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Final Report

ENGINEERING SOILS MAP OF
JOHNSON COUNTY, INDIANA

Wei-Yao Chen

PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

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FINAL REPORT
ENGINEERING SOILS MAPS OF JOHNSON COUNTY, INDIANA

by

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ENGINEERING SOILS MAP OF JOHNSON COUNTY, INDIANA

INTRODUCTION

The engineering soils map of Johnson County, Indiana that accompanies this report was prepared by airphoto interpretation techniques using accepted principles of observation and inference. The 7-inch x 9-inch aerial photographs used in this study were taken in the summer of 1971 for the United States Department of Agriculture. The airphotos have an approximate scale of 1:20,000, and the attached Engineering Soil Map was prepared at a scale ratio of 1:63,360 (1 inch = 1 mile).

Standard symbols were developed by the staff of the Airphoto Interpretation Laboratory of the School of Civil Engineering at Purdue University, and they were employed to delineate landform-parent material associations and soil textures. Extensive use was made of the Agricultural Soil Survey of Johnson County published in 1979 (1). It was particularly useful as a cross-reference to check soil boundaries, and to locate gravel pits and ponds that were not present on the 1971 aerial photographs.

The text of this report supplements the Engineering Soil Map. It includes general descriptions of the study area, and the different landform-parent material regions. Engineering considerations associated with each region are also briefly addressed.

The map and report are part of a continuing effort to complete a comprehensive soil survey for the state of Indiana. Included on the map is a set of subsurface soil profiles that illustrate the approximate variation of the soils in each landform-parent material area. The profiles were constructed from information obtained from

agricultural literature and from boring data collected from roadway and bridge site investigations (28-34)¹. Boring locations are shown on the map. Appendix A contains a summary of boring data and classification test results for these locations. The physical, chemical, and engineering index properties of these soils are included in Appendices B and C. Lastly, useful correlations for estimating soil properties are collected in Appendix E.

¹Numbers in parentheses refer to list of references.

DESCRIPTION OF THE AREA

GENERAL

Johnson County is located in the central part of the State of Indiana as illustrated in Figure 1. The county was established in 1822 and named in honor of Judge John Johnson of Indiana Supreme Court (2). The county is bordered by the Shelby County on the east, by Bartholomew and Brown Counties on the south, by Morgan County on the west, and by Marion County on the north. The county has its county seat at Franklin, which is about 20 miles south of Indianapolis. The county is about 16 miles wide (east-west) by 20 miles long (north-south), and consists of an area of 201,600 areas, or 315 square miles (1).

Johnson County is served by two railroads and two public airports. The two railroads are the Illinois Central and the Penn Central, which cross the county from north to south. The two airports are for light planes. One is located in the north part on the east edge of the city of Greenwood, and the other is about 4 miles south of the city of Franklin (1). The county also has about 17 miles of interstate highways, 257 miles of other federal highways and state highways, and 560 miles of county roads (1). The Interstate Highway 65, U.S. Highway 31 and State Road 135 are the major roads in north-south direction, whereas the State Roads 144, 252, 37, and 44 are in east-west direction. Most of the public roads in the county are paved (1).

The population of Johnson County was about 83,200 in 1986, and has grown steadily from 61,000 in 1970. The townships adjacent to Marion County are experiencing the greatest gain in population. The population density was 259 people per square mile. Franklin, the county seat, has a population of about 11,600 in 1980. A population summary of the important cities and towns in the county is given in Table 1.

Farming is the leading enterprise in the county. Cash grain and livestock are the major products. Corn, soybean, and wheat are the major crops. The major kinds of

Table 1. Population Summary of Johnson County (3)

	Population		Population Change (1970-1980)	
	1980 Census	1970 Census	Difference	% Change
City-Town				
Bergersville	1647	873	774	88.66
Edinburg	4856	5079	-223	-4.39
Franklin	11563	11477	86	0.75
Greenwood	19327	11869	7458	62.84
New Whiteland	4502	4200	302	7.19
Princes Lakes	937	597	340	56.95
Trafalgar	466	457	9	1.97
Whiteland	1956	1492	464	31.10
Urban Areas	45254	36044	9210	25.55
Rural Areas	31986	25094	6892	27.46
County Total	77240	61138	16102	26.34

livestock are hogs and beef cattle (1). The acreage percentage of farmland has decreased in recent years, but the average farm size has increased.

CLIMATE

The climate of Johnson County is humid and continental. The cool Canadian air masses with alternating tropical air masses from the south bring changes in climate within days (1). Table 2 and 3 give data on temperature and precipitation for this area as recorded at New Whiteland and Franklin, Indiana, respectively. Temperature over a 27-year period ranged from -17° to 104°F . About 32 days per year have temperatures of 90° or higher, and on 23 days a year the temperature does not rise above 32° . In July, the average daily maximum temperature is 88°F , whereas in January the average daily minimum temperature is 21°F (1). The annual precipitation is about 39.6 inches, and spring and early summer rainfall usually exceeds winter precipitation. Thunderstorms occur on about 44 days each year (1).

The average frost-free season is 184 days (11). Average seasonal snowfall is about 18 inches. The heaviest 1-day snowfall recorded was 9.5 inches on March 1, 1963. The average relative humidity is about 58 percent in summer, and 68 percent in the winter. The prevailing wind is from the southwest with the highest average wind speed, 11 miles per hour, occurring in the winter and spring(1).

DRAINAGE FEATURES

The county is drained by 2 major river systems. A line drawn from just east of Greenwood to Bargersville and south to a point slightly east of Peoga divides the county into the two drainage areas. The western part is drained by the West Fork of White River, whereas the eastern part the county is drained by the East Fork of White River and its tributaries such as Sugar Creek and Youngs Creek. Stream dissection is more complete in the western and southwestern parts than elsewhere. Some stream

Table 2. Climatological Summary For Johnson County (4)
Temperature in °F ; Precipitation in inches

Monthly statistics at New Whiteland

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1978	TMAX	24.6	26.5	41.5	63.9	69.9	83.4	85.3	83.2	82.3	63.9	55.5	41.0
	TMIN	6.1	-1.0	24.4	40.0	48.3	59.2	61.9	60.1	53.5	36.0	32.4	21.9
	PREC			3.09	3.81	4.50	6.41	6.71	4.80	0.54	2.69	2.66	2.53
	SNOW			4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1979	TMAX	25.4	27.3	51.6	59.6	73.2	83.0	83.1	82.1	79.5	65.4	52.4	42.8
	TMIN	5.5	1.8	30.7	39.0	47.3	59.1	62.3	61.0	51.1	41.7	30.3	23.5
	PREC	3.85	1.49	2.53	4.26	3.74	4.93	12.03	8.61	0.65	2.38	4.94	2.85
	SNOW	18.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
1980	TMAX	35.8	32.2	44.7	59.5	75.0	81.1	89.3	88.6	81.6	65.0	51.2	40.4
	TMIN	18.8	10.7	24.1	36.9	51.2	56.8	64.9	64.2	54.1	35.6	27.9	21.5
	PREC	1.47	2.15	4.36	2.40	2.78	4.06	3.57	6.73	2.43	2.21	1.28	1.06
	SNOW	0.5		2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.5
1981	TMAX	32.6	41.3	49.5	68.0	69.3	83.6	84.7	83.2	75.7	64.1	54.7	35.8
	TMIN	12.0	18.8	27.6	43.4	47.7	61.4	64.4	60.5	51.8	37.4	29.7	17.4
	PREC		3.17	1.80	6.18	10.11	3.52	5.02	3.01	2.32	2.26	1.39	2.61
	SNOW	2.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0
1982	TMAX	29.7	35.0	51.0	57.8	81.9	78.9	86.5	83.6	77.3	70.2	53.9	
	TMIN		14.5	28.1	37.0	55.1	55.8	63.9	58.0	52.0	40.3		
	PREC	3.39	0.87	5.61	2.15	4.63	3.29	3.12	2.48	1.01	0.91	3.96	
	SNOW	13.0	10.0	1.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	TMAX	37.5	46.4	53.1	58.1	71.6	85.7	90.9	90.4	82.8	67.5	55.4	27.8
	TMIN	21.1	22.3	31.0	38.7	47.2	59.9	64.8	63.1	50.2			14.0
	PREC	1.13	0.83	2.19	6.23	4.33	3.19	1.63	3.16	0.78	6.37	5.66	2.98
	SNOW	1.0		0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
1984	TMAX	31.0	45.0	39.4	59.2	68.9	85.0	82.3	85.0	75.6	68.7	50.3	46.5
	TMIN	12.9	27.2	24.1	40.8	49.1	63.9	60.0	61.7	52.8	49.9	30.1	29.3
	PREC	0.51	1.43	2.76	5.24	4.32	2.24	2.33	1.15	3.72	3.27	4.98	4.90
	SNOW	7.6	11.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	3.0
1985	TMAX	27.8	32.9	54.2	68.1	74.1	78.3	83.7	80.4	77.8	67.4	54.3	32.2
	TMIN	11.8	13.4	33.5	45.4	53.8	59.0	62.2	60.8	54.1	46.1	38.8	14.0
	PREC	1.06	2.95	6.53	2.06	4.17	4.75	3.55	7.00	1.47	2.40	8.21	2.31
	SNOW	4.8		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
1986	TMAX	36.9	38.5	52.2	66.8	72.5	82.1	86.3	81.6	80.0	64.6	47.3	37.7
	TMIN	17.3	22.9	31.2	42.0	53.7	62.5	66.0	57.1	57.3	44.8	31.3	25.0
	PREC	1.08	3.94	2.75	3.75	5.51	2.41	3.94	2.10	4.85	4.09	1.98	2.22
	SNOW		7.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	TMAX	34.0	42.8	54.1	62.3	80.1	83.6	84.8	84.7	81.2	60.3	56.7	41.6
	TMIN	20.2	24.7	32.5	40.1	54.9	62.2	65.0	62.2	53.9	34.2	34.3	28.6
	PREC	1.34	0.30	2.90	3.31	2.03	4.77	7.73	0.44	0.75	1.59	2.89	4.93
	SNOW	3.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	TMAX	33.0	35.2	50.3	62.5	77.1	86.3	87.7	87.1	77.3	58.2	51.5	39.6
	TMIN	14.4	17.5	30.0	39.0	49.6	57.0	62.6	63.0	52.6	33.5	31.7	19.6
	PREC	1.48	3.86	3.09	4.03	1.26	0.72	5.38	2.69	1.94	2.86	5.23	2.45
	SNOW	0.8	3.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0

Table 3. Thirty Four Year Normal Climate Data (1)
(Recorded in the period 1937-70 at Franklin, Indiana)

For The Period 1937-70				
	Temperature (F)			Average Precipitation
MONTH	Average daily maximum	Average daily Minimum	Average	(inches)
January	39	21		2.8
February	42	24		2.5
March	52	31		3.6
April	65	41		3.8
May	75	51		4.5
June	84	61		4.1
July	88	63		3.8
August	86	61		3.2
September	80	54		3.1
October	69	43		2.1
November	53	32		3.3
December	41	23		2.8
Annual	65	42		----

courses appear to have been influenced by the presence of the moraines. They are deflected and have increased densities of drainage patterns (5). Local watershed divides tend to follow the crests of sections of ridge moraines. Some of them are broad and nearly level (5). The drainage features of Johnson County are shown in Figure 2.

WATER SUPPLY

Johnson County lies entirely within the White River watershed and its East Fork subdivision (Figure 3). No natural lakes exist in the county, but ponds of various origins can be seen in some parts of the county (5).

The major water resource in Johnson County is groundwater (1). Johnson County is situated in the Southern Till Plain Section except the extreme southwestern corner, which is in Devonian and Mississippian siltstone and shales section (Figure 4).

The major aquifers in the Johnson County are the areas underlain by gravelly sand and sand along White River and Blue River, Sugar Creek, and the lower reaches of Hurricane Creek and Young Creek. For example, the city of Franklin obtains its water supply from wells in terraces and bottom lands along Hurricane Creek and Young Creek about a mile from the city. Wells in about the western one-third of the county are least productive and are usually seep wells. In this area, more and more ponds are being dug to supplement the water supply (1). The water use summary for Johnson County is shown in Table 4.

PHYSIOGRAPHY

The State of Indiana can be divided into two areas. The northern portion, covered by glacial drift, belongs to the great Central Lowland province, whereas the unglaciated southern section belongs to the Low Plateau province. The central Lowland province in Indiana can be further subdivided into two portions. These are the Northern Moraine and Lake Region (characterized by lakes and lake-bed deposits), and the Tipton Till

FIGURE 2. DRAINAGE MAP OF JOHNSON COUNTY (5)

FIGURE 3. MAJOR WATERSHEDS OF INDIANA (6)

FIGURE 4. GROUNDWATER SECTIONS OF INDIANA (6)

Table 4. Water Use Summary for Johnson County (7)
(1989 usage in millions of gallons)

MONTH	SOURCE		
	Ground	Surface	Total
January	245.29	0.00	245.29
February	214.21	0.00	214.21
March	258.08	0.00	258.08
April	255.70	0.00	255.70
May	288.96	1.64	290.60
June	317.88	1.42	319.30
July	320.58	1.84	322.42
August	301.15	1.42	302.57
September	266.26	0.94	267.20
October	283.42	1.10	284.52
November	243.33	0.46	243.79
December	260.43	0.00	260.43
Total	3255.30	8.82	3264.12

Plain (consisting of level or undulating deposits of drift without lakes or appreciable stream dissection) (8). On the other hand, the Low Plateau province can be subdivided into 7 divisions as shown in Figure 5. The northern part of Johnson County is located in the Tipton Till Plain, whereas the southern part is in the Scottsburg Lowland and Norman Upland physiographic regions (Figure 5).

