, Central Park, downtown Grand Forks, River Heights, The Point area in East Grand Forks, and the general area just north of the two cities. These areas are indicated by the light blue color band. With the exception of the 17th Avenue South and Belmont Road area, most of this zone lies at or below the confluence of the two rivers, indicating a tendency for development of a broader floodplain below their juncture.

The maximum probable flood, estimated at approximately 55 feet above gage datum, would likely cover most of both cities with shallow water, especially the streets. Only areas lying above about 833 feet on the north end of town and about 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 through Riverside Park and the other through Central Park, are shown on the following page. 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, 40, and 50 feet.



PROFILE OF THE FLOOD HAZARD AREA - RIVERSIDE PARK VICINITY

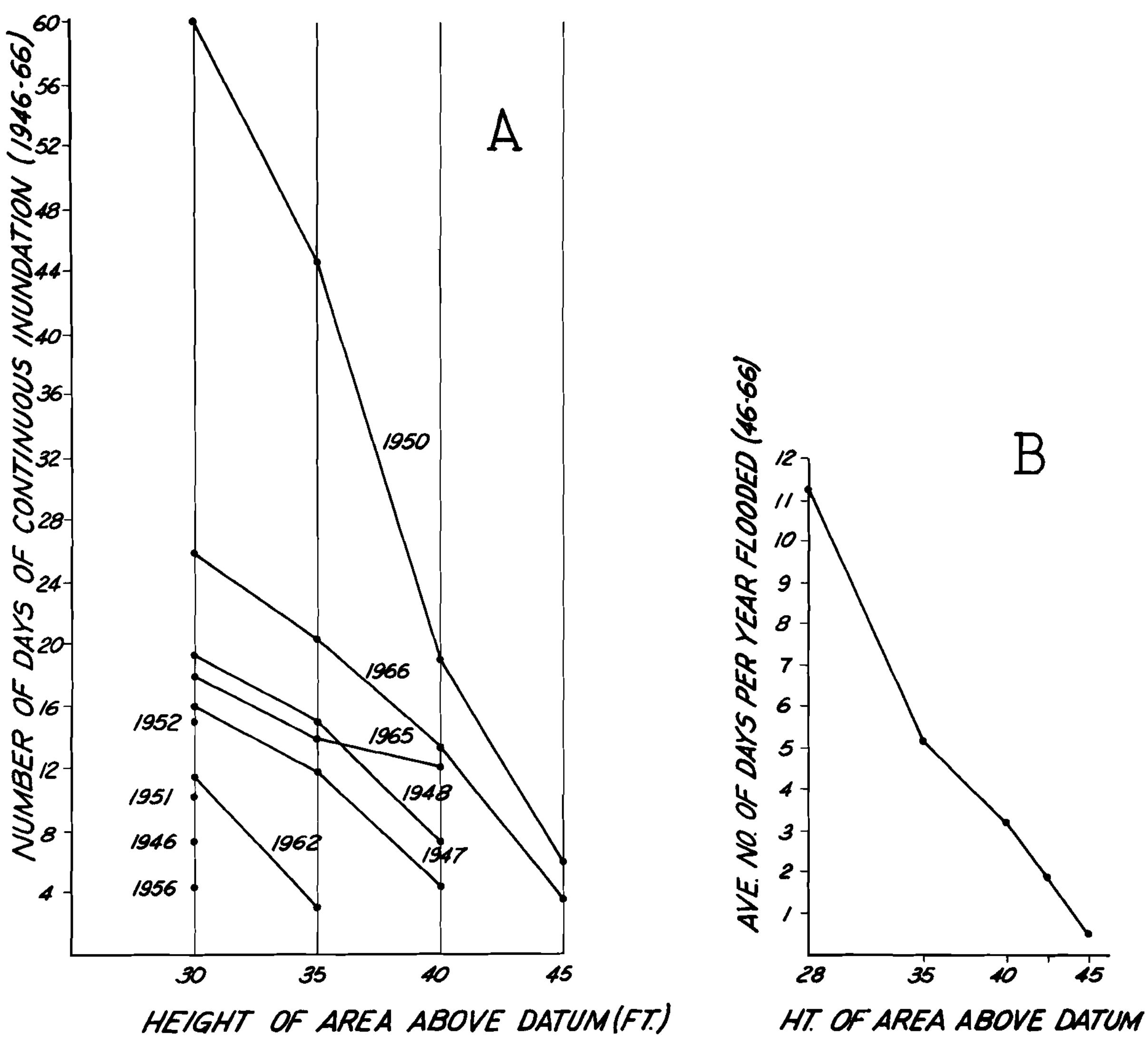


PROFILE OF THE FLOOD HAZARD AREA - CENTRAL PARK VICINITY

DURATION OF FLOODS

The general inconvenience and amount of damage resulting from flooding is in many cases directly related to the length of time an area or structure is inundated. The following graph (A) shows the number of days of continuous inundation for areas lying 30, 35, 40, and 45 feet above the gage datum for selected floods. As would be expected, the higher the land surface, the shorter the duration of flooding.

