ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

REPORT ON

WATER QUALITY AND WASTE-SOURCE INVESTIGATIONS BIG SIOUX RIVER AND SELECTED TRIBUTARIES

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER
DENVER, COLORADO
AND

REGION VII
KANSAS CITY, MISSOURI

REGION VIII
DENVER, COLORADO

JUNE 1973

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GLOSSARY OF TERMS

BOD	- Biochemical Oxygen Demand, 5-day
COD	- Chemical Oxygen Demand
DO	- Dissolved Oxygen
MPN	- Most Probable Number
MF	- Membrane Filter
NH_3-N	- Ammonia as Nitrogen
$NO_3 + NO_2$-N	- Nitrate and Nitrite as Nitrogen
TKN	- Total Kjeldahl Nitrogen
TOC	- Total Organic Carbon
Total P	- Total Phosphorus
RM	- River Mileage (e.g. 76.2/5.8) with first number denoting distance from mouth of the Big Sioux River to the confluence with a tributary stream, and second value indicating distance upstream of mouth of the tributary stream
$CaCO_3$	- Calcium Carbonate
$Ca(OH)_2$	- Calcium Hydroxide
WWTP	- Wastewater Treatment Plant
N	- Normal solution, one that contains 1 gram equivalent weight of solute per liter of solution
pH	- The logarithm (base 10) of the reciprocal of the hydrogen ion concentration
l	- Volume in liters = 0.2642 gallons
lm/m^2	- Measurement of light intensity = 10.76 foot candle
mg/l	- Concentration given in milligrams per liter
μg/l	- " " " micrograms " "

GLOSSARY OF TERMS (Cont.)

m	- Length in meters = 3.281 feet or 1.094 yards
km	- Distance in kilometers = 0.621 miles
cm	- Length in centimeters = 0.3937 in. or 0.03281 ft.
°C	- Temperature in degrees Celsius = 5/9 (°F-32)
cfs	- Flow rate given in cubic feet per second = 0.0283 cubic meters per second or 28.3 liters per second
cfm	- Flow rate given in cubic feet per minute = 0.4720 liters per second
gpd	- Flow rate in gallons per day = 0.003785 m^3/day
gpm	- Flow rate in gallons per minute = 0.0631 liters per second
m^3/sec	- Flow rate in cubic meters per second = 22.81 million gallons per second
mgd	- Flow rate in million gallons per day = 3.785 cubic meters per day
μmhos/cm	- Unit of specific conductance (mho--the inverse of the standard unit of electrical resistance, the ohm) measured over a 1-cm distance, conventionally at 25°C
kg	- Weight in kilograms = 2.205 pounds
ppm	- Concentration given in parts per million parts

I. INTRODUCTION

In the past, water-quality problems in the Big Sioux River have been manifested by the severe depletion of oxygen resources and by excessive ammonia concentrations downstream of Sioux Falls, South Dakota. Low-flow conditions occur periodically in the Big Sioux River, thus increasing its vulnerability to the effects of carbonaceous and nitrogenous waste loads. A major source of these wastes is the Sioux Falls Wastewater Treatment Plant that in turn receives large wastewater inputs from two meat-packing plants, the John Morrell and Company and Meilman Food Industries (formerly Spencer Foods, Inc.).

The Big Sioux River forms the boundary between South Dakota and Iowa from near Sioux Falls downstream to its confluence with the Missouri River near Sioux City, Iowa. In February 1972[1/] the Iowa State Department of Health conducted a limited water-quality survey of the lower Big Sioux River. This study concluded that as a result of waste discharges in South Dakota the Iowa Water Quality Standards for dissolved oxygen and ammonia were being violated. On 6 September 1972 Governor Robert D. Ray of Iowa requested EPA to call an enforcement conference, according to Section 10(D)(1) of the Federal Water Pollution Control Act, as amended. The Administrator of EPA replied to the Governor's letter on 21 November 1972, subsequent to the passage of the Federal Water Pollution Control Act Amendments of 1972. In his letter, the Administrator emphasized the regulatory procedures for pollution control under the new legislation (i.e., the permits system) and suggested that representatives of the States of Iowa, Minnesota, and South Dakota and the EPA hold an informal meeting in a cooperative and coordinated effort toward determining effluent limitations for all waste sources affecting the Big Sioux River. Moreover, the Administrator indicated that the agreements reached at this meeting may be later incorporated in the permits issued for these waste sources.

The National Field Investigations Center-Denver (NFIC-D) was requested by EPA Regions VII and VIII to conduct water-quality investigations in the Big Sioux River and selected tributaries prior to and during critical conditions of low flow and ice cover. The first phase of these investigations was undertaken during the period 15 September-5 October 1972 and was directed toward determining the effects of waste discharges on the water quality of the Big Sioux River and the resultant influences upon aquatic organisms. The second phase of the study included evaluating major waste sources and determining the effects of their discharges on receiving-water quality. The emphasis was placed on the evaluation of the Sioux Falls Wastewater Treatment Plant that, as indicated earlier, represents the major source of pollution in the basin. The investigations were conducted 24 January through 10 February 1973 and concentrated on the following objectives:

1. To characterize water quality in the Big Sioux River and its tributaries during critical low-flow, winter conditions and to determine whether or not interstate violations of Iowa Water Quality Standards occurred.
2. To evaluate existing waste-treatment processes at the Sioux Falls Wastewater Treatment Plant and to determine what improvements are needed to comply with existing water-quality standards

and the Federal Water Pollution Control Act Amendments of 1972.

3. To characterize major waste sources in the Big Sioux River Basin.

4. To provide recommendations for the development of compatible interstate water-quality standards for the Big Sioux River Basin States of Iowa, South Dakota, and Minnesota.

5. To provide technical information for the development of discharge permits pursuant to the requirements for the National Pollutant Discharge Elimination System of the Federal Water Pollution Control Act Amendments of 1972.

In these investigations valuable information and assistance were received from personnel of the City of Sioux Falls Wastewater Treatment Plant and from municipal, industrial, State, and Federal officials. The cooperation extended by these many individuals is gratefully acknowledged.

II. SUMMARY AND CONCLUSIONS

During the fall of 1972 and winter of 1973, studies were conducted to assess water quality in the Big Sioux River Basin, which comprises portions of Iowa, Minnesota, and South Dakota. A summary of the findings of these studies is as follows:

A. FALL STREAM SURVEY, 1972

1. Widespread urban, agricultural, and industrial pollution sources caused varying degrees of water-quality degradation in reaches of the Big Sioux River from Estelline, South Dakota (RM 263.5), to Sioux City, Iowa (RM 2.2). Dissolved-oxygen studies and examination of the stream biota disclosed that the most severe pollution occurred downstream from the City of Sioux Falls, South Dakota. Major sources of pollution in this area included "condenser" waters from the John Morrell and Company (RM 143.2), process wastes from Spencer Foods, Inc. (now Meilman Food Industries, RM 154.2), and wastewaters discharged from the Sioux Falls Wastewater Treatment Plant (RM 143.0).

2. During the fall, nitrogen was found to be the growth-limiting nutrient in test waters upstream of the Sioux Falls, South Dakota, municipal Wastewater Treatment Plant.

3. Algal assays indicated that there is sufficient nitrogen in the effluent from the Sioux Falls Wastewater Treatment Plant to stimulate algal growth in the Big Sioux River. However, field studies demonstrated that algal growth was reduced in the river downstream from the municipal wastewater treatment plant. This inhibition of primary production could have resulted from toxic chlorine and chloramines in the effluent.

B. WINTER 1973 STUDY (WASTE-SOURCES EVALUATION)

John Morrell and Company

1. The John Morrell and Company plays the dominant role in contributing to municipal wastewater treatment plant loadings, especially in contrast to the operating costs the firm is required to pay. During the seven-day evaluation Morrell accounted for 67 percent of the BOD load, 78 percent of the suspended solids, 70 percent of the total Kjeldahl nitrogen, and 57 percent of the total phosphorus entering the Sioux Falls Wastewater Treatment Plant. The contract between Morrell and the City of Sioux Falls, which is valid until 1 September 1975, requires annual sewer charges of $16,000 per year. This represents only 4.4 percent of the 1973 operating costs ($359,972) for the municipal wastewater treatment plant.

2. Current abatement plans by the John Morrell and Company call for reductions of present loadings of BOD and suspended solids to the treatment plant by 60 and 75 percent, respectively, by approximately 1 January 1974.

Meilman Food Industries (Formerly Spencer Foods, Inc.)

1. The abatement plans by John Morrell and Company (previously mentioned) will be largely offset by the recent connection of Meilman Food Industries into the Sioux Falls Wastewater Treatment Plant. Because wastewaters from Meilman discharge to the domestic sewerage system and enter the combined domestic-industrial activated sludge system, pretreatment in the two-stage trickling filter system is precluded. Consequently, even though Morrell decreases their daily average BOD loading to the wastewater treatment plant by about 19,050 kg

(42,000 lb), the addition of a predicted 5,440 kg (12,000 lb) from Meilman will increase the BOD loading to the City activated sludge system by approximately 725 kg/day (1,600 lb/day).

Sioux Falls, South Dakota, Wastewater Treatment Plant

1. Removal efficiencies measured during the 24-31 January 1973 study were as follows:

Parameters	Removals (%)
BOD	89
COD	88
TOC	89
Suspended Solids	93
Nitrogen	22
Total P	22

Considering both the effect of winter temperatures on biological systems and the organic overloads to the activated sludge system, one sees that these removals reflect a high degree of expertise on the part of plant personnel. However, the waste loadings discharged to the Big Sioux River were substantial. During the seven-day evaluation the effluent from the municipal treatment plant contributed, to the Big Sioux River, average daily loads of 3,370 kg BOD (7,420 lb @ 99 mg/l), 1,170 kg suspended solids (2,590 lb @ 37 mg/l); 1,690 kg total Kjeldahl nitrogen (3,720 lb @ 51 mg/l); and 470 kg total phosphorus (1,040 lb @ 14 mg/l). The by-pass of the municipal treatment plant added another 730 kg BOD (1,620 lb @ 1,010 mg/l); 187 kg suspended solids (413 lb @ 429 mg/l); 67 kg total Kjeldahl nitrogen (148 lb @ 131 mg/l); and 14 kg total phosphorus (31 lb @ 22 mg/l).

The removal efficiencies during the study are in marked contrast to previously reported removals. Wastewater-treatment-plant data showing the operations from July 1970 to September 1972 indicate that the monthly average influent BOD loads ranged from 39,690 to 70,010 kg/day (87,500 to 154,350 lb/day). During the same period the final effluent BOD load discharged to the Big Sioux River varied from 365 to 1,400 kg/day (800-3,100 lb/day). Overall BOD removal efficiencies, based on load figures, ranged from about 96 percent to greater than 99 percent. The average BOD loadings during the 24-31 January study were only 36,110 kg/day (79,600 lb/day); however, the average waste load discharged was 4,100 kg/day (9,040 lb/day), nearly three times as high as previously reported monthly averages.

2. The activated sludge portion of the Sioux Falls municipal treatment plant was grossly overloaded organically, thus corroborating the findings of a previous, 1972 EPA study.[2/] Overloads were evidenced by average food-to-microorganism (F/M) ratios of 1.1 g BOD/g (1.1 lb BOD/lb) mixed-liquor suspended solids (MLSS) under aeration and by loadings of 2,676 g/m^3 (167 lb BOD/1,000 ft^3) aeration-tank volume. Overloading was particularly evident in the quality of the effluent where, contrary to theory, the BOD exceeded the concentrations of suspended solids (99 mg/l vs. 37 mg/l).

3. Generally, the Sioux Falls, South Dakota, Wastewater Treatment Plant is ineffective in removing nitrogen as evidenced by overall removals of 22 percent. Overall "removals" of the total Kjeldahl nitrogen were 33 percent, resulting in a discharge, to the Big Sioux River, of 1,680 kg/day (3,720 lb/day @ 51 mg/l) in the effluent and 67 kg/day

(148 lb/day @ 131 mg/l) in the bypass. Much of this unoxidized nitrogen is needlessly discharged as a result of current, sludge-lagoon supernatant handling practices. During the seven-day study a daily average of 970 kg (2,150 lb @ 1,280 mg/l) of total Kjeldahl nitrogen, once having been segregated from the system, was reintroduced for subsequent discharge.

The abatement program of the John Morrell and Company may significantly decrease the TKN loading to the municipal treatment plant. Although Morrell officials are not prepared to estimate TKN-removal efficiencies, the fact that 85-percent of the total Kjeldahl nitrogen remains in the organic form should enable significant reductions by means of the capture of proteinaceous solids material. On the other hand, the addition of wastes, effected by the recent connection of Meilman Food Industries, will offset this reduction to some degree.

C. WINTER 1973 STUDY (STREAM SURVEY)

1. Although there are numerous waste sources in the Big Sioux River Basin [Appendix E], the City of Sioux Falls, South Dakota, was demonstrated to be a substantially more significant one than any of the others in adversely affecting the quality of the Big Sioux River. Consequently, any future improvement of water quality in the Big Sioux will largely be determined by abatement measures required of the Sioux Falls municipality.

2. Average concentrations of dissolved oxygen upstream of the Sioux Falls area (RM 243.9 near Volga, South Dakota, to RM 162.2 near Renner, South Dakota) ranged from 10.9 mg/l to 8.9 mg/l, indicative of an abundant oxygen resource. Downstream from the Sioux Falls area, however, the

wastewaters emanating from the Sioux Falls Wastewater Treatment Plant (RM 143.0) and the waters from the Rock River (RM 76.2) created a severely restricted oxygen resource. At RM 80.9, near Hudson, South Dakota, dissolved-oxygen concentrations were in violation of the South Dakota criterion of 5.0 mg/l on five of ten days (average = 4.8 mg/l). Iowa Water Quality Standards, on the other hand, specify that the dissolved oxygen should not be less than 5 mg/l during any 16-hr period nor less than 4.0 mg/l at any time during the 24-hr period. In the river reach extending from Hawarden, Iowa (RM 66.9), downstream to near Sioux City, Iowa (RM 5.0), DO concentrations were, in 22 of the 24 samples collected over the ten-day period, in violation of both Iowa and South Dakota criteria. At RM 5.0 the average DO concentration was 2.3 mg/l, indicative of a severely restricted oxygen resource.

3. The bacteriological quality of the Big Sioux River between RM 243.9 near Volga, South Dakota, and RM 143.2, immediately upstream of the wastewater treatment plant, was acceptable, with no log mean fecal-coliform bacterial density greater than 200/100 ml. Discharges from the Sioux Falls Wastewater Treatment Plant resulted in unacceptable bacterial quality between RM 143.0 and 128.5, approximately 2.5 km (1.5 mi) upstream of the Iowa-South Dakota state line. Log mean fecal-coliform bacterial densities ranged from 1,400 to 13,000/100 ml. *Salmonella*, attributable to the municipal treatment plant, were isolated in the Big Sioux River. The bacterial quality downstream from the state line (RM 127.0 to RM 5.0) was found to be acceptable with log mean fecal-coliform bacterial densities not exceeding 240/100 ml.

4. Concentrations of ammonia nitrogen were excessive downstream from the Sioux Falls, South Dakota, area as a result of discharges from the Sioux Falls Wastewater Treatment Plant. Whereas average concentrations upstream of Sioux Falls did not exceed 0.88 mg/l, downstream from the Sioux Falls Wastewater Treatment Plant they reached as high as 6.57 mg/l (at RM 134.5). Bioassays performed on the effluent from the municipal treatment plant indicated a 96-hr TL_m of 63.5 percent effluent or 35.5 mg/l NH_3-N. Applying a standard application factor of 1/20 yielded a chronic toxicity level for channel catfish of approximately three percent effluent or 1.8 mg/l NH_3-N. Other unidentified components present in the effluent could also increase or inhibit the toxicity of NH_3. However, the calculated chronic toxicity level (1.8 mg/l NH_3-N) closely correlates with the 2 mg/l criterion widely accepted as the maximum concentration of NH_3-N allowable in receiving waters. Thus, other components did not significantly influence ammonia toxicity levels determined in the study.

The South Dakota Water Quality Standards do not include a NH_3-N criterion; however, the Iowa Water Quality Standards stipulate that NH_3-N shall not exceed 2.0 mg/l. From the Iowa-South Dakota state line, at RM 127.0, to the furthest downstream station, at RM 5.0, 100 percent of the 47 samples collected exceeded 2.0 mg/l NH_3-N, thus violating Iowa Water Quality Standards. Average NH_3-N concentrations varied from 4.56 mg/l at RM 106.2, near Canton, South Dakota, to 2.32 mg/l at RM 5.0, near Sioux City, Iowa.

5. Mass-balance analyses employing decreases in stream TKN

loadings and increases in NO_2 + NO_3-N loadings, between Sioux Falls, South Dakota (RM 141.2) and Akron, Iowa (RM 46.8), were unable to demonstrate any significant degree of nitrification occurring in the Big Sioux River. There remains, however, a significant, potential nitrogenous oxygen demand during the warmer periods of the year when stream temperatures are amenable to the growth of nitrifying organisms.

6. Algal assay studies showed phosphorus to be the growth-limiting nutrient, during the winter, in test waters upstream of the Sioux Falls Wastewater Treatment Plant. There is sufficient phosphorus in the Sioux Falls Wastewater Treatment Plant effluent to stimulate algal growth in the Big Sioux River.

7. The Rock River was found to have a detrimental effect upon the Big Sioux River. This was manifested in lower DO concentrations and sustained, excessive NH_3-N concentrations. The average DO concentration on the Rock River (RM 76.2/5.8) was 3.0 mg/l, in violation of the Iowa 4.0-mg/l criterion on nine of ten days sampled. NH_3-N concentrations (average = 2.13 mg/l) were in violation of the Iowa 2.0 mg/l criterion on eight of ten days. The State of Minnesota has ordered that dischargers to the Rock River (including the towns of Luverne and Edgerton, Minnesota, and the Iowa Beef Packers Plant at Luverne) provide 180 days storage of wastewater flows with controlled release during periods of adequate streamflow. If Luverne and Edgerton desire to have a continuous discharge, the effluent must have BOD and suspended solids concentrations less than or equal to 5 mg/l.

III. RECOMMENDATIONS

In order to protect the water quality of Big Sioux River and its tributaries and to attain compliance with the Federal Water Pollution Control Act Amendments of 1972, it is recommended that:

1. The waste discharge permit issued to the City of Sioux Falls under the National Pollution Discharge Elimination System include the following effluent limitations (daily average concentrations):

   a) BOD_5 = 10 mg/l;

   b) SS = 15 mg/l;

   c) TKN = 2 mg/l;

The permit further stipulates that continuous disinfection be provided with no monthly average (logarithmic mean) fecal-coliform bacterial density exceeding 200/100 ml and no weekly average exceeding 400/100 ml;

2. The City of Sioux Falls establish enforceable pretreatment standards for those pollutants that are not susceptible to treatment by the municipal system or which may pass through, or otherwise interfere with, its operation, and that the ordinance establishing the pretreatment standards must include adequate sewer charges for all industrial waste sources to assure equitable recovery of treatment costs;

3. Bypassing of wastewaters by the City of Sioux Falls be eliminated;

4. The States of Iowa and Minnesota investigate all sources of wastewaters that could adversely affect the Rock River system and initiate appropriate abatement actions to insure compliance with the Federal Water Pollution Control Act Amendments of 1972; and

5. Existing water quality standards covering the Big Sioux River Basin for the States of South Dakota, Iowa, and Minnesota include the following additions or deletions applicable to all waters of the Big Sioux River Basin:

A. South Dakota

1. The intermittent classification with its resultant lesser quality requirements be abolished;
2. The minimum use on the Big Sioux River be classified for Desirable Species of Aquatic Life and Secondary Contact Recreation (boating, fishing and etc.);
3. A year-round DO criterion be established, requiring that DO concentrations shall not be less than 5 mg/l, except for 4 mg/l during short periods of time within a 24-hr period;
4. Consistent with the previously mentioned use classification, fecal coliform densities not exceed a geometric mean of 2,000/100 ml;
5. South Dakota Water Quality Standards do not include an ammonia nitrogen criterion; therefore, it is recommended that such a criterion be established consistent with Iowa and Minnesota requirements that NH_3-N concentrations not exceed 2.0 mg/l;

B. Iowa

1. The minimum use on the Big Sioux River be classified for Desirable Species of Aquatic Life and Secondary Contact Recreation (boating, fishing and etc.);

2. Currently no fecal coliform criterion exists; therefore, it is recommended that Iowa establish a fecal coliform criterion requiring that geometric mean densities not exceed 2,000/100 ml;

C. Minnesota

1. Currently no fecal coliform criterion exists; therefore, it is recommended that Minnesota establish a fecal coliform criterion requiring that geometric mean densities not exceed 2,000/100 ml;

2. Minnesota Water Quality Standards provide that the DO concentration must be greater than or equal to 3.0 mg/l from 1 June-31 March on all tributaries of the Big Sioux River with the exception of Split Rock Creek where it must be at least 5.0 mg/l; therefore, it is recommended that Minnesota adopt a DO criterion requiring that concentrations shall not be less than 5 mg/l except for 4 mg/l during short periods of time within a 24-hr period.

IV. DESCRIPTION OF AREA

A. PHYSICAL DESCRIPTION

The Big Sioux River Basin is located in eastern South Dakota, southwestern Minnesota, and northwestern Iowa [Figure IV-1 inside back cover and Figure IV-2]. Approximately sixty-nine percent of its drainage area (about 24,800 km^2 or 9,570 sq mi) is located in South Dakota, with 15 and 16 percent of the area located in Iowa and Minnesota, respectively. About 5,100 km^2 (1,970 sq mi) of the South Dakota portion of the Basin does not contribute surface runoff to the Big Sioux River. The mean elevation of the basin is approximately 430 m (1,400 ft) above sea level.

The Big Sioux River originates north of Watertown, South Dakota, and flows southward, about 675 km (420 river mi), to join the Missouri River near Sioux City, Iowa. The Rock River is the largest tributary, draining most of the Minnesota and Iowa portions of the basin (4,400 km^2 or 1,700 sq mi). Another tributary is Skunk Creek which has a drainage of 1,400 km^2 (540 sq mi) and enters the Big Sioux River at Sioux Falls, South Dakota. One other important tributary is Split Rock Creek which enters the Big Sioux River approximately 5 km (3 mi) upstream of the South Dakota-Iowa state line.

B. POPULATION AND THE ECONOMY

The topography within the basin varies from nearly level land to steep bluffs. The northern portion of the basin is primarily flat land with numerous pot holes and shallow lakes (caused by glaciers that once covered the area) and a poorly defined drainage pattern. There is little or no surface runoff to the Big Sioux River from most of this area. Downstream from Sioux Falls drainage patterns are well defined, and the river has developed a flood plain. This plain varies from 1 to 5 km (0.5 to 3 mi) in width. Near its mouth, the river flows across the Missouri River flood plain. Hills flanking the flood plain become progressively steeper and higher between Akron, Iowa, and the Missouri River bluffs.

Throughout most of the length of the Big Sioux River its channel is located in alluvial materials and is characterized by a meandering path with tree lined pools and shallow riffles. At normal and low-flow stages, flow velocities are slow and could approach zero in some locations. Two exceptions to the typical characteristics of the river are the Dells of the Big Sioux near Dell Rapids where the river cuts through a narrow rocky canyon, and the falls, in Sioux Falls, South Dakota, where the river flows over a rocky outcrop. The falls provide aeration of the river, often producing saturated dissolved oxygen levels.

