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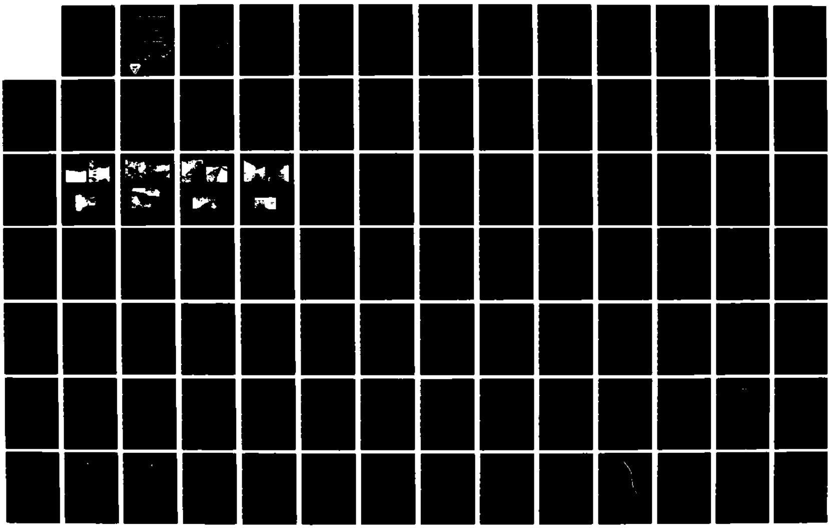

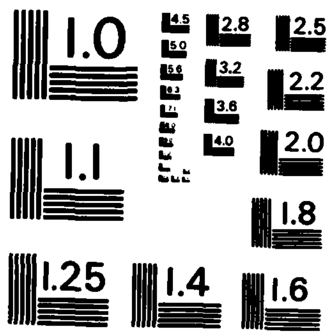

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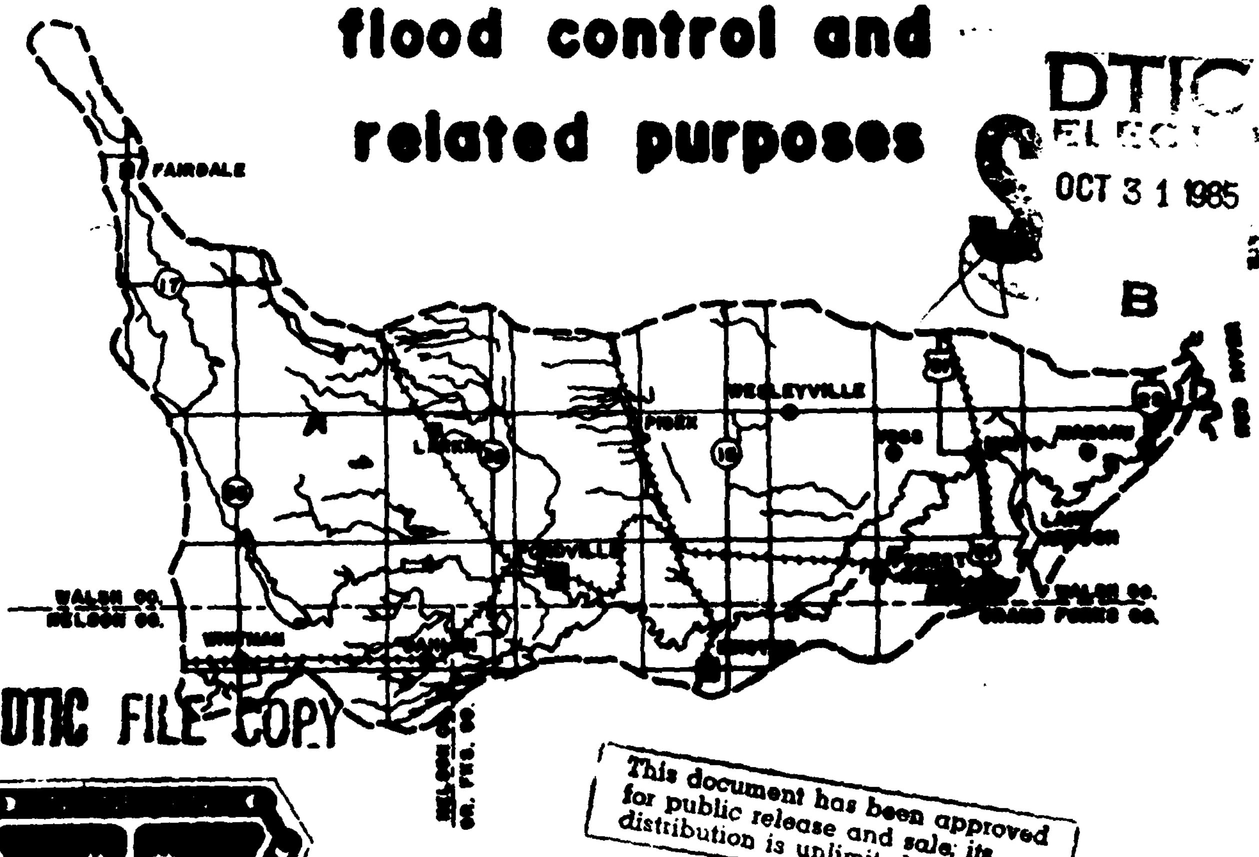

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The Forest River subbasin is located in northeastern North Dakota and is a tributary to the Red River of the North. In addition to frequent flooding, the city of Minto has a water supply problem. The purpose of this report is to summarize the problems, needs and alternatives for flood control and related water and land resources; to present the results of a preliminary examination of flood control alternatives; to insure adequate water supply for Minto; and to acquaint the public with information obtained during the study.

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PHASE I FEASIBILITY REPORT

FOR FLOOD CONTROL AND RELATED PURPOSES

FOREST RIVER SUBBASIN, NORTH DAKOTA

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PHASE I

FEASIBILITY REPORT

FOR FLOOD CONTROL AND RELATED PURPOSES

THE STUDY AND REPORT

PURPOSE AND AUTHORITY

The Forest River subbasin is located in northeastern North Dakota and is a tributary to the Red River of the North drainage basin. The Forest River has a history of periodic spring floods which inundate agricultural lands and small communities, including Forest River and Minto, North Dakota. In addition to frequent flooding, the city of Min also has a water supply problem. A dam built on the Forest River by the Works Progress Administration in the mid-thirties, impounds water that is now used for the city water supply. The dam was severely damaged in 1973 and emergency repairs were made to prevent complete failure.

The authority for this study is contained in a resolution of the Senate Committee on Public Works, adopted 12 July 1973, directing the Corps of Engineers "to review the reports on the Red River of the North, Minnesota and North Dakota, submitted in House Document No. 185, 81st Congress, and prior reports, with view to determining if the recommendations contained therein should be modified at this time in the interest of providing improvements for flood control and allied purposes on the Forest River, North Dakota."

SCOPE OF THE STUDY

As part of the Forest River subbasin feasibility study, this phase I study assesses the water and related land resource problems and potential solutions for flood damage reduction for two flood prone communities. The study also examines municipal water supply for the City of Minto, with a view towards developing a feasible plan and/or program to meet these needs.

Phase I consists of necessary field surveys, subsurface and hydrologic investigations and water quality and availability studies.

THE PHASE I REPORT

The purposes of this report are: (1) to summarize the problems, needs, and alternatives for flood control and related water and land resource purposes in the Forest River subbasin; (2) to present the results of a preliminary examination of alternatives for flood control in the basin; (3) to insure an adequate supply of water for the City of Minto and preliminary investigations for alternative sources of water, and (4) to acquaint the public with information obtained and conclusions drawn during the phase I studies. The phase I report evaluates engineering, economic, environmental and social effects of possible improvement alternatives to determine whether more detailed investigations are warranted. Based upon information presented herein, recommendations are made in the last section of this report regarding the need and extent of further studies.

STUDY PARTICIPANTS AND COORDINATION

Earliest attempts to address the water and related land resources problems of the Forest River subbasin consisted of watershed work plans for the North Branch Forest River Watershed, Middle-South Branch Forest River Watershed and Lower Forest River Watershed. The projects for watershed protection, flood protection and nonagricultural water management were sponsored by the Three Rivers Soil Conservation District, the Nelson and Walsh County Soil Conservation

Districts, the Eastern and Western Grand Forks County Soil Conservation Districts and the Walsh and Grand Forks County Conservation and Flood Control Districts. The Soil Conservation Service, U. S. Department of Agriculture, provided the technical assistance in preparing the work plans.

The U. S. Forest Service, the U. S. Fish and Wildlife Service, the U. S. Army Corps of Engineers, the U. S. Geological Survey, the North Dakota Geological Survey, the North Dakota State Game and Fish Department and the North Dakota State Water Commission have conducted investigations or prepared studies in the area.

PRIOR STUDIES AND REPORTS

Studies or reports that may provide valuable information regarding water resource problems and needs in the subbasin and previously recommended solutions to meet these needs include.

a. A survey report titled "Red River of the North Drainage Basin, Minnesota, South Dakota and North Dakota, for flood control and other purposes," dated 24 September 1974, considered the purposes of flood control, water supply and water quality in the basin. This report recommended that further improvement for these purposes not be undertaken at that time.

b. "Watershed Work Plan for Watershed Protection and Flood Prevention, North Branch Forest River Watershed," dated April 1959. The structural measures included in the plan consist of three floodwater retarding structures and 25.36 miles of channel improvement.

c. "North Dakota Ground Water Studies No. 28, Minto-Forest River Area, Walsh County," dated 1961. Groundwater conditions in this report were studied by means of test drilling and of geologic and groundwater reconnaissance.

d. "Watershed Work Plan for Watershed Protection and Flood Prevention, Middle-South Branch Forest River Watershed," dated April 1961. The structural measures consist of two floodwater retarding structures, one multiple purpose structure and 3.65 miles of floodway with appurtenances.

e. "Supplemental Watershed Work Plan, North Branch Forest River Watershed," dated July 1961.

f. "Watershed Work Plan for Watershed Protection and Flood Prevention, Lower Forest River Watershed," April 1962. The study includes land treatment measures that reduce runoff and 120 miles of channel improvement.

g. "Supplemental Watershed Work Plan, Middle-South Branch Forest River Watershed," dated 1970. The watershed work plan as modified by the supplement provides for three multiple-purpose structures, one floodway and approximately 25.8 miles of channel improvement known as the Fairdale Drain.

h. "Report of the Soil Conservation Service, Department of Agriculture, on the Watershed Work Plan for Middle-South Branch Forest River Watershed," dated April 1971.

i. "North Dakota State Water Commission County Ground Water Studies #17, Parts I-III," dated 1971-1973. These reports describe the geology, ground water basic data and the ground water resources.

j. "Souris-Red-Rainy River Basins Comprehensive Study," Souris-Red-Rainy River Basins Committee, 1972. The study report presents 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.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

AREA DESCRIPTION

The Forest River subbasin is located in northeastern North Dakota in Walsh, Grand Forks, Nelson and Ramsey Counties. The river drains an area of

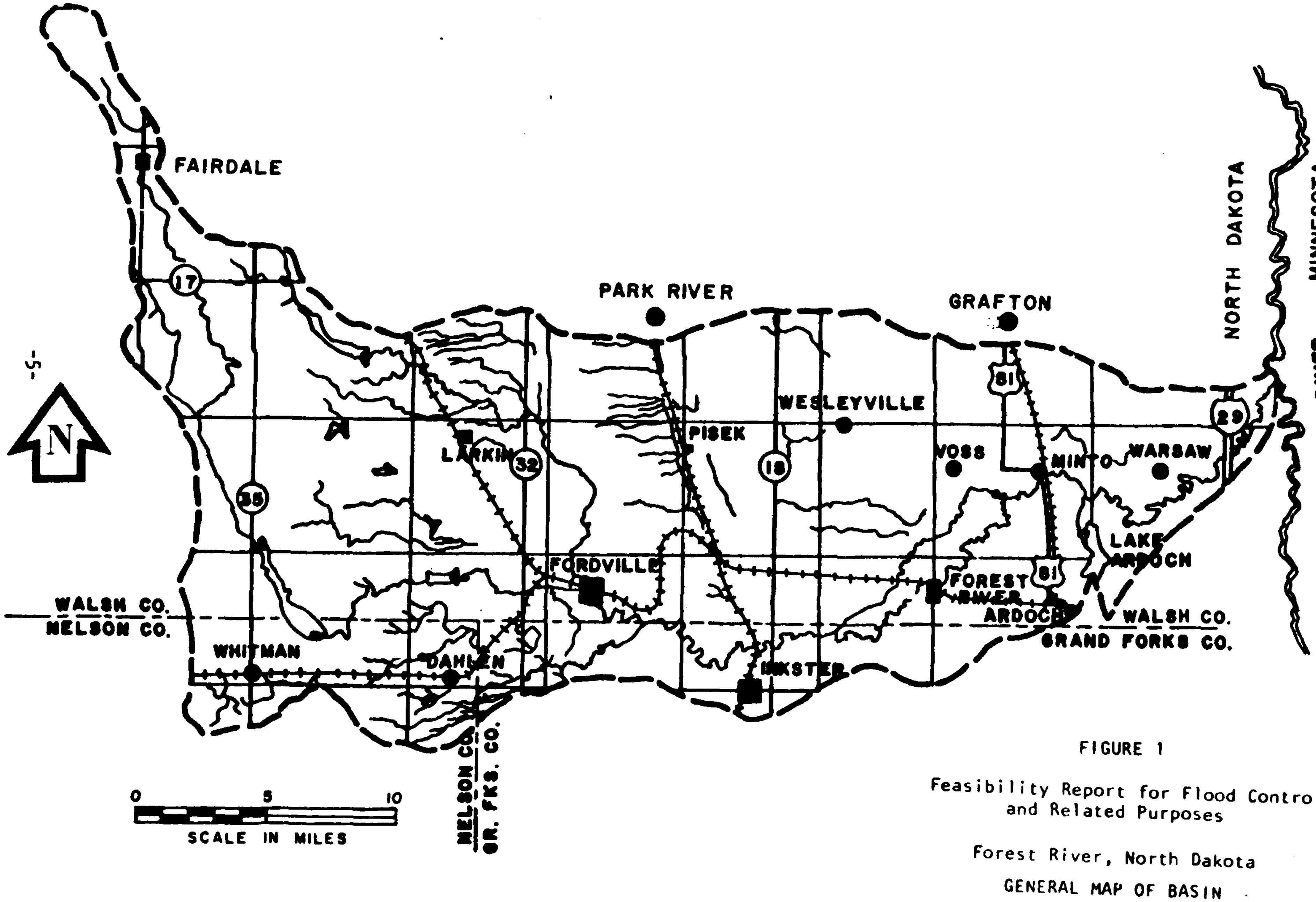


FIGURE 1

Feasibility Report for Flood Control and Related Purposes

Forest River, North Dakota

GENERAL MAP OF BASIN

1,016 square miles and empties into the Red River of the North about 30 miles north of Grand Forks. Major watersheds of the Forest River include the North Branch, Middle-South Branch and the Lower Branch. (Figure 1)

The North Branch Watershed of the Forest River, a tributary to the Red River of the North, is located in Walsh County, near the northeast corner of the State. The watershed lies within the Western Lake Section of the Central Lowlands Physiographic Province, an area of glacial drift and lacustrine plains formed by continental ice sheets during the Wisconsin stage of ice invasion. The watershed may be divided topographically into two principal areas with distinct identifying characteristics. These are the glacial Drift Prairie, which occupies roughly its western two-thirds, and the nearly level floodplain or floor of the ancient glacial Elk River Valley. The Elk River Valley is known locally as "Golden Valley" and it occupies the approximate eastern one-third of the North Branch Watershed. The numerous tributaries which give rise to the North Branch Watershed have their source in the Drift Prairie area. Their general direction of flow is to the east and into Golden Valley where they converge to form the main stem of the North Branch River. Within Golden Valley the drainage is generally south and east to its confluence with the Middle Branch of the Forest River near the town of Fordville. The channels in the Drift Prairie area are deeply incised throughout most of their lengths, and drainage to the floodplain of the main stem is very rapid. Elevations range from approximately 1,100 feet above sea level at the lower end of the watershed to about 1,500 feet at its headwaters. A narrow belt of typical "pothole" topography totaling less than 20 square miles borders the watershed along its western edge. Because of its poorly developed drainage this area does not contribute significantly to runoff to the main stem.

Glacial till forms the surface mantle over most of the upland. Outcrops of Pierre shale of Cretaceous Age are exposed along the more deeply dissected stream valleys and in road-cuts. The soils in the watershed range from drouthy light textured to medium textured soils in the floodplains. Medium textured soils predominate in the glaciated uplands.

Farms occupy 102,199 acres and 4,815 acres are in roads and miscellaneous uses. Approximately 72.3 percent of the farmland is in cultivation. Of the cultivated acreage, small grains are grown on 69.1 percent, row crops on 4.2 percent, and tame hay crops on 3.6 percent. About 23.1 percent of the cultivated land is in summer fallow. The acreages in various land uses are as follows:

Land Use	Acres	Percent
Cropland	77,404	72.3
Grassland	20,621	19.3
Woodland	4,174	3.9
Miscellaneous 1/	4,815	4.5
Total	107,014	100.0

1/ Includes areas in roads, railroads, towns and farmsteads.

The Middle-South Branch of the Forest River is a tributary of the Red River of the North. The watershed contains 219,520 acres located in Grand Forks, Nelson and Walsh Counties in northeastern North Dakota.

The watershed lies within the Western Lake Section of the Central Lowlands Physiographic Province, an area of glacial drift and lacustrine plains formed by continental ice sheets during the Wisconsin stage of ice invasion. The watershed may be divided topographically into two principal areas with distinctive identifying characteristics. One of these areas is the glacial Drift Prairie, which occupies the western two-thirds of the watershed. The remaining area is characterized by features associated with former glacial

Lake Agassiz--beach lines, lacustrine plains, and the Elk River Delta.

The numerous tributaries which give rise to the Middle-South Branch Forest River Watershed have their source in the glacial Drift Prairie area. Their general direction of flow is east. These streams merge with the North Branch of the Forest River near the town of Fordville to become the Forest River. The streams in their easterly flow are deeply incised throughout most of their course in the Drift Prairie area and in the portion where they traverse the Elk River Delta. The gradients of the tributaries in the uplands are moderately steep and drainage to the main stem is very rapid. Gradients diminish as the streams enter the old lake bottom plain and begin overflowing about four miles upstream from the town of Forest River. The main stem of the Forest River meanders through the beach lines and across the old lake bottom to its junction with the Red River of the North.

The watershed is elongated. It is 70 miles long and 13 miles at its widest point. Elevations range from approximately 800 feet above sea level at the lower end of the watershed to about 1,600 feet at its headwaters.

A narrow belt of typical "pothole" topography borders the watershed along its western edge. This area is only partially contributing because of its poorly developed drainage.

Glacial till forms the surface mantle over most of the upland. Outcrops of Pierre shale of Cretaceous Age are exposed along the more deeply dissected stream valleys and in road-cuts. The soils in the watershed range from drouthy light textured to medium and heavy textured soils in the floodplains. Medium textured soils predominate in the glaciated uplands.

Land use in the watershed shows 76.1 percent of the watershed under cultivation, 16.6 percent in grassland, 2.1 percent in woodland and 5.2 percent in other uses. Other uses include roads, railroads, towns and farmsteads.

A tabulation of land use in the watershed follows:

Land Use	Acres	Percent
Cropland		
Small Grain	112,394	51.2
Row Crop	8,781	4.0
Legume	6,366	2.9
Summer Fallow	39,514	18.0
Subtotal	167,055	76.1
Grassland	36,440	16.6
Woodland	4,610	2.1
Other	11,415	5.2
Total	219,520	100.0

The Lower Forest River Watershed is bordered by three watersheds. These are the Park River Watershed to the north, the North Branch Forest River Watershed to the west and the Middle-South Branch Forest River Watershed to the south.

Numerous intermittent streams make up the Lower Forest River and have their source in the morainic hills. They flow eastward across the floodplain to their junction with the main stem of the Forest River in the vicinity of Minto, North Dakota. These streams have definite channels as they leave the hills. Because of the flat gradient of the lake plain, the stream channels disappear. Where they cut through the eight beach ridges of glacial Lake Agassiz the channels are well defined. The main stem of the Forest River enters the watershed approximately two miles southwest of Minto. The Forest River flows northeasterly through Minto and turns south into Lake Ardoch, a Federal migratory wildlife refuge lake covering 1,150 acres. From Lake Ardoch the Forest River flows northeasterly to its junction with the Red River of the

North, approximately 12 miles northeast of Minto. The total length of the river is approximately 147 miles.

The watershed is rectangular. It is 32 miles long and 13 miles wide. Elevations range from approximately 1,225 feet above sea level at the headwaters to about 770 feet at the Red River of the North.

The watershed lies within the Western Lake Section of the Central Lowlands Physiographic Province, an area of glacial drift and lacustrine plains formed by continental ice sheets during the Wisconsin stage of ice invasion. With the exception of the narrow band of morainic hills on the western border, the watershed area is characterized by features associated with former glacial Lake Agassiz--broad level lacustrine plains with an occasional beach line.

Medium textured soils predominate in the glacial moraine upland. The soils in the rest of the watershed are medium textured to heavy textured with the exception of drouthy light textured soils on the beachlines.

Land use and crop distribution in the watershed is as follows:

Land Use	Acres	Percent
Cropland		
Small Grain	102,861	53.5
Row Crop	11,316	5.9
Legume	9,368	4.8
Summer Fallow	34,756	18.1
Subtotal	158,301	82.3
Grassland	21,630	11.2
Woodland	2,883	1.5
Other (roads, railroads, streams, lakes, towns, & farmsteads)	9,571	5.0
Total	192,385	100.0

GEOLOGY AND TOPOGRAPHY

The Forest River subbasin may be divided topographically into two principal physiographic areas. The upper portion of the subbasin and part of the Drift Prairie is covered by deposits of rolling and undulating glacial drift resulting from various glacial processes. An escarpment, which was the highest shoreline of Lake Agassiz, separates the Drift Prairie from the other area, the Red River Valley. This area is covered by sedimentary sediments deposited by glacial Lake Agassiz. The lacustrine deposits overlie glacial till throughout the valley and can be divided into two horizons; the upper layer is composed of mottled brown to gray-brown clays with interbedded sand and silts. Deposits are oxidized, laminated, varved and occasionally heavily iron stained. The lower layer is composed of plastic to highly plastic gray clays.

Published data on Lake Agassiz deposits suggests that the contact between the lower horizon and the overlying oxidized clays is variable. Possibly this suggests that the gray clays were deposited, the lake drained and then a time lapse to allow erosional features to develop on the lake plain prior to deposition of the upper horizon. Soil mechanics data further indicates a drying surface or period during temporary drainage of glacial Lake Agassiz.

STREAM AND STREAMFLOW CHARACTERISTICS

The average slope of the Forest River is about 5 feet per mile. The steepest reaches are in the headwater areas where slopes of 6 to nearly 9 feet per mile occur. In the lower reaches the slope is very flat, averaging less than 1 foot per mile between Minto and the mouth.

Flow at the gage near Minto during its period of operation has varied from a maximum of 16,600 cfs in April 1950 to a minimum of zero cfs. The highest discharges usually occur during the spring as a result of rapid snowmelt or heavy rainfall. During periods of high stages near Minto the flow overtops the banks and is diverted through coulees and over lowlands adjacent to the community. Discharge at the gage near Fordville during its period of operation has varied from a maximum of 16,400 cfs in April 1950 to a minimum of zero.

WATER SUPPLY AND WATER QUALITY

There are several sources of water in the subbasin. Springs are common in the region between the towns of Inkster and Forest River. Sand and gravel deposits in the same area yield excellent water which is reached by shallow wells at depths of 8 to 30 feet. East of Minto, however, shallow wells in the lacustrine silt furnish bitter, salty water. During drought years these wells become dry. Artesion wells located in an area extending east of Inkster to the Red River, produce waters that are also bitter and salty and can only be used for livestock. Water for domestic use in those areas where wells provide undesirable supplies is generally obtained either by collecting rain-water in cisterns, or by purchasing spring water hauled from Inkster and vicinity. In a few instances farmers use river water when it is available. During the drought of the 1930's the lowering of the groundwater level and the low flow in the streams of this area created an accute shortage of water for domestic and municipal purposes.

Undoubtedly, the most important sources of water in the subbasin are bedrock and glacial-drift aquifers. The Dakota aquifer is probably the most productive bedrock aquifer in Walsh County. The water-bearing materials consist primarily of fine-grained quartz sandstone interbedded with gray shale in varying proportions. The aquifer underlies all of Walsh County except the northeastern part. It is reached at depths of less than 200 feet below land surface in the eastern third of the county but is more than 1,000 feet below land surface in the western part of the county.

Below land surface of 900 feet in Walsh County most wells completed in the Dakota aquifer flow and many farms use this flow to supply water to livestock without pumping. Most of the wells are of small diameter and are screened only in the top few feet of the aquifer. Flows range from less than

1 gpm to about 2 gpm.

Water from the Dakota aquifer in Walsh County ranged in dissolved-solids content from 3,420 to 5,700 mg/l with a mean value for 24 samples of 4,560 mg/l. In general the water is a sodium chloride type. However, a number of samples contained a significant amount of sulfate and three were of a sodium sulfate type.

The Dakota aquifer has yielded large quantities of water for general farm use in the subbasin. However, in recent years use of the aquifer has decreased because of reduced hydraulic head and the general unsuitability of the water in modern plumbing and appliances. The primary use of water from the Dakota aquifer at the present time is for washing potatoes and livestock watering.

The Fordville aquifer is the largest and most productive glacial-drift aquifer in Walsh County. The aquifer extends from near the northern boundary of T 156N., R. 56 W., to south of the City of Fordville. It underlies about 33 square miles and has an average thickness of about 20 feet. Geologically the Fordville aquifer is a part of the Elk Valley delta deposits, which cover parts of Walsh, Grand Forks and Traill Counties. These deposits accumulated along the western edge of the Lake Agassiz basin during the period of time that glacial Lake Agassiz was in existence.

The Fordville aquifer consists mainly of gravel with interbedded silt and sand. The aquifer is composed of two units: a lower unit of silty sand composed mainly of shale fragments and an upper unit of sandy gravel composed mainly of granitic rocks with minor amounts of limestone and shale fragments.

Recharge to the aquifer is from direct precipitation on the aquifer surface, snowmelt in the spring and infiltration from the North Branch of the Forest River at times of high flow. The sandy permeable materials of the aquifer readily absorb rainfall and snowmelt. There is little surface runoff from the deposits and large areas are undissected by streams. On drainage maps, the Fordville aquifer stands out in contrast with adjacent areas to the west and east because of this lack of surface drainage.

The aquifer is unconfined and under watertable conditions. Ground water movement is generally southward to discharge areas along the North Branch and the main stem of the Forest River where the groundwater discharge augments the surface water flow. However, north of Section 27, T. 156 N., R. 56W., the North Branch of the Forest River is a losing stream that provides recharge to the Fordville aquifer. High water levels in select observation wells coincide with periods of high flow in the North Branch of the Forest River, and indicate that the river is a source of recharge to the aquifer in this area.

Water from the Fordville aquifer is a calcium sodium bicarbonate type of relatively good quality. Dissolved solids range from approximately 315 mg/l to 595 mg/l.

CLIMATE

The Forest River subbasin has a temperate climate with cold winters and warm summers. Records at the Grafton weather station, three miles north of the Lower Forest River Watershed, show an average annual temperature of 37°F. with mean monthly temperatures ranging from 69°F. in the summer to 3.5°F. in the winter. Extremes recorded are 109°F. and -44°F. The average annual precipitation is about 20 inches, with the greatest monthly amounts occuring during the growing season. Snowfall averages about 35 inches a year and generally accounts for about 18 percent of the annual precipitation. The average length of the growing season, between killing frosts, is about 131 days, extending from May 15 to September 24. Nevertheless, the long hours of summer sunshine in this latitude make it possible to grow and mature many different crops.

FISH AND WILDLIFE RESOURCES

There is no stream fishery of consequence in the subbasin. Streams and tributaries are either small and intermittent or contain low flows during much of the year. The most important fishing in the entire watershed is provided at existing floodwater retarding structures No. 1 and No. 6, known as Matejcek Dam and Whitman Dam repectively. These impoundments were constructed as part of the initial watershed work program (Public Law 566) and provide public fishing. Proposed floodwater retarding structure No. 4 will provide substantial public fishing opportunities if properly managed. When constructed, the 197 surface-acre recreation pool with 25 feet maximum depth will be capable for supporting a trout fishery.

Whitetail deer are found in the subbasin, but generally occur in low numbers due to lack of suitable woody and brush habitat. Although upland game habitat is limited, the Hungarian partridge is the most important upland game species and provides a moderate amount of hunting. Sharp-tailed grouse, cottontail rabbit and fox squirrels are low in numbers and provide little hunting. The area produces a good population of mourning doves. Other birds commonly found are sparrows, meadowlarks and several owls and hawk species. The important fur bearing animals include mink, muskrat, beaver, redfox and jackrabbit. Mink and muskrat are primarily associated with the permanent wetlands distributed throughout the area. Beaver populations are localized and found in some wooded areas along major streams.

Waterfowl are considered to be the most important wildlife resource in the subbasin. Waterfowl production in the area varies from year to year depending on precipitation, runoff and habitat conditions. The principal species in order of abundance include the blue-winged teal, mallard, coot, pintail, shoveller, gadwall, ruddy duck, redhead, green-winged teal and canvasback.

Numerous other species of shore birds, wading birds and some song birds also depend on the wetlands for reproduction habitat.

One of the most extensive waterfowl habitat areas within the subbasin is Ardoch National Wildlife Refuge located on the Forest River southeast of Minto. It provides habitat for nesting waterfowl, as well as an area for resting and feeding during migration periods.

The Fish and Wildlife Service has compiled a list of wildlife species found in northeastern North Dakota at various times of the year, Appendix A. Although not a complete list, all species have been reported or observed in northeastern North Dakota which includes the Forest River subbasin, and a similar species composition would be expected along the Forest River and its tributaries.

The only naturally occurring large herbivore found in the basin is the white-tailed deer. Deer are limited in the basin and their numbers are influenced primarily by habitat requirements and disturbances. At the present time densities are relatively low due to an unfavorable balance of cover and forage in the wooded areas and croplands.