The Tipton Till Plain, which includes more than three-fourths of the county, extends across the central portion of the state from east to west. It has more or less uniform topography compared with rugged and weathered southern Indiana. Since the region is monotonously flat; only an occasional break in topography can be seen resulting from small terminal moraines, knolls and kames (8).

In contrast to Tipton Till Plain, the southern one-fourth of the county has semi-rugged terrain. The Scottsburg Lowland is mostly nearly level to gently sloping terraces and outwash plains and nearly level river bottomland along Sugar Creek and Blue River, while the Norman Upland is characterized by gently sloping to moderately sloping, high, narrow ridgetops and strongly sloping to very steep, deep, V-shaped valleys.

TOPOGRAPHY

The general topography of Johnson County is shown in Figure 6. The county has a variety of landforms. The surface varies from a gently undulating glacial till plain to an almost rugged stream dissected residual upland. Some depressions are found in the northeast and southwest part of the county. Depressed areas occur along Grassy, Hurricane and Youngs Creeks (5). The highest altitude reaches 1002 feet above sea level, which is an area on a high ridge west of Peoga. The lowest point is 635 feet above sea level. It is in the northeastern part of the county where the East Fork of White River leaves Johnson County and enters Morgan County. The maximum local relief is about 225 feet (5).

FIGURE 6. TOPOGRAPHIC MAP OF JOHNSON COUNTY (10)

GEOLOGY OF JOHNSON COUNTY

Johnson County was completely glaciated and covered by glacial deposits left by the continental ice sheets. The surface drift in a small area in the southwestern part is Illinoian in age, whereas the remainder of the area is Wisconsin in age (5).

GLACIAL GEOLOGY

Johnson County is located near the southernmost limit of the continental ice sheets which retreated from Indiana about 20000 years ago (11). As the glaciers retreated, a series of moraines were left behind. These moraines consist of sand, gravel, clay and silt. The present day thickness of these deposits ranges from a few feet to over 200 feet east of Greenwood in the county. Johnson County is crossed by 3 moraines--the Bloomington Morainic System in the north, the Champaign in the central, and the Shelbyville in the south part (5).

BEDROCK GEOLOGY

The bedrocks in Johnson County are Devonian and Mississippian rocks. Figure 7 is a map of bedrock geology of Indiana. The map of bedrock geology of Johnson County is shown in Figure 8. The figure illustrates the disposition of the bedrock units as they would appear today if there were no unconsolidated deposits present to cover them.

The oldest bedrocks in Johnson County are Devonian rocks. They can be subdivided into Muscatatuck Group and New Albany Shale. The lower rocks, Muscatatuck Group, are made up of several kinds of carbonate and evaporite lithologies. The most common are limestone and dolomite (14). These rocks crop out under the glacial drift in the east-central and northeast edge of the county, but there is no surface exposures of them in Johnson County (11). The thickness of the Muscatatuck

FIGURE 7. BEDROCK GEOLOGY OF INDIANA (12)

FIGURE 8. BEDROCK GEOLOGY OF JOHNSON COUNTY (13)

EXPLANATION

FIGURE 8. BEDROCK GEOLOGY OF JOHNSON COUNTY (CONTINUED)

Group ranges from erosional zero to more than 250 feet in the Illinois and Michigan Basins.

Except where affected by post-Devonian erosion, the Muscatatuck is overlain by the dark shales of the New Albany Shale in southern Indiana. The New Albany Shale is composed of brownish-black carbon-rich shale, greenish-gray shale, and minor amounts of dolomite and dolomitic quartz sandstone (14). The formation crops out at a spot along Sugar Creek near Amity, and in Blue River at Edinburg (11). There are five members recognized in the formation. They are the Blocher Member, the Selmier Member, the Morgan Trail Member, the Camp Run Member, and the Clegg Creek Member in ascending order. The thickness of the New Albany Shale ranges from 0 to 140 feet in Johnson county.

The Rockford Limestone, typically gray, fine grained, argillaceous, ferruginous, and sparingly fossiliferous, overlies the New Albany Shale. Limestone is dominant in the Rockford, but shale, siltstone, and dolomite are also present (14). The Rockford Limestone crops out beneath the glacial drift in a very thin belt extending from south to north. The thickness is commonly 2 or 3 feet as shown in Figure 8.

The Borden Group in turn rests on the Rockford Limestone. It is composed of three formations. They are the New Province Shale, the Spickert Knob, and Edwardsville Formations in ascending order. The three formations represent three major settings. The New Province Shale resulted from prodelta deposits, the Spickert Knob Formation from delta-slope deposits, and the Edwardsville from delta-platform deposits (14).

The Borden Group is composed dominantly of gray argillaceous siltstone and of shale. Fine-grained sandstone is common. Lenses of crinoidal limestone can be found in the upper part (14). The Borden crops out in many road cuts and streams banks in the western, southwestern, and southern portion of the county. It reaches a maximum thickness of at least 700 feet in Johnson County (11).

The bedrock topography of Johnson County is shown in Figure 9. The lowest bedrock altitude exists in the eastern part of the county, which corresponds to the Sugar Creek, Youngs Creek and their tributaries.

PLEISTOCENE GEOLOGY

The Pleistocene sediments in Indiana are of continental origin rather than marine origin. Therefore, they are less homogeneous and continuous. The unconsolidated deposits encountered in Johnson County are illustrated in Figure 10. These sediments are of Wisconsinan and Illinoian ages.

The glacial drift is present at the surface throughout Johnson County except in most river valleys where it is overlain by deposits of present streams. Those materials deposited by earlier glaciers are not distinguishable at the surface now.

The Jessup Formation, which overlies the Borden Group rocks, is exposed as the surface unit in the southwestern part of the county. It consists of several beds of calcareous conglomeratic mudstone and intercalated lenses of clay, silt, sand, gravel, marl, and peat (18). These sediments were deposited on rocks of Paleozoic age by the Illinoian and older glaciers as they retreated. The thickness of the formation is extremely variable, because both upper and lower surfaces of the units are bounded by erosional unconformities (18). The weathering depth usually ranges from 3 to 4 meters if the formation is not covered by younger sediments (18).

Overlying the Jessup Formation is Trafalgar Formation. The Trafalgar Formation is named from the village of Trafalgar in Johnson County. The type section is exposed along Buckhart Creek about 2 miles east of Trafalgar and 500 feet north of Indiana State Highway 252. Tills of the Trafalgar Formation are most common as the surface unit in Johnson County as shown in Figure 10. They are primarily calcareous conglomeratic mudstones. Lenses of silt, sand, and gravel are also present in the Formation (18). Much of the area underlain by the formation is a relatively flat plain. Three

FIGURE 9. BEDROCK TOPOGRAPHY OF JOHNSON COUNTY (15)

FIGURE 10. UNCONSOLIDATED DEPOSITS OF JOHNSON COUNTY (16,17)

EXPLANATION

FIGURE 10. UNCONSOLIDATED DEPOSITS OF JOHNSON COUNTY
(CONTINUED)

environmental facies can be recognized. They are blanket till, end-moraine till and kame facies.

The Trafalgar Formation is overlain by the Atherton Formation. The Atherton Formation is a deposit of gravel, sand, silt, and clay derived from glacial outwash. Four facies are identifiable as Atherton Formation. They are outwash facies, dune facies, loess facies and lacustrine facies.

The youngest sediment in Johnson County is the Martinsville Formation. It is deposited by the modern streams, small lakes and sloughs. Silt, sands, and gravels are most commonly found. The Martinsville Formation includes two facies. One is associated with flood plain deposition and referred as Alluvial facies, the other is essentially formed in still water and named Paludal facies (18). The Alluvial facies contains silt, sand, and gravel, and the Paludal is rich in organic matter. The Paludal facies is also highly fossiliferous. Peat in the Martinsville Formation, containing abundant plant remains but rare mollusks, exist in a few locations.

The thickness of unconsolidated deposits is shown in Figure 11. The unconsolidated deposits are thickest in the area of T. 13N., R. 4E., and T. 14N., R. 4E., where they are more than 200 feet thick. In general, the areas of thickest deposits correspond to those places where the underlying bedrock surface is relatively low as shown in Figure 9. The relationships between unconsolidated deposits are shown in Figure 12.

FIGURE 11. THICKNEES OF UNCONSOLIDATED DEPOSITS (19)

EXPLANATION

FIGURE 12. SCHEMATIC SECTION SHOWING RELATIONSHIPS OF UNCONSOLIDATED DEPOSITS (16,17)

LANDFORM-PARENT MATERIAL REGIONS

The soils of Johnson County are primarily composed of unconsolidated sediments, such as clays, sands, and gravels. These soils are mapped into five groups and associated subgroups for the engineering purpose. The four parent material units are glacial drift, glacial-fluvial drift, fluvial drift, residual soils, and cumulose drift.

Each of the landform-parent material regions is characteristically identified by its surface texture, overall extent, and soil profiles. Available boring log data are collected in Appendix A. Classifications of the soils according to the American Association of State Highway and Transportation Officials (AASHTO) system are given along with the textures in terms of the designation adopted by the U.S. Department of Agriculture. In addition, the physical, chemical and engineering properties of the soils are summarized in Appendices B and C. Finally, Appendix E provides correlation charts and formulas for estimating soil properties based on their index parameters such as plasticity index and liquidity index.

The engineering considerations for each parent material unit are discussed here. For specific and detailed information, the reader should consult the boring reports listed in the references. This report only provides general information, and is not intended to replace site investigation for any engineering project.

GLACIAL DRIFT

Ice of Wisconsin age had a profound effect on the surficial geology of Johnson County (20). The majority of the area in Johnson County is covered by glacial drift, which is composed of soils with broad range of grain sizes.

Glacial Till

Glacial till is a poorly sorted mixture of gravel, sand, silt, and clay. These sediments are deposited by Wisconsinan and Illinoian glaciers. The surface is level to gentle rolling, sometimes broken by river courses or low knolls. Sections of three morainic systems cross the county from east to west. They are the Shelbyville in the south, the Champaign in the central, and the Bloomington in the northern part (11). Moraines are likely to be poorly drained, C-type gullies and V-type gullies can be found. The former is an indication of soils rich in clay or silty clay, whereas the latter is common in coarsed-grained soils such as sand and gravel (21-24).

The general soil profile in glacial till usually consists of clay, clay loam, silty clay, silty clay loam, or loam, underlain by subsurface soils of sandy loam, silt loam, clay loam, silty clay, or loam. Among these soils, the thickness of silty clay and loam may be as large as 9 feet.

The agricultural soils that form on glacial till are Brookston, Crosby, Fincastle, Hennepin, Hickory, Miami, Muren, and Parke series. Soil boring numbers 1-86 and 94-102 are located in glacial till.

Engineering Considerations in Glacial Drift

The typical engineering properties of glacial drift are poor drainage, low permeability and susceptibility to frost action.

Frost action will cause the volume of the soil to expand 10% or more upon freezing. The expansion is usually not uniform, thus causing serious damage to highway pavements and structures. Moreover, during the spring thaw the water content in the soil is increased by the melted ice lenses. This will weaken the soil and create additional damage to the pavements (25).

To avoid frost action, the material under highway should be drained and granular, usually not more than 3 percent of the material can be less than 0.02 mm in

diameter. Utilities lines and building footings should be placed well below the frost line (26).

Another highway pavement problem is pavement pumping at pavement joints. Pumping is common to rigid pavements over ground moraine (23). Usually soil particles are carried out from beneath the pavement by the ejection of water due to traffic loading (8). Thus, cavities are formed underneath the pavements and cracking and faulting follow. Again, pumping is restricted to poorly drained areas. The damage can be reduced by replacing the fine-grained soils by drained granular ones.

The soils on glacial drift usually have high water contents. Therefore, it may be difficult to compact the soil to required levels. If too great a compaction energy is applied, the soil will actually become weaker. This is called overcompaction (25). It is recommended to remove all wet and soft surface soils before construction of the roadways, and backfill to an elevation above the groundwater table if groundwater is encountered.

However, glacial till can be used as a fill material under certain conditions. Its high clay content makes it almost impermeable to water. Therefore, it can be used as the core of earth dam or fill material for underground cavities where subsurface drainage is a problem (20).

GLACIAL-FLUVIAL DRIFT

Outwash plains and terraces is the only recognized division of glacial-fluvial drift in Johnson County.

Outwash Plains and Terraces

Outwash plains and terraces occupies the second largest portion of the county. The outwash plains are broad plains formed by meltwater currents flowing from the glacier, and the terraces are developed from valley trains, which are also formed along

major drainage ways during glacial ages. They are grouped together due to their close relationship during deposition. The soils, consisting of silt, sand, and gravels, are highly stratified. The soils are also affected by the erosion and deposition actions of modern streams because the streams sometimes flow in abandoned channels of outwash plains (22, 27). A large quantity of sand and gravel as outwash material are found near Sugar Creek and the Big Blue River. These deposits are promising sources of sand and gravel (20).

The soils encountered in outwash plain are silt loam, clay loam, silty clay loam, and loam, underlain by clay loam, sandy clay loam, sandy loam, loam and sand.

No soil borings were made in outwash plains and terraces. The agricultural soils that form on this division are Fox, Nineveh, Ockley, Rensselaer, Sleeth, Westland, and Whitaker series.

Engineering Considerations in Glacial-Fluvial Drift

The textures of outwash deposits are usually medium to coarse-grained, and segregated into distinct phases. In general, the outwash plain provides adequate support for light to moderately loaded buildings in the sandy phase (27). Also, it is a good potential source for construction materials such as sand and gravels.

The permeability of the soils are high. This should be taken into account when planning sanitary facilities and landfill sites.

For terraces, high potential of erosion is the major engineering problems, especially on the side slopes. Circular types of slope failure are common after heavy rainfall.

FLUVIAL DRIFT

Fluvial drift appears in only one landform in Johnson County. It is the flood plain.