Within the Big Sioux River Basin, as over most of the country, there has been a gradual movement of people from rural to urban areas. From 1940 to 1960 the basin population increased 11 percent; from 1960 to 1970 it decreased two percent. The basin population was, at the time of the 1970 census, approximately 215,000 people. Most of the growth has occurred in the Sioux Falls Standard Metropolitan Statistical Area (SMSA), which had a 1970 population equal to 45 percent (95,209) of the basin total. Except for Brookings and Watertown, South Dakota, with 1970 population levels greater than 13,000, the remaining segment of

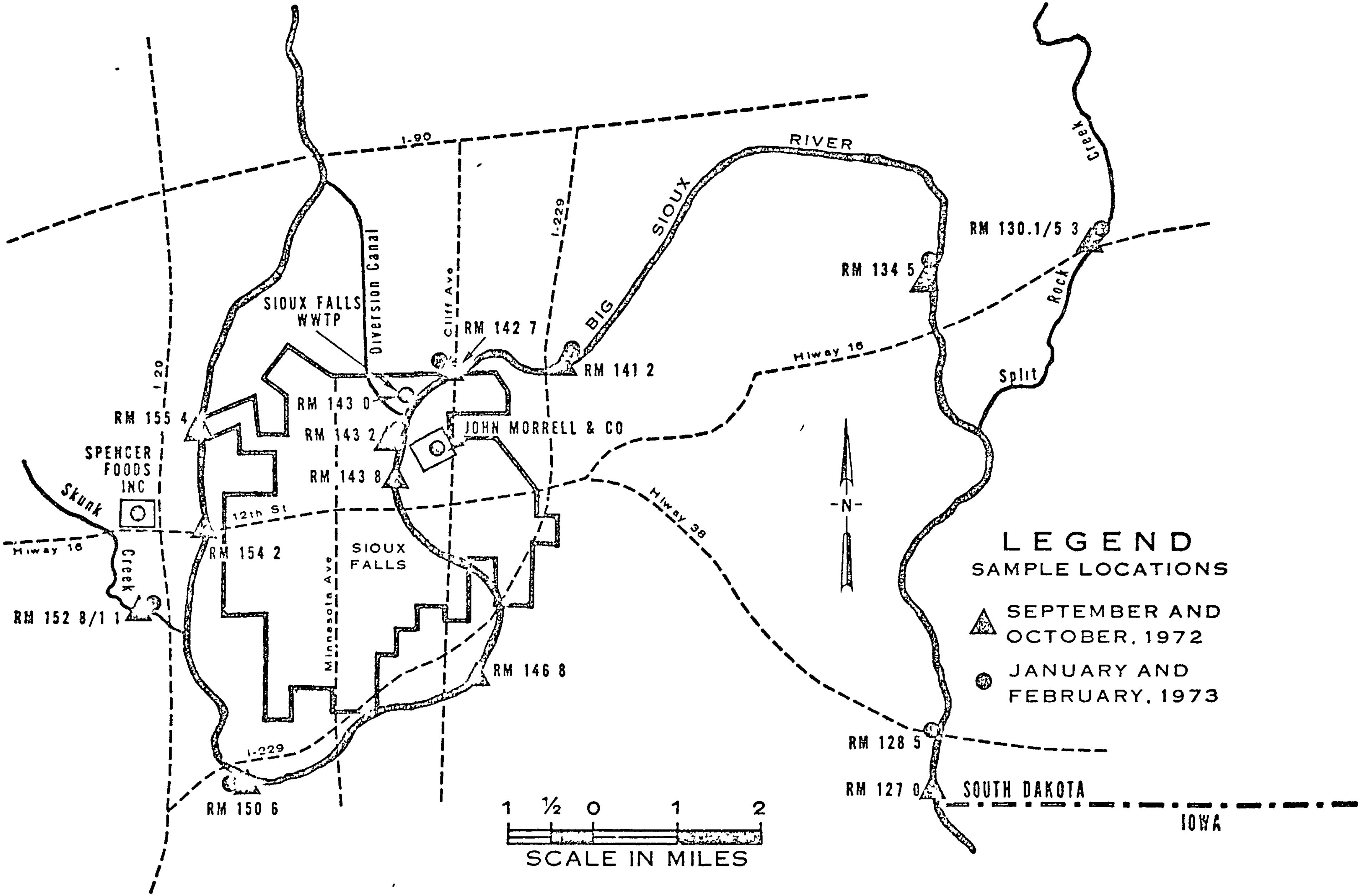

Figure IV-2. Sampling Locations, Big Sioux River and Selected Tributaries, Sioux Falls, South Dakota and Vicinity.

the basin population is located in small communities and on farms. Most of the future population growth of the basin is expected to occur in these three metropolitan areas.

Agriculture and related enterprises are the principal constituents of the basin's economy. The entire basin contains fertile farmland that produces high yields of corn, alfalfa, oats, and other feed crops. Farms throughout the basin are involved in cash-grain operations. Farm units average about one per km^2 (two to three per sq mi). In addition, most farms have some livestock production which includes beef and dairy cattle, sheep, and swine. The basin contains approximately 110,000 cattle on feed, 500,000 hogs, 200,000 sheep, and 1,500,000 chickens.

Livestock raising is generally found in the upper portion of the basin, and livestock feeding operations are located in the lower, or more southerly areas. Five cattle feeders in the basin carry more than 1,000 head. Very few hog, sheep, or poultry operations are large. Of the total annual cash farm income ($210 million) three-fourths is generated from sales of livestock, poultry, and related products.

Sioux Falls, South Dakota, has a number of manufacturing plants and is the central distributing center for many wholesale companies and sales outlets. According to the 1970 census, 5,835 people were employed in manufacturing activities, with 75 percent of these involved in the category of food and associated products. About half the people of this 75 percentage were employed in the meatpacking industry centered in Sioux Falls. The John Morrell and Company packing plant, located there, is one of the largest meat-packing plants in the nation. The Sioux Falls Livestock Market ranks among the top ten in the nation.

C. HYDROLOGY

The primary source of water in the Big Sioux River is direct surface runoff from many small westward flowing tributary streams. The Rock River, a major tributary, contributes more than 30 percent of the entire basin's annual flow. Skunk Creek, the principal western tributary, contributes only six percent of the average annual river flow. All of the runoff in the contributing area of the basin is uncontrolled. During the irrigation season diversions and return flows from about 12 km^2 (3,000 acres) of land upstream of Sioux Falls cause minor changes in stream flows. (Irrigation permits, granted up to 1969, would allow expansion of this area to approximately 57 km^2 or 14,000 acres.)

Of the annual basin runoff about 70 percent results from spring snowmelt and rain during the months of March through June. Most of this runoff is diverted from the lower part of the basin where the precipitation rate is greatest. During the remainder of the year, particularly during fall and winter months, ground-water storage is the principal source of streamflow. These ground-water resources are stored in areas of glacial outwash and alluvial deposits located along both glacial melt, water channels, and stream valleys. Recharge to the ground-water aquifers is primarily from precipitation filtering into the outwash deposits.

Near Watertown, South Dakota, in the upper reaches of the basin, the Big Sioux River does not normally flow during the fall and winter months. Downstream at Brookings the river flow has reached zero only a few times in the past two decades. From Dell Rapids on downstream, the river flow has never been recorded as zero for accretion from ground water sustains the river flow during fall and winter months.

The stream flows within the basin are highly variable. During the March through June period when most of the suface runoff occurs, the flow variation is the greatest. For example, during the past two decades, the average April flow has varied from 1.3 to 173 m^3/sec (45 to 6,104 cfs) in the Big Sioux River at Sioux Falls. For the period of record it has had instantaneous flow readings that varied from 0.01 to 390 m^3/s (0.5 to 13,800 cfs). The one- and seven-day minimum flows occurring once in ten years are 0.03 and 0.05 m^3/s (1.0 and 1.6 cfs), respectively. The flow variation can also be illustrated [Table IV-1] using mean monthly stream flows in the following table as reported by the Federal Water Pollution Control Administration.3/

TABLE IV-1

MEAN FLOW OF BIG SIOUX RIVER AT SIOUX FALLS, SOUTH DAKOTA

Month	Flow m^3/s	Flow (cfs)	Month	Flow m^3/s	Flow (cfs)
October	2.6	(93)	April	34.8	(1,228)
November	2.1	(75)	May	16.0	(564)
December	1.3	(47)	June	17.9	(634)
January	0.6	(22)	July	11.2	(397)
February	3.5	(123)	August	6.3	(223)
March	19.0	(671)	September	3.7	(131)

As indicated in the South Dakota Water Quality Standards [Appendix A], provisions are made for streams that sometimes fall into the intermittent-stream use category. This category alters water-quality requirements to meet various beneficial uses when the flow in the river is less than a specified flow. The intermittent classification is in effect downstream from Sioux Falls when flows at Brandon, South Dakota, are less than:

Season	Flow m^3/s	Flow (cfs)
Summer (June 15-September 15)	2.5	(90)
Fall (September 15-December 15)	1.0	(35)
Winter (December 15-March 15)	1.7	(60)
Spring (March 15-June 15)	1.0	(35)

The intermittent-stream use category generally is in effect from the middle of December through the end of February but also applies to some late summer or early fall periods.

There have been periods in which the flow of the Big Sioux River, downstream from Sioux Falls, was at least 50 percent wastewaters [Figure IV-3]. The duration of these periods has varied from less-than-one to greater than seven months. Although South Dakota classifies the Big Sioux as an intermittent stream during low-flow conditions, Iowa, the bordering state, does not have similar criteria. As a consequence, Iowa requires maintenance of considerably higher water quality during low-flow periods than does South Dakota.

Within the Big Sioux River Basin virtually all the incorporated municipalities obtain their water supply from ground-water sources -- with the exception of Sioux Falls and Watertown, South Dakota, which use a combination of both surface and ground water. Sioux Falls only

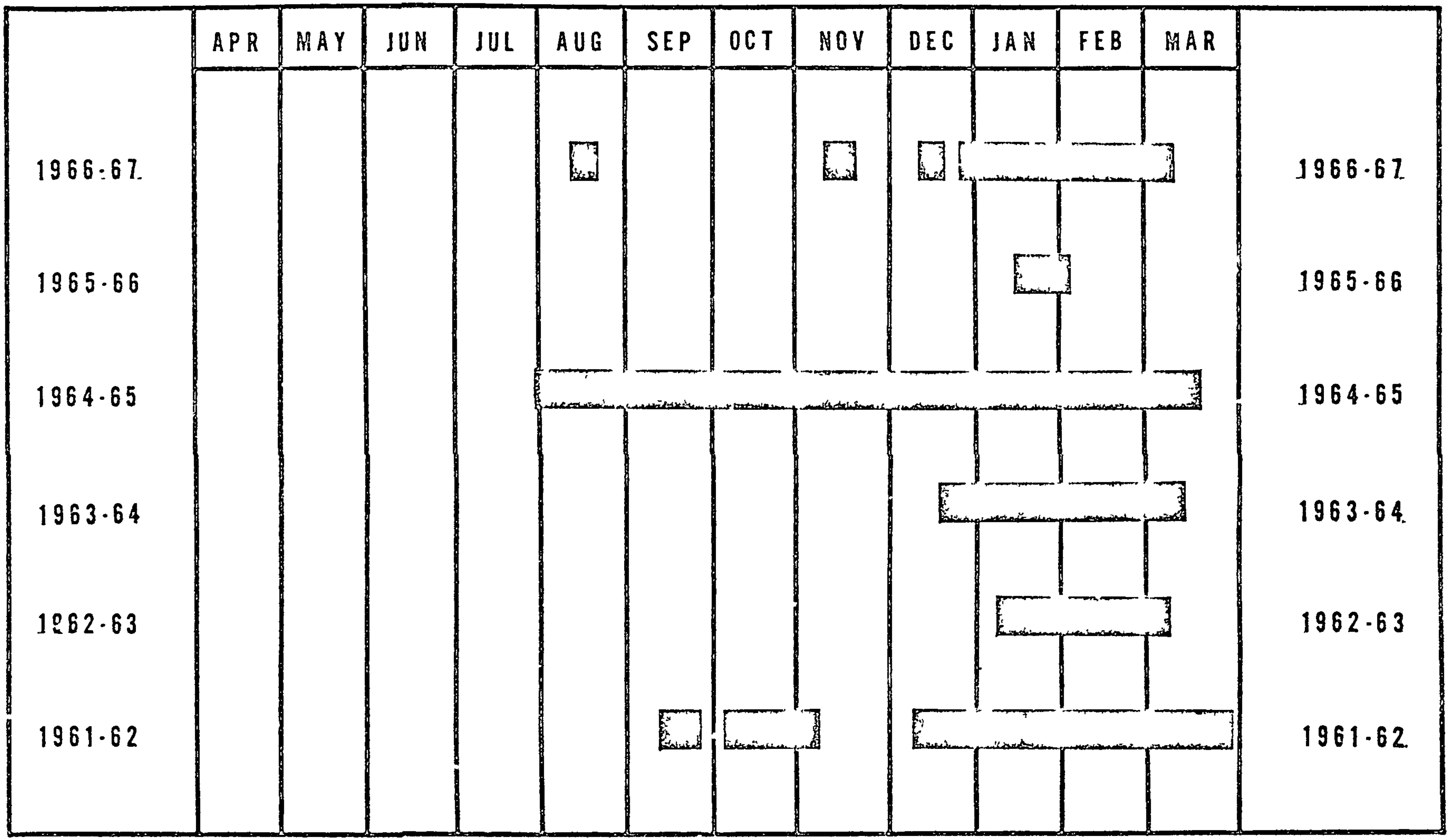

Figure IV-3. Periods During which Wastewaters were ≥ 50 Percent of Flows in the Big Sioux River Downstream from Sioux Falls, South Dakota (June 1961-March 1967) uses these surface-water intakes during peak summer conditions. This amounts to 0 to 1.5 percent of its total annual water production. Most of the wells for the municipalities are less than 150 m (500 ft) deep, but range in depth from 6 to 410 m (20 to 1,360 ft). The deeper wells (greater than 240 m or 800 ft) have more highly mineralized water than do the shallow wells. Most of the municipalities (85 percent) have water systems, but only 45 percent of these have treatment plants. The average daily water consumption of Sioux Falls during 1970 was approximately 42,770 m^3/day (11.3 mgd). The Sioux Falls municipal plant has been recently (1971) expanded to a total capacity of 196,820 m^3/day (52 mgd), with the majority of the supply collected from the Big Sioux River Aquifer. (This aquifer, located in the valley north of the city, is about 30 km or 18 mi long and from 2.5 to 3 km or 1.5 to 2 mi in width.)

D. CLIMATE

The climate of the Big Sioux River Basin may be described as mid-continental, sub-humid, and subject to rapid temperature fluctuation. Temperature extremes range from minus 41 to plus 46°C (-42° to 115°F); the basin has an average annual temperature of about 7°C (45°F). The frost-free period ranges from about 160 to 130 days in the southern and northern part of the basin, respectively.

Precipitation is greatest in the southeastern part of the basin, averaging about 66 cm (26 in) -- with the range being from 38 to 109 cm (15 to 43 in) per year. The annual precipitation decreases to about 51 cm (20 in) -- with the range being from 33 to 76 cm (13 to 30 in) in the northwestern part of the basin. Approximately three-fourths of the annual rainfall occurs between the months of April and September, with the greatest portion falling during June. Approximately 15 to 20 percent of the average annual precipitation is in the form of snow or sleet.

V. WATER QUALITY STANDARDS

A. INTRODUCTION

The Big Sioux River and/or its tributaries flow through or border the States of Iowa, Minnesota, and South Dakota. Waters of the Big Sioux River are subject to applicable, Federally approved water quality standards promulgated under the provisions of the Water Quality Act of 1965.

Pursuant to the Federal Water Pollution Control Act Amendments of 1972, existing water-quality standards for interstate waters are preserved. In addition, the Amendments require that water-quality standards be extended to intrastate waters during the first year after enactment of the Act.

The objective of the 1972 Amendments is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. National goals established to achieve the stated objective include: 1) that the discharge of pollutants into the navigable waters be eliminated by 1985; 2) that wherever attainable, an interim goal of water quality that provides for the protection and propagation of fish, shellfish and wildlife, and provides for recreation in and on the water be achieved by 1 July 1983; and 3) that the water-quality standards established shall be such that they protect the public health and welfare, enhance the quality of water, and serve the purposes of the Act.

It is the policy of the Environmental Protection Agency that all waters, as part of the National Water Quality Standards program, should be protected for recreational uses in or on the water and for the preservation and propagation of desirable species of aquatic biota. Use and value of water for public water supplies and for agricultural, industrial, and other purposes, as well as navigation, shall also be considered in setting standards.

In applying this policy, the terms "recreational use" and "desirable species of aquatic biota" must be given common-sense application. It is the policy of EPA that the existence of man-made pollution should be viewed as a problem to be solved, not as an impediment in assigning this use classification.

The Amendments also require that all point sources of pollution other than publicly owned treatment works that discharge directly into the waters of the United States are required to achieve, not later than 1 July 1977, effluent limitations which shall require the application of the best practicable control technology currently available as determined by the EPA. Not later than 1 July 1983, the same point sources must achieve effluent limitations that shall require the application of the best available technology economically achievable as determined by the EPA. Point sources discharging into publicly owned treatment works must comply with pretreatment standards promulgated by the EPA. Publicly owned treatment works must meet effluent limitations, by 1 July 1977, that are based on secondary treatment and, by 1 July 1983, the best practicable waste treatment technology.

In cases where compliance with prescribed effluent limitations will not achieve a level of water quality to comply with water-quality standards, EPA shall impose the more stringent effluent limitations, as would be necessary to achieve that goal, taking into account the benefits derived and the cost involved.

B. EXISTING WATER QUALITY STANDARDS

South Dakota Water Quality Standards established certain uses to be protected on the Big Sioux River [Appendix A]. Protection of specific uses is ensured by the maintenance of water quality as determined by the measurement of certain parameters. [In Table V-1 is a summary of the critical levels for these parameters.] Although there are differences in the water uses designated for each reach, the critical levels of many of the various pollutants are the same.

The South Dakota Water Quality Standards call for intermittent stream, water-quality criteria [Table V-2] to apply when the flow in a stream becomes zero or less than the daily average flow of wastewater. Between the lower end of the Sioux Falls Diverson Ditch and Klondike Dam, determination of applicable stream criteria is somewhat more complex. When the flows in the Big Sioux River at Brandon, South Dakota, equal or exceed the flows specified in the South Dakota Standards [Table V-3], the respective criterion of 4.0 mg/1, or 5.0 mg/1 dissolved oxygen, applies from Klondike Dam to the lower end of the Sioux Falls Diversion Ditch. When flows at Brandon are less than those indicated for 4 mg/1 DO, the "Intermittent Stream" category applies [Table V-3]. The Big Sioux River downstream from Sioux Falls is frequently classified under this intermittent category during low flow, fall and winter periods.

From immediately south of Sioux Falls, South Dakota, to Sioux City, Iowa, the Big Sioux River and several tributaries are subject to Iowa

TABLE V-1

SOUTH DAKOTA WATER QUALITY STANDARDS
BIG SIOUX RIVER BASIN

Summary of Critical Levels for Designated Reaches

Parameter	REACH: Missouri River to Klondike Dam	Klondike Dam to Sioux Falls Diversion Ditch	Sioux Falls Diversion Ditch to Headwaters	All Tributaries a/
D.O.	5.0 mg/l	5.0 b/ mg/l	5.0 mg/l	
H_2S	1.0	1.0	1.0	
Sus. Solids	90	90	90	
NO_3	50	50	45	50 mg/l
TDS	700-1,500	700-1,500	1,000	700-1,500
Iron (total)	0.2	0.2	0.2	
Alkalinity (as $CaCO_3$)	750	750	750	750
Cyanides	0.02	0.02	0.02	
pH	6.3-9.0	6.3-9.0	6.3-9.0	6.0-9.5
Temp. °F c/	90	90	90	
Turbidity (JTU)	100	100	100	
Elect. Conductivity $\frac{m\Omega}{cm}$	1,000-2,500	1,000-2,500	1,000-2,500	1,000-2,500
SAR	10-26	10-26	10-26	10-26
Soluble Sodium %	30-70	30-70	30-70	30-70
Coliform			$<\frac{5,000}{100\ ml}$ monthly average $\frac{20,000}{100\ ml}$ $\leq$ 5% of samples	
Fecal Coliform	$<\frac{200}{100\ ml}$ monthly average d/	$<\frac{1,000}{100\ ml}$ monthly average d/	$<\frac{1,000}{100\ ml}$ monthly average d/	$<\frac{1,000}{100\ ml}$ monthly average e/
Water Uses f/	2d,3a,3b,4,5	2d,2e,3b,4,5	2d,1,2e,3b,4,5	4,5

a/ Owens Creek is also classified 2c and 3b.
b/ See Appendix A for variation in D.O. criterion with flow.
c/ These values are equivalent to 32°C.
d/ Recreation criteria (3a, 3b) will normally apply only during the summer recreation season. However, if the receiving waters are used extensively for winter recreation, the criteria for limited contact recreation (3b) shall apply during the winter months.
e/ This value applies during irrigation season only.
f/ See Appendix A for description of water uses.

TABLE V-2

SUMMARY OF INTERMITTENT STREAM CRITERIA
SOUTH DAKOTA WATER QUALITY STANDARDS
BIG SIOUX RIVER BASIN

Parameter	Limit
BOD	30 mg/1
Suspended Solids	30 mg/1
pH	6.0-9.5
Coliforms	< 20,000/100 ml-monthly average < 50,000/100 ml-single sample

TABLE V-3

FLOW-DEPENDENT, DISSOLVED-OXYGEN CRITERION
-- FROM KLONDIKE DAM TO THE LOWER END OF SIOUX FALLS DIVERSION DITCH --
SOUTH DAKOTA WATER QUALITY STANDARDS
BIG SIOUX RIVER BASIN

Season	4.0 mg/1 1970 (flow-cfs)[a/]	5.0 mg/1 1970 (flow-cfs)[a/]
Summer (June 15-Sept. 15)	90	160
Fall (Sept. 15-Dec. 15)	35	45
Winter (Dec. 15-Mar. 15)	60	70
Spring (Mar. 15-June 15)	35	45

a/ The metric flow equivalent is 1 cfs = 0.0283 m^3/s.

Water Quality Standards [Appendix B]. Iowa Standards designate that the entire reach of the Big Sioux River bordering Iowa as well as the Rock River are classified as warm-water areas for the propagation of aquatic life. In addition, the Rock River upstream of Rock Rapids is classified for *primary* contact recreation. [The allowable limits of various parameters for warm water aquatic life and primary contact recreation are summarized in Table V-4.]

Several tributaries of the Big Sioux River head in Minnesota. Minnesota Water Quality Standards classify these streams for fish propagation, non-contact recreation, and general industrial use [Appendix C]. In addition, Split Rock Creek, from its source to Split Rock Lake outlet, is classified for *direct* contact recreation. [Water-quality criteria for these classifications are summarized in Table V-5.]

C. DIFFERENCES BETWEEN STATES

Comparison of South Dakota, Iowa, and Minnesota Water Quality Standards for the Big Sioux River Basin reveals significant differences in the criteria for dissolved oxygen, bacteria, and ammonia nitrogen. During low-flow conditions in the Big Sioux River, waters could be at the same time in compliance with the South Dakota water-quality standards and in violation of the Iowa standards. The South Dakota intermittent-stream category limits total coliform organisms to less than or equal to 20,000/100 ml but provides no requirements for dissolved oxygen or ammonia nitrogen. Iowa water-quality standards, on the other hand, provide no bacterial criterion but require DO concentrations of at least 4.0 mg/l and ammonia nitrogen of less than or equal to 2.0 mg/l.