Large carnivores were entirpated from the basin years ago leaving the red fox and an occasional coyote or bobcat as the major predators. Lynx and bobcat were once common to the area.

Numerous rodent species provide a major source of food for the common predators in the basin. Ground squirrels, gophers, squirrels and several species of mice are the most common rodents reported. Other mammals common to northeastern North Dakota and the Forst River subbasin include three species of weasel, skunk, badger, mink, jack rabbits, cottontail rabbits and five species of bats.

RECREATION

Recreation in the Forest River subbasin is concentrated mainly in the escarpment area and is centered around the seven Soil Conservation Service's reservoirs located in that area. Of these seven reservoirs, Matejcek and Whitman provides the most used and greatest variety of recreational facilities. The recreational activities enjoyed in the basin include fishing, boating, water skiing, swimming, camping, bicycle trails, picnicking, hiking and nature study. Hunting for both small and big game is also locally and regionally important throughout the basin.

RESOURCES AND ECONOMY OF STUDY AREA

POPULATION, EMPLOYMENT AND INCOME

The population of the Forest River subbasin in 1970 was about 11,000 with a density of about 11 persons per square mile. Approximately 20 percent of the population live in urban areas while the remaining 80 percent reside in rural areas. The largest municipalities in the basin are Minto, 636; Fordville, 361; Lankin, 221; Inkster, 198 and Forest River, 169. The population of the basin reached its maximum in 1910 and declined since that time.

Minto's 1970 population of 636 represents a density of about four persons per acre. Current projections indicate the city will increase in population by 18% by the year 2020. Historic and projected populations for Minto are shown in Figure 2. This table also identifies the population change by index for the city of Minto.

FIGURE 2 HISTORIC AND PROJECTED POPULATION AND INDEXES OF CHANGE FOR CITY OF MINTO 1910-2020

	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
Population	701	602	565	630	592	642	636	660	685	710	730	750
Index of Change	110	95	89	99	82	101	100	104	108	112	115	118

FIGURE 3 HISTORICAL AND PROJECTED EMPLOYMENT, PER CAPITA INCOME AND

TOTAL PERSONAL INCOME FOR CITY OF MINTO 1950-2020

	1950	1960	1970	1980	1990	2000	2010	2020
Employment	208	213	216	220	224	229	234	238
Per Capita Income	$1,497	$2,073	$2,583	$3,500	$4,700	$6,500	$9,000	$11,100
Total Personal Income	$886,224	$1,330,866	$1,642,788	$2,310,000	$3,219,500	$4,615,000	$6,570,000	$8,325,000

Employment increased 4% between 1950 and 1970 (see Figure 4) and is expected to increase, but at a slower rate than the population, up to the year 2020. The trend of population movement from large cities to smaller ones in the immediate area has extended to the Minto area. This would cause increases in both population and employment. Figure 3 also shows the histo-ical and projected per capita income and total personal income for the Minto area.

LAND USE

Approximately 97 percent of the land in the basin is in farms. The lower portion of the basin is essentially farmland of which about 89 percent is cultivated. The western part of the subbasin is situated in the glacial moraine uplands. As a consequence, farming tends to be more diversified than on the floodplain. General crop and livestock farming is practiced in the uplands and cash-grain crops, potatoes and sugar beets are grown in the floodplain.

RESOURCES

There are no mineral or timber resources in the basin that warrant commercial development. Deposits of sand and gravel found in the glacial drift and beaches of glacial Lake Agassiz are used primarily for road surfacing and concrete aggregate.

OCCUPATION AND INDUSTRIES

Agriculture is the major occupation in the area. The principal industries consist of retail outlets, processing of beef and dairy products and manufacturing of tow from flax straw. Other industry includes grain marketing and potato storage and processing facilities. Large cooperative and commercial potato warehouses provide storage, grading, washing and bagging facilities. One of the state's largest commercial sand and gravel processing plants, Bradshaw Gravel Supply, Inc., is located at Fordville.

TRANSPORTATION FACILITIES

The Soo Line and Burlington Northern railways traverse the subbasin. They provide the area with loading and transportation facilities for marketing farm products. Good highway service including State Highways 18 and 32 along with U. S. Highway 81 and Interstate I-29 links the basin to Grand Forks, Fargo and the Minneapolis-St. Paul metropolitan areas. The city of Grand Forks provides commercial airline service within a short driving distance of any point in the subbasin. A small airfield is also located at Grafton, approximately 9 miles north of Minto.

PROBLEMS AND NEEDS

The Forest River subbasin has a history of periodic flooding causing extensive rural and urban damages. River channels are choked with debris reducing channel capacities. Inadequate waterway openings on river crossings are causing restrictions and backwater from floating ice and debris. There is a lack of upstream sites to provide flood storage, which with poorly defined river channel and the natural flat topography causes overland sheet flooding and subsequent erosion and sediment damage.

The principal areas subject to flood damages are the communities of Forest River and Minto. There is also crop damage due to seeding delays as long as 6 weeks and inundation of crops during infrequent summer flood flows. Delayed seeding often results in reduced yields and lower quality grain. It also increases susceptibility to diseases, insect and frost damages. About 24,000 acres of cropland are affected by flooding. There is a need to provide

LOOKING ACROSS HIGHWAY 81 BRIDGE
UPSTREAM FROM PRESENT DAM SITE
(SEPTEMBER, 1974)

LOOKING DOWNSTREAM AT HIGHWAY 81 BRIDGE
(SEPTEMBER, 1974)

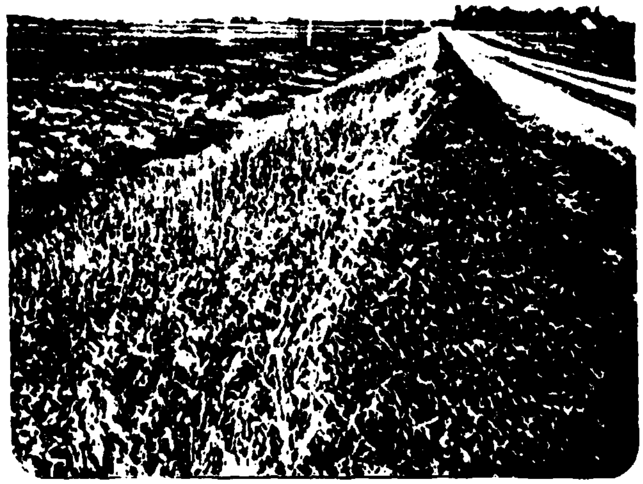
FIRST STREET BRIDGE CROSSING UPSTREAM FROM
PRESENT DAM SITE (SEPTEMBER, 1974)

LOOKING NORTH ALONG PRESENT MINTO CHANNEL DAM (SEPTEMBER, 1974)

LOOKING UPSTREAM ACROSS MINTO DAM, NOTE GAGING STATION IN BACKGROUND (SEPTEMBER, 1974)

LOOKING DOWNSTREAM ACROSS MINTO DAM NOTE RAILROAD BRIDGE (MARCH, 1973)

TOP OF MINTO DAM BEFORE
PLACEMENT OF CONCRETE CAP
(OCTOBER, 1973)



LOOKING NORTH ALONG ROAD IN AREA OF
POTENTIAL FLOODWAY (SEPTEMBER, 1974)

DEVELOPMENT IN THE PARK AREA IN THE FLOOD PLAIN AREA
(NOVEMBER, 1963)

RIVER CHANNEL UPSTREAM FROM PRESENT DAM SITE AT MINTO (SEPTEMBER, 1974)

RIVER CHANNEL DOWNSTREAM FROM PRESENT DAM SITE AT MINTO (SEPTEMBER, 1974)

RAILROAD BRIDGE AND RIVER CHANNEL DOWNSTREAM FROM PRESENT DAM SITE (SEPTEMBER, 1974) facilities for flood damage reduction in the communities of Forest River and Minto and also for rural areas.

Generally, an adequate quantity of water is available for livestock use from shallow wells sunk into the drift mantle. However, this water is not always potable and some farms and communities in the area must have water hauled in for domestic use. The Municipal water needs of Minto have previously been met by use of a small low-head water storage reservoir. However, this dam failed recently and has been temporarily repaired. The repairs made are not considered adequate to meet present and future water supply demands.

The absence of natural lakes in the subbasin precludes most water based recreation activities. However, water-based recreational opportunities do exist in the man-made lakes of the basin. Some of the identified recreational needs of the basin include swimming, fishing, boating and camping.

The basic objective of the Forest River subbasin investigation is to formulate the best overall plan for alleviating water and related land resource management problems. All potential solutions for solving the identified problems will be evaluated in cooperation with Federal, State and local assistance to insure compatibility with the long-term problems and needs of the area.

FLOODING

The city of Minto is partially located within the floodplain of the Forest River. Floods on the Forest River occur mainly in the spring following snowmelt, but also occasionally in the summer following intense storms. The areas subject to flooding includes both residential and recreational areas. The problem is compounded in that natural river channel capacity is relatively small and the surrounding floodplain is very flat. The flood flow exceeds channel capacity about once every three years. The residential areas are developed very close to the river and are subject to frequent flood damage. The discharge frequency curve for the Forest River at Minto is presented as Figure B-3.

The city of Forest River is located approximately ten miles southwest of Minto. The City in the past has had flooding problems with overflow from the Forest River. This flooding occurs mainly in the spring following snowmelt, but also in the summer following intense storms. A map of the flood prone areas in the Forest River subbasin was developed by the U. S. Geological Survey for the Federal Insurance Administration, Department of Housing and Urban Development, to meet provisions of the National Flood Insurance Act of 1968. A portion of this map for the flood prone areas in and around the communities of Forest River and Minto, are shown on Figures B-1 and B-4 in appendix B, respectively. Also the special flood hazard area for the city of Forest River is shown on Figure B-2. The flood prone areas on these maps were estimated from profiles based on high water marks and regional-stage-frequency relations. Therefore, these maps are considered preliminary and should only be used for insurance purposes.

The floodplain is relatively wide and covers an extensive area adjacent to the river. These floods also produce considerable damage to rural areas. The farm lands are occasionally inundated for such a duration as to prevent growing of crops. Because of the flat terrain, floodwaters cover large areas and deposit noxious weeds and debris which accounts for other agricultural damage in addition to direct damage to crops and pasture. The situation has become more critical the past few years.

Historic floods and flood of record are shown in Figure 4.

FIGURE 4 FLOOD PEAK FLOWS

Year	Month	Forest River near Fordville Drainage area (sq. mi.) - 456 Period of record (yrs.) - 35 Peak discharge (cfs)	Forest River at Minto Drainage area (sq. mi.) - 740 Period of record (yrs.) - 31 Peak discharge (cfs)
1948	April	14,600	11,500
1950	April	16,400	16,600
1956	June	3,370	2,930
1965	April	4,730	3,710
1969	April	3,290	3,900

Some of these flood stage readings are affected by backwater conditions produced by floating debris and ice jams caused by inadequate waterway openings on river crossings. The most apparent problem crossing is at the Burlington Northern Railroad bridge at Minto. Here, the restricted bridge opening and corresponding ice jams have caused an increase in upstream water surface profile during several earlier floods.

The map of flood prone areas was produced by the U. S. Geological Survey for the Federal Insurance Administration, Department of Housing and Urban Development, to meet provisions of the National Flood Insurance Act of 1968. The U.S.G.S. flood hazard study calculations show the 100 year flood to be 17,700 cfs. Figure B-4, the flood hazard map was determined by this method. The designated flood boundaries were estimated from profiles based on high water marks and regional stage-frequency relations. However, the 100 year flood used in this study is 10,800 cfs.

The drainage area of the watershed above Minto is about 720 square miles of which 623 square miles is contributing. The Soil Conservation Service of the U. S. Department of Agriculture has developed various projects within this drainage basin for the purposes of watershed protection, flood prevention, and agricultural water management. These projects are listed below:

On the North branch of the Forest River,

Dam #3	D.A.	= 8.8 square miles
Dam #6		= 5.9 square miles
Dam #5		= 3.3 square miles

On the Middle South branch of the Forest River,

Dam #1	D.A.	= 46 square miles
Dam #6		= 109 square miles
	Total D.A.	= 195 square miles

These dams serve to reduce the flood flows from these portions of the watershed. This area of 195 square miles is about 30% of the drainage basin and the remaining 70% does not have any flood protective works. Routing the flood flows through these reservoirs reduces the 100 year flood at Minto to 10,800 cfs.

Two more projects have been proposed by the Soil Conservation Service. These projects are Dam #4 on the Middle South Branch of the Forest River, D.A. = 41 square miles, and a floodway upstream from the town of Forest River, to divert flood waters to Lake Ardoch. This floodway would provide protection for the town of Forest River by intercepting part of the flood waters before they reach the city. It is designed for a capacity of 1860 cfs and will carry the water cross country to a natural channel which drains into Lake Ardoch.

These two proposed projects will serve to mitigate the flooding conditions at Minto. The benefits derived from the projects can only serve to protect Minto to a minor degree. These two projects are considered in one of the alternatives.

The benefits accrued by these existing and proposed flood protective works have in some cases been negated by the effects of indiscriminate farm drainage.

Many low areas that formerly retained runoff water for some period of time are now being drained and the waters reach the main stream sooner, increasing the flood stages.

Present flood damages include both tangible and intangible losses. Tangible losses suffered during floods include: damage to structures, utilities, and transportation facilities; flood-fighting costs; postflood cleanup costs; business losses; and increased expenses for normal operating and living during a flood situation. Based on the frequency of past flooding and damages sustained during these floods, the Forest River subbasin presently sustains an average of about $274,000 annually in flood damages. A breakdown of the average annual damages for the subbasin is shown on Figure 5. Intangible losses include: loss of life and injury; physical and mental strain; disruption of normal community activities; potential health hazards from contaminated water and food supplies; dislodged fuel storage tanks and pipelines; and flooding of sewage collection and treatment facilities.

Over the 50 year economic life of the proposed projects, flood damages would gradually increase at a rate proportional to growth of existing developments including repairs and improvements, increase in property values, and structural replacements. The value of the contents of structures would also increase with time. Due to floodplain regulations now in effect, vacant land in the floodplain would probably be used for recreational purposes instead of commercial or residential building. It is assumed in this analysis that the developed portion of the floodplain remains constant.

Flood damages for the 1950 flood and 2 hypothetical floods are summarized in Figure 6. All flood damages are August 1974 price levels.

FOREST RIVER, NORTH DAKOTA

FIGURE 5. ESTIMATED PRESENT AND FUTURE AVERAGE ANNUAL FLOOD DAMAGES WITHOUT PROTECTION AUGUST 1974 PRICES

Type of Damage and Area Affected	Weighted Average Damages Per Acre	Avg. Ann. Area Flooded	Average Annual Damages 1974 Conditions	Average Annual Damages 2024 Conditions	Increase in Damages 1974-2024	Avg. Ann. Equivalent over 100 year life	Total Avg. Ann. Damages
		(acres)	$	$			
1. Urban							
Minto			24,700	29,100[3]	4,400	1,500[2]	26,200
Forest River			9,600	-	-	-	9,600
Fordville			2,100	-	-	-	2,100
2. Crop	22.31	4,045	90,200[1]	133,500[1]	43,300[1]	14,600[2]	104,800
3. Other Agri.	4.46	4,045	18,000	26,600	8,600[1]	2,900[2]	20,900
4. Transportation			111,000	111,000	-	-	111,000
Totals			$255,600				$274,600

1. Growth factor for 50 years in crop production - 1.48 taken from Park River Report
2. Average annual equivalent factor - .3375 at 5 7/8% interest
3. Growth factor for 50 years taken from Soldier Grove, Wisconsin Data - 1.18

FIGURE 6 SUMMARY OF DAMAGES FOR MINTO, NORTH DAKOTA, AUGUST 1974 PRICE LEVEL

	1950	1950 Plus-1 ft.	1950 Minus-2 ft.
Residential Damages	$313,700	$352,800	$207,700
Commercial Damages	-	-	-
Public Damages	59,300	66,700	39,300
Totals	$373,000	$419,500	$247,000
Elevations	818.8'	819.8'	816.8'
Zero Damages Elev.	810.5'	810.5'	810.5'

Frequency - damage curves were developed for the "with ice conditions" and "ice free conditions" resulting in an average annual damage at Minto of $34,000 and $24,700, respectively. The increased flood damages at Minto are a result of an increased water surface profile caused by ice jams which restrict flow through the Burlington Northern Railroad bridge. The "with ice conditions" were derived from a preliminary modified rating curve and any "with ice" damages should be considered as an approximation. Figure 5 summarizes estimated present and future average annual flood damages for August 1974 prices for the Forest River subbasin.

EROSION AND SEDIMENTATION

Besides urban and rural flood problems, soil erosion and sedimentation in stream channels and floodplain areas are considered major problems in the Forest River subbasin. The major types of erosion in the basin include sheet, rill, gully and channel erosion. Erosion of cropland, pastureland, woodland, streambanks and gullies is considered to be the principal source of sediment. Three data samples on suspended sediments were taken during August and September 1974. The data on these samples is shown in Figure 7.

FIGURE 7 FOREST RIVER SUSPENDED SEDIMENTS AT MINTO

Date	Discharge (cfs)	Suspended Sediment Concentration (mg/l)	Suspended Sediment Land (t/d)
8/7/74	22	26	1.5
9/5/74	8.6	47	1.1
9/30/74	5.1	12	0.17

Erosion and sediment damage has been reduced considerably by the works installed in the upper reaches of the basin by the Soil Conservation Service's Watershed work plan. The project provided for floodwater retarding structures, channel improvements, grade stabilization and land treatment measures. In addition, potholes wherever possible, were preserved and those wetlands damaged by construction were replaced through development of artificial wetlands.

There is a need to provide for erosion and sedimentation reduction in the lower reaches of the basin.

WATER SUPPLY AND WATER QUALITY

The city of Minto received its municipal water supply from the impoundment of water by ` lowhead channel dam on the Forest River at Minto. As previously stated, this dam is in poor condition and in danger of failure. Previous to the mid-1960's the city obtained its municipal water supply from wells. Good quality ground water for domestic use is difficult to obtain in the north-eastern part of North Dakota.

Limited water quality data is available on the Forest River at Minto. Chemical analysis of the water quality is provided in Figure 8.

FIGURE 8 FOREST RIVER WATER QUALITY DATA AT MINTO

Date	Discharge (cfs)	Specific Conductance (micromhos)	Sodium (ppm)	Sulfate (ppm)	Bicarbonate (ppm)	Chloride (ppm)	Hardness (ppm)
4/15/61	14	556	21	91	223	15	249
10/12/71	12	694	28	120	292	24	320
11/19/71	18	688	26	130	283	15	320
12/14/71	6.3	916	37	170	377	26	450
1/10/72	1.0	1060	19	110	432	44	500
2/14/72	0.1	1350	80	220	484	100	550
3/17/72	2000*	284	7.2	36	104	4.4	120
5/9/72	65	731	33	130	298	14	340
6/14/72	28	758	34	130	307	18	340
7/10/72	9.8	757	33	140	305	23	330
9/14/72	4.2	885	60	130	284	67	330
5/14/74	205	830	51	220	266	25	380
8/6/74	12	528	23	120	260	7.6	290
9/5/74	8.6	760	33	140	270	31	340
Average	29.5	808.7	36.8	142.4	313.9	31.5	364.5

*Not representative of average flow of river, therefore not included in average

Generally the quality of water is good, except for hardness in accordance with U. S. Public Health Service standards. Water samples show the water is generally clear and odorless, but due to hardness water treatment is necessary. It is necessary to provide a firm water supply for the city of Minto.

RECREATION

The Forest River subbasin is within North Dakota planning regions 3 and 4 as indicated in the 1970 North Dakota Recreational Plan. The plan shows that major recreational needs for region 4 consist of water surface area for fishing, boating and water skiing. Additional facilities for camping, bicycle trails, picnicking, hiking, nature study, and scenic driving and sightseeing. As mentioned previously, Matejcek Dam provides for fishing and prime camping facilities along with two high quality beaches. The major needs of region three consist of additional facilities for camping, bicycle trails, picnicking, hiking and nature study. The summary of recreational needs in regions 3 and 4 for 1969, 1980 and 1985 is shown in Figure 9.

FIGURE 9 Recreational Needs in State Planning Regions 3 and 4

	Recreation Needs					
	Region 4			Region 3		
Activity	1969	1980	1985	1969	1980	1985
Fishing (acres)	4,450	6,370	7,270	0	0	0
Boating and water-skiing (acres)	2,730	3,780	4,330	0	0	0
Swimming (1) (beaches)	0	0	0	0	0	0
Camping (units)	354	622	767	155	238	286
Bicycle trails (miles)	98	130	146	42	49	53
Picnicking (tables)	0	72	136	176	206	231
Hiking and nature study (miles)	37	48	53	2	4	5
Scenic driving and sightseeing (miles)	37	48	52	0	0	0

(1) Existing beaches meet present demand, but some need to be replaced by higher quality beaches and facilities.

PUBLIC HEALTH AND SAFETY

The health and safety of residents in the study area are directly affected during major flood periods. A serious threat to the loss of life and limb is always present during floods due to flooded residences and related risk of drowning, electric shocks and other injuries that could occur in the flooded areas. Contamination or loss of water would create a serious threat to health and life. A loss of water supply creates a severe fire threat in time of flooding. The present dam at Minto will always be a threat to the city water supply until a new dam is built or another safe and good quality water supply is found.

FISH AND WILDLIFE

There is no significant fishing in the Forest River basin except at the U. S. Department of Agriculture Soil Conservation Service dams. Some rough fishing is available during periods when there is flow in the river. There is a small variety of wildlife in the area providing limited hunting.

EXISTING PROJECTS

There are seven dams located in the Forest River subbasin above Minto of which six were constructed by the U. S. Department of Agriculture, Soil Conservation Service. An eighth dam is to be constructed by the U. S. Department of Agriculture Soil Conservation Service in 1975. The seventh dam was constructed by the Federal Emergency Relief Association in the 1930's. Figure 10 lists the eight dams and their physical characteristics. Other improvements in the basin consist of channel changes, grade stabilization structures, channel improvements and several drains.

FLOOD EMERGENCY OPERATIONS

The largest floods of record in the Forest River basin occurred in 1950 when discharges recorded at gaging stations at Fordville and Minto exceeded 16,000 cubic feet per second. Emergency activities consisted of sand bagging areas threatened by floodwaters and provisions for evacuation. There were no permanent protective works installed.

IMPROVEMENTS DESIRED

Expressions were obtained from residents of the Forest River basin relative to their water management needs. The most important water resource needs were identified as follows:

FIGURE 10 DAMS ON FOREST RIVER ABOVE MINTO

Dam	Location (county)	Constructed By	Height of Dam (feet)	Maximum Water Depth (feet)	Average Depth (feet)	Capacity (acre-feet)	Area (acres)	Flood Storage (acre-feet)	Purpose
North Branch of the Forest River Dam #1	Walsh	USDA-SCS	59	56	11.8	708	59.8	4519	Flood control & Recreation
North Branch of the Forest River Dam #3	Walsh	USDA-SCS	19	16	2.4	76	32	1004	Flood control
North Branch of the Forest River Dam #5	Walsh	USDA-SCS	16	13	1.5	51	33	635	Flood control
North Branch of the Forest River Dam #6	Walsh	USDA-SCS	41	39	5.6	66	11.7	1201	Flood control
Matejcek Dam	Walsh	USDA-SCS	76	75	20.4	2745	134.8	8838	Flood control & Recreation
Whitman Dam	Nelson	USDA-SCS	50	48	16.8	2411	143.4	7750	Flood control & Recreation
Sarnia Dam	Nelson	FERA	17	15		220		336	Recreation
Middle South Branch of Forest River Dam #4 (proposed)	Grand Forks	USDA-SCS	52	51	26.0	5235	187	10,600	Flood control & recreation

a. Firm water supply for the city of Minto.

b. Flood protection for urban areas.

c. Flood protection for rural areas.

d. Improving erosion and sediment controls.

e. River channel, snagging and clearing.

Preservation of the natural environment, improving water quality in the river and protection of wildlife and wildlife habitat are also considered to be basin needs.

ALTERNATIVE PLANS TO BE CONSIDERED

FORMULATION AND EVALUATION CRITERIA FOR FLOOD CONTROL ALTERNATIVES

Preliminary analysis of alternatives was based on the planning objectives of national economic development and environmental quality as identified in the September 1973 Principles and Standards for planning water and related land resources. This standard set of criteria was adopted to permit an objective appraisal of merits and disadvantages of various alternatives. Criteria were considered under the major categories listed below:

a. Technical
b. Economic
c. Environmental

Technical criteria consist of appropriate engineering standards, regulations and guidelines. Since such a list would be extensive, it is not included.

Design criteria used for the flood control analysis was based on the 100 year flood frequency determined to be 10,800 cubic feet per second. This value was adjusted from 17,700 cfs by taking into consideration the flood storage provided by upstream dams.

Economic criteria follow existing policies that benefits must exceed project costs. Also, should a plan be ultimately recommended, it must provide maximum attainable net benefits. However, proposed developments providing less than the economic optimum could be recommended if appropriate gains in environmental quality, social well-being and regional development were shown. Annual costs and benefits are based on an interest rate of 5 7/8% and price levels and conditions existing in August, 1974. The amortization period depends on the type of improvement, but a 50-year amortization schedule was used for most features considered.

Environmental and other considerations call for the recommended plan to minimize any objectionable or adverse environmental effects and to maximize environmental benefits prior to, during, and following construction. Also, consideration will be given to plan modifications based on coordination with State and Federal agencies and interested local citizens. Public acceptance of proposed improvements and ability and willingness to meet local cooperation requirements are essential considerations.

POSSIBLE SOLUTIONS

Appropriate alternatives to meet identified basin needs are being considered. Structural flood control measures such as flood barriers that provide local protection and structural flood control measures such as reservoirs and channel modifications that provide both urban and rural flood protection are being examined. Non-structural floodplain management measures are being considered as a substitute for or a complement to structural flood control measures.

Appropriate alternatives will consist of both structural and nonstructural land treatment measures that will reduce erosion and minimize channel sedimentation. Structural measures include floodwater retarding structures, bank stabilization, etc. Land treatment measures include minimum tillage, strip cropping, terracing, etc. Land treatment measures will be considered as a substitute for or a compliment to structural measures.

The need for preservation of the natural environment including protection of scenic areas and wildlife habitat will be considered and incorporated as an integral part of any selected plan, as appropriate.

ALTERNATIVE FLOOD CONTROL PLANS ANALYZED

Various nonstructural and structural measures could reduce the potential for flood damage in the Forest River basin. Nonstructural alternatives include: no action, flood warning and emergency protection, permanent floodplain evacuation, flood proofing, flood insurance and floodplain regulation. Structural alternatives are: levees, channel modifications, upstream reservoirs, diversion channels, bridge modifications and combinations thereof. The above mentioned alternatives are evaluated for the flood prone communities of Minto, Forest River, and Fordville and for the rural areas of the basin. Because a discussion of the alternatives for each community would be repetitious only a detailed description of the flood damage reduction alternatives is presented for Minto. A brief synopsis of the various alternatives evaluated for the other flood prone communities follow the discussion about Minto.

NONSTRUCTURAL FLOOD CONTROL ALTERNATIVES FOR MINTO

Alternative 1: No Action

Doing nothing would obviously spare local interests and the Federal government the burden of certain financial costs, but this alternative would not solve Minto's flood problems since periodic flooding and associated damages would occur as in the past. Nevertheless, recurring flood damages would remain and, as such, would be a social and economic burden to the people. Flood hazards would also continue to threaten the health, public safety and social well-being of the people. In accordance with current Federal and State legislation, future growth and development in the floodplain could be slowed somewhat due to the lack of federal funding available to homes and businesses.

Alternative 2: Flood Warning and Emergency Protection

Flood warning would consist of reasonably predicting the time and magnitude of a flood and evacuating the flood prone areas or erecting emergency flood protection measures. While major spring floods caused by snowmelt runoff can be predicted with some reliability, more localized, high intensity-short duration summer rainstorms cannot. Emergency evacuation would be difficult because the time interval between rainfall occurrence, issuance of flood warnings and beginning of flooding are relatively short. Time limitations also would probably not permit construction of emergency flood protection works. Emergency protection may be adequate for smaller floods; however, floods of larger magnitude would create structural stability problems due to hasty construction and increase the danger of failure, with a great potential for loss of life. These measures would continually disrupt the biological systems and scenic quality of the flood prone areas of Minto. Also, these measures would cause much personal inconvenience and continual community disruption to residents of Minto. Therefore, flood warning is not considered socially, economically or environmentally acceptable as an effective means of solving flood problems in Minto.

Alternative 3: Floodplain Evacuation

Permanent evacuation of developed floodplain areas involves acquisition of lands by purchase, removel and relocation of improvements, evacuation and resettlement of population and permanent conversion of lands to uses less susceptible to flood damage. Lands acquired in this manner could be used for agriculture, parks or other purposes which would not interfere with flood flows. This is the only alternative which could permanently control flood damage as long as appropriate floodplain regulations were adopted for the lands evacuated. Movement out of the floodplain would result in the improvement of the natural habitat in some evacuated areas.

Personal inconveniences would be considerable but would be offset by teh elimination of inconvenience from periodic flooding. This alternative would be unacceptable to many residents with strong ties to their present homes and community. Individuals with investments in local businesses and real estate which might suffer from a relocation would also oppose evacuation. However, relocation onto uplands might be accomplished in such a manner as to result in a community which could be very desirable to live in and one which might be in haromny with environmental features. This alternative would have a first cost of about $1,200,000 with an average annual cost of $75,000. The benefit-cost ratio is 0.593.

Ecologically, this alternative is acceptable, as the biological systems in the floodplain would probably become more productive and/or diverse. Debris from the evacuation would leave a long-term scar on the floodplain; however, much of the material could be recycled or disposed of properly. Relocation of existing families and businesses would also require that the relocation site be subjected to disturbances, clearing of vegetation and permanent disruption of existing ecological relationships.

Alternative 4: Flood Proofing

Flood proofing would consist of a combination of structural changes and adjustments to properties subject to flooding primarily for reduction or elimination of flood damages. Although best applied to new construction, it is also applicable to existing facilities. During major floods, residences and businesses would become isolated, and therefore public health and safety would still be a concern due to the difficult access to these properties. Flood proofing is prohibitively expensive and would not be acceptable as a complete solution to flooding in Minto from the social well-being standpoint. An essential element of flood proofing is an education program for the floodplain user which includes flood hazard and flood proofing information.

