LAKE HURON BASIN

TITTABAWASSEE RIVER - MICHIGAN

WATER QUALITY DATA
1965 SURVEY

Clean Water Series DPO-11-C

U.S. DEPARTMENT OF THE INTERIOR

Federal Water Pollution Control Administration

Great Lakes Region

TITTABAWASSEE RIVER - MICHIGAN

WATER QUALITY DATA
1965 SURVEY

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JULY 1968

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Great Lakes Region
Detroit Program Office
U.S. Naval Air Station
Grosse Ile, Michigan
48138

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INTRODUCTION

The water quality data contained in this report are the results of field investigations and other studies conducted in 1965 and 1966 to provide information for a water pollution control plan for the Lake Huron Basin. The Lake Huron Basin Study is a part of the Great Lakes-Illinois River Basins Project, directed by the Great Lakes Region, Federal Water Pollution Control Administration (FWPCA) and under authority of Public Law 84-660 (33 U.S.C. 466 et seq.).

> Sec. 3. (a) The Secretary shall, after careful investigation, and in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses. For the purpose of this section, the Secretary is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substance which may adversely affect such waters.

Total water quality planning begins in the headwaters of the individual river basins and continues downstream through the major tributaries to and including the Great Lakes. The extent and complexity of the Great Lakes and tributaries are shown on Figures 1, 2, and 3.

Water quality standards for interstate waters (Lake Huron) have been adopted by the State of Michigan and approved by the Secretary of the Interior. Intrastate standards for Michigan are being implemented by the Michigan Water Resources Commission. These standards will form a basis for long-range plan for controlling pollution and maintaining water quality for Lake Huron and its tributaries.

ACKNOWLEDGMENTS

The principal agencies taking an active part in providing assistance in the preparation of the report are as follows:

State Agencies - Michigan Water Resources Commission
Michigan Department of Public Health

Federal Agencies - U.S. Department of Commerce
Weather Bureau
Office of Business Economics
Bureau of Census

U.S. Department of the Interior
Bureau of Commercial Fisheries
Bureau of Sport Fisheries and Wildlife
Bureau of Outdoor Recreation
Geological Survey

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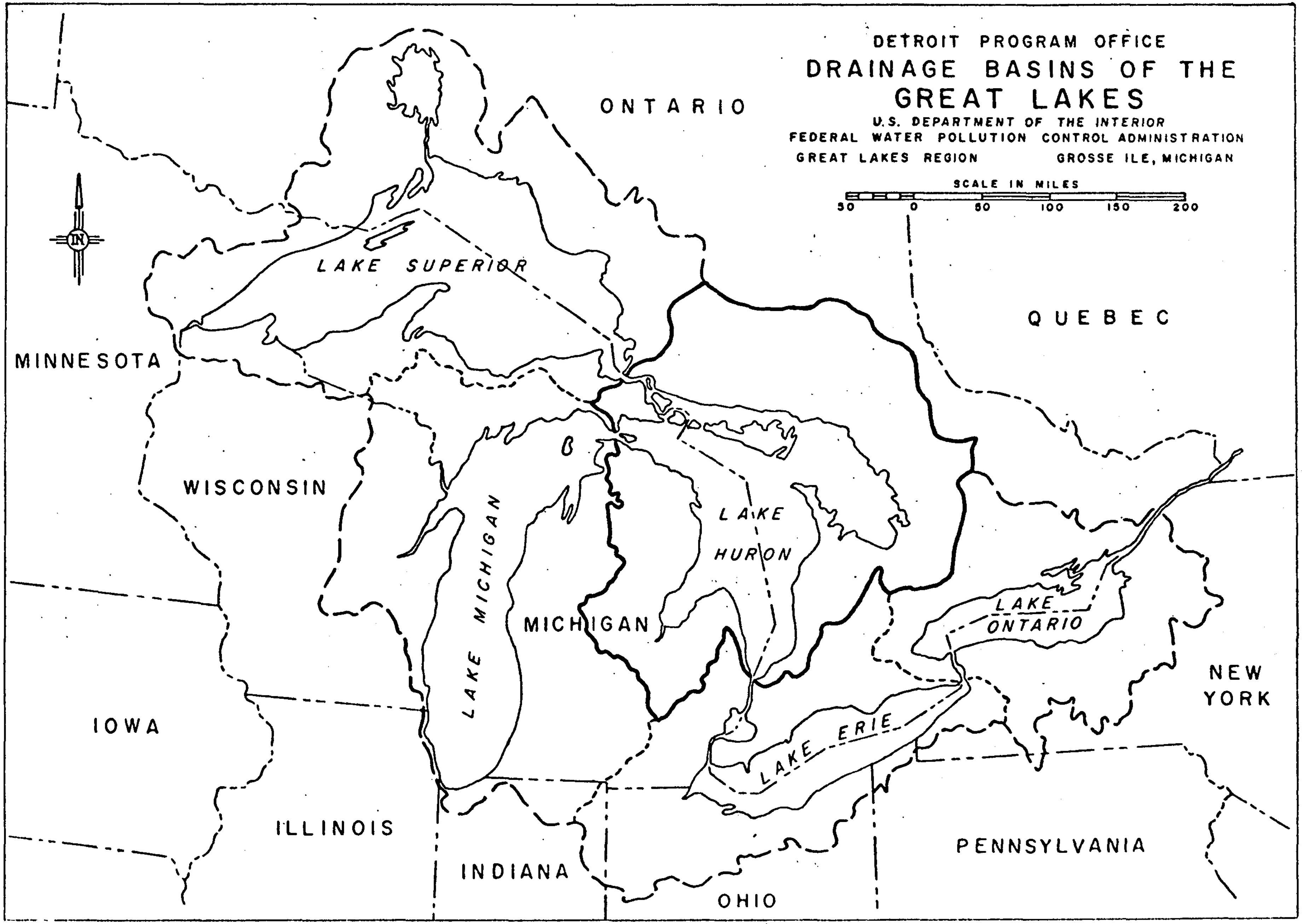
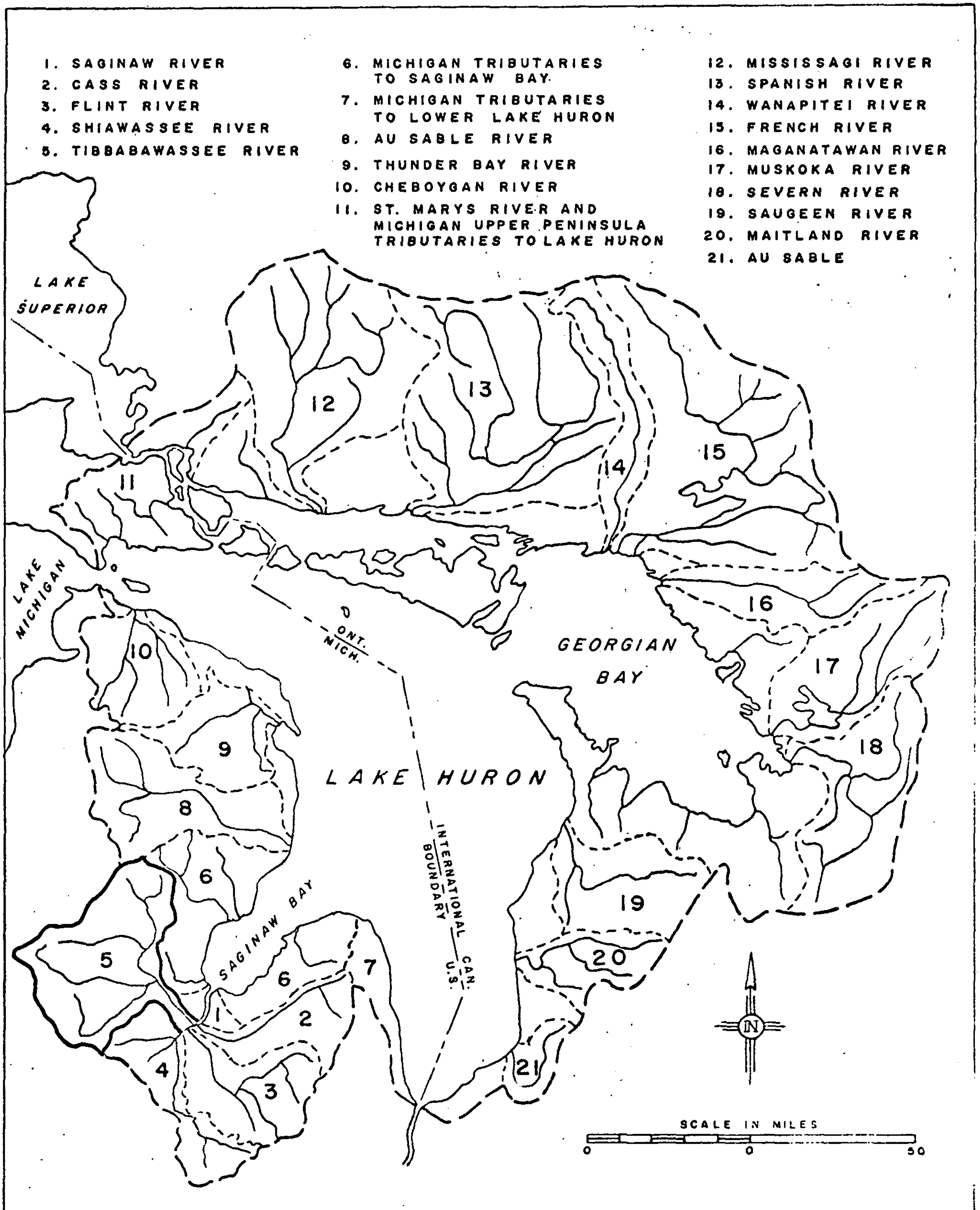

DETROIT PROGRAM OFFICE
DRAINAGE BASINS OF THE GREAT LAKES
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION GROSSE ILE, MICHIGAN
SCALE IN MILES
50 0 50 100 150 200
ONTARIO
QUEBEC
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
N

FIGURE 1

FIGURE 2



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LAKE HURON BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION GROSSE ILE, MICHIGAN

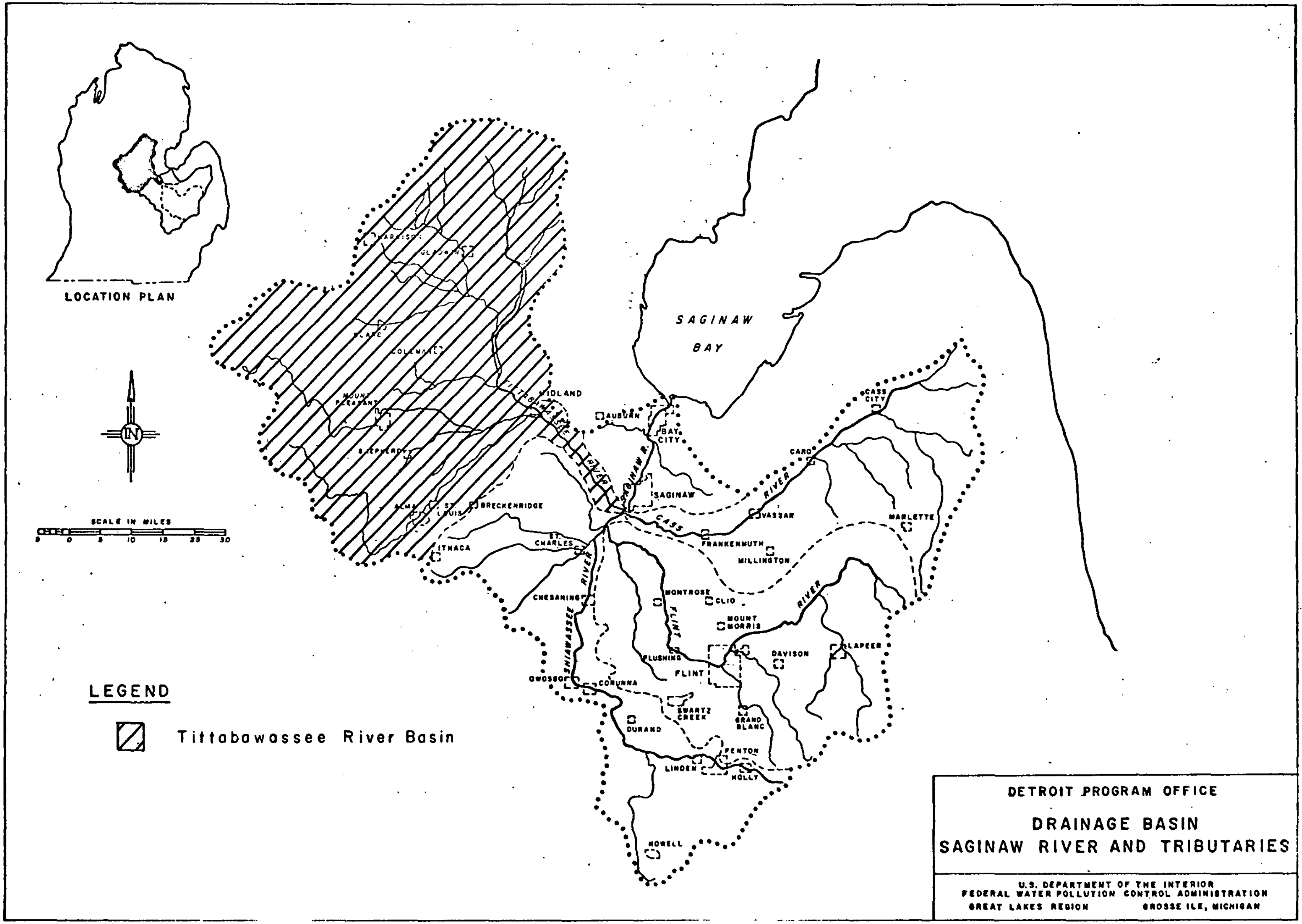

LOCATION PLAN
SAGINAW BAY
SCALE IN MILES
LEGEND
Tittabawassee River Basin
TITTABAWASSEE RIVER
SAGINAW R.
CASS RIVER
FLINT RIVER
SHIAWASSEE RIVER
MIDLAND
AUBURN
BAY CITY
SAGINAW
CASS CITY
CARO
VASSAR
FRANKENMUTH
MILLINGTON
MARLETTE
BRECKENRIDGE
ITHACA
ST. CHARLES
CHESANING
MONTROSE
CLIO
MOUNT MORRIS
DAVISON
LAPEER
FLUSHING
FLINT
OWOSSO
CORUNNA
SWARTZ CREEK
GRAND BLANC
DURAND
FENTON
LINDEN
HOLLY
HOWELL
DETROIT PROGRAM OFFICE
DRAINAGE BASIN
SAGINAW RIVER AND TRIBUTARIES
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION
GROSSE ILE, MICHIGAN

FIGURE 3

GENERAL DESCRIPTION

Area Description

The Tittabawassee River is the largest of the four main tributaries of the Saginaw River Basin. The total drainage area of the Tittabawassee River Basin is approximately 2,520 square miles. All or part of Clare, Gladwin, Gratiot, Isabella, Mecosta, Midland, Montcalm, Ogemaw, Roscommon, and Saginaw Counties lie within the Tittabawassee River Basin. With the headwaters in the southeastern part of Roscommon County and the southwestern part of Ogemaw County, the river flows southerly to Midland, where it then flows southeasterly to its junction with the Saginaw River near Saginaw.

The basin is irregular in shape, as shown in Figure 4, with a maximum width and length of approximately 60 miles each. Near the mouth of the Tittabawassee River, the basin narrows to less than five miles in width. The total length of the river from the headwaters to the junction of the Saginaw River is approximately 86 miles.

The Tittabawassee River Basin is bounded on the south by the Grand, and Shiawassee Basins; on the east by land tributary to the Saginaw River and Saginaw Bay; on the northeast by the Rifle Basin; on the north by the Au Sable Basin; and on the west by the Muskegon Basin.

The four major tributaries to the Tittabawassee River are the Tobacco, Salt, Chippeaw, and Pine Rivers. Flowing from the western portion of the basin, these tributaries join the Tittabawassee River at or above the City of Midland. The Tobacco River, with its headwaters in Clare County, drains 531 square miles. The Salt River, rising in

Isabella County, drains 231 square miles. The Chippeaw River, with its headwaters in Isabella County, drains an area of 605 square miles. The Pine River rising in Mecosta County drains 397 square miles.

The Tittabawassee River Basin is sparsely settled. Midland and Mt. Pleasant are the two largest cities. Major industrial developments center around the extensive brine fields underlying the basin in the vicinity of Midland, with its chemical companies, and several oil fields in the vicinity of Mt. Pleasant.

The topography of the eastern and southeastern part of the basin is comparatively flat. In the western and northern portions, the topography is rolling and hilly. The basin contains relatively few lakes and little swampland.

The eastern section of the Tittabawassee River Basin consists primarily of glacial lake deposits which are composed of fine sand with imbedded clay layers. North of Saginaw, the Tittabawassee River follows the western border of the Port Huron moraine. This moraine is characterized by low relief and interbedding of glacial till with lake sediments.

Climate

The Tittabawassee River Basin, located in central Michigan, has a climate that conforms to the general weather pattern existing over the lower Great Lakes region. This weather pattern is a direct result of the close proximity of the large bodies of water in the area. These large masses cool the air in the summer and warm it in the winter, with the result that Michigan has a much more moderate climate than is experienced in the areas to the west and southwest. There is a wide seasonal temperature, with many storms and a relatively constant yearly precipitation distribution. In the winter, this precipitation is usually in the form of snow.

The mean yearly temperature is about 47°F (at Mt. Pleasant) with reported high and low temperatures of over 105°F and under -30°F, respectively. The mean summer and winter temperatures are 70°F and 25°F (at Mt. Pleasant), respectively. There is an average precipitation at Mt. Pleasant of 29 inches. The growing season varies from 150 days in the southern portion of the basin to 120 days in the north.

Hydrology

The slope of the Tittabawassee River below Midland averages about one foot per mile. Four power dams are located above Midland where the slope of the stream bed varies from 3-1/2 feet to 4 feet per mile. The headwaters of each dam nearly reach the tailwater of the next dam upstream.

The flow of the Tittabawassee River is modified by the power dams located upstream of Midland and the tributaries to the Tittabawassee River - Tobacco, Pine, and Chippewa Rivers. The flow of the Tittabawassee River and its main tributaries is measured at several stream gaging stations. The stations are operated by the U.S. Geological Survey.

Location of U.S. Geological Survey Gages

There are seven U.S. Geological Survey (USGS) stream gaging stations in the Tittabawassee River Basin, of which three were utilized by the Federal Water Pollution Control Administration.

The first of these is Chippewa River near Midland, Michigan. It has a drainage area of 597 square miles and is located on the bridge on Meridian Road, six miles southwest of Midland. It has been in operation from October 1947 to the present. The FWPCA sampling station X-740 is located at this bridge.

The second USGS gaging station is Pine River near Midland, Michigan. It is located on the Meridian Road bridge and has a drainage area of approximately 390 square miles. It has been in operation from May 1934 to September 1938 and from February 1948 to the present. The Meridian Road bridge is the site of the FWPCA sampling station X-820.

The third USGS gaging station is Tittabawassee River at Midland, Michigan. It is located one-half mile downstream from the Dow Chemical Company powerplant in Midland and one mile upstream from Bullock Creek. The drainage area for this gage is approximately 2,400 square miles (this gage has been in operation since March 1936). The Dow Chemical Company diverts some water from the Tittabawassee River above the gage and returns it below the gage. This diversion is reported to the USGS on a monthly basis and must be added to the flow at the gage to obtain the correct discharge in the river below the gage.

The range of observed discharges at these gaging stations are as follows:

Chippewa River near Midland	Maximum	8,510 cfs
	Average	411 cfs
	Minimum	44 cfs
Pine River near Midland	Maximum	6,360 cfs
	Average	263 cfs
	Minimum	not determined
Tittabawassee River at Midland	Maximum	34,000 cfs
	Average	1,511 cfs
	Minimum	39 cfs

Time of Passage

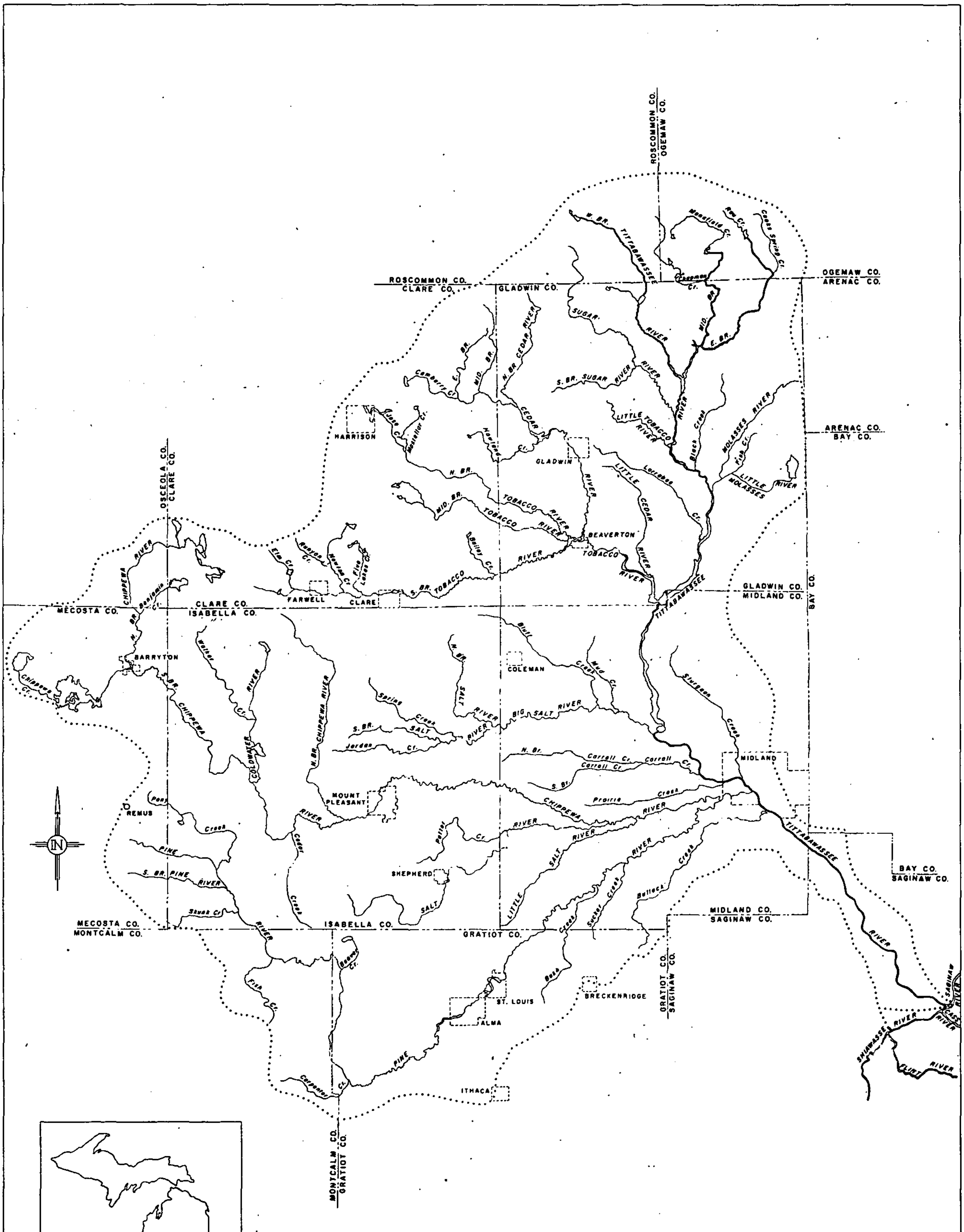
Time of passage determinations were made on the Tittabawassee River to establish waste decay rates. Recorded flows for the gage "Tittabawassee River at Midland, Michigan" were used in these computations and were corrected to include diversion.

Field studies of time of passage on the Tittabawassee River were made by the Detroit Program Office during 1965. These studies used multiple releases of Rhodamine B dye and measured the time of occurrence and concentration of the dye at downstream points. The reaches measured coincide with the intensive sampling areas below Midland.

In a report by C. J. Velz for the Michigan Water Resources Commission, times of passage were calculated for the river. These values showed close agreement with FWPCA studies.

Drought Flow

The calculation of the Tittabawassee River drought flows is complicated because the Dow Chemical Company diverts water around the USGS gage located in Midland, Michigan. The amount of diverted water is reported to the USGS as a monthly average. When calculating drought flows, this monthly diversion must be included in the computation. In this office, the reported diversion for the month of September 1965 was added to the previously arrived at one and seven-day low flows for each year. These adjusted values were then plotted on Gumbel Extremal Probability paper to yield the drought flow at the Midland gage. The flow at the remaining stations along the river was based on the ratio of the drainage area to that of the Midland gage (2,400 square miles).