TABLE V-4

IOWA WATER QUALITY STANDARDS
BIG SIOUX RIVER BASIN

Water Uses: Warm Water Aquatic Life and Primary Contact Recreation[a/]

Parameter[b/]	Limit
DO	$\geq$5.0 for 16 hr
	$\geq$4.0 for 24 hr
pH, S.U.	6.8-9.0
Temp., °F	$\leq$90°[c/] or $\leq$ 5° over background
Ammonia (N)	2.0
Cyanide	0.025
Phenols	0.001 (other than natural sources)
As[d/]	1.0
Ba	5.0
Cd	0.03
Cr^{+6}	0.05
Cr^{+3}	1.00
Cu	0.10
Pb	0.10
Zn	1.0
Fecal Coliform, numbers[e/]	$\leq$200/100 ml

a/ *Primary* contact recreation applies to portions of Rock River, a tributary of Big Sioux.
b/ All units are mg/l unless otherwise noted.
c/ This value is equivalent to 32°C.
d/ The total heavy metals is less than or equal to 5.0 mg/l.
e/ Applied only to *primary* contact recreation.

TABLE V-5

MINNESOTA WATER QUALITY STANDARDS
BIG SIOUX RIVER BASIN

Summary of Critical Levels for Designated Reaches

Parameter	REACH: Split Rock Creek from source to Split Rock Lake outlet	REACH: All other Minnesota Tributaries of Big Sioux River[a]
Chlorides	100 mg/l	100 mg/l
Hardness	250 mg/l	250 mg/l
pH	6.5-9.0	6.0-9.5
Temp.	≤86°F July & Aug.[b] ≤80°F June & Sept. ≤67°F May & Oct. ≤55°F April & Nov. ≤43°F March & Dec. ≤37°F Jan. & Feb. 5° above ambient, whichever is greater but not to exceed 90°F	≤86°F July & Aug. ≤86°F June & Sept. ≤75°F May & Oct. ≤63°F April & Nov. ≤51°F March & Dec. ≤45°F Jan. & Feb. 5° above ambient, whichever is greater but not to exceed 90°F
Total Coliform	1,000/100 ml	5,000/100 ml
Dissolved Oxygen	≥6 mg/l April 1-May 31 ≥5 mg/l June 1-March 31	≥5 mg/l April 1-May 31 ≥3 mg/l June 1-March 31
Ammonia (N)	1 mg/l	2 mg/l
Chromium	0.05 mg/l	0.05 mg/l
Copper	0.2 mg/l	0.2 mg/l
Cyanides	0.02 mg/l	0.02 mg/l
Oil	Not to exceed a trace	Not visible or to adversely affect fish, biota, or watercourse
Phenols	0.01 mg/l	None that could impart taste or odor to fish flesh
Radioactive Materials	Lowest concentration allowed by controlling authority	Lowest concentration allowed by controlling authority

a/ The Public Health Service Drinking Water Standards (1962) also apply.
b/ The metric equivalent is °C = 5/9 (°F-32).

The Rock River is another example of conflicting water-quality standards. Minnesota requires DO of greater than or equal to 3.0 mg/l; a NH_3-N of less than or equal to 2.0 mg/l; and total coliform organisms of less than or equal to 5,000/100 ml. Iowa, on the other hand, requires a DO of greater than or equal to 4.0 mg/l; a NH_3-N of less than or equal to 2.0 mg/l and includes no bacterial criteria.

On Split Rock Creek, the other major interstate tributary, the standards of Minnesota and South Dakota are not compatible. Minnesota requires a DO of at least 3.0 mg/l; a NH_3-N of not more than 2.0 mg/l; and total coliform organisms not to exceed 5,000/100 ml; South Dakota sets no limits on Split Rock Creek for these parameters. Incorrect, SD has a DO of 5.0 mg/l and total coliform of 5000/100 ml.

VI. STREAM SURVEY

Water-quality investigations of the Big Sioux River and selected tributaries were conducted prior to and during critical conditions of low flow and ice cover.

The first phase was conducted during the fall of 1972 (15 Sept.-5 Oct.) with primary emphasis on the effects of waste discharges on Big Sioux River quality and influences upon aquatic organisms. The second phase was conducted during the winter of 1973 (1-10 Feb.). Primary emphasis was placed on quality of the Big Sioux River as affected by major waste sources and tributary inflows.

A. FALL STREAM SURVEY, 1972

During late September and early October 1972, a biological survey was conducted from Estelline, South Dakota (RM 263.5), downstream to near confluence with the Missouri River (Sioux City, Iowa). Throughout this river reach the Big Sioux is a prairie stream, characterized by a well-entrenched channel, moderate gradient, and by a mud or sand bottom with few riffle areas. Consequently, organic materials contributed to the river by both agricultural and domestic sources are assimilated slowly. [Study methods for the survey are included in Appendix D. Data summaries are included in Appendix K.]

Near Estelline, South Dakota (RM 263.5), the Big Sioux River was enriched. Attached algae (periphyton) grew profusely on artificial substrates, as evidenced by high chlorophyll *a* levels [Appendix K, Table K-2 and Figure VI-1]. Dissolved-oxygen concentrations as high as 12.8 mg/l [Appendix K, Table K-1] were an additional manifestation of the presence of abundant algae. Although the diversity* of benthic invertebrates was low ($\bar{d}$ = 1.15), most of the organisms collected were pollutant sensitive [Appendix K, Table K-9].

Water quality improved downstream near Volga, South Dakota (RM 243.9). Periphyton densities decreased [Figure VI-1], and the diversity of benthic macroinvertebrates increased to an acceptable 3.65.

Downstream from Brookings, South Dakota (RM 237.6), Big Sioux water quality was judged moderately degraded. Attached algae grew profusely on artificial substrates, and the benthic species diversity decreased to 2.46. The benthic community was dominated by a variety of sensitive forms.

From the vicinity of Flandreau, South Dakota, at RM 206.1 downstream to Renner, South Dakota (RM 162.2), the water quality of the Big Sioux River was acceptable. Periphyton growth on artificial substrates was restricted [Figure VI-1], and the species diversity of benthic invertebrates increased to values greater than 3.0 [Appendix K, Table K-3]. However, some of the field measurements provided indirect evidence of enrichment throughout this river reach; turbidity increased from a range of 7 to 17 units in the reach upstream from Flandreau to 25 to 32 units at Renner. High DO concentrations (in excess of saturation) were detected throughout the river reach [Appendix K, Table K-1], indicating considerable photosynthetic activity.

In the reach of the Big Sioux River between northwest Sioux Falls

* See Methods of Analysis [Appendix D] for "diversity."

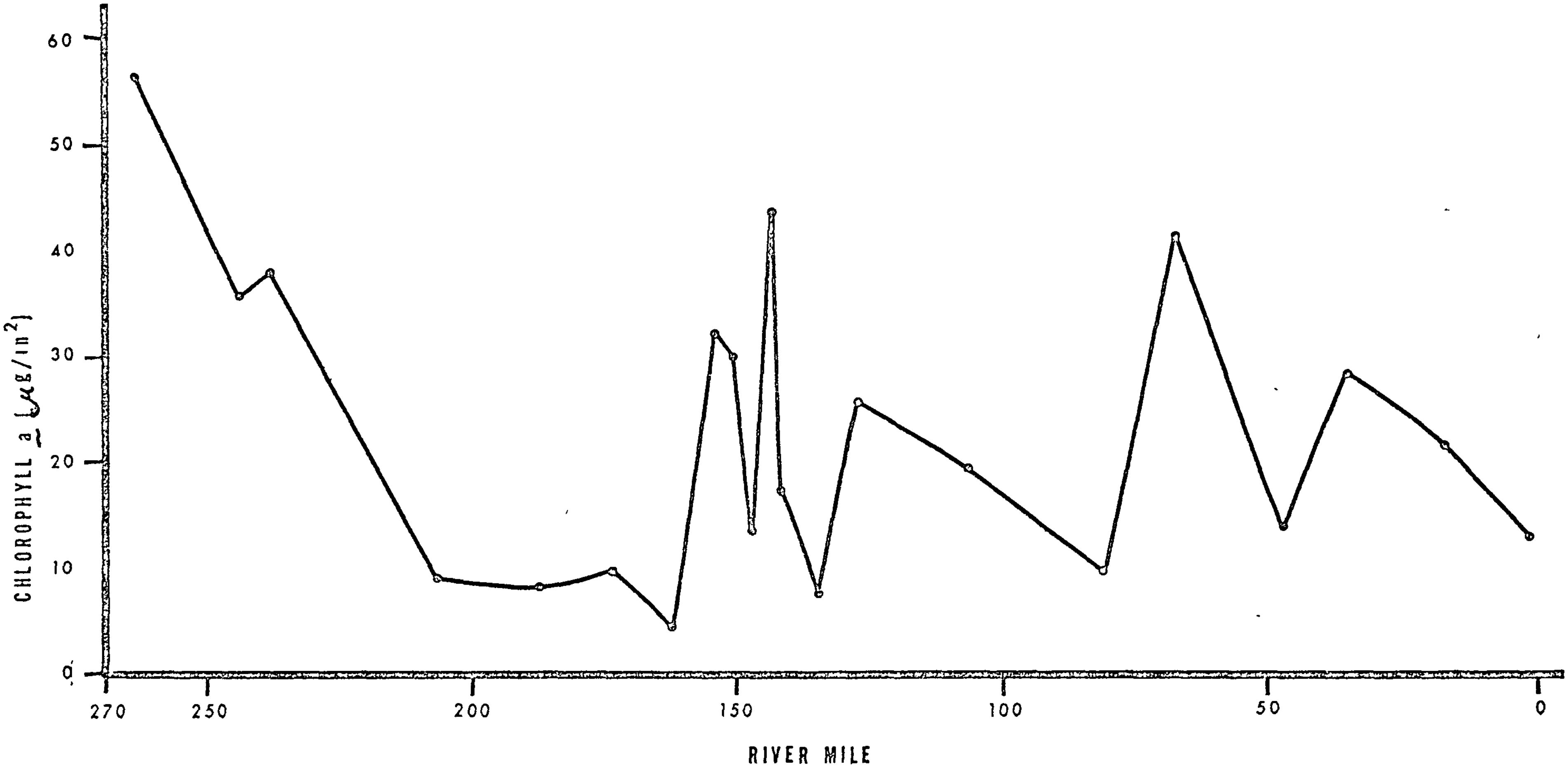

Figure VI-1. Chlorophyll a from Periphyton, Big Sioux River.
10 September to 3 October 1972

and the Iowa-South Dakota state line, numerous factors operate to influence water quality. As this is the largest urban and industrial area in the river basin, diverse pollutional sources, such as storm run-off, and domestic and industrial wastes combine with already enriched Big Sioux River waters, resulting in varied water quality. The Spencer Foods, Inc. (now Meilman Food Industries) meat-packing plant, located in Northwest Sioux Falls, discharged inadequately treated wastes [Appendix K, Table K-4] to the Big Sioux River (RM 154.2). The John Morrell and Company packing plant discharged most of its wastes to the Sioux Falls Wastewater Treatment Plant which discharges to the Big Sioux at RM 143.0. Also at the time of the 1972 study[2/] Morrell discharged "condenser" water to the Big Sioux River at RM 143.2. In addition, minor amounts of untreated domestic and industrial wastes were being discharged through numerous outfalls in the Sioux Falls area.

In the vicinity of Sioux Falls, the physical characteristics of the river are variable. Unlike most of the river, which flows smoothly over a mud or sand bottom, the Sioux Falls reach consists of a series of riffles and pools, and in places the bottom is smooth rock. In the riffle areas re-aeration occurs, and the effects of organic pollutants are often not apparent for a considerable distance downstream. Conversely, in reaches with smooth rock substrates where benthic habitats are poor and the benthos is sampled therefore with difficulty, water quality could be better than biological sampling would seem to indicate.

At RM 155.4, in northwest Sioux Falls, the Big Sioux River was moderately degraded. The specific sources of this degradation are not known. The diversity of the benthos decreased to 2.62, and dissolved-oxygen concentrations decreased to less than saturation. However, turbidity values were low, and no ammonia was detected [Appendix K, Table K-1].

At RM 154.2, the river carried wastes discharged immediately upstream by Spencer Foods. Ammonia concentrations increased to as much as 4.5 mg/l, and DO concentrations were less than 10 mg/l [Appendix K, Table K-1]. Periphyton densities increased [Appendix K, Table K-2], and the midday DO concentration decreased 5 mg/l from value found upstream at RM 155.4.

Skunk Creek (RM 152.8/1.1) contributed poor-quality water to the Big Sioux. Dissolved-oxygen concentrations as high as 17.1 mg/l (175 percent saturation) were detected, and the DO varied as much as 5 mg/l. These conditions reflect photosynthetic activity by large densities of algae. The diversity of benthic invertebrates was severely restricted ($\bar{d}$ = 0.98) in this tributary.

From RM 154.2 to RM 143.2, immediately upstream of the Sioux Falls WWTP, the water quality in the Big Sioux was moderately degraded. Ammonia was detected at most sampling locations in the reach, with the highest concentrations at points nearest the Spencer-Foods discharge [Table K-1]. Periphyton populations increased [Figure VI-1], indicating nutrient enrichment. Although the diversity of the benthos was variable, most of the variability is attributed to substrate differences. At two locations (RM 150.6 - $\bar{d}$ = 1.41 and RM 143.8 - $\bar{d}$ = 1.73) benthic diversity was unacceptably low.

Algal-growth-potential (AGP)* studies were conducted for the following purposes: (1) to assess the potential of wastes from the Sioux Falls WWTP for stimulating primary production in the Big Sioux River; (2) to determine how this stimulation might change under differing waste-discharge loadings; and (3) to determine whether either nitrogen or phosphorus is the cause of algal stimulation. Grab samples from the river upstream of the waste discharge were tested using final clarifier (not chlorinated) overflow and combinations of nitrogen and phosphorus.

Waste effluent containing 15.5 mg/l P and 18.9 mg/l inorganic N stimulated algal growth when added to river-water samples taken upstream of the municipal wastewater treatment plant. The amounts of the additions correlated closely (R = 0.90) with increases in production [Appendix K, Table K-7]. A 50-percent effluent addition would have increased production by about a factor of three, and about eight times as much algae would be produced if the river flow were 80-percent effluent. During the study period, the effluent from the municipal wastewater treatment plant made up about 40 percent of the river flow.

Additions of phosphorus to the water of the Big Sioux River did not stimulate algal growth [Appendix K, Table K-8], thus indicating that phosphorus was not limiting; i.e., production was not inhibited by phosphorus deficiencies in the river at the time of the fall survey. The water sample tested contained, before any additions, 1.1 mg/l phosphorus, a concentration considered sufficient for algal blooms in flowing waters.

Nitrogen additions of up to 10 mg/l stimulated algal growth, and

* The method is described in Appendix D.

the increased production correlated closely with the amounts of the additions. The addition of 10 mg/l N (without phosphorus additions) stimulated a seven-fold increase in algal growth [Appendix K, Table K-8]. Ten mg/l was the highest nitrogen concentration used in the nitrogen addition test. Undiluted wastewater containing 22.9 mg/l N stimulated even more production [Appendix K, Table K-7].

To ascertain whether primary production in the Big Sioux River was actually being stimulated by wastes discharged from the Sioux Falls WWTP, photosynthesis was measured at seven points along the river [Appendix K, Table K-6]. These measurements indicated that, contrary to what would be expected from the AGP test results, photosynthesis was inhibited downstream from the wastewater discharge. Photosynthesis (and carbon fixation) was stimulated between RM 162.2 and 143.2, became severely depressed downstream from the wastewater discharge at RM 141.2, and did not recover until RM 106.2 near Canton, South Dakota. A possible cause of the difference between the AGP and photosynthesis-test results is the chlorination of the effluent from the municipal wastewater treatment plant during the fall. The waste used in the AGP test was not chlorinated, whereas the chlorinated wastewaters discharged to the Big Sioux River probably contained toxic concentrations of chlorine and chloramines.

From the point of discharge of the Sioux Falls WWTP (RM 143.0) downstream to Hudson, South Dakota (RM 80.9), severe-to-moderate pollution was detected. Ammonia concentrations as high as 14.0 mg/l were detected in this reach and were as high as 2.7 mg/l at the South Dakota-Iowa state line [Appendix K, Table K-1]. A dissolved-oxygen profile [Appendix K, Table K-5 and Figure VI-2] showed generally declining DO in Sioux Falls upstream of the municipal wastewater treatment plant and rapid DO depression downstream from the plant. The most severe DO depression occurred at the Iowa state line (RM 127.0); downstream near Canton, South Dakota (RM 106.2), the river had not completely recovered. Probable causes of DO depression were supression of photosynthesis in the affected reach and the demand for oxygen by carbonaceous and nitrogenous materials.

Downstream from the Sioux Falls WWTP discharge, damage to Big Sioux River biota was moderate to severe. Between RM 142.7 and 127.0 the diversity of benthic invertebrates increased to accepteble levels ($\bar{d}$ = 2.17 to 4.52), then decreased to as low as 0.94 at RM 80.9. The diversity decrease of Big Sioux River benthos closely paralleled the DO depression but was displaced downstream [Figures VI-2 and VI-3]. Benthic invertebrates are long-term river inhabitants, and their diversity reflects water quality for the entire year. Consequently, the apparent delay in damaging effects to benthos is attributed to waste assimilation and oxygen depletion proceeding at a slower rate during the cold winter months.

The growth of attached algae was also affected by pollutants between RM 141.2 and 80.9. These organisms, grown on artificial substrates, reflect short-term water quality. Downstream from the Sioux Falls WWTP effluent at RM 141.2 and 134.5, periphyton growth was inhibited [Figure VI-1], probably by the same factors that inhibited photosynthesis in this reach. Split Rock Creek (confluence at RM 130.1) discharged highly enriched water to the Big Sioux. Dissolved oxygen reached concentrations as high as 11.8 mg/l and fluctuated widely in the creek, but no ammonia was detected [Appendix K, Table K-1]. Periphyton growths were abundant [Appendix K, Table K-2], and benthic species diversity ($\bar{d}$ = 2.02) was low. Downstream from the Split Rock Creek at RM 127.0, Big Sioux River periphyton growths increased, then gradually diminished [Figure VI-1].

The Rock River (RM 76.2) discharged highly enriched water to the Big Sioux. Dissolved-oxygen concentrations were as high as 12.8 mg/l and varied greatly at different times of the day [Appendix K, Table K-1]. Periphyton growths in this tributary were abundant [Appendix K, Table K-2], and the diversity of benthic invertebrates was moderately low ($\bar{d}$ = 2.36).

Downstream from the Rock River (RM 66.9 to RM 2.2) the Big Sioux River was enriched. The waters were generally supersaturated with DO [Appendix K, Table K-1]. Periphyton growths increased greatly at RM 66.9, then, as the river assimilated the enrichment, they gradually diminished downstream [Figure VI-1]. Benthic species diversity increased [Figure VI-3] and remained at values indicative of clean or moderately enriched water.

At the sampling location farthest downstream (RM 2.2 in Sioux City, Iowa), the Big Sioux River was backed up by the Missouri River and flowed very slowly. Benthic habitat was poor, causing diversity to decrease ($\bar{d}$ = 1.82). Dissolved-oxygen concentrations were as high as 18.0 mg/l (about 180 percent saturation) at midday but only decreased to 13.0 mg/l in the early morning.

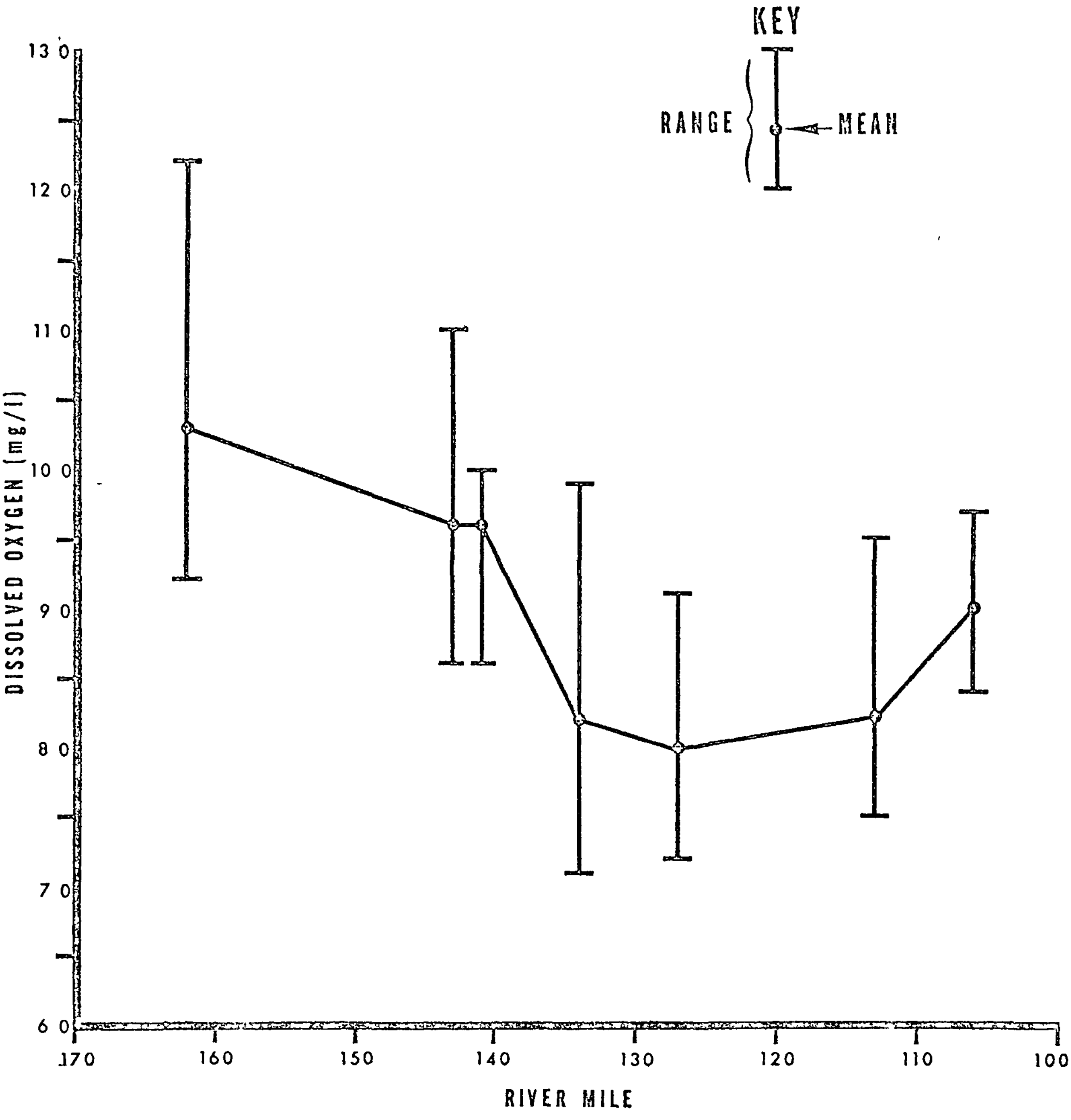

Figure VI-2. Dissolved Oxygen Profile, Big Sioux River, Renner to Canton, South Dakota, 0600 to 1200 Hours (CDT), 9/26-27/72

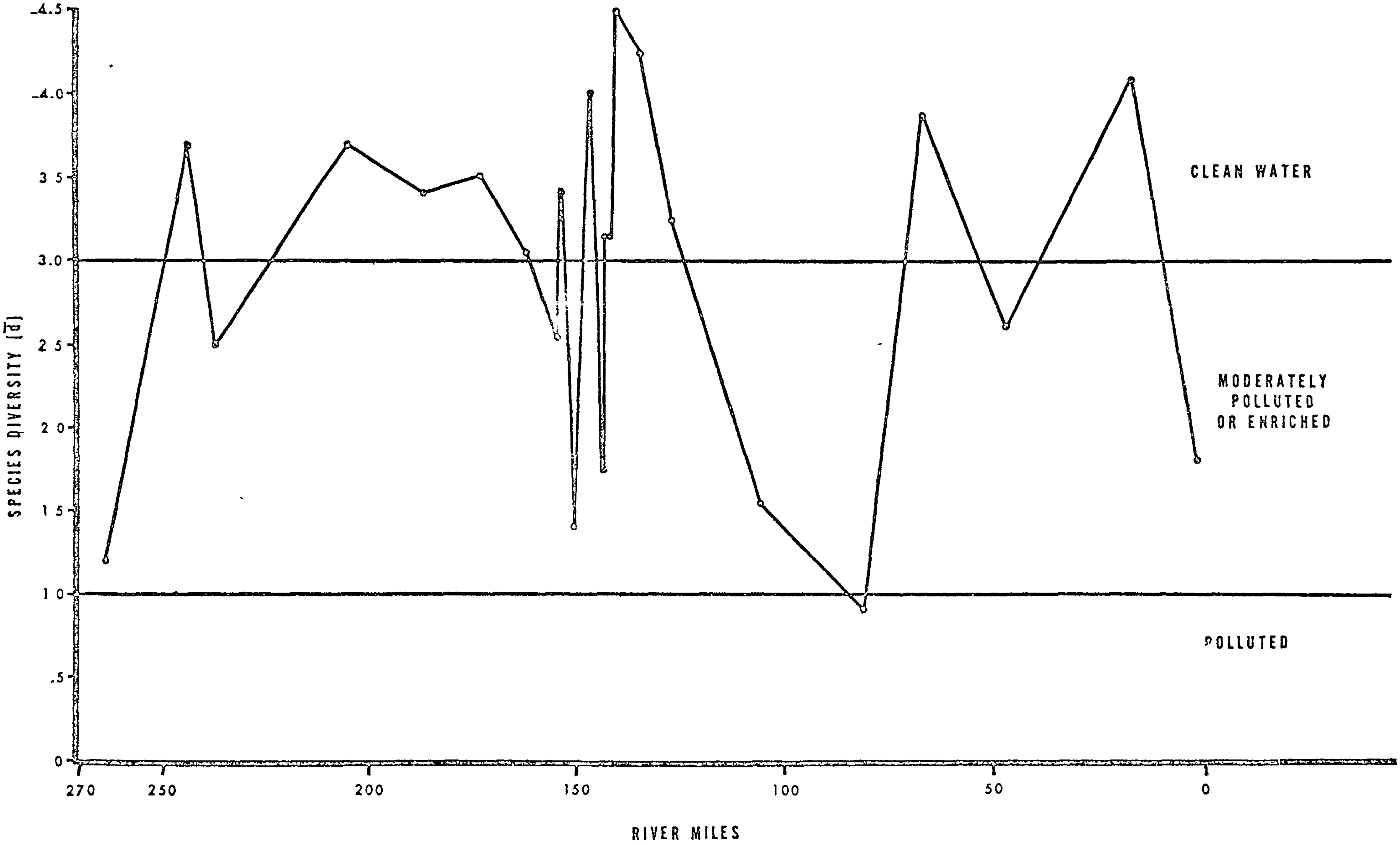

Figure VI-3. Species Diversity (d̄) of Benthic Invertebrates, Big Sioux River.