Alternative 5: Floodplain Regulation at Minto

Floodplain regulation consists primarily of regulating new development in existing floodplain areas. The State of North Dakota has no floodplain regulation law that requires flood prone governmental units (counties, cities, villages) to adopt, enforce and administer sound floodplain management ordinances within their respective jurisdictions whenever sufficient technical information is available for delineation of floodplains and floodways on their watercourses. Floodplain regulations do not currently exist at Minto, nor are they considered appropriate as an effective means of reducing damages to existing flood prone property at Minto. Although not a complete solution to flood damage reduction, floodplain regulations should be an integral part of any flood protection system and could be effective at Minto.

Selection of the range of permitted uses in a prohibitive flood zone district should be guided by two criteria; that the uses will create a minimum obstruction to flood waters and that they will resist the damaging effects of flood conditions. It is suggested that permitted uses should be as follows:

a) Agricultural cropland, livestock feeding and grazing (in compliance with public health standards) or open-type public and private recreational areas. Such uses would include limitations on the types and locations of tree plantings.

b) Some uses accessory to institutions (school yards), residences and commerce (parking lots and storage yards), which have low damage surfaces. Equipment and material should be properly anchored to prevent movement into bridges or other debris-catching areas; it should be removable within the limited time available after a flood warning; and it should not be subject to major damages by floods. The storage of chemicals or materials which are explosive, buoyant, or flammable-liquid would not be permitted in large quantities.

c) Utilities, railroads, streets, bridges and public utility wire and pipelines for transmission and local distribution.

d) Fences (especially wire fences for agricultural purposes), walls or other appurtenances which would not constitute an obstruction or debris-catching obstacle to the passage of flood waters.

e) Non-restrictive improvements in stream channel alignment, cross-section and capacity and the normal maintenance thereof.

f) Structures that are designed and constructed to have a minimum effect upon the flow of water and that are firmly anchored to prevent floatation.

Other flood zoning districts may be less restrictive but it would be required that appropriate regulations, which relate to the land use and conditions of use, be developed for all zoning districts. These may be either simple or detailed provisions which give recognition of the flood hazard.

Alternative 6: Flood Insurance at Minto

Flood insurance does not prevent or reduce flood damages, but assists in reimbursing affected property owners for losses sustained from flood damages. It does, however, afford the individual affected some economic protection from flood loss by spreading his losses over a larger portion of the population. Flood insurance, used as a supplement to floodplain regulations and other flood damage reduction measures, could provide limited economic protection for existing developments at Minto. Federally subsidized flood insurance has not been applied for and is not currently available at Minto. Currently under Federal laws, communities such as Minto must establish land-use controls and participate in the flood insurance program by 1 July 1975 to be eligible for future disaster relief loans. This measure is not considered an adequate solution to Minto's flood problems.

STRUCTURAL ALTERNATIVES

Alternative 1: Widen Railroad Bridge

This alternative would consist of enlarging the Burlington Northern Railroad bridge so that it would be capable of handling the 100 year flood of 10,800 cfs. The existing bridge causes ice jams and a resulting increase in water surface profile.

The bridge waterway opening could be increased to such an extent that the average velocity of the water would be reduced to about 5 feet/second. The water surface profile would be lowered so that there would be less chance for a channel obstruction to develop.

This waterway would therefore need to provide at least 2,160 cubic feet of opening at an elevation of 816.0, in order to insure that the channel would not become obstructed by the development of ice jams. This bridge waterway would be riprapped to prevent scour at this point.

The environmental effects of this project would be minor. This construction operation would cause some disruption in the area, but the site would be restored upon completion of the project.

This project would cost about $250,000 and reduce the average annual flood damages from $34,000 to $24,700. The benefit-cost ratio is 0.6.

Alternative 2: Widen Railroad Bridge, Improve River Channel, and Construct Dikes

This alternative would consist of widening the railroad bridge (see Alternative 1); improving the river channel by widening, snagging and clearing, and straightening, etc.; and construction of dikes as required.

FIGURE NO. 11

MINTO STRUCTURAL ALTERNATIVES

Alternative No.	Cost	Annual Cost	Ann. Cost With O and M	Benefits	Cost-Benefit Ratio
1. Widen Railroad Bridge	$250,000	$15,585	$16,000	$ 9,300	0.6
2. Widen Railroad Bridge, Improve Channel and Construct Dikes	$1,508,000	$94,000	$97,000	$44,500	0.4587
3. Upstream Reservoirs	0	0	0	0	0
4. Construct Exterior Dike and South Diversion Channel	$5,063,000	$316,000	$333,000	$44,500	0.1348
5. Construct Exterior Dike, South and North Diversion Channels	$4,188,000	$261,000	$274,000	$44,500	0.1624
6. Construct Exterior Dike, and Reduced South Diversion Channel	$3,688,000	$230,000	$242,000	$44,500	0.1838
7. Construct Exterior Dike and Reduced North and South Diversion Channels	$3,813,000	$238,000	$250,000	$44,500	0.178

The channel would be so improved that its channel capacity would be capable of handling the 100 year frequency flood flow of 10,800 cfs. The dikes would be constructed to an elevation of 821.0, providing 3 feet of freeboard above the 100 year flood stage elevation of 818.0. The alternative would also require modification of the U. S. Highway No. 81 bridge and the city bridge.

The environmental effectw of the project would include destruction of the existing vegetative cover along the channel and the disruptive effects of the construction efforts along the channel. The brush cover would be destroyed and would have to be replaced by a grassed waterway zone. The trees and brush would not be allowed to grow back, since they would reduce the channel capacity. This would result in the destruction of a certain amount of wildlife habitat and the creation of a less aesthetically pleasing area. It would also result in some hardship to those people whose homes would be purchased or relocated. The benefit-cost ratio of this alternative is 0.4587.

Alternative 3: Upstream Reservoirs

The watershed has been studied by the Soil Conservation Service and available sites for upstream reservoirs have already been incorporated into their watershed program.

These dams have been designed to use all available storage offered by the topography and no further flood storage is attainable. The data describing these dams is tabulated in Figure 10.

Alternative 4: Exterior Dike and 8000 cfs South Diversion Channel

This would involve construction of an exterior dike at Minto and an 8,000 cfs diversion channel routing the floodwaters directly to Lake Ardoch. This would require a channel 530 feet wide with a flow depth of five feet and a velocity of 3.0 feet/second. Also required would be bridges of over 530 feet in length on U. S. Highway No. 81 and the Burlington Northern Railroad. Texas crossings would be constructed at various gravel road crossings.

The diversion ditch would require about 300 acres for channel area and spoil disposal. The areas disturbed by construction efforts would be seeded to produce a grassed waterway.

The environmental effects of constructing this alternative will be relatively small. Most of the area is presently farmed land and the ditch area will be seeded to produce a permanent grass cover. This should provide a better cover for most wildlife than does the area under cultivation.

The construction of the exterior dike would be accomplished by raising the existing gravel roadway to the west and south of the town to an elevation of 821.0. There will be a certain amount of unavoidable social impact due to relocation of some homes and farms. The cost of this alternative is $5,063,000 with a benefit-to-cost ratio of 0.1348.

Alternative 5: Exterior Dike with Both North and South Diversion Channel

This would involve construction of an exterior dike at Minto, north diversion channel just outside of the dike and also a south diversion channel. Under this proposal, both diversion channels would be designed for a capcity of 4,000 cfs, with a 260-foot wide channel, five feet flow depth and a velocity of three feet/second. Bridges would be required just south of Minto and also three miles south for both U. S. Highway No. 81 and the Burlington Northern Railroad. These bridges would have to be about 260 feet in length. The gravel roads intersected by the diversion channels would be crossed by Texas crossings. Land required would approximate 200 acres. The diversion channels would both be seeded to produce grassed waterways. The exterior dike would again be produced by raising the existing gravel roadway. There would be a control structure at the point of diversion to limit the flow entering the existing channel to about 2500 cfs. The balance of the northward routed flow, 4,000 cfs, would flow through the north diversion channel.

The south diversion channel would be similar to Alternative 4, except that the flow would be 4,000 cfs in this case.

The environmental impact would also be similar to that described in Alternative 4. The cost-benefit ratio of this alternative is 0.1624.

Alternative 6: Exterior Dike and A South Diversion Channel with A 6000 CFS Capacity

It would involve a channel 400 feet wide with a flow depth of five feet and a velocity of 3.00 feet/second. Also required would be bridges of over 400 feet in length on U. S. Highway No. 81 and the Burlington Northern Railroad. Texas crossings would be constructed at the various gravel road crossings. The diversion ditch would require 230 acres for channel area and spoil disposal.

This alternative is similar to Alternative 4, with the exception that the flood flow has been reduced by 2000 cfs due to upstream construction of additional flood control works.

The environmental impact of this alternative would be essentially the same as for Alternative 4. The cost-benefit ratio for this alternative is 0.1838.

Alternative 7: Exterior Dike, A 3000 CFS South Diversion Channel and A 3000 CFS North Diversion Channel

This alternative would require a south diversion channel about 200 feet wide and bridges about 200 feet in length on both U. S. Highway No. 81 and the

Burlington Northern Railroad. The land requirement would be about 115 acres. The land requirements of the north portion of the project would be about 40 acres.

This alternative is similar to Alternative 5, with the exception that the flood flow has been reduced by 2000 cfs due to upstream construction of additional flood control works.

The environemental impact of this alternative would be essentially the same as for Alternative 5. The cost-benefit ratio of this alternative is 0.178.

FLOOD CONTROL ALTERNATIVES AT FOREST RIVER AND FORDVILLE

At Forest River and Fordville the nonstructural flood damage reduction alternatives of no action, flood warning and emergency protection, floodplain evacuation, flood proofing, floodplain regulation, and flood insurance would be similar in social acceptability, environmental effects and economic feasibility to that discussed for Minto. Also for each community structural alternatives would not be economically feasible.

SUMMARY OF FLOOD CONTROL ALTERNATIVES ANALYZED

All flood control alternatives were compared within the context of the plan formulation and evaluation criteria outlined earlier. The alternatives were analyzed based on their respective contributions to providing increased gains in national economic efficiency, environmental quality, and social well-being of the people in the area.

A review of the nonstructural and structural alternatives evaluated for the flood prone communities of Minto, Forest River, and Fordville and the rural areas of the basin follows.

The no action alternative and nonstructural measures such as flood warning and emergency protection, floodplain evacuation, flood proofing, floodplain regulation, and flood insurance provide or maintain high environmental quality but fail to meet either the social well-being or economic efficiency objective, or both. Of the structural alternatives considered, reservoirs, levees, diversion channels, widening the railroad bridge and combinations thereof are clearly not economically feasible. Also most of these alternatives would cause significant disruption to the existing natural vegetation.

ALTERNATIVE WATER SUPPLY FOR THE CITY OF MINTO

Municipal Water Supply

Six alternatives were investigated for supplying water to the city of Minto; two using water directly from the Forest River, two using ground-water supply and two using water from the Red River. All water system alternatives were based on population estimated at 750 by 2020, and an average daily consumption of 100,000 gal/day. The present average daily consumption is 55,000 gal/day and a peak demand of 80,000 gal/day. The present water plant and distribution system has a rated capacity of 150 gpm (216,000 gpd) with a storage capacity of 70,000 gallons. The treatment plant is in good condition and is presently treating for hardness and biological agent.

Presently the city of Minto has a two inch feeder line to the existing Walsh County Rural Water District line, one mile north of the city. The pipeline north of Minto is a four inch line and does not have the capacity to meet existing or projected needs of Minto.

Alternative 1: Main Stream Forest River at Minto

The city of Minto currently receives its municipal water supply from the main stream of the Forest River. The water is stored within the channel of the Forest River by a lowhead channel dam. The existing dam is in a state of temporary repair and construction of a new dam has been proposed.

A new dam could be constructed at one of three sites: (1) the existing dam site; (2) 100 feet upstream from the existing site, and (3) 2,200 feet downstream from the existing site, Figure C-5. The capacity of these impoundments at control elevation 808.0 are:

The existing site	48 acre-feet
The upstream site	47 acre-feet
The downstream site	68 acre-feet

The dam would be a low-head reinforced concrete channel dam designed with a capacity sufficient to handle the bank full flood stage without creating any backwater effect.

Upgrading of a dam on the Forest River would require construction of new intake facilities for municipal water supply. Estimated costs for a dam and related facilities are $406,000 with annual operation and maintenance costs totaling $1200.

Alternative 2: Fordville Aquifer

As previously mentioned, the Fordville aquifer is 21 miles west of Minto and is the largest and most productive glacial-drift aquifer in Walsh County, Figure C-6. Ground-water withdrawals from the Fordville aquifer are by wells. A well field consisting of 10 wells, each capable of producing 144,000 gpd, has been installed in the northern part of the aquifer by the U. S. Army for the purpose of supplying water to military installations. The city of Fordville, near the south end of the aquifer, pumps about 30,000 gpd. The total well pumpage for all purposes including farm use probably is small compared to the quantities that are being discharged naturally.

The aquifer-test data and test drilling indicate that yields of more than 500 gpm are obtainable from the northeastern part of the Fordville aquifer. Based on an areal extent of 33 square miles, an average saturated thickness of 20 feet and a storage coefficient of 0.15, about 63,000 acre-feet of water is in storage.

Water from the Fordville aquifer is a calcium sodium bicarbonate type of relatively good quality. Dissolved solids range from 315 mg/l to 595 mg/l.

Based on studies by the North Dakota State Water Commission additional development of the Fordville aquifer for the Minto city water supply is feasible. The system serving Minto would have two production wells located in the northeastern portion of the aquifer with a rated capacity of 75 gpm for each well. Pumping and control facilities would be constructed at the Fordville site. Twenty one miles of four inch plastic pipe would be required to connect the well field to the city of Minto. Roadway right-of-way would undoubtedly have to be purchased for pipeline construction. The estimated cost for this plan is $211,000 with operating and maintenance averaging $2,700 per year. Project location is shown on Figure C-6.

Alternative 3: Red River Direct to Minto

This alternative involves the diversion of water from the Red River of the North twelve miles east to Minto. A lowhead dam would be constructed on the Red River to provide a pumping pool. A pumping station with a rated capacity of 150 gpm (two 75 gpm pumps) would be constructed adjacent to the river and within the pumping pool. In addition, two pumps would be installed to increase the reliability of the system and a telemetering system installed to provide for constant monitoring at the city water works. A four inch plastic line running east from the pumping station, parallel to existing roadways, would connect the pump site to Minto's existing treatment plant, Figure C-7. The water quality in the Red and Forest Rivers is basically the same; therefore, the present treatment system should be adequate to treat water from the Red River. The estimated costs for this alternative are $566,000 with annual operating and maintenance costs averaging $3700.

Alternative 4: City of Grafton

At the present time the city of Grafton is considering installing a water supply system from the Red River. The proposed plan would involve construction of a check dam on the Red River to serve as a pumping forebay, pumping facilities and a 20-inch, 14 mile pipeline to deliver water to the water treatment plant at Grafton. The system would provide Grafton with an assured supply of 1.6 million gallons per day. The estimated cost of this system is $3,100,000 plus an additional $500,000 to upgrade the water treatment plant.

Construction of this diversion system may allow the city of Minto to purchase treated water from Grafton. Minto would have to construct a pipeline from Grafton to the existing distribution system. A four inch line could parallel existing roadways between Grafton and Minto, as shown in Figure C-8. The estimated costs for the pipeline are $73,000 with average annual operation and maintenenace costs of $500. The estimated average monthly cost for treated water delivered to the city of Minto is $1200 at a rate of 100,000 gpd. This does not include any charges for the water which Grafton may choose to apply.

Alternative 5: Desalination of Ground Water

The Dakota Formation which underlies the Minto area is a possible water supply source; however, the water from this aquifer is highly saline, a T.D.S. of 4,000 mg/l, and would require desalination. The reverse osmosis process was used to estimate the cost of this alternative.

The salt brine from the desalting process could be disposed of by expanding the current sewage lagoon system. The estimated costs for this project are $550,000 with annual operating and maintenance costs averaging $46,000.

Alternative 6: Upstream Reservoir

The Soil Conservation Service has constructed six reservoirs and plans to construct one additional reservoir in the upper reaches of the Forest River. Of these seven reservoirs, only three have sufficient storage to meet Minto's requirements of 111 acre-feet per year. Whitman Dam, 41 miles southwest and Matejcek Dam, 31 miles southwest of Minto, have sufficient storage to meet Minto's present and future needs.

Dam No. 4 located on the Middle-South Branch of the Forest River in the SE¼ Section 6 and the NE¼ Section 7, Township 154 North, Range 55 West, in Grand Forks County, is scheduled for construction in 1976. The structure is primarily flood control and recreation. However, the dam could provide municipal water supply to the city of Minto. A pumping station would be located along the reservoir above the maximum pool elevation. A plastic pipeline would connect the pumping plant at the dam site to Minto's existing treatment plant. The line would make use of existing road rights-of-way wherever possible. The estimated cost for this alternative is $320,000 with average annual operation and maintenance costs of $5000.

Summary of Water Supply Alternatives for the City of Minto

As previously stated, the city of Minto receives its municipal water supply from the impoundment of water by a lowhead channel dam on the Forest River. This dam is in poor condition and in danger of failing. Also, groundwater sources at Minto are not considered adequate for domestic use. Therefore, based on the existing water supply problems at Minto and the projected water supply demands, development of a new source for water supply is needed. Of the water supply alternatives identified and evaluated the Fordville Aquifer, and the city of Grafton are the most economical sources and both have very little effect on the natural environment. However, the costs and charges identified for the city of Grafton alternative do not include any charges for the water which Grafton may choose to apply.

Considering all water resource planning objectives, either the pipeline from Grafton or a pipeline from the Fordville Aquifer would provide the best single-purpose water supply alternatives.

COORDINATION

The study findings and the conclusions that further investigation by the Corps of Engineers was not warranted at this time were presented and discussed at a public meeting in Minto, North Dakota, on 7 May 1975. The general conclusions reached at this public meeting were that (a) action should be taken to adopt and enforce a sound floodplain regulation and flood insurance program, (b) local interests should continue to work through the North Dakota State Water Commission to obtain an assured water supply.

CONCLUSIONS AND RECOMMENDATION

No economically feasible structural measures that would reduce the flood damages were identified. However, sufficient information is available to permit the adoption of nonstructural flood programs. The present adopted policies and procedures do not permit the Corps of Engineers to assist local interests with the construction of a single-purpose water supply project.

Therefore I recommend that no further investigation be made of the water problems on the Forest River at this time.

FEASIBILITY

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APPENDIX A

WILDLIFE SPECIES

FIGURES

FIGURE A-1 BIRDS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN

Horned Grebe	Eared Grebe
Western Grebe	Pied-billed Grebe
White Pelican	Double-crested Cormorant
Great Blue Heron	Black-crowned Night Heron
American Bittern	Whistling Swan
Canada Goose	White-fronted Goose
Snow Goose	Blue Goose
Mallard	Black Duck
Gadwall	Pintail
Green-winged Teal	Blue-winged Teal
American Widgeon	Shoveler
Wood Duck	Redhead
Ring-necked Duck	Canvasback
Gray Partridge	Sandhill Crane
Virginia Rail	Sora
American Coot	Semipalmated Plover
Killdeer	Black-bellied Plover
Common Snipe	Upland Plover
Spotted Sandpiper	Willet
Greater Yellow-legs	Lesser Yellow-legs
Lesser Scaup	Common Goldeneye
American Golden Plover	Bufflehead
White-winged Scoter	Ruddy Duck
Hooded Merganser	Common Merganser
Cooper's Hawk	Red-tailed Hawk

FIGURE A-1 BIRDS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN (CONTINUED)

Short-billed Marsh Wren	Catbird
Brown Thrasher	Robin
Palm Warbler	Yellowthroat
Short-eared Owl	Common Nighthawk
Chimney Swift	Ruby-throated Hummingbird
Belted Kingfisher	Yellow-shafted Flicker
Red-headed Woodpecker	Hairy Woodpecker
Downy Woodpecker	Swainson's Thrush
Gray-cheeked Thrush	Veery
Eastern Bluebird	Bohemian Waxwing
Cedar Waxwing	Northern Shrike
Loggerhead Shrike	Starling
Red-eyed Vireo	Black-and-white Warbler
Myrtle Warbler	Blackburmian Warbler
Grasshopper Sparrow	LeConte's Sparrow
Sharp-tailed Sparrow	Vesper Sparrow
Lark Sparrow	Slate-colored Junco
Tree Sparrow	American Redstart
House Sparrow	Bobolink
Western Meadowlark	Yellow-headed Blackbird
Red-winged Blackbird	Baltimore Oriole
Common Grackle	Brown-headed Cowbird
Scarlet Tanager	Rose-breasted Grosbeak
Purple Finch	Common Redpoll
American Goldfinch	Lark Bunting

FIGURE A-1 BIRDS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN (CONTINUED)

Golden Eagle	Bald Eagle
Marsh Hawk	Prairie Falcon
Sparrow Hawk	Greater Prairie Chicken
Sharp-tailed Grouse	Ring-necked Pheasant
Marbled Godwit	American Avocet
Wilson's Phalarope	Northern Phalarope
Herring Gull	Ring-billed Gull
Franklin's Gull	Forster's Tern
Common Tern	Black Tern
Mourning Dove	Black-billed Cuckoo
Great Horned Owl	Snowy Owl
Pectoral Sandpiper	White-rumped Sandpiper
Least Sandpiper	Short-billed Dowitcher
Long-billed Dowitcher	Semipalmated Sandpiper
Western Sandpiper	Eastern Kingbird
Western Kingbird	Eastern Phoebe
Traill's Flycatcher	Least Flycatcher
Horned Lark	Tree Swallow
Bank Swallow	Rough-winged Swallow
Barn Swallow	Cliff Swallow
Purple Martin	Blue Jay
Black-billed Magpie	Common Crow
Black-capped Chickadee	White-breasted Nuthatch
Red-breasted Nuthatch	Brown Creeper
House Wren	Long-billed Marsh Wren

FIGURE A-1 BIRDS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN (CONTINUED)

Savannah Sparrow	Chipping Sparrow
Clay-colored Sparrow	White-throated Sparrow
Fox Sparrow	Swamp Sparrow
Song Sparrow	Snow Bunting

FIGURE A-2 MAMMALS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN

COMMON NAME	SCIENTIFIC NAME
Artic shrew	Sorex arcticus
Masked shrew	Sorex cinereus
Pigmy shrew	Microsorex hoyi
Shorttail shrew	Blarina brevicauda
Starnose mole	Condylura cristata
Little brown bat	Myotis lucifugus
Keen's bat	Myotis keenii
Silver-haired bat	Lasionycteris noctivagans
Hoary bat	Lasiurus cinereus
Big brown bat	Eptesicus fuscus
Woodchuck	Marmota monax
Richardson ground squirrel	Citellus richardsonii
Franklin ground squirrel	Citellus franklinii
Thirteen-lined ground squirrel	Citellus tridecemlineatus
Eastern Chipmunk	Tamias striatus
Eastern gray squirrel	Sciurus carolinensis
Eastern fox squirrel	Sciurus niger
Red squirrel	Tamiasciurus hudsonicus
Northern flying squirrel	Glaucomys sabrinus
Northern pocket gopher	Thomomys talpoides
Plains pocket gopher	Geomys bursarius
Northern grasshopper mouse	Onychomys leucogaster
Deer mouse	Peromyscus maniculatus
White-footed mouse	Peromyscus leucopus

FIGURE A-2 MAMMALS FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN (CONTINUED)

COMMON NAME	SCIENTIFIC NAME
Beaver	Castor canadensis
Meadow vole	Microtus pennsylvanicus drummondii (Bailey)
Prairie vole	Microtus pedomys ochrogaster
Boreal redback vole	Clethrionomys gapperi
Muskrat	Ondatra zibethicus
Norway rat	Rattus norvegicus
House mouse	Mus musculus
Meadow jumping mouse	Zapus hudsonius
Porcupine	Erethizon dorsatum
Whitetail jackrabbit	Lepus townsendii
Snowshoe hare	Lepus americanus
Eastern cottontail	Sylvilagus floridanus
Coyote	Canis latrans
Red fox	Vulpes fulva
Raccoon	Procyon lotor
Least weasel	Mustela rixosa
Shorttail weasel	Mustela erminea
Longtail weasel	Mustela frenata
Mink	Mustela vison
Badger	Taxidea taxus
Striped skunk	Mephitis mephitis
Lynx	Lynx canadensis
Bobcat	Lynx rufus
White-tailed deer	Odocoileus virginianus
Moose	Alces alces

FIGURE A-3 AMPHIBIANS AND REPTILES FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN

COMMON NAME	SCIENTIFIC NAME
Eastern tiger salamander	*Ambystoma tigrinum tigrinum*
Gray tiger salamander	*Ambystoma tigrinum diaboli*
Dakota toad	*Bufo hemiophrys*
Boreal chorus frog	*Pseudacris triseriata maculata*
Northern leopard frog	*Rana pipiens*
Wood frog	*Rana sylvatica*
Common snapping turtle	*Chelydra serpentina*
Western painted turtle	*Chrysemys picta belli*
Northern red-bellied snake	*Storeria occipitomaculata occipitomaculata*
Western plains garter snake	*Thamnophis radix haydeni*
Red-sided garter snake	*Thamnophis sirtalis parietalis*
Western smooth green snake	*Opheodrys vernalis blanchardi*

FIGURE A-4 FISH FOUND IN NORTHEASTERN NORTH DAKOTA AND THE FOREST RIVER SUBBASIN

COMMON NAME	SCIENTIFIC NAME
Northern pike	*Esox lucius*
Carp	*Cyprinus carpio*
Spottail shiner	*Notropis hudsonius*
Plains shiner	*Notropis percobromus*
Banded killifish	*Fundulus diaphanus*
Fathead minnow	*Pimephales promelas*
Brook stickleback	*Eucalia inconstans*
Green sunfish	*Lepomis cyanellus*
Yellow perch	*Perca flavescens*
Freshwater drum	*Aplodinotus grunniens*
Walleye	*Stizostedion vitreum*
Sauger	*Stizostedion canadense*