DETROIT PROGRAM OFFICE

TITTABAWASSEE RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION GROSSE ILE, MICHIGAN

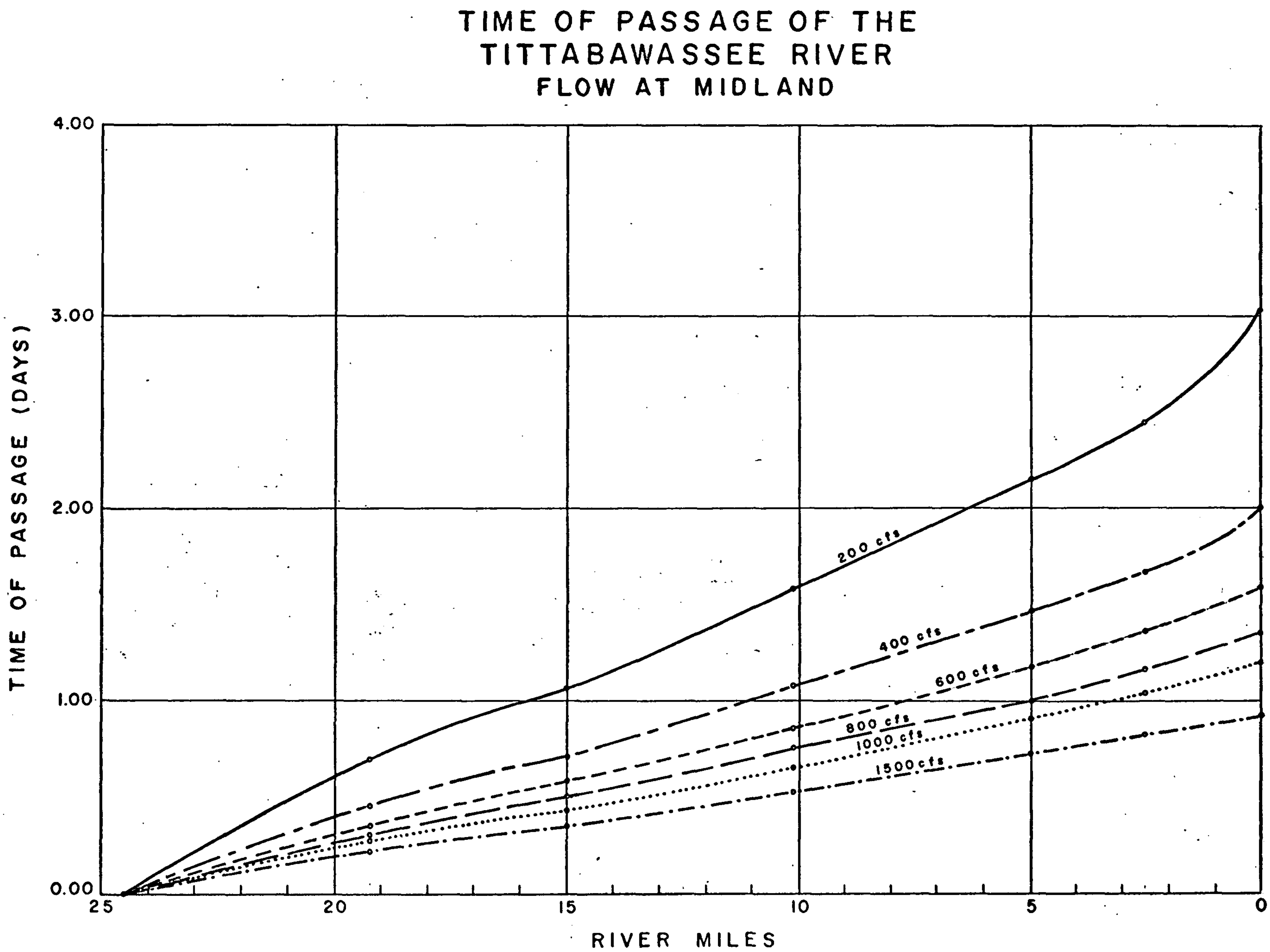

TIME OF PASSAGE OF THE
TITTABAWASSEE RIVER
FLOW AT MIDLAND
4.00
3.00
2.00
1.00
0.00
TIME OF PASSAGE (DAYS)
25
20
15
10
5
0
RIVER MILES
200 cfs
400 cfs
600 cfs
800 cfs
1000 cfs
1500 cfs

FIGURE 5

TABLE 1. DROUGHT FLOWS
(Once in Ten Years)

Station	Drainage Area (square miles)	1-Day Flow cfs	7-Day Flow cfs
X-452	1,400	116.2	145.9
X-440	2,462	204.3	256.5
X-430	2,479	205.8	258.3
X-420	2,492	206.8	259.7
X-410	2,509	208.2	261.4
X-405	2,514	208.7	262.0
Mouth	2,518	209.0	262.4

FIGURE 6

FLOW DURATION CURVE
TITTABAWASSEE RIVER AT MIDLAND
1937—1964

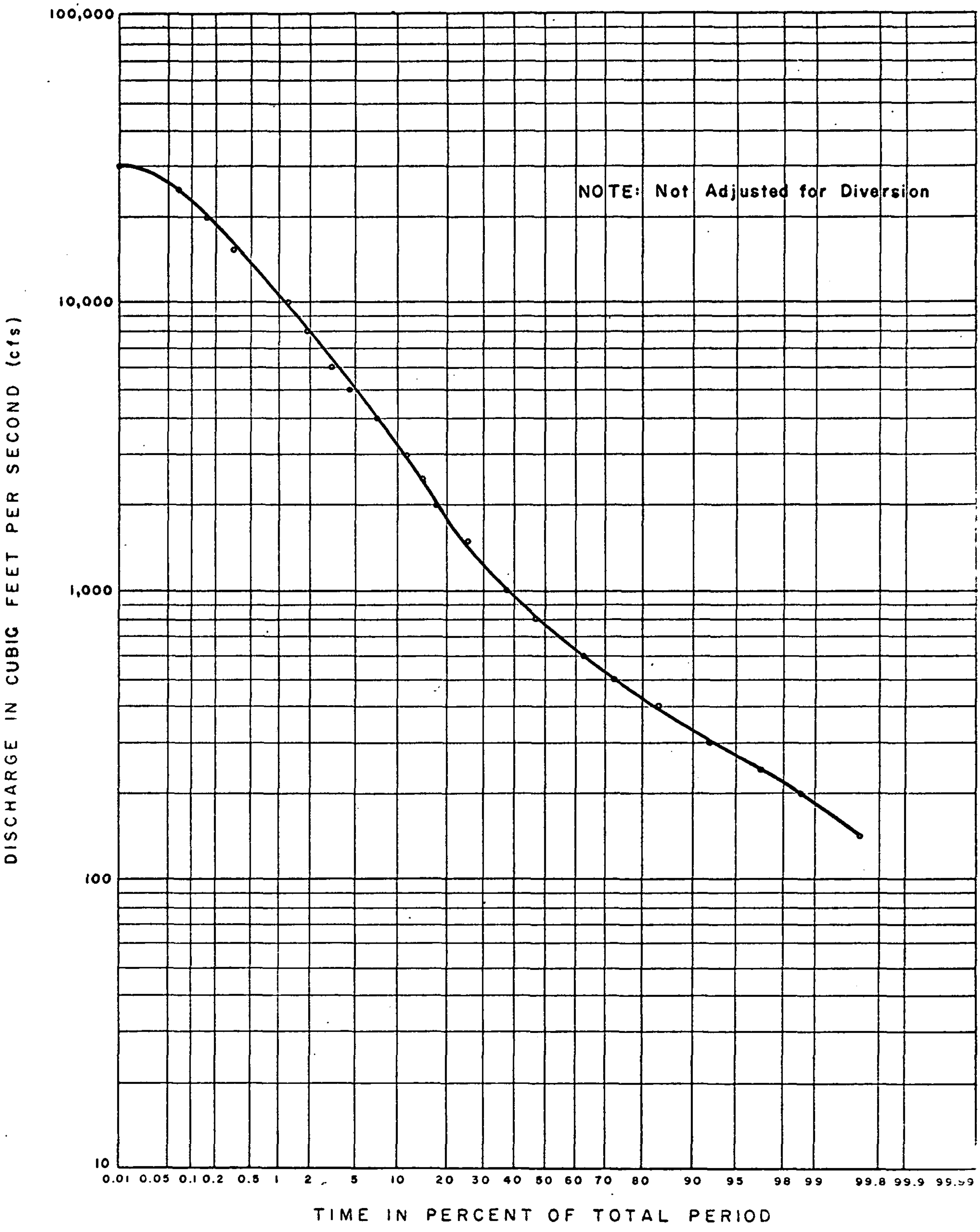


FIGURE 7

DRAINAGE AREA VS. RIVER MILES
TITTABAWASSEE RIVER

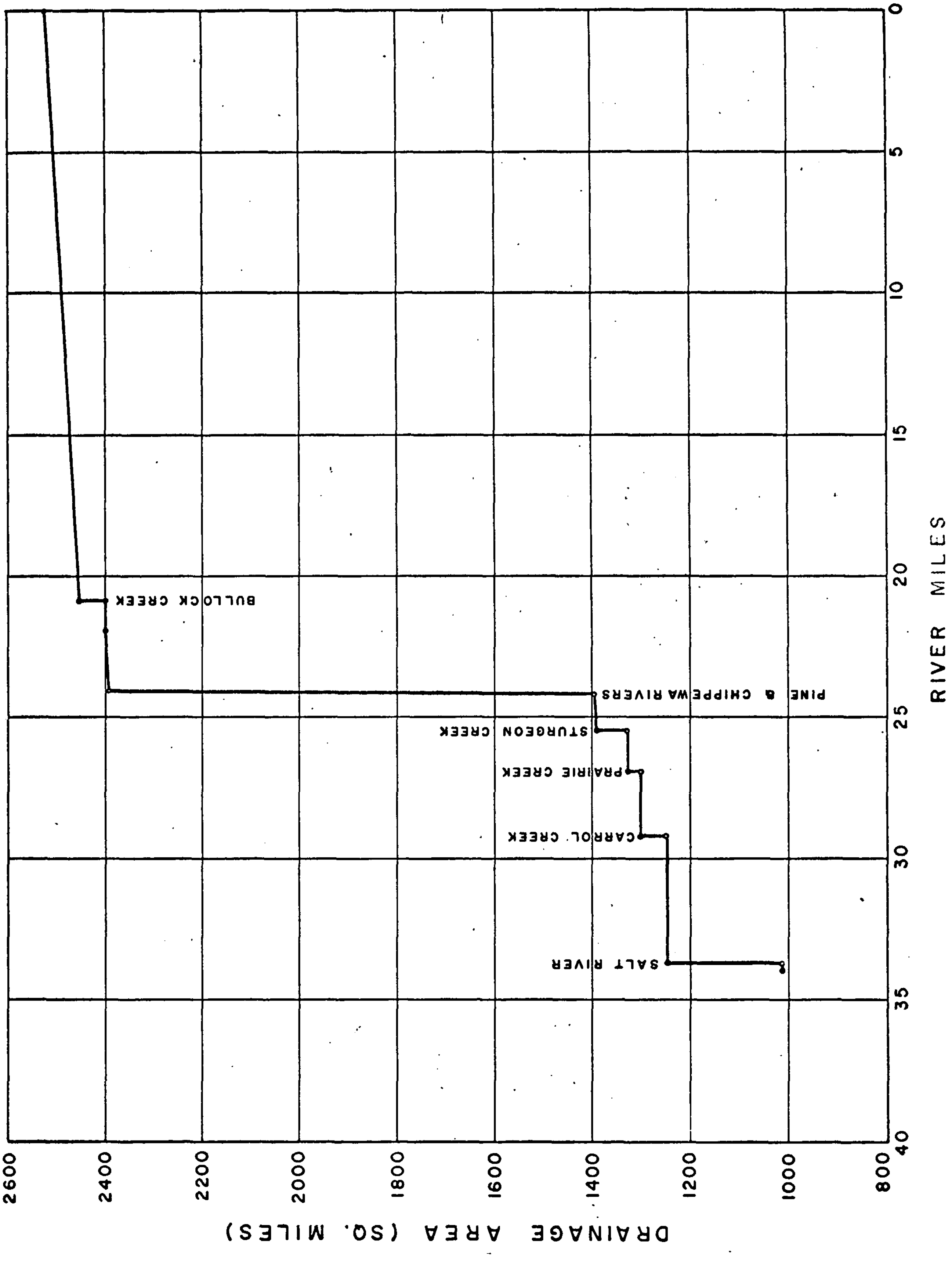


TABLE 2. TITTABAWASSEE RIVER SAMPLING STATIONS

Mainstream Stations

Station	Mile Point	Location
X-405	2.5	N. Center Road bridge near Shields
X-410	5.0	M-46 Gratiot Road bridge, east of Shields
X-420	10.2	West bank of river, Dice Road and N. River Road
X-430	15.0	W. Freeland Road bridge in Freeland
X-440	19.2	Bridge on Smith's Crossing Road
X-449	24.2	Midland sewage treatment plant
X-452	24.5	Bridge at Currie Parkway
X-460	34.0	Saginaw Road bridge in Sanford

Tributary Stations

Station	Mile Point	On Tributary	Confluence Mile Point	Location
X-730	5.8	Chippewa River	24.2	Homer Street bridge
X-740	7.7	"	"	M-30 bridge near Gordonville (USGS)
X-745	10.5	"	"	Bridge at 8-Mile Road
X-750	14.7	"	"	End of 11-Mile Road off N. Bank
X-755	17.0	"	"	Bridge at Magrudder Road
X-758	19.5	"	"	Bridge at S. Geneva Road
X-760	22.7	"	"	Bridge at Coleman Road
X-762	25.3	"	"	Bridge at Chippewa Road
X-764	28.4	"	"	Bridge at Loomis Road

TABLE 2. TITTABAWASSEE RIVER SAMPLING STATIONS (cont'd)

Tributary Stations (cont'd)

Station	Mile Point	On Tributary	Confluence Mile Point	Location
X-766	32.0	Chippewa River	24.2	Bridge at Leaton Road
X-770	37.8	"	"	Bridge at N. Mission Road (U.S. 27)
X-780	42.1	"	"	Bridge at S. Lincoln Road
X-810	.7	Pine River	2.7*	Bridge at Prairie Road
X-815	4.1	"	"	Edge of Homer Road off E. bank - 5 miles up-stream from Midland
X-820	6.5	"	"	Bridge at Meridian Road (M-30) (USGS)
X-830	11.4	"	"	Bridge at S. 9-Mile Road
X-835	14.5	"	"	Bridge at Porter Road
X-840	21.2	"	"	Bridge at Redstone Road
X-850	24.4	"	"	Bridge at Bagley Road
X-870	26.3	"	"	Bridge at McGregor Road
X0875	31.3	"	"	Bridge at M-27 Road
X-880	33.7	"	"	Bridge at Woodworth Road in Alma
X-520	5.1	Tobacco River	44.7	Bridge at Dale Road
X-530	9.2	"	"	Bridge at Glidden Road (USGS)
X-535	11.8	"	"	Bridge at Roehrs Road
X-540	15.2	"	"	Bridge at Grout Road
X-545	18.8	"	"	Bridge at Bard Road

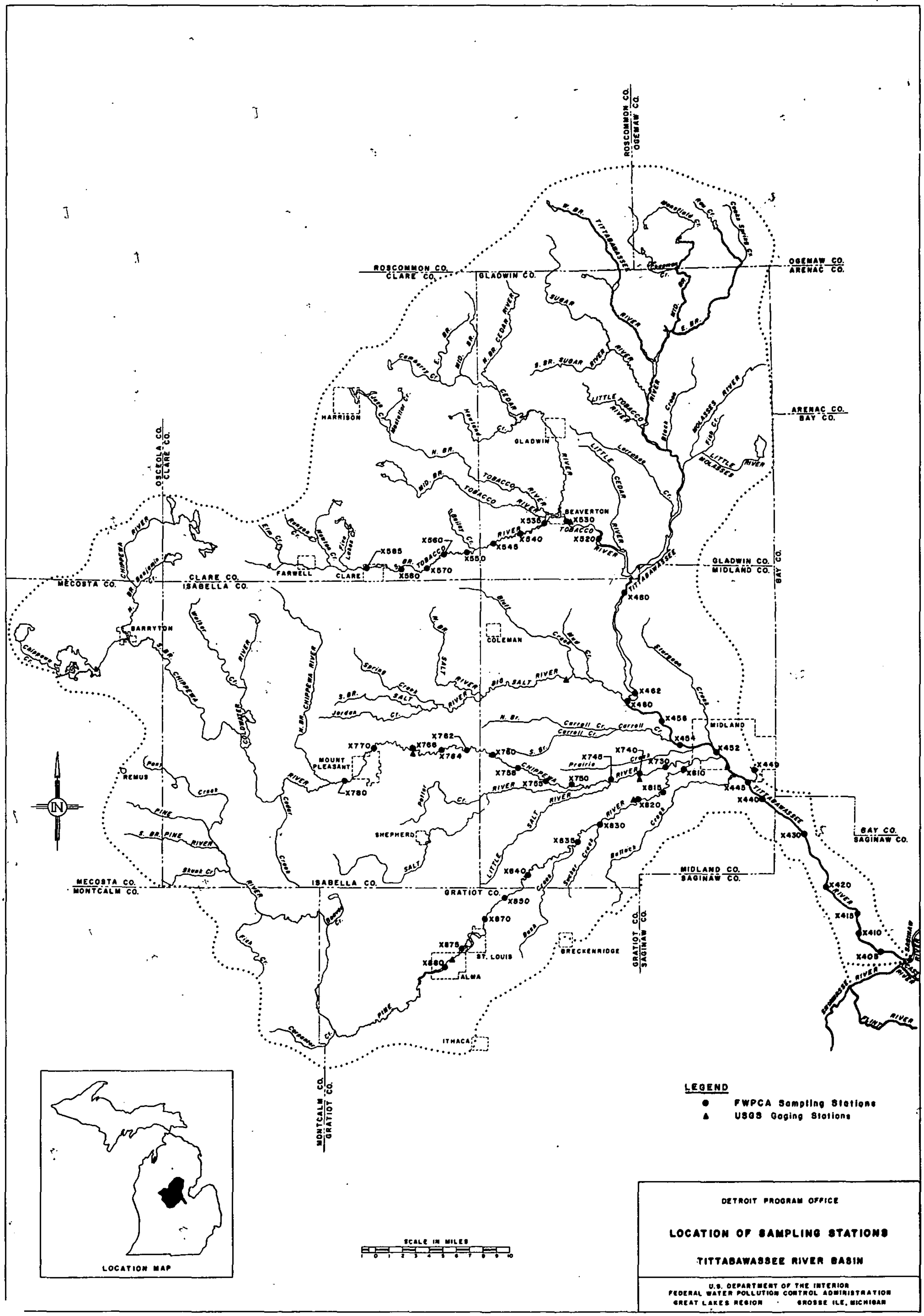
* Miles on Chippewa River

TABLE 2. TITTABAWASSEE RIVER SAMPLING STATIONS (cont'd)

Tributary Stations (cont'd)

Station	Mile Point	On Tributary	Confluence Mile Point	Location
X-550	21.6	Tobacco River	44.7	Off S. bank 50 yards downstream from Hoover Avenue and Oak Road
X-560	24.2	"	"	Bridge at Colonville Road
X-570	26.6	"	"	Bridge at Brand Avenue
X-580	28.6	"	"	Bridge at Cornwell Road
X-585	31.9	"	"	Bridge at Woodlawn Street

FIGURE 8



DETROIT PROGRAM OFFICE

LOCATION OF SAMPLING STATIONS

TITTABAWASSEE RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION · GROSSE ILE, MICHIGAN

WATER USE
1965

Municipal Water Supply

The water supply for the 75,000 people served in the Tittabawassee River Basin comes from local wells except for the City of Midland, which obtains its water from the Saginaw-Midland Water Authority intake in Lake Huron at Whitestone Point. Population served in 1990 and 2020 for the basin is estimated to be 150,000 and 300,000 people, respectively. These figures should not be construed to be total population in the basin.

Table 3 lists the individual municipality in the basin and gives the water source. Projections for total water used in the basin in 1990 and 2020 are shown in Table 4.

Industrial Water Use

Dow Chemical Company is by far the largest water user in the basin. Several other industries in the basin use smaller amounts of water. Dow Chemical uses in excess of 200 million gallons per day (MGD) for cooling water and obtains approximately 10 MGD from the Saginaw-Midland Water Authority for process water.

Table 5 lists the individual water users and the use. Projections of industrial water use in 1990 and 2020 are shown in Table 4.

Water-related Recreation

In the Tittabawassee River Basin north of Midland, water-related recreation opportunities are extensive and actively used. Some parts of the area are in the semiwilderness state typical of the northern lower peninsula areas. Its proximity to the populous and industrialized Flint-Saginaw-Midland complex make it desirable for outdoor recreation activities. The number of state owned recreation areas is limited, but there are many local and private sites, especially in the headwaters of the Chippewa and Pine Rivers and upper Tittabawassee River. For the boating enthusiast, there are numerous water access sites. Many impoundments along the basin streams were created primarily for power production. but are now used primarily for recreation. The 257 natural and artificial lakes in the basin vary in size from a few acres to the 2,000 acres of Wixom Reservoir on the Tittabawassee River. Most of the rivers are shallow except where impounded. The Michigan Tourist Council and the State Conservation Department have designated the Chippewa River, lower Tobacco River, and the Tittabawassee River as canoe trails.

The basin waters are extensively used for fishing, swimming, water-skiing, and boating. Almost all 9,000 boats registered in the basin in 1965 were under 20 feet in length. An active trout managing program is conducted by the State Conservation Department, and many stream segments have been improved and classified as trout waters.

Water-enhanced activities such as hunting, camping, skiing, hiking, and sightseeing are extensively practiced in the basin. A hiking trail has been designated which parallels the Tittabawassee River, extending from the Saginaw area to the Mackinac Straits. A great potential exists in the basin for the development of more recreation areas, both water-dependent and water-enhanced. A more detailed discussion of basin recreation is contained in the Bureau of Outdoor Recreation publication "Water-Oriented Outdoor Recreation, Lake Huron Basin" 1967.

TABLE 3. MUNICIPAL WATER SUPPLIES*
Tittabawassee River Basin

Municipality	1960 Pop.	Owner***	Source	Treatment***
Thomas Twp.	4,631	T	Wells in drift 145' deep	5
Freeland	850	T	Wells in drift 166' deep	-
Alma	8,978	M	400' of 36" intake 7' deep in Pine River; wells in drift 82' to 164' deep, stand-by well in rock 550' deep. Piped to filter plant	2 & 6
St. Louis	3,808	M	Wells in drift 213' to 223' deep	
Breckenridge	1,131	M	Wells in rock 393' to 402' deep	3 & 4
Coleman	1,264	M	Well in drift 155' deep; well in rock 555' deep	4
Midland	27,779	M	Lake Huron 10,000' of 66" intake, 51' deep at White-stone Point in Arenac County	2 & 6
Mt. Pleasant	14,875	M	Ground water collector with horizontal laterals near Chippewa River north of Broomfield Road	5 & 6**
Mt. Pleasant State Home & Training School	1,500	S	Water from City of Mt. Pleasant	-
Shepherd	1,293	M	Well in drift 151' deep and 160' deep	-
Clare	2,442	M	Wells in drift 60' to 125' deep	4 & 5

* Taken from "Data on Public Water Supplies in Michigan," Engineering Bulletin No. 4 by the Michigan Department of Public Health.
** Part of municipality
*** See Owner and Treatment Code, page 24.

TABLE 3. MUNICIPAL WATER SUPPLIES* (cont'd)
Tittabawassee River Basin

Municipality	1960 Pop.	Owner***	Source	Treatment***
Farwell	737	M	Wells in drift 229' deep	-
Harrison	1,072	M	Wells in drift 225' deep	-
Beaverton	926	M	Wells in drift 93' deep	-
Gladwin	2,226	M	Wells in rock 470' to 600' deep	-

* Taken from "Data on Public Water Supplies in Michigan," Engineering Bulletin No. 4 by the Michigan Department of Public Health.
*** See Owner and Treatment Code, page 24.

OWNER AND TREATMENT CODE

Owner Code

M = City or Village

T = Township

P = Private

D = District

C = County

S = State

U.S. = Federal

Treatment Code

1. Std. Filtration*
2. Lime softening**
3. Zeolite softening
4. Iron removal
5. Chlorination
6. Fluoridation

* Implies at least chlorination, chemical coagulation, and rapid sand filtration.

** Lime softening includes filtration.

TABLE 4. PROJECTED WATER USE
(million gallons per day)
Tittabawassee River Basin

	1965	1990	2020
Municipal*	18	32	61
Industrial	235	650	1,430
TOTAL	253	682	1,491

* Includes water for small industries and commercial use.

TABLE 5. INDUSTRIAL WATER USE
Tittabawassee River Basin

Name of User	Quantity Used (MGD)	Source	Use
Alma Products Co.	0.11	Wells	Process
Leonard Refineries Inc.	0.3	Wells	Process & Cooling
Michigan Chemical Corp.	10	Pine River and wells	Process & Cooling
Ferro Stamping and Mfg. Co.	0.06	Chippewa River	Process & Cooling
Remus Cooperative Creamery Co.	0.02	Wells	Process
Dow Chemical Co.	223	Tittabawassee River, Saginaw-Midland Water Authority	Process & Cooling

SOURCES AND CHARACTERISTICS OF WASTE - 1965 SURVEY

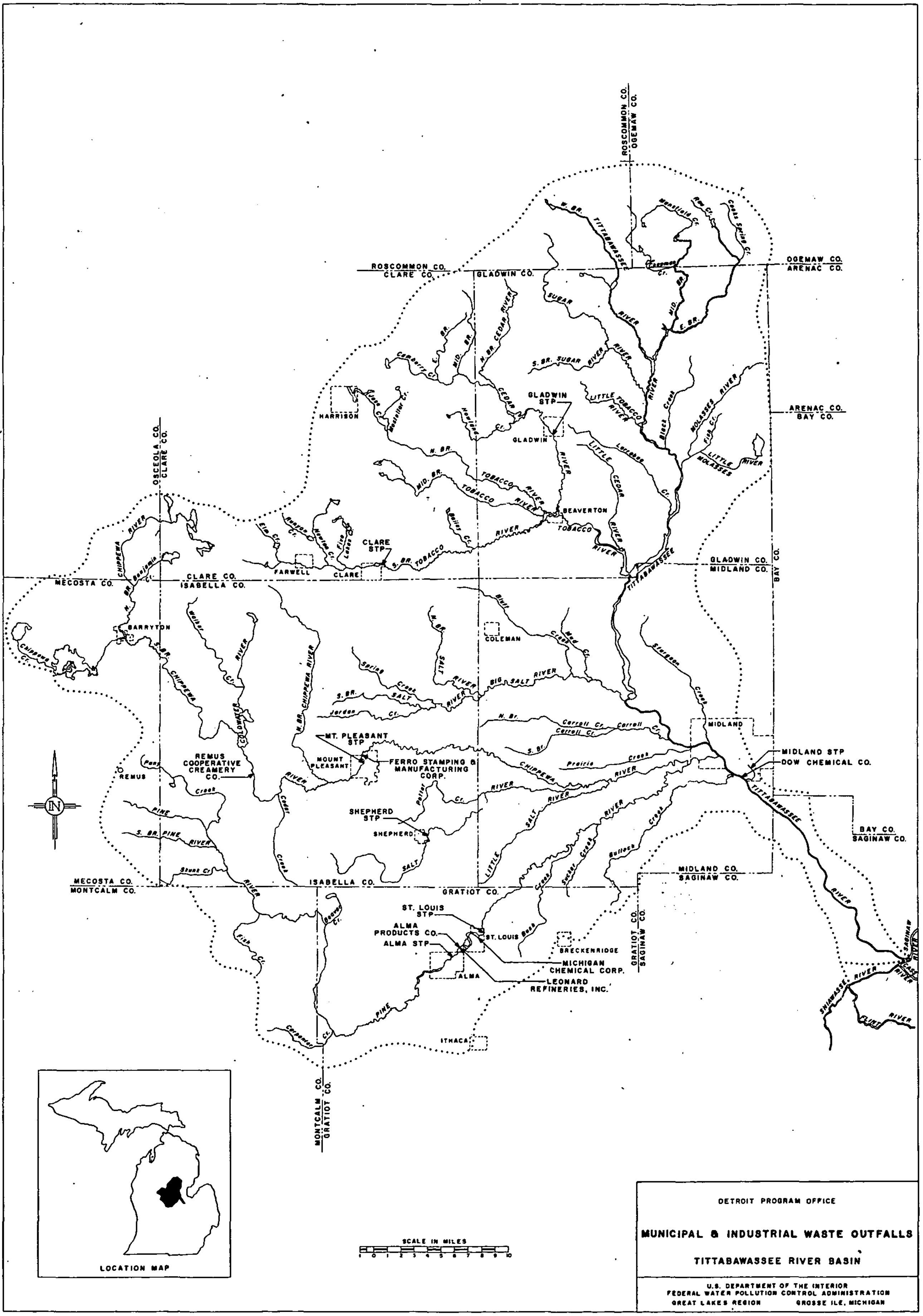
Municipal

The Tittabawassee River Basin is one of the largest (in area) in the State of Michigan. Total municipal waste sources in the basin have an approximate flow of 10 MGD from about 58,800 people. In addition, Dow Chemical Company in Midland has a 50 MGD industrial waste treatment plant.

Essentially, all of the population served by municipal sewer systems live in Midland, Mt. Pleasant, St. Louis, Clare, and Alma. There are several communities in the basin that have no sewer system but are served by private septic tanks and drain fields. Some of this septic tank effluent apparently reaches watercourses in villages such as Beaverton, Coleman, Remus, and Farwell. The construction of a sewer system and waste stabilization lagoon at Beaverton is underway. The communities of Breckenridge, Barryton, Coleman, Remus, Chippewa Lake, and Rosebush have been cited or contacted by the Michigan Water Resources Commission to correct pollution discharges.