September-October, 1972

B. WINTER STREAM SURVEY, 1973

During 1 through 10 February 1973, a water-quality study of the Big Sioux River Basin was conducted from Estelline, South Dakota (RM 263.5) to Sioux City, Iowa (RM 5.0). The major waste sources in the study reach are the Sioux Falls Wastewater Treatment Plant and Meilman Food Industries (formerly Spencer Foods, Inc.). The tributaries that were monitored included Skunk Creek, Split Rock Creek, and the Rock River. Nineteen stream stations were selected [Figures IV-1 and IV-2, and in Appendix H, Table H-1].

Stream samples were single grab samples. Samples from the Sioux Falls WWTP and Meilman discharges were collected over a 24-hr period using SERCO automatic samplers. The treatment plant samples were flow composited; those from Meilman were time composited.

Field measurements were carried out for determination of temperature, pH, and conductivity, and laboratory analyses were performed to determine BOD, COD, TOC, total and suspended solids, total Kjeldahl nitrogen, NH_3-N, NO_2 + NO_3-N, and total phosphorus. In addition, there were bacteriological analyses performed to quantify the total and fecal coliforms and fecal streptococci. *Salmonella* analyses were also performed on samples collected at selected locations. Biological studies included fish assays and algal-growth potentials.

A major objective of the study was to determine water quality during critical low flows in the Big Sioux River. Kerwin Luther Rakness, in an M.S.-degree thesis[4/], determined that 50 percent of the time flows would equal or exceed 0.6 m^3/s (22 cfs) during 1 through 10 February at

Brandon, South Dakota, approximately 14 km (9 mi) downstream from the Sioux Falls WWTP and only 10 percent of the time would flows equal or exceed 0.9 m^3/s (32 cfs). These data were based on records from 1959-65. Statistical data from the former gaging station in Sioux Falls (1943-60) indicated that, for 50 percent of the time, flows would equal or exceed 0.3 m^3/s (10 cfs) and for only 10 percent of the time would flows exceed 2.0 m^3/s (70 cfs). If one considers that the Sioux Falls WWTP alone discharged approximately 0.4 m^3/s (14 cfs), there would be greater than a 50-percent chance that the wastewaters from the Sioux Falls plant would equal or exceed half of the total flow in the stream downstream from the plant. However, as a result of an unusually mild winter, flows [Appendix I, Table I-1] at the Cliff Avenue gaging station, 0.5 km (0.3 mi) downstream from the plant discharges, far exceeded anticipated flows, averaging 3.4 m^3/s (122 cfs) over the 10-day period. Because of these abnormally high flows, the South Dakota intermittent stream classification was not in effect, and criteria previously mentioned [Table V-3] applied. During the survey the plant effluent comprised approximately 11 percent of the total stream flow. Despite abnormally high flows, there was a severe degradation of downstream water quality.

Flow records from seven U. S. Geological Survey gaging stations were employed [Appendix I, Table I-1]. Gage readings were recorded daily by EPA personnel and submitted to the USGS for computation of flows, with a correction for ice-cover conditions. EPA personnel also gaged the river at Akron, Iowa, to determine flows during the survey.

In addition to monitoring receiving-water quality at low-flow conditions, the study was planned for conditions of ice cover when minimal re-aeration would be expected. It is estimated that more than 90 percent of the Big Sioux River from Estelline, South Dakota (RM 263.5), to the mouth was covered. The only significant, open-water stretch was from the spillway of the diversion canal (RM 143.0) to near RM 130.0. The entire flow of the Big Sioux River was diverted through the diversion canal [Figure IV-2]. This is not the normal practice but was done to facilitate bridge-construction work in the downtown area along the main stem. Consequently, the only flow in the main stem of the Big Sioux River from the diversion point, at RM 158.8, to the diversion spillway, at RM 143.0 was approximately 0.3 m^3/s (10 cfs), emanating from Skunk Creek 0.(0.2 m^3/s or 6 cfs); from Meilman Food Industries (0.01 m^3/s or 0.5 cfs); and from miscellaneous sources including ground waters pumped from a rock quarry and accretions of ground water (0.1 m^3/s or 3.5 cfs). No other waste sources of any consequence were observed in this stream reach (RMs 158.8-143.0).

The biological, bacteriological, and chemical quality of the Big Sioux River and selected tributaries are discussed in the following subsections.

Biological Conditions

Algal Assays — Additions of 40, 60, 80, and 100 percent of the waste effluent from the Sioux Falls Wastewater Treatment Plant to test water obtained from the Big Sioux River, upstream of the plant, stimulated algal bloom conditions (visible green) in the laboratory-assay studies. The percent effluent added correlated closely (R = 0.87) with increases in algal production [Appendix K, Table K-12].

Additions of primary trickling-filter underflow by-passed directly to the Big Sioux River stimulated algal growth at additions through 60 percent [Appendix K, Table K-13]. At 80 and 100 percent, inhibition took place. A toxic effect was probable.

Additions of nitrogen to Big Sioux water did not stimulate algal growth [Appendix K, Table K-12], thus indicating that nitrogen was not limiting. The water sample contained 0.55 mg/l ammonia nitrogen before additions.

Phosphorus additions of up to 10 mg/l stimulated algal growth [Appendix K, Table K-14], and the increased production correlated closely with the amounts of the additions. Although 10 mg/l was the highest phosphorus concentration used in the test, higher phosphorus concentrations could stimulate additional growth.

In tests using nutrient-stripped effluent, algal bloom (visible green) conditions were stimulated only by 80- and 100-percent effluent [Appendix K, Table K-15]. Phosphorus was the growth-limiting nutrient [Appendix K, Table K-16].

In summary, the growth-limiting nutrient was nitrogen in the fall and phosphorus in the winter. Algal problems that can occur during periods of low-flow downstream from the Sioux Falls WWTP have been discussed previously. The potential for algal problems in this Big Sioux River reach during the winter is slight because ice cover, cold temperatures, or dilution of the nutrient-rich wastewaters in the river generally inhibit algal growth.

Fish Assays -- A flow-through bioassay was conducted in order to evaluate the final effluent from the Sioux Falls, South Dakota, Wastewater Treatment Plant from 30 January through 3 February 1973 (96 hr). Of special interest was the NH_3 present in the final effluent. [Water chemistry data from the experimental conditions are shown in Appendix K, Table K-10 together with mortality data.]

In general, the test organisms were fairly tolerant to the unchlorinated final effluent. The determined 96-hr TL_m was 63.5 percent effluent or 35.5 mg/l NH_3-N. Applying a standard application factor of 1/20 yields a chronic toxicity level for channel catfish of approximately three percent effluent or 1.8 mg/l NH_3-N. Other components in the effluent that were not identified could increase or inhibit the toxicity of ammonia. However, the calculated chronic toxicity level (1.8 mg/l NH_3-N) correlates closely with the 2 mg/l criterion widely accepted as the maximum allowable in receiving waters. Therefore, the conclusion is reached that other components did not significantly influence ammonia toxicity levels determined in the study.

With an average discharge of 56 mg/l NH_3-N from the wastewater treatment plant, the effluent must constitute less than 63 percent of the stream flow in order to prevent an acutely toxic condition and less than three percent to prevent chronic toxicity. In addition, the toxicity of NH_3-N is greatly influenced by physical and chemical factors, such as pH. During the bioassay, the pH of the river (dilution water) was approximately 7.5, thus minimizing toxicity. At other times of the year the pH of the river is approximately 8.5, and the toxicity of NH_3-N could be considerably greater.

Channel catfish exposed *in situ* in the main outfall of the municipal wastewater treatment plant survived the first 48 hr, but after 96 hr only 20 percent survived. Mortality of these fish could have been a result of a power failure, after 72 hr of exposure, which resulted in industrial wastes being routed through the combined domestic-industrial system without pretreatment.

All fish exposed *in situ* at the four river sites [Appendix K, Table K-11] survived the 96-hr exposure period. During this period, NH_3-N concentrations in the river were as high as 7.45 mg/l -- a concentration sufficient to be chronically toxic, but lower than the acute toxicity level. The duration of exposure (96 hr) was insufficient to monitor chronic toxicity.

Bacteriological Conditions

Big Sioux River and Selected Tributaries -- During the 1-through-10-February-1973 study, the bacteriological quality of the Big Sioux River and tributaries was monitored from near Volga, South Dakota (RM 243.9), downstream to Sioux City, Iowa (RM 5.0) [Appendix F, Table F-1]. As mentioned previously, no fecal-coliform criterion exists on the Big Sioux River during the non-recreation season.

The upper reaches (RM 243.9 to RM 143.0) of the Big Sioux River were of acceptable bacterial quality [Figure VI-4 and Appendix F, Table F-1]. Fecal-coliform bacterial densities did not exceed 200/100 ml* at any of the sampling stations between RM 243.9, near Volga, South Dakota, and the Sioux Falls, South Dakota WWTP (RM 143.0).

* All bacteria densities are reported as log mean.

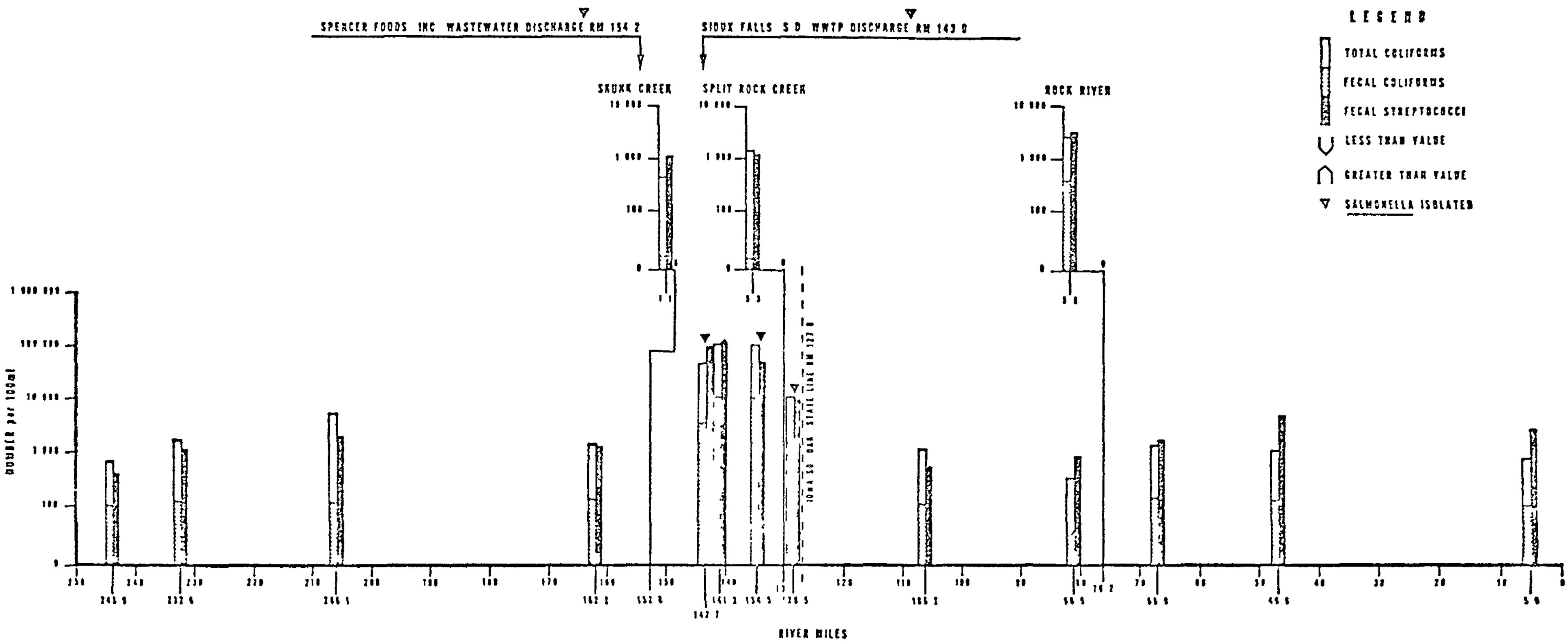

Figure VI 4 Bacterial Densities (Logarithmic Mean)--Big Sioux River, South Dakota
February 1973

The flow in the main stem of the Big Sioux River between RM 158.8 and RM 143.0 was about 0.3 m^3/s (10 cfs). The majority of this flow (approx. 0.2 m^3/s or 6 cfs) originated from Skunk Creek which was of acceptable bacterial quality (FC = < 24/100 ml). Approximately 0.01 m^3/s (0.5 cfs) was discharged by Meilman Food Industries. These wastewaters contained total (TC) and fecal coliform (FC) densities of 210,000/100 ml and 57,000/100 ml, respectively. The fecal streptococci (FS) density was 3,300,000/100 ml. In addition the pathogens, *Salmonella siegburg, S. tennessee,* and *S. binza*, were isolated [Appendix F, Table F-3]. The presence of these pathogenic bacteria constitutes a serious health hazard to individuals coming in contact with such contaminated water. *Salmonella* were not isolated from background station in the diversion canal (RM 143.0/0.2).

The Sioux Falls WWTP discharges contained excessive bacterial densities. In the effluent organism densities were greater than 1,300,000/100 ml for total coliform bacteria, greater than 180,000/100 ml for fecal coliforms, and 2,000,000/100 ml for fecal streptococci. The by-pass contained densities of 16,000,000/100 ml, total coliform; 4,300,000/100 ml, fecal coliforms; and greater than 82,000,000/100 ml, fecal streptococci. *S. heidelberg* and *S. organienburg* were isolated from the wastewater-treatment-plant effluent, and *S. heidelberg* and *S. anatum* were isolated from the by-pass.

Bacterial contamination [Figure VI-4] attributed to the Sioux Falls WWTP discharges was evident from RM 142.7 to the Iowa-South Dakota state line (RM 127.0). The apparent anomaly represented by increases in bacterial densities between RM 142.7 and 141.2 is probably the result of inadequate mixing at the Cliff Avenue Station (RM 142.7).

In addition to high densities of indicator organisms, *Salmonella* were also isolated downstream of the treatment plant. The presence of *S. heidelberg* at RM 128.5, RM 134.5, and RM 142.7, as well as in the discharges from the Sioux Falls, South Dakota, WWTP indicates that the pathogenic bacteria are contributed by the treatment plant.

Split Rock Creek (RM 130.1/5.3) was found to be of acceptable bacterial quality (FC = 19/100 ml). Also, selected Big Sioux River sampling stations along the Iowa-South Dakota state line at RMS 106.2, 80.9, 66.9, 46.8, and 5.0 exhibited acceptable bacterial quality. Log mean fecal-coliform bacterial densities did not exceed 240/100 ml.

Rock River -- The bacterial quality of the Rock River near its mouth (RM 76.2/5.8) was poorer than that of the Big Sioux upstream of the confluence (RM 76.2). The fecal-coliform bacterial density was 630/100 ml whereas upstream on the Big Sioux (RM 80.9) it was less than 55/100 ml.

During the last two days of the study additional sampling was conducted on certain portions of the Rock River (RM 76.2/52.5 to RM 76.2/5.8) and at one station on the Little Rock (RM 76.2/22.1/4.0) [Appendix F, Table F-2]. The background station, upstream of Luverne, Minnesota (RM 76.2/52.5), showed acceptable quality water; the fecal-coliform bacterial density was 11/100 ml. Downstream, at the Minnesota-Iowa state line (RM 76.2/40.8), the bacterial density increased (FC = 410/100 ml). This increase was attributed to the Luverne, Minnesota, Wastewater Treatment Plant; however, the bacterial densities from this source were not determined. The Iowa Beef Packers Plant* at Luverne is another potential source of pollution, but it was not discharging wastes to the Rock River during the sampling period. At the station (RM 76.2/25.7) just upstream of the Little Rock River the fecal-coliform bacterial density increased slightly to 690/100 ml and was sustained downstream near the mouth (RM 76.2/5.8). The Little Rock River (RM 76.2/23.1/4.0) was found to be of acceptable bacterial quality (FC = 31/100 ml).

As discussed previously [Section V], no fecal coliform criterion applies to either the Minnesota or Iowa portions of the Rock River during the non-recreation season. Minnesota Water Quality Standards include a total-coliform-bacterial-density criterion of less than 5,000/100 ml, but this criterion was not violated [Appendix F, Table F-1]. Iowa Water Quality Standards do not include a bacterial criterion.

<u>Chemical Quality</u>

<u>Dissolved Oxygen-(Big Sioux River and Selected Tributaries)</u> -- Dissolved-oxygen levels [Figure VI-5] upstream of the Sioux Falls area (RM 243.9 near Volga, South Dakota to RM 162.2 near Renner) averaged 8.9 to 10.9 mg/l, sufficient to support diverse communities of aquatic life.

As previously mentioned, the Big Sioux River was diverted in its entirety at RM 158.8 leaving only about 0.3 m^3/s (10 cfs) in the main stem. The approximately 0.2 m^3/s (6 cfs) from Skunk Creek (RM 152.8/1.1)

* The Minnesota Pollution Control Agency has ordered Iowa Beef Packers to provide 180 day storage capacity for wastewater flows with controlled discharge during periods of adequate streamflow. Construction must be completed by 15 December 1973.

contained an average DO concentration of 7.4 mg/l. The combined 0.3 m^3/s (10 cfs), after flowing as open water for a portion of the metropolitan main stem and passing over the falls, contained 13.2 mg/l DO immediately upstream (RM 143.2) of the confluence with the diverted flow.

Immediately downstream of the Sioux Falls WWTP, at RM 142.7 and 141.2, the average DO concentrations were 12.9 and 12.6, respectively (saturation = 13.9 mg/l), because of the re-aeration afforded by the diversion canal spillway. The average DO concentration at RM 134.5 (Brandon Road Bridge) was 11.0 mg/l. Downstream from this station, however, the effects of the BOD (3,715 kg, or 8,190 lb, or 108 mg/l) from the Sioux Falls WWTP accompanied by the minimal re-aeration under ice cover was evident. The DO concentration at RM 128.5, approximately 2.5 km (1.5 mi) upstream of the Iowa-South Dakota state line, declined to 7.8 mg/l. This was in part due to the Split Rock Creek inflow (0.6 m^3/s or 22 cfs) that contained 6.8 mg/l of DO.

Downstream from the state line DO concentrations continued to decline. The average concentration at RM 106.2, near Canton, South Dakota, was 6.5 mg/l. At RM 80.9, near Hudson, South Dakota, it was 4.8 mg/l, a violation of the South Dakota water quality criterion of 5.0 mg/l. However, this was not a violation of Iowa Water Quality Standards for the State of Iowa specifies that DO shall not be less than 5 mg/l during any 16-hr period nor less than 4.0 mg/l at any time during the 24-hr period.