The average number of days per year that areas lying 28, 35, 40, and 45 feet above the datum would be inundated (not necessarily continuous inundation) is indicated in graph "B" (based on 21 years of record). Areas lying just above the banks of the rivers (about 28 feet above datum) will be inundated an average of 11 days per year, whereas those areas 35 feet above the datum will be dry all but about 5 days per year on the average. Finally, those areas lying more than 45 feet above the datum will average less than one day of flooding per year.


A
NUMBER OF DAYS OF CONTINUOUS INUNDATION (1946-66)
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
1950
1966
1965
1952
1948
1951
1946
1962
1947
1956
30
35
40
45
HEIGHT OF AREA ABOVE DATUM (FT.)
B
AVE. NO. OF DAYS PER YEAR FLOODED (46-66)
12
11
10
9
8
7
6
5
4
3
2
1
28
35
40
45
HT. OF AREA ABOVE DATUM

FLOOD FORECASTING

Forecasts of flood crests are important inasmuch as they allow time for necessary precautions to be taken in order to reduce flood damage. Essentially, the prediction of flood crests for the Red and Red Lake rivers involves evaluation of all the flood-producing factors discussed earlier. To reiterate, some of the factors important in flood forecasting include:

1. Slope, size, and shape of the drainage basin
2. Condition of soil, depth of frost, and ice thickness on the river
3. Snow accumulation, spring precipitation, and time and rapidity of spring thaw

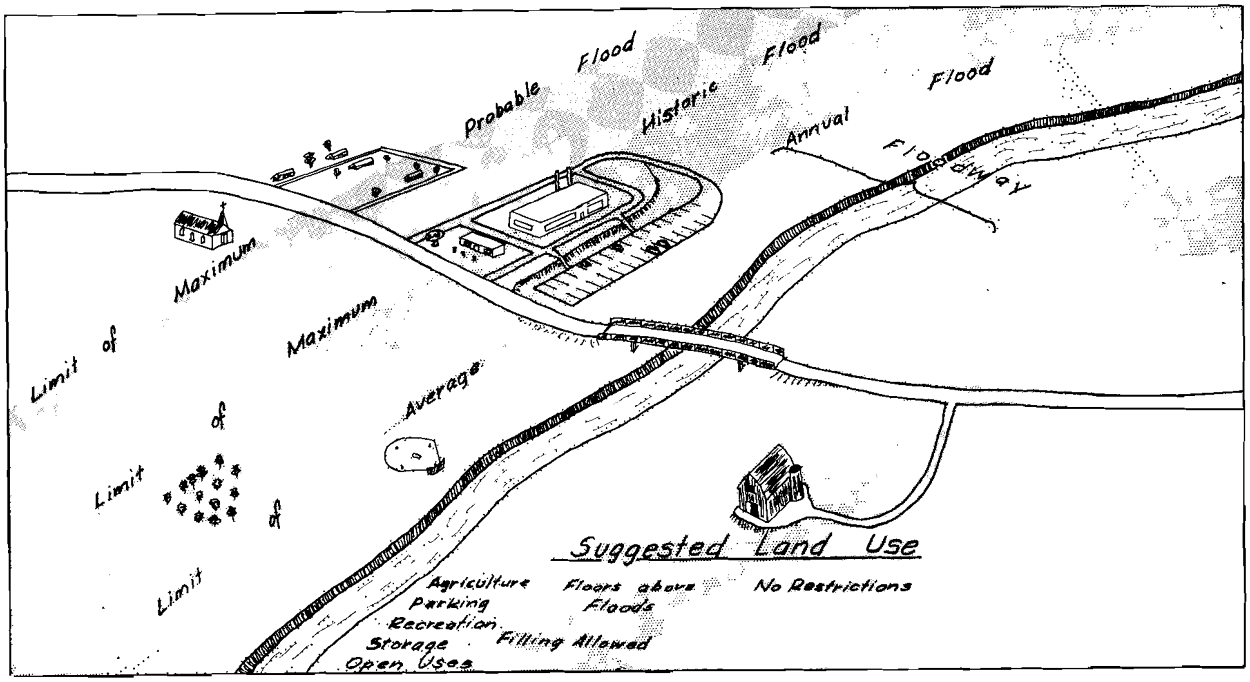
Use is made of past flood records by correlating each of the variables, or weather factors, with past flood magnitudes.