Flood Plain

Flood Plains are distributed along White River system in Johnson County. All of them are narrow and restricted in aerial extent. The flood plains are formed as a result of modern stream deposition and become a veneer of outwash material (20). The thickness of flood plains range from 0 to 20 feet along Sugar Creek, Big Blue River, Herriotts Creek, and Youngs Creek (20).

The soil profile of flood plains varies from place to place. The soils in the profile include loam, clay loam, sandy loam, sand, silty clay loam, sandy clay loam, and silt loam.

Soil borings located in flood plain were numbers 87-93 and 103-126. The agricultural soils that form on this landform are Eel, Genesee, Ross, Shoals, and Sloan series.

Engineering Considerations in Fluvial Drift

Fluvial deposits are usually layered and highly variable (27). The permeability in the horizontal direction tends to be much greater than the vertical direction. Furthermore, the permeabilities in the surface layers are usually lower compared with the sublayers. Flooding, differential settlements and low shear strength are greatest concerns in the flood plain. Flood plains are not suitable for sanitary landfill sites, either. This is due to the possibilities of flooding and ground water contamination.

The ground water table is close to the surface in flood plains. This makes excavation difficult. A dewatering scheme is recommended.

RESIDUAL SOILS

The residual soils in Johnson County are developed from the decomposition of rocks such as sandstone, shale, and siltstone. They constitute the surface soils or near-

surface soils for southwestern parts of the county, where the bedrocks outcrop. The thickness of these residual soils is highly variable.

Residuum Developed from Interbedded Sandstone, Siltstone and Shale

Small areas of residuum of sandstone, shale, and siltstone are found in the southwest corner, which are very likely derived from rocks of the Borden Group.

This map unit makes up small percentage of the county. The soils in this area are generally unsuited to sanitary facilities and dwellings. Typically, the surface layer is silt loam or loam. The subsoils consist of silt loam, silty clay loam, clay loam, and loam.

The agricultural soils that form on the sandstone, shale and siltstone residuum are Muskingum and Wellston series.

No borings were located in this region.

Engineering Considerations in Residual Soils

The residual soils, either derived from sandstone or shale, are susceptible to weathering. In southern Indiana, the residual soils developed from limestone and shale are relatively deep, and it is seldom that the unweathered rock formations are within 10 feet of the ground surface. However, chert fragments are present in these residual soils at almost every location and depths.

In the sandstone-shale area, care should be taken on fill material of embankment in highway construction. Shale fragments are unsuited because of their low slaking durability and difficulty in compaction. A mixture of sandstone and shale fragments is also unfavorable.

CUMULOSE DRIFT

Cumulose drift occurs in the form of organic deposits in Johnson County.

Organic Deposits over Mineral Material

Organic Deposits (muck basins) are deposits associated with muck and highly organic matter. The sizes of muck basin are small and limited in number in Johnson County. Some of them are distributed just east of the town of Amity. The thickness of muck varies. Usually, the surface layer is highly organic material, underlain by silt loam and sandy loam.

No soil boring reports are available for muck basins at the time of preparing this report. The agricultural soil that forms on muck basins is Palms series.

Engineering Considerations in Cumulose Drift

The characteristics of muck basin are high organic content, high water content, high porosity, high compressibility, low permeability, and low strength. Therefore, the muck basin is unsuited for roads or buildings. Usually, constructions on muck basins are avoided. However, if economically feasible, the soils in muck basin can be replaced by soils with adequate engineering properties.

MISCELLANEOUS

Gravel Pits

Johnson County has commercially valuable deposits of sand and gravel. In fact, eastern Johnson County has large sand and gravel deposits which can supply aggregate necessary for the future expansion of Indianapolis and adjacent areas (20). A few gravel pits exist in the area due to the construction of Interstate Highway 65. Other areas producing sands and gravels are located in the northwestern and northern parts (5). Each year a vast amount of sand and gravel is used in construction projects such as highways, bridges, foundations, and buildings. Sand and gravel are classified according to their grain sizes. Loosely speaking, the coarse-grained soil with particle

size greater than 2 mm are termed gravels, whereas sand is defined as soils with grain size less than 2mm.

Gravel has been found along major streams. Some wind-deposited sands are found in the White River valley (5).

SUMMARY OF ENGINEERING CONSIDERATIONS IN JOHNSON COUNTY

Table 5 is the summary of engineering considerations for different landform-parent material regions in Johnson County. Each landform-parent material and its associated engineering problems are included in the table. However, the ranking shown in the table is recommended to be used as a general guideline only. Site specific investigation is always needed.

Sometimes a rough estimate of soil properties such as preconsolidation pressure and undrained shear strength is needed from available data in the preliminary stage of site investigation. These existing data are usually index parameters such as the liquid limits and plastic limits contained in Appendix A. Therefore, correlations between index parameters and engineering properties of soils are needed. There are many correlations existing in the literature, and some of them are summarized in Appendix E. These charts and formulas are intended to give engineers a feel about soil properties before performing more sophisticated soil tests. For more correlations such as those between in-situ tests and soil properties, reader can refer to reference 36.

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APPENDIX A

CLASSIFICATION TEST RESULTS FOR SELECTED
ENGINEERING PROJECTS IN JOHNSON COUNTY (28-34)

Appendix A1: continued

[illegible]

Appendix A2: continued

Boring No.	Project	Sample No.	Station No.	Offset FL	Ground Elevation FL	Sample Depth FL	Soil Description		Blow per ft.	ACD %	Grain Size			Distribution			LL	PL	PI
							Texture	AASHTO			Gravel	Sand	Silt	Clay					
37		1	722+50	42LT	740.3	1.0-2.0	clay loam	A-7-6	--	--	--	--	--	--	--	--	--	--	
		2	"	"	"	5.0-6.0	loam	A-4	--	--	--	--	--	--	--	--	--	--	
		3	"	"	"	9.0-10.0	"	"	--	--	--	47	39	14	20	12	8		
		4	"	"	"	13.0-14.0	"	"	--	--	--	--	--	--	--	--	--	--	
38		1	730+50	42LT	740.6	0.5-2.0	clay loam	A-7-6	--	--	--	--	--	--	--	--	--	--	
		2	"	"	"	2.0-3.0	"	"	--	--	--	--	--	--	--	--	--	--	
39		1	740+50	42RT	739.0	0.5-1.5	clay	A-7-6	--	--	--	--	--	--	--	--	--	--	
		2	"	"	"	1.5-2.5	"	"	--	--	--	--	--	--	--	--	--	--	
		3	"	"	"	5.0-6.0	loam	A-4	--	--	--	--	--	--	--	--	--	--	
40		1	747+00	42RT	743.5	1.0-2.0	loam	A-4	--	--	--	--	--	--	--	--	--	--	
		2	"	"	"	3.0-4.0	"	"	--	--	--	--	--	--	--	--	--	--	
		3	"	"	"	5.0-6.0	"	"	--	--	--	--	--	--	--	--	--	--	
41		Box	750+00	42RT	745.2	1.0-3.0	clay loam	A-7-6(19)	--	--	--	17	61	22	50	27	29	29	

Appendix A2: continued

Boring No.	Project	Sample No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	RCO %	Grain Size			LL	PL	PI
							Texture	AASHTO			Gravel	Sand	Silt			
59		--	877+00	CL	790.7	0.0-3.5	silty clay loam	"	--	--	--	--	--	--	--	--
		--	"	"	"	3.5-6.0	silty clay	"	--	--	--	--	--	--	--	--
60		--	884+50	42RT	788.2	0.0-2.5	silty clay loam	A-7-6	--	--	--	--	--	--	--	--
		--	"	"	"	2.5-6.0	silty clay	"	--	--	--	--	--	--	--	--
61		1	891+00	42LT	792.5	2.0-4.0	silty clay loam	A-7-6 (13)	--	--	--	20	53	27	43	21
62		1	906+25	42RT	798.8	0.0-1.0	silty clay loam	A-7-6	--	--	--	--	--	--	--	--
		2	"	"	"	2.0-4.0	silty clay	"	--	--	--	--	--	--	--	--
63		Bag	975+00	42LT	810.0	1.5-3.0	clay	A-7-6 (12)	--	--	--	--	--	--	--	--
		2	"	"	"	5.0-6.0	"	"	--	--	--	--	--	--	--	--
		3	"	"	"	7.0-8.0	"	"	--	--	--	--	--	--	--	--
64		1	979+40	42RT	801.0	1.0-2.0	silty clay loam	A-7-6	--	--	--	--	--	--	--	--
		2	"	"	"	5.0-6.0	silty clay	"	--	--	--	--	--	--	--	--

Appendix A2: Continued.

[illegible]

Appendix A3: continued

Boring No.	Project	Sample No.	Station No.	Offset Fl.	Ground Elevation Fl.	Sample Depth Fl.	Soil Description		Blow per Fl.	MOO %	Grain Size			LL	PL	PI
							Texture	AASHTO			Gravel	Sand	Silt			
B1		SS-1	110+00	25HT	809.9	1.0-2.5	silty clay loam	A-4	6	---	---	---	---	---	---	---
		SS-2	"	"	"	3.5-5.0	"	"	9	---	---	---	---	---	---	---
		SS-3	"	"	"	6.0-7.5	"	"	4	---	---	---	---	---	---	---
		SS-4	"	"	"	8.5-10.0	"	"	20	---	---	---	---	---	---	---
		SS-5	"	"	"	13.5-15.0	loam	"	27	---	---	---	---	---	---	---
B2		SS-1	112+00	CL	808.8	1.0-2.5	silty clay loam	A-4	6	---	---	---	---	---	---	---
		SS-2	"	"	"	3.5-5.0	"	"	8	---	---	---	---	---	---	---
		SS-3	"	"	"	6.0-7.5	"	"	15	---	---	---	---	---	---	---
		SS-4	"	"	"	8.5-10.0	loam	"	42	---	---	---	---	---	---	---
B3		SS-1	120+00	CL	831.5	1.0-2.5	silty clay loam	A-4	6	---	---	---	---	---	---	---
		SS-2	"	"	"	3.5-5.0	"	"	11	---	---	---	---	---	---	---
		SS-3	"	"	"	6.0-7.5	loam	"	17	---	---	---	---	---	---	---
		SS-4	"	"	"	8.5-10.0	"	"	36	---	---	---	---	---	---	---
		SS-5	"	"	"	13.5-15.0	loam to silty clay loam	"	13	---	---	---	---	---	---	---
		SS-6	"	"	"	8.5-20.0	silty clay loam	"	11	---	---	---	---	---	---	---

Appendix A3: continued

Boring No.	Project	Sample No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil Description		Blow per Ft.	RQD %	Grain Size			Distribution			LL	PL	PI
							Texture	ASTM			Gravel	Sand	Silt	Clay					
84		SS-1	126+100	CL	806.8	1.0-2.5	loam	A-4	4	100	0	100	0	0	0	100	0	0	
		SS-2	"	"	"	3.5-5.0	"	"	5	100	0	100	0	0	0	100	0	0	
		SS-3	"	"	"	6.0-7.5	"	"	23	100	0	100	0	0	0	100	0	0	
		SS-4	"	"	"	8.5-10.0	silty clay loam	"	73	100	0	100	0	0	0	100	0	0	
85																			
		SS-1	131+06	10LT	820.3	1.0-2.5	fill	----	4	100	0	100	0	0	0	100	0	0	
		SS-2	"	"	"	3.5-5.0	silty clay loam	A-4	4	100	0	100	0	0	0	100	0	0	
		SS-3	"	"	"	6.0-7.5	"	"	6	100	0	100	0	0	0	100	0	0	
		SS-4	"	"	"	8.5-10.0	silt	A-4(5)	5	100	7	31	48	14	25	15	10	0	
		SS-5	"	"	"	13.5-15.0	silty clay loam (fill)	A-4	21	100	0	100	0	0	0	100	0	0	
		SS-6	"	"	"	18.5-20.0	loam	"	21	100	0	100	0	0	0	100	0	0	
86																			
		SS-1	135+00	12RT	835.8	1.0-2.5	silty clay loam	A-4	4	100	0	100	0	0	0	100	0	0	
		SS-2	"	"	"	3.5-5.0	"	"	5	100	0	100	0	0	0	100	0	0	
		SS-3	"	"	"	6.0-7.5	"	"	3	100	0	100	0	0	0	100	0	0	
		SS-4	"	"	"	8.5-10.0	silty clay	A-4(8)	3	100	0	13	60	27	35	21	14	0	
		SS-5	"	"	"	13.5-15.0	loam	A-4	12	100	0	100	0	0	0	100	0	0	

Appendix A4: Continued.