Municipal waste treatment plants are described in Table 6. The information is based on 1965 records of the Michigan Department of Public Health. Prior to January 1967, all plants were required to practice disinfection from May 15 to September 15. Since that date, continuous year-round disinfection is required by Michigan Department of Public Health regulation. Effluent characteristics based on the 1965 plant operating records are also listed in Table 6 and outfall locations are shown on Figure 9.

FIGURE 9



DETROIT PROGRAM OFFICE
MUNICIPAL & INDUSTRIAL WASTE OUTFALLS
TITTABAWASSEE RIVER BASIN
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION
GROSSE ILE, MICHIGAN
LOCATION MAP
SCALE IN MILES
GLADWIN STP
GLADWIN
BEAVERTON
CLARE STP
CLARE
FARWELL
HARRISON
BARRYTON
REMUS
REMUS COOPERATIVE CREAMERY CO.
MT. PLEASANT STP
MOUNT PLEASANT
FERRO STAMPING & MANUFACTURING CORP.
SHEPHERD STP
SHEPHERD
COLEMAN
MIDLAND
MIDLAND STP
DOW CHEMICAL CO.
ST. LOUIS STP
ST. LOUIS
ALMA PRODUCTS CO.
ALMA STP
ALMA
MICHIGAN CHEMICAL CORP.
LEONARD REFINERIES, INC.
BRECKENRIDGE
ITHACA
ROSCOMMON CO.
OGEMAW CO.
CLARE CO.
GLADWIN CO.
ARENAC CO.
BAY CO.
OSCEOLA CO.
MECOSTA CO.
ISABELLA CO.
MIDLAND CO.
SAGINAW CO.
MONTCALM CO.
GRATIOT CO.
TITTABAWASSEE
TITTABAWASSEE RIVER
CHIPPEWA RIVER
PINE RIVER
SALT RIVER
TOBACCO RIVER
CEDAR RIVER
SUGAR RIVER
MOLASSES RIVER
SHIAWASSEE RIVER
FLINT RIVER
SAGINAW RIVER

TABLE 6. MUNICIPAL WASTE EFFLUENTS**
1965

Community	Type	Percent Removal	Pop. Served	Flow (MGD) Avg.	Flow (MGD) Max.	Flow (MGD) Min.	Temp. °F	BOD_5 (mg/l) Avg.	BOD_5 (mg/l) Max.	BOD_5 (mg/l) Min.	Susp. Solids (mg/l)	Vol. Susp. Solids (mg/l)	pH
Clare*	primary	41	2,500	0.47	-	-	50	149	-	-	96	79	-
Alma	primary		9,000	1.50	2.76	9.90	62	123	183	65	107	65	7.7
St. Louis	primary		4,000	0.65	1.52	0.32	55	71	99	42	97	74	7.7
Mt. Pleasant	primary	33	12,000	1.90	2.75	1.36	59	135	177	110	100	80	7.3
Shepherd	lagoon		1,200	0.16	-	-	-	-	-	-	-	-	-
Gladwin	primary	40	2,000	0.61	1.00	0.38	54	70	104	42	61	48	7.7
Midland	secondary		31,400	5.30	7.80	3.80	57	26	35	16	21	16	7.4

* Scheduled for addition of aerated lagoon.
** Based on information from Michigan Department of Public Health.

Industrial

The major industries in the Tittabawassee River Basin are: Dow Chemical Company, Michigan Chemical Corporation, Alma Products Company, Leonard Refineries, Inc., Remus Cooperative Creamery Company, and Ferro Stamping and Manufacturing Corporation. Except for Remus Creamery, all of these industries have treatment facilities. The Michigan Water Resources Commission rates these plants annually on the facilities provided and effluent quality.

Industrial outfalls and listings of the chemical characteristics are shown on Figure 9 and in Table 7, respectively. Industrial waste survey data of the Michigan Water Resources Commission are listed on Table 8.

Dow Chemical Company

The Midland plant of Dow Chemical is one of the largest chemical complexes in the world. The plant has a 50 MGD biological waste treatment unit for treating organic wastes and trickling filters for phenolic wastes that are pretreated in equalization ponds, holding lagoons for chloride wastes which are discharged when river flow is sufficient, and deep well injection for concentrated waste. They also use in excess of 200 MGD for cooling water.

Alma Products Company

This plant, located in Alma, discharges its waste flow of 0.11 MGD to the Pine River via a county drain. Wastes constituents include oil, copper, zinc, and chromium. Treatment facilities consist of oil separation, skimmer, and lagoon.

Leonard Refineries Incorporated

Located in Alma, it discharges a waste flow of approximately 0.3 MGD to a county drain which flows into the Pine River. Phenolic compounds, oil, and chlorides are part of the waste load. Treatment facilities consist of deep well injections, lagoons, settling tanks, and air floatation devices.

Michigan Chemical Corporation

This plant is located on the Pine River in St. Louis. The plant uses about 10 MGD of water from their reservoir on the Pine River next to the plant. The water is returned to the reservoir and reused. Waste constituents include general chemical wastes and chlorides.

Ferro Stamping and Manufacturing Company

This plant is located on the Chippewa River in Mt. Pleasant. The waste flow of 0.06 MGD contains such elements as cyanide and zinc. Treatment consists of chemical addition and settling.

Remus Cooperative Creamery

This is a small milk processing plant located in Remus on the Chippewa River. They have no treatment facilities at present.

TABLE 7. INDUSTRIAL WASTE INVENTORY
Tittabawassee River Basin

Industry	Location	Receiving Stream	Waste Constituents	Waste Flow (MGD)	Treatment Provided
Alma Products Co.	Alma	County Drain Pine River	Zinc, copper, chromium, oil	0.11	Oil separation lagoon, skimmer
Leonard Refineries Inc.	Alma - (BR 27)	County Drain Pine River	Oil wastes, oil chlorides, phenol wastes	0.3	lagoons, settling, air floatation, groundwater
Michigan Chemical Corp.	St. Louis	Pine River	Solids, brine wastes	10	Recovery and reuse
Ferro Stamping and Manufacturing Co.	Mt. Pleasant	Chippewa River	Cyanide, zinc	0.06	Settling, chemical treatment of cyanide wastes
Remus Cooperative Creamery Co.	Remus	Chippewa River (Pine Lake Drain)	Milk wastes		None
Dow Chemical Co.	Midland	Tittabawassee	Brine wastes, Oxygen Demand Wastes Taste and odor producing wastes	47.6	Conv. secondary, deep well injection

TABLE 8. INDUSTRIAL WASTE CHARACTERISTICS
(mg/l)
Tittabawassee River Basin

Industry		Flow (MGD)	Temp. °C	Susp. Solids	Vol. Susp. Solids	Total Solids	Chlorides	(µg/l) Phenols	pH
Dow Chemical Co.	1965	47.600	-	60	-	-	3,860	0.12	-
Alma Products Co.	1963	0.144	10	-	-	-	-	-	6.3
	1964	0.108	-	42	12	-	-	5.40	-
Leonard Refineries Inc.	1964								
	Sept.	0.290	-	-	-	-	-	0.01	7.8
	Nov.	0.580	24	-	-	-	-	0.70	3.0
Michigan Chemical Corp.									
Outfall #1	1965	0.540	-	336	46	30,260	16,500	-	8.8
Outfall #2	1965	0.090	3	-	-	-	2,000	-	8.1
Outfall #3	1965	0.120	19	-	-	-	850	-	2.2
Outfall #4	1965	0.060	3	-	-	-	20	-	8.0
Ferro Stamping and Manufacturing Co.	1965	0.140	-	57	-	-	-	-	8.4
	1966	0.050	-	136	-	-	-	-	9.2
Remus Cooperative Creamery Co.	1965	0.026	-	350	350	-	-	-	-

TABLE 8. INDUSTRIAL WASTE CHARACTERISTICS (Cont'd)
(mg/l)
Tittabawassee River Basin

Industry		BOD_5	COD	DO	NH_3-N	CN	Cl_2	Fe	Mg	Ca	Br	Na	Cu	Zn	Cr^6	Cr^3	Oil
Dow Chemical Co.	1965	18.4	114														
Alma Products Co.	1963	23						54									
	1964	20				0.5											
Leonard Refineries Inc.	1964																
	Sept.	1.2		1.8													
	Nov.					0.85									10	7	
Michigan Chemical Corp.																	
Outfall #1	1965								240	7,400	60	1,800					
Outfall #2	1965								24	720	5	460					
Outfall #3	1965				6				14	170	120	310	25				
Outfall #4	1965																
Ferro Stamping and Manufacturing Co.	1965													1.8			132
	1966					18	168							9.2			
Remus Cooperative Creamery Co.	1965	1,440															

POPULATION AND WASTE LOAD PROJECTIONS

Demographic studies were conducted by the Great Lakes-Illinois River Basins Project, Chicago, for the Lake Huron Basin. Population trends on a national, regional, and county basis were analyzed, and population projections were developed for the various areas of the Lake Huron Basin. In 1960, approximately 1.2 million persons lived in the Lake Huron Watershed, about double the 1920 population. By the year 2020, it is estimated that the population of the watershed will be approximately 3.2 million.

The four major areas in the Tittabawassee River Basin are: Midland (27,700), Clare (2,500), Alma-St. Louis (13,000), and Mt. Pleasant (14,900), according to the 1960 census figures. For this report, each area and the surrounding communities were analyzed as a unit, assuming that by 2020 the area will be urbanized and served by water and sewer systems. For these areas, the total 1965 population served by sewerage systems was estimated to be 58,800 and projected to be 125,000 by 1990 and 255,000 by the year 2020.

BOD_5 projections were based on 1965 inventory information obtained from the Michigan Water Resources Commission, the Michigan Department of Public Health, and the U.S. Public Health Service. Municipal and industrial water use growth rates and BOD_5 production in terms of population equivalents were determined from studies on the Lake Michigan Basin and applied to the inventory data obtained for the Tittabawassee River Basin.

The results of these projections are shown on Table 9. For example, in 1965, a total of 78,920 pounds per day of BOD_5 was produced in the Midland area, of which 89 percent was removed by treatment, leaving 8,477 pounds of BOD_5 which was discharged to the river. By the year 2020, with the same percentage of treatment, 53,000 pounds would reach the river. In order to show an improvement over present water quality, 99 percent or more removal will be necessary at that time.

Table 10 shows the estimated waste flow in million gallons per day for the various areas.

TABLE 9. BOD_5 PROJECTIONS
(#/day)

	1965	1990	2020
Midland Area			
Residential	5,340	12,600	32,800
Industrial	510	1,430	3,150
Total Municipal	5,850	14,030	35,950
Present 80% removal	1,170	2,860	7,170
With 90% removal	468	1,403	3,595
With 95% removal	234	702	1,788
Industrial (direct to river)	73,070	204,500	446,000
Present 90% removal	7,307	20,450	44,600
With 90% removal	7,307	20,450	44,600
With 95% removal	3,653	10,225	22,300
Total (before treatment)	78,920	218,530	481,950
Present removal	8,477	23,310	51,770
With 90% removal	7,892	21,853	48,195
With 95% removal	3,946	10,926	24,096
Alma-St. Louis Area			
Residential	2,210	4,140	7,800
Industrial	793	2,220	4,840
Total Municipal	3,003	6,360	12,640
With 30% removal	-	4,450	8,840
Present 36% removal	1,920	4,070	8,080
With 90% removal	300	636	1,264
With 95% removal	150	318	632
Industrial (direct to river)	390	1,090	2,380
With 30% removal	273	763	1,665
Present 10% removal	340	981	2,142
With 90% removal	39	109	238
With 95% removal	20	55	119
Total (before treatment)	3,393	7,450	15,020
With 30% removal	-	5,213	10,505
Present removal	2,260	5,051	10,222
With 90% removal	339	745	1,502
With 95% removal	170	372	751

TABLE 9. BOD_5 PROJECTIONS (cont'd)
(#/day)

	1965	1990	2020
Mt. Pleasant Area			
Residential	2,040	4,860	9,000
Industrial	950	2,565	4,560
Total Municipal	2,990	7,425	13,560
With 30% removal	-	5,200	9,480
Present 30% removal	2,090	5,200	9,480
With 90% removal	299	742	1,356
With 95% removal	150	371	673
Industrial (direct to river)	-	-	-
With 30% removal	-	-	-
Present removal	-	-	-
With 90% removal	-	-	-
With 95% removal	-	-	-
Total (before treatment)	2,990	7,425	13,560
With 30% removal	-	5,200	9,480
Present 30% removal	2,090	5,200	9,480
With 90% removal	299	742	1,356
With 95% removal	150	371	673
Clare Area			
Residential	408	810	1,520
Industrial	559	1,680	3,350
Total Municipal	967	2,490	4,870
With 30% removal	-	1,740	3,410
Present 40% removal	580	1,495	2,920
With 90% removal	97	249	487
With 95% removal	48	125	244
Industrial (direct to river)	-	-	-
With 30% removal	-	-	-
Present 40% removal	-	-	-
With 90% removal	-	-	-
With 95% removal	-	-	-
Total (before treatment)	967	2,490	4,870
With 30% removal	-	1,740	3,410
Present 40% removal	580	1,495	2,920
With 90% removal	97	249	487
With 95% removal	48	125	244

TABLE 9. BOD_5 PROJECTIONS (cont'd)
(#/day)

	1965	1990	2020
Total Basin			
Municipal			
Residential	9,998	22,410	51,120
Industrial	2,812	7,895	15,900
Total Municipal	12,810	30,305	67,020
Present 55% removal	5,764	13,637	30,159
With 90% removal	1,281	3,030	6,702
With 95% removal	640	1,515	3,351
Industrial (direct to river)	73,460	205,590	448,380
Present 90% removal	7,346	20,559	44,838
With 90% removal	7,346	20,559	44,838
With 95% removal	3,673	10,280	22,419
Total (before treatment)	86,270	235,895	515,400
Present 84% removal	13,803	37,743	82,464
With 90% removal	8,627	23,590	51,540
With 95% removal	4,314	11,795	25,770

TABLE 10. WASTE FLOW PROJECTIONS
(MGD)

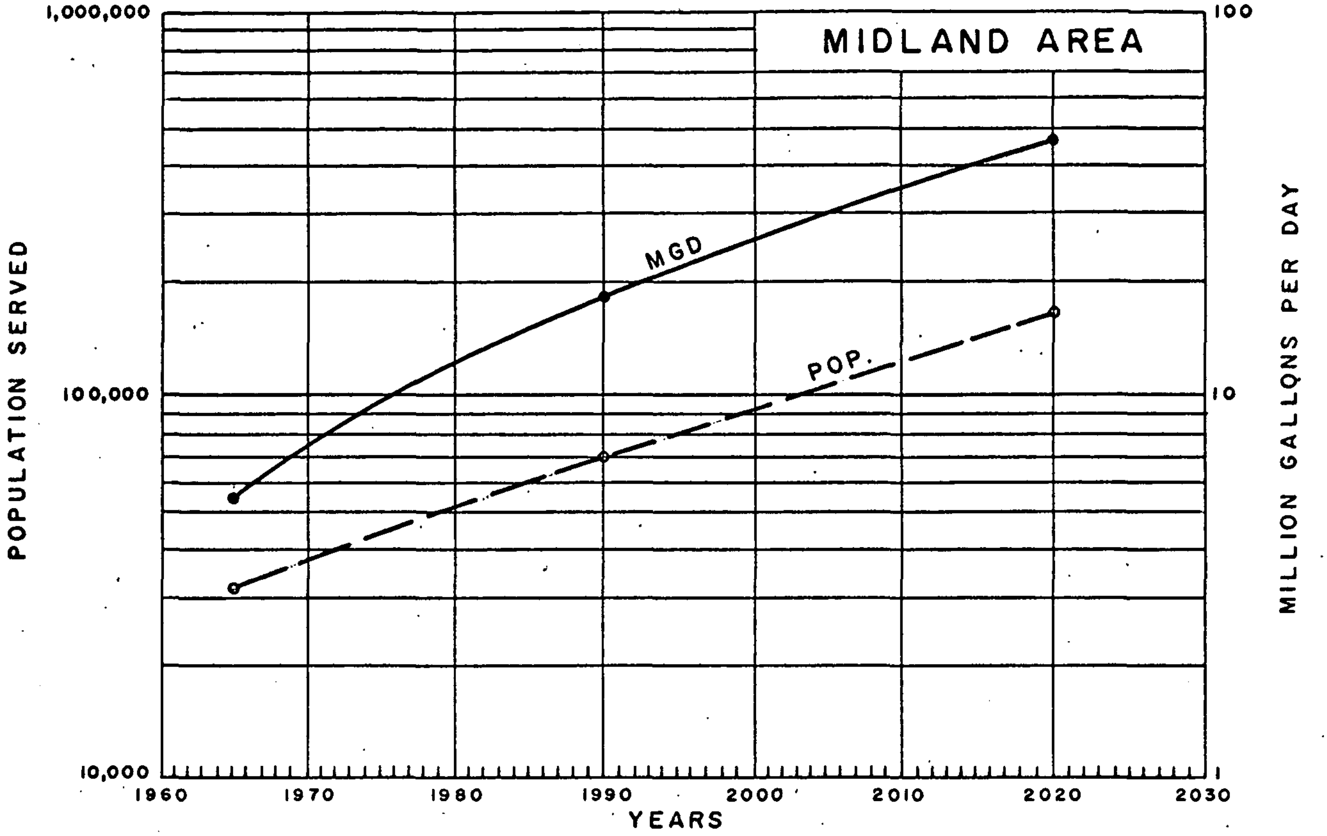
	1965	1990	2020
Midland Area			
Municipal			
Residential	4.6	15.9	39.8
Industrial	0.8	2.2	4.9
Total	5.4	18.1	44.7
Industrial (direct to river)	48	135	293
Total to River	53.4	153.1	337.7
Alma-St. Louis Area			
Municipal			
Residential	1.2	2.5	4.6
Industrial	1.1	3.1	6.7
Total	2.3	5.6	11.3
Industrial (direct to river)	10	28	61
Total to River	12.3	33.6	72.3
Mt. Pleasant Area			
Municipal			
Residential	1.5	3.9	7.0
Industrial	0.4	1.1	2.4
Total	1.7	5.0	9.4
Industrial (direct to river)	-	-	-
Total to River	1.7	5.0	9.4

TABLE 10. WASTE FLOW PROJECTIONS (cont'd)
(MGD)

	1965	1990	2020
Clare Area			
Municipal			
Residential	0.2	0.5	0.9
Industrial	0.2	0.6	1.2
Total	0.4	1.1	2.1
Industrial (direct to river)	-	-	-
Total to River	0.4	1.1	2.1
Total Basin			
Municipal			
Residential	7.5	22.8	52.3
Industrial	2.5	7.0	15.2
Total	10.0	29.8	67.5
Industrial (direct to river)	58	163	354
Total to River	68	192.8	421.5

FIGURE 10a

POPULATION & MUNICIPAL WASTE FLOW PROJECTIONS FOR THE MIDLAND & ALMA-ST. LOUIS AREAS IN THE TITTABAWASSEE RIVER BASIN



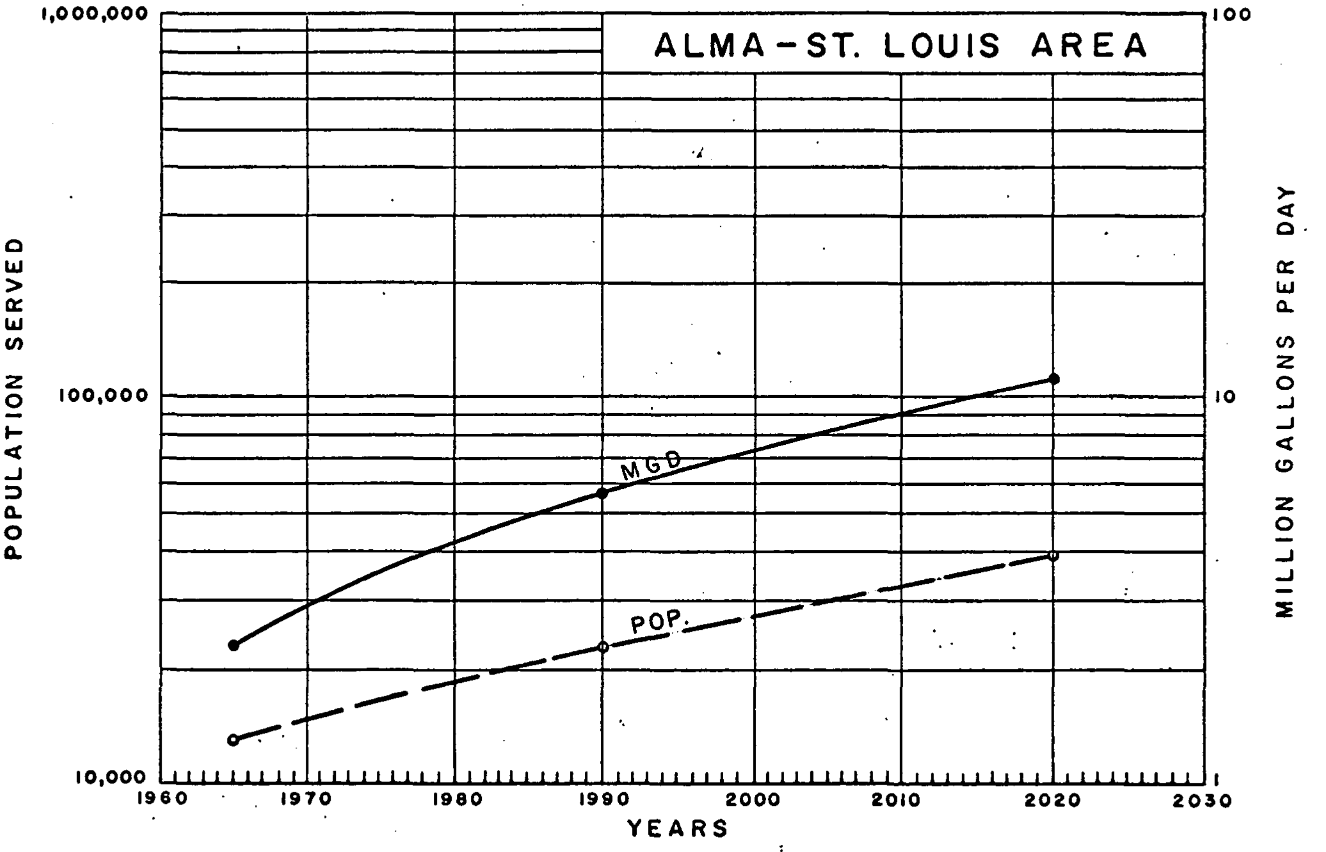
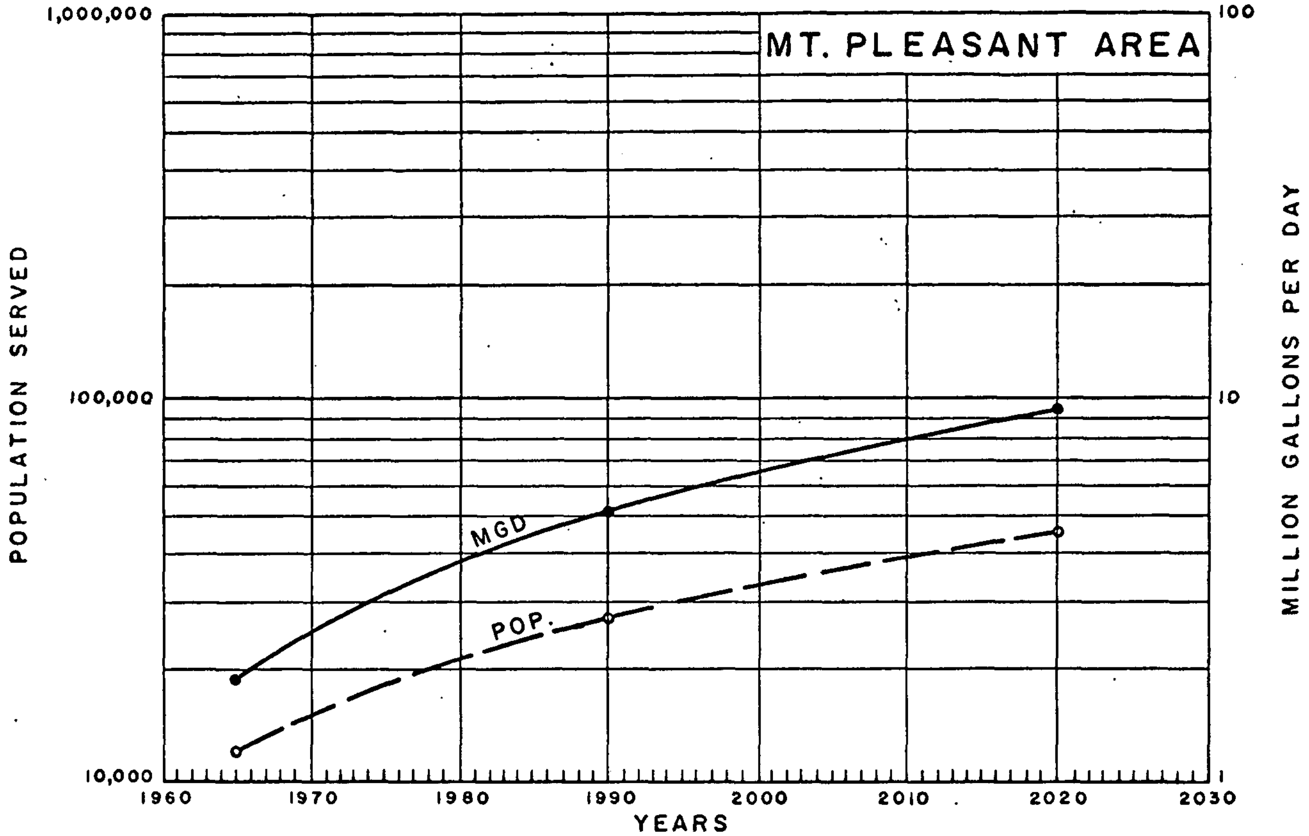