The average DO concentration of 3.3 mg/l at RM 66.9, north of Hawarden, Iowa, was in violation of both Iowa and South Dakota Water

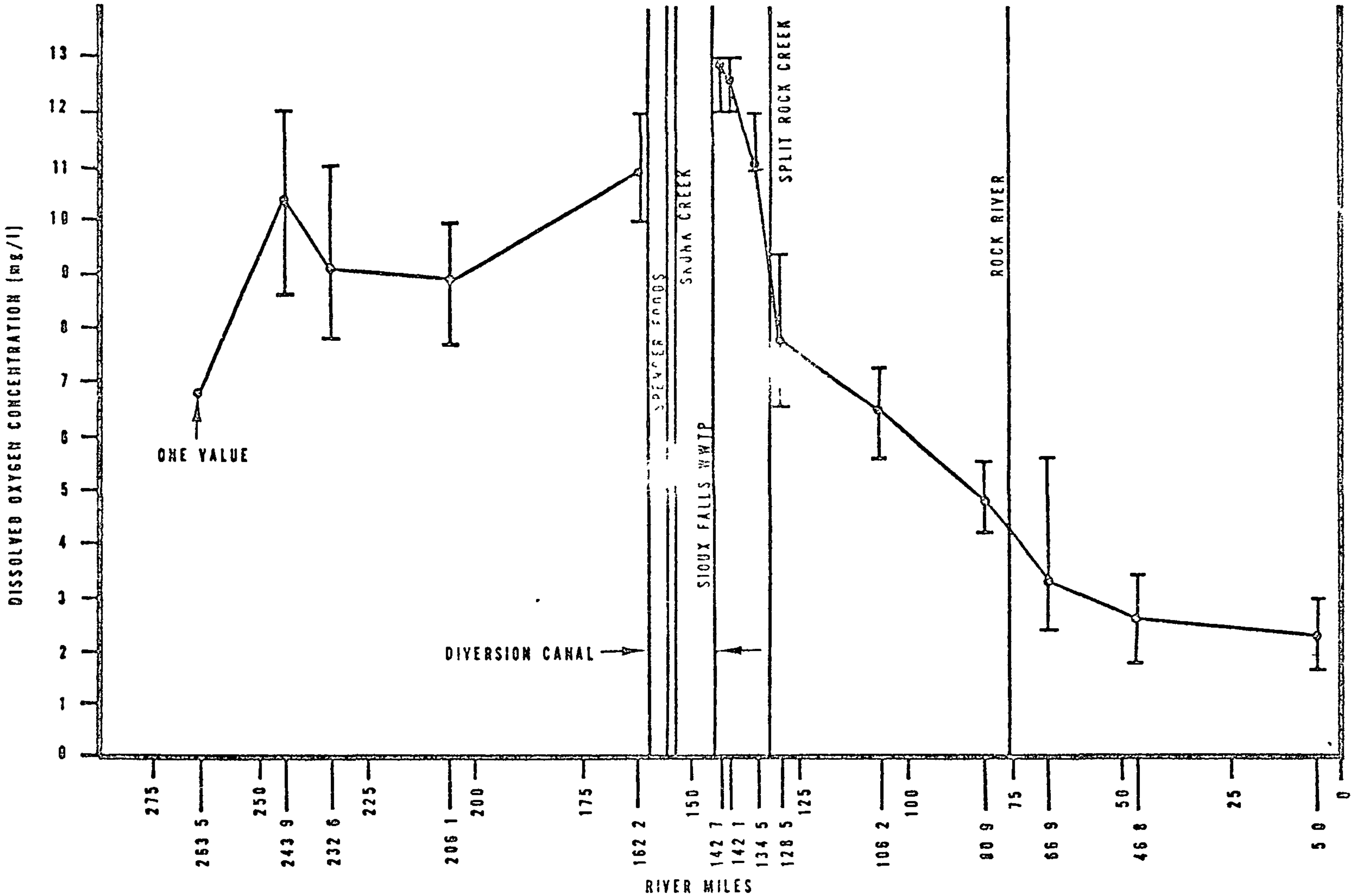

Figure VI-5 Dissolved Oxygen Profile, Big Sioux River
Estelline, South Dakota to Sioux City, Iowa
1-10 February 1973

Quality Standards. On eight out of ten days monitored the DO was less then 4.0 mg/l, reaching a low of 2.4 mg/l. At Akron, Iowa (RM 46.8), the DO ranged from 1.8 to 3.4 mg/l (average = 2.6 mg/l), a violation of Iowa and South Dakota Water Quality Standards on all ten days of sampling.

The DO levels were monitored for four days at the furthest downstream station in north Sioux City, Iowa (RM 5.0). Concentrations ranged from 1.7 to 3.0 mg/l, in violation of both Iowa and South Dakota Water Quality Standards, indicating that the river had not recovered from the impact of upstream waste loads.

Dissolved Oxygen (Rock River) -- The previously mentioned decline in DO in the Big Sioux River between RM 80.9 and 66.9 was largely attributed to the Rock River, which joins the Big Sioux at RM 76.2. The flow of the Rock River was about 5.7 m^3/s (200 cfs) with an average DO concentration of only 3.0 mg/l. DO concentrations in the Rock River (RM 76.2/5.8) were in violation of the Iowa Water Quality Standards on nine of the ten days sampled. The average DO concentration in the Big Sioux River (approx. 4.8 m^3/s or 170 cfs), 7.6 km (4.7 mi) upstream from the confluence with the Rock River, was 4.8 mg/l. BOD loads were approximately the same (5.9 mg/l in the Rock River vs. 5.7 mg/l in the Big Sioux). Hence, by dilution alone the Rock River was capable of lowering the DO concentration to about 3.8 mg/l, which is 0.5 mg/l greater than the value actually measured at RM 66.9. It should be noted, however, that DO profiles in the Big Sioux exhibited a rapid decline from the Sioux Falls area downstream to the Rock River, thus indicating the stream was approaching a restricted oxygen resource even without the Rock River input.

As previously mentioned, additional sampling was conducted 9 and 10 February 1973, on the Rock River. At the Minnesota-Iowa state line (RM 76.2/40.8) the average DO concentration was 3.8 mg/l, which is in violation of the 4.0 mg/l Iowa criterion but not in violation of the Minnesota 3.0 mg/l criterion. At the background station (RM 76.2/52.5), upstream of the Luverne, Minnesota* (pop., 4,750), municipal WWTP and other significant sources, the average DO concentration was 2.4 mg/l, a violation of Minnesota Water Quality Standards. A minor upstream source of pollution is Edgerton, Minnesota* (pop., 1,119), which is approximately 32 km (20 mi) upstream of the background station. The causes of low DO concentrations upstream of Luverne are unknown and are indicative of the complex stream dynamics existing during ice-cover conditions. The increases in dissolved oxygen downstream from Luverne at RM 76.2/25.7 (average = 6.6 mg/l) could be due, in part, to the re-aeration effect of the small dams at Luverne, Minnesota, and Rock Rapids, Iowa.

The Little Rock (RM 76.2/23.1) which, according to USGS personnel, could have carried as much as 3.5 m^3/s (125 cfs) of the 5.7 m^3/s (200 cfs) measured in the Rock River was in violation of Iowa Water Quality Standards, with an average DO of 2.4 mg/l. The flows contributed by Little Rock tended to sustain the previously mentioned depressed-oxygen levels downstream in the Rock River (RM 76.2/5.8).

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* The Minnesota Pollution Control Agency has ordered Luverne and Edgerton, Minnesota, to either (1) provide storage capacity for 180 days of flow with controlled release during periods of adequate stream flow, or (2) provide facilities capable of producing an effluent of 5 mg/l BOD and suspended solids if a continuous discharge is to be made. Compliance schedules include 15 December 1974 for Luverne and 30 September 1973 for Edgerton.

Ammonia Nitrogen-(Big Sioux River and Selected Tributaries) -- Ammonia, under certain conditions of pH, DO, CO_2, etc., can be very toxic to aquatic life. In order to protect aquatic life from the toxic effects of ammonia, many states, including Iowa, have established an ammonia criterion in their water-quality standards. The Iowa Water Quality Standards specify that NH_3-N concentrations shall not exceed 2.0 mg/l. South Dakota, on the other hand, has not established any ammonia criterion. As determined by the bioassay studies, the 96-hr TL_m for unchlorinated Sioux Falls Wastewater Treatment Plant effluent was 63.5 percent effluent or 35.5 mg/l NH_3-N. On a chronic basis, the value toxic to channel catfish would be approximately three percent effluent (1.8 mg/l NH_3-N), depending on the chemical nature of the receiving waters. At the time of the 1 through 10 February 1973, study the Sioux Falls WWTP effluent constituted approximately 11 percent of the total flow in the Big Sioux River immediately downstream from the plant. This percentage, as previously mentioned, exceeds 50 percent during many winter and late-summer periods.

In spite of above-normal flows during the 1 through 10 February 1973 study, ammonia levels in the Big Sioux River were excessive -- as a result of discharges from the Sioux Falls Wastewater Treatment Plant. Whereas upstream average concentrations [Figure VI-6] varied from 0.88-0.38 mg/l NH_3-N, the average value, downstream from the treatment plant at RM 141.2, jumped to 4.7 mg/l. The plant discharged about 34,070 m^3/day (9 mgd) containing an average concentration of 40 mg/l NH_3-N and 12 mg/l of org-N.

Both NH_3-N and organic-N concentrations increased in the river water between RM 141.2 and 134.5. This sudden change is not supported by changes in other indicator parameters, such as microbiological analyses, BOD, COD, TOC, or solids. A mass balance of upstream inputs of TKN, versus the TKN at RM 134.5, was not able to account for that high a quantity of nitrogen, leaving this anomaly unexplained.

Both Skunk and Split Rock Creeks were monitored for NH_3-N during the survey. Average concentrations in Skunk Creek (RM 152.8/1.1) were 0.94 mg/l and in Split Rock Creek (RM 130.1/5.3), 1.74 mg/l.

From the Iowa-South Dakota state line, at RM 127.0, to the furthest downstream station, at RM 5.0, 100 percent of the 47 samples collected from the Big Sioux River exceeded the Iowa 2.0 mg/l NH_3-N criterion. Average NH_3-N concentrations varied from 4.56 mg/l at RM 106.2 near Canton, South Dakota, to 2.32 mg/l at RM 5.0 near Sioux City, Iowa.

Ammonia Nitrogen-(Rock River) -- The Rock River (RM 76.2/5.8) contained an average NH_3-N concentration of 2.13 mg/l. Concentrations ranged from 1.89 to 2.72 mg/l, in violation of the 2.0 mg/l Iowa criterion on eight of the ten days of sampling. Additional sampling, 9 and 10 February, on the Rock River did not pinpoint any significant sources of ammonia. Average NH_3-N concentrations varied from 1.56 mg/l at the control station upstream of the Luverne, Minnesota, WWTP (RM 76.2/52.5) to 1.66 mg/l at RM 76.2/25.7 [Appendix F, Table F-3]. The Little Rock River (RM 76.2/23.1/4.0) contained 1.47 mg/l NH_3-N. The only potential source of pollution downstream from the Little Rock confluence is Rock Rapids, Iowa (pop., 2,632), at RM 76.2/18 (approx.).

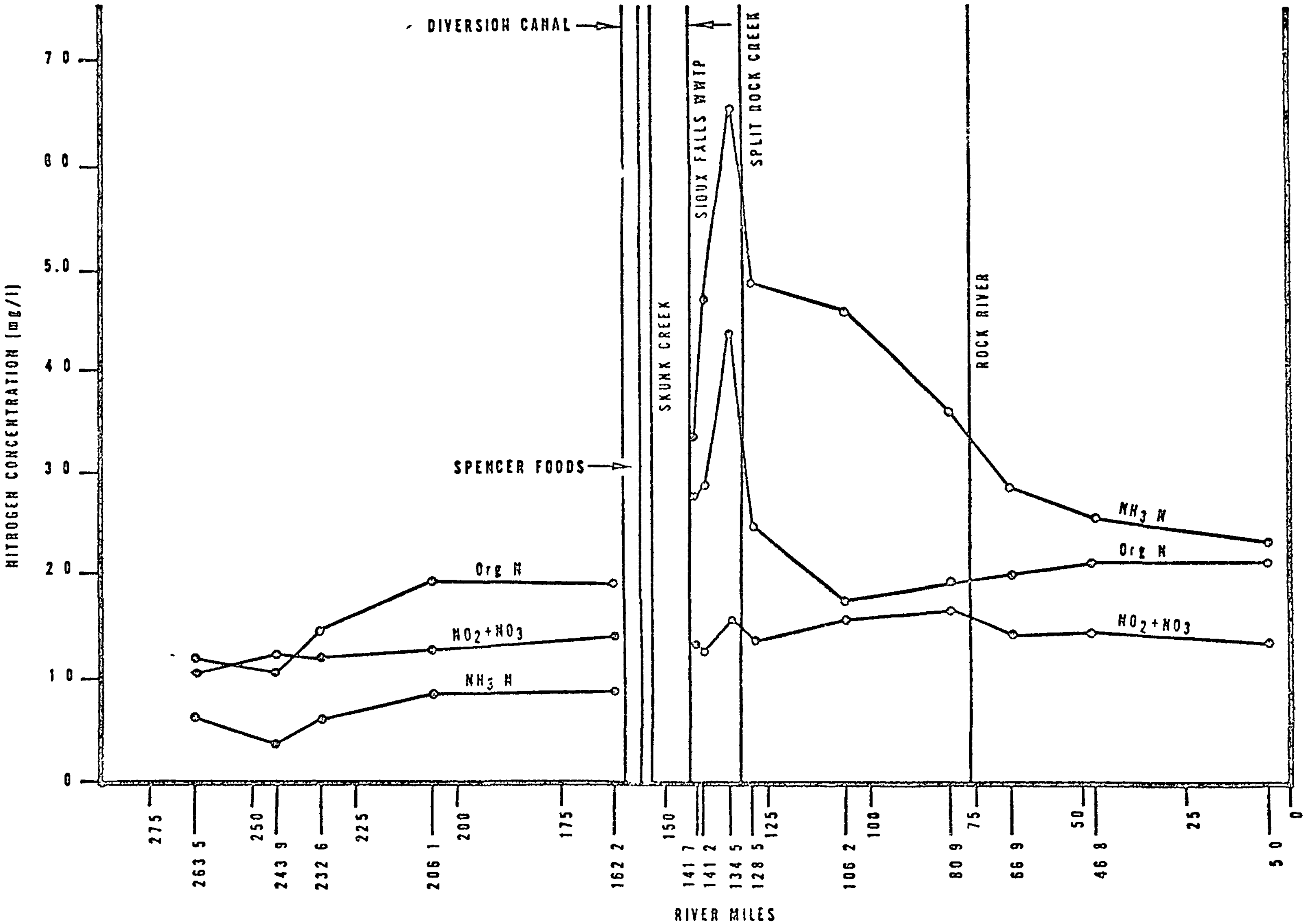

Figure VI-6 Nitrogen Profile, Big Sioux River
Estelline, South Dakota to Sioux City, Iowa
1 10 February 1973

Nitrogenous Oxygen Demand -- Nitrogen, in the reduced forms of NH_3 and organic nitrogen, has a further potential for creating a significant demand upon the oxygen resources of the stream. The mechanism involved includes hydrolysis of the organic form to NH_3, followed by the oxidation to NO_2 and then NO_3 by autotrophic organisms. Oxidation of NH_3 to NO_2 is rate limiting followed by rapid oxidation to NO_3. Thus, the presence of NO_2 in the aquatic environment is generally a fleeting state. The rate of oxidation or nitrification is a temperature-dependent reaction, becoming minimal at low temperatures.

The wastewaters discharged from the Sioux Falls WWTP are especially rich in nitrogen, largely as a result of proteinaceous waste material received from the John Morrell and Company facility. During the stream-survey portion of the study, the Sioux Falls WWTP discharged an average of about 1,810 kg or (4,000 lb), 52 mg/l, of total Kjeldahl nitrogen per day. From a stoichiometric standpoint, approximately 2.0 kg (4.5 lb) of O_2 are required to oxidize 0.4 kg (1 lb) of nitrogen. Hence, these wastewaters had a potential demand of 8,165 kg (18,000 lb) of oxygen. If this demand were exerted upon oxygen resources of the Big Sioux River, especially under adverse conditions of minimal re-aeration (i.e., ice cover), significant dissolved-oxygen depressions would be expected. As discussed previously, severe DO depressions did develop, raising a question of whether nitrification played a role in these depressions.

In order to determine whether nitrification was occurring in the Big Sioux River, an attempt was made to balance the mass of nitrogen in the stream between Sioux Falls, South Dakota, and Akron, Iowa. From

USGS and EPA measurements of discharge, made during the study, average cross-sectional velocities were obtained on the Big Sioux at Cliff Avenue in Sioux Falls (RM 142.7), Split Rock Creek (RM 130.1/3.5), Rock River (RM 76.2/11.8), and Big Sioux River at Akron, Iowa (RM 46.8). Using these velocities and known distances between points, an approximation of time of travel was made between Sioux Falls (RM 141.2) and Split Rock Creek (RM 130.1), Split Rock Creek and Rock River (RM 76.2), and Rock River and Akron, Iowa (RM 46.8), yielding an overall flow time of about six days. From these flow times, data were selected to route units of mass down the Big Sioux River. The parameter selected for the initial mass balance was TKN which under ice-cover conditions should be conserved except for the amount nitrified (sedimentation considered negligible). This approach led to the following balance:

Inputs	Dates	Avg TKN Loading kg	Avg TKN Loading lb
Big Sioux River (RM 141.2)	2/1-4	2,073	4,570
Split Rock Creek (RM 130.1/5.3)	2/2-5	213	468
Rock River (RM 76.2/5.8)	2/5-8	2,000	4,410
		4,286	9,448
Big Sioux River (RM 46.8)	2/7-10	-4,128	-9,100
		158	348

As noted above, approximately 158 kg (348 lb) total Kjeldahl nitrogen, or four percent of the mass, was either oxidized or otherwise "lost" within the system.

In an attempt to refine the previous balance, the quality, as measured at RM 141.2, was replaced with its individual inputs, including the Big Sioux River upstream of Sioux Falls at Renner, South Dakota; Skunk Creek; the effluent from Meilman Food Industries; and the WWTP effluent and by-pass. This approach yielded the following balance:

Inputs	Dates	Avg TKN Loadings kg	Avg TKN Loadings lb
Individual Loadings to Big Sioux River that comprise flow at RM 141.2	2/1-4	2,303	5,078
Split Rock Creek (RM 130.1/5.3)	2/2-5	213	468
Rock River (RM 76.2/5.8)	2/5-8	2,000	4,410
		4,516	9,956
Big Sioux (RM 46.8)	2/7-10	-4,128	-9,100
		388	856

This 388 kg (856 lb) of TKN still constitutes only nine percent of the total Kjeldahl nitrogen into the system.

The converse to considering the "loss" of total Kjeldahl nitrogen in the stream, ostensibly to nitrification, is to investigate the increase in oxidation products, NO_2 and NO_3. Employing the same logic, as previously mentioned, yielded the following balance:

Inputs	Dates	Avg $NO_2 + NO_3$-N Loadings kg	Avg $NO_2 + NO_3$-N Loadings lb
Big Sioux River (RM 141.2)	2/1-4	371	817
Split Rock Creek (RM 130.1/5.3)	2/2-5	52	115
Rock River (RM 76.2/5.8)	2/5-8	649	1,430
		1,072	2,362
Big Sioux (RM 46.8)	2/7-10	-1,423	-3,138
		351	776

gained between Sioux Falls and Akron

Whereas this represents an increase of 33 percent over the inputs to the system, a more detailed analysis, as before, considering individual inputs that make up the Big Sioux River at Sioux Falls does not support this increase.

Inputs	Dates	Avg $NO_2 + NO_3$-N Loadings kg	lb
Individual inputs that comprise flow at RM 141.2	2/1-4	686	1,512
Split Rock Creek (RM 130.1/5.3)	2/2-5	52	115
Rock River (RM 76.2/5.8)	2/5-8	649	1,430
		1,387	3,057
Big Sioux River (RM 46.8)	2/7-10	-1,423	-3,138
		36	81

gained between Sioux Falls and Akron

This represents an increase of only three percent.

This analysis indicates that significant nitrification was not occurring during the 1 through 10 February survey. As has been stated previously, the potential nitrogenous oxygen demand of wastewaters of the Sioux Falls WWTP is approximately 8,165 kg (18,000 lb)/day. Climatic conditions during February precluded the growth of nitrifying organisms. However, under low-flow conditions and warmer temperatures during the summer or early fall the nitrogenous demand could seriously deplete stream-oxygen resources.

VII. WASTE-SOURCES EVALUATION

A. GENERAL

Numerous municipal and industrial waste sources discharge into the Big Sioux River Basin [Appendix E]. Based on a study of the basin and review of existing data, it was determined that three sources were potentially the most significant dischargers, directly or indirectly, to the Big Sioux River.

As previously mentioned, the population of the Sioux Falls, South Dakota, metropolitan area constitutes 45 percent of the population of the entire basin, making it the major municipal waste source. With the exception of two industrial waste sources the majority discharging to the Big Sioux River are of relatively minor importance.

The John Morrell and Company of Sioux Falls, one of the Nation's largest meat packing plants, is the largest industrial waste source in the basin. The Company discharges virtually all its wastewaters into the Sioux Falls sewerage system and contributes greater than 70 percent of the BOD, suspended solids, and nitrogen load received at the municipal wastewater treatment plant.

Meilman Food Industries (formerly Spencer Foods, Inc.), another meat-packing plant in the Sioux Falls area, discharged directly to the Big Sioux River but has recently expanded production and connected into the city sewerage system. This industry will have a major impact on the Sioux Falls Wastewater Treatment Plant. All three of these sources were evaluated during the Winter 1973 study. The following discussion will center on the findings of those evaluations.

B. SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT

During 24 through 31 January 1973, the Sioux Falls, South Dakota, Wastewater Treatment Plant was evaluated in order to:

1. Characterize the wastewaters;
2. Determine unit-process removal efficiencies;
3. Assess the impact of industrial wastes (from John Morrell and Company) on the system;
4. Determine the waste loads discharged to the Big Sioux River;
5. Ascertain pollution abatement necessary to meet water-quality standards and to comply with the Water Pollution Control Act Amendments of 1972.

Treatment Facilities

The Sioux Falls treatment system [Figures VII-1 and VII-2] consists of a two-stage, trickling filter system for industrial-waste pretreatment, followed by a complete-mixed activated sludge system that treats both the pretreated industrial wastes and domestic wastes. The physical plant consists of a potpourri of units, vintage 1920-1960's, that creates considerable maintenance work load for plant personnel.

Industrial Waste Pretreatment System -- The industrial waste pretreatment system receives wastewaters primarily from the John Morrell and Company meat-packing plant. These wastewaters, in addition to those from a small residential area, the stockyards, and various smaller industries are pumped to a flocculator that merely serves to combine raw indistrial wastes, sludge, and lagoon supernatant prior to their entry into the industrial primary clarifiers.