[illegible]

Appendix A5: Borehole Data for S.B. 44 over South Prong of Stotts Creek

Boring No.	Project	Sample No.	Station No.	Offset FL	Ground Elevation FL	Sample Depth FL	Soil Description		Blow per Fl.	RQD %	Grain Size			LL	PL	PI
							Texture	AASHTO			Gravel	Sand	Silt	Clay		
103		155	137+15	6RT	768.3	1.0-2.5	silty loam	A-6(10)	7	--	1	7	74	18	32	20
		255	"	"	"	3.5-5.0	"	"	5	--	--	--	--	--	--	--
		355	"	"	"	6.0-7.0	silty loam to siltstone	--	--	--	--	--	--	--	--	--
		1RC	"	"	"	8.0-13.0	siltstone	--	--	27	--	--	--	--	--	--
		2RC	"	"	"	13.0-18.0	"	--	--	77	--	--	--	--	--	--
104																
		155	137+41	6RT	766.1	1.0-2.5	silty loam	A-6	6	--	23	44	29	4	NP	NP
		255	"	"	"	3.5-5.0	sandy loam w/gravel	A-2-4(0)	38	--	--	--	--	--	--	--
		1RC	"	"	"	6.0-11.0	siltstone	--	--	0	--	--	--	--	--	--
		2RC	"	"	"	11.0-16.0	"	--	--	55	--	--	--	--	--	--
105																
		155	137+86	28RT	775.0	1.0-2.5	fill	A-6	29	--	--	--	--	--	--	--
		255	"	"	"	3.5-5.0	sandy loam w/gravel	A-2-4	10	--	--	--	--	--	--	--
		355	"	"	"	6.0-7.5	"	"	13	--	--	--	--	--	--	--
		455	"	"	"	8.5-10.0	silty loam	A-4(6)	8	--	0	30	57	13	33	23
		1RC	"	"	"	13.0-18.0	siltstone	--	--	0	--	--	--	--	--	--
		2RC	"	"	"	18.0-23.0	"	--	--	63	--	--	--	--	--	--

Appendix A5: continued

Boring No.	Project	Sample No.	Station No.	Offset Ft.	Ground Elevation Ft.	Sample Depth Ft.	Soil		Description	Blow per Ft.	RQD %	Grain Size			LL	PL	PI
							Texture	AASHTO				Gravel	Sand	Silt	Clay		
109		155	133+25	55RT	799.9	1.0-2.5	loam	A-6		39	--	--	--	--	--	--	--
		255	"	"	"	3.5-5.0	"	"		35	--	--	--	--	--	--	--
		355	"	"	"	6.0-7.5	sandy clay loam	"		76	--	--	--	--	--	--	--
		455	"	"	"	8.5-10.0	"	"		38	--	--	--	--	--	--	--
		555	"	"	"	11.0-12.5	"	"		33	--	--	--	--	--	--	--
		655	"	"	"	13.5-15.0	"	"		59	--	--	--	--	--	--	--
		755	"	"	"	16.0-17.5	"	"		53	--	--	--	--	--	--	--
		855	"	"	"	18.5-20.0	"	"		40	--	--	--	--	--	--	--
		955	"	"	"	21.0-22.5	siltstone	--		40	--	--	--	--	--	--	--
		1055	"	"	"	23.5-25.0	"	--		71	--	--	--	--	--	--	--
110		1A0	133+25	40RT	808.5	1.0-6.5	loam	A-6		--	--	--	--	--	--	--	--
111		155	140+00	30LT	772.3	1.0-2.5	loam	A-6		8	--	--	--	--	--	--	--
		255	"	"	"	3.5-5.0	"	"		12	--	--	--	--	--	--	--
		355	"	"	"	6.0-7.5	"	"		5	--	--	--	--	--	--	--
		455	"	"	"	8.5-10.0	1990 siltstone	--		35	--	--	--	--	--	--	--

Appendix A6: continued

[illegible]

Appendix A6: continued

[illegible]

APPENDIX B

PHYSICAL AND CHEMICAL PROPERTIES OF AGRICULTURAL SOILS IN JOHNSON COUNTY (1)

APPENDIX B. PHYSICAL AND CHEMICAL PROPERTIES OF AGRICULTURAL SOILS IN JOHNSON COUNTY (1)

Soil series and map symbols	Depth Fe	Permeability In/hr	Available water capacity In/in	Soil reaction pH	Salinity Mmhos/cm	Shrink-swell potential	Risk of corrosion		Erosion factors		Wind erodibility group
							Uncoated steel	Concrete	K	T	
Brookston: Br	0-17 17-46 46-60	0.6-2.0 0.6-2.0 0.2-0.6	0.21-0.24 0.15-0.19 0.05-0.10	6.0-7.3 6.6-7.3 7.4-8.4	<2 <2 <2	Moderate Moderate Moderate	High High High	Low Low Low			7
Cresley: CrA	0-13 13-30 30-60	0.6-2.0 0.00-0.2 0.00-0.6	0.20-0.24 0.15-0.20 0.05-0.19	5.1-6.5 5.1-7.3 7.9-8.4	<2 <2 <2	Low Moderate Low	High High High	Moderate Moderate Low	0.37 0.37 0.37	3-2	5
CaB27: Cresley part	0-13 13-30 30-60	0.6-2.0 0.00-0.2 0.00-0.6	0.20-0.24 0.15-0.20 0.05-0.19	5.1-6.5 5.1-7.3 7.9-8.4	<2 <2 <2	Low Moderate Low	High High High	Moderate Moderate Low	0.37 0.37 0.37	3-2	5
Miami part	0-14 14-34 34-60	0.6-2.0 0.6-2.0 0.00-2.0	0.20-0.24 0.15-0.20 0.05-0.19	5.6-7.3 5.6-6.0 6.6-8.4	<2 <2 <2	Low Moderate Low	Low Moderate Low	Moderate Moderate Low	0.32 0.32 0.43	4-3	5
Ed: Ea	0-17 17-40 40-60	0.6-2.0 0.6-2.0 0.6-2.0	0.20-0.24 0.17-0.22 0.19-0.24	6.6-7.3 6.6-7.8 7.4-7.8	<2 <2 <2	Low Low Low	Moderate Moderate Moderate	Low Low Low			5
Vincastle: FvA	0-12 12-33 33-45 45-60	0.6-2.0 0.2-0.6 0.00-0.6 0.00-0.6	0.22-0.24 0.18-0.20 0.15-0.19 0.05-0.19	5.1-6.5 5.1-5.5 5.1-6.0 7.4-8.4	<2 <2 <2 <2	Low Moderate Moderate Low	High High High High	Moderate Moderate Moderate Low	0.37 0.37 0.37 0.37	4-3	5
Fox: FoA, FoB2, FvC2	0-15 15-31 31-60	0.6-2.0 0.6-2.0 >20	0.20-0.22 0.12-0.14 0.02-0.04	5.6-6.5 6.1-7.8 7.9-8.4	<2 <2 <2	Low Moderate Low	Low Low Low	Low Low Low	0.32 0.32 0.10	3-2	6
Genesee: Gs	0-8 8-40 40-60	0.6-2.0 0.6-2.0 0.6-2.0	0.20-0.24 0.17-0.22 0.19-0.21	6.1-7.8 6.1-8.4 7.4-8.4	<2 <2 <2	Low Low Low	Low Low Low	Low Low Low			5
Hemlock: HsF	0-6 6-14 14-60	0.6-2.0 0.2-2.0 0.2-2.0	0.18-0.24 0.14-0.22 0.07-0.11	6.1-7.8 6.1-7.8 6.1-8.4	<2 <2 <2	Low Low Low	Low Low Low	Low Low Low	0.32 0.32 0.32	5-4	5
Hickory: HsD2, HsF	0-13 13-63 63-73	0.6-2.0 0.6-2.0 0.6-2.0	0.20-0.22 0.15-0.19 0.11-0.19	4.5-6.0 5.1-5.5 5.1-8.4	<2 <2 <2	Low Moderate Low	Low Moderate Low	High Moderate Low	0.32 0.32 0.32	5-4	6
Miami: MiB2, MiC2, MiD2, MiE	0-14 14-34 34-60	0.6-2.0 0.6-2.0 0.00-2.0	0.20-0.24 0.15-0.20 0.05-0.19	5.6-7.3 5.6-6.0 6.6-8.4	<2 <2 <2	Low Moderate Low	Low Moderate Low	Moderate Moderate Low	0.32 0.32 0.43	4-3	5
MtB3, MiC3, MiD3	0-7 7-34 34-60	0.6-2.0 0.6-2.0 0.00-2.0	0.17-0.19 0.15-0.20 0.05-0.19	5.6-7.3 5.6-6.0 6.6-8.4	<2 <2 <2	Moderate Moderate Low	Moderate Moderate Low	Moderate Moderate Low	0.32 0.32 0.43		4
Muen: MuA	0-14 14-46 46-60	0.6-2.0 0.2-0.6 0.6-2.0	0.22-0.24 0.18-0.20 0.20-0.22	5.1-6.0 5.1-6.0 5.6-7.3	<2 <2 <2	Low Low Low	Moderate High Moderate	Moderate Moderate Moderate	0.37 0.43 0.43	4-3	5

APPENDIX B. (CONTINUED)

Masking: MxG	0-10 10-25 25-34 34	2.0-6.0 0.6-2.0 0.6-2.0 0.6-2.0	0.12-0.18 0.08-0.14 0.02-0.12	4.5-6.0 4.5-5.5 4.5-5.5	<2 <2 <2	Low Low Low	Low Low Low	High High High	0.28 0.28 0.17	3	5
Nineveh: NnA	0-8 8-27 27-36 36-60	0.6-2.0 0.6-2.0 0.6-2.0 >20	0.20-0.22 0.15-0.10 0.13-0.10 0.02-0.04	6.6-7.3 6.6-7.3 6.6-7.8 7.4-8.4	<2 <2 <2 <2	Low Low Low Low	Low Low Low Low	Low Low Low Low	0.28 0.28 0.10 0.10	3-2	5
Ockley: OcA, OcB2	0-11 11-22 22-50 50-60	0.6-2.0 0.6-2.0 0.6-2.0 >20	0.20-0.24 0.15-0.20 0.12-0.14 0.02-0.04	5.6-6.5 4.5-6.0 5.6-6.5 7.4-8.4	<2 <2 <2 <2	Low Moderate Moderate Low	Low Moderate Moderate Low	Moderate Moderate Moderate Low	0.37 0.37 0.24 0.10	4-3	5
Palma: Pa	0-28 28-60	2.0-6.0 0.6-2.0	0.35-0.45 0.05-0.19	5.1-7.8 6.1-8.4	<2 <2	High High	High High	Moderate Low			3
Parker: PAB2, PaC2	0-13 13-36 36-60	0.6-2.0 0.6-2.0 0.6-2.0	0.22-0.24 0.18-0.20 0.16-0.18	5.1-6.5 4.5-5.0 4.5-5.5	<2 <2 <2	Low Low Low	Moderate Moderate Moderate	Moderate High High	0.37 0.37 0.28	4-3	5
Rensselaer: Re	0-14 14-42 42-60	0.00-0.2 0.00-0.2 0.6-2.0	0.21-0.23 0.15-0.19 0.10-0.21	6.6-7.3 6.6-7.3 7.9-8.4	<2 <2 <2	Moderate Moderate Low	Moderate Moderate Low	High High High			7
Rose: Rs	0-22 22-60	0.6-2.0 0.6-2.0	0.10-0.22 0.10-0.22	6.1-7.8 6.1-7.8	<2 <2	Low Low	Low Low	Low Low			5
Shush: Sh	0-8 8-35 35-60	0.6-2.0 0.6-2.0 0.6-2.0	0.22-0.24 0.20-0.22 0.19-0.21	6.6-7.3 6.6-7.3 6.6-7.3	<2 <2 <2	Low Low Low	Low Low Low	Low Low Low			5
Sheeth: Sk	0-17 17-27 27-48 48-60	0.6-2.0 0.6-2.0 0.6-2.0 >20	0.20-0.24 0.15-0.19 0.14-0.16 0.02-0.04	6.6-7.3 5.6-6.5 6.6-8.4 7.9-8.4	<2 <2 <2 <2	Low Moderate Moderate Low	Low Moderate Moderate Low	Low Low Low Low			5
Shuan: Sn	0-14 14-38 38-60	0.6-2.0 0.2-2.0 0.2-2.0	0.20-0.24 0.15-0.19 0.16-0.20	6.1-7.8 6.1-7.8 6.6-7.8	<2 <2 <2	Moderate Moderate Low	Moderate Moderate Low	High High High			5
Wellston: WsC2	0-8 8-27 27-52 52	0.6-2.0 0.6-2.0 0.6-2.0	0.18-0.22 0.17-0.21 0.12-0.17	5.1-6.5 4.5-6.0 4.5-6.0	<2 <2 <2	Moderate Moderate Moderate	Moderate Moderate Moderate	Moderate High High	0.32	4-3	5
Westland: We	0-15 15-38 38-48 48-60	0.6-2.0 0.00-0.2 0.00-0.2 >20	0.18-0.21 0.15-0.19 0.14-0.16 0.02-0.04	5.6-7.3 5.6-7.3 5.6-7.3 7.1-8.4	<2 <2 <2 <2	Moderate Moderate Moderate Low	Moderate Moderate Moderate Low	High High High Low			5
Whitaker: Wh	0-12 12-16 16-60	0.6-2.0 0.6-2.0 0.6-6.0	0.20-0.24 0.15-0.19 0.10-0.21	5.6-7.3 5.1-6.0 6.6-8.4	<2 <2 <2	Low Moderate Low	Low Moderate Low	Moderate Moderate Low	0.37 0.37 0.37	5	5

APPENDIX C

ENGINEERING INDEX PROPERTIES OF AGRICULTURAL
SOILS IN JOHNSON COUNTY (1)

APPENDIX C. ENGINEERING INDEX PROPERTIES OF AGRICULTURAL SOILS IN JOHNSON COUNTY (1)