FIGURE 10b

POPULATION & MUNICIPAL WASTE FLOW PROJECTIONS FOR THE MT. PLEASANT & CLARE AREAS IN THE TITTABAWASSEE RIVER BASIN



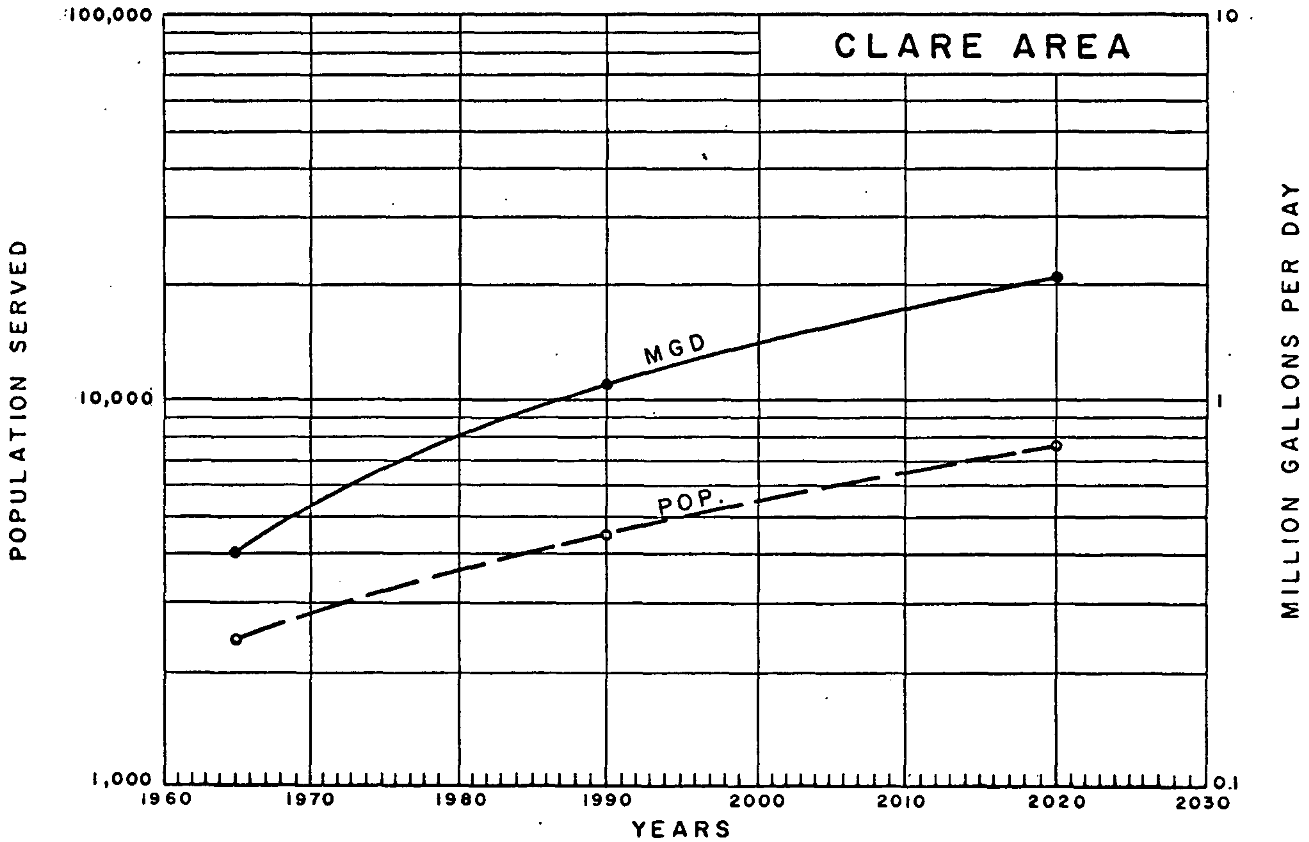
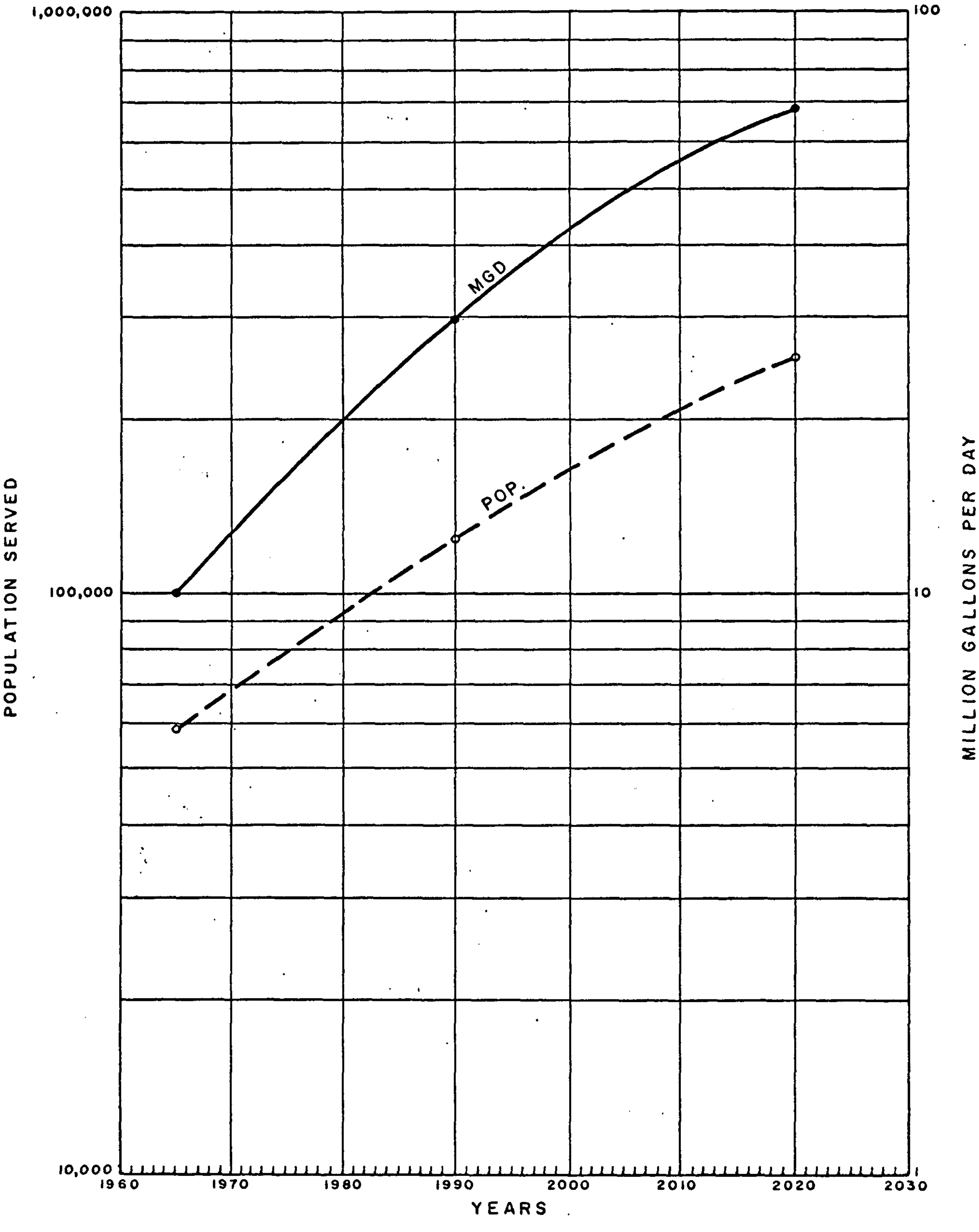


FIGURE 10c

POPULATION AND MUNICIPAL WASTE FLOW PROJECTIONS FOR THE TITTABAWASSEE RIVER BASIN



WATER QUALITY DATA

The Detroit Program Office conducted water quality surveys of the Tittabawassee River and its tributaries (Chippewa, Pine, and Tobacco Rivers) during 1965. Station locations are shown on Figure 8.

Reconnaissance surveys of the main stem Tittabawassee River, and the Tobacco, Pine, and Chippewa Rivers, were conducted during February 1965. Single grab samples were collected at many locations and analyzed for alkalinity, chloride, conductivity, dissolved oxygen, and total coliform concentrations. On the basis of these surveys, a number of locations were selected for routine sampling, which was conducted approximately twice a month for one year.

An intensive survey was conducted September 15-16, 1965 to determine the effect of waste loading on the lower 25 miles of the Tittabawassee River from Midland to the mouth. Six locations at about 5-mile intervals along the river were sampled every 4 hours for 24 hours. Dissolved oxygen and temperature were determined on each sample. Composites were prepared for other parameters. Samples for bacteriological analyses were collected twice per day.

Additional surveys were conducted on the major tributaries - Tobacco, Chippewa, and Pine Rivers - in the fall of 1965 to determine the effect of waste loadings on dissolved oxygen profile. Samples were collected on each of two runs at many stations on the rivers.

The results of these surveys are described in the following sections. Data tabulations and graphical presentations for the surveys are included on Tables 11 to 34 and Figures 11 to 15.

Reconnaissance Surveys

The survey of the Tobacco River from above Clare to below Beaverton (Table 11) indicated high levels of coliform bacteria below Clare. Chloride levels doubled below the city but decreased downstream.

The survey of the Chippewa River from above Mt. Pleasant to near the confluence with the Pine River (Table 12) indicated excessive coliform levels below Mt. Pleasant. These levels persisted for about 20 miles. Chloride levels increased moderately.

The survey of the Pine River from above Alma to near the confluence with the Chippewa (Table 13) indicated high coliform densities below the Alma-St. Louis area. These levels persisted for about 10 miles. Chloride levels increased tenfold below St. Louis and the conductivity more than doubled.

The survey of the Tittabawassee River from above Sanford Lake to the confluence with the Saginaw River (Table 14) indicated a low level of bacterial contamination, with the exception of a sample collected near Lingle Drain, the effluent from the Midland sewage treatment plant. Conductivity increased sixfold at Midland and chloride levels increased 50 times. A part of this increase was from the Pine River; however, most of the waste load was from the Midland plant of the Dow Chemical Company.

Regular Tributary Sampling

The following eleven stations on the Tittabawassee River and tributaries were sampled approximately twice a month during 1965:

Tittabawassee River	Tobacco River	Chippewa River	Pine River
X460	X585	X780	X880
X440	X580	X770	X870
X410		X740	X820

The stations are described in Table 2 and located on Figure 5. Tables 15 to 18 list the water quality data obtained during the 1965 survey. Data are listed for each station. Also included are seasonal groupings of certain parameters and yearly averages for all stations in the basin (Tables 19 to 24). In general, major waste sources or tributaries enter the streams between the first two stations. The third station is generally about twenty miles below the major waste sources.

Dissolved oxygen levels were high throughout the basin (Tables 15 to 18). With the exception of a single value of 2.2 mg/l, 24 percent saturation, reported in the Pine River below the Alma-St. Louis area, all tributary concentrations were above 7 mg/l. With the exception of this location, the yearly averages for tributaries were above 10 mg/l. In the main stem of the Tittabawassee River, below Midland, dissolved oxygen average concentrations were above 9 mg/l, with a minimum of 5.3 mg/l (62 percent). The minimum level above Midland was 6.3 mg/l (74 percent).

Organic matter (Tables 15 to 18), expressed in terms of five-day BOD (BOD_5) and ammonia and organic nitrogen, was low throughout the basin, with the exception of the Pine River below Alma-St. Louis. A maximum BOD_5 level of 11 mg/l occurred at this location, with an average annual concentration of 5 mg/l. Maximum ammonia and organic nitrogen levels were 2.7 mg/l and 0.5 mg/l, with average values of .96 mg/l and .21 mg/l. With respect to organic concentrations, this location was the most polluted in the basin, exceeding the level of the Tittabawassee River downstream from Midland. BOD_5 levels throughout the remainder of the basin averaged 1 to 2 mg/l. Ammonia levels were generally well below 0.5 mg/l, except in the Tittabawassee River below Midland. As indicated in Tables 19 through 22, there was no significant seasonal variation apparent in the basin for the organic parameters.

Nutrient levels expressed in terms of nitrate as nitrogen, and total and soluble phosphorous as phosphate, were moderately high throughout the basin (Tables 15 to 18). Nutrient levels in the Tobacco River, the Chippewa River above Mt. Pleasant, the Pine River above Alma-St. Louis, and the Tittabawassee River above Midland, were low, with average nitrate-nitrogen and total phosphate concentrations of less than 0.5 mg/l and 0.2 mg/l, respectively. Average concentrations below the cities were considerably higher, especially in the Pine River below Alma-St. Louis where the average levels were 1.3 and 1.0 mg/l, respectively. The concentrations of nutrients increased downstream to levels of 1.5 and 1.1 mg/l nitrate and phosphate, respectively. The maximum levels of 3.1 and 4.6 mg/l in the basin occurred at this location. Average levels in the Tittabawassee and Chippewa Rivers downstream of the waste sources were about 0.8 mg/l nitrate and 0.4 mg/l phosphate.

Chlorides and other dissolved solids are the greatest delineators of industrial waste discharges in the basin. As indicated in Tables 15 to 18, distinct differences are apparent in basin water quality by the use of these parameters. Both the petrochemical industries in Alma-St. Louis and at Midland are discernible in their effect upon the chloride level in the Pine and Tittabawassee Rivers. Above these sources, the average total solids concentration is about 300 mg/l and below these sources, about 1,100 mg/l - a fourfold increase. Although there is an increase in the chloride levels below the cities on the Tobacco and Chippewa Rivers, the average concentration above major industrial sources is less than 25 mg/l. Below these industrial sources, the level averages about 400 mg/l - a sixteenfold increase. The increase on the Tittabawassee River from 14 to 417 mg/l is due both to the Chippewa-Pine tributary and to the industrial source at Midland.

There was no apparent seasonal variation in total solids or chloride concentration upstream of the industrial sources (Tables 19 through 22). On the Pine River below Alma-St. Louis, the chloride and total solids concentrations were lowest in the spring, averaging one-half to three-quarters of the annual concentration. In the Tittabawassee River, however, the lowest concentrations occurred during the summer season, although the seasonal difference was not as great. These average concentrations of chloride and total solids in the Pine River below Alma-St. Louis and the Tittabawassee River below Midland are extremely high in comparison to the recommended drinking water level of 250 mg/l.

Bacterial quality of the basin waters was, in general, severely impaired as measured by total coliform, fecal coliform, and fecal streptococcus concentrations (Tables 15 to 18). On the Tobacco, Chippewa, and Pine Rivers, the annual median concentration averaged 1,000 organisms/100 ml total coliform above the major cities. Annual median concentrations below these cities ranged from 32,000 organisms/100 ml on the Pine River to 70,000 organisms/100 ml on the Tobacco and Chippewa Rivers. At locations 20 miles below the major sources, the annual medians were 6,000 organisms/100 ml on the Tittabawassee, Chippewa, and Pine Rivers. Generally, comparable levels of fecal coliform and fecal streptococcus were found, although above the municipalities the fecal coliform to total coliform ratio was not as great as below the municipalities.

During the disinfection or summer season (Table 24), the median total coliform level was below 5,000 organisms/100 ml, except on the Tobacco River below the City of Clare. Maximum levels at all locations during the period ranged from 5,000 to 220,000 organisms/100 ml, or about the same as the range over the entire year. In general, the bacterial quality of the Tittabawassee River below Midland was better than the quality of the tributaries during the disinfection and non-disinfection periods.

During the nondisinfection period - September 15 to May 15 - median total coliform concentrations ranged from a minimum of about 200 organisms/100 ml on the Tittabawassee River below Sanford Dam to 82,000 organisms/100 ml on the Chippewa River below Mt. Pleasant. The maximum observed concentration was 420,000 organisms/100 ml below Mt. Pleasant. Maximum fecal coliform levels of 38,000 organisms/100 ml and fecal streptococcus levels of 15,000 organisms/100 ml occurred below Alma-St. Louis.

Radiochemistry data based on the 1965 regular tributary sampling program are listed on Tables 25 through 28 for the Tittabawassee River and main tributaries: Tobacco, Chippewa, and Pine Rivers. The data are listed in pico curies per liter of water sample. The sample is reported in terms of suspended (nonfiltrable) and dissolved (filtrable) portion. Alpha emitters and beta emitters were measured. Many of the samples indicated levels of less than 0.05 pico curies per liter (10^{-12} curies/liter). Maximum levels of alpha emitters were 2.5 pc/l dissolved and 0.6 pc/l suspended. Maximum levels of beta emitters were 22 pc/l dissolved and 3.6 pc/l suspended. These maximum levels occurred in the Pine River. For most samples the standard counting error exceeded the level of the sample, indicating a very low level of radioactivity in the sample.

Tittabawassee River Dissolved Oxygen Profile Study

Data collected during the intensive survey on September 15-16, 1965 are listed on Table 29 and shown on Figures 11 to 15. During this survey, water quality was similar to the annual average water quality at those stations routinely sampled. Exceptions were in dissolved oxygen (DO) levels and bacterial densities.

The DO profile (Figure 11) indicates a minor depression occurs below the Midland area. Average depletion was about 1 mg/l from the upstream concentration. Both the average level and the minimum levels indicate a sufficiently high level of DO existed in the stream.

Diurnal variation in DO level was a maximum of about 2 mg/l. Minimum DO observed was 6.1 mg/l, which occurred near the confluence with the Saginaw River in a mid-morning sample. During a mid-summer intensive DO study of the Saginaw River, a minimum value of 5.2 mg/l or 61 percent saturation was observed in the Tittabawassee River near this location. Diurnal variation (Table 30) for various surveys indicates that a moderate amount of photosynthetic activity exists in the Tittabawassee River. As indicated in this table, DO levels are considerably lower during the warmer months.

Organic matter expressed as five-day BOD (Figure 11 and Table 29) was at a low level, indicating that under the survey flow conditions only moderate organic pollution existed in the stream. Nitrògenous oxygen demanding materials expressed in terms of ammonia and organic nitrogen were at moderate levels. There was little change in the level of the BOD and nitrogen parameters throughout the stream below the waste sources, indicating a slow decay rate. The intensive survey levels of these parameters compare favorably with the average annual concentration.

Nutrient levels, in terms of phosphates and nitrate nitrogen (Figures 13 and 12 and Table 29), were high, with average nitrate nitrogen concentrations of 1.0 mg/l and total phosphorous expressed as phosphate of 0.5 mg/l. Soluble phosphate level was 0.1 mg/l less.

By far, the greatest indicator of pollution in the Tittabawassee River is the level of chlorides and other dissolved solids (Figure 14 and Table 29). During the intensive survey, chloride level increased fifteenfold below the Midland waste sources. This increase was from a level of 28 mg/l to a level of 420 mg/l. The concentration of the tributaries, Chippewa and Pine Rivers, were 34 and 40 mg/l, respectively. On the basis that during this intensive survey, the flow from each tributary was equal and together equivalent to the upstream flow of the Tittabawassee River, most of the increased chloride concentration occurs in the Midland area. The levels of both chloride and total solids were the same in the lower Tittabawassee River as the average annual concentration. The levels of chloride at the upper station (above the confluence of the Chippewa-Pine) were considerably greater than at the routine sampling station below Sanford Dam.

Total coliform densities (Figure 15 and Table 29) indicated moderate pollution during this survey, with only a single sample exceeding a level of 5,000 organisms/100 ml. Although there was a gradual increase in the coliform level, this increase was not significant. Survey levels compared favorably with the annual median level at the downstream location. At the upstream survey location, which is located within the City of Midland, the survey level was significantly higher than at the year-round station below Sanford reservoir.

In general, this intensive survey compared favorably with the results of the year-round sampling. It indicated that for most parameters there is little change in level in the twenty miles of stream from the major waste sources to the confluence with the Saginaw River, and that the use of a single station near the mouth of the Tittabawassee River is a good indicator of water quality.

Intensive Tributary Studies

Tobacco River

Seven stations were sampled on the Tobacco River. The data (Table 31) indicate low levels of pollution in the Tobacco River. With the exception of bacterial densities and chloride levels, there was no significant change in the water quality below the waste sources. DO levels were high and BOD_5 levels were low, averaging 1 mg/l. Chloride concentrations doubled below the City of Clare and remained at this level until after the confluence of the Cedar River at Beaverton. Bacterial densities for total and fecal coliform and fecal streptococcus increased below the City of Clare and gradually decreased downstream. An increase again occurred below the confluence of the Cedar River at Beaverton. The City of Gladwin is located on the Cedar River about five miles above the confluence.

The results of the intensive study compared very favorably with the regular tributary sampling at the two stations above and below Clare, with the exception of DO and coliform levels. Minimum DO levels were significantly lower as expected, due to the higher temperature conditions included during the summer months of the regular tributary sampling. Minimum coliform levels were also lower during the regular sampling season due to disinfection practiced in the summer months, at the time of the survey.

Chippewa River

Eight stations were sampled on the Chippewa River. The data (Table 32) indicate that moderate amounts of pollution exist from Mt. Pleasant downstream. A minor depression of DO level was noted below Mt. Pleasant. The BOD_5 level increased (from 1 mg/l to 2 mg/l) downstream of the city. Minor increases in the nitrate and chloride levels were also indicated. A significant increase in bacterial densities occurred below Mt. Pleasant. These levels gradually decreased downstream, although remaining excessive even near Midland, a distance of 40 miles. All other parameters indicated no significant change due to effluents from Mt. Pleasant.

The results of the intensive survey compare favorably with the regular tributary sampling at the three stations included in both series. DO levels were higher during the intensive survey due to the decreased stream temperatures. Minimum bacterial levels at the two regular stations below Mt. Pleasant were significantly lower during the regular sampling period, which included the summer disinfection season.

Pine River

Seven stations were sampled on the Pine River. The data (Table 33) indicate that moderate levels of pollution exist below the Alma-St. Louis area. A minor DO depression exists for some distance below these cities. There is recovery, however, within ten miles downstream of the two cities, with the maximum DO level being found near Midland. Ammonia nitrogen levels increased below Alma and then again below St. Louis. Phosphate levels also increased substantially. Chlorides, dissolved solids, and conductivity increased substantially below St. Louis, reflecting the industrial wastes of the petrochemical industries. The microbiological quality is severely degraded below Alma. Partial recovery is achieved below St. Louis, and a gradual decline in the numbers of coliform organisms occurred with the bacteriological quality near Midland, approximately the same as that above Alma-St. Louis.

The results of the intensive survey compare favorably with the regular tributary sampling at the three stations included in both series. DO levels were higher during the intensive survey period due to the higher temperature period included in the year-round sampling. Minimum bacterial levels were significantly lower at the two stations below the Alma-St. Louis area during regular sampling as a result of disinfection practiced during the summer months at the time of the survey. The chloride and associated parameters (conductivity, dissolved solids, and other minerals) were at the maximum yearly level on one of the intensive survey runs.

Three stations on the Tittabawassee River - below Sanford, below Midland, and at Shields - were also sampled during the intensive surveys on the Tobacco, Chippewa, and Pine Rivers. The data (Table 34) at the Sanford station indicated a very favorable comparison with the yearly data, with the exception of DO and bacterial level. Data at the two stations below Midland indicated that the quality of the Tittabawassee River, especially relating to chloride and associated parameters, are highly variable. The influence of the Midland area on lessening water quality of the Tittabawassee River is apparent from these intensive surveys.

NOTES
FOR
WATER QUALITY TABLES

NS - Number of Samples

Chemical Parameters

Cl	Chloride	Mg	Magnesium
Fe	Iron	Na	Sodium
SO_4	Sulfate	K	Potassium
Si	Silica	CO_3	Carbonate
Ca	Calcium	HCO_3	Bicarbonate

Total hardness: reported as $CaCO_3$

Nitrogens: ammonia (NH_3), organic, nitrates (NO_3), and nitrites (NO_2) reported as nitrogen equivalent (N)

Phosphates: reported as PO_4

Total phosphates include: ortho, poly, biological, and organic.
Total soluble phosphates include: soluble ortho, soluble poly, and soluble organic.

pH: reported in standard units

All results recorded in milligrams per liter (mg/1) except:

phenols and iron - micrograms per liter (μg/1)
conductivity - micromhos per centimeter (μmhos/cm)

Microbiological Parameters

Total Coliform)
Fecal Coliform) reported as organisms(MF)/100 ml
Fecal Streptococcus)

Total Plate Count: number of bacteria/ml

Median value is used for "average" statistic except as noted.

- -

Indeterminate values (less than $<$ or greater than $>$) not used in calculating average.

TABLE 11. WATER QUALITY DATA - RECONNAISSANCE SURVEY
TOBACCO RIVER

February 9-10, 1965

Station	River Mile*	Alkalinity	Dissolved Oxygen	pH	Total Coliform	Conductivity	Chloride
X-585	31.9	168	13.8	8.0	1,000	342	11
X-580	28.6	162	13.8	7.7	150,000	412	17
X-570	26.6	154	12.5	7.7	30,000	392	23
X-560	24.2	162	12.5	7.7	20,000	394	23
X-550	21.6	164	11.2	7.6	20,000	396	22
X-545	18.8	150	11.2	7.5	20,000	388	25
X-540	15.2	145	11.2	7.6	21,000	414	22
X-535	11.8	150	11.2	7.6	7,600	412	25
X-530	9.2	172	13.8	7.8	21,000	398	13
X-520	5.1	178	12.5	7.6	5,600	408	13

* miles above confluence with Tittabawassee River.

TABLE 12. WATER QUALITY DATA - RECONNAISSANCE SURVEY
CHIPPEWA RIVER

February 16, 1965

Station	River Mile*	Alkalinity	Dissolved Oxygen	pH	Total Coliform	Conductivity	Chloride
X-780	42.1	152	14.0	8.0	6,200	380	19
X-770	37.8	156	12.9	8.0	66,000	380	21
X-766	32.0	158	11.7	8.0	69,000	390	21
X-764	28.4	154	11.3	8.0	53,000	400	23
X-762	25.3	151	11.8	7.8	60,000	400	25
X-760	22.7	154	12.4	8.0	67,000	420	31
X-758	19.5	154	11.8	8.0	53,000	420	32
X-755	17.0	152	11.1	8.0	40,000	410	30
X-750	14.7	144	11.0	7.9	72,000	390	26
X-745	10.5	128	10.9	7.8	12,000	350	21
X-740	7.7	116	10.7	8.0	7,400	370	32
X-730	5.8	118	10.6	7.8	19,000	350	25

* miles above confluence with Tittabawassee River.

TABLE 13. WATER QUALITY DATA - RECONNAISSANCE SURVEY
PINE RIVER

February 17, 1965

Station	River Mile*	Alkalinity	Dissolved Oxygen	pH	Total Coliform	Conductivity	Chloride
X-880	33.7	134	15.5	7.7	1,800	370	20
X-875	31.3	134	13.9	7.6	12,000	370	19
X-870	26.3	124	11.7	7.6	15,000	840	193
X-850	24.4	123	10.6	7.7	16,000	680	135
X-840	21.2	125	9.4	7.8	31,000	630	118
X-835	14.5	120	8.9	7.8	9,300	690	141
X-830	11.4	122	8.9	7.6	8,400	600	108
X-820	6.5	114	8.3	7.6	6,200	570	98
X-815	4.1	120	9.4	7.9	7,200	580	106
X-810	0.7	116	8.9	7.7	5,400	580	106

* miles above confluence with Chippewa River.

TABLE 14. WATER QUALITY DATA - RECONNAISSANCE SURVEY
TITTABAWASSEE RIVER

February 17, 1965

Station	River Mile*	Alkalinity	Dissolved Oxygen	pH	Total Coliform	Conductivity	Chloride
X-480	43.9	155	10.0	8.0	1,700	360	11
X-462	35.1	176	10.0	8.2	700	400	13
X-460	34.0	179	10.5	8.2	600	390	12
X-456	31.2	172	10.0	8.2	700	390	14
X-454	27.9	172	10.5	7.8	1,000	400	16
X-452	24.5	130	11.1	7.8	1,500	460	45
X-445	21.4	132	10.0	7.6	15,000	2,240	715
X-440	19.2	136	10.0	7.8	900	2,620	865
X-430	15.0	144	10.0	7.8	100	2,700	1,015
X-420	10.2	140	10.0	8.1	100	2,120	685
X-415	6.7	146	10.5	7.9	200	1,920	600
X-410	5.0	140	10.0	7.8	100	1,820	575
X-405	2.5	144	10.0	7.8	600	1,740	530

* miles above confluence with Saginaw River.