PRELIMINARY FEASIBILITY

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APPENDIX B

PROBLEMS AND NEEDS

FIGURES

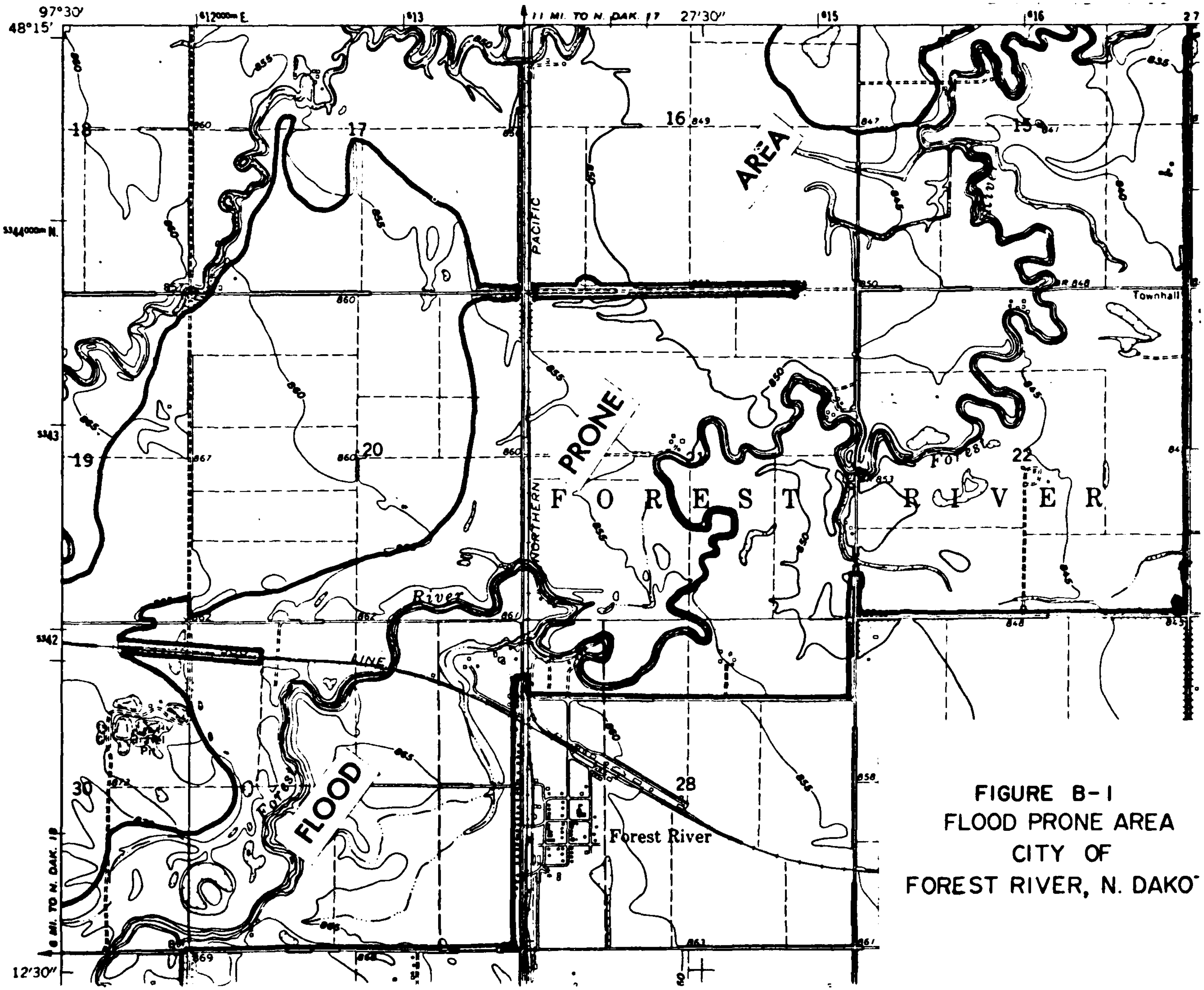


FIGURE B-1
FLOOD PRONE AREA
CITY OF
FOREST RIVER, N. DAKO

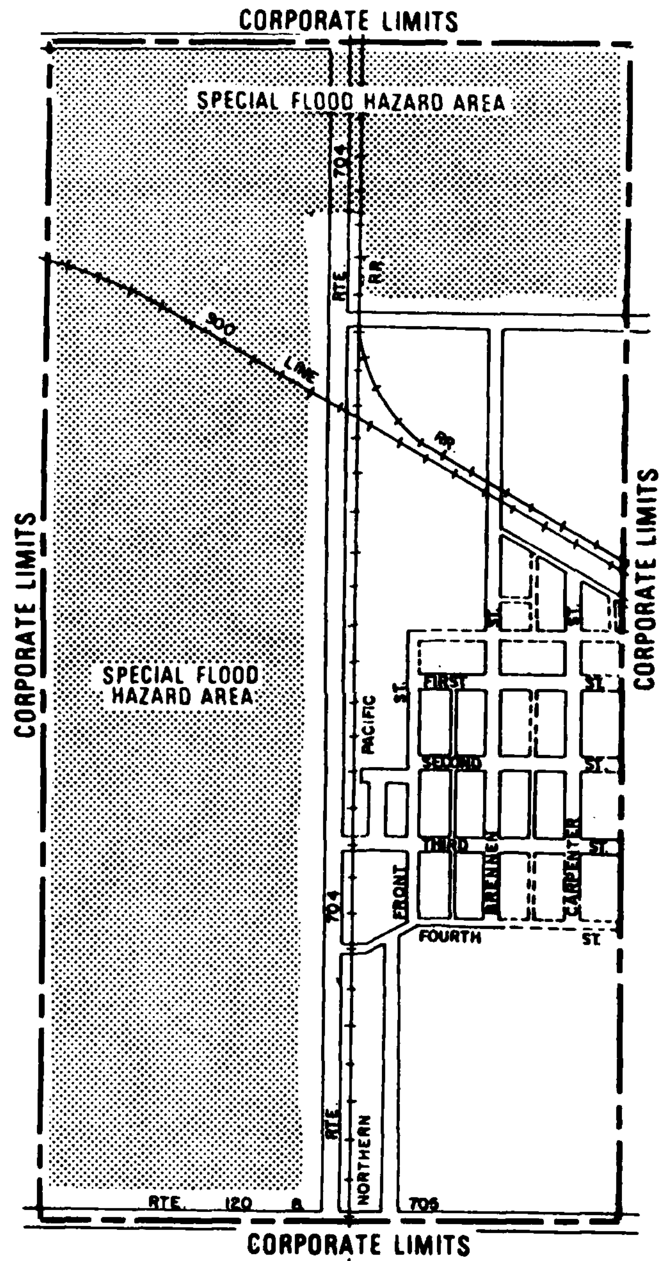
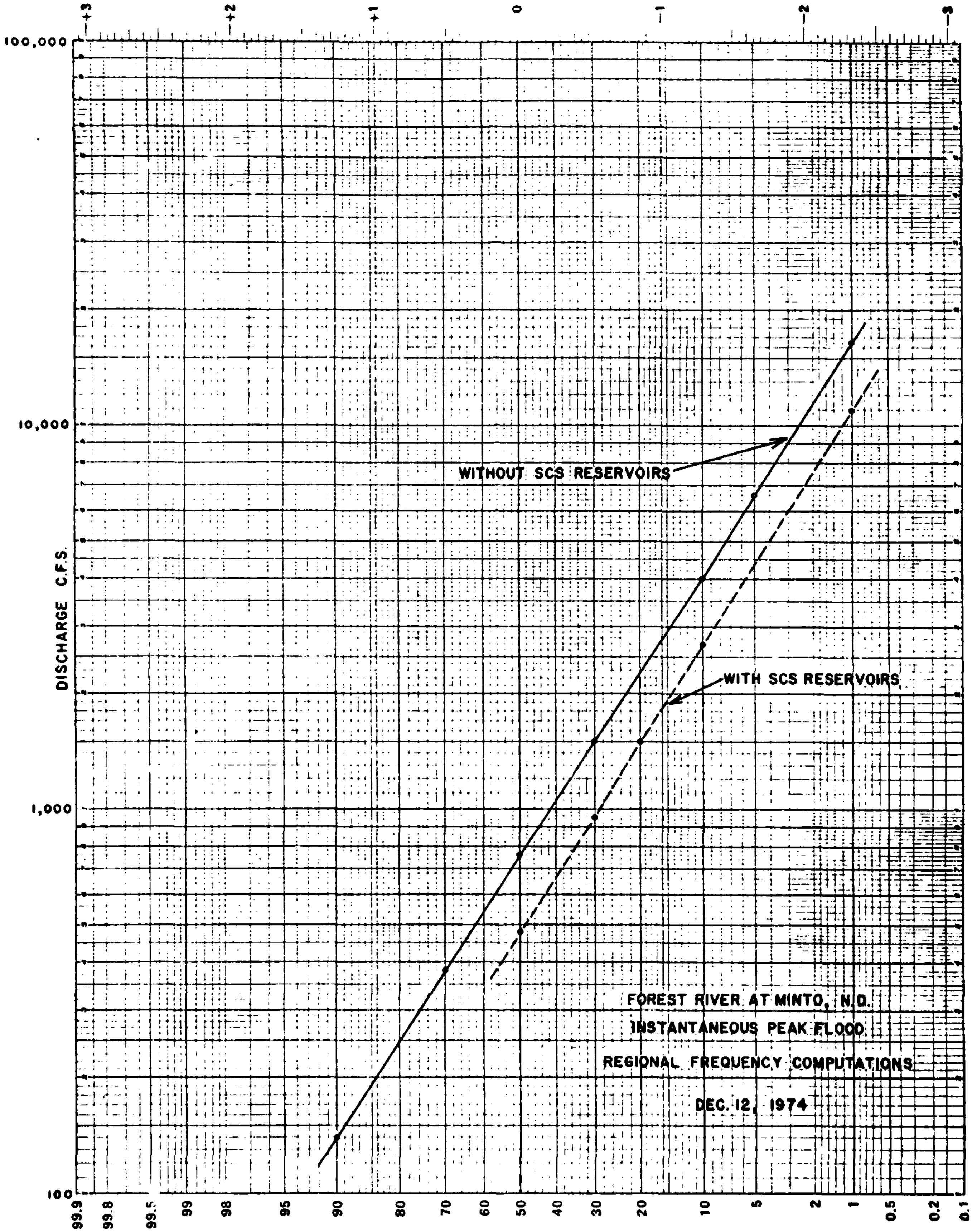


FIGURE B-2
FLOOD PRONE AREA
CITY OF
FOREST RIVER, N. DAKOTA



% CHANCE

DISCHARGE-FREQUENCY CURVE

FIGURE B-3

B-3

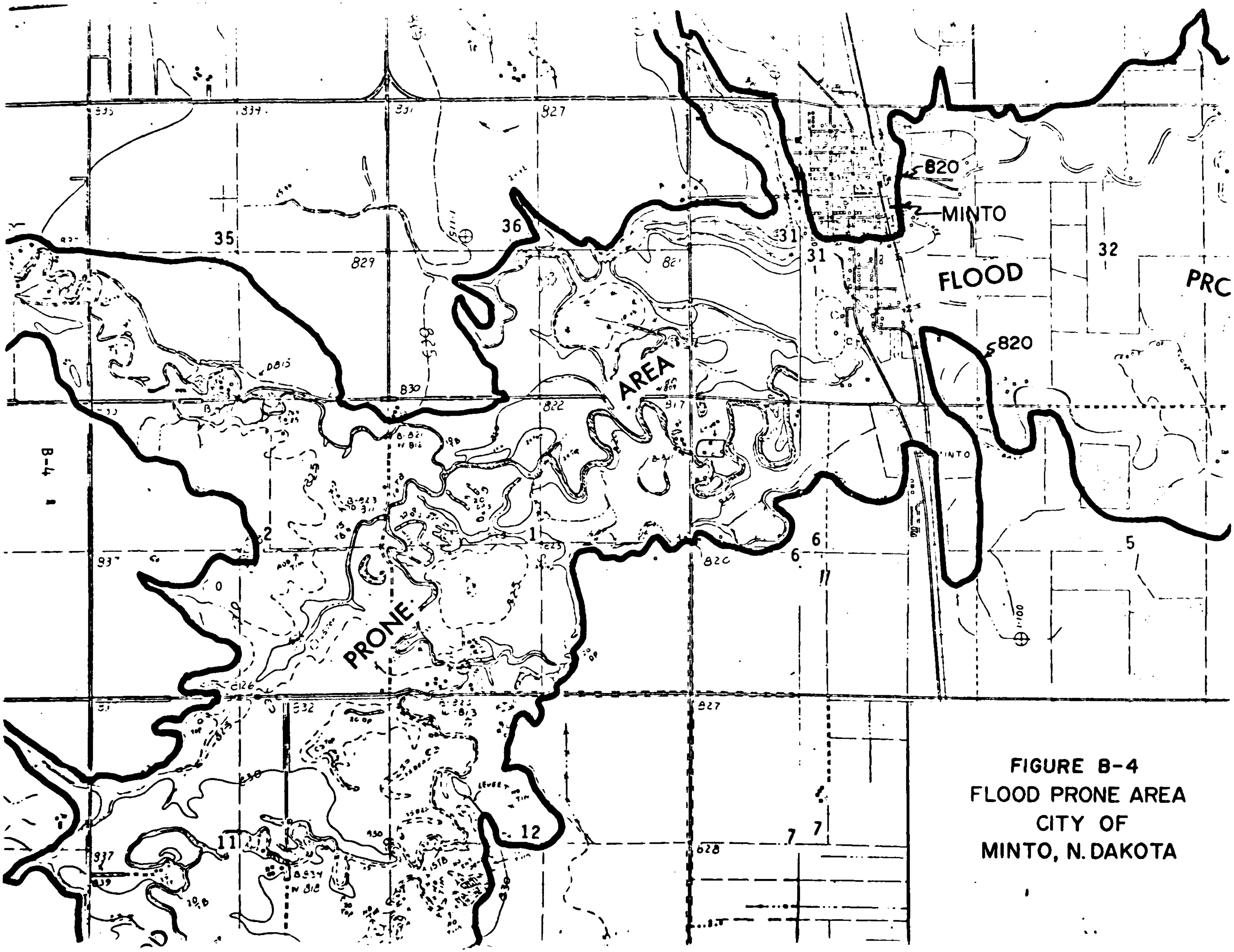


FIGURE B-4
FLOOD PRONE AREA
CITY OF
MINTO, N. DAKOTA

PRELIMINARY FEASIBILITY

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APPENDIX C

ALTERNATIVE PLANS TO BE CONSIDERED

FIGURES

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FIGURES (CONT)