Soil series and map symbols	Depth	USDA texture	Classification		Fring-ments >3 inches	Percentage passing sieve number—				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
Brookston: Br	0-17	Silty clay loam	CL, CH	A-6, A-7	0	100	98-100	95-100	75-95	26-48	16-20
	17-40	Clay loam	CL	A-6, A-7	0	98-100	90-100	85-95	75-85	36-52	18-30
	40-60	Loam	CL	A-6, A-6	0-3	90-100	85-95	78-90	55-70	22-30	7-15
Crealey: CrA	0-13	Silt loam	CL, CL-MI	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	13-30	Clay loam	CL, CH	A-6, A-7	0-3	92-99	89-97	78-93	64-76	37-55	17-31
	30-60	Loam	CL, MI, CL-MI	A-4, A-6	0-3	88-91	83-89	74-87	50-64	17-30	2-14
CaB2 ² : Crealey part	0-13	Silt loam	CL, CL-MI	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	13-30	Clay loam	CL, CH	A-6, A-7	0-3	92-99	89-97	78-93	64-76	37-55	17-31
	30-60	Loam	CL, MI, CL-MI	A-4, A-6	0-3	88-91	83-89	74-87	50-64	17-30	2-14
Miami part	0-14	Silt loam	CL, CL-MI	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	14-31	Clay loam	CL	A-6, A-7	0	92-99	89-97	78-93	64-76	37-55	17-31
	31-60	Loam	CL, CL-MI	A-4, A-6	0-3	88-91	83-89	74-87	50-64	17-30	2-14
Ed: Ee	0-17	Silt loam	MI, CL	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	17-40	Silt loam, loam	MI, CL	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	40-60	Stratified sandy loam to silt loam	MI, CL	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
Fincaisle: FoA	0-12	Silt loam	CL, MI	A-4, A-6	0	100	100	80-100	50-90	22-31	6-15
	12-33	Silty clay loam	CL, CH	A-6, A-7	0	95-100	90-100	85-95	61-95	37-50	17-31
	33-45	Clay loam	CL, CL	A-7	0	95-100	90-100	85-95	61-95	37-50	17-31
Fox: FoA, FoB2, FxC2 ²	45-60	Loam	CL, MI	A-4	0-3	88-96	82-90	70-86	50-66	18-24	6-10
	0-15	Loam	MI	A-4	0	95-100	90-100	85-95	55-90	20-30	2-4
	15-34	Sandy clay loam, gravelly sandy clay loam	CL, SC	A-6	0	85-100	75-95	65-95	45-75	25-35	10-20
Geneese: Ge	34-60	Sand and gravel	SP, SP-SM	A-1	0-5	55-75	40-65	20-40	2-10	NP	NP
	0-8	Loam	MI, CL	A-4, A-6	0	100	100	80-100	50-90	26-40	5-15
	8-40	Silt loam	MI, CL	A-4, A-6	0	100	100	80-100	50-90	26-40	5-15
Hazenpin: HeF	40-60	Stratified sandy loam to silt loam	MI, CL	A-4, A-6	0	100	90-100	70-80	50-70	26-40	5-15
	0-6	Loam	CL, CL-MI	A-4, A-6	0-5	90-100	85-100	70-100	60-95	25-40	6-20
	6-14	Loam	CL, CL-MI	A-4, A-6, A-7	0-5	85-100	80-100	65-100	60-95	20-50	6-25
Hickory: HxD2, HxF	14-60	Loam	CL, CL-MI	A-4, A-6, A-7	0-5	85-100	80-100	65-100	60-95	20-50	5-25
	0-13	Silt loam	CL, MI, CL	A-6, A-4	0-5	95-100	90-100	80-100	85-95	20-35	6-15
	13-63	Clay loam	CL	A-6, A-7	0-5	95-100	90-100	80-95	75-90	30-50	15-30
	63-73	Loam	CL-MI, CL	A-4, A-6	0-5	85-100	85-95	80-95	60-80	20-40	6-20

APPENDIX C (CONTINUED)

Soil series and map symbols	Depth	USDA texture	Classification		Frag- ments > 3 inches	Percentage passing sieve number—				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
Black: Sk	0-17	Loam	CL, ML	A-2, A-6	0	100	60-100	75-95	50-85	22-30	4-12
	17-27	Clay loam	CL	A-6	0	85-95	85-95	80-90	65-75	20-40	20-30
	27-48	Gravelly clay loam	CL	A-6	0-3	65-75	60-70	55-70	50-70	30-40	20-30
	48-60	Stratified sand to gravelly sand	SP, GP, SP-SM	A-1	1-5	30-70	22-55	7-20	2-10		NP
Brown: So	0-14	Clay loam, silty clay loam	CL, ML	A-6, A-7, A-2	0	100	95-100	85-100	70-95	30-50	8-15
	14-38	Clay loam	CL, ML	A-6, A-7, A-4	0	100	90-100	85-100	75-95	30-45	8-18
	38-60	Stratified loam to silty clay loam	ML, CL	A-1, A-6	0	95-100	90-100	80-95	65-90	25-40	0-1
	0-8	Silt loam	ML	A-4	0	95-100	90-100	85-100	70-95	20-34	4-10
Wellston: WoC2	8-27	Silt loam, silty clay loam	CL, ML	A-6, A-4	0-5	75-100	70-100	60-95	60-90	25-40	8-18
	27-52	Silt loam	ML, CL, GM	A-1, A-6	0-10	65-100	65-100	60-90	40-65	20-35	5-14
	52	Unweathered bedrock									
	0-15	Clay loam	CL	A-6	0	95-100	90-100	85-95	65-75	27-38	11-20
Westland: Wo	15-38	Clay loam	CL	A-6	0	95-100	90-100	80-90	65-75	30-40	20-30
	38-48	Gravelly clay loam	CL	A-6	0-5	65-75	60-70	55-70	50-70	30-40	20-30
	48-60	Stratified sand to gravelly sand	SP, GP, SP-SM	A-1	1-5	30-70	22-55	7-20	2-10		NP
	0-12	Silt loam	CL, CL, ML	A-1, A-6	0	100	95-100	80-100	60-90	22-33	4-12
Whitaker: Wb	12-46	Clay loam, loam	CL	A-6, A-7	0	100	95-100	90-100	70-80	30-47	12-20
	46-60	Stratified coarse sand to silt clay loam	CL, SC, CL, ML, SM	A-4	0	100-100	98-100	94-100	40-60	5-24	4-9

APPENDIX D

STATISTICAL STREAM FLOW DATA FOR SELECTED
STREAMS IN JOHNSON COUNTY (35)

APPENDIX D-1 (CONTINUED)

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
0	0.00	0	15341	100.00	12	11.0	917	11115	72.45	24	340.0	358	1060	6.91
1	0.50	6	15341	100.00	13	15.0	832	10198	66.48	25	460.0	219	702	4.58
2	0.66	11	15335	99.96	14	20.0	956	9366	61.05	26	610.0	172	483	3.15
3	0.88	31	15324	99.89	15	27.0	951	8410	54.82	27	810.0	131	311	2.03
4	1.2	45	15293	99.69	16	35.0	1140	7459	48.62	28	1100.0	67	180	1.17
5	1.6	141	15248	99.29	17	47.0	1168	6319	41.19	29	1400.0	48	113	0.74
6	2.1	291	15107	98.47	18	63.0	931	5151	33.58	30	1900.0	32	65	0.42
7	2.8	531	14816	96.58	19	83.0	884	4270	27.51	31	2500.0	14	33	0.22
8	3.7	806	14285	93.12	20	110.0	842	3236	21.75	32	3300.0	11	19	0.12
9	4.9	860	13479	87.86	21	150.0	504	2494	16.26	33	4400.0	7	8	0.05
10	6.4	957	12619	82.26	22	190.0	560	1990	12.97	34	5900.0	1	1	0.01
11	8.6	547	11662	76.02	23	260.0	370	1430	9.32					

VALUE EXCEEDED "P" PERCENT OF TIME

P95 +	3.2
P90 +	4.4
P75 +	9.3
P70 +	12.6
P50 +	33.2
P25 +	94.8
P10 +	247.0

LOWEST MEAN DISCHARGE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR (ENDING MARCH 31)

YEAR	1	3	7	14	30	60	90	120	183
1944	1.80 6	1.80 6	2.10 6	2.70 11	3.20 11	4.30 13	4.50 8	5.70 10	13.00 13
1945	0.80 3	0.83 3	0.93 2	1.10 2	1.40 1	2.10 4	4.40 7	4.50 6	5.30 3
1946	2.70 22	2.80 21	3.20 22	3.50 22	3.80 20	11.00 35	16.00 35	48.00 39	49.00 35
1947	0.80 4	0.93 4	1.30 3	1.50 3	2.20 5	4.30 14	4.90 10	8.10 17	15.00 15
1948	2.80 25	2.80 22	3.30 23	3.80 24	4.10 25	5.80 21	6.80 21	7.90 16	16.00 17
1949	2.00 14	2.20 12	2.30 10	2.40 9	2.60 7	3.70 8	6.20 18	28.00 36	37.00 31
1950	2.50 19	2.60 17	3.00 19	4.70 31	7.50 34	14.00 37	15.00 34	19.00 30	22.00 24
1951	4.90 36	5.00 33	5.40 34	5.60 32	6.10 31	10.00 33	20.00 36	19.00 31	38.00 32
1952	1.90 10	2.30 15	2.90 16	3.30 19	3.80 21	4.10 12	5.00 11	11.00 24	48.00 34
1953	1.80 7	1.80 7	2.00 6	2.20 6	2.50 6	3.40 5	4.10 6	4.60 7	8.50 9
1954	0.50 1	0.53 1	0.73 1	0.86 1	1.40 2	2.00 1	2.40 1	2.80 2	3.40 2
1955	0.60 2	0.77 2	1.30 4	1.70 5	2.10 3	2.20 2	2.40 2	2.70 1	3.30 1
1956	1.90 11	2.20 13	2.40 11	2.90 13	3.20 12	5.20 20	12.00 32	17.00 29	35.00 30
1957	2.10 15	2.20 14	2.70 14	3.00 14	3.50 16	4.40 15	5.40 15	7.50 14	21.00 23
1958	4.70 33	5.30 36	5.60 35	5.70 33	8.00 35	9.30 31	11.00 30	24.00 33	97.00 41
1959	18.00 42	18.00 42	20.00 42	24.00 42	25.00 42	47.00 42	54.00 42	68.00 41	83.00 40
1960	2.70 23	2.70 18	2.90 17	3.00 15	3.70 18	5.80 23	6.60 19	8.40 18	15.00 16
1961	1.80 8	1.80 8	2.00 7	2.30 7	2.80 8	4.00 11	5.20 12	5.40 8	8.00 8
1962	2.20 16	2.70 19	3.10 20	3.10 17	4.00 22	5.70 22	6.10 17	7.60 15	12.00 12
1963	4.80 34	5.00 34	5.30 33	6.10 35	6.50 33	7.40 28	7.60 25	8.60 20	14.00 14
1964	2.00 12	2.10 10	2.20 9	2.30 8	2.80 9	3.60 6	3.40 4	4.00 4	7.60 7
1965	1.40 5	1.50 5	1.60 5	1.60 4	2.10 4	2.60 3	2.80 3	3.60 3	5.80 4
1966	3.60 31	3.60 31	3.80 29	4.20 27	5.60 28	13.00 36	21.00 37	24.00 34	28.00 27
1967	2.00 13	2.20 11	2.60 13	2.70 12	3.40 14	4.50 16	7.10 22	11.00 25	20.00 20
1968	2.20 17	2.40 16	2.90 18	3.00 16	3.30 13	3.80 9	4.60 9	5.50 9	11.00 10
1969	4.40 32	4.60 32	4.80 32	5.90 34	6.30 32	7.20 27	7.50 24	23.00 32	44.00 33
1970	8.30 40	8.60 40	9.60 40	13.00 40	14.00 40	17.00 40	29.00 40	58.00 40	63.00 37
1971	3.20 29	3.50 28	3.80 30	4.30 28	4.60 26	4.90 18	5.90 16	7.20 13	11.00 11
1972	2.50 18	2.90 23	3.10 21	3.20 18	3.50 15	3.70 7	4.00 5	4.10 5	6.70 5
1973	2.70 24	3.20 26	3.50 26	3.50 23	3.70 19	5.00 19	8.70 28	9.80 22	28.00 28
1974	6.00 37	6.10 37	6.50 36	7.60 38	10.00 39	11.00 34	14.00 33	26.00 35	66.00 38
1975	4.80 35	5.30 35	7.20 39	8.10 39	8.50 36	16.00 39	24.00 38	33.00 38	56.00 36
1976	3.00 27	3.40 27	3.70 27	4.30 29	5.20 27	6.50 26	8.20 26	15.00 27	31.00 29
1977	1.90 9	2.00 9	2.40 12	2.60 10	3.00 10	4.00 10	5.30 13	6.50 12	7.60 6
1978	2.60 20	2.70 20	2.80 15	3.40 20	5.80 30	8.10 30	10.00 29	16.00 28	20.00 21
1979	6.00 38	6.30 38	6.90 37	7.20 36	9.40 38	15.00 38	25.00 39	32.00 37	68.00 39
1980	16.00 41	16.00 41	17.00 41	18.00 41	20.00 41	26.00 41	46.00 41	98.00 42	109.00 42
1981	6.60 39	7.00 39	7.00 38	7.30 37	9.20 37	9.70 32	12.00 31	12.00 26	21.00 22
1982	3.40 30	3.60 29	4.00 31	4.70 30	5.70 29	7.60 29	8.50 27	9.30 21	25.00 25
1983	2.90 26	3.00 24	3.40 25	3.90 25	4.00 23	4.50 17	5.40 14	6.30 11	17.00 18
1984	2.60 21	3.00 25	3.30 24	3.40 21	3.60 17	6.00 25	6.60 20	11.00 23	27.00 26
1985	3.20 28	3.60 30	3.70 28	3.90 26	4.10 24	5.90 24	7.10 23	8.50 19	20.00 19

APPENDIX D-1 (CONTINUED)