For the Grand Forks-East Grand Forks area, official predictions are made by the U.S. Weather Bureau in Fargo. Specific factors used in their predictions are (9):

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
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 flood-loss-reduction measures to be taken. After the advance prediction is made, the prediction is altered and the range of the expected crest heights decreased every few days as temperature and precipitation fluctuate. Future research, especially in the field of long-range weather forecasting, will continually improve the accuracy of flood predictions.

Although many different flood-forecasting procedures are used in other areas, all deal more or less with the same basic factors. A method differing slightly from the Weather Bureau procedure has been suggested for use in the Red River Valley by Joseph R. Schwendeman, a former University of North Dakota geographer (14). His method entails detailed analysis of winter and spring temperatures and precipitation over the 10-year period prior to the anticipated flood, with emphasis on the preceding winter. Preliminary testing of the proposed procedure shows that predicted flood heights compare favorably with Weather Bureau predictions. Schwendeman's method, however, enables predictions to be made further in advance of the flood. For instance, on April 10, 1965, Schwendeman predicted a flood crest of 42.9 feet for Grand Forks. The following day the Weather Bureau predicted a 29-to 32-foot crest. The actual crest, which occurred on April 16, was 44.9 feet. Further testing of this proposed forecasting procedure is necessary, however, before a sound evaluation of its accuracy can be made.



Flood Damage Reduction

The solution to the flood problem is not simply to remove all structures from the floodplains and prohibit any future development. There are many definite advantages for developing the floodplains, despite the flood hazard. The problem, however, is that once individuals have developed the floodplain (occupied it) they subject the local community to considerable financial loss. If the individuals bore the entire flood-damage loss themselves, floodplain development would be of little concern to various branches of government--except as a moral responsibility to the individual because he suffers due to his unawareness of the flood hazard. Rarely, however, does the individual accept the full responsibility. Various 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 floodplains, and these developed areas are a potential permanent drain on the economy of cities. Intelligent planning and regulating of development in these floodplain areas is imperative, therefore, if damage from flooding is to be reduced.

POSSIBLE MEANS OF REDUCING FLOOD-LOSS

In order to reduce flood losses, some of the following methods are usually employed (11):

1. Engineering works, such as levees, reservoirs, channel enlargement and straightening, and channel by-passes. This is usually thought of as the best universal solution to the flood problem. Experience has shown, however, that often such protection is

economically impractical and the following measures should be considered.
2. Regulation of development--this doesn't necessarily prohibit development, but defines the type of buildings permissible on the floodplain.
3. Adjustments in structures--this includes land fill, changing the design and layout of buildings, elevating equipment, water proofing structures, etc. This is generally referred to as flood-proofing.
4. Temporary evacuation of flooded areas and rescheduling of services, transport routes, etc.
5. Flood insurance may sometimes be available from the federal government to distribute losses.