FLOOD CONTROL ALTERNATIVE

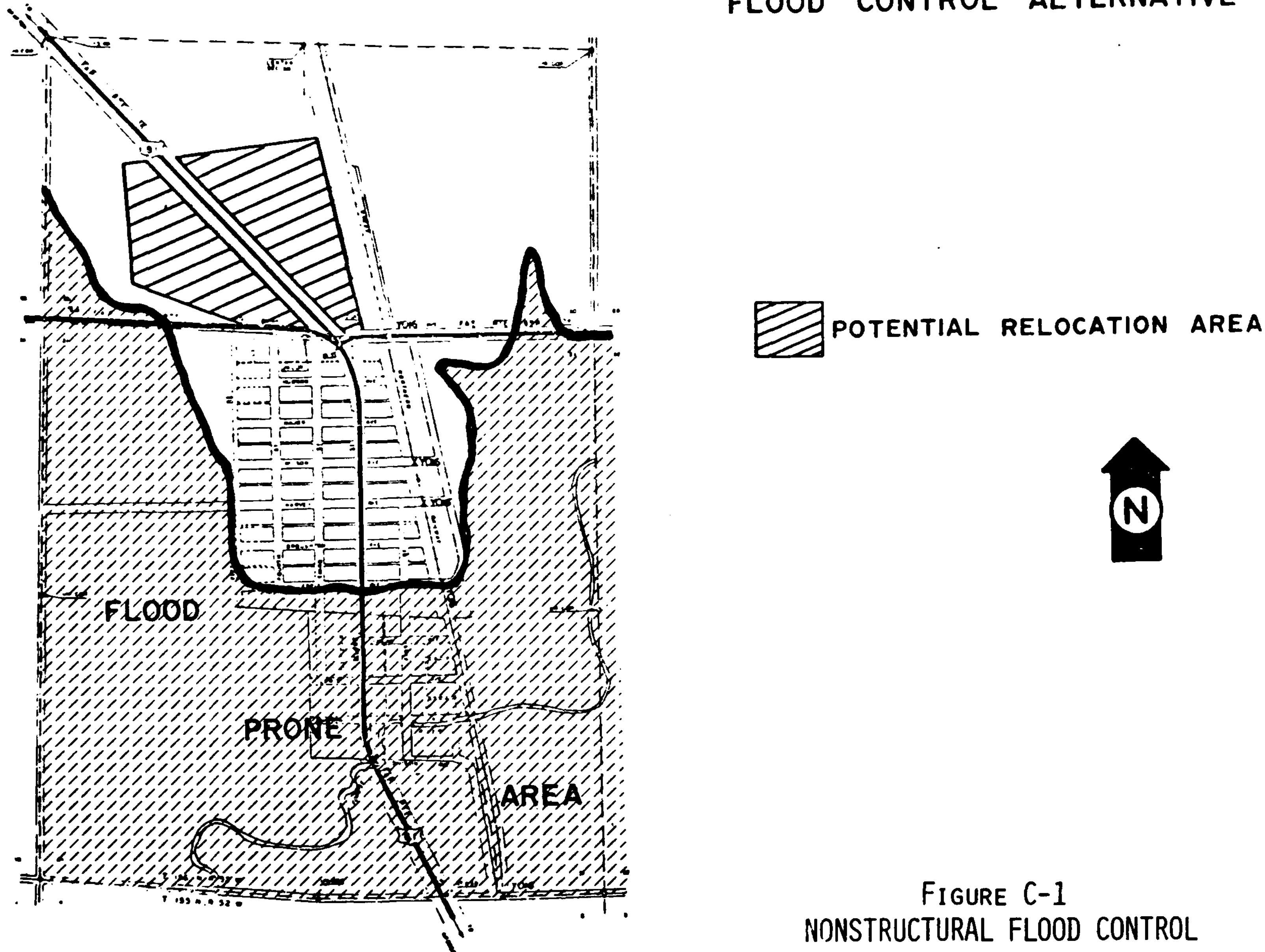


FIGURE C-1
NONSTRUCTURAL FLOOD CONTROL
ALTERNATIVE #3
FLOODPLAIN EVACUATION

FLOOD CONTROL ALTERNATIVE

POTENTIAL CHANNEL IMPROVEMENTS

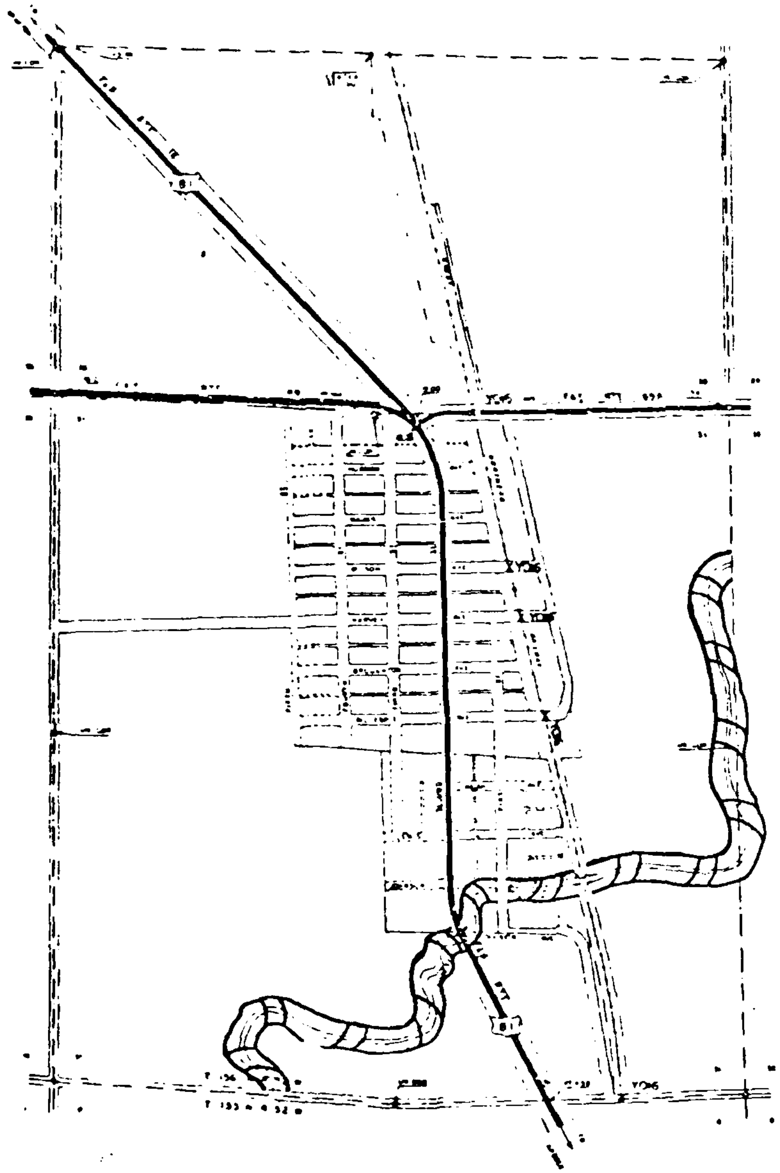


FIGURE C-2
STRUCTURAL FLOOD
CONTROL ALTERNATIVE #2
CHANNEL IMPROVEMENTS

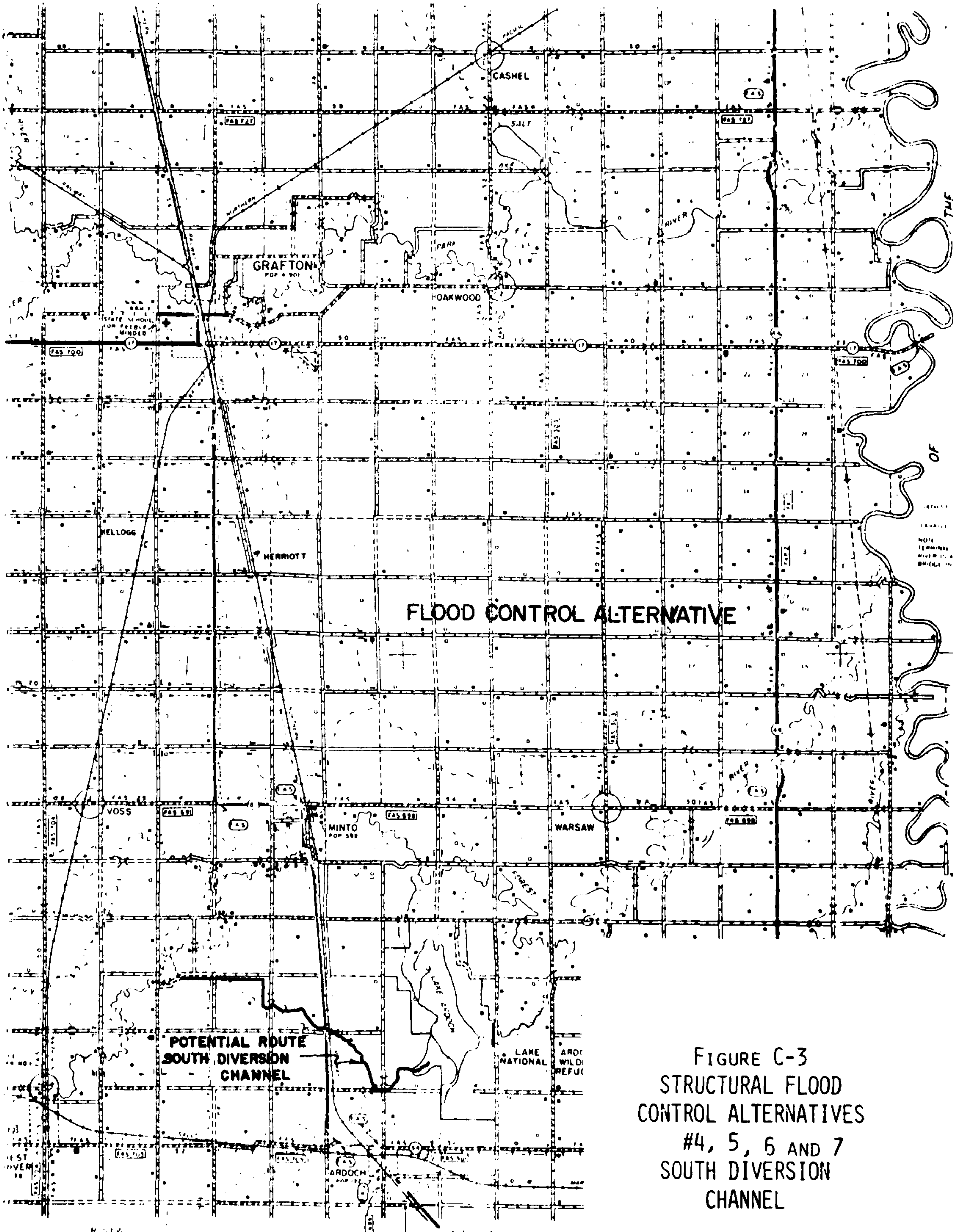


FIGURE C-3
STRUCTURAL FLOOD
CONTROL ALTERNATIVES
#4, 5, 6 AND 7
SOUTH DIVERSION
CHANNEL

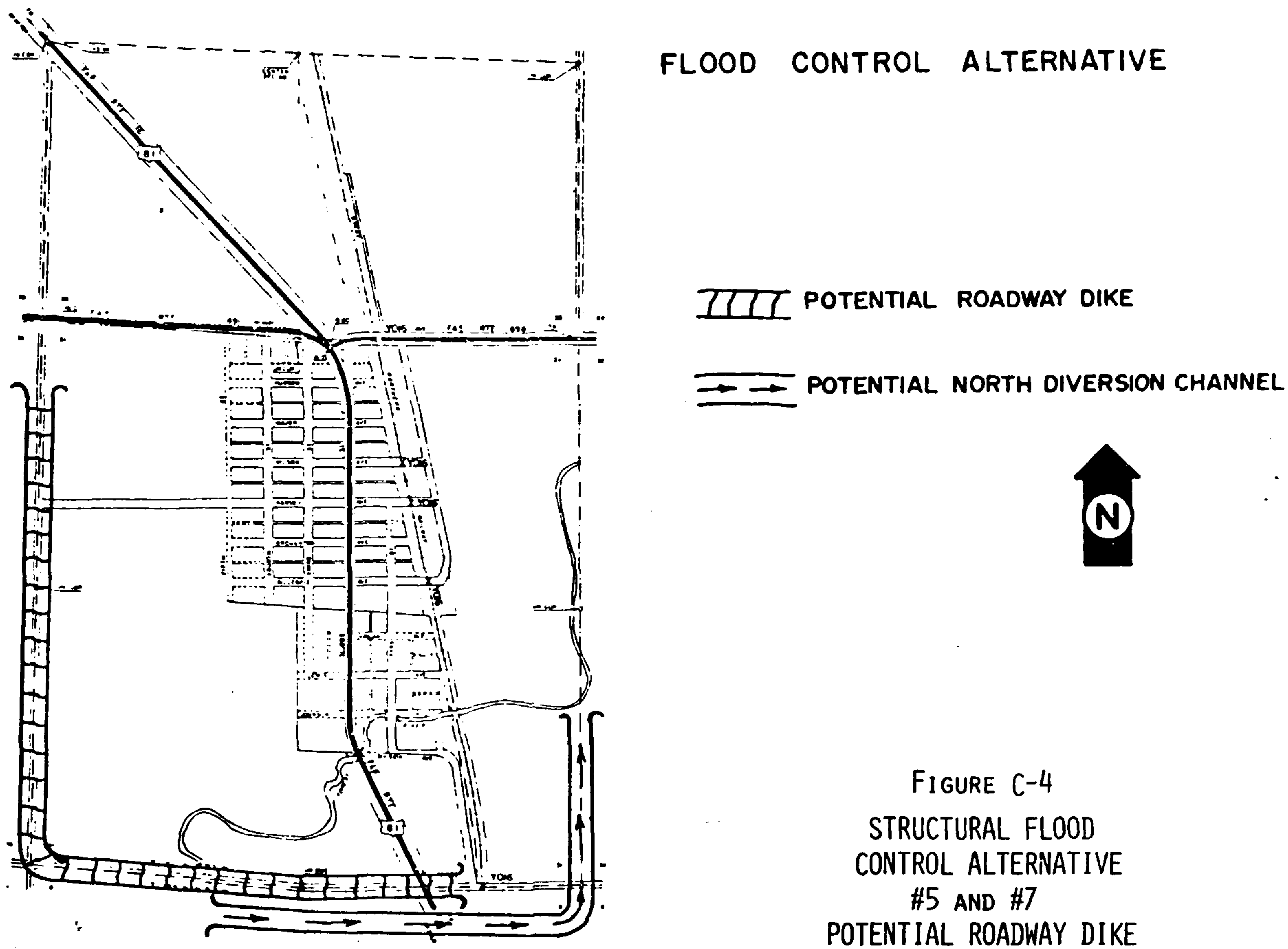


FIGURE C-4
STRUCTURAL FLOOD CONTROL ALTERNATIVE #5 AND #7
POTENTIAL ROADWAY DIKE AND NORTH DIVERSION CHANNEL

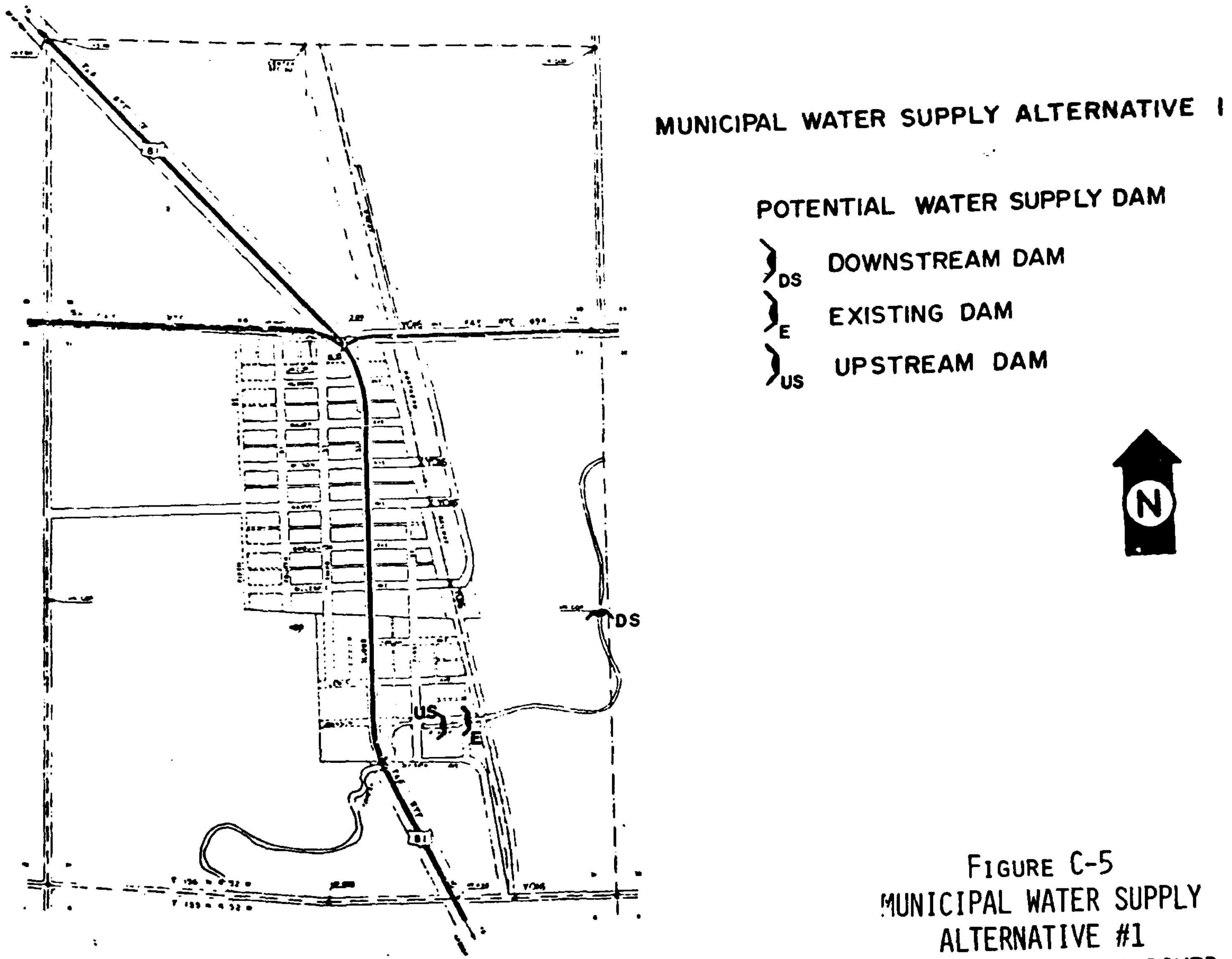


Figure C-5
MUNICIPAL WATER SUPPLY
ALTERNATIVE #1
MAIN STREAM FOREST RIVER
AT MINTO

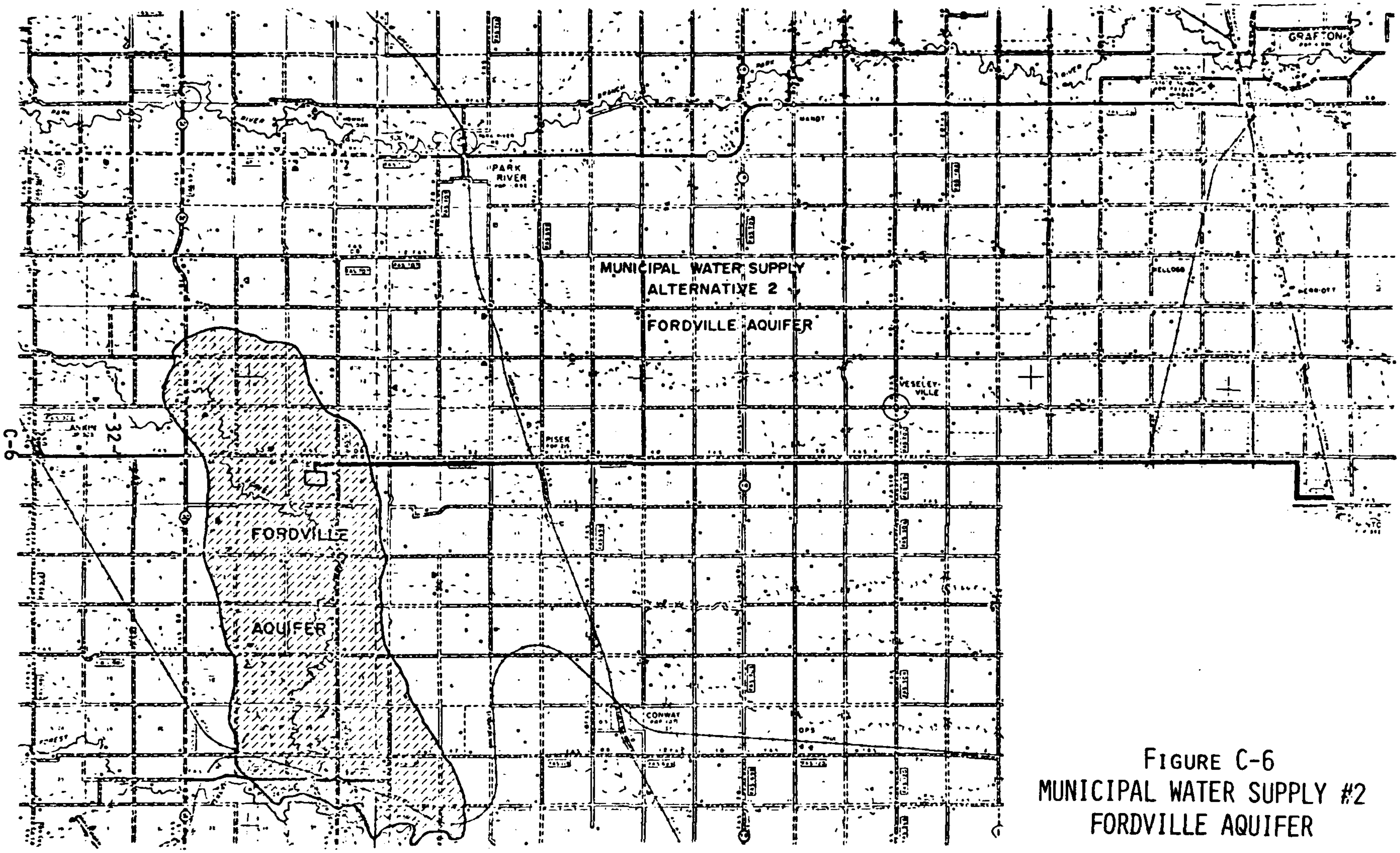


FIGURE C-6
MUNICIPAL WATER SUPPLY #2
FORDVILLE AQUIFER

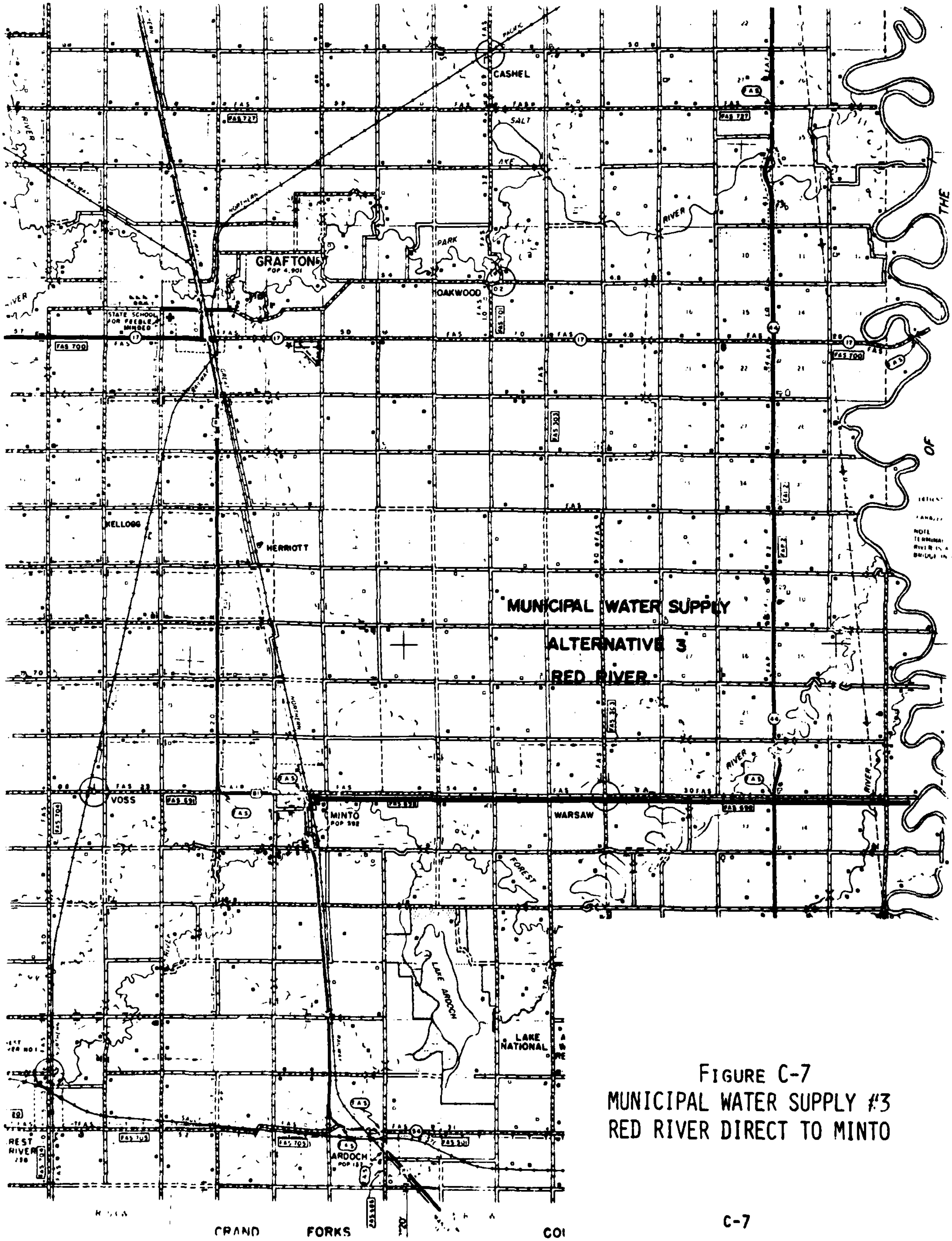


Figure C-7
MUNICIPAL WATER SUPPLY #3
RED RIVER DIRECT TO MINTO

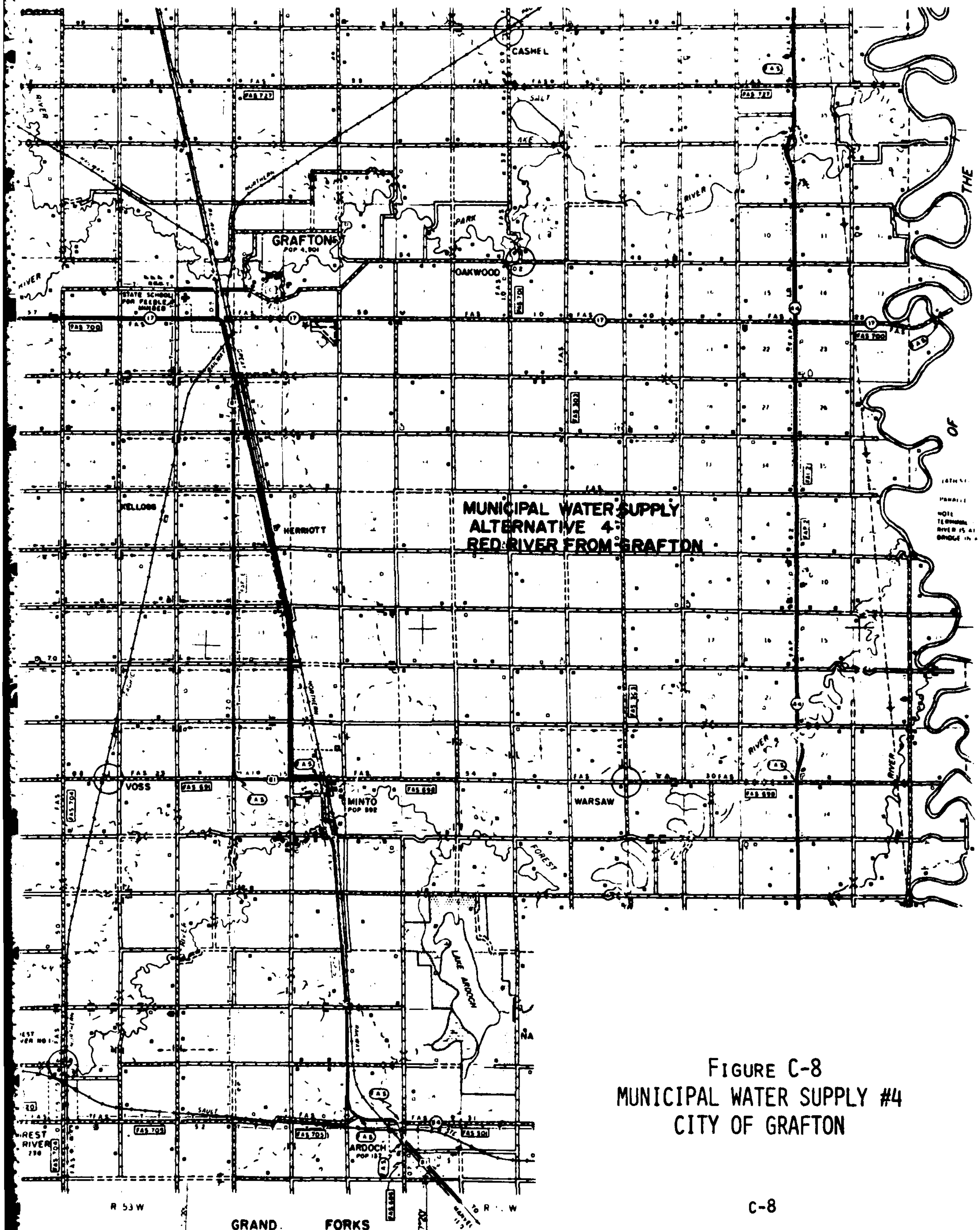


Figure C-8
MUNICIPAL WATER SUPPLY #4
CITY OF GRAFTON

GROUND WATER DATA FOR FORDVILLE AQUIFER

The amount of ground water discharged from much of the Fordville aquifer to the Forest River on June 4, 1968, is shown in Figure C-9. The flow measurements shown were made after a period of dry weather and the values listed are the base flow of the stream, at the time of measurement. The discharge measurements on the North Branch indicate that about 2.2 cfs, or 990 gpm, was flowing from the aquifer into the stream at the time the measurements were made.

An aquifer test was conducted (Schmid, 1968) on the Fordville aquifer in June 1968. The test site was located in Sections 26 and 27, Township 156 North, Range 56 West, near the area of maximum aquifer thickness, as indicated by test drilling. The well was located at 156-56-26BCC, had a diameter of 8 inches and was cased to 38 feet with an additional 9.5 feet of 35-slot screen. The well was pumped by a turbine pump set 45 feet below land surface. Seven observation wells were drilled at distances of 49, 100, 304, 402, 700 and 1,320 feet from the production well. All wells completely penetrated the aquifer; however, the observation wells were screened only in the lower three feet of the aquifer. All wells were measured at frequent intervals during the test. The rate of flow from the production well was maintained at 300 $\pm$ 10 gpm during the test period of 80 hours (4,800 minutes).

Data from the Fordville aquifer test were analyzed by the Theis (1935) nonequilibrium method. A plot of data from observation well 5 is shown in Figure C-10 along with the trace of the Theis-type curve. Figure C-9 lists the transmissivities and storage coefficients determined at four well sites used in the Fordville aquifer test.

FIGURE C-9 TRANSMISSIVITIES AND STORAGE COEFFICIENTS FROM THE FORDVILLE AQUIFER TEST WELLS

Well Number	Transmissivity: Gallons per day per foot	Transmissivity: Square feet per day	Storage Coefficient
Production well			
(drawdown)	43,500	5,830	-
(recovery)	52,100	6,980	-
Obs. Well 1	53,700	7,200	0.18
Obs. Well 2	66,100	8,860	.17
Obs. Well 5	55,500	7,440	.15

Data shown in Figure C-10 from short-term tests on the production wells in the U.S. Army well field indicate that the Army wells have a higher specific capacity than the aquifer-test well. This may be due, in part, to differences in well construction; however, it may also indicate significant differences in the hydrologic properties of the aquifer between the aquifer-test location and the location of the army well field.

The following water permits from the Fordville Aquifer are on file with the North Dakota State Water Commission:

Number	Name	Quantity
1163	Kenneth Walker	340 acre-feet
1267	Floyd Greenwood	17 acre-feet
1679	A.B.M. Complex	1613.01 acre-feet
1876	Walsh County Water Users	235.0 acre-feet

FIGURE C-10 SUMMARY OF SPECIFIC-CAPACITY DATA OF WELLS TAPPING THE FORDVILLE AQUIFER

Well Location	Date	Well Depth (feet)	Saturated Interval (feet)	Screened Interval (feet)	Pumping Rate (gallons per minute)	Test Duration (minutes)	Specific Capacity (gallons per minute per foot)
155-56-1BBC	11- 4-68	35	14-35	25-35	300	600	47
155-56-1BCD	11- 5-68	36	11-36	26-36	300	600	60
155-56-2DAD	11- 6-68	33	10-33	23-33	300	600	107
155-56-2DDD2	11- 7-68	34	13-34	24-34	300	600	50
155-56-11AAD	11- 8-68	35	16-35	25-35	300	600	136
156-56-26DBC5	10-31-68	55	31-55	45-55	300	600	77
156-56-35ABA	11- 1-68	42	18-42	32-42	300	600	70
156-56-35DAA	11- 3-68	30	14-30	20-30	300	600	71
156-56-36CCD	10-30-68	32	10-32	22-32	300	600	44
156-56-26BCC	6-19-68	47	18-47	38-47	300	4,800	24

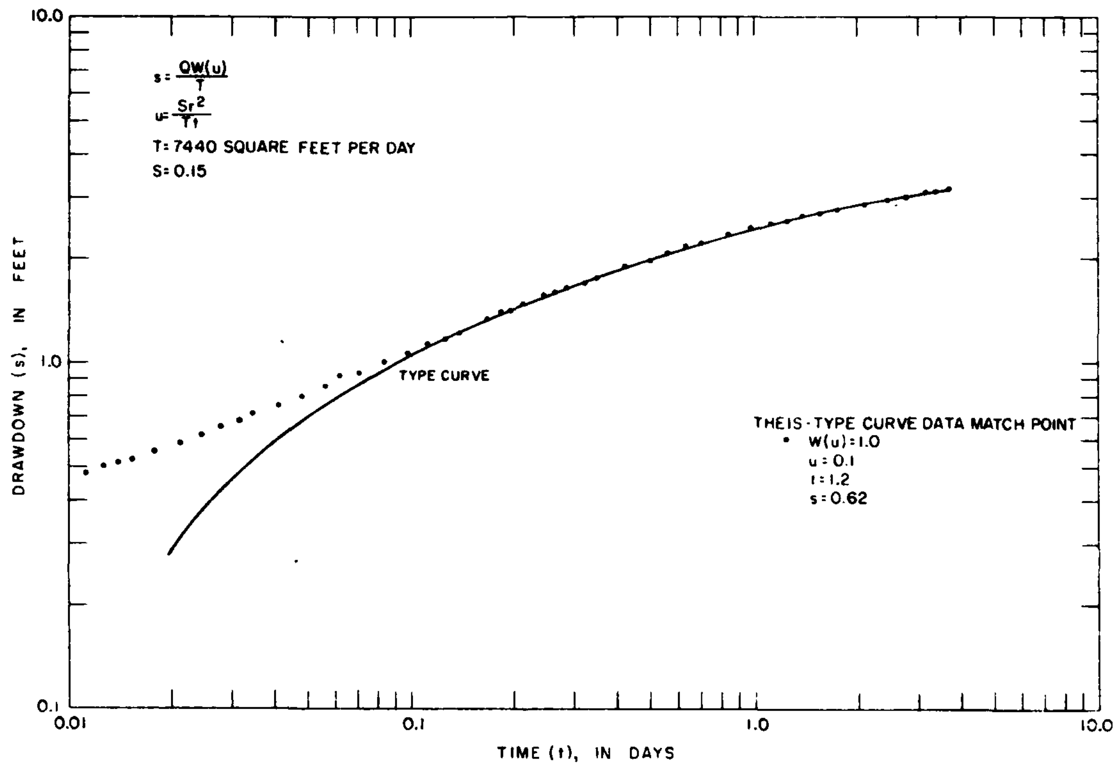
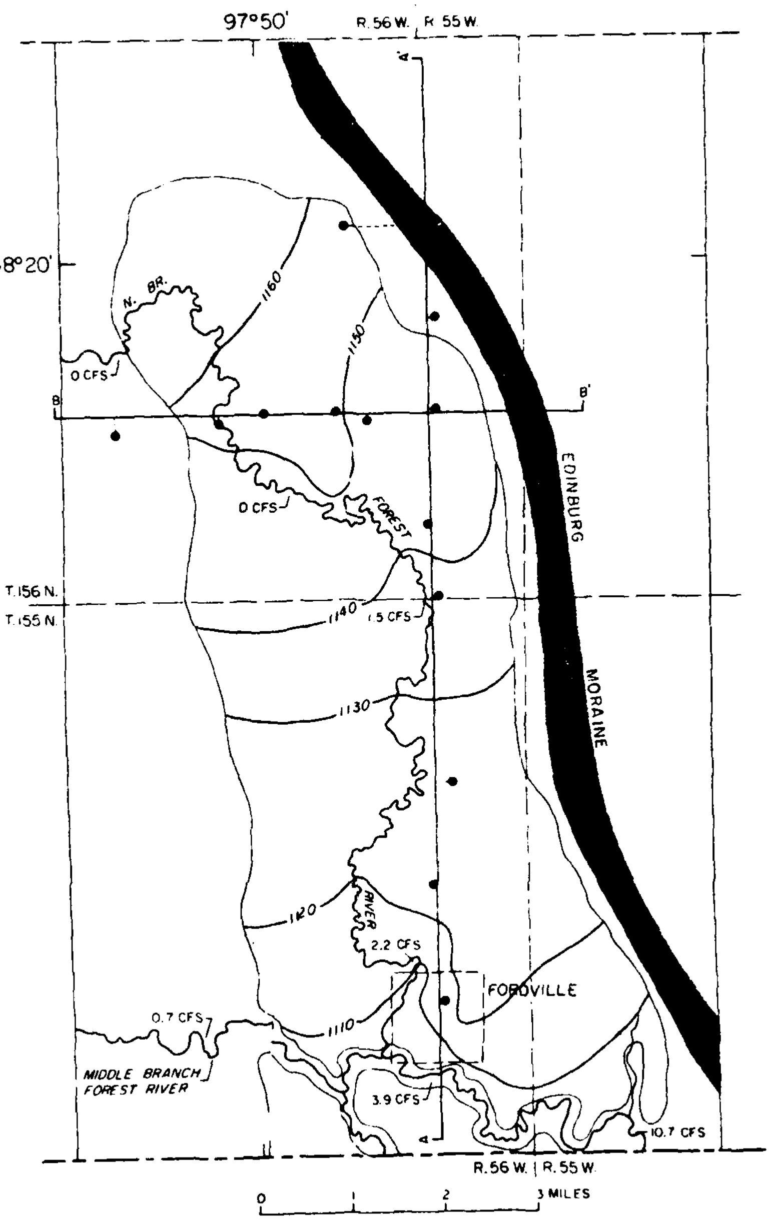


FIGURE C-11 PLOT OF DATA FROM OBSERVATION WELL 5

FORDVILLE AQUIFER TEST



EXPLANATION

TEST HOLE LOCATION

WATER TABLE CONTOUR, SUMMER, 1968, SHOWS ALTITUDE OF WATER TABLE. CONTOUR INTERVAL 10 FEET. DATUM IS MEAN SEA LEVEL.

3.9CFS
DISCHARGE OF STREAM, IN CUBIC FEET PER SECOND JUNE 4, 1968

LOCATION OF GEOLOGIC SECTION

FIGURE C-12 WATER-TABLE MAP OF THE FORDVILLE AQUIFER, WALSH COUNTY

FIGURE C-13 WATER LEVELS IN SELECTED WELLS TAPPING

THE DAKOTA AQUIFER IN WALSH COUNTY

Well	Water Level, in Feet Above Land Surface 1/	Elevation of Water Level, in Feet Above Mean Sea Level
157-52-7DCD	14	826
157-53-10AAC	8	838
157-53-16CBB	16	856
157-53-16DAB	18	858
157-53-22CBB	21	856
157-53-22DDC	9	844
157-54-1CCD1	7	873
157-54-12DAA	16	876
158-52-30CCC	25	852
158-53-20BCA	9	857
158-53-23CCC	21	861

1/ Values shown are those measured or reported during this study. Wells that are many years old may have casing that leaks when the well is closed causing a lower pressure to be shown at the well head than naturally exists in the aquifer.

FIGURE C-14 MEAN CHEMICAL COMPOSITION OF WATER FROM THE

DAKOTA AQUIFER IN WALSH COUNTY

Sample Size: 24 Analyses

Constituent	Mean, in Milligrams Per Liter
Silica (SiO_2)	12
Iron (Fe)	5
Calcium (Ca)	121
Magnesium (Mg)	43
Sodium (Na)	1,435
Potassium (K)	19
Bicarbonate (HCO_3)	677
Sulfate (SO_4)	794
Chloride (Cl)	1,611
Fluoride (F)	2
Nitrate (NO_3)	12
Boron (B)	3
Dissolved Solids	4,510

PRELIMINARY FEASIBILITY

REPORT

FOR FLOOD CONTROL AND

RELATED PURPOSES

FOREST RIVER SUBBASIN

NORTH DAKOTA

APPENDIX D

PRELIMINARY SOIL INVESTIGATION REPORT

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FIGURES

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AD-A160 792 FOREST RIVER BASIN NORTH DAKOTA FEASIBILITY REPORT FOR FLOOD CONTROL AND RELATED PURPOSES PHASE I(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT JUN 75 2/2

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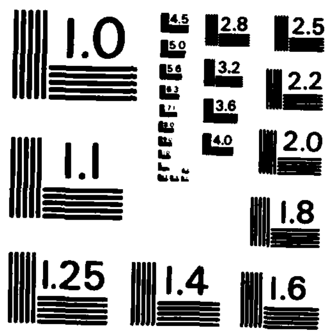


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

PRELIMINARY SOIL INVESTIGATION REPORT

INTRODUCTION

A subsurface investigation was conducted by the State Water Commission to determine the feasibility of a concrete channel dam at two proposed sites on the Forest River, near the city of Minto. Four test borings, two at each respective dam site, were drilled and tested by Soil Exploration Company, St. Paul, Minnesota, in September 1974.

Descriptive logs of the geologic deposits penetrated in each of the test borings were made and core samples taken at prescribed depths. Representative soil samples recovered by split-barrel sampling were obtained for identification purposes and laboratory tests, consisting of particle-size analysis and soil constants determination. In conjunction with the aforementioned testing, the contractor performed both unconfined compression and triaxial shear tests on selected thin-wall tube samples.

The purpose of this report is to describe the soil conditions encountered at the sites, to analyze and evaluate these conditions and the laboratory test results; and based on this data, to indicate the foundation capabilities of the subsurface deposits.

INVESTIGATION PROCEDURES

General

As previously mentioned, four test borings were drilled during a period from September 9 to 12, 1974. The test borings were made on the river banks along the structural centerline of each proposed dam site. The locations of the test broings are shown on dam site topographic drawing numbers 8674-448-9 and 8673-448-8. All boring elevations are referenced to mean sea level datum. No foundation exploration was made at the existing damsite in view of its nearness to one of the alternate sites. For the purpose of this report, the proposed dam site upstream from the existing structure is hereafter referred to as Dam No. 1 and the proposed dam site downstream as Dam No. 2.

Soil Sampling Methods

All of the test borings were made with a truck mounted rotary drill rig. Soil sampling procedures to obtain representative samples were performed in accordance with ASTM Designation D 1586. Using this procedure, a 2 inch O. D. split-barrel sampler is driven into previous undisturbed soil with a 140 pound weight and a 30 inch drop. After an initial set of 6 inches, the number of blows required to drive the sampler an additional 12 inches is known as the penetration resistance or (N) value of the soil. The N value is an index of the relative density of cohesionless soils and the consistency of cohesive soils. Thin wall tube samples were obtained in accordance with ASTM Designation D 1587 and are indicated by appropriate symbol on the boring logs.

GEOLOGY AND PHYSIOGRAPHY

The proposed Minto dam sites, as described in this report, are located in Sections 31 and 32, Township 156 North, Range 52 West, in Walsh County, in northeastern North Dakota. The surficial geology is primarily of glacial origin being situated in the Agassiz Lake Plain Division of the Central Lowland Physiographic Province of North Dakota.

The area covered in this investigation lies entirely within the glacial Lake Agassiz plain. It has little relief and the major topographic features are the youthful stream valleys cut in the glacial Lake Agassiz sediments. Drainage is generally eastward toward the north flowing Red River which marks the eastern boundary of Walsh County.

The lake-plain deposits consist almost entirely of silt and clay and are essentially gravel free. The material is commonly laminated and varved, with very few pebbles and little sand. Underlying these lake deposits, glacial till is encountered. The till is a hetrogeneous mixture of clay, silt, sand and gravel.

SOIL CONDITIONS

The textural quality of the soils encountered in the four test borings appears to be relatively uniform, consisting of brown to gray brown interbedded sand-silt-clay mixtures in the upper portion, gray-slick clay in the middle portion and silty or clayey fine sands or clayey silts in the lower portion. For the purpose of describing the geologic deposits at the two sites, the soil foundation will herein be divided into three zones in descending order.

Zone No. 1

Zone One varies in depth from 18 to 35 feet below land surface. The upper portion of the zone ranges from 7 to 14 feet in thickness, containing black topsoil and dark brown to brown silty fines. The deposits are faintly laminated and oxidized with occasional ironstaining along the laminations. The soils were logged predominantly within the CL and CH group.

The lower portion of Zone One ranges from 10 to 21 feet in thickness. The deposits consist essentially of moderately plastic to plastic clays of the CL and CH soil group, although layers of fine non-plastic sands and clayey sands of the SM and SC soil group respectively are included. Coloration is brown, gray-brown and brown mottled. Deposits are laminated, oxidized and heavily iron stained. Thin layers of black-odorous organic clays occur throughout.

To determine the allowable load carrying capacity of the deposits within Zone One, both unconfined compression and unconsolidated-undrained triaxial shear tests were performed. Tests indicate that the upper portion of the zone or that portion of the soil foundation above approximate elevation 794 have unconfined compressive strength values from 530 to 1500 pounds per square foot.

With the exception of one test, strength tests indicate that the lower portion of the zone or that portion of the soil foundation below elevation 794 (the proposed footings elevation) have unconfined compressive values on the order of 1100 to 1300 pounds per square foot. Strength determinations based on CU-UU (staged) triaxial shear tests, further indicate that the lower portion of Zone One has a cohesive shear strength on the order of 1500 to 1900 pounds per square foot. It would appear that the tests within this portion have strength values as good or better than normally inferred from the penetration resistance.

Zone No. 2

This zone extends from the basal boundary of Zone One to its contact with the underlying glacial till. The soil within this zone is a heavy (fat) type lacustrine clay. Except for occasional silt laminations and a corresponding increase in the silt content near the lower portion of the zone, the entire zone is a massive clay rich deposit.

Particle size analyses ranged from 5 to 28 percent silt and 72 to 95 percent clay. The soil zone is further identified by its high plasticity, natural water content and liquid limit.

There is no significant angle of internal friction in this soil zone. Therefore, the shear strength is approximately equal to its cohesive strength. Based on seven unconfined compression tests, the unconfined compressive strength ranges from a low value of 500 pounds per square foot to a high value of 1900 pounds per square foot. Penetration resistance values range from 2 to 8, indicating a very soft to medium stiff consistency. No triaxial shear tests were performed within this zone.

Zone No. 3

Zone Three, the lowermost stratum of the soil foundation extends from the basal boundary of Zone Two to the final depth of boring numbers one at each dam site.

Texturally, the till stratum varies from silt to sand or silty sand of the ML and SM soil groups. Where present, the sands are sometimes under a hydrostatic head of sufficient pressure to cause a free flow of water to the land surface. Deposits are brownish-gray to gray, unoxidized, non-plastic and very dense and compact. The till samples contain from 1 to 88 percent retained on the #200 sieve and from 12 to 99 percent fines.

In view of its texture and very low plasticity, the shear strength of this zone is governed predominantly by its angle of internal friction. This is estimated at 25 degrees. Penetration resistance values greater than 100 and not less than 50, indicate the highest shear and load bearing values within the soil foundation.

Laboratory Tests Conclusions

"With respect to the unconfined compressive strengths, the following applies. The friction angle for the samples initially consolidated under loads equal to the existing overburden and then stressed under undrained conditions without allowing further consolidation for the final stage are significantly higher than normally expected for silty clay type materials. This indicates some internal drainage and subsequent consolidation and/or the reorientation of particles did occur, probably due to seams or traces of silt and sand within most of the samples. The friction angle for the first series tested on a sample 29½' - 31½' from boring #1 was definitely much higher than normally expected (19 degrees). Therefore, a second series was run, which indicated a somewhat lower angle of 12 degrees. Although the friction angles vary somewhat, the shear strength for the respective confinements are in fairly good agreement. It should be noted that all of the samples were allowed to saturate with just a 1' to 2' pressure head and that it would be necessary to use a fairly high head and back pressure in order to completely saturate the samples. If this were done it would be reasonable to assume that the friction angle on the above given conditions would be near zero degrees, certainly less than 5 degrees. In summary we suggest using a conservative angle in friction under U-U conditions of about 5 degrees."

(Soil Exploration Company, St. Paul, Minnesota, Nov. 25, 1974, written communication from Thomas K. Smith, P.E.)

Based on determination of index properties, unconfined compression and triaxial shear tests at Dam No. 2, it is the opinion of the testing contractor that unconfined compression tests performed at Site No. 1 are sufficient for preliminary design purposes, since the clays are of high plasticity and low, if any friction angle.