HIGHEST MEAN DISCHARGE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183
1944	3610.00 11	2400.00 9	1410.00 7	757.00 15	497.00 16	345.00 18	282.00 16	221.00 22	152.00 28
1945	2380.00 25	1660.00 23	1150.00 18	666.00 18	482.00 20	382.00 11	288.00 15	264.00 10	198.00 17
1946	1800.00 30	1270.00 30	733.00 32	396.00 35	260.00 37	214.00 35	220.00 27	179.00 31	167.00 26
1947	3410.00 15	2030.00 16	1410.00 8	773.00 12	492.00 18	399.00 9	316.00 9	248.00 18	219.00 12
1948	1450.00 32	905.00 34	696.00 33	445.00 33	381.00 26	254.00 28	217.00 29	187.00 29	136.00 33
1949	4490.00 8	2460.00 8	1230.00 16	769.00 14	694.00 2	487.00 2	398.00 3	332.00 4	244.00 7
1950	3610.00 12	2390.00 10	1510.00 4	1250.00 1	866.00 1	625.00 1	482.00 1	410.00 1	298.00 1
1951	2290.00 26	1490.00 26	868.00 26	568.00 23	359.00 29	332.00 19	297.00 10	282.00 8	249.00 5
1952	5880.00 2	3240.00 2	1550.00 3	1000.00 3	585.00 6	484.00 3	398.00 4	370.00 2	294.00 2
1953	1450.00 33	890.00 36	524.00 37	353.00 38	261.00 36	180.00 38	183.00 35	155.00 35	123.00 37
1954	381.00 42	272.00 42	166.00 42	99.00 42	81.00 42	66.00 42	52.00 42	48.00 42	38.00 42
1955	960.00 41	589.00 41	498.00 40	299.00 40	241.00 39	176.00 40	147.00 40	131.00 39	105.00 39
1956	4610.00 7	2520.00 6	1250.00 12	712.00 17	405.00 23	260.00 26	213.00 31	213.00 25	183.00 21
1957	4620.00 6	2290.00 11	1430.00 5	870.00 8	518.00 13	459.00 6	366.00 5	355.00 3	273.00 3
1958	3420.00 14	1690.00 22	1250.00 13	739.00 16	514.00 14	375.00 12	297.00 11	251.00 15	194.00 19
1959	3730.00 10	2260.00 13	1100.00 19	597.00 21	506.00 15	362.00 16	279.00 17	251.00 16	201.00 15
1960	2150.00 27	1390.00 27	849.00 27	492.00 27	324.00 33	206.00 36	174.00 36	157.00 34	135.00 34
1961	5700.00 3	3470.00 1	1820.00 2	954.00 5	659.00 3	465.00 5	416.00 2	326.00 5	220.00 11
1962	2820.00 20	2080.00 15	1060.00 20	524.00 26	363.00 28	243.00 31	221.00 26	186.00 30	159.00 27
1963	5560.00 4	2950.00 4	1410.00 6	809.00 11	555.00 9	315.00 22	217.00 30	169.00 32	129.00 35
1964	4130.00 9	2520.00 7	1350.00 11	771.00 13	522.00 12	474.00 4	329.00 8	251.00 17	170.00 24
1965	2960.00 17	1580.00 24	869.00 25	466.00 31	388.00 24	251.00 29	242.00 24	198.00 26	142.00 30
1966	1000.00 40	750.00 39	461.00 41	275.00 41	180.00 41	140.00 41	116.00 41	99.00 41	84.00 40
1967	2780.00 22	2210.00 14	1370.00 10	1040.00 2	595.00 5	365.00 15	291.00 13	260.00 13	228.00 10
1968	6260.00 1	3180.00 3	1830.00 1	981.00 4	562.00 8	326.00 21	263.00 21	260.00 14	229.00 9
1969	3490.00 13	2270.00 12	1220.00 17	870.00 9	583.00 7	373.00 13	290.00 14	236.00 19	187.00 20
1970	1150.00 37	787.00 37	516.00 39	374.00 36	243.00 38	178.00 39	174.00 37	154.00 36	138.00 32
1971	2020.00 28	1280.00 29	1010.00 21	644.00 19	435.00 21	270.00 25	202.00 32	164.00 33	126.00 36
1972	1930.00 29	1090.00 31	782.00 29	534.00 25	337.00 32	223.00 34	174.00 38	146.00 38	113.00 38
1973	1300.00 34	894.00 35	607.00 35	475.00 28	421.00 22	329.00 20	262.00 22	234.00 20	231.00 8
1974	1290.00 35	1070.00 32	678.00 34	470.00 30	343.00 31	254.00 27	221.00 25	219.00 23	198.00 16
1975	2900.00 18	1950.00 17	1010.00 22	596.00 22	486.00 19	397.00 10	348.00 6	309.00 6	248.00 6
1976	1050.00 39	777.00 38	527.00 36	307.00 39	274.00 35	228.00 33	218.00 28	195.00 27	144.00 29
1977	1090.00 38	623.00 40	519.00 38	371.00 37	222.00 40	183.00 37	148.00 39	116.00 40	83.00 41
1978	2560.00 23	1890.00 19	1240.00 14	853.00 10	493.00 17	311.00 23	276.00 19	265.00 11	195.00 18
1979	5340.00 5	2580.00 5	1230.00 15	936.00 6	606.00 4	400.00 8	292.00 12	263.00 12	269.00 4
1980	1270.00 36	983.00 33	748.00 31	446.00 32	315.00 34	241.00 32	184.00 33	187.00 28	176.00 23
1981	2420.00 24	1930.00 18	1390.00 9	872.00 7	553.00 10	371.00 14	269.00 20	222.00 21	167.00 25
1982	3120.00 16	1860.00 20	932.00 24	618.00 20	528.00 11	433.00 7	340.00 7	289.00 7	212.00 14
1983	1690.00 31	1350.00 28	766.00 30	423.00 34	371.00 27	246.00 30	183.00 34	154.00 37	139.00 31
1984	2880.00 19	1560.00 25	835.00 28	475.00 29	344.00 30	297.00 24	242.00 23	213.00 24	180.00 22
1985	2810.00 21	1760.00 21	943.00 23	560.00 24	383.00 25	354.00 17	277.00 18	268.00 9	214.00 13

ANNUAL VALUES

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING MARCH 31

1944	84.00 14
1945	105.00 22
1946	126.00 26
1947	71.00 9
1948	127.00 28
1949	153.00 36
1950	145.00 34
1951	142.00 33
1952	168.00 39
1953	81.00 13
1954	38.00 2
1955	51.00 5
1956	103.00 21
1957	80.00 12
1958	180.00 42
1959	178.00 41
1960	86.00 15

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING SEPTEMBER 30

1944	78.00 33
1945	109.00 22
1946	102.00 24
1947	120.00 17
1948	81.00 31
1949	132.00 12
1950	166.00 3
1951	153.00 5
1952	170.00 2
1953	65.00 37
1954	20.00 42
1955	59.00 39
1956	133.00 10
1957	150.00 7
1958	155.00 4
1959	118.00 18
1960	82.00 29

APPENDIX D-1 (CONTINUED)

ANNUAL VALUES--Continued

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING MARCH 31

1961	79.00 10
1962	126.00 27
1963	86.00 16
1964	61.00 7
1965	95.00 18
1966	69.00 8
1967	114.00 25
1968	95.00 19
1969	148.00 35
1970	107.00 23
1971	80.00 11
1972	35.00 1
1973	124.00 31
1974	120.00 30
1975	162.00 37
1976	99.00 20
1977	40.00 3
1978	94.00 17
1979	140.00 32
1980	170.00 40
1981	51.00 4
1982	165.00 38
1983	53.00 6
1984	108.00 24
1985	128.00 29

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING SEPTEMBER 30

1961	114.00 19
1962	100.00 25
1963	70.00 35
1964	87.00 27
1965	81.00 30
1966	50.00 40
1967	129.00 13
1968	133.00 11
1969	129.00 14
1970	80.00 32
1971	68.00 36
1972	63.00 38
1973	152.00 6
1974	121.00 16
1975	141.00 8
1976	84.00 28
1977	46.00 41
1978	134.00 9
1979	176.00 1
1980	112.00 20
1981	90.00 26
1982	112.00 21
1983	76.00 34
1984	106.00 23
1985	129.00 15

NORMAL MONTHLY MEANS (ALL DAYS)

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT
1943	*	*	103.00	58.90	148.00	252.00	57.00	443.00	118.00	13.70	15.20	37.10
1944	3.23	5.62	4.89	30.50	65.50	206.00	476.00	123.00	14.30	2.03	5.87	9.94
1945	2.83	6.05	5.26	15.20	149.00	456.00	237.00	94.60	238.00	17.10	18.40	69.80
1946	90.60	52.00	151.00	129.00	189.00	241.00	32.30	248.00	48.90	20.80	17.40	3.08
1947	5.57	10.60	71.70	232.00	68.60	86.70	285.00	210.00	404.00	15.30	45.90	7.92
1948	4.56	8.06	12.10	130.00	156.00	257.00	198.00	65.30	15.20	123.00	7.51	3.21
1949	8.48	108.00	144.00	576.00	254.00	229.00	56.60	33.70	29.90	23.00	14.00	14.70
1950	40.40	12.10	91.50	837.00	402.00	195.00	167.00	78.20	84.70	24.60	7.48	46.20
1951	8.86	216.00	204.00	320.00	340.00	223.00	184.00	95.70	87.70	150.00	11.20	4.27
1952	4.07	47.10	442.00	490.00	234.00	263.00	272.00	53.30	196.00	22.90	5.43	5.17
1953	2.94	5.29	17.60	78.30	72.20	249.00	101.00	186.00	22.00	38.90	3.54	2.48
1954	1.82	3.91	3.95	29.80	15.10	42.40	52.80	56.50	29.50	2.61	2.43	2.36
1955	3.71	4.31	21.60	86.30	117.00	231.00	75.60	76.00	30.40	25.10	4.82	32.80
1956	41.90	291.00	58.80	22.80	379.00	122.00	146.00	150.00	133.00	157.00	15.10	6.35
1957	3.76	7.10	56.50	81.20	148.00	64.40	426.00	437.00	225.00	305.00	31.40	10.10
1958	9.41	66.20	299.00	123.00	41.00	75.70	87.50	167.00	463.00	216.00	118.00	87.00
1959	26.30	101.00	67.80	324.00	286.00	198.00	131.00	207.00	43.10	15.60	7.69	5.62
1960	7.59	32.40	83.40	126.00	281.00	105.00	58.20	56.70	189.00	41.30	12.40	7.09
1961	2.82	6.11	7.24	17.60	72.60	475.00	243.00	475.00	27.20	14.90	6.24	7.55
1962	5.69	13.10	72.40	206.00	178.00	267.00	52.30	67.70	19.40	263.00	26.80	29.30
1963	7.19	9.01	7.16	23.10	15.30	498.00	113.00	22.80	24.50	51.50	55.90	6.18
1964	3.26	4.43	2.90	11.20	18.30	410.00	516.00	46.00	11.80	13.30	3.24	2.62
1965	2.69	6.31	6.45	71.90	266.00	221.00	237.00	47.90	13.30	48.70	7.24	64.50
1966	24.70	14.40	26.90	121.00	162.00	65.50	50.00	82.50	15.40	27.10	5.05	8.12
1967	8.34	294.00	415.00	77.70	135.00	246.00	96.60	218.00	34.30	8.15	4.59	3.27
1968	6.63	11.30	238.00	146.00	277.00	99.10	96.90	510.00	126.00	24.60	55.80	7.03
1969	7.44	78.90	180.00	446.00	195.00	40.90	173.00	35.00	50.00	304.00	26.40	16.00
1970	46.50	157.00	68.30	128.00	160.00	123.00	186.00	54.80	28.60	10.30	5.08	5.32
1971	8.95	20.00	41.80	66.10	441.00	120.00	28.30	70.10	37.40	7.42	3.81	4.14
1972	4.58	3.97	53.20	56.20	35.50	114.00	331.00	72.10	57.40	14.60	5.33	7.95
1973	12.90	277.00	191.00	150.00	125.00	365.00	280.00	45.50	179.00	145.00	41.60	10.20
1974	12.60	110.00	204.00	264.00	116.00	157.00	186.00	195.00	110.00	18.80	16.90	64.80
1975	25.20	98.30	183.00	268.00	428.00	256.00	169.00	50.50	80.60	30.10	7.41	7.29
1976	27.10	59.20	197.00	229.00	181.00	154.00	35.50	25.50	50.40	25.30	21.00	6.74
1977	11.30	8.38	6.52	3.13	118.00	172.00	99.20	69.00	22.20	24.50	9.87	8.98
1978	41.10	32.80	300.00	35.60	23.20	446.00	112.00	235.00	136.00	149.00	59.00	20.10
1979	17.30	50.30	118.00	190.00	237.00	360.00	252.00	65.40	58.20	492.00	231.00	31.50
1980	22.70	223.00	200.00	94.50	83.30	280.00	158.00	77.50	61.30	19.90	111.00	15.00
1981	10.10	12.00	16.50	9.32	81.90	45.90	143.00	512.00	130.00	45.50	60.00	10.40
1982	8.06	9.37	59.50	316.00	390.00	308.00	109.00	44.50	81.40	23.90	6.64	5.47
1983	4.51	11.20	156.00	64.10	73.70	55.30	235.00	246.00	38.00	17.70	8.37	3.75
1984	32.00	138.00	159.00	39.00	126.00	250.00	339.00	129.00	39.60	13.20	6.58	6.29
1985	8.40	60.60	259.00	119.00	280.00	293.00	197.00	123.00	87.30	20.70	88.00	21.00

APPENDIX D-1 (CONTINUED)

OCT	NOV	DEC	JAN	FEB	MARCH
TWENTY FIFTH PERCENTILE					
4.40	7.82	17.60	39.00	73.70	114.00
FIFTIETH PERCENTILE					
8.37	17.19	72.40	119.00	149.00	223.00
SEVENTY FIFTH PERCENTILE					
23.19	99.00	191.00	229.00	266.00	293.00
APRIL	MAY	JUNE	JULY	AUG	SEPT
TWENTY FIFTH PERCENTILE					
87.50	54.80	28.60	15.30	5.87	5.32
FIFTIETH PERCENTILE					
158.00	78.20	50.40	24.50	11.20	7.92
SEVENTY FIFTH PERCENTILE					
237.00	207.00	126.00	51.50	31.40	20.10

APPENDIX D-2 (CONTINUED)