Flows in excess of the maximum influent pumping rate of 22,710 m^3/day (6 mgd) enter an 1,890-m^3 (0.5 x 10^6 gal.) equalization basin that normally

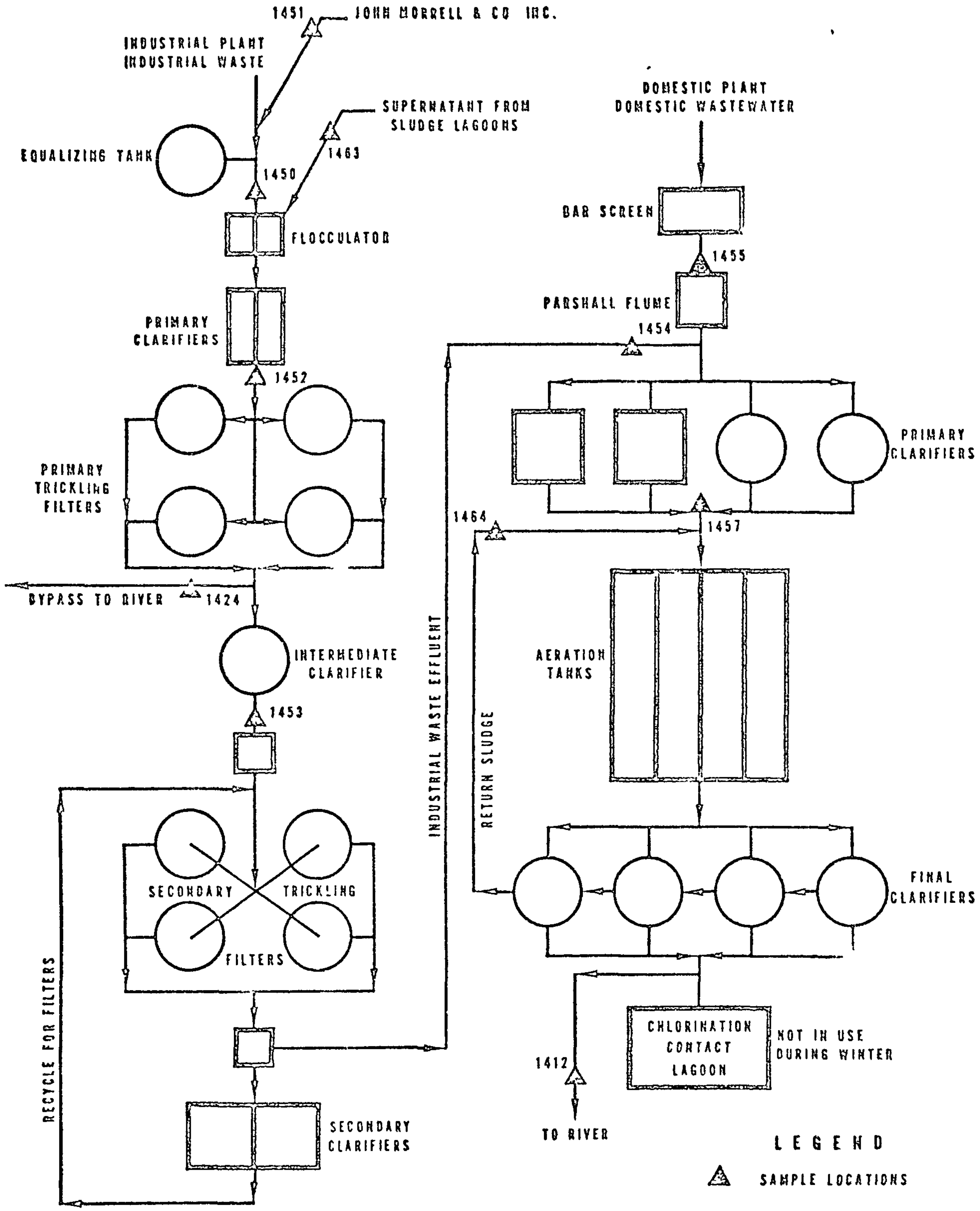

Figure VII-1. Wastewater Treatment Plant, Sioux Falls, South Dakota
24-31 January, 1973

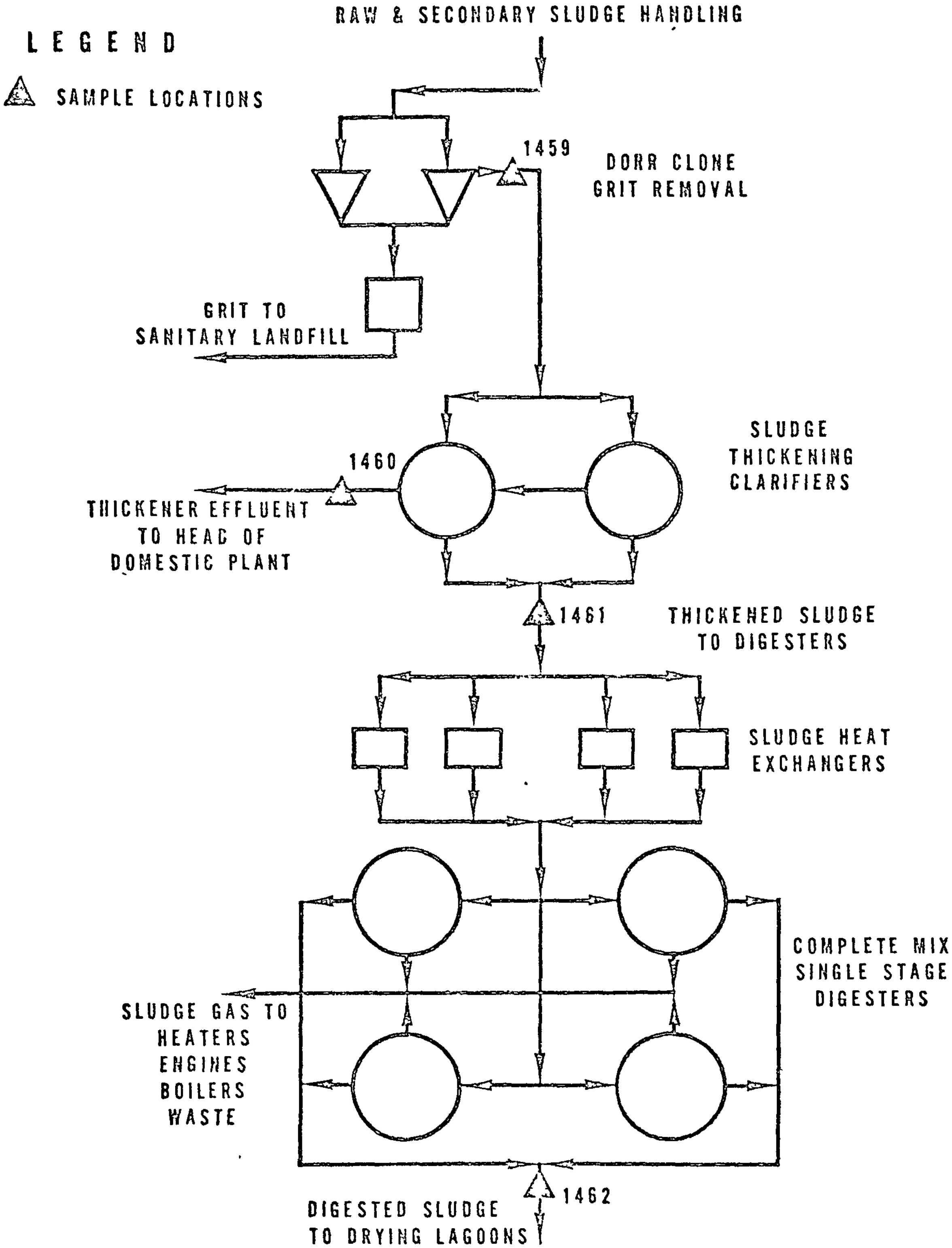

Figure VII-2. Wastewater Treatment Plant Study, Sioux Falls, South Dakota
24-31 January, 1973

is filling during the peak industrial uses (approx. 6:00 AM - 6:00 PM) and then is draining into the flocculator as the industrial flow decreases. When flows to the equalization basin exceed its capacity, the excess flow enters the head end of the combined domestic-industrial system.

After the flocculator, industrial wastes enter primary clarifiers, followed by primary trickling filters, an intermediate clarifier, and secondary trickling filters. Most of the secondary trickling filter under-flow is sent to the head end of the combined domestic-industrial system without settling. However, a portion is sent to the industrial secondary clarifiers, with subsequent recycle to the secondary filters.

Combined Domestic-Industrial System -- Domestic wastewaters entering the plant pass through a screen house, combine with the effluent of the industrial-waste-pretreatment system, and enter the primary clarifiers. After primary clarification, wastewaters go into a complete-mixed activated sludge system, followed by final clarification and discharge to the Big Sioux River. Although the plant chlorinates its final effluent during the spring, summer, and fall months, no disinfection is practiced during winter months.

Sludge System -- Sludge generated in the secondary clarifiers of the industrial-waste-pretreatment system, as well as waste activated sludge, is returned to the primary clarifier of the industrial waste pretreatment system for sedimentation and removal. The sludge thus generated, as well as that collected from the combined domestic-industrial primary clarifiers, is combined and sent to Dorr Clone units, [Figure VII-2] for grit removal.

Following passage through the Dorr Clones, the degritted sludge is gravity thickened, with subsequent return of supernatant to the combined domestic-industrial primary clarifiers. The underflow from the thickeners is sent to single-stage, complete-mix digesters, followed by discharge to sludge lagoons adjacent to the plant. Partially dewatered digested sludge is pumped from the lagoons, hauled away, and spread on farm land that the City of Sioux Falls owns about 6.5 km (4 mi) northeast of the plant. Supernatant from the lagoons is returned intermittently to the flocculator at the head of the industrial pretreatment system.

Results of In-Plant Study

Fifteen sampling stations [Figures VII-1 and VII-2 and Appendix H, Table H-2], including monitoring the waste input of the John Morrell and Company, were established at the treatment plant. Samples were composited on the basis of flow over a 24-hr period. With the exception of grab compositing of the sludge lagoon supernatant, underflow from the sludge thickeners, and effluent from the complete mixed digesters, automatic sampling equipment was used at all points. In order to reflect both processing and non-processing conditions at the Morrell Company, the analytical data were examined on the basis of the full seven days, five weekdays, and two weekend days covered during the study.

[Summaries of data collected during the 24 through 31 January 1973, evaluation of the treatment plant are presented in Appendix F.] Major findings of the evaluation follow.

Wastewater Treatment Plant Flows -- During the seven-day study total flow into the Sioux Falls WWTP averaged 33,380 m^3/day (8.82 mgd). Of this, flows entering the industrial waste pretreatment system averaged 14,800 m^3/day (3.91 mgd), of which 12,110 m^3/day (3.20 mgd) or 36 percent of the total treatment-plant flow emanating from the Morrell Company. Influent domestic waste flows averaged 18,580 m^3/day (4.91 mgd). Weekend and weekday flows differed (as seen in the following tabular material), reflecting reduced domestic-water use as well as cessation of processing by the company over the weekend of the study period.

SIOUX FALLS, SOUTH DAKOTA
WASTEWATER TREATMENT PLANT DAILY AVERAGE FLOWS*

	Industrial			
	Combined	John Morrell & Co.	Domestic	Total
7-Day				
(m^3/day)	14,800	12,110	18,580	33,380
(mgd)	(3.91)	(3.20)	(4.91)	(8.82)
Weekday				
(m^3/day)	17,830	14,650	19,680	37,510
(mgd)	(4.71)	(3.87)	(5.20)	(9.91)
Weekend				
(m^3/day)	7,150	5,830	15,820	22,970
(mgd)	(1.89)	(1.54)	(4.18)	(6.07)

Waste Loadings from John Morrell & Co. -- There is a dominant role [Table VII-1] played by the Company waste loading to the municipal wastewater treatment plant. As noted, during the weekdays Morrell contributed greater than 70 percent of the treatment-plant BOD, COD, TOC, SS, and TKN loadings. Although the wasteloads from Morrell dropped sharply over the weekend [Appendix F, Table F-5, Station 1451], they still constituted a significant percentage [Table VII-1] of the total raw waste load. [In Table VII-2 are illustrated the effects the Morrell operation have on waste loadings received at the WWTP.]

* Daily flows are tabulated in Appendix J.

TABLE VII-1

JOHN MORRELL AND COMPANY CONTRIBUTION TO
LOADS RECEIVED AT SIOUX FALLS WWTP (PERCENT)

	7-DAY PERIOD	WEEKDAY	WEEKEND
BOD	67	70	42
COD	73*	74*	57
TOC	76*	78*	43
SS	78*	81*	63*
TKN	70*	74*	29
Total P	57*	61*	37*

* As a result of the difficulty in obtaining a representative sample of the solid-laden Morrell wastewaters, these analyses indicated a greater loading from Morrell than in the combined loading to the industrial pretreatment system [Appendix F, Table F-5 (Stations 1451 and 1450)]. In these cases the figure for the combined load to the pretreatment system was used in determining the Morrell contribution to the total wastewater treatment plant loading. Hence these percentages are conservative estimates.

TABLE VII-2

AVERAGE RAW WASTE LOADINGS (PER DAY)
SIOUX FALLS WASTEWATER TREATMENT PLANT

	Domestic					
	7 Days		Weekdays		Weekend	
	kg	lb	kg	lb	kg	lb
BOD	9,980	22,000	11,430	25,200	6,350	14,000
COD	14,200	31,100	16,510	36,400	8,030	17,700
TOC	2,840	6,270	3,260	7,180	1,820	4,020
SS	4,230	9,320	4,580	10,100	3,350	7,390
TKN	780	1,720	820	1,810	680	1,500
Total P	270	590	280	620	230	500
	Industrial Pretreatment					
BOD	26,130	57,600	33,300	73,400	8,210	18,100
COD	38,010	83,800	48,080	106,000	12,520	27,600
TOC	9,070	20,000	11,380	25,100	3,250	7,160
SS	15,380	33,900	19,320	42,600	5,580	12,300
TKN	1,860	4,110	2,370	5,220	590	1,310
Total P	360	790	450	990	130	290
	Total					
BOD	36,110	79,600	44,720	98,600	14,560	32,100
COD	52,120	114,900	64,600	142,400	20,550	45,300
TOC	11,910	26,270	14,640	32,280	5,070	11,180
SS	19,600	43,220	23,900	52,700	8,930	19,690
TKN	2,640	5,830	3,190	7,030	1,280	2,810
Total P	620	1,370	730	1,610	350	780

By-passing of Wastewaters -- During the 24 through 31 January 1973, evaluation the treatment plant by-passed inadequately treated industrial wastewaters to the Big Sioux River [Figure VII-1]. Waste loadings discharged via the by-pass were dramatically reduced, however, on 25 January when plant personnel discovered and repaired a partially destroyed by-pass gate in the industrial-waste-pretreatment secondary clarifiers. The by-pass flow rate dropped from 3,030 to 190 m^3/day (0.8 to 0.05 mgd). The decline in waste loading is reflected [Appendix F, Table F-5 (1424)] in average daily weekend (following repair) vs. weekday BOD loadings of 85 and 990 kg (190 and 2,190 lb), respectively.

Negative Removals -- Both the intermediate clarifier of the industrial waste pretreatment system and the primary clarifiers for combined domestic industrial waste system provided negative removals of BOD [Figure VII-3]. In the case of the former, the removal over the seven-day period was a negative two percent. Probably, this was a result of excessive hydraulic conditions that subjected it to an average overflow rate of 36.0 $m^3/day/m^2$ (884 gpd/ft^2) -- (43.4 $m^3/day/m^2$ or 1,065 gpd/ft^2 during weekdays). However, the unit was able to remove 14 percent of the WWTP influent, suspended-solids loading.

Negative removals through the combined domestic-industrial primary clarifier were the result of several causes. During the seven-day period an average of 6,030 kg/day (13,300 lb/day) of BOD contained in the sludge-thickener supernatant (4,500 m^3/day or 1.19 mgd) was returned directly to the clarifier. In addition, during the 24-hr period beginning on 24 January 1973, the clarifier received sludge-lagoon supernatant

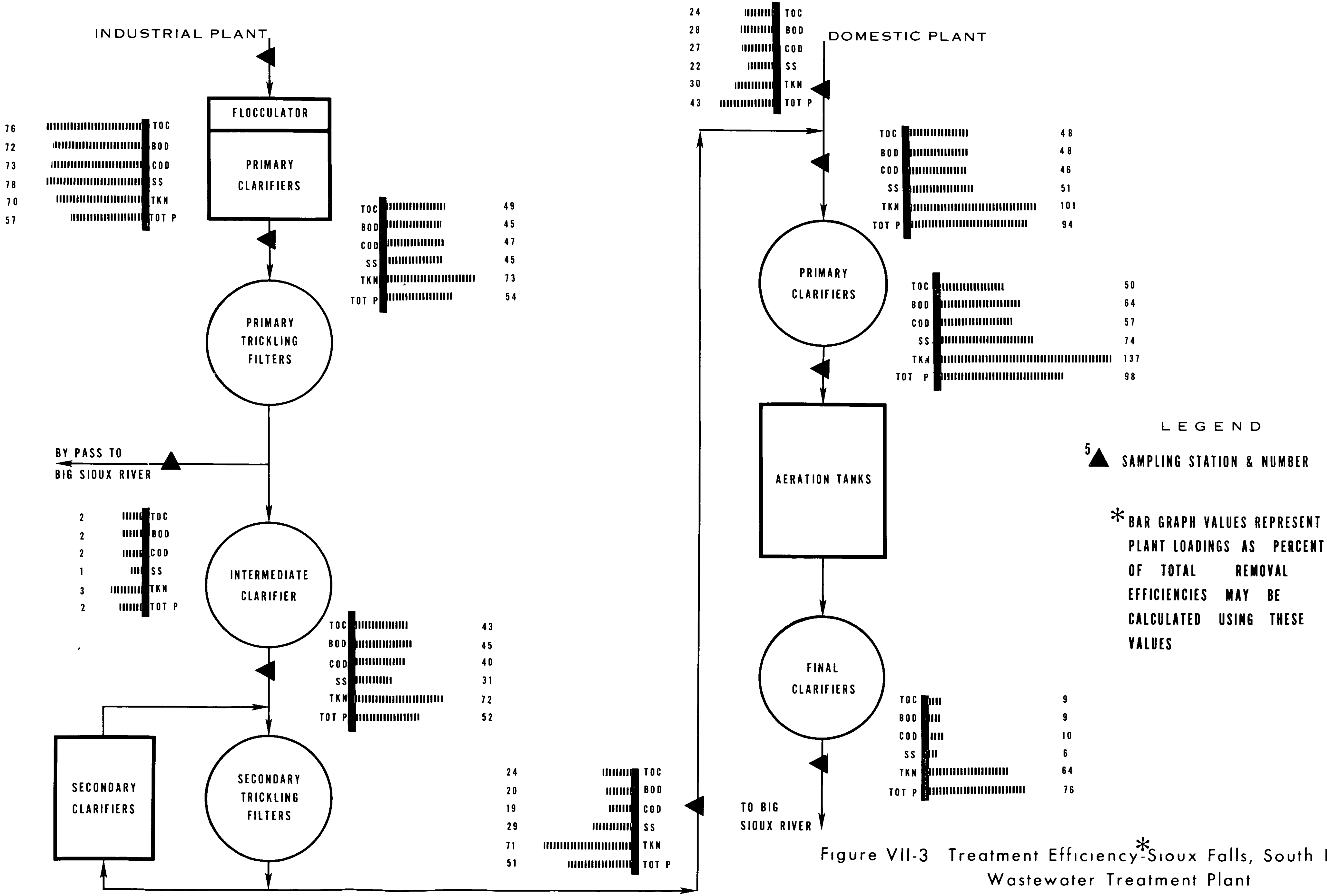

Figure VII-3 Treatment Efficiency*-Sioux Falls, South Dakota Wastewater Treatment Plant
24-31 January 1973
"7 DAY AVERAGE"

containing about 2,000 kg (4,400 lb) of BOD. The normal practice is to return this supernatant to the head of the industrial waste system, but clogged lines required returning it to the primary clarifier. The primary-clarifier overflow BOD measured for the 24-hr period (61,240 kg or 135,000 lb BOD @ 1,700 mg/l) greatly affected the seven-day average loading. If this value were ignored, the average daily loading would be 16,830 kg (37,100 lb) BOD rather than 23,180 kg (51,100 lb), or a plus-0.9-percent removal through the primary clarifiers. Suspended-solids removals through the primary clarifier were also negative [Figure VII-3]. However, if the loading for 24 January 1973, were ignored, the average overflow loading would be 7,200 kg (15,900 lb) rather than 14,380 kg (31,700 lb), yielding an overall 13.9-percent removal.

Domestic Wastes — Domestic wastes (BOD equals 520 mg/l) entering the Sioux Falls WWTP are considerably more concentrated than are normal domestic wastes (i.e., BOD of about 200 mg/l). A number of creameries discharge to the city sewerage system; this could account for these abnormally high concentrations. This hypothesis is supported by influent, suspended-solids concentrations of only 227 mg/l. Dairy wastes include a predominance of soluble BOD that could cause the influent BOD concentrations to exceed suspended solids; this relationship is atypical of normal domestic wastes.

Organic Overloading — Organic loadings to the activated sludge system were excessive; this concurs with the findings of an earlier EPA study.[2/] Even if the value for 24 January 1973, is neglected, daily organic loadings still average 2,676 g BOD/m^3 (167 lb BOD/1,000 ft^3) of aeration tank volume. In the EPA analysis of WWTPs past operating records,[2/] average daily loadings were 1,280 g BOD/m^3 (80 lb BOD/ 1,000 ft^3). These loadings greatly exceed the generally recommended value of about 640 g BOD/m^3 (40 lb BOD/1,000 ft^3). Food-to-micro-organism (F/M) ratios also dramatically reflect this organic overloading. The F/M was 1.1 g BOD/g (1.1 lb/lb) of mixed liquor suspended solids (MLSS) under aeration, which is in marked contrast to recommended values of about 0.4. The organic overload was especially evident in effluent quality where, contrary to theory, the average BOD exceeded suspended solids (99 mg/l versus 37 mg/l).

Treatment Efficiencies -- [Overall WWTP removals as well as the portions removed by the industrial pretreatment system and combined domestic industrial system are presented in Table VII-3. Figures VII-3 to VII-5 enable the same computations, as well as removals between individual units.] In calculating overall removal efficiencies, the amount by-passed must be subtracted from the apparent removal. For example, although the apparent removal of BOD during the seven-day period is 91 percent, 2 percent was by-passed, yielding an overall removal of 89 percent.