FOUNDATION ANALYSIS AND RECOMMENDATIONS

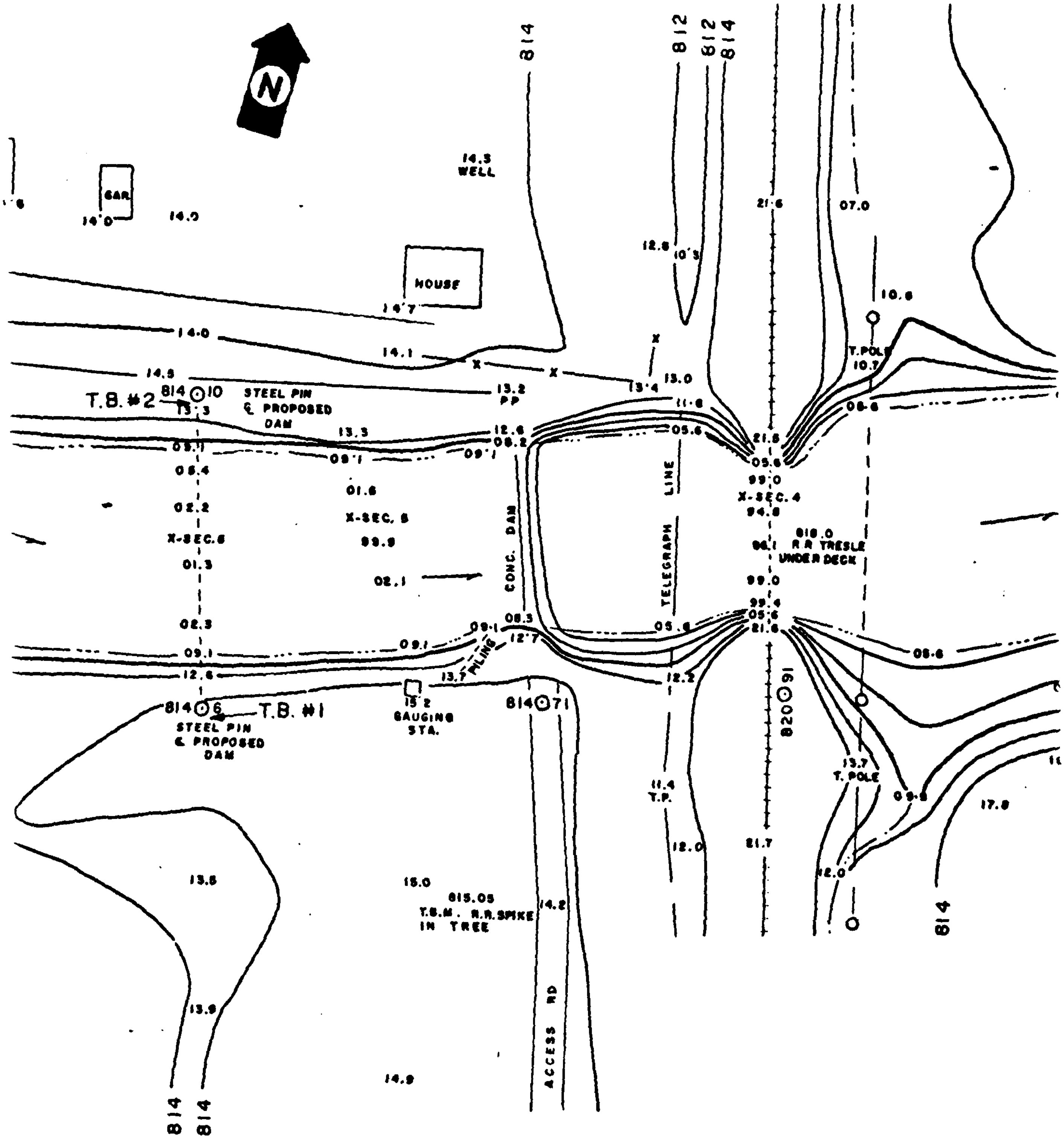
Proposed plans are to construct a concrete channel dam across the Forest River. A preliminary evaluation of anticipated structural loads was made without any definite design loads or details.

It is proposed to support the structure on a mat or raft foundation. As previously mentioned, the spread foundation would be at approximate elevation 794.0 msl. With reference to the laboratory tests data and soil profiles shown on the boring logs, it appears that Dam Site No. 2 would provide better foundation conditions for support of the structural load. This opinion is based on the assumption that construction would consist primarily of a reinforced concrete channel dam on a mat or raft foundation exerting a 1000 pound per square foot pressure to the soils at a depth of approximately 20 feet below existing grade. This is based on the higher shear strength and lower compressibility indications from the laboratory tests.

In the event a channel dam with gates is constructed, loadings for continuous footings and moderately heavy individual column footings will have to be analyzed. Shear strengths will be reevaluated and both total and differential settlements carefully analyzed.

To increase the bearing value of the soils and maintain settlements within tolerable limits, it may be necessary to over-excavate the foundation area and backfill with several feet of select pit-run sand and gravel. Based on anticipated loads, the granular cushion should be placed to the desired grade and compacted to a density equal to 95 percent of the maximum dry density in accordance with Method A, ASTM D 698.

It seems reasonable to consider a mat foundation at Dam Site No. 2. However, inadequate or marginal bearing values and/or excessive potential settlements may warrant consideration of a shallow pile foundation. Either steel or concrete piling could be utilized.



TEST BORINGS FOR PROPOSED DAM SITE #1 FIGURE D-1

SECTION FROM S.W.C. DRAWING NO. 8674-448-9

NORTH DAKOTA STATE WATER COMMISSION

FOUNDATION SOIL TEST BORING

Project Name: MINTO DAM (SITE #1)   Boring No: 1 (Rt. BANK)

Project No: 448   Date Drilling Started: 9-9-74

County: WALSH   Date Finished: 9-10-74

SYMBOL DEFINITION

▽ Water level   2TW 2" thin wall tube sampler

SS 2 3/8" O.D. split spoon sampler   3TW 3" thin wall tube sampler

Depth 1" = 5'	Elev. MSL	Classification Symbol Letter	Classification Symbol Graphic	Sample No. And Type	Classification and Description of Material
0.0	815.0				
3.5	811.5				Topsoil, Black with Organic Material
8.0	807.0	OH		1-1 SS	Silty Clay, Dark Brown to Black Highly Organic, Little Fine Sand Plastic, Moist, Medium Stiff
18.0	797.0	CL & CH		1-1A 2TW 1-2 SS 1-3 SS	Silty Clay, Mottled Brown Laminated, Oxidized Trace of Fine Sand Plastic, Moist to Wet Medium Stiff
		CH		1-4 SS 1-4A 3TW 1-5 SS 1-5A 3TW 1-6 SS	Clay, Gray, Fat, Massive Unoxidized, Slick Little to Some Silt Highly Plastic Very Moist Medium Stiff to Very Soft

FIGURE D-2

FORM 177

Depth 1" = 5'	Elev. MSL	Classification Symbol		Sample No. And	Classification and Description of Material
		Letter	Graphic	Type	
30		CH			
		CH		1-6A 3TW	
35		CH		1-7 SS	
40		CH			
		CH		1-7A 2TW	
45		CH		1-8 SS	
50		CH			
		CH		1-8A 2TW	
55		CH		1-9 SS	
60		CH			
65		CH		1-10 SS	
70		CH			
75		CH		1-11 SS	FIGURE D-2 Cont.

Depth 1" = 5'	Elev. MSL	Classification Symbol Letter	Classification Symbol Graphic	Sample No. And Type	Classification and Description of Material
75					
80					
		CH			
85					
90					
91.5	723.5				
		ML		1-12 SS	Sandy Silt, Gray, Laminated Fine Sand and Silt Mixture, Non Plastic Little Clay, Moist, Very Dense
95	720.0				
		SM			Sand, Gray Predominantly Fine Silt Laminae, Trace of Clay Non Plastic, Water-Bearing Very Dense
101.0	714.0			1-13 SS	END OF BORING
105					
110					

W.L. Remarks: Boring plugged with foreign objects - No final water level.

FIGURE D-2 Cont.

SWC FORM NO. 177

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #1) Test Boring No. 1

Project No. 448 County Walsh

Sample No.	448-1-1	448-1-2	448-1-3	448-1-4	448-1-5
Depth, Feet	4.5-6.0	11.0-12.5	14.5-16.0	19.5-21.0	24.5-26.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	7	4	0	0	0
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	1	1	0	0	0
(c) % Fine Sand (-#40 + #200)	6	3	0	0	0
(3) % Silt Size (0.074-0.005 mm)	50	57	48	7	6
(4) % Clay Size (Smaller than 0.005 mm)	43	40	52	93	94
(5) % Shale & Soft Rock					
Moisture Content %	33	36	36	72	47
Liquid Limit %	60	42	53	81	86
Plasticity Index	29	21	29	50	54
Shrinkage Limit %	22	18	19	16	18
Shrinkage Ratio	1.65	1.79	1.76	1.87	1.77
Specific Gravity	2.60	2.66	2.66	2.69	2.62
Color	Black	Mottled Brown	Mottled Brown	Gray	Gray
Typical Name	Silty Clay	Silty Clay	Silty Clay	Clay	Clay
Soil Group (U.S.C.S.)	OH	CL	CH	CH	CH

SWC Form #179A 300/4-71

TABLE D-1

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #1) Test Boring No. 1

Project No. 448 County Walsh

Sample No.	448-1-6	448-1-7	448-1-8	448-1-9	448-1-10
Depth, Feet	29.5-31.0	35.5-37.0	44.5-46.0	54.5-56.0	64.5-66.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	0	0	0	0	0
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	0	0	0	0	0
(c) % Fine Sand (-#40 + #200)	0	0	0	0	0
(3) % Silt Size (0.074-0.005 mm)	9	5	5	10	18
(4) % Clay Size (Smaller than 0.005 mm)	91	95	95	90	82
(5) % Shale & Soft Rock					
Moisture Content %	77	80	90	98	67
Liquid Limit %	86	102	88	83	78
Plasticity Index	51	65	51	48	47
Shrinkage Limit %	18	18	21	24	26
Shrinkage Ratio	1.78	1.77	1.70	1.67	1.60
Specific Gravity	2.61	2.62	2.65	2.81	2.71
Color	Gray	Gray	Gray	Gray	Gray
Typical Name	Clay	Clay	Clay	Clay	Clay
Soil Group (U.S.C.S.)	CH	CH	CH	CH	CH

SWC Form #179A 300/4-71

TABLE D-1 Cont.

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #1) Test Boring No. 1

Project No. 448 County Walsh

Sample No.	448-1-11	448-1-12	448-1-13		
Depth, Feet	74.5-76.0	92.5-93.5	99.5-101.0		
(1) Gravel, Pass 3" & Retained on #4	0	0	0		
(a) % Coarse Gravel (-3" + 3/4")	0	0	0		
(b) % Fine Gravel (-3/4" + #4)	0	0	0		
(2) Sand, Pass #4 & Retained on #200	0	36	88		
(a) % Coarse Sand (-#4 + #10)	0	0	0		
(b) % Medium Sand (-#10 + #40)	0	0	0		
(c) % Fine Sand (-#40 + #200)	0	36	88		
(3) % Silt Size (0.074-0.005 mm)	19	55	11		
(4) % Clay Size (Smaller than 0.005 mm)	81	9	1		
(5) % Shale & Soft Rock					
Moisture Content %	70	20	19		
Liquid Limit %	76	24			
Plasticity Index	46	Non-plastic			
Shrinkage Limit %	25	24			
Shrinkage Ratio	1.58	1.62			
Specific Gravity	2.65	2.64	Assumed 2.60		
Color	Gray	Gray	Gray		
Typical Name	Clay	Sandy Silt	Sand		
Soil Group (U.S.C.S.)	CH	ML	SM		

SWC Form #179A 300/4-71

TABLE D-1 Cont.

NORTH DAKOTA STATE WATER COMMISSION

PROPOSED MINTO DAM SITE NO. 1
Project No. 448

Laboratory Test Data

Test Boring No.	1	1	1	1	2
Depth (feet)	9½-11	33½-35½	43-44½	53-54½	8-9½
Thin Wall Tube Size	2"	3"	2"	2"	2"
Soil Type	CL	CH	CH	CH	OH
Atterberg Limits:					
Liquid Limit (%)	45	111	125	120	53
Plastic Limit (%)	25	33	33	36	36
Moisture Content (%)	32	78	82	89	50
Dry Density (pcf)	87	54	53	50	68
Unconfined Compressive Strength (psf)	1300	1000	700	500	750

TABLE D-2

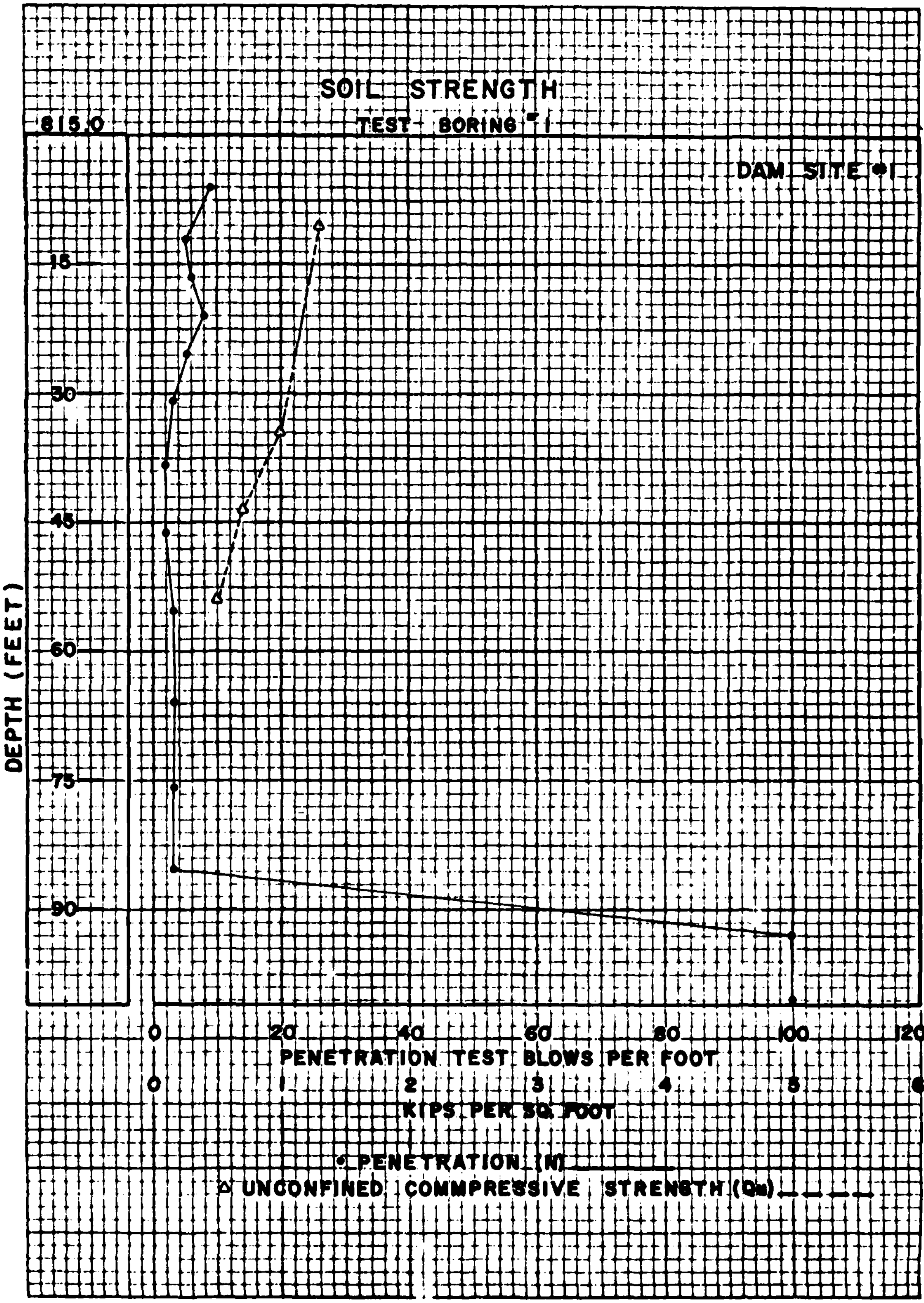

SOIL STRENGTH
815.0
TEST BORING #1
DAM SITE #1
15
30
45
60
75
90
DEPTH (FEET)
0
20
40
60
80
100
120
PENETRATION TEST BLOWS PER FOOT
0
1
2
3
4
5
6
KIPS PER SQ. FOOT
• PENETRATION (N)
△ UNCONFINED COMMPRESSIVE STRENGTH (Qu)

FIGURE D-3

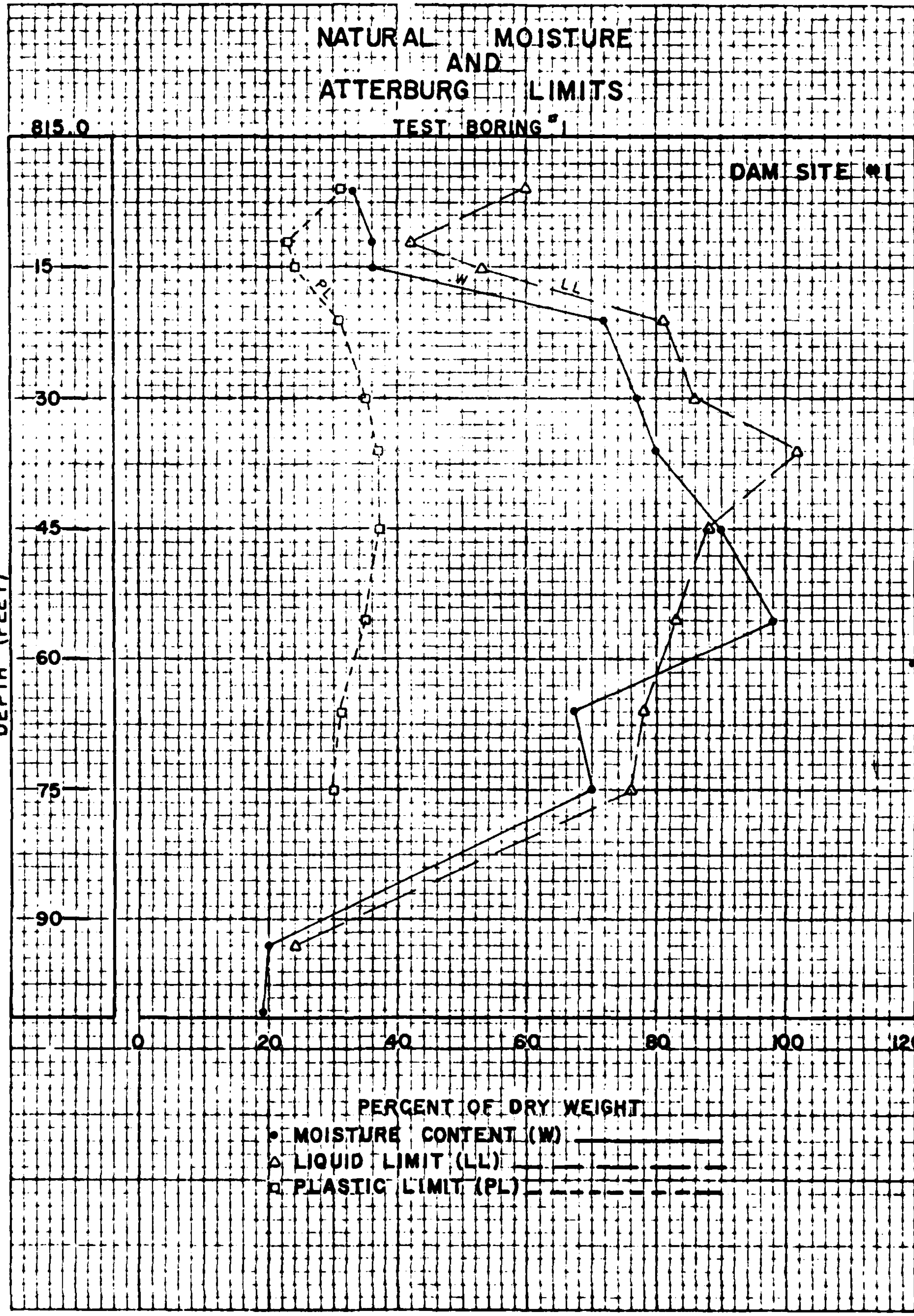

NATURAL MOISTURE
AND
ATTERBURG LIMITS
815.0
TEST BORING #1
DAM SITE #1
DEPTH (FEET)
15
30
45
60
75
90
W
LL
PL
0
20
40
60
80
100
120
PERCENT OF DRY WEIGHT
• MOISTURE CONTENT (W)
△ LIQUID LIMIT (LL)
□ PLASTIC LIMIT (PL)

FIGURE D-4

FOUNDATION SOIL TEST BORING

Project Name: MINTO DAM (SITE #1) Boring No: 2 (Lt. BANK)

Project No: 448 Date Drilling Started: 9-10-74

County: WALSH Date Finished: 9-10-74

SYMBOL DEFINITION

▽ Water level

2TW 2" thin wall tube sampler

SS 2 3/8" O.D. split spoon sampler

3TW 3" thin wall tube sampler

Depth 1" = 5'	Elev. MSL	Classification Symbol Letter	Classification Symbol Graphic	Sample No. And Type	Classification and Description of Material
0.0	814.0				
3.0	811.0				Topsoil, Black with Organic Material
5 7.0	807.0	ML		2-1 SS	Silt, Dark Brown Little Fine Sand with Some Clay Non Plastic, Moist, Very Soft
▽--- 10 15 20 24.0	790.0	ML & CL		2-1A 2TW 2-2 SS 2-3 SS 2-3A 2TW 2-4 SS	Clayey Silt & Silty Clay Brown to Gray Brown Laminated, Oxidized Little to Some Silt Interbedded Black Organic Clay - Odorous Moderately Plastic, Very Moist Soft to Stiff
25 30		CH		2-4A 3TW 2-5 SS	Clay, Gray, Fat, Massive Unoxidized, Slick Little Silt, Highly Plastic Very Moist, Soft

FIGURE D-5

FORM 177

Foundation Soil Test Boring, Cont.

Depth 1" = 5'	Elev. MSL	Classification Symbol: Letter	Classification Symbol: Graphic	Sample No. And Type	Classification and Description of Material
30		CH			
35				2-5A 3TW	
				2-6 SS	
40					
45				2-6A 2TW	
				2-7 SS	
50					
55				2-8 SS	
60					
65				2-9 SS	
68.0	746.0				END OF BORING
70					W.L. Remarks: 7.7 feet (0800 hrs. 9-11-74) Final water level recorded at 7.7 feet below land surface in an uncased hole. Water level influenced by drilling water.
75					

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #1) Test Boring No. 2

Project No. 448 County Walsh

Sample No.	448-2-1	448-2-2	448-2-3	448-2-4	448-2-5
Depth, Feet	4.5-6.0	9.5-11.0	14.5-16.0	21.0-22.5	28.0-29.5
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	15	4	21	12	0
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	0	0	1	1	0
(c) % Fine Sand (-#40 + #200)	15	4	20	11	0
(3) % Silt Size (0.074-0.005 mm)	66	68	56	57	12
(4) % Clay Size (Smaller than 0.005 mm)	19	28	23	31	88
(5) % Shale & Soft Rock					
Moisture Content %	43	46	35	34	77
Liquid Limit %	38	48	43	41	90
Plasticity Index	Non Plastic	16	14	19	59
Shrinkage Limit %	28	30	26	21	18
Shrinkage Ratio	1.54	1.49	1.53	1.69	1.85
Specific Gravity	2.69	2.70	2.55	2.61	2.78
Color	Dark Brown	Brown	Gray-Brown	Brown	Gray
Typical Name	Silt	Clayey Silt	Clayey Silt	Silty Clay	Clay
Soil Group (U.S.C.S.)	ML	ML	ML	CL	CH

SWC Form #179A 300/4-71

TABLE D-3

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #1) Test Boring No. 2

Project No. 448 County Walsh

Sample No.	448-2-6	448-2-7	448-2-8	448-2-9	
Depth, Feet	36.5-38.0	46.5-48.0	56.5-58.0	66.5-68.0	
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	
(2) Sand, Pass #4 & Retained on #200	0	0	0	0	
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	
(b) % Medium Sand (-#10 + #40)	0	0	0	0	
(c) % Fine Sand (-#40 + #200)	0	0	0	0	
(3) % Silt Size (0.074-0.005 mm)	7	9	14	11	
(4) % Clay Size (Smaller than 0.005 mm)	93	91	86	89	
(5) % Shale & Soft Rock					
Moisture Content %	91	79	76	77	
Liquid Limit %	88	101	81	91	
Plasticity Index	56	68	49	59	
Shrinkage Limit %	17	18	23	20	
Shrinkage Ratio	1.84	1.84	1.76	1.74	
Specific Gravity	2.68	2.75	2.95	2.67	
Color	Gray	Gray	Gray	Gray	
Typical Name	Clay	Clay	Clay	Clay	
Soil Group (U.S.C.S.)	CH	CH	CH	CH	

SWC Form #179A 300/4-71

TABLE D-3 Cont.

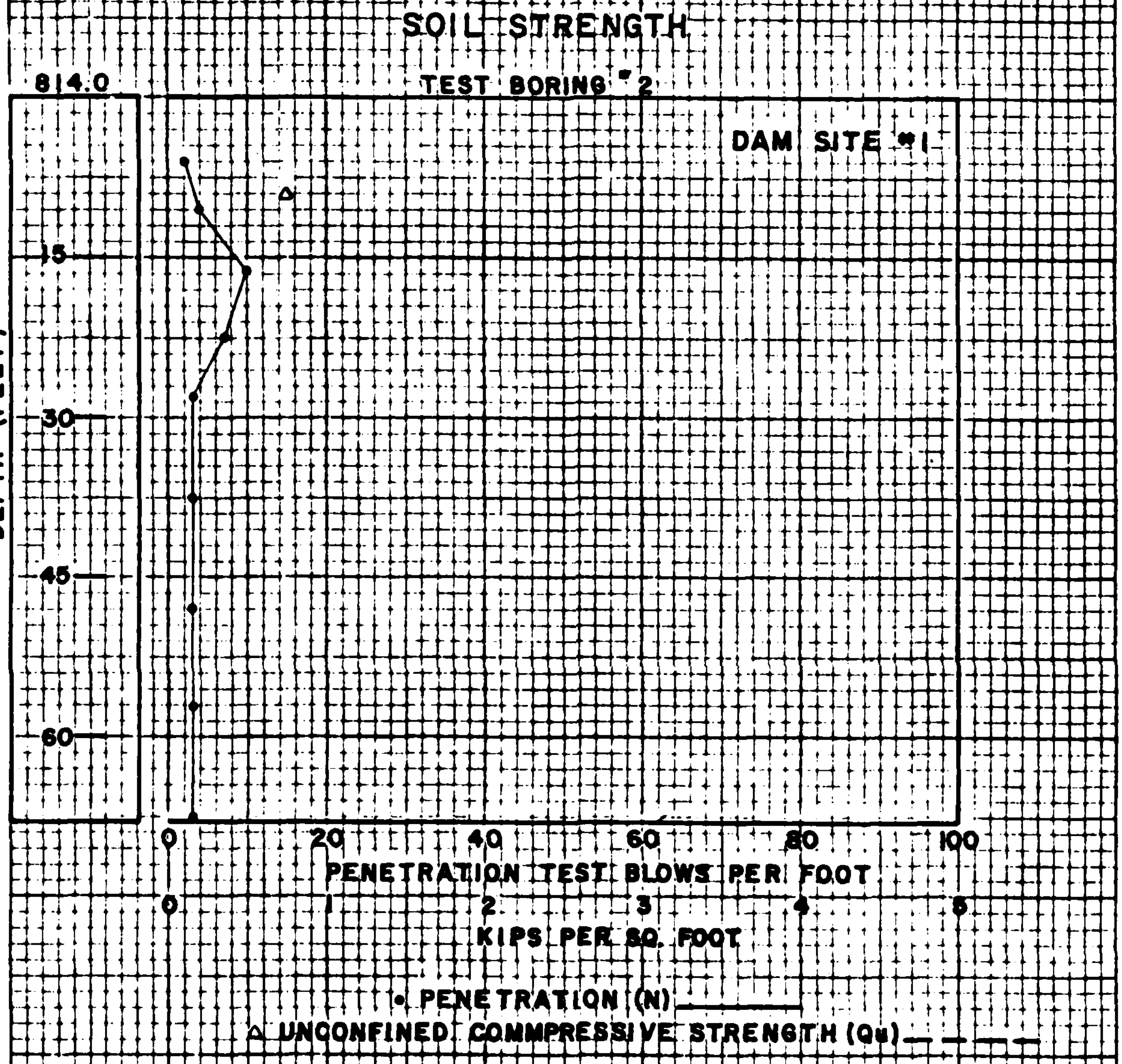

SOIL STRENGTH
814.0
TEST BORING #2
DAM SITE #1
DEPTH (FEET)
15
30
45
60
0
20
40
60
80
100
PENETRATION TEST BLOWS PER FOOT
0
1
2
3
4
5
KIPS PER SQ. FOOT
• PENETRATION (N)
△ UNCONFINED COMMPRESSIVE STRENGTH (Qu)