CLASS	VALUE	TOTAL	ACCU	PERCT	CLASS	VALUE	TOTAL	ACCU	PERCT	CLASS	VALUE	TOTAL	ACCU	PERCT
0	0.0	0	15341	100.00	12	110.0	1010	10052	65.52	24	1600.0	286	1003	6.54
1	9.2	12	15341	100.00	13	140.0	816	9047	58.94	25	2000.0	203	737	4.80
2	12.0	10	15329	99.92	14	170.0	950	8226	53.62	26	2500.0	159	534	3.48
3	14.0	19	15319	99.86	15	210.0	1124	7276	47.43	27	3100.0	131	375	2.44
4	18.0	115	15300	99.73	16	270.0	882	6152	40.10	28	3900.0	106	244	1.59
5	23.0	263	15185	98.98	17	330.0	987	5270	34.25	29	4900.0	55	138	0.90
6	28.0	360	14922	97.27	18	420.0	730	4283	27.92	30	6100.0	38	83	0.54
7	35.0	698	14562	94.92	19	520.0	701	3553	23.16	31	7700.0	22	45	0.29
8	44.0	718	13864	90.37	20	650.0	610	2852	18.59	32	9600.0	13	23	0.15
9	55.0	1033	13146	85.69	21	810.0	472	2242	14.61	33	12000.0	8	10	0.07
10	69.0	1121	12113	78.96	22	1000.0	455	1770	11.54	34	15000.0	2	2	0.01
11	87.0	940	10992	71.65	23	1300.0	312	1315	8.57					

VALUE EXCEEDED 'P' PERCENT OF TIME

P95 *	34.8
P90 *	44.9
P75 *	78.7
P70 *	93.2
P50 *	193.0
P25 *	481.0
P10 *	1160.0

LOWEST MEAN DISCHARGE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	14	30	60	90	120	183
1944	30.00 15	31.00 15	35.00 17	38.00 18	40.00 16	45.00 16	50.00 14	52.00 10	62.00 7
1945	18.00 4	18.00 3	19.00 3	20.00 2	22.00 3	23.00 2	28.00 4	29.00 2	32.00 1
1946	51.00 33	51.00 32	53.00 30	54.00 29	60.00 29	109.00 37	119.00 36	235.00 38	240.00 32
1947	20.00 6	21.00 6	23.00 6	25.00 9	27.00 8	31.00 7	38.00 7	48.00 8	89.00 13
1948	47.00 27	50.00 28	55.00 32	57.00 30	64.00 34	74.00 31	80.00 28	91.00 27	152.00 27
1949	34.00 19	35.00 18	37.00 18	41.00 20	42.00 19	45.00 17	57.00 19	126.00 32	155.00 28
1950	47.00 28	50.00 29	51.00 27	53.00 27	63.00 31	68.00 34	102.00 34	112.00 30	123.00 24
1951	55.00 35	58.00 36	63.00 37	65.00 36	72.00 36	100.00 36	157.00 38	148.00 33	286.00 35
1952	28.00 14	30.00 14	30.00 14	31.00 13	34.00 11	36.00 11	41.00 8	61.00 16	157.00 29
1953	32.00 16	35.00 19	37.00 19	39.00 19	40.00 17	44.00 15	52.00 15	53.00 11	85.00 11
1954	17.00 2	18.00 4	19.00 4	22.00 5	23.00 4	25.00 4	27.00 3	33.00 5	45.00 4
1955	9.20 1	9.60 1	10.00 1	12.00 1	12.00 1	18.00 1	20.00 1	28.00 1	34.00 2
1956	23.00 8	23.00 7	24.00 7	25.00 6	29.00 9	52.00 20	110.00 35	165.00 36	246.00 33
1957	32.00 17	32.00 16	33.00 15	34.00 15	34.00 12	35.00 8	41.00 9	49.00 9	81.00 10
1958	42.00 26	43.00 26	44.00 25	45.00 23	57.00 25	65.00 24	75.00 25	102.00 28	343.00 39
1959	106.00 41	109.00 41	122.00 41	141.00 42	148.00 42	188.00 42	295.00 42	302.00 40	504.00 41
1960	33.00 18	35.00 17	35.00 16	36.00 16	42.00 18	52.00 21	62.00 20	71.00 20	102.00 19
1961	36.00 21	38.00 22	40.00 22	43.00 21	44.00 20	49.00 18	54.00 17	58.00 14	71.00 9
1962	26.00 12	26.00 11	26.00 11	30.00 11	39.00 15	41.00 14	47.00 13	59.00 15	88.00 12
1963	48.00 29	49.00 27	53.00 28	57.00 31	59.00 28	74.00 32	79.00 26	77.00 21	93.00 17
1964	23.00 9	24.00 9	25.00 9	25.00 7	26.00 7	29.00 6	31.00 5	32.00 3	45.00 3
1965	18.00 3	18.00 2	19.00 2	21.00 3	22.00 2	24.00 3	27.00 2	32.00 4	62.00 5
1966	35.00 20	36.00 20	37.00 20	38.00 17	44.00 21	64.00 23	80.00 27	82.00 25	92.00 16
1967	24.00 10	25.00 10	26.00 10	29.00 10	34.00 13	40.00 12	46.00 12	54.00 12	90.00 14
1968	19.00 5	20.00 5	21.00 5	22.00 4	23.00 5	28.00 5	33.00 6	39.00 6	65.00 8
1969	55.00 36	58.00 37	60.00 34	61.00 34	62.00 30	68.00 27	94.00 31	178.00 37	246.00 34
1970	50.00 31	56.00 34	60.00 35	70.00 37	88.00 39	112.00 38	171.00 39	284.00 39	320.00 37
1971	40.00 25	41.00 23	42.00 23	46.00 24	50.00 23	57.00 22	67.00 21	78.00 22	91.00 15
1972	50.00 32	51.00 30	54.00 31	54.00 28	58.00 26	66.00 25	68.00 22	68.00 19	108.00 20
1973	58.00 38	58.00 38	60.00 36	65.00 35	70.00 35	80.00 33	101.00 33	118.00 31	202.00 31
1974	66.00 39	66.00 39	66.00 38	70.00 38	83.00 38	89.00 35	97.00 32	151.00 34	330.00 38
1975	55.00 37	57.00 35	66.00 39	78.00 39	80.00 37	135.00 39	156.00 37	154.00 35	294.00 36
1976	39.00 23	41.00 24	42.00 24	44.00 22	48.00 22	50.00 19	57.00 18	67.00 18	118.00 21
1977	27.00 13	28.00 13	30.00 12	33.00 14	36.00 14	41.00 13	53.00 16	62.00 17	62.00 6
1978	37.00 22	38.00 21	40.00 21	47.00 25	64.00 32	68.00 28	73.00 24	80.00 23	120.00 22
1979	85.00 40	86.00 40	89.00 40	93.00 40	117.00 40	143.00 40	208.00 40	317.00 41	436.00 40
1980	120.00 42	122.00 42	123.00 42	127.00 41	134.00 41	168.00 41	266.00 41	478.00 42	512.00 42
1981	53.00 34	54.00 33	57.00 33	60.00 33	64.00 33	67.00 26	83.00 29	83.00 26	141.00 26
1982	49.00 30	51.00 31	53.00 29	57.00 32	59.00 27	69.00 29	71.00 23	80.00 24	137.00 25
1983	25.00 11	27.00 12	30.00 13	31.00 12	33.00 10	35.00 9	43.00 11	48.00 7	94.00 18
1984	22.00 7	23.00 8	24.00 8	25.00 8	26.00 6	35.00 10	41.00 10	57.00 13	123.00 23
1985	40.00 24	41.00 25	45.00 26	48.00 26	51.00 24	74.00 30	91.00 30	110.00 29	182.00 30

APPENDIX D-2 (CONTINUED)

HIGHEST MEAN DISCHARGE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183
1944	10600.00 10	8150.00 10	5650.00 5	3180.00 12	2120.00 13	1540.00 14	1210.00 17	961.00 25	659.00 29
1945	6310.00 26	4420.00 30	3250.00 27	2320.00 26	1760.00 24	1410.00 19	1110.00 23	1030.00 20	760.00 24
1946	4480.00 34	3970.00 33	3410.00 24	1990.00 28	1320.00 34	1030.00 33	1020.00 28	835.00 31	775.00 23
1947	9220.00 14	6580.00 18	4570.00 16	2720.00 20	1700.00 26	1500.00 16	1250.00 13	1010.00 21	914.00 16
1948	6170.00 27	4690.00 27	3800.00 23	2480.00 24	2190.00 10	1370.00 21	1120.00 21	981.00 23	728.00 26
1949	10200.00 12	8280.00 9	4720.00 15	3140.00 13	2860.00 3	2060.00 3	1740.00 3	1450.00 3	1070.00 6
1950	12700.00 6	9520.00 5	6280.00 2	5610.00 1	4140.00 1	3110.00 1	2410.00 1	2020.00 1	1520.00 1
1951	7680.00 20	5520.00 22	3380.00 25	2470.00 25	1540.00 28	1370.00 22	1240.00 14	1160.00 12	1050.00 7
1952	12500.00 7	8100.00 11	4310.00 18	3260.00 11	1990.00 17	1530.00 15	1430.00 7	1310.00 6	1090.00 5
1953	6900.00 23	4450.00 29	2530.00 35	1610.00 36	1160.00 37	797.00 37	791.00 35	674.00 36	577.00 36
1954	2190.00 41	1870.00 41	1280.00 42	1020.00 41	786.00 41	561.00 41	453.00 41	403.00 41	291.00 42
1955	2010.00 42	1770.00 42	1650.00 40	1180.00 40	977.00 39	778.00 38	645.00 39	593.00 39	493.00 39
1956	19200.00 1	11100.00 1	5930.00 4	2990.00 16	1740.00 25	1190.00 28	959.00 31	1090.00 16	861.00 19
1957	8960.00 15	6920.00 16	4870.00 14	3020.00 14	1830.00 20	1720.00 8	1460.00 6	1320.00 5	1020.00 10
1958	6900.00 24	6130.00 20	4050.00 22	3000.00 15	1800.00 22	1740.00 7	1330.00 10	1170.00 9	888.00 17
1959	10800.00 9	8850.00 8	5100.00 11	2780.00 17	2310.00 7	1800.00 12	1240.00 15	1100.00 15	868.00 18
1960	5470.00 30	4080.00 32	3020.00 31	1810.00 32	1190.00 36	778.00 39	681.00 38	611.00 38	568.00 37
1961	14600.00 2	10800.00 3	6140.00 3	4230.00 2	2960.00 2	2120.00 2	1930.00 2	1530.00 2	1050.00 8
1962	4980.00 32	3810.00 34	2330.00 36	1720.00 34	1590.00 27	1080.00 31	979.00 30	805.00 32	617.00 33
1963	13500.00 4	10700.00 4	5530.00 7	3310.00 8	2520.00 4	1560.00 13	1120.00 22	882.00 28	634.00 30
1964	10900.00 8	8900.00 7	5630.00 6	3260.00 9	2120.00 14	1920.00 5	1260.00 8	1040.00 19	729.00 25
1965	6760.00 25	5240.00 24	3040.00 30	1730.00 33	1460.00 29	1080.00 32	1070.00 26	887.00 27	632.00 31
1966	2900.00 40	2250.00 40	1540.00 41	962.00 42	675.00 42	521.00 42	453.00 42	395.00 42	336.00 41
1967	8770.00 17	7730.00 13	5340.00 8	3260.00 10	2120.00 15	1280.00 26	1060.00 27	1010.00 22	930.00 15
1968	12900.00 3	11000.00 2	6740.00 1	3880.00 4	2290.00 8	1370.00 23	1170.00 19	1130.00 14	992.00 12
1969	12800.00 5	9230.00 6	4910.00 13	3440.00 6	2500.00 5	1640.00 11	1260.00 12	1050.00 18	844.00 21
1970	3990.00 36	3120.00 37	2290.00 37	1550.00 38	1080.00 38	822.00 36	824.00 34	744.00 34	668.00 28
1971	6110.00 28	5120.00 25	4180.00 21	2770.00 18	1940.00 18	1240.00 27	937.00 32	767.00 33	599.00 34
1972	4350.00 35	3370.00 36	2570.00 34	1970.00 29	1290.00 31	968.00 35	780.00 36	680.00 35	591.00 35
1973	5840.00 29	4720.00 26	2880.00 32	2140.00 27	1900.00 19	1460.00 17	1180.00 18	1070.00 17	1100.00 3
1974	5010.00 31	4610.00 28	3320.00 26	2500.00 23	1780.00 23	1320.00 24	1160.00 20	1140.00 13	1020.00 9
1975	10000.00 13	7400.00 14	4300.00 19	2570.00 21	2010.00 16	1700.00 9	1530.00 4	1370.00 4	1100.00 4
1976	3630.00 38	2890.00 38	2160.00 38	1590.00 37	1290.00 35	1100.00 29	997.00 29	871.00 29	625.00 32
1977	3120.00 39	2400.00 39	1940.00 39	1450.00 39	893.00 40	753.00 40	634.00 40	505.00 40	362.00 40
1978	8150.00 18	7140.00 15	4990.00 12	3620.00 5	2190.00 11	1290.00 20	1210.00 16	1170.00 10	940.00 14
1979	10300.00 11	7770.00 12	5230.00 9	4120.00 3	2380.00 6	1750.00 6	1290.00 11	1160.00 11	1130.00 2
1980	3960.00 37	3530.00 35	3150.00 28	1910.00 31	1400.00 30	1100.00 30	859.00 33	844.00 30	808.00 22
1981	7750.00 19	6560.00 19	5180.00 10	3320.00 7	2130.00 12	1430.00 18	1080.00 25	889.00 26	690.00 27
1982	7200.00 21	5680.00 21	4320.00 17	2760.00 19	2260.00 9	1940.00 4	1530.00 5	1300.00 7	968.00 13
1983	4580.00 33	4090.00 31	2810.00 33	1660.00 35	1380.00 32	979.00 34	744.00 37	640.00 37	567.00 38
1984	7100.00 22	5260.00 23	3150.00 29	1950.00 30	1360.00 33	1310.00 25	1100.00 24	967.00 24	845.00 20
1985	8880.00 16	6710.00 17	4200.00 20	2520.00 22	1810.00 21	1650.00 10	1340.00 9	1220.00 8	1000.00 11