Whereas overall removal efficiencies during the study are admirable considering both the effect of winter temperature on biological system and the organic overloads to the activated sludge system, the waste loadings to the Big Sioux River were substantial. During the seven-day evaluation the effluent from the WWTP contributed a daily average load of:

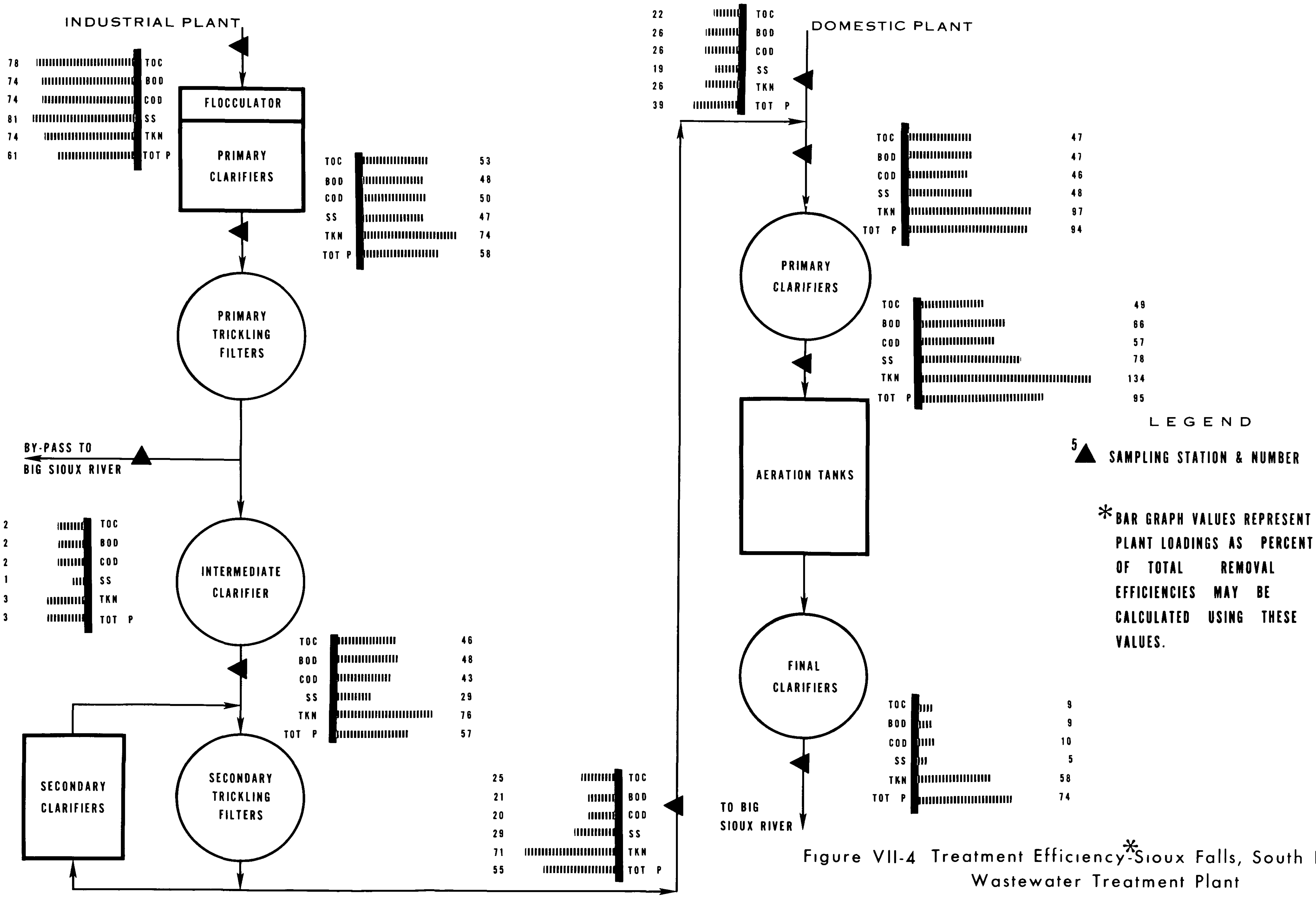

Figure VII-4 Treatment Efficiency*-Sioux Falls, South Dakota
Wastewater Treatment Plant
24-31 January 1973
"WEEKDAY AVERAGE"

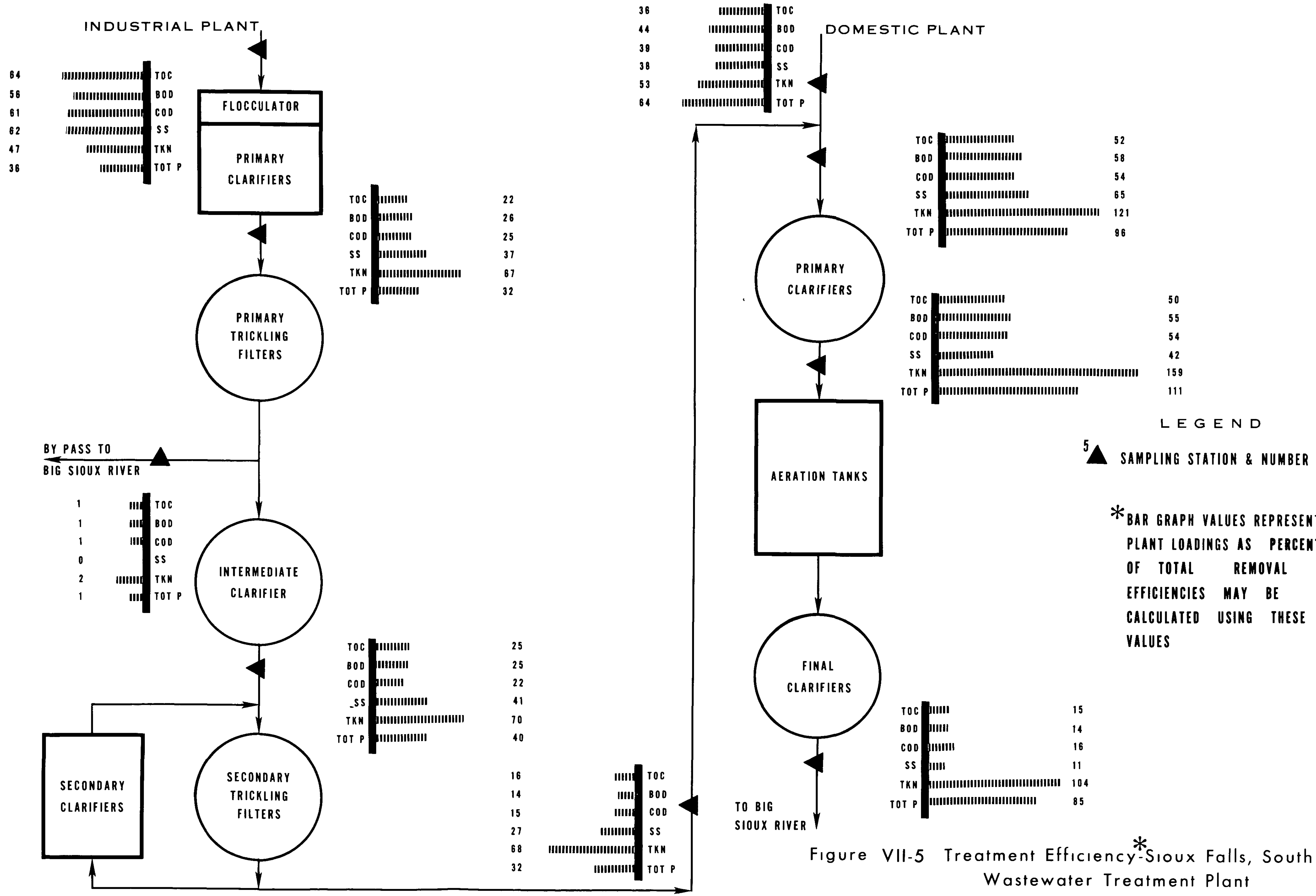

Figure VII-5 Treatment Efficiency*-Sioux Falls, South Dakota Wastewater Treatment Plant
24-31 January 1973
"WEEKEND AVERAGE"

TABLE VII-3

WASTEWATER TREATMENT PLANT REMOVAL EFFICIENCIES (PERCENT)

	7-Day Period			Weekday			Weekend		
	IPS[a/]	CDIS[b/]	Total	IPS	CDIS	Total	IPS	CDIS	Total
BOD	50	39	89	51	38	89	41	44	85
COD	52	36	88	52	36	88	45	38	83
TOC	50	39	89	51	38	89	47	37	84
SS	48	45	93	51	43	94	35	54	89
TKN	-4	37	33	0	39	39	-23	17	-6
Total P	4	18	22	3	20	23	3	11	14

a/ This is an acronym for Industrial Pretreatment System.
b/ This is an acronym for combined Domestic-Industrial System.

EFFLUENT

Parameter	Load kg/day	Load lb/day	Conc. mg/l
BOD	3,370	7,420	99
SS	1,175	2,590	37
TKN	1,690	3,720	51
Total P	470	1,040	14

The WWTP by-pass discharged an additional:

BY-PASS

Parameter	Load kg/day	Load lb/day	Conc. mg/l
BOD	735	1,620	1,010
SS	190	413	429
TKN	67	148	131
Total P	14	31	22

Nitrogen Balance -- Special emphasis was placed on determining the fate of nitrogenous compounds in the treatment plant. Sampling stations were selected to monitor changes of nitrogen forms within the treatment system, the nitrogen taken out in the sludge, and that returned via sludge-thickener supernatant and sludge-lagoon supernatant. A precise assessment of the total nitrogen balance was hampered by difficulties in performing the NO_2 + NO_3-N analysis. An undetermined interference prevented reduction of NO_3 to NO_2 in certain samples. However, in comparison to the values obtained for the total Kjeldahl nitrogen most NO_2 + NO_3-N values throughout the treatment plant were insignificant, affording a reliable balance.

During the seven-day evaluation the industrial pretreatment system received an average daily TKN loading of 1,865 kg (4,110 lb) at 121 mg/l

[Appendix F, Table F-5]. Of this, 76 percent was in the org-N form and 24 percent in the NH_3-N form. The $NO_2 + NO_3$-N concentrations were reported as less than 0.5 mg/l, indicating an insignificant contribution to the total nitrogen load. The John Morrell and Company accounted for virtually 100 percent of the industrial pretreatment loading, or 70 percent of the total WWTP loading of total Kjeldahl nitrogen.

As the wastes passed through the industrial primary clarifiers, the TKN loading remained essentially constant (1,940 kg or 4,280 lb in overflow vs. 1,865 kg or 4,110 lb in influent). Significant, however, was the change in nitrogen forms. The organic-N fraction decreased to 54 percent, reflecting the hydrolysis of the organic-N to NH_3-N and of the input of sludge-lagoon supernatant. The latter contained an average daily loading of 975 kg (2,150 lb) at 1,280 mg/l total Kjeldahl nitrogen of which 71 percent was in the NH_3-N form. The $NO_2 + NO_3$-N in the overflow of the primary clarifier remained insignificant (<0.5 mg/l).

As the wastewaters passed through the primary trickling filter and overflowed the intermediate clarifier, the TKN loading remained essentially constant (1,900 kg or 4,190 lb vs. 1,865 kg or 4,110 lb in raw waste). The organic-N fraction continued to decrease to 47 percent. $NO_2 + NO_3$-N remained insignificant (<0.5 mg/l).

After passing through the secondary filter, the TKN loading remained unchanged from the raw waste load (1,865 kg or 4,110 lb @ 126 mg/l). The organic-N fraction declined further, to 27 percent, a decrease of 49 percent from influent values. The $NO_2 + NO_3$-N concentrations were indicated as less than 10.0 mg/l, but this calculation can be further refined by performing an analysis of concentrations in the combined domestic-industrial, primary clarifier overflow, a value reported as less than 2.0 mg/l. This flow was made up of 18,600 m^3/day (4.91 mgd) of domestic raw waste containing less than 2.0 mg/l; and 14,800 m^3/day (3.91 mgd) of industrial waste. If one back calculated, the industrial effluent concentration of NO_2 + NO_3-N was less than 4.3 mg/l. This value is fortified by unchanged TKN loadings throughout the industrial pretreatment system and indicates only a minor degree of nitrification.

The domestic raw waste (18,600 m^3/day or 4.91 mgd) contained 780 kg (1,720 lb) TKN (@ 42 mg/l) which is within the typical ranges cited in the literature for domestic wastes. Of this 780 kg (1,720 lb), 34 percent was in the form of organic N and 66 percent in the NH_3-N form. Combined with the 1,865 kg (4,110 lb) of TKN in the effluent of the industrial waste pretreatment the loading to the primary clarifier was 2,640 kg (5,830 lb) (29 percent being in the organic-N form and 71 percent in the NH_3-N form).

After passing through the primary clarifier, the TKN loadings increased by 37 percent to 3,630 kg (8,010 lb @ 105 mg/l) as a result of the introduction of the sludge-thickener supernatant and of the 24-January return of sludge-lagoon supernatant previously mentioned. The organic-N fraction in the primary-clarifier overflow increased to 46 percent, and the NH_3-N fraction decreased to 54 percent. If one disregards the TKN data for 24 January 1973 (7,350 kg or 16,200 lb @ 180 mg/l), the TKN loading in the primary clarifier overflow would average 3,010 kg (6,640 lb)/day rather than 3,630 kg (8,010 lb) with

64 percent NH_3-N and 36 percent organic N. The NO_2 + NO_3-N concentrations in primary clarifiers overflow were less than 2.0 mg/l, indicating only a minor amount of nitrification.

The effluent TKN loading was 1,690 kg (3,720 lb @ 51 mg/l) representing a 36-percent removal. Because approximately three percent of this was discharged through the plant by-pass, the actual removal was 33 percent. Virtually all of the removal was accomplished in the activated-sludge portion of the plant. The effluent TKN consisted of 13 percent organic-N form and 87 percent NH_3-N.

The NO_2 + NO_3-N in the effluent was reported as less than 15 mg/l during the plant portion of the study. This can be refined, however, by employing values obtained during the following ten days of stream study. The loads of total Kjeldahl nitrogen discharged during the stream survey were similar to those measured during the plant evaluation. Hence, the NO_2 + NO_3-N values found during the stream survey were considered representative of effluent quality. On this basis the average effluent NO_2 + NO_3-N load would be 295 kg (647 lb @ 8.8 mg/l). From this loading, of the 33-percent TKN "removals," 11 percent was oxidized to NO_2 + NO_3-N forms, and 22 percent was actually removed from the system.

A nitrogen balance [Table VII-4] accounted for all but 5.9 percent of the nitrogen entering the plant. It is especially noteworthy that a daily average of 975 kg (2,150 lb) of nitrogen was reintroduced into the plant in the sludge-lagoon supernatant. Further nitrogen reductions would be realized by not returning this supernatant to the plant. Had this method not been employed during the survey, as much as 1,570 kg (3,465 lb) of nitrogen could have been removed, thus affording a 59-percent

TABLE VII-4

SIOUX FALLS, SOUTH DAKOTA
WASTEWATER TREATMENT PLANT NITROGEN BALANCE

24-31 JANUARY 1973

	kg	(lb)				
Nitrogen Entering Wastewater Treatment Plant:						
Industrial Pretreatment Raw Waste Load	1,865	(4,110)				
Domestic Raw Waste Load	780	(1,720)				
	2,645	(5,830)	2,645	(5,830)		
Nitrogen Leaving Wastewater Treatment Plant:						
Effluent:						
As TKN	1,690	(3,720)				
As $NO_2 + NO_3$-N	290	(647)				
Wastewater Treatment Plant Bypass	70	(148)				
	2,050	(4,515)	-2,050	(-4,515)		
Nitrogen removed in wastewater treatment plant			595	(1,315)	595	(1,315)
Nitrogen Removed as Monitored Within Wastewater Treatment Plant:						
Nitrogen Taken out in Raw and Secondary Sludge			2,125	(4,680)		
Nitrogen returned via Supernatants:						
Sludge Thickener Supernatant	710	(1,560)				
Sludge Lagoon Supernatant	975	(2,150)				
	1,685	(3,710)	-1,685	(-3,710)		
			440	(970)	-440	(-970)
Nitrogen Removed but not Accounted for					155	(345)

reduction in nitrogen rather than a 22-percent reduction. It must be remembered, however, that this potential, 59-percent reduction in nitrogen would not be continuous as supernatant is pumped intermittently from the sludge lagoons.

C. JOHN MORRELL AND COMPANY

As discussed previously, the waste flow from the John Morrell and Company facility to the municipal system was monitored separately [Appendix F, Table F-5 (1451)] in order to determine its relative contributions to the WWTP loadings. (By employing 2,800 persons, this meat-packing plant is one of the mainstays of the Sioux Falls, South Dakota, economy.) Morrell is the major waste source in the Sioux Falls area. The plant operates on an approximate 40-hr kill week, slaughtering and processing hogs, cattle, and sheep at a site just across the river -- to the east, from the Sioux Falls Wastewater Treatment Plant. [During the study period the plant processed the number of animals tabulated in Table VII-5.]

A "typical" day includes kill operations from approximately 6:00 AM-3:00 PM, followed by major cleanups between 3:00 and 6:00 PM and minor cleanups between 6:00 PM and 6:00 AM. Some special processing, such as bacon or sausage slicing, might occur during the evening hours but is not considered a significant water use.

Pretreatment Facilities

Current pretreatment facilities are minimal. Blood is recovered and sold for use, primarily, in animal feeds. Recoverable meat scraps, etc., are collected on the kill floors, and additional large scraps are

TABLE VII-5

ANIMALS PROCESSED BY JOHN MORRELL AND COMPANY
24 JANUARY THROUGH 10 FEBRUARY 1973

	Hogs			Cattle			Sheep		
		Live Wt.			Live Wt.			Live Wt.	
Date	No. Head	kg	lb	No. Head	kg	lb	No. Head	kg	lb
1/24/73	4,843	544,803	1,201,064	857	414,247	913,244	1,964	91,340	201,369
1/25/73	4,860	546,715	1,205,280	880	447,481	986,510	1,960	97,227	214,346
1/26/73	5,560	625,460	1,378,880	782	386,761	852,648	1,760	85,558	188,619
1/27/73	0	0	0	0	0	0	760	38,831	85,606
1/28/73	0	0	0	0	0	0	0	0	0
1/29/73	4,727	561,772	1,238,474	678	352,307	776,690	1,561	78,001	171,960
1/30/73	4,696	558,088	1,230,352	680	328,382	723,946	1,962	96,854	213,524
1/31/73	4,554	541,212	1,193,148	683	337,188	743,360	1,965	96,958	213,753
2/1/73	4,760	559,751	1,234,020	677	307,885	678,758	1,960	103,228	227,576
2/2/73	5,388	640,327	1,411,656	778	435,801	960,760	1,953	92,628	204,206
2/3/73	0	0	0	0	0	0	0	0	0
2/4/73	0	0	0	0	0	0	0	0	0
2/5/73	5,426	622,692	1,372,778	731	309,388	682,072	1,764	85,696	188,924
2/6/73	5,396	619,249	1,365,188	782	428,700	945,105	1,960	95,876	211,366
2/7/73	5,550	636,922	1,404,150	880	452,219	996,956	1,962	98,911	218,057
2/8/73	4,835	554,868	1,223,255	856	469,381	1,034,790	1,959	96,218	212,121
2/9/73	4,618	529,965	1,168,354	876	454,897	1,002,860	1,960	97,325	214,561
2/10/73	0	0	0	0	0	0	0	0	0

collected in floor-drain baskets. Solids passing the floor-drain screens go to a collection basin for solids capture and grease recovery, followed by rotary screening for the capture of additional solids. Paunch manure by-passes the collection basin and combines with the plant wastewaters at the rotary screens. Screenings are hauled away for land disposal. Then, screened wastewaters flow into a pumping station on the east bank of the Big Sioux River and are pumped across the river into the Sioux Falls WWTP industrial pretreatment system.

Until recently, Morrell had a separate "condenser-water" discharge. The quality of this discharge varied widely due to boilovers and miscellaneous sewer connections. In late 1972, the Company connected this discharge (approximately 1,890 m^3/day or 0.5 mgd) into the main plant sewer to the treatment plant.

Proposed Abatement Measures

Morrell is expanding its Sioux Falls operations; they are to include the modification and construction of pollution control facilities. New construction will also include cured-meat and rendering facilities. The cured-meat facility will include grease interception and solids capture [Figure VII-6]. The new rendering facility is designed to eliminate direct application of steam to the raw material, thereby eliminating some of the contamination inherent in the older rendering systems that employ direct steam application. Excess heat leaving the system is designed to be recovered prior to discharge of exhaust gases, thereby eliminating the need for barometric condensers and the inherent pollution.

Proposed pretreatment facilities [Figure VII-6] will include the following.

1. There will be dry removal of paunch manure (currently not practiced in existing facilities).
2. There is to be segregation of storm drains from waste discharge lines.
3. Modification of catch basins is designed to achieve more efficient solids-and-grease capture. The influent to the catch basins will include "strong wastes" from the basic plant and liquid wastes from the rendering plant. Grease recovered by the skimmers will be sent to the rendering system, and solids settled will be hauled to the municipal sanitary landfill. Screens will be added to the system to enhance solids capture.
4. Air-flotation system -- the liquid effluent from the catch basins as well as the effluent from the cured-meats system will be sent to an air-flotation system. The grease recovered from the system will be returned to the rendering plant whereas solids are to be hauled to the municipal sanitary landfill.
5. The effluent from the air-flotation system, as well as "weak wastes" from the basic plant, will be sent to a rotary screening system for further solids capture and disposal. Wastewaters passing the screens will be discharged to the Sioux Falls WWTP.

According to plant personnel, the pretreatment facility that is scheduled to be in operation by 1 January 1974, will reduce present BOD loadings to the municipal wastewater treatment plant by 60 percent,

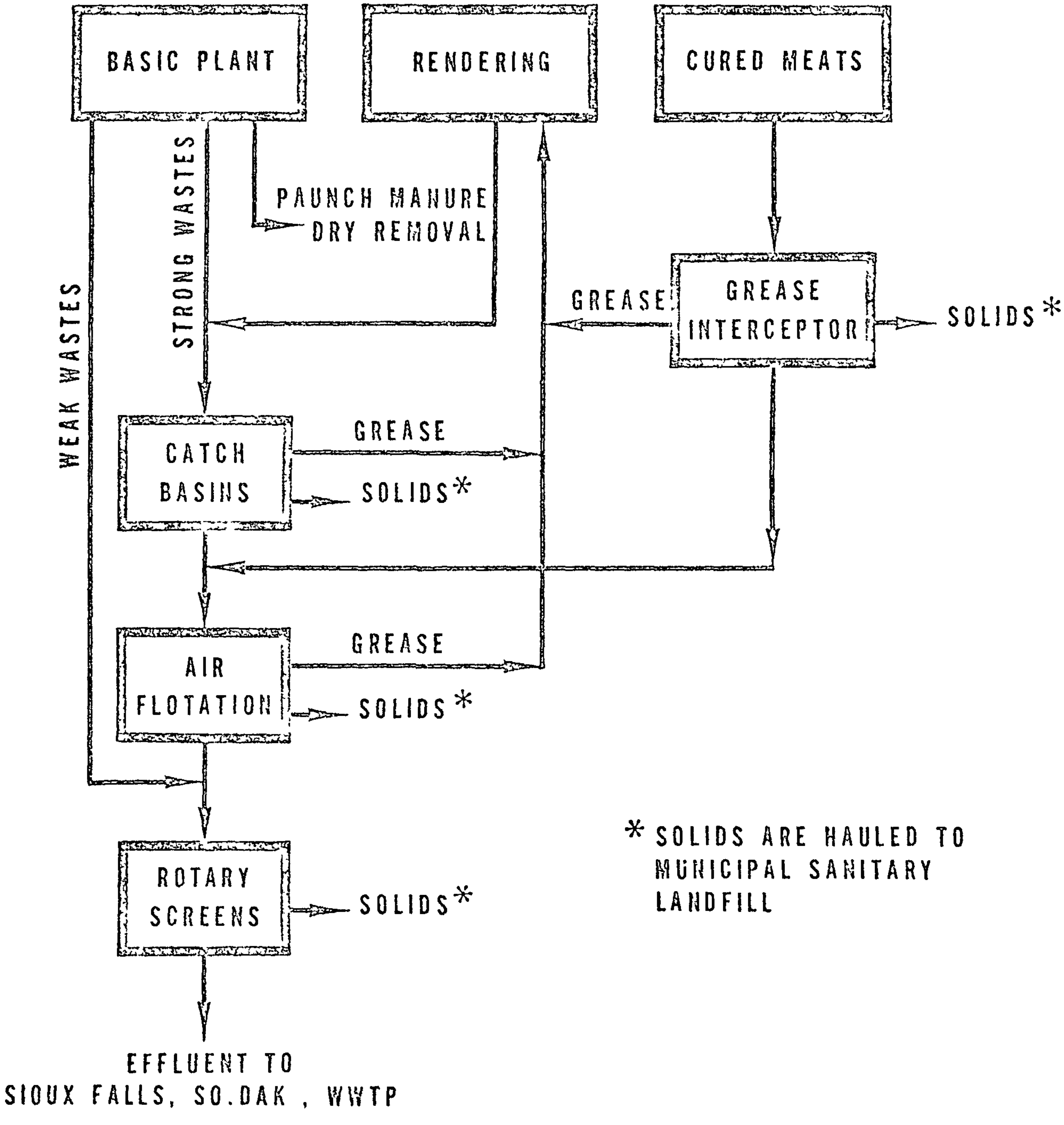

Figure VII-6. Proposed Pretreatment Facilities-Flow Schematic
John Morrell and Company, Sioux Falls Operation

suspended solids by 75 percent, and grease by 80 percent. On the basis of survey data for the processing week, the following loadings would result:

	Present		Anticipated	
	kg/day	(lb/day)	kg/day	(lb/day)
BOD	31,525	(69,500)	12,610	(27,800)
SS	26,950	(59,400)	6,740	(14,850)

Sewer Charges Levied by City

As mentioned previously, during the seven-day survey period the wastes from Morrell represented, on an average, 67 percent of the BOD, 78 percent of the suspended solids, 71 percent of the total Kjeldahl nitrogen, and 57 percent of the total phosphorus loads entering the Sioux Falls WWTP. Morrell, however, pays the City only $16,000 per year; this represents only 4.4 percent of the 1973 operating costs ($359,972) for the Sioux Falls WWTP.