FIGURE D-6

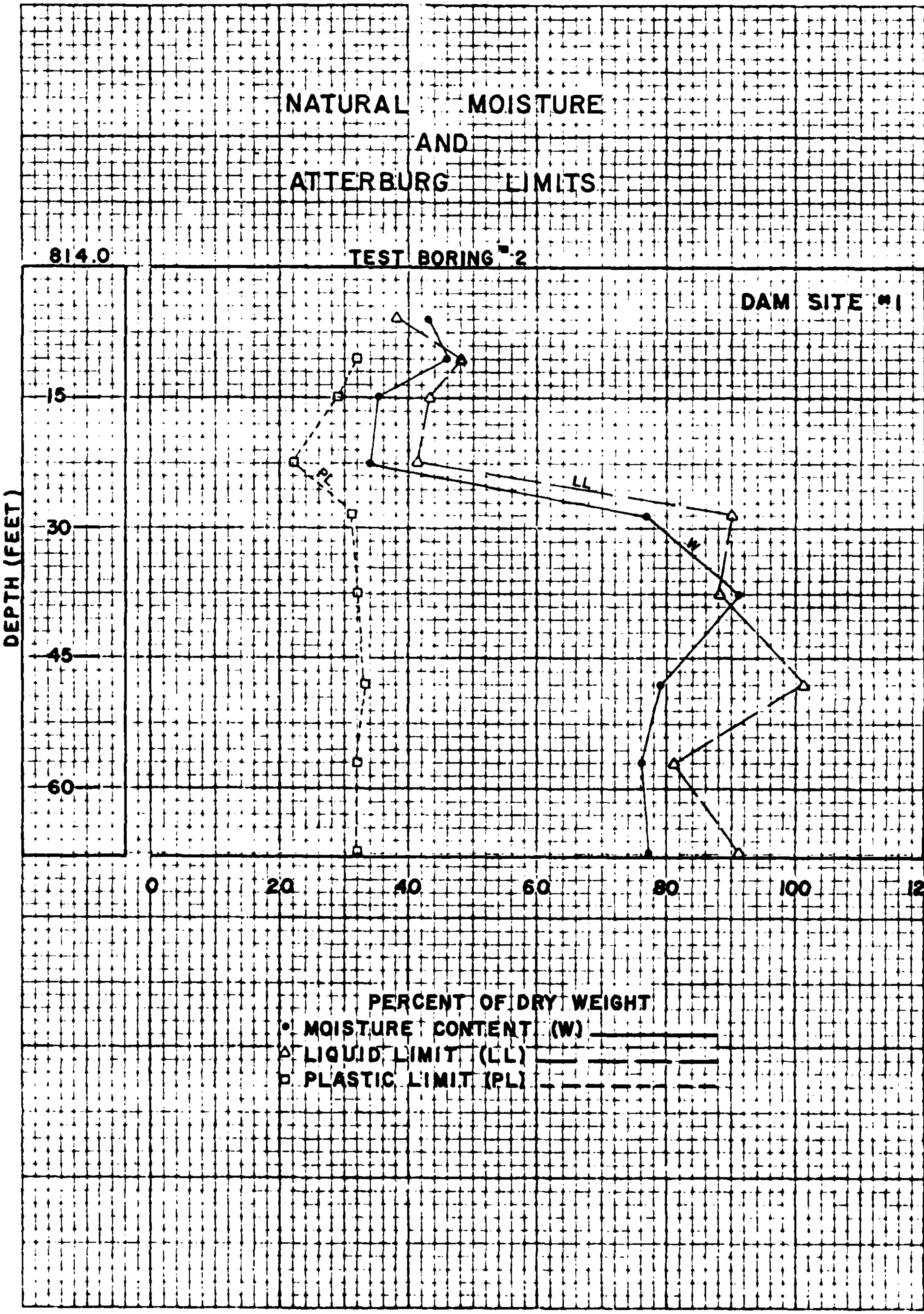
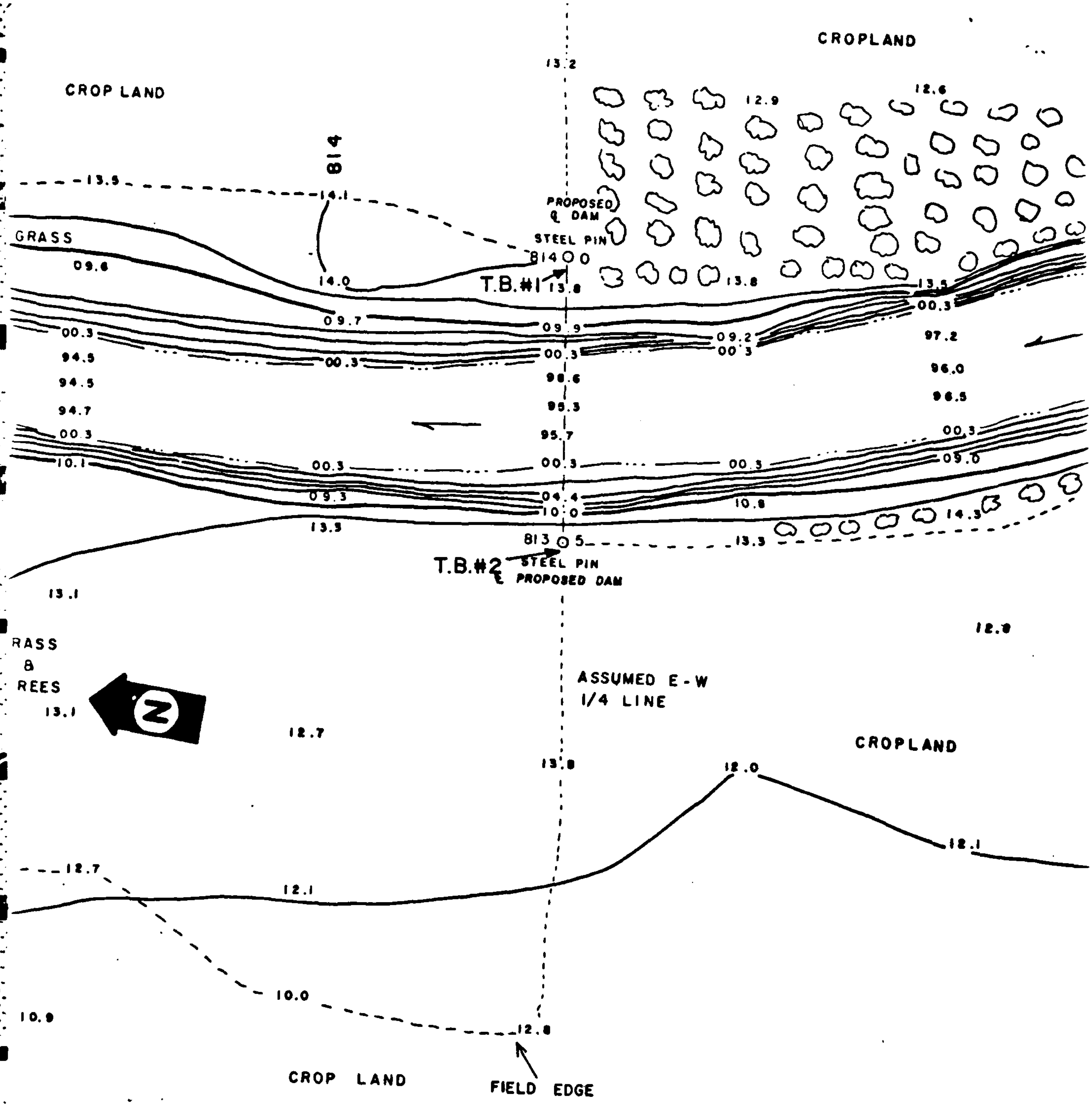

NATURAL MOISTURE
AND
ATTERBURG LIMITS
814.0
TEST BORING #2
DAM SITE #1
DEPTH (FEET)
15
30
45
60
PL
LL
W
0
20
40
60
80
100
120
PERCENT OF DRY WEIGHT
• MOISTURE CONTENT (W)
△ LIQUID LIMIT (LL)
□ PLASTIC LIMIT (PL)

FIGURE D-7



TEST BORINGS FOR PROPOSED DAM SITE #2
SECTION FROM S.W.C. DRAWING NO. 8673-448-8

FIGURE D-8

NORTH DAKOTA STATE WATER COMMISSION

FOUNDATION SOIL TEST BORING

Project Name: MINTO DAM (SITE #2) Boring No: 1 (Rt. BANK)

Project No: 448 Date Drilling Started: 9-11-74

County: WALSH Date Finished: 9-11-74

SYMBOL DEFINITION

▽ Water level

2TW 2" thin wall tube sampler

SS 2 3/8" O.D. split spoon sampler

3TW 3" thin wall tube sampler

Depth 1" = 5'	Elev. MSL	Classification Symbol Letter	Classification Symbol Graphic	Sample No. And Type	Classification and Description of Material
0.0	814.0				
3.5	810.5				Topsoil, Black with Organic Material
▽ 5		CL & CH		1-1 SS	Silty Clay Dark Brown Faintly Laminated Little Fine Sand Plastic, Moist Medium Stiff
10				1-1A 2TW	
				1-2 SS	
14.0	800.0				
15		CL & SM		1-2A 2TW	Clay & Sand Clay Mixtures Brown to Brown Gray Laminated, Oxidized Sand Lenses Throughout Predominantly Fine, Non Plastic Interbedded Black Clay With Organic Remains (Shells & Wood) Very Moist to Wet, Plastic Soft to Medium Stiff
				1-3 SS	
20				1-3A 3TW	
				1-4 SS	
25				1-4A 3TW	
				1-5 SS	Note: Predominantly Fine - Non Plastic Sand Below 30 Feet
30				1-5A 3TW	

FORM 177

FIGURE D-9

Depth 1" = 5'	Elev. MSL	Classification Symbol: Letter	Classification Symbol: Graphic	Sample No. And Type	Classification and Description of Material
30		SM		1-6 SS	
35	779.0				
40				1-6A 2TW	
45					
50		CH			Clay, Gray, Fat, Massive Unoxidized, Slick Little to Some Silt Highly Plastic Very Moist Very Soft to Soft
55				1-7 SS	
60					
65					
70				1-7A 2TW 1-8 SS	
75					

FIGURE D-9 Cont.

Foundation Soil Test Boring, Cont.

Depth 1" = 5'	Elev. MSL	Classification Symbol: Letter	Classification Symbol: Graphic	Sample No. And Type	Classification and Description of Material
75					
80		CH			
83.5	730.5				
85		ML		1-9 SS	Silt, Gray, Laminated Trace of Fine Sand Little Clay, Non Plastic Wet, Very Dense
				1-10 SS	
91.0	723.0				END OF BORING
95					
100					
105					
110					

W.L. Remarks: 4.4 feet (1550 hrs. 9-11-74)

Final water level recorded at 4.4 feet below land surface in an uncased hole.

Water level influenced by drilling water.

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) Test Boring No. 1

Project No. 448 County Walsh

Sample No.	448-1-1	448-1-1A	448-1-2	448-1-2A	448-1-3
Depth, Feet	4.5-6.0	9.5-11.5	11.5-13.0	14.5-16.5	16.5-18.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	11	5	8	31	40
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	0	0	0	1	13
(c) % Fine Sand (-#40 + #200)	11	5	8	30	27
(3) % Silt Size (0.074-0.005 mm)	57	44	51	46	35
(4) % Clay Size (Smaller than 0.005 mm)	32	51	41	23	25
(5) % Shale & Soft Rock					
Moisture Content %	27	38	38	29	44
Liquid Limit %	49	62	54	39	37
Plasticity Index	23	34	27	16	17
Shrinkage Limit %	24	24		20	20
Shrinkage Ratio	1.54	1.59		1.70	1.72
Specific Gravity	2.46	2.56		2.57	2.65
Color	Dark Brown	Dark Brown	Dark Brown	Brown	Brown-Gray
Typical Name	Silty Clay	Clay	Silty Clay	Clay	Clay
Soil Group (U.S.C.S.)	CL	CH	CH	CL	CL

SWC Form #179A 300/4-71

TABLE D-4

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) | Test Boring No. 1

Project No. 448 | County Walsh

Sample No.	448-1-4	448-1-5	448-1-6	448-1-7	448-1-8
Depth, Feet	21.5-23.0	26.5-28.0	31.5-33.0	56.5-58.0	71.5-73.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	14	22	59	0	0
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	0	2	1	0	0
(c) % Fine Sand (-#40 + #200)	14	20	58	0	0
(3) % Silt Size (0.074-0.005 mm)	52	54	26	12	24
(4) % Clay Size (Smaller than 0.005 mm)	34	24	15	88	76
(5) % Shale & Soft Rock					
Moisture Content %	37	35	31	79	59
Liquid Limit %	44	37	0	87	77
Plasticity Index	22	14	Non Plastic	53	48
Shrinkage Limit %	20	21	21	41	26
Shrinkage Ratio	1.75	1.71	1.70	1.28	1.59
Specific Gravity	2.72	2.68	2.62	2.70	2.68
Color	Gray	Gray	Gray	Gray	Gray
Typical Name	Silty Clay	Silty Clay	Sand	Clay	Clay
Soil Group (U.S.C.S.)	CL	CL	SM	CH	CH

SWC Form #179A

300/4-71

TABLE D-4 Cont.

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) Test Boring No. 1

Project No. 448 County Walsh

Sample No.	448-1-9	448-1-10			
Depth, Feet	84.5-86.0	89.5-91.0			
(1) Gravel, Pass 3" & Retained on #4	0	0			
(a) % Coarse Gravel (-3" + 3/4")	0	0			
(b) % Fine Gravel (-3/4" + #4)	0	0			
(2) Sand, Pass #4 & Retained on #200	1	13			
(a) % Coarse Sand (-#4 + #10)	0	0			
(b) % Medium Sand (-#10 + #40)	0	0			
(c) % Fine Sand (-#40 + #200)	1	13			
(3) % Silt Size (0.074-0.005 mm)	85	77			
(4) % Clay Size (Smaller than 0.005 mm)	14	10			
(5) % Shale & Soft Rock					
Moisture Content %	26	23			
Liquid Limit %	30	27			
Plasticity Index	Non Plastic	Non Plastic			
Shrinkage Limit %	27	26			
Shrinkage Ratio	1.54	1.58			
Specific Gravity	2.64	2.71			
Color	Gray	Gray			
Typical Name	Silt	Silt			
Soil Group (U.S.C.S.)	ML	ML			

SWC Form #179A 300/4-71

TABLE D-4 Cont.

NORTH DAKOTA STATE WATER COMMISSION

PROPOSED MINTO DAM SITE NO. 2
Project No. 448

Laboratory Test Data

Test Boring No.	1	1	1	1	1	1
Depth (feet)	9½-11½	14½-16½	19½-21½	24½-26½	29½-31½	39½-41½
Thin Wall Tube Size	2"	2"	3"	3"	3"	2"
Soil Type	CH	CL	CL	CL-CH	CL	CH
Atterberg Limits:						
Liquid Limit (%)	62	39	43	50	35	99
Plastic Limit (%)	28	23	22	26	24	32
Moisture Content (%)	38	29	28	35	34	51
Dry Density (pcf)	81	93	92	86	86	72
Unconfined Compressive Strength (psf)	No test	532	1,100	1,300	See Triaxial Test	1,900

TABLE D-5

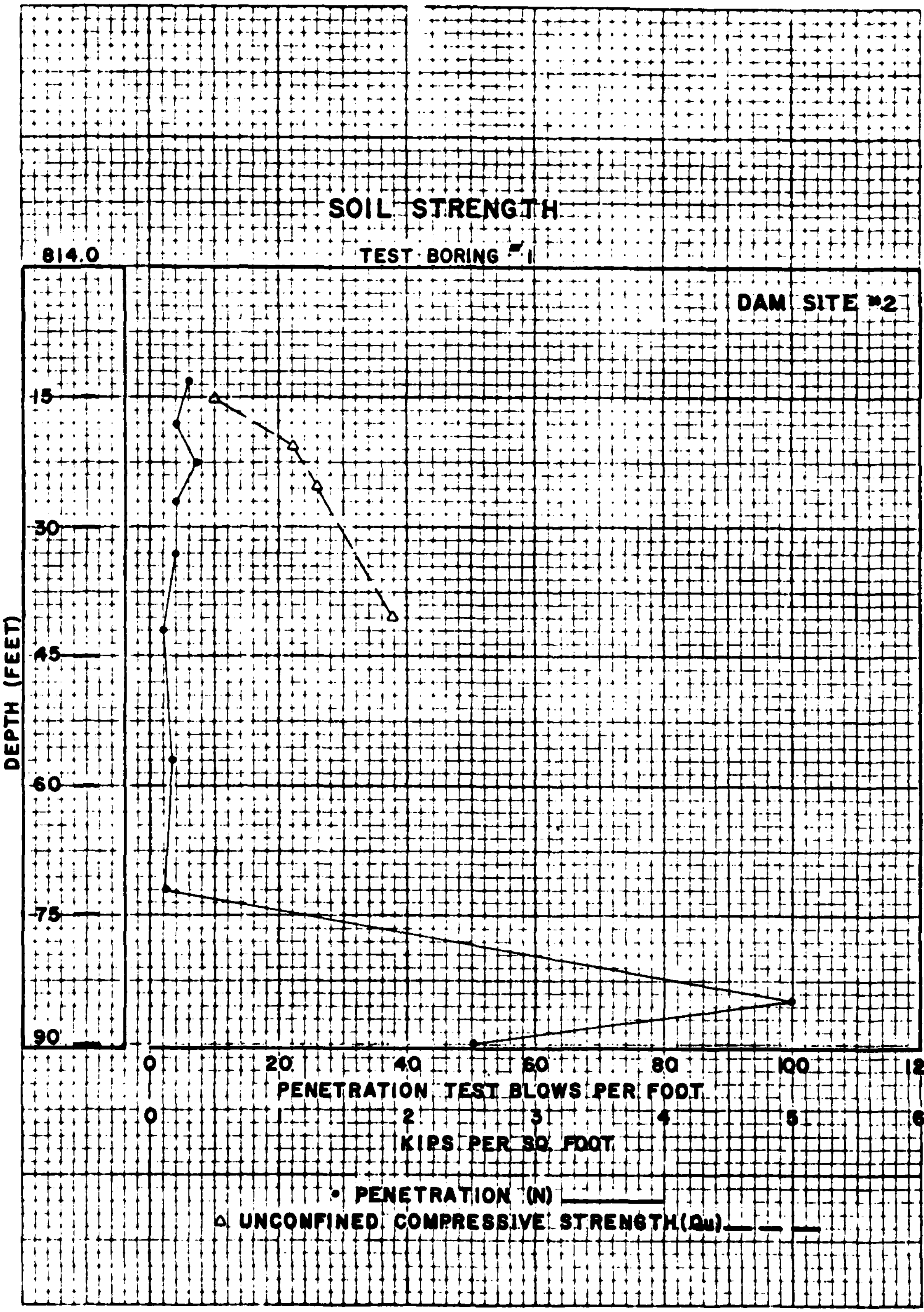

SOIL STRENGTH
814.0
TEST BORING #1
DAM SITE #2
DEPTH (FEET)
15
30
45
60
75
90
0
20
40
60
80
100
120
PENETRATION TEST BLOWS PER FOOT
0
2
3
4
5
6
KIPS PER SQ. FOOT
• PENETRATION (N)
△ UNCONFINED COMPRESSIVE STRENGTH(Qu)

FIGURE D-10

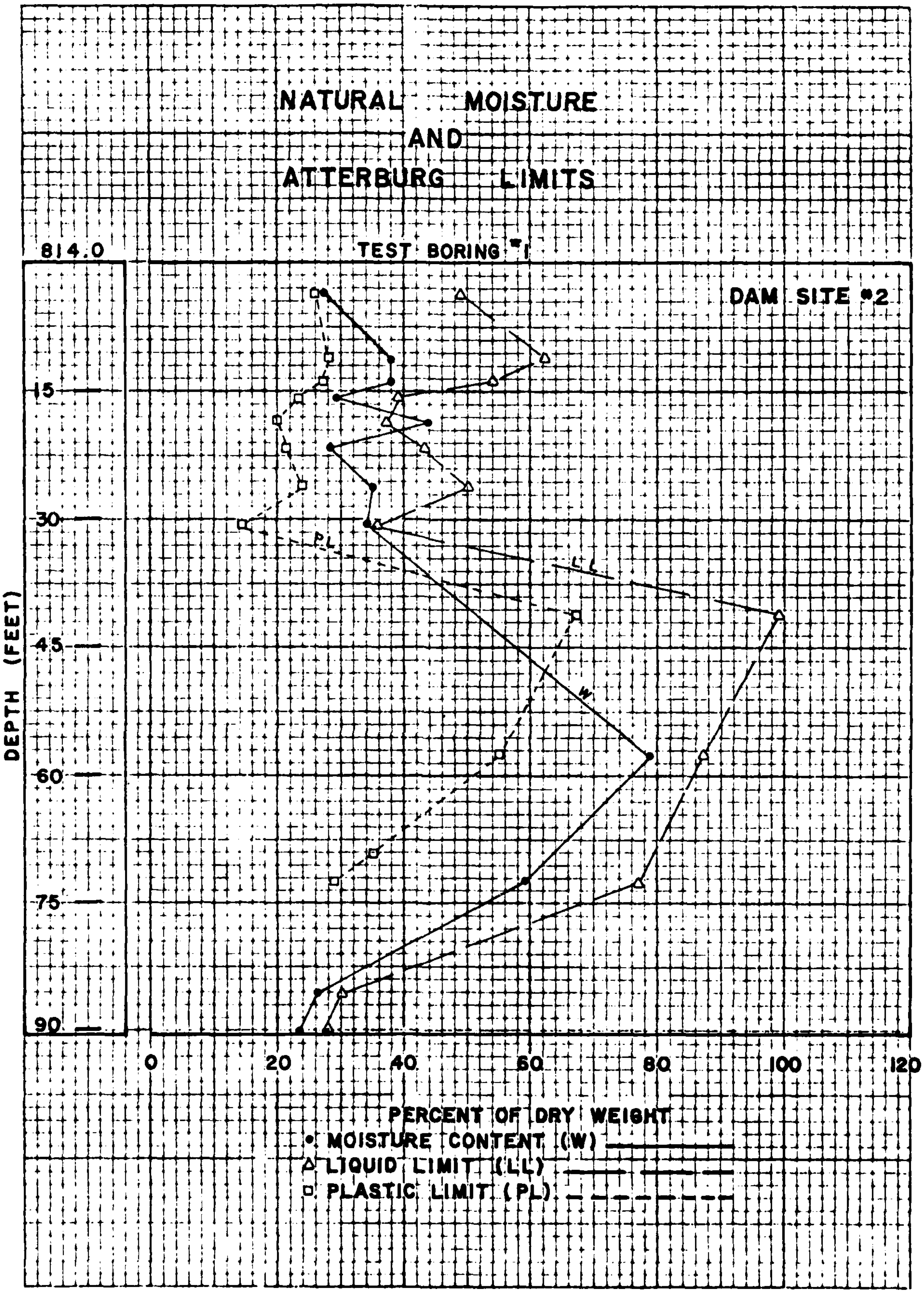
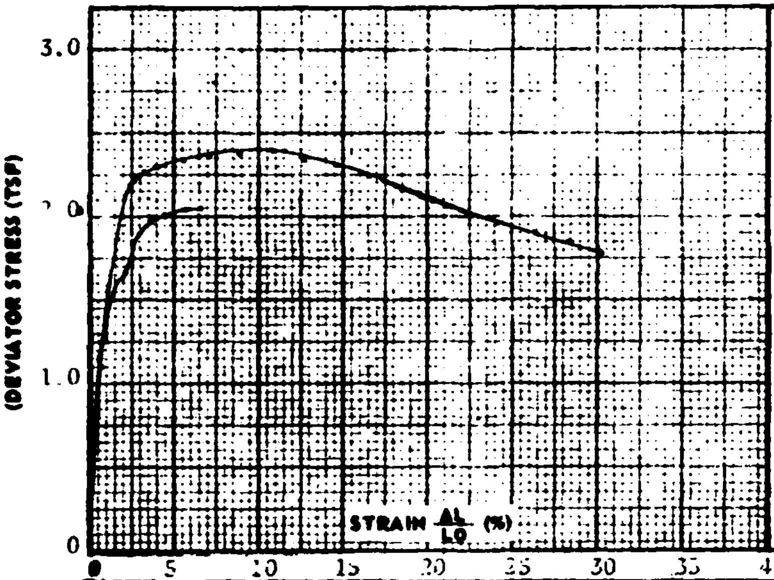

NATURAL MOISTURE
AND
ATTERBURG LIMITS
814.0
TEST BORING #1
DAM SITE #2
DEPTH (FEET)
15
30
45
60
75
90
PL
LL
W
0
20
40
60
80
100
120
PERCENT OF DRY WEIGHT
• MOISTURE CONTENT (W)
△ LIQUID LIMIT (LL)
□ PLASTIC LIMIT (PL)

FIGURE D-11



TRIAXIAL TEST DATA

SOIL EXPLORATION COMPANY
662 CROMWELL AVENUE
ST. PAUL, MN. 55114
PHONE 612/645-6446

JOB NO. 500-634

PROJECT MINTO DAM SWC PROJECT #448 (Site #2)

BORING NO. 1 **SAMPLE NO.** Top **DEPTH** 24½ 26½

TYPE OF TEST CU UU (staged)

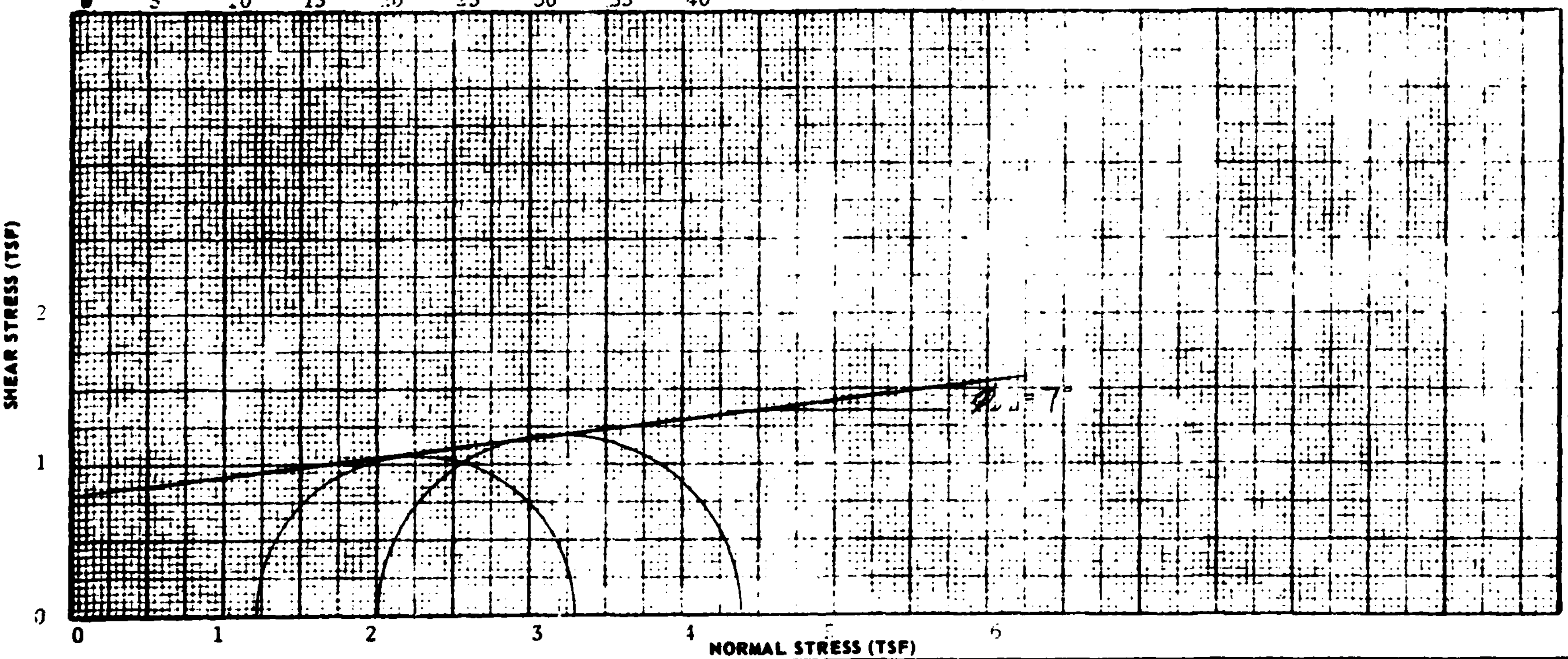
SAMPLE SIZE: 1 3/8 x 2 3/4

SOIL TYPE: Silty Clay (CL-OH)

MOISTURE-DENSITY: ______ % - ______ PCF

ATTERBERG LIMITS: LL ______ PL ______

REMARKS Samples consolidated to existing overburden lines closed stressed to peak strength, load released, confinement increased stressed to well past failure. strain rates 0.06"/min.