ANNUAL VALUES

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING MARCH 31

1944	362.00 12
1945	405.00 17
1946	576.00 26
1947	341.00 9
1948	593.00 29
1949	689.00 35
1950	734.00 39
1951	661.00 32
1952	617.00 30
1953	374.00 13
1954	225.00 2
1955	257.00 5
1956	521.00 24
1957	376.00 14
1958	698.00 36
1959	808.00 42
1960	361.00 11

ANNUAL MEAN DISCHARGE AND RANKING
IN YEAR ENDING SEPTEMBER 30

1944	350.00 35
1945	423.00 24
1946	482.00 23
1947	539.00 18
1948	422.00 25
1949	605.00 13
1950	849.00 1
1951	627.00 9
1952	644.00 7
1953	332.00 37
1954	160.00 42
1955	292.00 39
1956	662.00 5
1957	555.00 17
1958	688.00 4
1959	521.00 21
1960	365.00 31

APPENDIX D-2 (CONTINUED)

ANNUAL VALUES--Cont Inund

ANNUAL MEAN DISCHARGE AND RANKING IN YEAR ENDING MARCH 31

1961	394.00 15
1962	585.00 27
1963	347.00 10
1964	288.00 6
1965	422.00 18
1966	291.00 7
1967	446.00 21
1968	422.00 19
1969	686.00 34
1970	540.00 25
1971	401.00 16
1972	246.00 4
1973	661.00 31
1974	668.00 33
1975	747.00 41
1976	447.00 22
1977	198.00 1
1978	436.00 20
1979	704.00 37
1980	742.00 40
1981	299.00 8
1982	720.00 38
1983	245.00 3
1984	492.00 23
1985	593.00 28

ANNUAL MEAN DISCHARGE AND RANKING IN YEAR ENDING SEPTEMBER 30

1961	558.00 16
1962	387.00 28
1963	358.00 33
1964	383.00 30
1965	353.00 34
1966	203.00 41
1967	525.00 19
1968	605.00 14
1969	626.00 10
1970	404.00 26
1971	349.00 36
1972	363.00 32
1973	762.00 3
1974	630.00 8
1975	626.00 11
1976	386.00 29
1977	213.00 40
1978	660.00 6
1979	785.00 2
1980	561.00 15
1981	390.00 27
1982	525.00 20
1983	320.00 38
1984	506.00 22
1985	613.00 12

NORMAL MONTHLY MEANS (ALL DAYS)

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT
1943	*	*	*	*	*	*	269.00	1698.0	520.00	164.00	97.40	72.10
1944	40.70	58.70	49.70	105.00	254.00	995.00	2060.0	442.00	119.00	34.70	33.10	29.50
1945	22.20	36.50	37.10	62.00	412.00	1593.0	1143.0	434.00	854.00	123.00	146.00	232.00
1946	448.00	248.00	558.00	697.00	798.00	1260.0	195.00	1030.0	317.00	116.00	76.30	31.50
1947	31.50	56.60	258.00	987.00	472.00	498.00	1213.0	828.00	1464.0	257.00	281.00	124.00
1948	67.90	85.80	92.90	701.00	579.00	1433.0	1167.0	359.00	132.00	336.00	69.30	44.40
1949	61.00	434.00	572.00	2782.0	1158.0	1163.0	313.00	197.00	223.00	149.00	126.00	89.80
1950	154.00	83.20	354.00	4000.0	2192.0	993.00	753.00	405.00	772.00	200.00	75.20	292.00
1951	103.00	818.00	912.00	1232.0	1500.0	949.00	885.00	408.00	280.00	400.00	66.80	37.80
1952	34.70	194.00	1343.0	1529.0	1123.0	1102.0	1192.0	266.00	645.00	187.00	51.10	73.30
1953	41.10	52.60	177.00	371.00	329.00	1119.0	433.00	771.00	148.00	406.00	82.50	26.10
1954	24.40	33.40	49.10	182.00	182.00	350.00	700.00	248.00	93.90	29.50	25.40	13.40
1955	46.80	40.20	104.00	430.00	431.00	931.00	544.00	264.00	325.00	210.00	53.90	133.00
1956	500.00	1720.0	328.00	122.00	1556.0	589.00	763.00	1372.0	480.00	453.00	79.80	52.00
1957	34.10	42.20	153.00	318.00	505.00	265.00	1825.0	1530.0	973.00	843.00	116.00	70.10
1958	67.90	252.00	1689.0	496.00	205.00	270.00	285.00	696.00	1608.0	1216.0	1046.0	371.00
1959	168.00	447.00	314.00	1478.0	1316.0	787.00	583.00	749.00	247.00	101.00	64.60	46.20
1960	80.70	177.00	335.00	484.00	1077.0	417.00	303.00	313.00	685.00	386.00	87.90	70.30
1961	45.30	55.80	63.80	112.00	305.00	2281.0	1524.0	1769.0	260.00	109.00	85.90	42.50
1962	40.40	88.90	228.00	932.00	682.00	1249.0	270.00	290.00	128.00	512.00	97.30	121.00
1963	88.10	89.60	59.70	118.00	93.30	2245.0	781.00	241.00	179.00	178.00	151.00	39.20
1964	27.50	37.10	30.40	60.70	74.80	1642.0	2076.0	300.00	95.80	188.00	43.90	25.90
1965	22.40	37.20	49.60	352.00	1031.0	912.00	1230.0	255.00	82.50	156.00	47.20	129.00
1966	79.10	75.20	103.00	478.00	589.00	302.00	221.00	339.00	85.50	96.50	43.40	42.60
1967	55.10	739.00	1716.0	385.00	568.00	1048.0	509.00	965.00	179.00	63.60	36.20	24.50
1968	40.40	59.20	944.00	530.00	1335.0	409.00	702.00	1971.0	620.00	142.00	441.00	83.40
1969	64.10	331.00	777.00	1703.0	1195.0	220.00	777.00	258.00	387.00	1503.0	222.00	101.00
1970	243.00	734.00	352.00	536.00	798.00	593.00	906.00	339.00	141.00	108.00	89.10	54.70
1971	74.80	108.00	226.00	338.00	1937.0	625.00	170.00	303.00	303.00	103.00	61.60	74.00
1972	72.10	66.00	564.00	427.00	235.00	573.00	1360.0	369.00	378.00	132.00	81.20	112.00
1973	153.00	1518.0	924.00	700.00	620.00	1606.0	1261.0	277.00	1080.0	688.00	243.00	94.00
1974	83.60	441.00	968.00	1453.0	631.00	800.00	974.00	829.00	865.00	175.00	107.00	231.00
1975	135.00	357.00	768.00	1240.0	1910.0	1462.0	889.00	323.00	302.00	115.00	54.90	50.00
1976	80.70	126.00	639.00	1040.0	1070.0	705.00	177.00	120.00	191.00	323.00	122.00	46.50
1977	65.50	88.50	58.10	36.50	441.00	720.00	498.00	339.00	84.10	103.00	68.30	67.10
1978	283.00	160.00	1277.0	221.00	155.00	1920.0	633.00	926.00	747.00	594.00	661.00	262.00
1979	165.00	292.00	635.00	851.00	1108.0	1588.0	1080.0	277.00	280.00	1564.0	1348.0	217.00
1980	144.00	972.00	897.00	467.00	403.00	1220.0	786.00	413.00	482.00	138.00	692.00	113.00
1981	68.70	73.90	112.00	77.50	445.00	215.00	526.00	2011.0	595.00	271.00	178.00	99.00
1982	71.30	74.50	271.00	1090.0	2028.0	1499.0	502.00	244.00	396.00	127.00	63.30	39.40
1983	34.60	68.90	572.00	286.00	355.00	261.00	904.00	1018.0	162.00	107.00	48.50	27.10
1984	85.90	538.00	870.00	216.00	708.00	1227.0	1338.0	563.00	202.00	168.00	103.00	68.60
1985	100.00	517.00	1034.0	637.00	1356.0	1097.0	1223.0	648.00	373.00	107.00	245.00	78.10

APPENDIX D-2 (CONTINUED)

OCT	NOV	DEC	JAN	FEB	MARCH
TWENTY FIFTH PERCENTILE					
40.60	59.10	104.00	220.00	391.00	554.00
FIFTIETH PERCENTILE					
70.00	98.80	344.00	481.00	626.00	971.00
SEVENTY FIFTH PERCENTILE					
111.00	436.00	877.00	1000.00	1167.00	1303.00
APRIL	MAY	JUNE	JULY	AUG	SEPT
TWENTY FIFTH PERCENTILE					
498.00	277.00	162.00	109.00	61.60	42.50
FIFTIETH PERCENTILE					
777.00	405.00	303.00	168.00	85.90	70.30
SEVENTY FIFTH PERCENTILE					
1192.00	829.00	620.00	386.00	151.00	113.00

APPENDIX E
CORRELATIONS BETWEEN SOIL PROPERTIES AND
INDEX PARAMETERS (36)

Effective Preconsolidation Stress in Cohesive Soils

Correlation with Index Parameters

(I) Stas and Kulhawy¹:

$$\frac{\bar{\sigma}_p}{P_a} = 10^{(1.11 - 1.62LI)}$$

where $\bar{\sigma}_p$ = largest preconsolidation stress

P_a = atmospheric stress in the desired stress units

LI = liquidity index

(II) NAVFAC²:

where S_t = sensitivity

¹Stas, C. V., and Kulhawy, F. H. "Critical Evaluation of Design Methods for Foundations Under Axial Uplift and Compression Loading," Report EL-3771, Electric Power Research Institute, Palo Alto, 1984, 198p.

²NAVFAC, Soil Mechanics (DM7.1) Naval Facilities Engineering Command, Alexandria, 1982, 355p.

Undrained Shear Strength of Cohesive Soils

Correlation with Index Parameters for Undisturbed Clays

(I) Skempton¹:

where S_u = undrained shear strength
VST = vane shear test
 $\bar{\sigma}_{v0}$ = effective vertical stress

Note:

- (1) for NC clay only
- (2) The value of S_u determined from the VST should not be used directly in analysis, because it needs to be corrected for the strain rate during testing and the soil anisotropy.

(II) Jamiolkowski et al²:

for low OCR clays with low to moderate PI

$$\frac{S_u}{\bar{\sigma}_p} = 0.23 \pm 0.04$$

where $\bar{\sigma}_p$ = preconsolidation stress

S_u corresponds to direct simple shear conditions

¹Skempton, A. W. "Discussion of Planning and Design of New Hong Kong Airport," Proceedings, Institution of Civil Engineers, Vol. 7, June 1957, pp. 305-307.

²Jamiolkowski, M., Ladd, C. C., Germaine, J. T., and Lancellotta, R. "New Developments in Field and Laboratory Testing of Soils," Proceedings, 11th International Conference on Soil Mechanics and Foundation Engineering, Vol. 1, San Francisco, 1985, pp. 57-153.

(III) Bjerrum and Simons³:

where CIUC = consolidated isotropic undrained triaxial compression

(IV) Mesri⁴:

$$\frac{S_u}{\sigma_p} = 0.22$$

S_u corresponds to direct simple shear conditions

³Bjerrum, L., and Simons, N. E. "Comparison of Shear Strength Characteristics of Normally Consolidated Clays," ASCE Research Conference on Shear Strength of Cohesive Soils, Boulder, 1960, pp. 711-726.

⁴Mesri, G. "A Re-evaluation of $S_u(\text{mob}) = 0.22\sigma_p'$ using Laboratory Shear Tests," Canadian Geotechnical Journal, Vol. 26, No. 1, Feb. 1989, pp. 162-164.

Undrained Shear Strength of Cohesive Soils

Correlation with Index Parameters for Remolded Clays

(I) Mitchell¹:

where

s_{ur} = remolded undrained shear strength

P_a = atmospheric pressure or stress

¹Mitchell, J. K. Fundamentals of Soil Behavior, John Wiley and Sons, New York, 1976, p228.

GENERAL SOIL PROFILES

GLACIAL DRIFT
CLAY, SILT
SAND, GRAVEL

GLACIAL-FLUVIAL DRIFT
CLAY, SILT
SAND, GRAVEL
BEDROCK

FLUVIAL DRIFT
CLAY, SILT
SAND, GRAVEL

RESIDUAL SOILS
SAND, SILT
CLAY, GRAVEL

ORGANIC DEPOSITS

TEXTURAL SYMBOLS
FOR SOIL PROFILES

ENGINEERING SOILS MAP JOHNSON COUNTY

INDIANA

UNIVERSITY OF INDIANA
SCHOOL OF CIVIL ENGINEERING

JOHN WILSON, ASSISTANT PROFESSOR

PUBLISHED BY

1988

LEGEND

PARENT MATERIALS

(GROUPED ACCORDING TO
LAYER THICKNESS AND GRAIN)

- CLAYE, FILL
- SANDS, SILTS, AND CLAYS
- SAND, SILT, AND CLAY
- SAND, SILT, AND CLAY
- SAND, SILT, AND CLAY
- SAND, SILT, AND CLAY

MISCELLANEOUS

- LAKE AND POND
- ROAD
- RAILROAD

ENGINEERING SOILS MAP JOHNSON COUNTY

INDIANA

RESEARCH MAP

1971, 1984, 1985, 1986, 1987, 1988

JOHN WILSON, RESEARCH PROJECT

AT

Purdue University

1988

Scale of Map