TABLE 15. WATER QUALITY
TOBACCO RIVER
1965

Parameters	X585 above Clare NS	Avg.	Low	High	X580 below Clare NS	Avg.	Low	High
Dissolved Oxygen	11	10.9	8.9	13.5	11	10.6	7.5	13.4
5-day BOD	7	1	<1	2	7	2	1	3
NH_3-N	13	0.23	0.10	0.45	13	0.27	0.16	0.53
Org-N	13	0.15	0.07	0.32	11	0.15	0.06	0.32
NO_3-N	14	0.3	0.1	0.9	13	0.5	0.1	1.0
NO_2-N	10	0.01	<0.01	0.01	9	0.01	0.01	0.01
Total PO_4	14	0.2	<0.1	0.6	13	0.2	<0.1	0.4
Total Sol. PO_4	14	0.1	<0.1	0.4	13	0.1	<0.1	0.2
Total Solids	14	261	215	324	13	299	229	396
Suspended Solids	14	16	1	105	13	9	2	27
Vol. Susp. Solids	12	11	<1	92	12	3	<1	9
Cl^-	16	11	7	30	15	17	10	26
Phenol	14	4	<1	8	14	3	<1	5
pH	16	8.0	7.7	8.4	15	7.9	7.2	8.3
Temperature	16	4.5	0	19.0	15	5.5	0	22.0
% Saturation	11	87	70	100	11	86	71	99

TABLE 15. WATER QUALITY (cont'd)
TOBACCO RIVER
1965

Parameters	X585 above Clare				X580 below Clare			
	NS	Avg.	Low	High	NS	Avg.	Low	High
Total Iron	14	550	<100	2,000	13	840	<100	3,800
Sodium	11	17	5	64	10	16	6	44
Potassium	11	4	1	10	10	3	2	5
Calcium	14	55	44	62	13	60	43	73
Magnesium	14	18	10	28	13	19	13	31
Sulfate	14	32	15	42	13	47	28	80
Total Hardness	14	199	150	228	13	214	152	250
Conductivity	16	370	280	440	15	420	280	510
Total Coliform	14	700	90	5,000	14	71,500	40	220,000
Fecal Coliform	14	120	20	9,700	12	8,800	15	26,000
Fecal Strep	14	90	4	1,700	12	1,250	20	4,400

TABLE 16. WATER QUALITY
CHIPPEWA RIVER
1965

Parameters	X780 above Mt. Pleasant NS	Avg.	Low	High	X770 below Mt. Pleasant NS	Avg.	Low	High	X740 near Midland NS	Avg.	Low	High
Dissolved Oxygen	11	10.8	7.5	16.0	11	10.4	7.6	13.4	13	10.3	7.8	14.0
5-day BOD	7	2	1	4	7	2	2	3	9	2	1	3
NH_3-N	14	0.26	0.14	0.49	14	0.44	0.18	0.92	15	0.30	0.06	0.53
Org-N	13	0.20	0.06	0.42	12	0.19	0.06	0.41	14	0.19	0.07	0.36
NO_3-N	14	0.8	0.1	1.2	14	0.8	0.2	1.5	16	1.0	0.1	2.5
NO_2-N	10	0.01	<0.01	0.02	10	0.01	<0.01	0.02	10	0.01	0.01	0.02
Total PO_4	14	0.2	<0.1	0.4	14	0.4	0.04	1.7	16	0.3	0.1	0.4
Total Sol. PO_4	14	0.1	<0.1	0.3	14	0.3	<0.04	1.3	16	0.2	0.04	0.4
Total Solids	13	290	234	343	13	304	251	351	15	317	72	480
Suspended Solids	14	24	3	124	14	18	6	66	16	20	4	57
Vol. Susp. Solids	13	5	1	9	11	6	1	11	15	5	<1	12
Cl^-	16	19	12	23	16	25	13	39	18	36	17	69
Phenol	15	4	<1	8	15	6	<1	28	16	4	<1	6
pH	16	7.9	7.5	8.2	16	7.9	7.6	8.2	18	7.9	7.5	8.3
Temperature	16	6.0	<0	21.5	16	6.0	0	24.0	18	7.0	<0	24.5
% Saturation	11	89	67	109	11	86	68	93	13	88	61	114

TABLE 16. WATER QUALITY
CHIPPEWA RIVER (cont'd)
1965

	X780 above Mt. Pleasant				X770 below Mt. Pleasant				X740 near Midland			
Parameters	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Total Iron	14	1,350	<100	5,700	14	1,140	<100	5,800	16	960	<100	3,300
Sodium	11	15	5	40	10	23	6	60	12	29	7	106
Potassium	11	4	2	8	10	5	2	11	12	6	2	13
Calcium	14	55	43	70	14	57	42	75	15	61	34	85
Magnesium	14	19	11	27	14	19	10	29	15	19	7	31
Sulfate	14	35	25	49	14	38	26	53	15	47	22	63
Total Hardness	14	208	142	254	14	213	138	290	15	223	112	302
Conductivity	16	390	270	490	16	410	270	520	18	460	270	660
Total Coliform	15	2,300	80	17,000	15	66,000	1,000	420,000	17	8,000	<10	30,000
Fecal Coliform	12	290	130	2,000	13	6,100	160	58,000	14	1,000	<10	3,700
Fecal Strep	13	<100	20	12,000	13	1,500	100	5,400	14	160	<5	2,300

TABLE 17. WATER QUALITY
PINE RIVER
1965

Parameters	X880 above Alma-St. Louis NS	Avg.	Low	High	X870 below Alma-St. Louis NS	Avg.	Low	High	X820 near Midland NS	Avg.	Low	High
Dissolved Oxygen	10	10.6	8.8	12.3	11	9.0	2.2	12.1	12	10.4	7.8	13.3
5-day BOD	7	2	1	3	7	5	2	11	8	3	2	5
NH_3-N	13	0.26	0.04	0.59	14	0.96	0.48	2.70	14	0.53	0.11	1.00
Org-N	13	0.17	0.05	0.47	14	0.21	>0.09	0.50	11	0.29	0.09	0.66
NO_3-N	14	0.8	0.1	1.7	14	1.3	0.3	2.3	15	1.5	0.5	3.1
NO_2-N	10	0.01	0.01	0.02	10	0.04	0.01	0.09	10	0.03	0.01	0.09
Total PO_4	14	0.2	<0.1	0.7	14	1.0	0.2	2.9	15	1.1	0.2	4.6
Total Sol. PO_4	14	0.1	<0.1	0.6	14	0.8	0.2	2.5	15	0.8	0.1	4.0
Total Solids	13	350	163	426	13	1,166	313	2,679	14	1,008	19	2,063
Suspended Solids	13	5	< 1	15	14	15	1	48	15	26	2	78
Vol. Susp. Solids	10	3	<1	<11	12	6	2	17	14	8	1	23
Cl^-	15	28	8	48	16	396	57	1,188	17	360	40	876
Phenol	15	4	<1	9	15	8	<1	23	16	7	<1	24
pH	15	7.9	7.5	8.5	16	7.8	7.4	8.3	17	7.9	7.4	8.4
Temperature	15	6.5	0	24.0	16	7.0	0	26.0	17	7.0	0	25.5
% Saturation	10	91	69	106	11	74	24	89	12	89	61	111

TABLE 17. WATER QUALITY
PINE RIVER (cont'd)
1965

Parameters	X880 above Alma-St. Louis				X870 below Alma-St. Louis				X820 near Midland			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Total Iron	14	610	100	3,200	14	810	<100	2,800	15	1,010	<100	3,100
Sodium	11	19	4	50	12	89	15	224	12	96	18	315
Potassium	11	5	1	8	12	20	3	40	12	22	3	55
Calcium	14	81	34	211	14	212	51	524	13	199	52	412
Magnesium	14	22	7	36	14	27	10	42	14	27	9	52
Sulfate	14	55	35	75	14	69	35	90	13	73	35	101
Total Hardness	14	270	112	472	14	570	164	1,360	14	559	160	1,095
Conductivity	15	480	260	610	16	1,480	220	3,860	17	1,420	360	3,060
Total Coliform	13	1,000	190	7,900	14	32,000	1,500	170,000	16	6,400	< 20	51,000
Fecal Coliform	11	90	30	1,300	12	12,000	530	38,000	13	2,500	20	13,000
Fecal Strep	12	75	4	4,000	12	1,300	55	15,000	13	100	8	2,400

TABLE 18. WATER QUALITY
TITTABAWASSEE RIVER
1965

Parameters	X460 below Sanford				X440 below Midland				X410 at Shields			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved Oxygen	10	9.7	6.3	12.2	6	9.7	7.0	11.8	12	9.3	5.3	12.0
5-day BOD	6	2	1	3	6	3	2	4	7	3	3	4
NH_3-N	13	0.26	0.12	0.42	6	0.78	0.25	2.60	13	0.84	0.24	1.52
Org-N	13	0.18	0.07	0.40	6	0.35	0.13	0.99	12	0.25	0.11	0.59
NO_3-N	13	0.5	0.1	1.8	6	1.1	0.3	1.8	14	1.1	0.3	2.0
NO_2-N	10	0.01	$<$0.01	0.02	1	0.01	-	-	10	0.02	0.01	0.04
Total PO_4	13	0.2	$<$0.1	0.6	6	0.5	0.1	1.4	14	0.6	0.1	1.6
Total Sol. PO_4	13	0.1	$<$0.1	0.4	6	0.2	0.04	0.5	12	0.4	0.04	1.2
Total Solids	13	269	193	356	6	1,149	618	1,430	14	1,100	722	1,601
Suspended Solids	13	13	3	31	6	22	11	34	14	30	6	63
Vol. Susp. Solids	11	5	3	9	6	7	$<$1	14	13	8	$<$1	26
Cl^-	15	14	8	36	6	402	138	558	15	424	200	830
Phenol	14	5	1	13	6	22	9	39	15	13	2	31
pH	15	8.0	7.6	8.4	6	7.6	6.9	8.2	16	7.8	6.9	8.3
Temperature	15	6.5	0	22.5	7	10.5	2.0	19.0	17	8.0	0	24.0
% Saturation	10	81	70	97	7	88	76	94	12	79	62	98

TABLE 18. WATER QUALITY
TITTABAWASSEE RIVER (cont'd)
1965

Parameters	X460 below Sanford				X440 below Midland				X410 at Shields			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Total Iron	13	1,060	<100	3,600	6	130	<100	300	13	1,220	<100	4,300
Sodium	11	16	3	36	6	84	28	>100	13	145	48	305
Potassium	11	4	2	6	6	23	13	32	13	27	9	71
Calcium	13	54	32	67	6	121	61	188	14	128	50	182
Magnesium	13	17	7	28	6	23	14	29	14	28	16	48
Sulfate	13	41	30	50	6	70	60	90	13	70	14	106
Total Hardness	12	194	106	252	6	424	278	560	15	567	260	2,620
Conductivity	14	350	230	450	6	1,610	800	2,070	17	1,510	840	2,500
Total Coliform	14	190	8	5,600	6	21,500	<100	41,000	16	3,600	>10	54,000
Fecal Coliform	12	12	2	490	6	2,350	<5	7,600	12	790	10	>3,000
Fecal Strep	12	12	<2	1,100	6	215	<4	530	12	105	10	1,700

TABLE 19. TITTABAWASSEE RIVER BASIN WATER QUALITY 1965 SEASONAL VARIATION

January - April

River	Dissolved Oxygen Avg.	Dissolved Oxygen Max.	Dissolved Oxygen Min.	BOD_5	NH_3-N	Org-N	NO_3-N	Tot. PO_4	Tot. Sol. PO_4	Total Sol.	Susp. Sol.	Vol. Susp. Sol.	Cl	Phenols
Tittabawassee														
X410	11.2	12.0	10.0	-	1.15	0.29	1.23	0.74	.50	1,093	28	6	467	16
X460	10.2	10.5	10.0	-	0.30	0.17	0.42	0.16	.08	246	10	3	11	4
Chippewa														
X740	10.8	12.4	9.0	-	0.42	0.14	1.15	0.30	.20	291	20	6	37	4
X770	11.9	13.4	9.7	-	0.56	0.18	1.05	0.51	.34	300	19	5	23	6
X780	12.5	16.0	9.4	-	0.34	0.22	1.01	0.20	.13	291	36	6	18	3
Pine														
X820	10.9	12.4	8.9	-	0.85	0.28	1.51	0.80	.56	723	29	8	259	7
X870	11.2	12.1	9.4	-	0.89	0.18	1.37	1.06	.81	827	14	6	255	10
X880	11.4	12.3	10.0	-	0.35	0.12	1.01	0.11	.11	321	4	2	24	3
Tobacco														
X580	12.1	13.4	10.0	-	0.32	0.14	0.66	0.17	.10	283	9	2	16	3
X585	12.0	13.5	9.7	-	0.30	0.15	0.43	0.11	.10	259	11	3	11	4

TABLE 20. TITTABAWASSEE RIVER BASIN WATER QUALITY 1965 SEASONAL VARIATION

May - September

River	Dissolved Oxygen Avg.	Dissolved Oxygen Max.	Dissolved Oxygen Min.	BOD_5	NH_3-N	Org-N	NO_3-N	Tot. PO_4	Tot. Sol. PO_4	Total Sol.	Susp. Sol.	Vol. Susp. Sol.	Cl	Phenols
Tittabawassee														
X410	6.5	9.4	5.2	3	0.94	0.18	0.42	0.46	0.34	966	23	7	370	8
X460	8.0	9.4	6.3	1	0.26	0.21	0.22	0.28	0.21	278	15	4	20	6
Chippewa														
X740	8.6	9.4	7.8	2	0.30	0.17	0.38	0.24	0.17	333	26	5	35	4
X770	8.1	8.7	7.6	2	0.25	0.25	0.27	0.20	0.15	314	18	8	26	4
X780	8.3	8.7	7.5	1	0.20	0.20	0.30	0.10	0.10	291	11	5	20	3
Pine														
X820	8.8	9.9	7.8	3	0.23	0.37	0.98	1.86	1.44	1,423	30	8	451	3
X870	6.4	8.7	2.2	5	0.78	0.24	1.12	1.20	0.88	1,368	17	5	502	5
X880	9.1	9.8	8.8	1	0.16	0.22	0.12	0.10	0.06	378	6	3	37	2
Tobacco														
X580	8.3	9.0	7.5	2	0.26	0.18	0.12	0.22	0.12	317	12	4	18	3
X585	9.1	9.3	8.9	1	0.18	0.14	0.22	0.25	0.18	269	36	28	10	4

TABLE 21. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 SEASONAL VARIATION

October - December

River	Dissolved Oxygen Avg.	Dissolved Oxygen Max.	Dissolved Oxygen Min.	BOD_5	NH_3-N	Org-N	NO_3-N	Tot. PO_4	Tot. Sol. PO_4	Total Sol.	Susp. Sol.	Vol. Susp. Sol.	Cl	Phenols
Tittabawassee														
X410	9.3	11.5	8.7	3	0.29	.17	1.28	.32	.19	1,212	25	8	400	10
X460	11.7	12.2	11.3	1	0.12	.12	1.00	.35	.04	329	16	8	15	3
Chippewa														
X740	12.0	14.0	10.2	1	0.10	.27	1.42	.20	.10	351	10	2	35	2
X770	11.3	12.6	10.6	2	0.36	.13	0.73	.25	.16	299	11	4	24	4
X780	11.9	12.4	11.4	1	0.16	.14	0.80	.11	.07	283	11	4	19	3
Pine														
X820	12.1	13.3	11.1	2	0.38	.21	2.50	.70	.33	966	10	7	511	10
X870	9.3	11.9	8.0	4	1.35	.22	1.40	.63	.53	1,944	11	7	676	4
X880	11.7	12.3	10.8	1	0.16	.25	1.00	.28	.23	394	4	3	26	4
Tobacco														
X580	11.6	12.4	10.2	1	0.17	.15	0.50	.18	.07	306	5	1	17	2
X585	11.8	12.3	10.9	1	0.15	.14	0.30	.09	.09	252	2	1	9	1

TABLE 22. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 SEASONAL VARIATION

Annual

River	Dissolved Oxygen Avg.	Dissolved Oxygen Max.	Dissolved Oxygen Min.	BOD_5	NH_3-N	Org-N	NO_3-N	Tot. PO_4	Tot. Sol. PO_4	Tot. Sol.	Susp. Sol.	Vol. Susp. Sol.	Cl	Phenols
Tittabawassee														
X410	7.8	12.0	5.2	3	.83	.21	0.95	.55	.36	1,083	26	7	417	12
X460	9.6	12.2	6.3	1	.26	.17	0.45	.23	.12	269	13	4	14	4
Chippewa														
X740	10.3	14.0	7.8	1	.29	.18	0.97	.26	.17	317	20	5	36	4
X770	10.4	13.4	7.6	2	.43	.18	0.76	.37	.25	304	17	5	24	5
X780	10.8	16.0	7.5	1	.26	.20	0.76	.15	.10	290	23	5	19	3
Pine														
X820	10.3	13.3	7.8	3	.53	.29	1.53	1.13	.81	1,008	25	8	360	6
X870	8.9	12.1	2.2	4	.96	.20	1.30	1.01	.77	1,165	14	6	396	7
X880	10.6	12.3	8.8	1	.26	.17	0.75	0.14	.12	350	4	3	28	3
Tobacco														
X580	10.6	13.4	7.5	1	.27	.15	0.46	0.19	.10	299	9	3	16	2
X585	10.9	13.5	8.9	1	.23	.14	0.34	0.15	.12	260	16	11	10	3

TABLE 23. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 SEASONAL NUTRIENT VARIATION

River	Nitrate-Nitrogen (mg/l)				Total Phosphate (mg/l)			
	Jan.-Apr.	May-Sept.	Oct.-Dec.	Annual	Jan.-Apr.	May-Sept.	Oct.-Dec.	Annual
Tittabawassee								
X410	1.23	0.42	1.28	0.95	0.74	0.46	0.65	0.95
X460	0.42	0.22	1.00	0.45	0.16	0.28	0.32	0.45
Chippewa								
X740	1.15	0.38	1.42	0.97	0.30	0.24	0.20	0.26
X770	1.05	0.27	0.73	0.76	0.51	0.20	0.25	0.37
X780	1.01	0.30	0.80	0.76	0.20	0.10	0.11	0.15
Pine								
X820	1.51	0.98	2.50	1.53	0.80	1.86	0.70	1.13
X870	1.37	1.12	1.40	1.30	1.06	1.20	0.63	1.01
X880	1.01	0.12	1.00	0.75	0.11	0.10	0.28	0.14
Tobacco								
X580	0.66	0.12	0.50	0.46	0.17	0.22	0.18	0.19
X585	0.43	0.22	0.30	0.34	0.11	0.25	0.09	0.15

TABLE 24. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 SEASONAL COLIFORM VARIATION

Location	January-April			May-September			October-December			Annual		
	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low	High
Tittabawassee												
X410	2,650	<10	30,000	3,500	1,500	6,800	27,000	12,000	54,000	4,100	<10	54,000
X460	210	<10	5,600	1,750	100	4,000	-	60	60	190	<10	5,600
Chippewa												
X740	8,000	2,100	26,000	480	<10	25,000	20,000	12,000	30,000	8,000	<10	30,000
X770	82,000	23,000	420,000	5,000	1,000	220,000	227,000	64,000	390,000	66,000	1,000	420,000
X780	4,500	100	17,000	4,550	80	16,000	835	740	930	2,300	80	17,000
Pine												
X820	9,300	1,500	51,000	900	<20	25,000	1,200	300	2,100	6,400	20	51,000
X870	34,000	15,000	170,000	5,600	1,500	88,000	74,500	29,000	120,000	32,000	1,500	170,000
X880	2,800	500	7,900	740	400	5,200	595	190	1,000	1,000	190	7,900
Tobacco												
X580	56,500	25,000	160,000	66,650	40	220,000	160,000	140,000	180,000	71,500	40	220,000
X585	230	90	2,800	2,050	700	5,000	830	700	960	700	90	5,000

TABLE 25. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 RADIOACTIVITY
Tobacco River

	X580				X585							
Parameters	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved												
ALPHA	8 (3)	<0.05	<0.05	<0.05	9 (3)	<0.05	<0.05	<0.05				
Error	8 (3)	1.4	1.2	1.7	9 (3)	1.1	1.1	1.2				
BETA	8 (3)	5.1	4.3	5.6	9 (3)	4.4	2.9	5.4				
Error	8 (3)	2.4	1.7	2.8	9 (3)	1.7	1.5	1.9				
Suspended												
ALPHA	8 (3)	0.10	<0.05	0.20	9 (3)	0.17	<0.05	0.40				
Error	8 (3)	0.3	0.2	0.4	9 (3)	0.3	0.2	0.4				
BETA	8 (3)	<0.05	<0.05	<0.05	9 (3)	1.1	0.2	2.3				
Error	8 (3)	1.4	0.9	1.6	9 (3)	1.0	0.9	1.1				

TABLE 26. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 RADIOACTIVITY
Chippewa River

Parameters	X740				X745				X770			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved												
ALPHA	10 (3)	<0.05	<0.05	<0.05	2 (1)	<0.05	-	-	9 (3)	-0.47	<0.05	1.30
Error	10 (3)	1.4	0.8	1.7	2 (1)	1.8	-	-	9 (3)	1.2	0.4	2.1
BETA	10 (3)	7.1	3.6	9.1	2 (1)	6.2	-	-	9 (3)	5.48	<0.05	12.00
Error	10 (3)	2.6	2.0	3.1	2 (1)	2.9	-	-	9 (3)	2.6	1.5	3.2
Suspended												
ALPHA	10 (3)	<0.05	<0.05	<0.05	2 (1)	<0.05	-	-	9 (3)	<0.05	<0.05	<0.05
Error	10 (3)	0.3	0.2	0.5	2 (1)	0.2	-	-	9 (3)	0.5	0.2	0.6
BETA	10 (3)	1.5	1.1	2.1	2 (1)	<0.05	-	-	9 (3)	0.43	<0.05	1.20
Error	10 (3)	1.6	1.0	1.9	2 (1)	1.6	-	-	9 (3)	1.6	1.1	2.0

TABLE 26. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 RADIOACTIVITY
Chippewa River (cont'd)

Parameters	X780											
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved												
ALPHA	9 (3)	<0.05	<0.05	<0.05								
Error	9 (3)	0.9	0.4	1.2								
BETA	9 (3)	7.5	5.5	11.0								
Error	9 (3)	2.6	1.5	3.5								
Suspended												
ALPHA	9 (3)	<0.05	<0.05	<0.05								
Error	9 (3)	0.5	0.3	0.6								
BETA	9 (3)	2.4	1.2	3.1								
Error	9 (3)	1.8	1.0	2.3								

TABLE 27. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 RADIOACTIVITY
Pine River

Parameters	X820				X870				X880			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved												
ALPHA	9 (3)	<0.05	<0.05	<0.05	8 (3)	<0.05	<0.05	<0.05	9 (3)	1.42	<0.05	2.50
Error	9 (3)	5.0	3.7	6.4	8 (3)	5.1	3.3	7.5	9 (3)	1.5	0.9	1.9
BETA	9 (3)	14.7	9.2	22.0	8 (3)	9.35	<0.05	15.00	9 (3)	3.78	<0.05	9.20
Error	9 (3)	7.6	6.5	9.5	8 (3)	7.8	7.0	9.1	9 (3)	2.2	1.4	3.2
Suspended												
ALPHA	9 (3)	<0.05	<0.05	<0.05	8 (3)	<0.05	<0.05	<0.05	9 (3)	0.20	<0.05	0.50
Error	9 (3)	1.5	1.4	1.6	8 (3)	1.2	0.7	1.7	9 (3)	0.3	0.2	0.5
BETA	9 (3)	1.62	<0.05	3.00	8 (3)	1.2	<0.05	3.6	9 (3)	0.23	<0.05	0.60
Error	9 (3)	4.6	4.0	5.3	8 (3)	4.7	4.4	5.4	9 (3)	1.2	0.8	1.8

TABLE 28. TITTABAWASSEE RIVER BASIN WATER QUALITY
1965 RADIOACTIVITY
Tittabawassee River

Parameters	X410				X440				X460			
	NS	Avg.	Low	High	NS	Avg.	Low	High	NS	Avg.	Low	High
Dissolved												
ALPHA	7 (2)	<0.05	<0.05	<0.05	5 (1)	<0.05	-	-	8 (3)	0.68	<0.05	1.10
Error	7 (2)	2.9	1.2	4.6	5 (1)	5.0	-	-	8 (3)	1.4	1.2	1.7
BETA	7 (2)	14.5	12.0	17.0	5 (1)	11.0	-	-	8 (3)	6.8	4.9	7.8
Error	7 (2)	5.5	3.3	7.7	5 (1)	7.1	-	-	8 (3)	2.2	1.8	2.8
Suspended												
ALPHA	7 (2)	0.33	<0.05	0.60	5 (1)	<0.05	-	-	8 (3)	<0.05	<0.05	<0.05
Error	7 (2)	0.9	0.8	0.9	5 (1)	1.4	-	-	8 (3)	0.3	0.2	0.4
BETA	7 (2)	0.18	<0.05	0.30	5 (1)	<0.05	-	-	8 (3)	1.4	0.6	1.9
Error	7 (2)	3.2	1.9	4.4	5 (1)	3.8	-	-	8 (3)	1.2	0.9	1.8

TABLE 29. INTENSIVE DISSOLVED OXYGEN SURVEY
TITTABAWASSEE RIVER

September 15-16, 1965

Station	Avg. Temp. (°C)	Dissolved Oxygen Avg.	Dissolved Oxygen Max.	Dissolved Oxygen Min.	Percent Saturation Avg.	Percent Saturation Max.	Percent Saturation Min.	BOD_5	Nitrogen NH_3	Nitrogen Org.	Nitrogen NO_3	Phosphates Total	Phosphates Soluble	Phenols
X-452	18	8.2	9.1	7.6	87	99	80	4	.11	.10	0.3	0.08	0.08	3
X-740	18	7.8	-	-	82	-	-	3	.50	.10	0.6	0.1	0.05	4
X-820	19	7.8	-	-	85	-	-	3	.30	-	1.4	1.1	0.6	4
X-440	21	7.5	8.2	6.9	85	89	80	6	.26	.21	1.0	1.5	0.2	21
X-430	21	7.2	7.5	6.7	81	84	76	6	.61	.10	1.0	0.5	0.3	18
X-420	21	7.0	7.7	6.2	79	87	69	4	.64	.06	1.0	0.6	0.4	24
X-410	20	6.6	7.4	6.2	74	82	68	4	.56	.09	1.1	0.5	0.4	9
X-405	20	6.8	7.3	6.1	75	81	69	4	-	-	1.0	0.6	0.3	29

Station	Solids Total	Solids Suspended	Solids Volatile	Chlorides	Conductivity	Alkalinity	pH	Iron	Total Coliform Max.	Total Coliform Min.
X-452	312	12	3	28	450	150	7.8	0.6	1,800	250
X-740	375	51	10	34	480	156	7.5	0.3	2,600	-
X-820	1,134	38	10	40	1,200	178	8.0	0.6	320	-
X-440	1,105	13	7	425	1,500	150	7.6	0.8	1,600	1,400
X-430	1,028	11	3	430	1,450	146	7.4	0.7	2,900	1,800
X-420	1,033	18	-	350	1,300	150	7.6	1.2	2,600	2,200
X-410	1,016	20	5	405	1,500	150	7.6	0.3	5,800	2,600
X-405	1,035	38	-	390	-	146	7.7	0.1	3,900	2,200