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

EXISTING FLOOD PROTECTION IN GRAND FORKS-EAST GRAND FORKS

Permanent flood protection in both cities as of 1967 consists entirely of flood levees, locally referred to as dikes. An approximately 1 1/4-mile-long dike in the Lincoln Park area of Grand Forks was completed in 1958 (see flood-extent map). This dike is primarily earthen, with a small portion of the south end being constructed of concrete. The top of the 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 have a recurrence interval of about 100 years. The area behind the dike is also protected from back-flooding through storm sewers by an emergency pumping system. 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 (5).

Permanent dikes in East Grand Forks also total about 1 1/4 miles in length. These dikes were for the most part constructed during 1966 in the few weeks prior to the flood. Because they were originally built as emergency dikes, most of the construction cost 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 (6), which have a recurrence interval of about 50 years. In the event of a flood over 47-48 feet, the existing dikes would have to be topped with sandbags. The cost of these dikes was not readily obtainable.

At present there are about 52 homes in Grand Forks which require emergency sandbag diking for floods much over 40 feet high. Most of these homes are located in the vicinity of Central and Riverside parks. For floods less than 48 feet high, the most vulnerable areas in East Grand Forks appear to lie in the point between the two rivers and in the park just south of the River Heights development on the north edge of the city.

FUTURE FLOOD-LOSS REDUCTION

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. The Corps has offered a flood-relocation plan to the residents of low-lying areas in Riverside and Central parks. Under this plan, 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 be required to furnish all lands, easements, and rights-of-way for relocating the houses. The area formerly occupied by the relocated homes would be added to the already existing parks. This proposal was submitted to the residents of these flood areas in the spring of 1967. Although some of the landowners were in favor of the proposal, the acceptance was not unanimous, and therefore 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. Thus, in the event of another flood such as those of 1965 and 1966, no dikes will be constructed in these areas unless some agreement is reached.

Although many of the residents of the Riverside and Central Park areas are in favor of a permanent dike or levee such as the one in Lincoln Park, the Corps of Engineers considers such construction economically impractical, considering the few homes that would be protected. According to estimates made by the Corps, flood walls and levees would cost $1,092,000 for the Riverside Park area and $333,000 for Central Park. This would result in average annual charges of $39,500 and $12,600 for the two areas respectively, with corresponding average annual benefits of only $20,000 and $10,500. This produces unfavorable benefit-cost ratios of 0.5 for Riverside Park and 0.8 for Central Park. The permanent evacuation of these areas, however, as proposed earlier by the Corps, would result in favorable benefit-cost ratios of 1.8 for Riverside Park and 1.4 for Central Park. The Corps does not feel that any additional studies of flood control in these areas are warranted at the present time.

Even though the present flood problem in Grand Forks-East Grand Forks is not critical, it did cost the federal government over $1,000,000 for emergency diking and damages during the 1966 flood alone. It is estimated that by 1980 the population of Grand Forks will grow from its present 35,000 to 50,000; and East Grand Forks will increase from about 8,000 in 1960, to 12,000. As a result, many new homes will undoubtedly be constructed in the areas bordering the rivers north and south of the present residential limits. The obvious answer to mounting flood-protection costs, then, is intelligent regulation of the development of these flood-hazard areas.

The solution is not simply the adoption and enforcement of new regulations, however. The Grand Forks City Planning Commission would like to pass floodplain zoning ordinances. The problem they are confronted with, however, is that they cannot legislate on land that is already developed. When new areas come into the city, they have already been developed while part of the county. The County Commissioners have enacted no floodplain zoning and feel no need to, because until the land is heavily developed, no demand for flood protection is requested of the county by the land owners. By the time development has reached the point where there might be some demand for flood protection, these areas request to be included within the city. Hence, the City Planning Commission is then faced with another new area which has already been developed without regard to floodplain zoning.

It would appear, then, that the zoning might have to be enacted by state or federal agencies. In this way, all undeveloped floodplain areas, whether or not they are within city limits, would be affected by the regulations.