SL-6 (70-A)

FIGURE D-12

TRIAXIAL TEST DATA

SOIL EXPLORATION COMPANY

862 CROMWELL AVENUE
ST. PAUL, MN. 55114
PHONE 612/645-6446

JOB NO. 500 634

PROJECT MINTO DAM SWC PROJECT #448 (Site #2)

BORING NO. 1 **SAMPLE NO.** ______ **DEPTH** 24', 26'

TYPE OF TEST C D (staged)

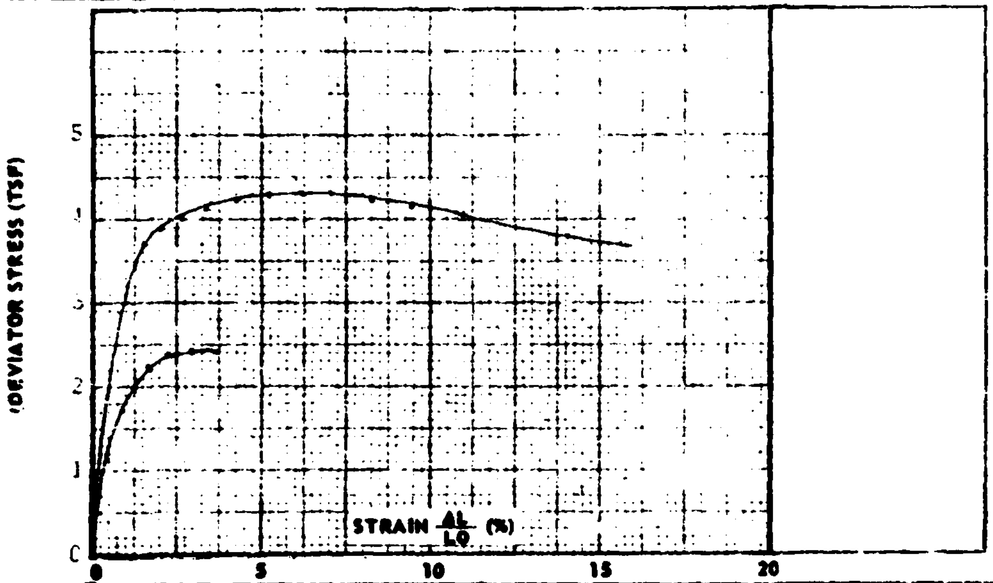
SAMPLE SIZE: 1 3/8 x 2 3/4

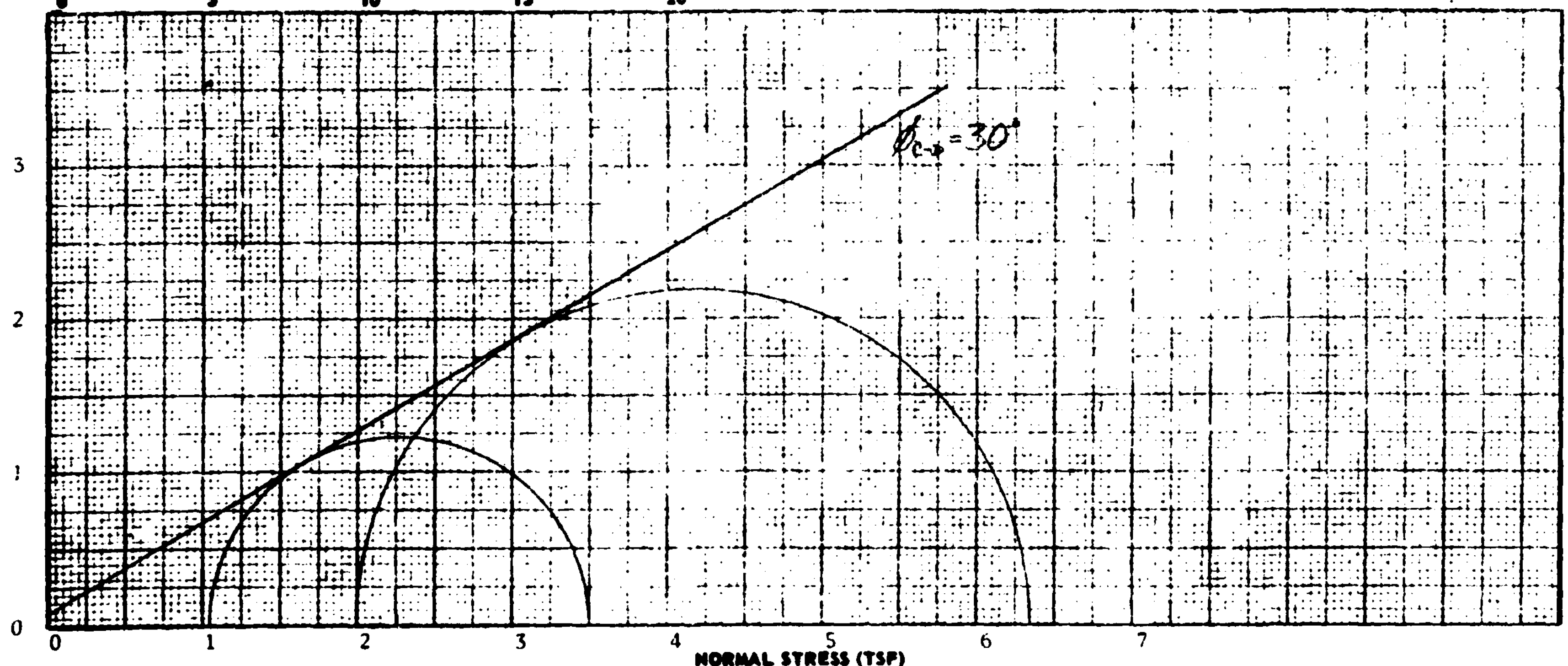
SOIL TYPE: Silty Clay (CL OH)

MOISTURE-DENSITY: ______ % - ______ PCF

ATTERBERG LIMITS: LL ______ PL ______

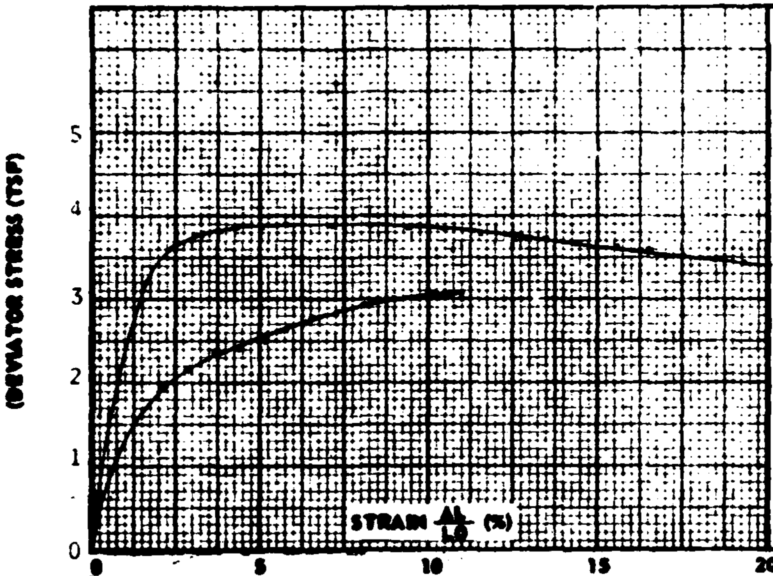
REMARKS Sample consolidated to existing overburden stressed to peak strength at 0.0008' [illegible] released confinement increased consolidated stressed to well past failure





SL-5 (70-A)

FIGURE D-13



TRIAXIAL TEST DATA

SOIL EXPLORATION COMPANY
662 CROMWELL AVENUE
ST. PAUL, MN. 55114
PHONE 612/645-6446

JOB NO. 500-634

PROJECT MINTO DAM - SWC PROJECT #448 (Site #2)

BORING NO. 1 SAMPLE NO. ______ DEPTH 29½, 31½

TYPE OF TEST CU UU (staged)

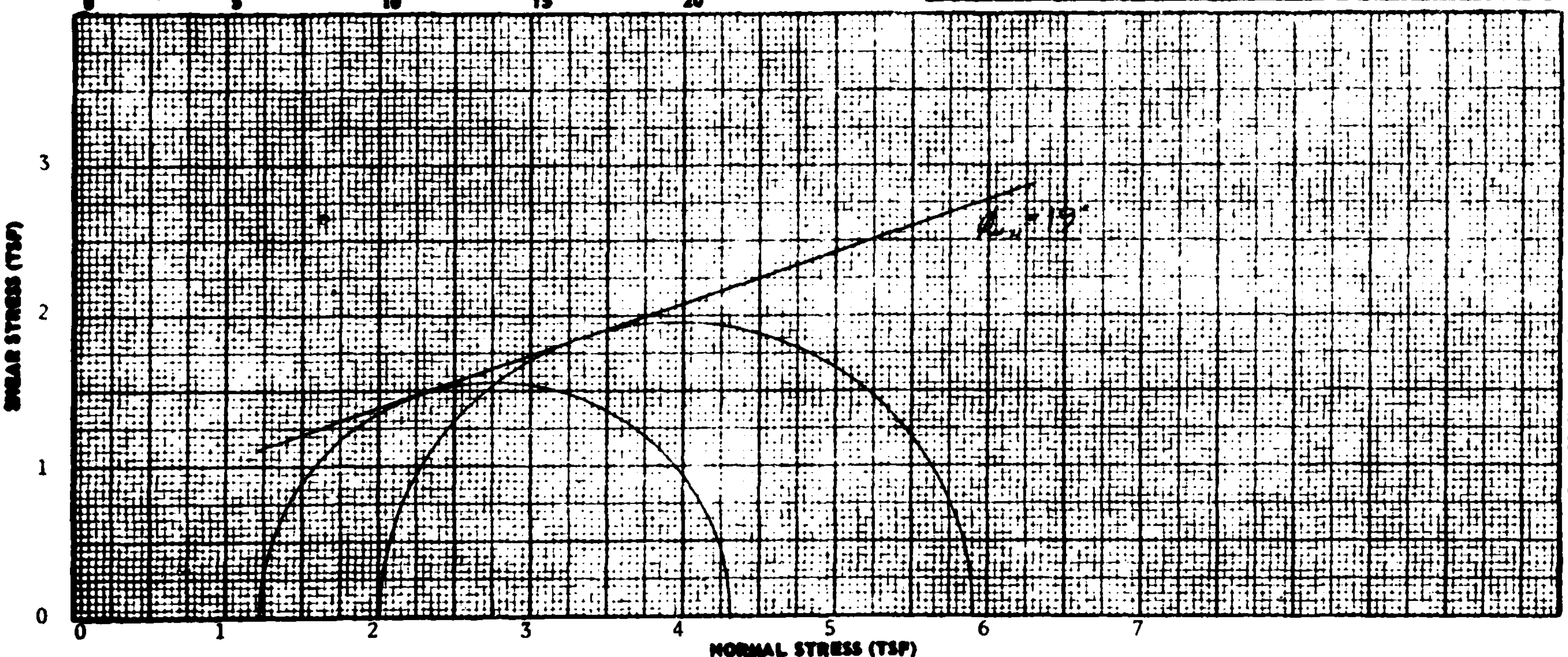
SAMPLE SIZE: 1 3/8 x 2 3/4

SOIL TYPE: Silty Clay (CL)

MOISTURE-DENSITY: ______ % - ______ PCF

ATTERBERG LIMITS: LL ______ PL ______

REMARKS Sample consolidated to existing overburden. lines closed, stressed to peak strength load released confinement increased stressed to well past failure. strain rates 0.06" min.



SL-6 (70-A)

FIGURE D-14

soil exploration company

662 CROMWELL AVENUE
ST PAUL, MN 55114
PHONE 612/645-6446

TRIAXIAL TEST DATA

JOB NO. 500 654

PROJECT MINTO DAM SWC PROJECT #448 (Site #2)

BORING NO. 1 SAMPLE NO. ____ DEPTH 29½-31½

TYPE OF TEST CU UU (staged)

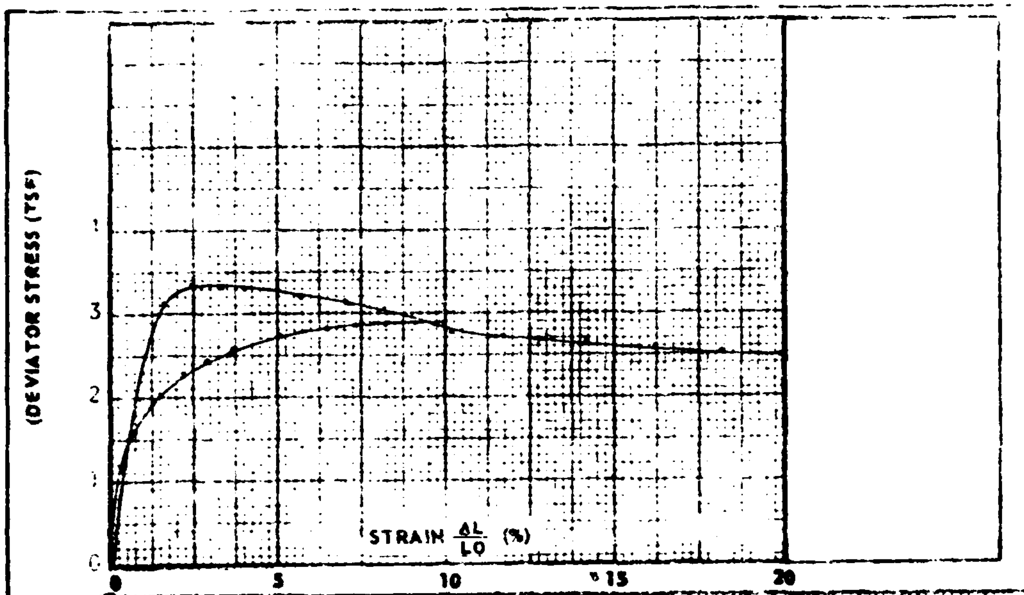
SAMPLE SIZE: 1 3/8 x 2 3/4

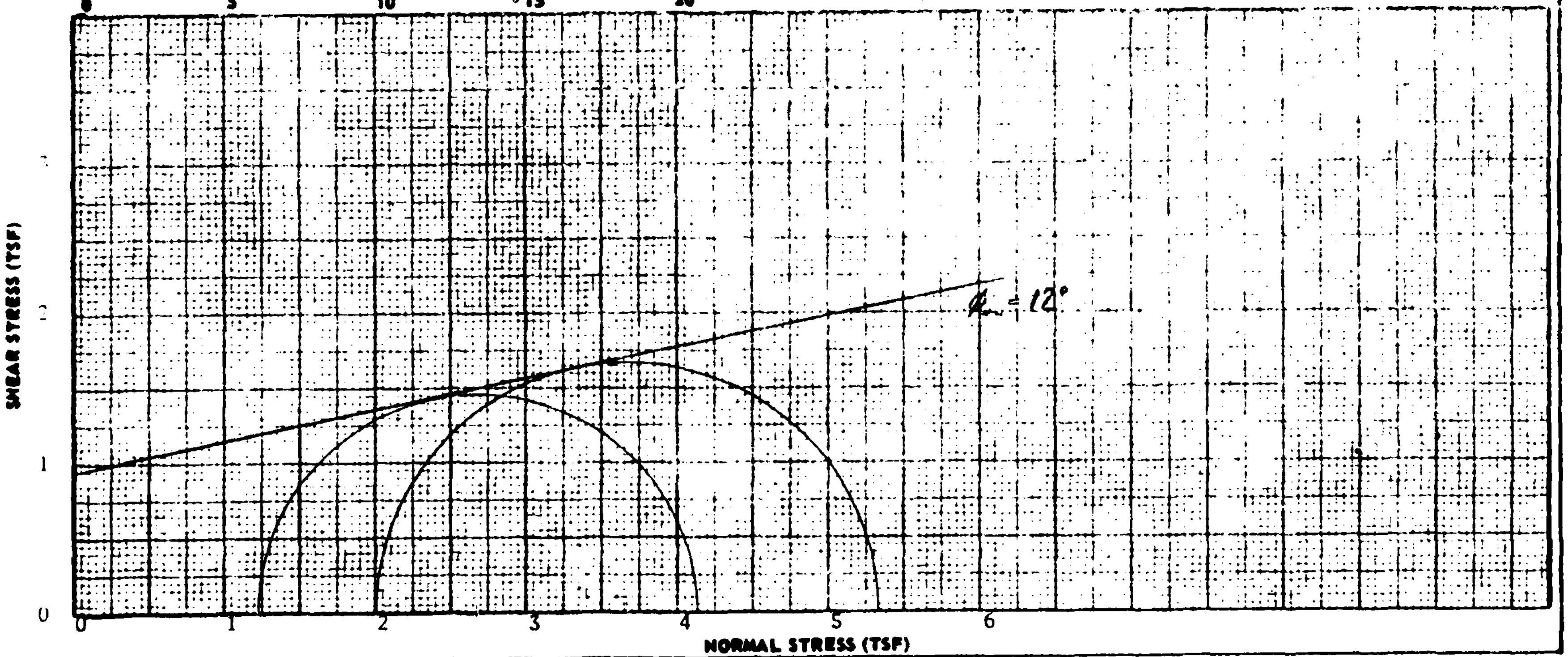
SOIL TYPE: Silty Clay (CL)

MOISTURE-DENSITY: ____ % - ____ PCF

ATTERBERG LIMITS LL ____ PL ____

REMARKS Sample consolidated to existing overburden lines closed, stressed to peak strength, load released, confinement increased, stressed to well past failure, strain rate: 0.0?%/min.





SL-5 (70-A)

FIGURE D-15

NORTH DAKOTA STATE WATER COMMISSION

FOUNDATION SOIL TEST BORING

Project Name: MINTO DAM (SITE #2) Boring No: 2 (Lt. BANK)

Project No: 448 Date Drilling Started: 9-11-74

County: WALSH Date Finished: 9-12-74

SYMBOL DEFINITION

▽ Water level

2TW 2" thin wall tube sampler

SS 2 3/8" O.D. split spoon sampler

3TW 3" thin wall tube sampler

Depth 1" = 5'	Elev. MSL	Classification Symbol Letter	Classification Symbol Graphic	Sample No. And Type	Classification and Description of Material
0.0	814.0				
3.0	811.0				Topsoil, Black with Organic Material
5				2-1 SS	
▽		CL			Silty Clay, Dark Brown Faintly Laminated, Oxidized Some Fine Sand Moderately Plastic, Moist
10				2-1A 2TW	Laminations Become More Pronounced at Base
				2-2 SS	Medium Stiff to Soft
13.5	800.5				
15				2-2A 2TW	Clay & Sand Clay Mixtures
		CL		2-3 SS	Brown to Brown Gray Laminated, Oxidized Abundant Fine Sand Lenses
20		SM		2-4 SS	Non Plastic to Moderately Plastic Interbedded Black Clay with Organic Remains (Shells & Wood)
25		SC		2-4A 3TW	Very Moist to Wet Soft to Medium Stiff
				2-5 SS	
29.0	785.0				
30		CH		2-5A 3TW	

FIGURE D-16

FORM 177

Depth 1" = 5'	Elev. MSL	Classification Symbol: Letter	Classification Symbol: Graphic	Sample No. And Type	Classification and Description of Material
30					
				2-6 SS	
35				2-6A 3TW	
				2-7 SS	
40					
45				2-7A 2TW	
				2-8 SS	Clay, Brown Gray to Gray Fat, Massive Unoxidized, Slick, Little Silt Highly Plastic Very Moist Medium Stiff to Very Soft
		CH			
50					
55				2-8A 2TW	
				2-9 SS	
60					
65					
				2-10 SS	
68.0	746.0				END OF BORING
					W.L. Remarks: 6.7 feet (1130 hrs. 9-12-74)
70					Final water level recorded at 6.7 feet below land surface in an uncased hole. Water level influenced by drilling water.
75					

SWC Form No. 177

FIGURE D-16 Cont.

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) Test Boring No. 2

Project No. 448 County Walsh

Sample No.	448-2-1	448-2-1A	448-2-2	448-2-2A	448-2-3
Depth, Feet	4.5-6.0	9.5-11.5	11.5-13.0	14.5-16.5	16.5-18.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	20	38	24	46	52
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	0	1	1	2	5
(c) % Fine Sand (-#40 + #200)	20	37	23	44	47
(3) % Silt Size (0.074-0.005 mm)	53	41	50	36	31
(4) % Clay Size (Smaller than 0.005 mm)	27	21	26	18	17
(5) % Shale & Soft Rock					
Moisture Content %	31	31	35	30	28
Liquid Limit %	40	39	40	38	61
Plasticity Index	15	15	16	14	40
Shrinkage Limit %	24	22	24	22	20
Shrinkage Ratio	1.57	1.68	1.59	1.65	1.70
Specific Gravity	2.49	2.64	2.59	2.61	2.59
Color	Dark Brown	Brown	Dark Brown	Dark Brown	Brown-Gray
Typical Name	Silty Clay	Clay	Silty Clay	Clay	Clayey Sand
Soil Group (U.S.C.S.)	CL	CL	CL	CL	SC

SWC Form #179A

TABLE D-6

300/4-71

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation. D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) Test Boring No. 2

Project No. 448 County Walsh

Sample No.	448-2-4	448-2-5	448-2-6	448-2-7	448-2-8
Depth, Feet	19.5-21.0	26.5-28.0	31.5-33.0	36.5-38.0	46.5-48.0
(1) Gravel, Pass 3" & Retained on #4	0	0	0	0	0
(a) % Coarse Gravel (-3" + 3/4")	0	0	0	0	0
(b) % Fine Gravel (-3/4" + #4)	0	0	0	0	0
(2) Sand, Pass #4 & Retained on #200	40	58	1	0	0
(a) % Coarse Sand (-#4 + #10)	0	0	0	0	0
(b) % Medium Sand (-#10 + #40)	7	0	0	0	0
(c) % Fine Sand (-#40 + #200)	33	58	1	0	0
(3) % Silt Size (0.074-0.005 mm)	35	28	9	9	10
(4) % Clay Size (Smaller than 0.005 mm)	25	14	90	91	90
(5) Shale & Soft Rock					
Moisture Content %	51	33	46	82	79
Liquid Limit %	38	27	91	90	91
Plasticity Index	16	Non Plastic	57	56	40
Shrinkage Limit %	23	22	16	18	21
Shrinkage Ratio	1.63	1.67	1.85	1.76	1.72
Specific Gravity	2.58	2.65	2.63	2.60	2.72
Color	Mottled Brown	Gray	Brown	Gray	Gray
Typical Name	Clay	Sand	Clay	Clay	Clay
Soil Group (U.S.C.S.)	CL	SM	CH	CH	OH

SWC Form #179A

TABLE D-6 Cont.

300/4-71

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Minto Dam (Site #2) Test Boring No. 2

Project No. 448 County Walsh

Sample No.	448-2-9	448-2-10			
Depth, Feet	56.5-58.0	66.5-68.0			
(1) Gravel, Pass 3" & Retained on #4	0	0			
(a) % Coarse Gravel (-3" + 3/4")	0	0			
(b) % Fine Gravel (-3/4" + #4)	0	0			
(2) Sand, Pass #4 & Retained on #200	0	0			
(a) % Coarse Sand (-#4 + #10)	0	0			
(b) % Medium Sand (-#10 + #40)	0	0			
(c) % Fine Sand (-#40 + #200)	0	0			
(3) % Silt Size (0.074-0.005 mm)	12	28			
(4) % Clay Size (Smaller than 0.005 mm)	88	72			
(5) % Shale & Soft Rock					
Moisture Content %	72	62			
Liquid Limit %	86	77			
Plasticity Index	54	48			
Shrinkage Limit %	22	25			
Shrinkage Ratio	1.67	1.57			
Specific Gravity	2.67	2.59			
Color	Gray	Gray			
Typical Name	Clay	Clay			
Soil Group (U.S.C.S.)	CH	CH			

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TABLE D-6 Cont.

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NORTH DAKOTA STATE WATER COMMISSION

PROPOSED MINTO DAM SITE NO. 2
Project No. 448

Laboratory Test Data

Test Boring No.	2	2	2	2	2	2
Depth (feet)	9½-11½	14½-16½	24½-26½	29½-31½	44½-46½	54½-56½
Thin Wall Tube Size	2"	2"	3"	3"	2"	2"
Soil Type	CL	CL	CL	CH	CH	CH
Atterberg Limits:						
Liquid Limit (%)	39	38	38	92	108	99
Plastic Limit (%)	24	24	21	34	34	32
Moisture Content (%)	31	30	36	44	75	69
Dry Density (pcf)	86	87	83	78	56	59
Unconfined Compressive Strength (psf)	1,500	1,500	600	1,300	600	760

TABLE D-7

SOIL STRENGTH

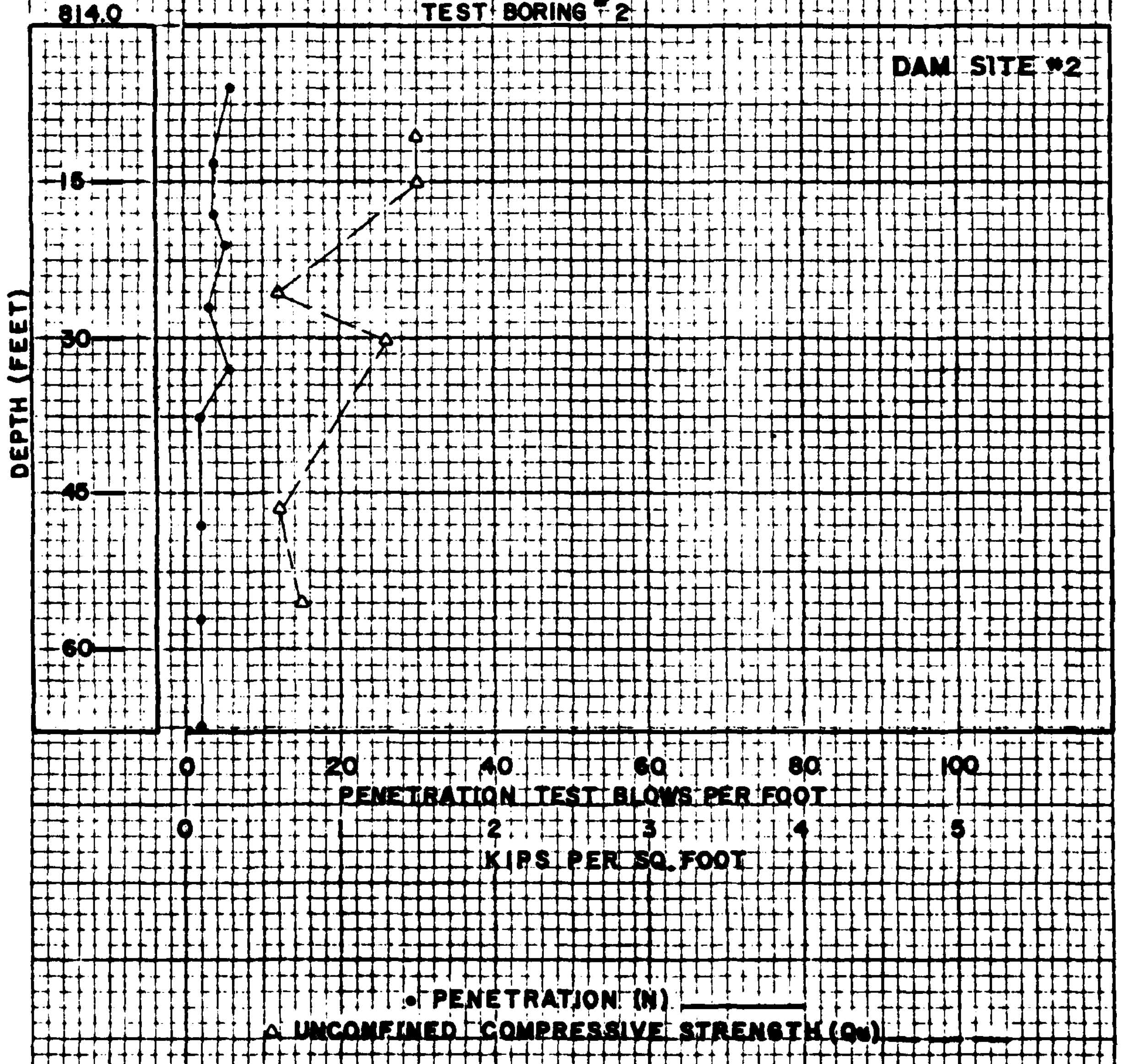

FIGURE D-17

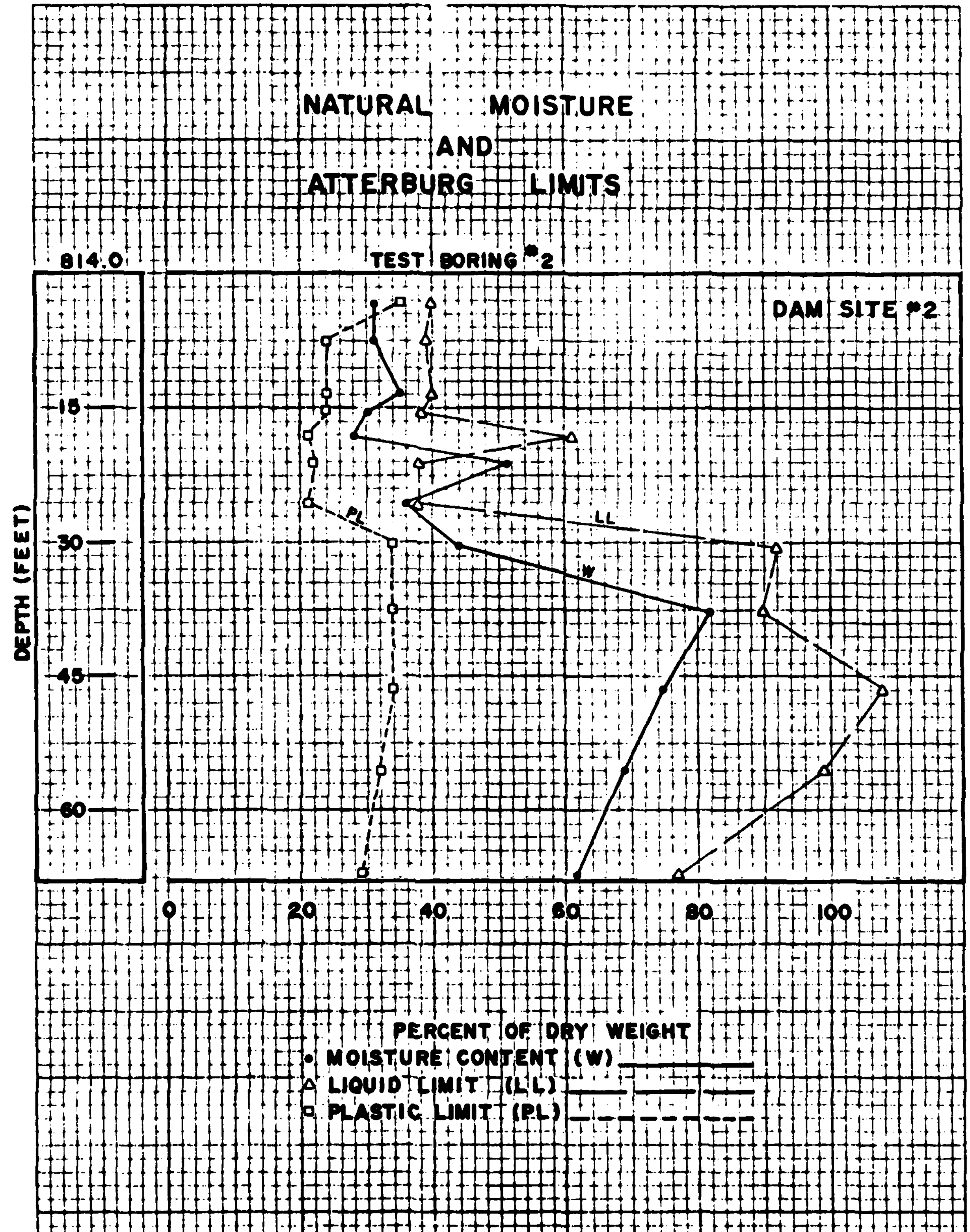
NATURAL MOISTURE
AND
ATTERBURG LIMITS
814.0
TEST BORING #2
DAM SITE #2
DEPTH (FEET)
15
30
45
60
LL
PL
W
0
20
40
60
80
100
PERCENT OF DRY WEIGHT
MOISTURE CONTENT (W)
LIQUID LIMIT (LL)
PLASTIC LIMIT (PL)

FIGURE D-18

END

FILMED

12-85

DTIC