TABLE 30. DIURNAL DISSOLVED OXYGEN FLUCTUATION
TITTABAWASSEE RIVER
Station X410

Date 1965	Time	Temp. (°C)	DO (mg/1)	Percent Saturation
7/20	0920	23	5.2	61
	1315	25	6.5	79
	1654	26	7.2	90
	2050	24	6.4	77
7/21	0035	24	5.9	71
	0425	23	5.7	67
7/21	1120	24	7.2	86
	1520	27	8.4	107
	1855	27	9.4	119
	2250	24	7.6	91
7/22	0230	25	5.8	71
	0635	24	5.4	65
9/15	0935	21	6.2	70
	1315	21	6.8	77
	1715	20	6.2	69
	2130	20	7.4	82
9/16	0130	20	6.9	76
	0535	19	6.2	68
10/26	0820	10	9.4	84
	1220	11	9.4	86
	1620	11	9.4	86
	2025	10	9.0	80
10/27	0025	10	8.7	77
	0415	10	8.7	77
10/27	1030	10	9.7	86
	1500	11	9.8	89
	1900	10	9.6	85
	2235	10	9.3	83
10/28	0220	10	8.9	78
	0630	9	8.9	77

TABLE 31. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Tobacco River

Station	Date 1965	Temp. °C	DO	Percent Saturation	BOD_5	Nitrogen NH_3	Nitrogen Org.	Nitrogen NO_3	Phosphates Total	Phosphates Soluble	Phenols	Solids Diss.	Solids Susp.	Solids Vol. Susp.
X-585	10/6	7.0	10.9	89	1	0.24	0.16	0.20	0.20	0.20	0	260	3	3
	11/9	4.5	12.2	94	1	0.11	0.18	0.30	<0.04	<0.04	1	250	3	1
X-580	10/6	8.5	10.2	87	2	0.18	-	0.30	0.10	0.10	0	320	2	2
	11/9	6.0	12.4	99	1	0.19	0.20	0.20	0.40	0.08	3	290	6	0
X-570	10/6	8.0	10.0	84	2	0.52	0.42	0.40	0.20	0.20	0	330	-	-
	11/9	6.0	12.2	98	1	0.12	0.10	0.30	0.06	0.06	1	290	8	0
X-560	10/6	8.0	10.0	84	2	0.08	0.26	0.40	0.30	0.20	1	330	11	1
	11/9	5.0	12.2	95	1	0.15	0.22	0.30	0.08	0.06	0	320	7	0
X-545	10/6	8.0	10.1	85	2	0.58	0.22	0.50	0.20	0.20	0	330	13	4
	11/9	5.0	11.7	91	1	0.18	0.29	0.20	0.60	0.40	1	300	12	3
X-540	10/6	8.0	10.6	89	2	0.06	0.25	0.50	0.10	0.10	1	340	9	2
	11/9	5.0	12.2	95	4	0.15	0.18	0.20	0.04	<0.04	1	350	8	3
X-530	10/6	10.5	11.0	99	2	0.15	0.18	0.30	<0.04	<0.04	1	340	13	3
	11/9	6.5	12.7	103	1	0.14	0.24	0.10	<0.04	<0.04	0	1,290	7	2

TABLE 31. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Tobacco River (cont'd)

Station	Date 1965	Chlorides	Conductivity	Alkalinity	pH	Iron	Coliform Total	Coliform Fecal	Fecal Strep.
X-585	10/6	10	410	188	8.0	<100	700	20	70
	11/9	10	420	180	8.1	<100	960	130	90
X-580	10/6	19	490	195	7.2	<100	140,000	18,000	770
	11/9	17	470	172	8.1	<100	180,000	26,000	1,600
X-570	10/6	17	500	200	7.9	<100	58,000	11,000	620
	11/9	15	500	203	8.1	<100	32,000	5,200	710
X-560	10/6	17	490	202	8.1	200	57,000	7,400	1,100
	11/9	15	490	206	8.0	100	37,000	5,300	900
X-545	10/6	19	510	204	7.9	<100	13,000	2,400	340
	11/9	15	500	206	8.0	<100	25,000	4,800	840
X-540	10/6	17	510	205	8.2	100	6,900	400	100
	11/9	18	520	210	8.1	<100	9,100	3,100	410
X-530	10/6	13	460	197	8.1	<100	34,000	1,900	570
	11/9	11	460	203	8.3	<100	36,000	1,900	270

TABLE 32. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Chippewa River

Station	Date 1965	Temp. °C	DO	Percent Saturation	BOD_5	Nitrogen NH_3	Nitrogen Org.	Nitrogen NO_3	Phosphates Total	Phosphates Soluble	Phenols	Solids Diss.	Solids Susp.	Solids Vol. Susp.
X-780	10/5	10.0	11.9	106	1	0.16	0.16	0.70	0.20	0.10	5	300	8	5
	11/9	6.0	11.4	91	1	0.16	0.16	0.60	0.08	0.06	0	270	8	4
X-770	10/5	9.5	10.6	93	3	0.57	0.08	1.10	0.60	0.40	9	300	11	1
	11/9	6.5	10.7	87	2	0.34	0.18	0.50	0.10	<0.04	0	300	7	4
X-766	10/5	10.0	10.5	93	1	0.32	0.20	0.70	<0.04	<0.04	7	310	5	2
	11/9	6.5	9.7	78	3	0.26	0.14	0.60	0.20	0.10	0	290	9	4
X-764	10/5	10.0	10.7	95	2	0.26	0.17	1.20	0.20	0.10	9	300	11	5
	11/9	6.0	10.5	84	3	0.22	0.16	0.60	0.30	0.20	0	290	8	5
X-760	10/5	9.0	10.7	93	2	0.20	0.25	0.80	0.20	0.10	9	320	7	3
	11/9	6.0	8.9	71	1	0.30	0.28	0.70	0.30	0.20	0	320	9	5
X-755	10/5	9.0	10.3	90	3	0.14	0.15	1.20	0.20	0.10	6	340	9	5
	11/9	5.5	10.2	80	1	0.12	0.09	0.60	<0.04	<0.04	0	310	12	9
X-745	10/5	9.0	11.1	96	1	0.18	0.37	0.37	0.10	0.10	7	360	8	2
	11/9	6.0	10.2	82	3	0.10	0.14	2.40	0.04	<0.04	0	320	9	3
X-740	10/5	9.0	11.2	97	1	0.12	0.36	1.90	0.20	0.10	3	400	5	1
	11/9	6.0	10.2	82	1	0.14	0.20	0.60	0.10	0.08	0	340	9	2

TABLE 32. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Chippewa River (cont'd)

Station	Date 1965	Chlorides	Conductivity	Alkalinity	pH	Iron	Coliform Total	Coliform Fecal	Fecal Strep.
X-780	10/5	18	410	172	8.0	<100	930	160	40
	11/9	22	450	184	8.1	<100	740	160	30
X-770	10/5	25	450	178	8.0	100	64,000	58,000	54,000
	11/9	27	460	191	7.9	<100	390,000	46,000	2,200
X-766	10/5	23	450	180	7.9	100	73,000	11,000	700
	11/9	27	490	190	8.0	<100	400,000	45,000	3,000
X-764	10/5	25	450	182	8.0	100	190,000	17,000	900
	11/9	29	500	190	7.9	<100	180,000	42,000	2,500
X-760	10/5	30	480	180	7.8	100	100,000	16,000	1,700
	11/9	39	530	191	8.1	<100	75,000	17,000	2,400
X-755	10/5	30	480	181	7.8	100	48,000	6,800	<100
	11/9	28	500	187	8.0	<100	34,000	4,500	170
X-745	10/5	30	520	187	7.9	100	26,000	2,000	<100
	11/9	31	500	191	8.0	<100	32,000	4,100	140
X-740	10/5	34	530	190	8.1	100	20,000	1,000	<110
	11/9	36	500	192	8.1	<100	30,000	2,800	210

TABLE 33. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Pine River

Station	Date 1965	Temp. °C	DO	Percent Saturation	BOD_5	Nitrogen			Phosphates		Phenols	Solids		
						NH_3	Org.	NO_3	Total	Soluble		Diss.	Susp.	Vol. Susp.
X-880	10/5	9.0	10.8	94	1	0.21	0.40	0.90	0.70	0.60	9	450	4	0
	11/2	6.0	12.2	98	1	-	-	0.40	0.10	0.04	0	400	-	-
X-875	10/5	9.5	9.8	86	2	0.40	0.34	1.50	0.40	0.30	5	420	6	2
	11/2	6.0	10.7	86	3	0.34	0.04	0.50	0.60	0.30	0	400	11	8
X-870	10/5	10.0	8.0	71	4	0.80	0.36	1.60	0.60	0.40	5	1,620	8	7
	11/2	7.0	8.0	66	4	2.70	0.18	2.30	0.80	0.70	4	2,660	17	13
X-850	10/5	10.0	7.9	70	3	0.42	0.61	3.00	0.90	0.60	3	1,450	3	3
	11/2	6.5	7.9	64	4	-	-	3.10	-	-	1	2,450	-	-
X-840	10/5	9.0	8.6	75	7	0.34	0.22	2.80	0.60	0.40	3	1,400	4	3
	11/2	6.0	-	-	4	-	-	2.60	1.40	0.60	3	2,380	-	-
X-835	10/5	9.0	10.1	88	3	0.37	0.34	3.30	0.60	0.40	4	1,440	2	2
	11/2	6.0	10.4	83	2	-	-	3.10	1.10	0.70	6	2,450	-	-
X-820	10/5	9.0	11.1	96	2	0.11	0.15	2.80	0.70	0.20	6	1,330	8	4
	11/2	6.0	13.3	106	2	0.47	0.37	3.10	1.20	0.70	2	870	-	-

TABLE 33. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Pine River (cont'd)

Station	Date 1965	Chlorides	Conductivity	Alkalinity	pH	Iron	Coliform Total	Coliform Fecal	Fecal Strep.
X-880	10/5	27	600	228	8.0	<100	1,000	90	55
	11/2	31	590	232	8.2	<100	900	60	25
X-875	10/5	29	600	228	8.0	100	140,000	32,000	2,200
	11/2	33	580	233	8.2	<100	490,000	71,000	7,500
X-870	10/5	486	1,760	214	8.2	100	120,000	17,000	580
	11/2	1,188	3,860	209	7.6	100	29,000	11,000	1,200
X-850	10/5	446	1,880	214	8.0	100	22,000	3,000	270
	11/2	1,050	3,460	202	7.5	200	2,800	1,300	500
X-840	10/5	404	1,760	203	8.0	100	7,600	2,100	240
	11/2	1,019	3,400	204	7.6	<100	3,100	1,500	500
X-835	10/5	419	1,820	210	8.2	100	2,000	120	80
	11/2	1,029	3,440	204	7.8	<100	600	90	80
X-820	10/5	374	1,700	194	7.8	100	2,100	110	8
	11/2	876	3,060	208	8.0	100	300	20	16

TABLE 34. INTENSIVE TRIBUTARY SURVEY
TITTABAWASSEE RIVER BASIN

Tittabawassee River

Station	Date 1965	Temp. °C	DO	Percent Saturation	BOD_5	Nitrogen NH_3	Nitrogen Org.	Nitrogen NO_3	Phosphates Total	Phosphates Soluble	Phenols	Solids Diss.	Solids Susp.	Solids Vol. Susp.
X-460	11/2	7.5	11.3	94	1	0.12	0.15	0.20	0.30	<0.04	1	330	16	9
X-440	10/6	15.0	9.3	93	2	2.60	0.15	1.50	0.50	0.10	26	1,230	18	8
	11/9	10.0	9.8	87	3	0.34	0.29	0.90	-	-	13	1,160	19	7
X-410	10/6	12.5	9.2	86	3	0.38	0.34	1.30	0.40	0.20	13	940	29	7
	11/2	10.0	9.3	83	3	0.42	0.11	2.00	0.40	0.10	21	1,570	36	9

Station	Date 1965	Chlorides	Conductivity	Alkalinity	pH	Iron	Coliform Total	Coliform Fecal	Fecal Strep.
X-460	11/2	16	410	168	8.2	100	60	20	<5
X-440	10/6	417	1,760	179	8.0	100	<100	<5	<5
	11/9	424	1,660	142	7.4	100	13,000	4,000	340
X-410	10/6	293	1,340	179	8.0	<100	34,000	1,100	80
	11/2	629	2,340	179	7.9	<100	54,000	1,800	130