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

Rank	Height	Year	Interval	Rank	Height	Year	Recurrence Interval
1	51.2	1852	114	44	25.0	1936	2.0
2	50.2	1897	86	45	24.67	1957	2.0
3	48.0	1882	43	46	24.63	1953	1.9
4	45.63	1966	28.6	47	24.10	1942	1.9
5	45.61	1950	21.5	48	23.2	1919	1.8
6	45.5	1893	17.2	49	23.1	1885	1.8
7	44.92	1965	14.3	50	22.71	1964	1.8
8	42.2	1883	12.3	51	22.07	1931	1.7
9	41.68	1948	10.7	52	21.8	1928	1.7
10	41.0	1920	9.6	53	21.8	1940	1.6
11	41.0	1916	8.6	54	21.7	1927	1.6
12	40.71	1947	7.8	55	21.23	1963	1.6
13	40.65	1904	7.2	56	20.9	1921	1.6
14	39.95	1907	6.6	57	20.9	1899	1.5
15	38.16	1943	6.1	58	20.6	1886	1.5
16	36.0	1906	5.7	59	20.13	1939	1.5
17	35.45	1962	5.4	60	19.79	1944	1.5
18	33.9	1917	5.1	61	19.0	1925	1.4
19	33.60	1952	4.8	62	18.9	1930	1.4
20	33.52	1951	4.5	63	18.8	1909	1.4
21	33.4	1892	4.3	64	18.63	1954	1.4
22	33.23	1946	4.1	65	18.1	1926	1.3
23	32.8	1908	3.9	66	17.7	1891	1.3
24	32.0	1945	3.7	67	17.5	1914	1.3
25	32.0	1896	3.6	68	16.3	1887	1.3
26	31.1	1884	3.4	69	16.10	1959	1.3
27	30.8	1915	3.3	70	16.03	1958	1.2
28	30.7	1910	3.2	71	15.49	1938	1.2
29	29.5	1888	3.1	72	15.18	1933	1.2
30	29.11	1949	3.0	73	15.0	1898	1.2
31	28.88	1960	2.9	74	13.2	1900	1.2
32	28.72	1922	2.8	75	13.07	1935	1.2
33	28.3	1929	2.7	76	12.73	1912	1.1
34	28.0	1903	2.6	77	12.0	1889	1.1
35	27.86	1941	2.5	78	11.57	1937	1.1
36	26.9	1894	2.5	79	11.3	1918	1.1
37	26.7	1913	2.4	80	10.7	1911	1.1
38	26.60	1923	2.3	81	10.6	1890	1.1
39	26.3	1901	2.3	82	10.02	1934	1.1
40	26.17	1955	2.2	83	9.9	1895	1.0
41	26.11	1905	2.1	84	9.75	1961	1.0
42	26.0	1902	2.1	85	8.2	1924	1.0
43	25.50	1956	2.0	86	6.48	1931	1.0

Recurrence interval computed using U.S. Geological Survey method:

$$RI = \frac{n+1}{m}$$

n = years of record
m = rank of flood

MS-35


Flood Extent Map
of
Grand Forks, North Dakota
East Grand Forks, Minnesota
English Coulee
Mill Road
RED RIVER OF THE NORTH
Riverside Park
20th Ave. NW
19th Ave. NW
18th Ave. NW
17th Ave. NW
Park Ave.
Conklin Ave.
Fenton Ave.
Seward Ave.
Gateway Drive
11th Ave. N.
10th Ave. N.
University Av.
Demers Ave.
EAST GRAND FORKS
GRAND FORKS
RED LAKE RIVER
Central Park
Lincoln Park Golf Course
Chestnut St.
Belmont Road
17th Av. S
32nd Av. S
34th Av. S
47th Ave. So
N
0 2 4 6 8 1000 14 18 2500
Feet
LEGEND
Railroads
Dikes
Flood extent behind the dikes is shown as if the dikes were not present. Dikes shown on the map protect the Lincoln Park area from floods up to 52 feet. In East Grand Forks diked areas are protected from floods up to about 48 feet.
COLOR CODE
Extent of 10 year flood (42 ft.)
Extent of 30 year flood (47.5 ft.)
Extent of 100 year flood (51 ft.)