TITTABAWASSEE RIVER
DISSOLVED OXYGEN AND BOD
SEPTEMBER 15-16, 1965 SURVEY

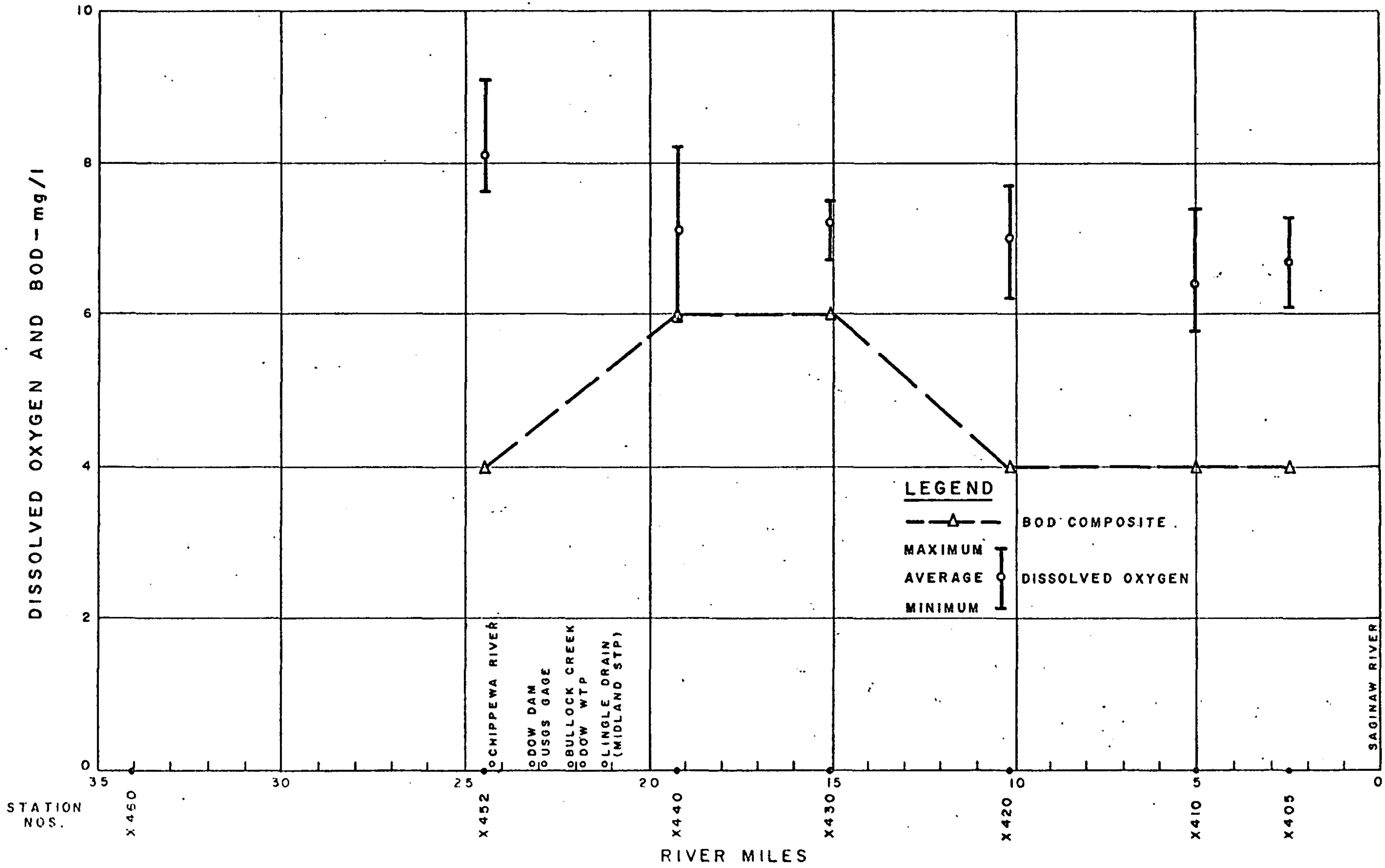


FIGURE 11

TITTABAWASSEE RIVER
NITRATE CONCENTRATION
SEPTEMBER 15-16, 1965 SURVEY

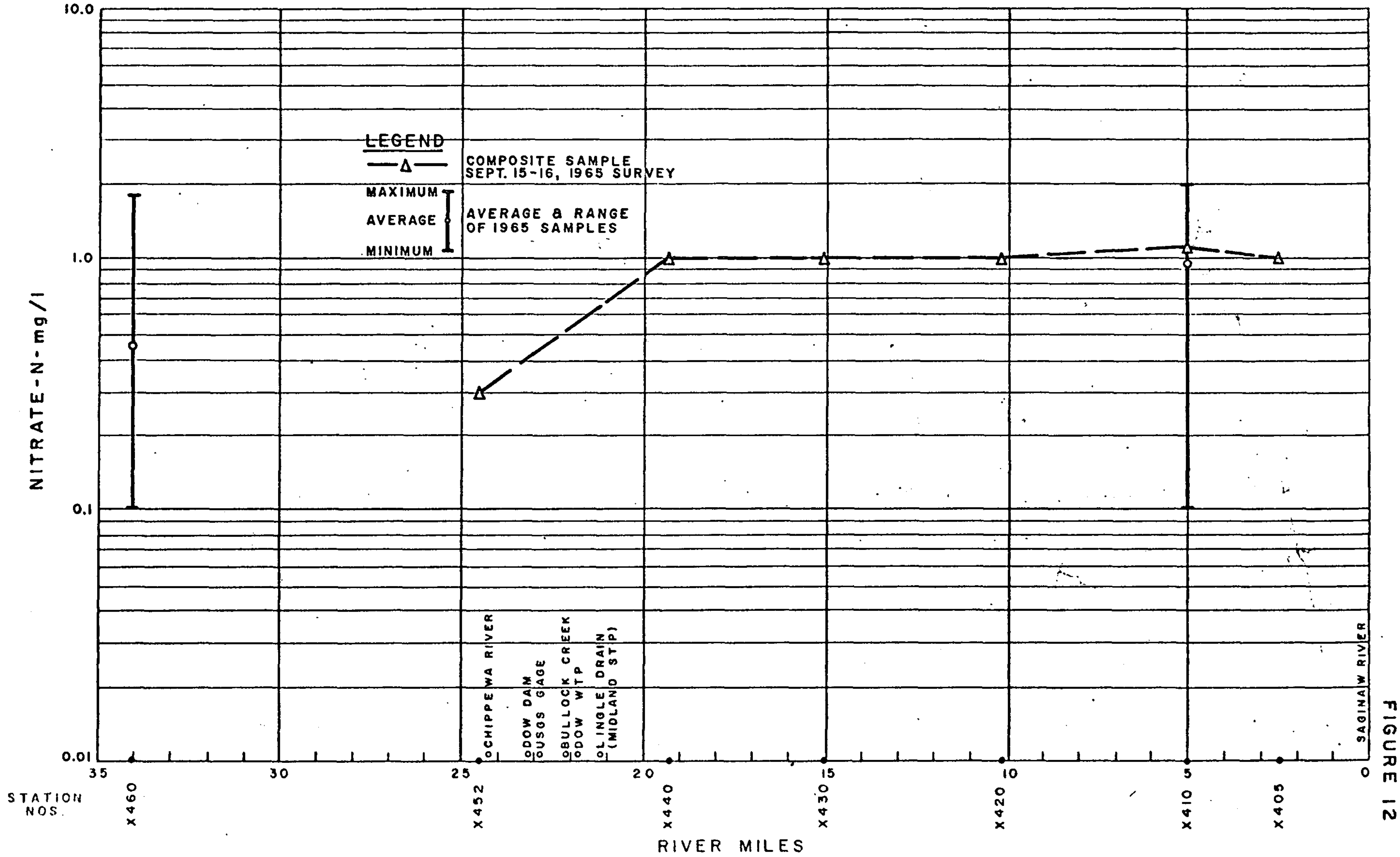


FIGURE 12

TITTABAWASSEE RIVER
TOTAL AND SOLUBLE PHOSPHATE
SEPTEMBER 15-16, 1965 SURVEY

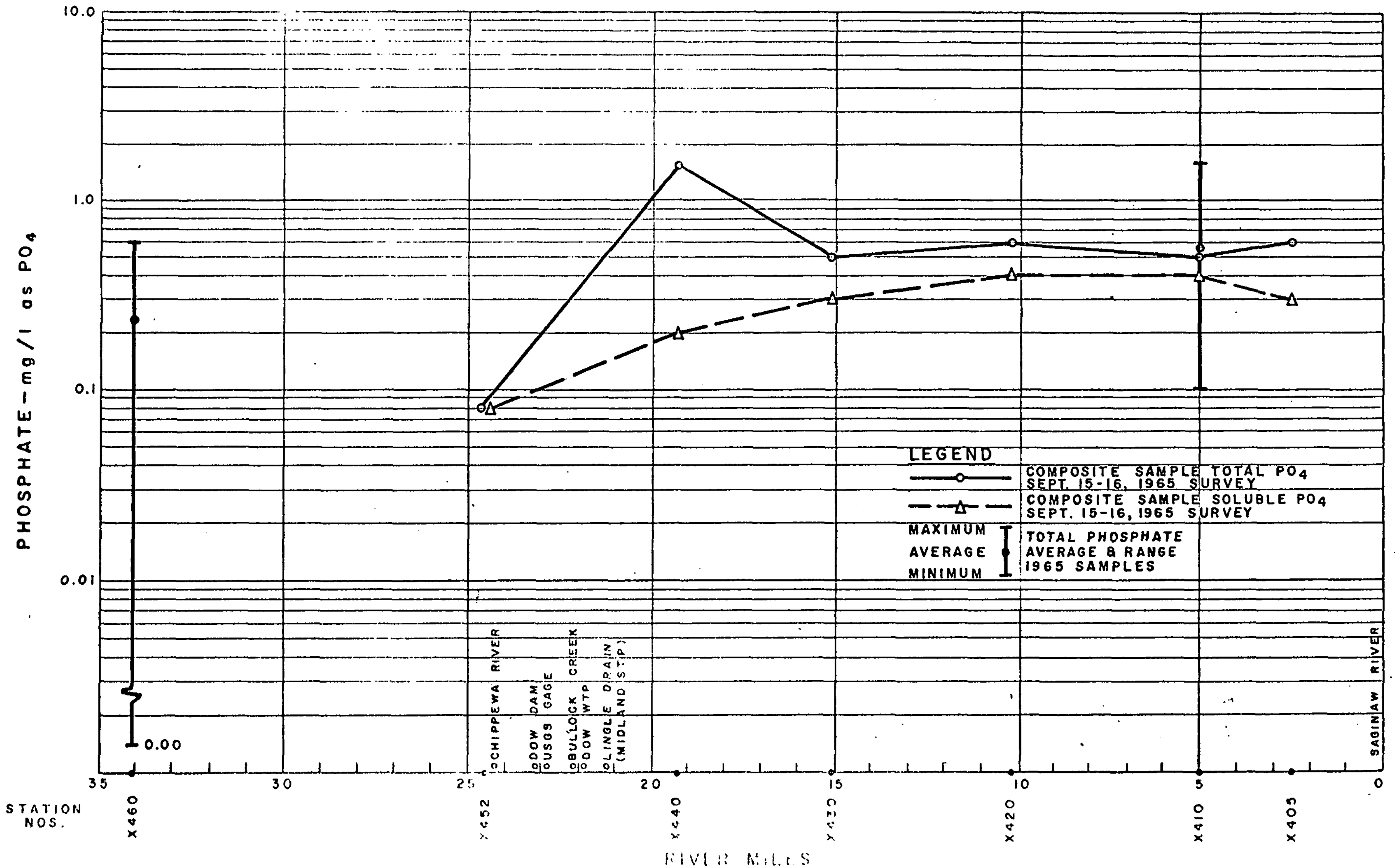


FIGURE 13

TITTABAWASSEE RIVER
TOTAL SOLIDS AND CHLORIDES
SEPTEMBER 15-16, 1965 SURVEY

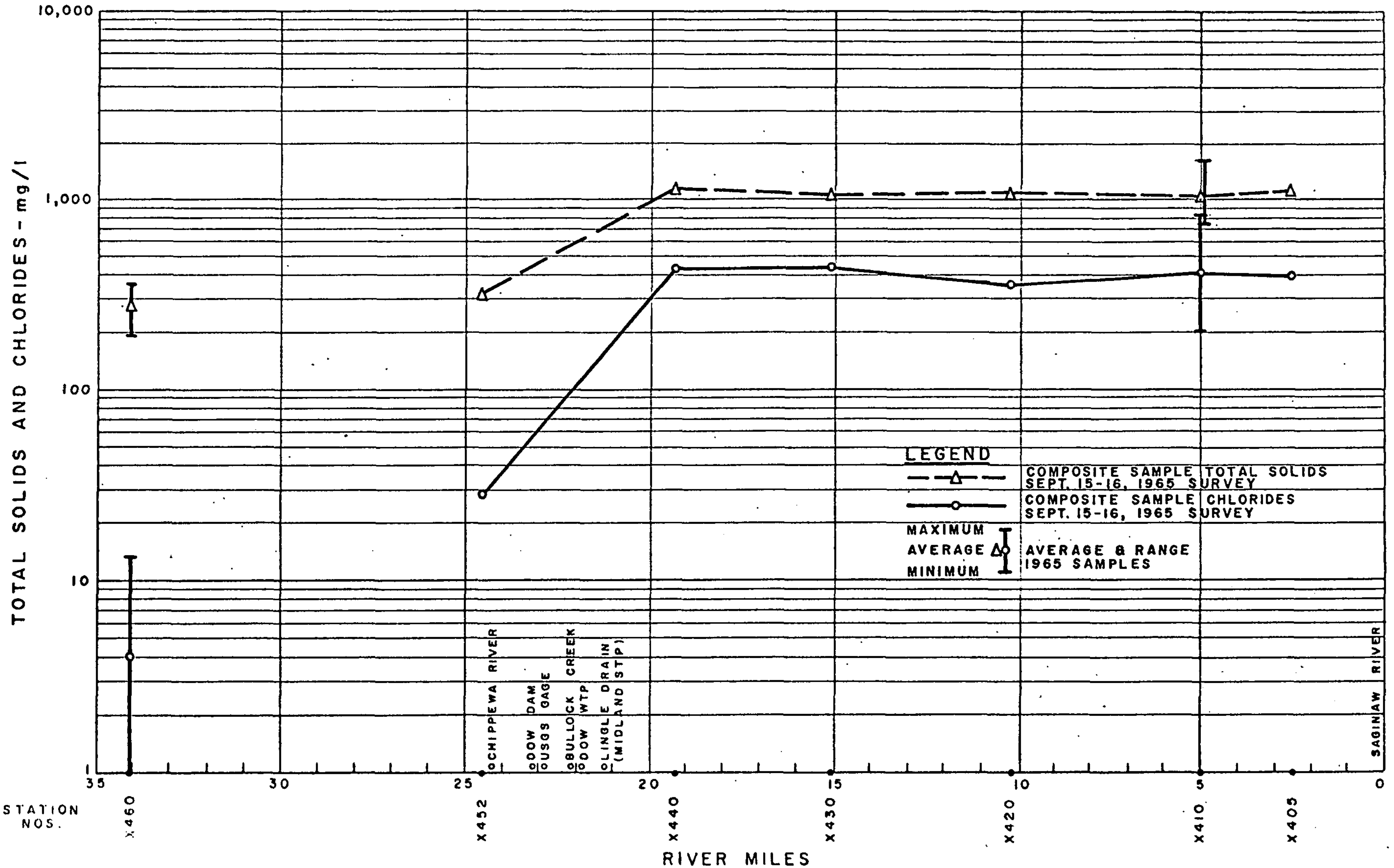


FIGURE 14

TITTABAWASSEE RIVER
TOTAL COLIFORM DENSITIES
SEPTEMBER 15-16, 1965 SURVEY

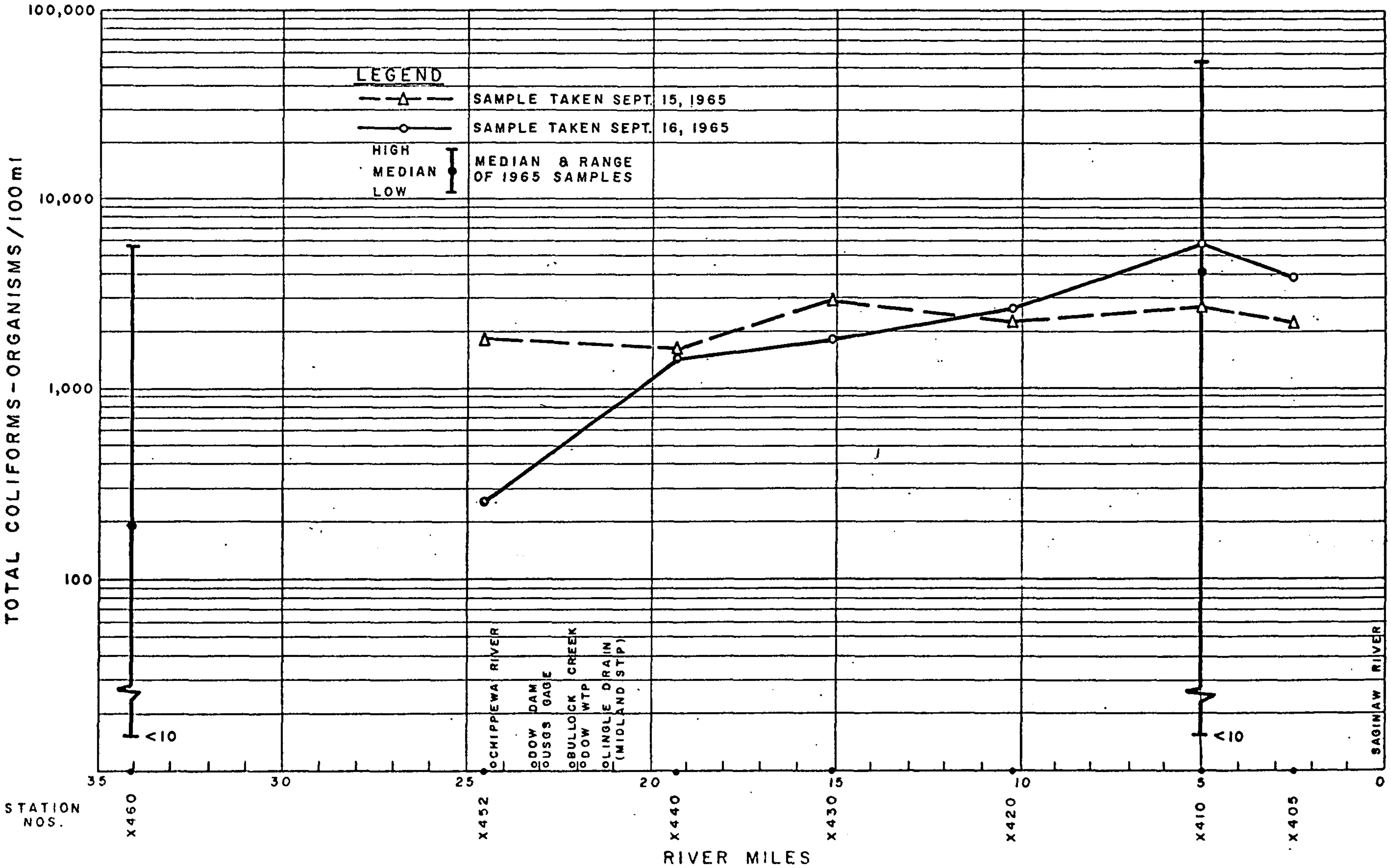


FIGURE 15

Biology

Investigations on the biological condition of the Tittabawassee River and its three main tributaries were conducted from October 1964 through November 1965, as a part of the water quality study of Lake Huron and its major tributaries. Eleven locations were sampled for phytoplankton and benthic organisms within the Tittabawassee River Basin.

Physical observations on the Tittabawassee River and the three tributaries (Chippewa, Pine, and Tobacco Rivers) are presented in Table 35. The water transparency was reduced at some stations by spring rains; however, secchi disc readings ranged from 0.8 feet up to 6 feet. Light penetration to the bottom of these shallow rivers was common. Aquatic vascular plant growth was sparce except at X870 on the Pine River, downstream from Alma and St. Louis. Strong chemical odors in the water and bottom muds were noted below Midland at stations X440 and X410. No chemical smells were detected at X460 upstream from Midland. An oily, and sometimes septic, smelling river bottom was found in the Chippewa River below Mt. Pleasant.

The species of bottom-dwelling invertebrates in this basin, presented in Table 36, changed from clean water forms above the major cities of Mt. Pleasant and Midland to pollution tolerant communities downstream. Observations in the Pine River above Alma and St. Louis revealed a variety of intolerant organisms; however, below these towns at station X870, the river appeared highly enriched. *Potomogeton* choked the river channel, attached algae covered the submerged rocks, and blue-green algae coated the river banks. Sludgeworms and bloodworms comprised the entire benthic fauna community. Station X410, near the confluence of the Tittabawassee and Saginaw Rivers, had moderate numbers of pollution tolerant organisms, along with some intolerant forms, indicating a recovery of the benthic community. The furthest downstream stations on the Chippewa and Pine Rivers also had clean water communities. The Tobacco River supported a large variety of intolerant organisms above the City of Clare.

Populations of the phytoplankton of the Tittabawassee River and the three tributaries are presented in Table 37. Algae populations of the Tittabawassee River were dominated by the diatom, Cyclotella-Stephanodiscus, and by green flagellated forms usually common in nutrient-enriched midwestern streams.

Summer phytoplankton populations averaged 740 organisms/ml at the upper Tittabawassee River station (X460) above Midland. During the same time, phytoplankton populations at station X440, located a short distance below Midland, averaged 5,960 organisms/ml. Further downstream at the lower station (X410), the phytoplankton populations averaged 3,190 organisms/ml. This indicates more nutrient enrichment of the water at the two lower stations.

Phytoplankton populations varied considerably at the downstream stations on the three tributaries of the Tittabawassee River. The average populations per milliliter for the summer sampling period at the lower stations were: Tobacco River - 860; Chippewa River - 1,040; and Pine River - 25,060.

Data from samples collected from the three Pine River stations on July 9, 1965 show a large increase in the standing crop. At the upstream station (X880), 120 organisms/ml were recorded; at the station below St. Louis (X870), 2,770 organisms/ml were recorded; and at the lower station (X820), 25,060 organisms/ml were recorded. These values indicate that the Pine River received considerable nutrient-enrichment below Alma and St. Louis.

Spirogyra was noted at three Tittabawassee River stations in the fall of 1964. *Oscillatoria* was noted at one station. These algae are typically found in enriched waters.

Physical observations, benthic and phytoplankton community evaluations point out water quality impairments below the cities of Midland, Mt. Pleasant and Alma-St. Louis. The lower sections of the tributaries and the Tittabawassee River seem to be somewhat improved, however, standing crops of algae often are increased.

TABLE 35. PHYSICAL OBSERVATIONS
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station	Date	Depth (ft.)	Bottom Type	Bottom Odor	Water Odor	Secchi Disc (ft.)	Remarks
Tittabawassee River							
X460	10/21/64	3	Sand	Normal	Normal	5.0	Water turbid.
	4/23/65	6	Gravel, rock	Normal	Normal	0.8	Water is turbid, high, and swift
	7/9/65	5	Rock	Normal	Normal	1.5	Water muddy, moderate flow; no vegetation or filamentous algae
	9/18/65	3	Sand, gravel, rock	-	Normal	2.0	No emergent vegetation
X440	10/21/64	5	Sand	Sewage or chemical	Sewage	5.0	Water greenish and turbid.
	4/24/65	7	Sand, rock	Chemical	Normal	2.5	Water swift, turbid and high.
	7/8/65	3	Sand	Chemical	Chemical	1.5	No vegetation.
	9/18/65	3	Sand, gravel, rock	Petro-chemical	Chemical	1.5	No vegetation. Rocks slimy; water suds when shaken.
X430	10/21/64	3	Silt, sand	Sewage	-	1.5	Water greenish and turbid, algal slime along the shore; chemical smell in the air; large sewage outfall below bridge.

TABLE 35. PHYSICAL OBSERVATIONS (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station	Date	Depth (ft.)	Bottom Type	Bottom Odor	Water Odor	Secchi Disc (ft.)	Remarks
X410	4/24/65	7	Sand, snail shells	Chemical	Chemical	2.5	Water swift, turbid, and high.
	7/8/65	3	Sand, rock	Normal	Chemical	1.5	Water turbid, flow slow, little vegetation.
	9/18/65	5	Silt, fine sand	Chemical	Chemical	1.5	Rapid flow, no emergent vegetation.
Tobacco River							
X585	4/19/65	3	Sand, rock	Normal	Normal	To Bottom	No vegetation, fairly good quality.
	7/9/65	1.5	Silt, sand detritus	Normal	Normal	To Bottom	Clear water, minnows and water striders, no aquatic plants or attached algae.
	9/14/65	-	Sand, gravel	-	Normal	To Bottom	Water clean and clear, no emergent vegetation or attached algae, "typical" trout stream.
X580	4/19/65	6	Sand, gravel	Normal	Normal	2.5	More polluted than upstream.
	9/14/65	-	Sand	Normal	Normal	To Bottom	Very little emergent vegetation, degraded from upstream.

TABLE 35. PHYSICAL OBSERVATIONS (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station	Date	Depth (ft.)	Bottom Type	Bottom Odor	Water Odor	Secchi Disc (ft.)	Remarks
Chippewa River							
X780	4/19/65	6	Sand, rock	Normal	-	1.5	Water turbid and high; water treatment plant upstream.
	7/9/65	3	Sand, gravel rock	Normal	-	To Bottom	Vegetation sparse but varied, algae, minnows, rock bass.
	9/14/65	-	Clay, sand, gravel, rock	Normal	-	To Bottom	Dark tea color, slight foam patches; appears good quality.
X770	4/19/65	7	Silt, sand	Petro.	Normal	1.5	Very turbid, slight oil slick.
	7/9/65	3	Silt, sand, gravel	Sewage	Sewage	To Bottom	Water muddier than at X780. Minnows, rock bass, algae on rock and bottom.
	9/14/65	3	Clay, sand, gravel, rock	Petro	Normal	To Bottom	Blue-green scum on rocks and bottom, slight oil slick on surface, small tarry particles on water.
X740	4/23/65	5	Gravel, rock	Normal	-	2.5	Appears cleaner than the Tittabawassee River in this area
	7/9/65	1.5	Sand, gravel, rock	Normal	Normal	To Bottom	No aquatic plants, much filamentous algae on bottom, suckers.
	7/18/65	3	-	-	Normal	To Bottom	Shallow, rapid, clean and clear.

TABLE 35. PHYSICAL OBSERVATIONS (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station	Date	Depth (ft.)	Bottom Type	Bottom Odor	Water Odor	Secchi Disc (ft.)	Remarks
Pine River							
X880	4/18/65	7	Rubble, rock	-	Normal	6.0	Water tea colored.
	7/9/65	4.5	Silt, sand, gravel, rubble	Normal	Normal	To Bottom	Water clean; pike and panfish; aquatic plants scarce but of wide variety.
	9/13/65	-	Gravel, rock, detritus	-	Normal	To Bottom	Water tea colored, appears clearer than before; suds on water.
X870	4/18/65	5	Sand	-	-	To Bottom	Water tea colored; no aquatics.
	7/9/65	1.5	Silt, sand, gravel, rock	-	Normal	To Bottom	Massive Potomogeton growths extend far upstream. Carp.
	9/13/65	5	Sand, gravel	Sewage and sulfur	Normal	2.5	Water whitish cast; abundant Potomogeton, although less than previous survey.
X820	4/23/65	3	Sand	Normal	Normal	1.5	Water tea colored; high and turbid.
	7/9/65	3	Silt, sand, gravel	Normal	Normal	1.5	Dark water with foam particles.
	9/18/65	3	Sand	-	-	To Bottom	Clear, tea colored; minnows; no emergents.

TABLE 36. BENTHIC MACROINVERTEBRATES
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

		Organisms per Square Foot							
Station	Date	Oligochaeta	Tubificidae	Tendipedidae	Pulmonata	Ephemeroptera	Trichoptera	Others*	Total
Tittabawassee River									
X410	4/24/65	-	28	-	-	-	-	-	28
	7/8/65	-	6	14	-	-	5	-	25
	9/18/65	4	9	13	-	2	-	(e) 2	30
X430	10/21/64	-	19	-	-	-	-	-	19
X440	4/24/65	-	10	2	-	-	-	-	12
	7/8/65	-	9	4	-	-	-	-	13
	9/8/65	-	7	-	-	-	-	(b) 1	8
X460	4/23/65	-	-	8	-	-	5	-	13
Tobacco River									
X585	7/9/65	19	-	110	1	1	-	(b) 16, (f) 2, (d) 2, (a) 1	152
Chippewa River									
X740	7/9/65	-	1	29	-	13	21	(e) 1	65
X770	7/9/65	20	-	260	18	-	-	-	298
X780	7/9/65	4	3	150	-	-	3	-	160

* see following page for explanations.

TABLE 36. BENTHIC MACROINVERTEBRATES (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station	Date	Oligo-chaeta	Tubifi-cidae	Tendi-pedidae	Pulmonata	Ephemer-optera	Trich-optera	Others*	Total
Pine River									
X820	7/9/65	1	8	21	16	1	1	(f) 4	52
X870	7/9/65	-	35	25	-	-	-	-	60
X880	7/9/65	82	75	360	8	-	-	(b) 11, (c) 9 (g) 1, (h) 1	547

Others*
a. Plecoptera
b. Diptera
c. Isopoda
d. Sphaeriidae
e. Zygoptera
f. Coleoptera
g. Nematoda
h. Hemiptera

TABLE 37. PHYTOPLANKTON
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station/ Season*	Number of Samples	Average Number per Milliliter: Centric Diatoms	Pennate Diatoms	Green Coccoids	Blue-Green Coccoids	Blue-Green Fila-mentous	Green Flag-ellates	Brown Flag-ellates	Total	Predominant Genera** (10% or more)
Tittabawassee River										
X460										
Spring 1965	2	150	90	60	-	10	-	-	310	a, h, k
Summer 1965	2	200	30	40	-	60	270	140	740	a, g, p
Fall 1965	2	330	60	40	-	-	300	-	730	a, o, p
X440										
Fall 1964	1	220	420	20	-	20	130	-	810	a, g, h, p
Summer 1965	1	1,090	630	2,140	-	-	2,100	-	5,960	a, k, p
Fall 1965	7	540	450	140	10	10	80	220	1,450	a, g
X430										
Fall 1965	1	130	370	40	-	20	530	-	1,090	a, g, p
X410										
Winter 1964	1	100	250	40	-	20	-	-	410	a, g, f, p
Spring 1965	6	370	360	100	-	10	180	120	1,140	a, g, p
Summer 1965	2	60	420	870	20	1,820	-	-	3,190	a, e, p
Fall 1965	7	640	640	140	10	70	230	30	1,760	a, c, p

*Season: Winter = Dec., Jan., Feb.
Spring = March, April, May
Summer = June, July, Aug.
Fall = Sept., Oct., Nov.

** see explanation list, page 108.

TABLE 37. PHYTOPLANKTON (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station/ Season*	Number of Samples	Average Number per Milliliter: Centric Diatoms	Pennate Diatoms	Green Coccoids	Blue-Green Coccoids	Blue-Green Fila-mentous	Green Flag-ellates	Brown Flag-ellates	Total	Predominant Genera** (10% or more)
Tobacco River										
X585										
Spring	2	30	360	10	-	-	110	-	510	f, j, p
Summer	1	40	630	40	-	-	60	20	790	d, g
Fall	3	70	240	10	-	-	60	10	390	a, e, g, h, p
X580										
Spring	1	80	190	-	-	40	-	-	310	a, f, g, j
Summer	1	340	310	150	-	-	60	-	860	a, g, j
Fall	4	30	300	180	-	-	-	-	510	g, j, m
Chippewa River										
X780										
Spring	1	670	440	-	-	150	40	-	1,300	a, f, m
Summer	1	130	190	190	-	-	-	-	510	a, e, l
Fall	3	480	1,150	40	10	-	-	-	1,680	a, g, h
X770										
Spring	2	340	430	-	-	-	-	-	770	a, f, g, h
Summer	1	460	670	100	-	-	-	-	1,230	a, g
Fall	2	90	780	10	-	10	-	-	890	a, g, h

*Season: Winter = Dec., Jan., Feb.
Spring = March, April, May
Summer = June, July, Aug.
Fall = Sept., Oct., Nov.

** see explanation list, page 108.

TABLE 37. PHYTOPLANKTON (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station/ Season*	Number of Samples	Average Number per Milliliter: Centric Diatoms	Pennate Diatoms	Green Coccoids	Blue-Green Coccoids	Blue-Green Fila-mentous	Green Flag-ellates	Brown Flag-ellates	Total	Predominant Genera** (10% or more)
Chippewa River										
X740										
Spring	2	460	480	20	-	-	80	-	1,040	a, f
Summer	1	100	730	150	-	-	60	-	1,040	a, h, i, c, l
Fall	6	130	930	20	x	-	30	-	1,110	a, g, m
Pine River										
X880										
Spring	2	210	170	30	-	20	8,540	-	8,970	p
Summer	1	20	100	-	-	-	-	-	120	a, b, f, j
Fall	4	50	150	50	-	-	20	-	270	a, j
X870										
Spring	2	80	170	150	-	20	20	-	440	a, j, m
Summer	1	860	150	1,660	60	-	40	-	2,770	a, k, l, m
Fall	3	40	140	30	x	60	10	-	280	a, g, p, h

*Season: Winter = Dec., Jan., Feb.
Spring = March, April, May
Summer = June, July, Aug.
Fall = Sept., Oct., Nov.

** see explanation list, page 108.

x less than 10

TABLE 37. PHYTOPLANKTON (cont'd)
TITTABAWASSEE RIVER BASIN
FALL 1964-FALL 1965

Station/ Season*	Number of Samples	Average Number per Milliliter: Centric Diatoms	Pennate Diatoms	Green Coccoids	Blue-Green Coccoids	Blue-Green Filamentous	Green Flagellates	Brown Flagellates	Total	Predominant Genera** (10% or more)
Pine River										
X820										
Spring	2	90	350	30	-	-	20	-	490	a, f, g, j
Summer	1	6,300	630	13,580	70	-	4,480	-	25,060	a, k, l, p
Fall	3	970	880	250	-	10	540	-	2,650	a, g, p

*Season: Winter = Dec., Jan., Feb.
Spring = March, April, May
Summer = June, July, Aug.
Fall = Sept., Oct., Nov.

** see explanation list, page 108.

EXPLANATION LIST FOR PREDOMINANT PHYTOPLANKTON GENERA (Table 37)

<u>Centric Diatoms</u>

a. Cyclotella-Stephanodiscus

<u>Pennate Diatoms</u>

b. Amphora
c. Cocconeis
d. Cymbella
e. Diatoma
f. Gomphonema
g. Navicula
h. Nitzschia
i. Synedra
j. Unidentified

<u>Green Coccoids</u>

k. Ankistrodesmus
l. Scenedesmus
m. Unidentified

<u>Blue-Green Filamentous</u>

n. Oscillatoria

<u>Green Flagellates</u>

o. Trachelomonas
p. Unidentified

<u>Brown Flagellates</u>

q. Ceratium

DISSOLVED OXYGEN PROJECTIONS

The water quality data described in previous sections of this report were submitted to analyses in a mathematical model depicting oxygen balance in streams. This particular model is a modification of the classical Streeter-Phelps formulation for oxygen balance in a stream. This equation includes an additional nonconservative oxygen demand (Kjeldahl nitrogen), which acts in a similar fashion to the BOD factor in the original formulation.

Long-term oxygen demand and nitrogen balance determinations were made on stream and waste source samples to determine a laboratory K-rate in order to calculate the ultimate carbonaceous oxygen demand. The ultimate carbonaceous oxygen demand stream profile was constructed and the stream BOD decay rate determined. A similar profile of the Kjeldahl nitrogen yielded the nitrogenous demand decay rate. These profiles were checked by a wastes loadings profile. All rates were converted from the stream temperature to 20°C.

Reaeration rates were initially calculated based on the O'Connor-Dobbins formulation for natural streams using computed reach velocities and depths. These values were used for initial match runs, but were then modified somewhat in the final match run for simplicity in the projection runs.

An apparent nitrogen lag was simulated by the use of a low (.01) nitrogen decay rate in the initial reaches. The stream nitrogen level was low, preventing the abnormally high decay rate found previously on other streams. With the exception of the initial low nitrogen K-rate, uniform rates were used for all stream reaches. The computed match run profiles are shown superimposed on the survey data (Figures 16 to 17). Loadings for the final match run are included in Table 38.

The characteristics determined by the match run were used to project the expected DO profiles for a number of flow and loading conditions. Minor modifications were made for ease in projection changes. Both the Chippewa-Pine River and Tittabawassee River above Midland were assumed to have the average of the parameter values found during the survey. The flow from both of these sources was approximately the same. A constant stream temperature was assumed to occur throughout the stream for all projection runs. Calculations based on previously (1957) measured heat loadings indicated that extremely high temperatures could be expected to occur downstream of the heat source; however, these high temperatures could be expected to decay to ambient temperature over the entire stream. The assumption of a constant temperature as used for projection runs will result in an approximate average profile over the entire stream. These projected profiles are shown in Figures 18 thru 20.

Figures 18 thru 20 are dissolved oxygen profiles for five stream temperature ranges: 15 to 35°C at 5 degree increments; three flow regimes - survey (800 cfs), seven-day (250 cfs), and one-day (200 cfs); and three loadings - 1965 (100 percent), 1990 (287 percent), and 2020 (633 percent) of the 1965 survey waste flows. The BOD concentration of the municipal source assumed for these projections is the survey value occurring during the effluent chlorination period and approximates 95 percent removal. The nonchlorinated effluent samples had a yearly average (1965) concentration of 26 mg/l of five-day BOD. Projection runs were also made for the above conditions using an ultimate BOD concentration of 30 mg/l. For all projection runs, the tributary and initial stream parameters, with the exception of flow, remained constant.

The minimum stream DO for both the 95 percent and 80 percent removal were plotted and are shown on Figure 21. The influence of the higher municipal waste concentration is readily apparent at the low stream flow and higher waste flow. Figure 22 is a plot of the effect of streamflow, temperature, waste flow, and municipal BOD concentration on the dissolved oxygen level at the confluence of the Tittabawassee River with the Saginaw River. The anomalous curves are due, in part, to a higher decay rate at elevated temperatures, with less oxygen demanding material remaining at the downstream point.

TABLE 38. LOADINGS FOR MATCH RUN - 1965 MODEL TITTABAWASSEE RIVER

	Flow		5-Day BOD		Ultimate BOD**		Kjeldahl Nit.		Diss. Oxygen	
	MGD	cfs	mg/l	#/day	mg/l	#/day	mg/l	#/day	mg/l	#/day
Municipal Wastes										
Midland	5.4	8.4	7	315	8	360	11.2	504	4.0	180
Industrial Wastes										
Dow water treatment plant	48.1	74.0	15	6,020	30	12,040	1.0	401	4.0	1,605
Cooling Water	150.0	232.0	5	6,240	5	6,240	1.0	1,250	6.7	8,380
Lingle Drain*	7.1	11.0	4	237	8	474	1.0	59	4.0	237
Bullock Creek*	13.0	20.0	3	325	6	651	1.0	108	6.0	651
Tributary Flow										
Tittabawassee	279.3	432.0	4	9,320	5.7	13,300	.4	932	7.8	18,200
Chippewa-Pine	248.2	384.0	3	6,210	4.3	8,900	.6	1,240	7.8	16,100

* These sources were combined with the Dow water treatment plant effluent on flow basis for projection runs.

** K-1 Rates = .18 - Midland sewage treatment plant
.06 - Dow water treatment plant, Lingle Drain, Bullock Creek
.105 - Tittabawassee River above Midland, Chippewa - Pine River

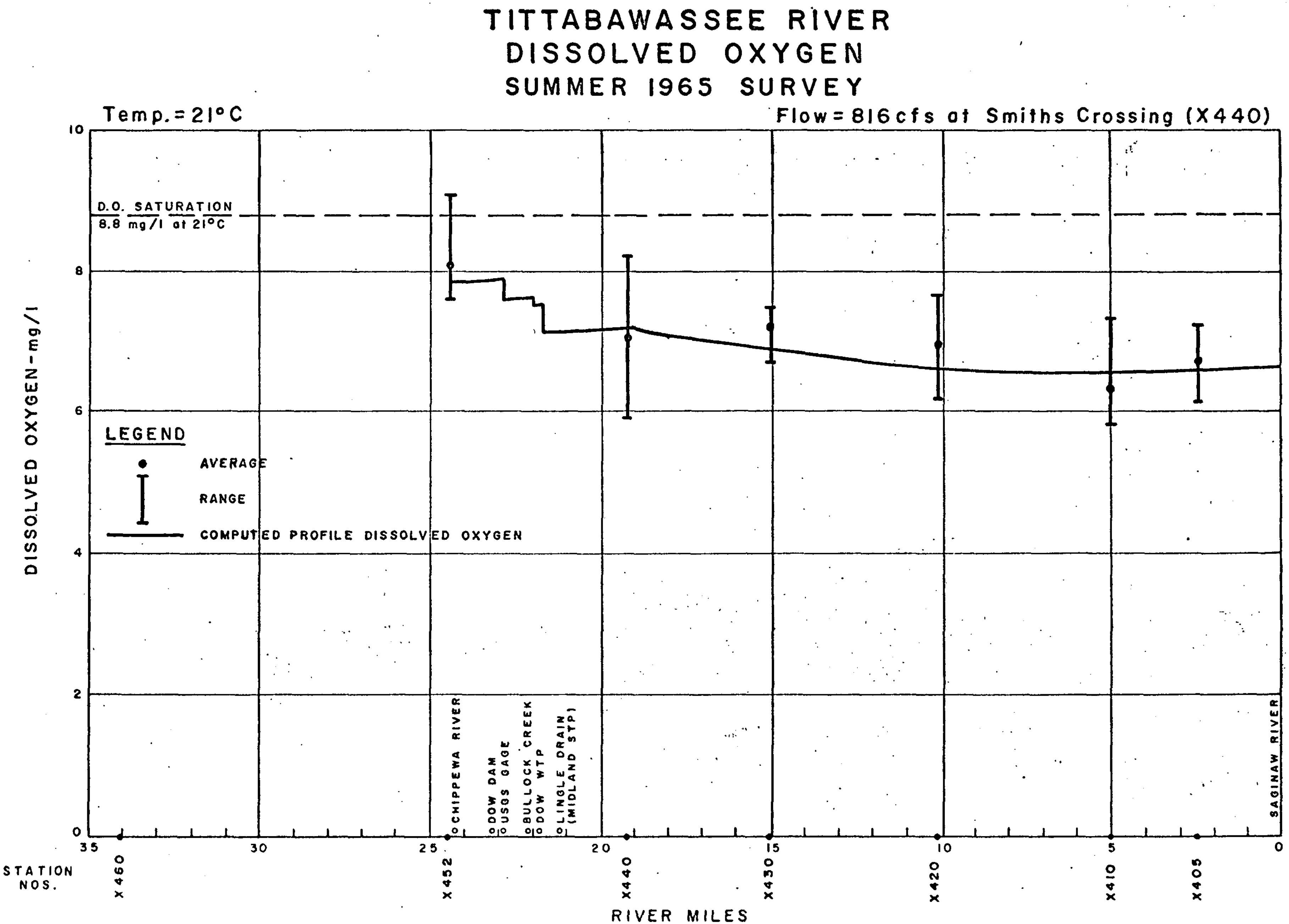

TITTABAWASSEE RIVER
DISSOLVED OXYGEN
SUMMER 1965 SURVEY
Temp. = 21°C
Flow = 816 cfs at Smiths Crossing (X440)
D.O. SATURATION
8.8 mg/l at 21°C
LEGEND
AVERAGE
RANGE
COMPUTED PROFILE DISSOLVED OXYGEN
DISSOLVED OXYGEN - mg/l
10
8
6
4
2
0
CHIPPEWA RIVER
DOW DAM
USGS GAGE
BULLOCK CREEK
DOW WTP
LINGLE DRAIN (MIDLAND STP)
SAGINAW RIVER
35
30
25
20
15
10
5
0
STATION NOS.
X460
X452
X440
X430
X420
X410
X405
RIVER MILES

FIGURE 16

TITTABAWASSEE RIVER
KJELDAHL NITROGEN as N AND 5-DAY BOD
SUMMER 1965 SURVEY

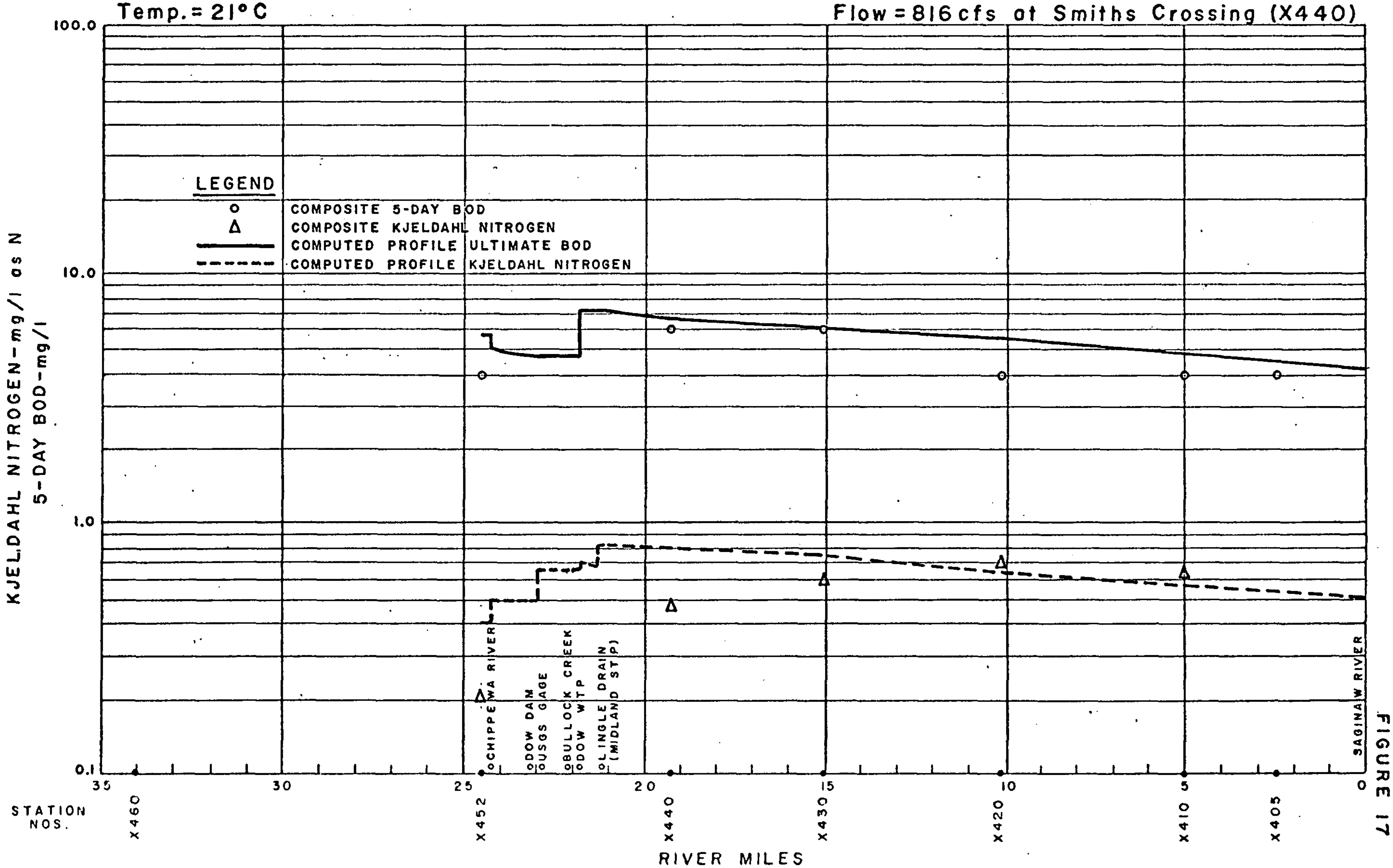


FIGURE 17

FIGURE 18

TITTABAWASSEE RIVER
COMPUTED DISSOLVED OXYGEN PROFILES
EFFECT OF TEMPERATURE AND FLOW
1965 LOADINGS

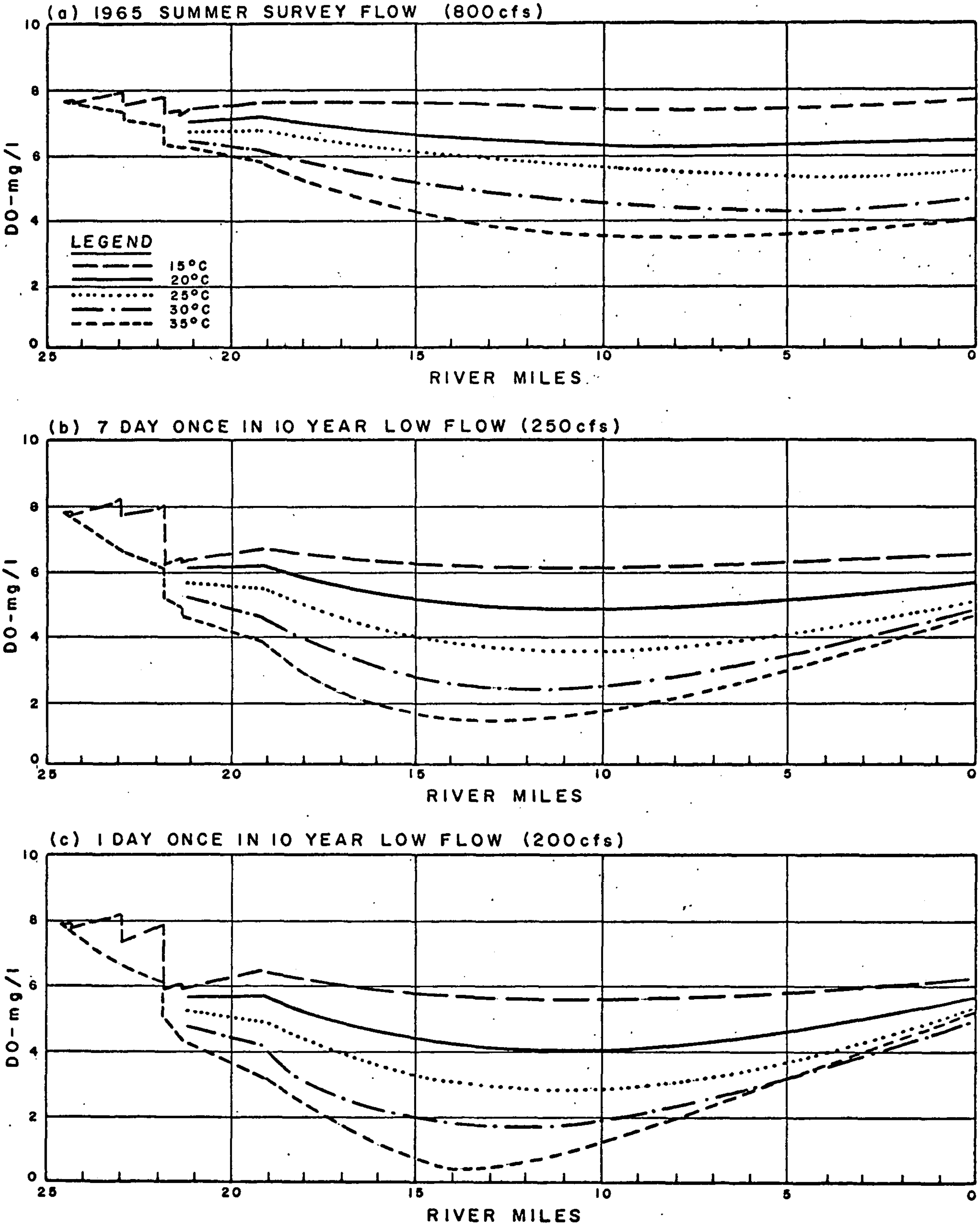


FIGURE 19

TITTABAWASSEE RIVER
COMPUTED DISSOLVED OXYGEN PROFILES
EFFECT OF TEMPERATURE AND FLOW
1990 LOADINGS

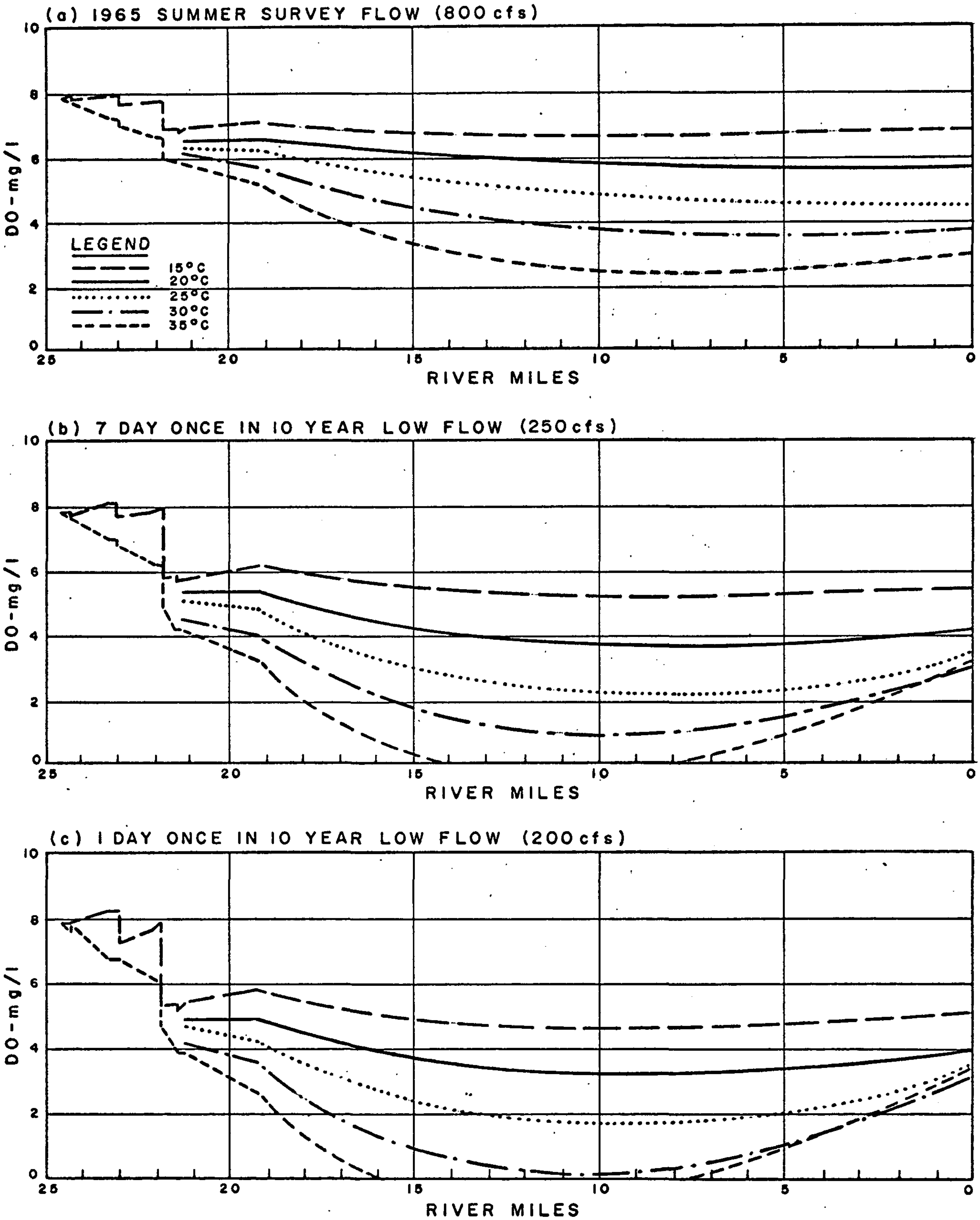


FIGURE 20

TITTABAWASSEE RIVER
COMPUTED DISSOLVED OXYGEN PROFILES
EFFECT OF TEMPERATURE AND FLOW
2020 LOADINGS

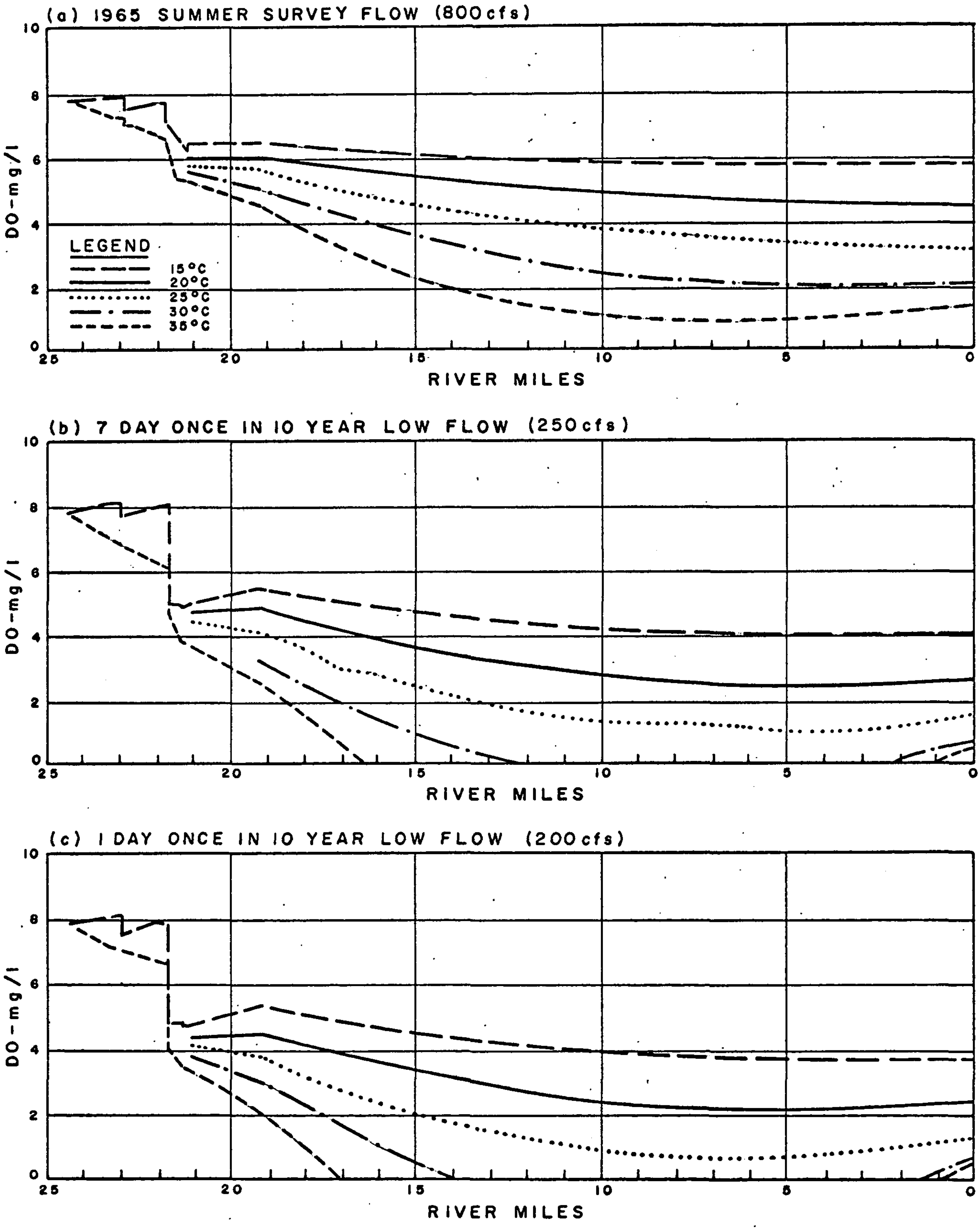
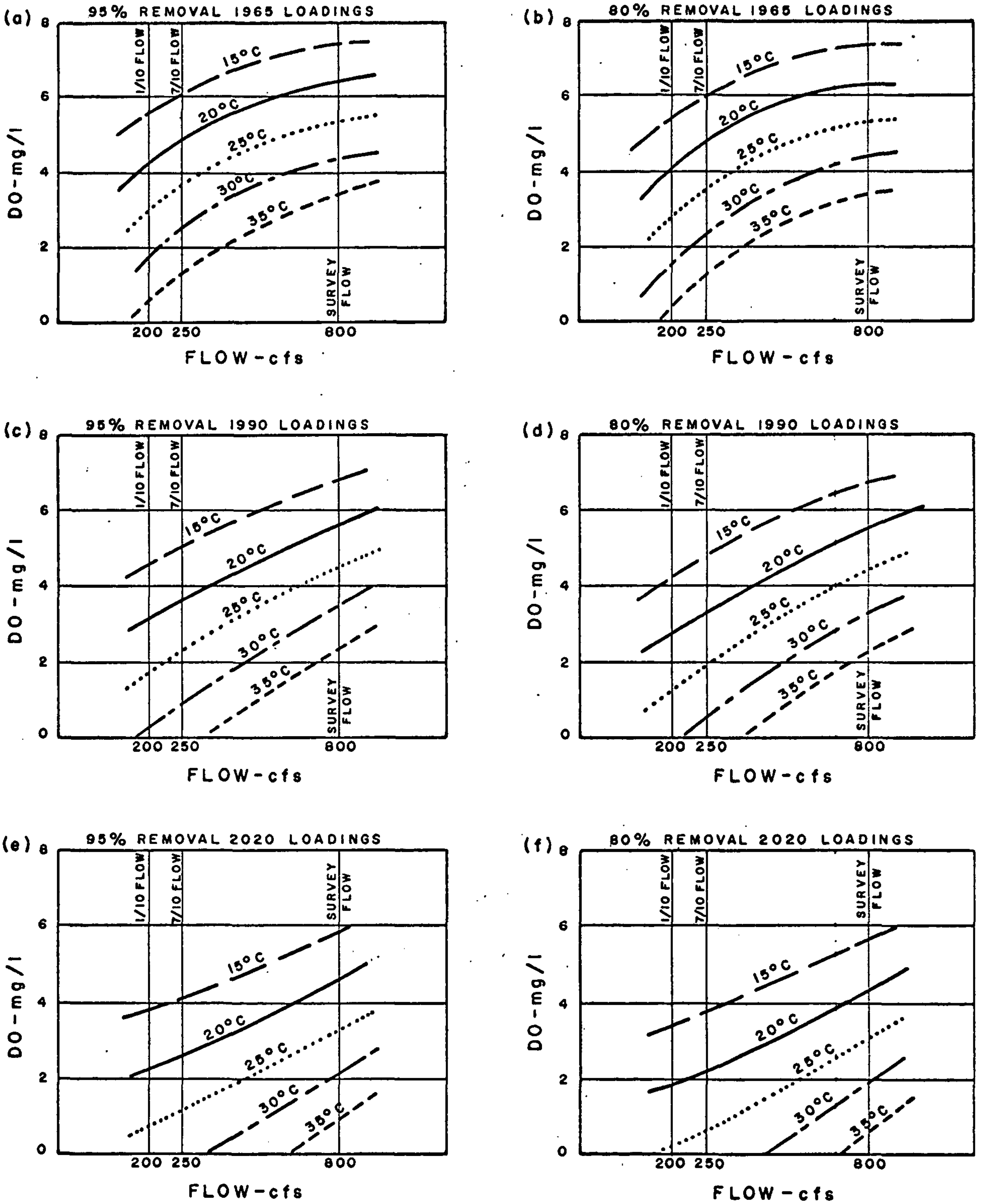
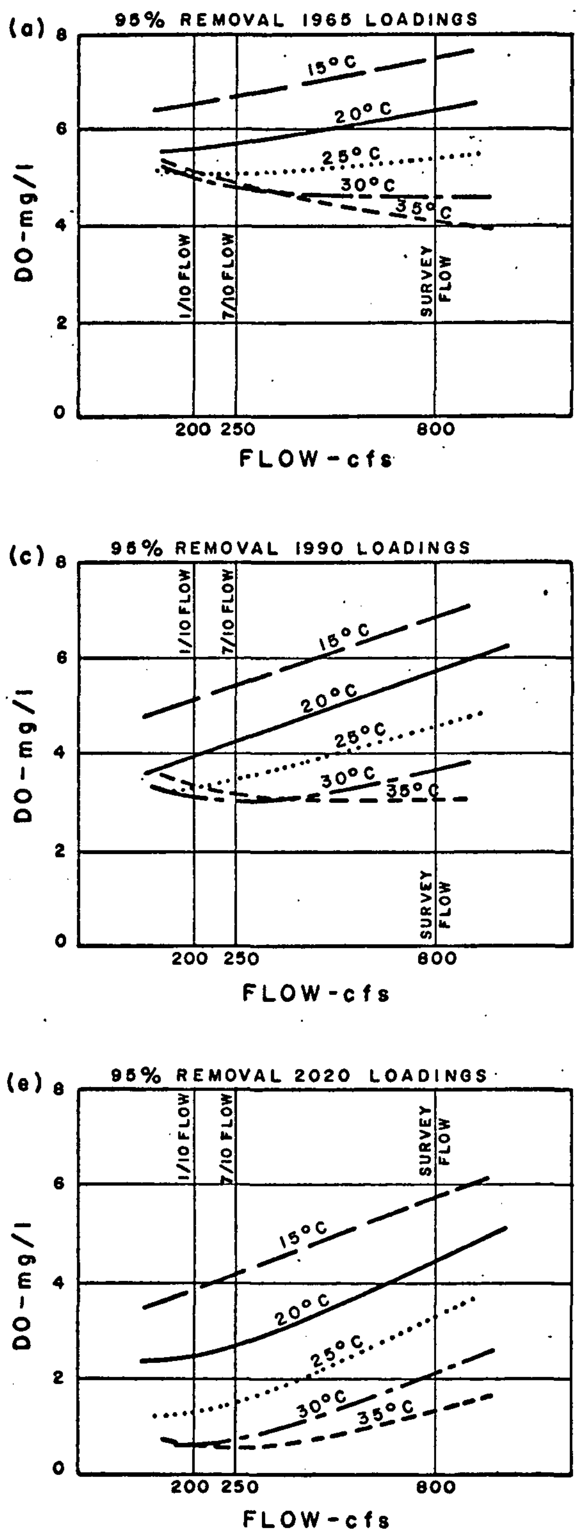


FIGURE 21

TITTABAWASSEE RIVER
COMPUTED MINIMUM DISSOLVED QXYGEN LEVEL
EFFECT OF MUNICIPAL WASTE BOD CONCENTRATION



TITTABAWASSEE RIVER
COMPUTED FINAL DISSOLVED QXYGEN LEVEL
EFFECT OF MUNICIPAL WASTE BOD CONCENTRATION



WATER QUALITY PROBLEMS

Field studies conducted by the FWPCA in 1965 indicated that the upper reaches of the Tittabawassee River and tributaries above the municipalities were of good quality. Stream reaches below the municipalities were moderately to excessively polluted, from a bacteriological standpoint. The Pine River below Alma-St. Louis and the Tittabawassee River below the Chippewa (Pine) River confluence at Midland had excess levels of chlorides, conductivity, total solids, and hardness.

Effluent from the Clare primary sewage treatment plant increased the coliform level of the Tobacco River significantly. This increase was less during the summer period when chlorination was practiced. Bacterial contamination also existed below the Gladwin sewage treatment plant.

The coliform level in the Chippewa River was increased significantly by effluent from the Mt. Pleasant primary sewage treatment plant. This increase was less during the summer chlorination season. During the nonchlorination period, the bacterial level must be considered excessive under any set of criteria.

A significant increase in pollution level of the Pine River occurred in the Alma-St. Louis area, because of the primary sewage treatment plants at Alma and St. Louis and the industrial waste effluents of Alma Products Company and Leonard Refineries Incorporated, both in Alma, and Michigan Chemical Corporation in St. Louis. The chloride increase of fourteenfold below the chemical company was the most obvious, together with the conductivity (threefold) and dissolved solids (threefold) increases. The nitrogen levels - nitrate, nitrite, and ammonia - also increased, as did the phosphates (sevenfold). Bacterial densities were at high pollution levels.

Pollution of the Tittabawassee River increased in the Midland area downstream from the Midland secondary treatment plant and industrial effluents of Dow Chemical Company, especially brine wastes. The chloride increase of thirtyfold was most obvious, together with the conductivity (fourfold) and dissolved solids (fourfold) increases. The total nitrogen levels - nitrate, nitrite, ammonia, and organic - doubled, as did total and soluble phosphate levels. Bacterial densities increased.

The Tittabawassee River, with 42 percent of the tributary drainage area to the Saginaw River, contributed on an annual average basis 95 percent of the chlorides, 90 percent of the dissolved solids, and 80 percent of the phenols which entered the Saginaw River.