The existing contract that is valid until 1 September 1973, stipulates that hydraulic loadings shall not exceed an average daily flow of 18,920 m^3/day (5 mgd) but makes no waste-loading stipulation other than "The strength of the sewage, as determined by the total Kjeldahl nitrogen shall not exceed an average daily weight of five thousand seven hundred fifty pounds, based on the number of working days in any calendar month, but a maximum weight of seven thousand pounds Kjeldahl nitrogen shall be permitted as a maximum daily load." Although the Morrell wastes were not sampled on enough working days to determine compliance with the average monthly load of 2,610 kg (5,750 lb) total Kjeldahl nitrogen, the average

TKN load during five days of sampling (2,600 kg or 5,730 lb) approached this limit. There was a violation on 26 January when the maximum daily load limit of 3,175 kg (7,000 lb) TKN was exceeded; the plant received 4,110 kg (9,070 lb) of total Kjeldahl nitrogen. The contract further stipulates that "It is agreed that if and when the flow of sewage and industrial waste from the John Morrell Company plant shall exceed in gallons or in strength the maximum provided herein, or shall become of such a character as not to be amenable to treatment by the existing processes, due to any changes in processing made by John Morrell and Company plant at Sioux Falls, then this contract shall be renegotiated".

The inequity of the contract between the City and Morrell can readily be seen by comparing it with that entered into by the City and Greenlee Packing Company, Inc. of Sioux Falls (formerly Spencer Food, Inc., and now Meilman Food Industries). The latter includes sewer charges of $.01/lb of BOD and $.02 per 1,000 gal. During the seven days of monitoring the Morrell waste discharges, the average BOD and flow rate was 24,270 kg (53,500 lb) and 12,110 m^3/day (3.2 mgd), respectively. If Morrell were charged in a similar manner, the annual sewer charge would be $219,000, or an increase of $203,000 over current conditions. With the aforementioned installation of pretreatment facilities by Morrell these charges are estimated at $110,000/year which is still almost seven times the present contract price.

D. MEILMAN FOOD INDUSTRIES (FORMERLY SPENCER FOOD, INC.)

Meilman Food Industries (formerly Spencer Food, Inc.) slaughtered, processed and rendered approximately 700 to 800 head of beef per day at its plant in western Sioux Falls, South Dakota. Wastewaters generated in the process were discharged to a three-cell aerated lagoon, with subsequent discharge to the Big Sioux River (RM 154.2). During January 1973, the industry completed its connection to the city sewerage system. It was originally planned to sample the Spencer raw-waste load in order to predict the effects on the Sioux Falls WWTP. On 26 January 1973, the plant closed to facilitate process changes required by new owners, Meilman Food Industries; hence, the plant generated no raw waste loads during the 1-through-10-February-1973 study. However, contents of the lagoon system were continuously discharged, from 31 January through 9 February, to the Big Sioux River (RM 154.2) and were monitored.

Average flows during the nine days of sampling were 1,400 m^3/day (0.37 mgd). Efforts to measure daily BOD loadings proved fruitless as a result of an unknown toxicant. The daily COD and suspended solids loads averaged 560 kg (1,240 lb @ 420 mg/l) and 118 kg (261 lb @ 90 mg/l), respectively. The effluent also contained an average TKN loading of 128 kg (283 lb @ 94 mg/l), and a total P loading of 15 kg (34 lb @ 11.6 mg/l). As discussed in a previous section, bacterial indicator densities were excessive (FC=56,000/100 ml and FS=3,300,500/100 ml). Pathogens, including *Salmonella siegburg*, *S. tennessee*, and *S. binza*, were also isolated.

Since the completion of the study, Meilman Foods negotiated an agreement with the City of Sioux Falls, South Dakota, to discharge the remainder of the lagoon contents to the sewerage system. Having completed this, they are now filling in the former lagoons with earthen material. During the week of 26 March 1973, kill operations resumed on a limited scale, with wastewaters discharged to the Sioux Falls WWTP. Current plans call for a full-scale operation to include kills of approximately 1,000 to 1,200 head of beef per day, of which approximately 25 percent will be a kosher operation.

Current pretreatment facilities are minimal. Process wastes containing any fatty materials are sent to a settling tank from which the skimmed and settled material is then forwarded to the rendering system. Wastewaters leaving the tank combine with other plant wastes and are discharged to the municipal sewerage system. Paunch manure is wet-removed and screened for subsequent land disposal.

Projected loadings for the full-scale operation are unavailable. However, use of standard raw-waste loads indicate the Meilman Food Industries waste loading to the combined, domestic-industrial system will offset the current abatement program of the John Morrell and Company. As previously discussed, weekday average BOD loadings from Morrell are expected to decrease from 31,525 to 12,610 kg (69,500 to 27,800 lb or a 60-percent reduction). If the two-stage, trickling-filter system provides the same levels of removals (69 percent), and the remainder of the BOD loadings to the industrial-waste pretreatment system remains constant at 1,770 kg (3,900 lb), loadings in the pretreatment system effluent will be 4,410 kg (9,730 lb) rather than 9,210 kg (20,300 lb). Adding the current domestic raw waste load of 11,430 kg (25,200 lb) yields a loading to the combined, domestic-industrial system of about 15,830 kg (34,900 lb) rather than the 20,640 kg (45,500 lb) measured during the survey. If one considers a standard raw-waste load of 6.0 kg BOD/500 kg live weight killed* (12.1 lb BOD/1,000 lb LWK) and an average live weight of about 500 kg (1,000 lb)/head of beef, Meilman Food Industries will have a loading that is to be approximately 5,490 kg (12,100 lb) BOD. Wastewaters from Meilman Industries discharge to the City of Sioux Falls domestic sewerage system; hence, the meat-packing plant wastes enter the combined, domestic industrial system rather than the industrial-waste pretreatment system.

With the addition of this projected loading from Meilman the combined domestic-industrial-system waste loading will be 21,320 kg (47,000 lb). Consequently, even though the John Morrell and Company could decrease their BOD load to the industrial-waste pretreatment system by 18,910 kg (41,700 lb), loadings to the combined domestic industrial system, as a result of Meilman will increase by 680 kg (1,500 lb). If the activated-sludge system provides comparable removals to those found during the recent study (81 percent reduction), effluent loadings will be 4,050 kg (8,930 lb) rather than 3,910 kg (8,620 lb), an increase of 140 kg (310 lb). Even if higher degrees of removal as reported in a previous EPA report[2] were accomplished in both the trickling filter (87 percent) and activated sludge (92 percent) systems, the addition of Meilman Food Industries to the domestic system will largely offset planned reductions by the John Morrell and Company.

* This was an industrial waste study performed for the Environmental Protection Agency by the North Star Research and Development Institute.

VIII. POLLUTION ABATEMENT NEEDS

Studies during the fall of 1972 and winter of 1973 have demonstrates the Big Sioux River to be a sensitive ecosystem. Documented, undesirable effects included a severely restricted oxygen resource, potentially toxic conditions, and impaired bacterial quality.

A. RESTRICTED OXYGEN RESOURCE

The winter-1973 study disclosed that dissolved-oxygen levels were severely depressed downstream from the Sioux Falls, South Dakota, area in spite of abnormally high flows. The major cause of depressed-oxygen level was the oxygen demand of a large waste load (Sioux Falls, South Dakota, WWTP) vs. a receiving stream of minimal assimilative capacity. Because the elements governing the assimilative capacity, including minimal re-aeration during periods of ice cover and recurrent low-flow conditions, are fixed, the only effective controls are at the waste source itself. The WWTP effluent, often constituting greater than 50 percent of the downstream flows, must be viewed as an integral part of the stream and consequently must approach the upstream water quality. In the case of the Big Sioux River, this quality was defined by a BOD and suspended solids level of less than 10 and 15 mg/l, respectively. Unless the Sioux Falls Wastewater Treatment Plant is capable of continuously producing a comparable quality effluent, the Big Sioux River will continue to be a severely restricted resource during at least some of the low-flow-winter and late-summer portions of the year. The Sioux Falls Wastewater Treatment Plant personnel are extremely competent. However, the evaluation of the plant demonstrated that present activated sludge facilities are organically overloaded, thereby precluding, on a continuous basis, an effluent of the quality previously mentioned.

B. POTENTIALLY TOXIC CONDITIONS

The Winter-1973 study established a chronic-toxicity level of three-percent effluent, or 1.8 mg/l NH_3-N. Despite abnormally high flows, NH_3-N concentrations downstream of the Sioux Falls area were found to be in excess of this level. These conditions resulted from the discharge of nitrogenous materials from the municipal treatment plant. During the 17 days of monitoring, the Sioux Falls WWTP discharged an average of 1,760 kg (3,880 lb @ 52 mg/l) of total Kjeldahl nitrogen. As the plant effluent can constitute upwards of 100 percent of downstream flows, the treatment plant must produce an effluent with a TKN of less than or equal to 2.0 mg/l in order to preclude potentially toxic conditions. This will require a highly nitrified effluent that will also remove the potential of a nitrogenous oxygen demand (stochiometrically about 8,150 kg/day or 18,000 lb/day) upon the Big Sioux River. This latter accomplishment could prove to be paramount in the low-flow-summer and early fall months when stream temperatures are conducive to the growth of nitrifying organisms.

Nitrification is recommended; complete nitrogen removal is not. The removal of oxygen-demanding carbonaceous and nitrogenous materials from the Sioux Falls WWTP effluent, should offset diurnal oxygen sags related to the algal community.

Three sources of nitrogen are especially amenable to exclusion or treatment. The first is wastewaters from the John Morrell and Company that contributed about 74 percent of the load of total Kjeldahl nitrogen received by the Sioux Falls plant during the work week. Steps should be taken immediately by Morrell to ascertain what degree of removal will be accomplished in their abatement program. This will enable an assessment of need for further pretreatment-versus-treatment by the City. The second controllable source is the sludge-lagoon supernatant that is returned to the head of the industrial pretreatment system. During the 24 through 31 January 1973, evaluation this accounted for an average of 975 kg (2,150 lb @ 1,280 mg/l) TKN being reintroduced into the plant; this represents 56 percent of the TKN discharged from the municipal wastewater treatment plant (1,750 kg or 3,868 lb). The TKN load in the sludge-lagoon supernatant should be removed, using, for example, land application of supernatant or separate treatment at the plant.

Meilman Food Industries while not a part of the Sioux Falls, South Dakota, sewerage system during the survey, is also expected to contribute a substantial nitrogen load to the plant. The City must ascertain the magnitude of the load and require either pretreatment by the industry or adequate remuneration to pay for treatment costs at the plant.

C. IMPAIRED BACTERIAL QUALITY

Studies performed during the winter of 1973 demonstrated that the Sioux Falls WWTP was causing impaired bacterial quality downstream from the Sioux Falls area. This resulted from the decision by the City to eliminate disinfection during winter months. It is recommended that the plant provide continuous disinfection of wastewaters with no monthly average (logarithmic mean) fecal-coliform bacterial density exceeding 200/100 ml and no weekly average exceeding 400/100 ml.

The Federal Water Pollution Control Act Amendments of 1972 require by 1 July 1977, publicly owned treatment works meet effluent limitations based upon secondary treatment, as defined by the Administrator. It is recognized that aforementioned effluent-quality recommendations for the City of Sioux Falls, South Dakota (i.e., BOD $\leq$ 10 mg/l, SS $\leq$ 15 mg/l, and TKN $\leq$ 2 mg/l) are more stringent than this. However, the Act also provides that in instances such as the Big Sioux River, where compliance with prescribed effluent limitations will not assure compliance with water quality standards, EPA shall impose more stringent effluent limitations.

In summary, in order to improve and protect the water quality of the Big Sioux River, it will be necessary for the City of Sioux Falls, South Dakota, to take the following steps:

1. Establish enforceable pretreatment standards for those pollutants that are not susceptible to treatment by the municipal system or which pass through, or otherwise interfere with its operation. The ordinance establishing the pretreatment standards must include adequate sewer charges for all industrial waste sources to assure equitable recovery of treatment costs.

2. Continue to pretreat industrial waste in the existing two-stage, trickling-filter system.
3. Treat sludge lagoon supernatant separately or use land application.
4. Oxidize carbonaceous materials in the activated-sludge system. This will necessitate the expansion or replacement of existing aeration facilities to eliminate organic overloads.
5. Nitrify wastewaters to a TKN of $\leq$ 2 mg/l. This could possibly be combined with the system included for oxidation of carbonaceous materials but probably will require a separate system to assure a nitrifying environment.
6. Provide tertiary filtration of wastewaters to assure a continuous high quality effluent with a BOD $\leq$ 10 mg/l and SS $\leq$ 15 mg/l.
7. Provide continuous disinfection of wastewaters with no monthly average (logarithmic mean) fecal coliform density exceeding 200/100 ml and no weekly average exceeding 400/100 ml.

REFERENCES

1/ *Water Pollution Report for the Iowa Reach of the Big Sioux River*, Iowa Water Pollution Control Commission. Limnology Division of the State Hygienic Laboratory. Des Moines, Iowa. 30 March 1972.

2/ *Investigation of the City of Sioux Falls, South Dakota Municipal Wastewater Treatment Facility, July 13 and 14, 1972.* Environmental Protection Agency, National Field Investigations Center-Cincinnati. Cincinnati, Ohio. October 1972.

3/ *Water Quality Control Study-Big Sioux River Basin, Iowa, Minnesota, and South Dakota*, U. S. Department of the Interior, Missouri Basin Region, Federal Water Pollution Control Administration. Kansas City, Missouri. September 1969.

4/ Kerwin Luther Rakness, *Analysis of the Flow Variation of the Big Sioux River* - A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science Major in Civil Engineering. South Dakota State University, Brookings, South Dakota. (1970)

APPENDIX A

WATER QUALITY STANDARDS

for the

SURFACE WATERS OF SOUTH DAKOTA

(Portion applicable to Big Sioux River Basin)

CATEGORY NUMBER 1 - DOMESTIC WATER SUPPLY

Definition: Waters in this category shall be suitable for use for human consumption, culinary or food processing purposes and other household purposes after suitable treatment by conventional processes.

General: Waters in this category shall be such that with treatment consisting of coagulation, sedimentation, filtration and disinfection, or its equivalent, the treated water will meet in all respects the mandatory requirements of the "Drinking Water Standards-1962" prepared by the Public Health Service of the United States Department of Health, Education and Welfare.

Criteria presented herein pertain to the untreated water.

Criteria:

Parameter	Limit	Frequency Code
Total dissolved solids	1000 mg/1	c
Coliform Organisms	Not to exceed a MPN or MF of 5000/100 ml as a monthly average value; nor to exceed this value in more than 20% of the samples examined during any one month; nor to exceed 20,000/100 ml in more than 5% of the samples examined in any one month.	
Nitrates	10 mg/1 (as N) or 45 mg/1 (as NO_3)	a
pH	Greater than 6.0 and less than 9.0	a

CATEGORY NUMBER 2 - FISH LIFE PROPAGATION

Description: All waters in this category shall be such that they will provide a satisfactory environment for the class of fish described and for all other aquatic life essential to the maintenance and propagation of fish life. There shall be separate quality criteria for each of the following five sub-categories:

a. Cold water permanent — All lakes, streams and reservoirs in this category shall be capable of supporting a good permanent trout fishery from natural reproductions or fingerling stockings.

b. Cold water marginal	All lakes, streams and reservoirs in this category shall be suitable for supporting stockings of catchable size trout during portions of the year but due to low flows, siltation and warm temperatures will not support a permanent cold water fish population.
c. Warm water permanent	Lakes, streams and reservoirs in this category shall be suitable for permanent maintenance of warm water fish including walleyes, black bass or blue gills.
d. Warm water semi-permanent	Lakes, streams and reservoirs in this category shall be suitable for a quality warm water fishery but may suffer occasional fish kills because of critical natural conditions. Principal species managed in these waters will include walleyes, perch, northern pike or channel catfish.
e. Warm water marginal	Lakes, streams and reservoirs in this category shall be suitable for supporting more tolerant species of fish with frequent stocking and intensive management. Principal species managed in these lakes include perch, northern pike or bullheads.

Criteria:

Criteria for each of the described sub-categories are presented in tabular form on the following page.

Criteria: (Fish Life Propagation-continued)

Parameter	a	b	c	d	e	Frequency Code
Chlorides	100					c
Cyanides	0.02	0.02	0.02	0.02	0.05	a
Dissolved Oxygen (greater than)	6.0	5.0	5.0	5.0	2.0	a
Hydrogen Sulfide	0.3	0.5	0.5	1.0	1.0	a
Iron (total)	0.2	0.2	0.2	0.2		b
pH*	6.6-8.6	6.5-8.8	6.5-8.8	6.3-9.0	6.0-9.3	a
Suspended Solids	30	90	90	90	150	c
Temperature (degrees F)	68	75	80	90	93	a
Turbidity**	25	50	50	100		c

Note: All values in mg/1 unless indicated otherwise. The frequency code shown applies to all sub-categories.
* in pH units.
**Jackson Candle units

Pesticides, herbicides and related compounds shall be treated as toxic materials and taste and odor producing chemicals and controlled under the provisions of Chapter II, Section II, subsection 2 and 4.

Temperatures shall not be affected by more than 4°F. in sub-categories a, b and c, 5°F. in sub-category d, and 8°F. in subcategory e.

CATEGORY NUMBER 3 - RECREATION

Definitions: Water in this category shall be suitable for swimming, water skiing, skin diving, fishing, boating, sailing, picnicking and other water related types of recreation. There shall be separate quality criteria for each of the following two sub-categories:

a. Immersion Sports which would include swimming, water skiing, skin diving and other water sports.

b. Limitied Contact Recreation which would include fishing, boating, sailing, picnicking and other water related recreation.

General: The criteria for recreation will normally apply only during the summer recreation season. However, if the receiving waters are used extensively for winter recreation, the criteria for limited contact recreation shall apply during the winter months.

Criteria:

Parameter	Limit	Frequency Code
a. Immersion Sports		
"Fecal Coliform Organisms	Not to exceed a concentration of 200/100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 500/100 ml on any one day during the recreation season."	
Dissolved Oxygen	Greater than 2 mg/1	a
b. Limited Contact Recreation		
"Fecal Coliform Organisms	Not to exceed a concentration of 1,000/100 ml as a monthly average; nor to exceed this value in more than 20% of the sample examined in any one month; nor to exceed 2,000/100 ml on any one day during the recreation season."	
Dissolved Oxygen	Greater than 2 mg/1	a

CATEGORY NUMBER 4 - WILDLIFE PROPAGATION AND STOCK WATERING

Definition: Waters in this category shall be satisfactory as habitat for aquatic and semi-aquatic wild animals and fowl and shall be suitable for watering domestic and wild animals and fowl.

General: No pollution shall be permitted to enter waters in this category which will produce inhibited growth, physical impairment or injurious effects on wild or domestic animals and fowl normally inhabiting or using the water.

Criteria:

Parameter	Limit	Frequency Code
Alkalinity (Total) (as $CaCO_3$)	750 mg/l	c
Total dissolved solids	2,500 mg/l	c
Electrical conductivity	4,000 micromhos/cm @ 25°C.	c
Nitrates (as NO_3)	50 mg/l	b
pH	Greater than 6.0 and less than 9.5	a

CATEGORY NUMBER 5 - IRRIGATION

Definition: Waters in this category shall be suitable for irrigating farm and ranch lands, gardens and recreation areas.

General: Since the suitability of a water for irrigation is primarily dependent on characteristics of the irrigated soil, only ranges for upper limits of pollutional parameters affecting irrigation have been specified. The required water quality will be established by the Committee on an individual basis after giving due consideration to appropriate soil test results and other pertinent information.

Criteria for coliform organisms apply only to waters used to irrigate root crops and recreation areas.

Irrigation criteria apply during the irrigation season only. In the enforcement of these criteria, the Committee will specify which parameters shall be used between total dissolved solids and electrical conductivity and between sodium absorption ratio and soluble sodium percentage, it being understood that the criteria for total dissolved solids and electrical conductivity apply to the same pollution characteristic as do the criteria for sodium adsorption ratio and soluble sodium percentage.

IRRIGATION (continued)

Criteria:

Parameter	Limit	Frequency Code
"Fecal Coliform Organisms	The concentration shall not exceed 1,000/100 ml as a monthly average; nor shall the number exceed 2,000/100 ml in any one sample. (Root crops and recreation)."	
Total dissolved solids	700 to 1500 mg/l	d
Electrical conductivity	1000 to 2500 micromhos/cm @ 25°C	d
Sodium adsorption ratio*	10 to 26	d
Soluble sodium percentage**	30 to 70%	d

Note: When two values are given, they are ranges in the premissable limit.

* Calculated from: $SAR = \frac{Na}{[1/2(Ca + Mg)]^{1/2}}$ where Na, Ca, and Mg are concentrations of sodium, calcium and magnesium in milliequivalents per liter of water

**Calculated from: $Na\% = \frac{100\ Na}{Na + Ca + Mg + K}$ where Na, Ca, Mg and K are concentrations of sodium, calcium, magnesium and potassium in mg/liter.

CATEGORY NUMBER 7 - INTERMITTENT STREAM

Definition: Most watercourses with zero flow; flows less than the daily average waste flow; or with flows less than the daily average irrigation return flow shall be placed in this category.

General: All wastes discharged to streams, lakes or reservoirs in this category shall have been subjected to at least secondary treatment or its equivalent and, if prescribed by the Committee, approved tertiary treatment shall be provided. Industrial or other waste waters not amenable to biological treatment shall be physically or chemically treated as directed by the Committee after giving due consideration to downstream land and water uses. The criteria for coliform organisms may be waived at the

INTERMITTENT STREAM (continued)

discretion of the Committee if downstream land and water uses do not warrant such control. The provisions of these criteria will apply to irrigation return flows and other similar waters discharged to surface lakes, streams or reservoirs.

Criteria:

Parameter	Limit	Frequency Code
Coliform organisms	Not to exceed a MPN or MF of 20,000/100 ml as a monthly average value; nor to exceed this value in more than 20% of the samples tested in any one month; nor to exceed 50,000/100 ml in any of the samples tested.	
Biochemical oxygen demand (5 day 20°C)	30 mg/l	b
pH	Greater than 6.0 and less than 9.5	a
Suspended solids	30 mg/l	b

Note: The provisions of Chapter II, Section II, subsection 1, 2, 3, and 4 shall also apply to this category.

Section V - Designation of Beneficial Uses of Surface Waters

Beneficial uses of the surface waters of South Dakota are designated herein for the purpose of specifying quality objectives of all lakes, streams and reservoirs. The designation does not limit beneficial uses nor prohibit beneficial uses other than those listed.

Categories of use are indicated by number and letter as follows:

1. Domestic water supply

2. Fish life propagation

   2a Cold water permanent
   2b Cold water marginal
   2c Warm water permanent
   2d Warm water semi-permanent
   2e Warm water marginal

Section V - (continued)

3. Recreation

   3a Immersion sports
   3b Limited contact recreation

4. Wildlife propagation and stock watering

5. Irrigation

6. Commerce and industry

7. Intermittent stream (this category is not indicated since it application is automatic depending upon stream flow.)

Names and locations of lakes, reservoirs and marshes are as shown on maps and lake inventory records maintained by the South Dakota Department of Game, Fish and Parks. Stream names and locations are as shown on the drainage map of the State of South Dakota, edition of 1963, as compiled by the United States Geological Survey in 1961.

STREAMS

BASIN	TRIBUTARY	LOCATION	USE
BIG SIOUX	*Main stem	Missouri River to Klondike Dam	2d,3a,3b,4,5
		Klondike Dam to Lower End of Sioux Falls Diversion Ditch	2d,2e,3b,4,5
		Lower End of Sioux Falls Diversion Ditch to headwaters	1,2d,2e,3b,4,5
	Owens Creek	Day and Roberts Counties	2c,3b,4,5
	All other tributaries		4,5

* Interstate Waters

Big Sioux River has been classified as "2d" except under the following conditions:

Then flows in the Big Sioux River at Brandon equal or exceed the flows given below, the respective criterion of 4.0 mg/1 or 5.0 mg/1 dissolved oxygen applies from Klondike Dam to the lower end of Sioux Falls Diversion Ditch:

SEASON	4.0 mg/1 D.O. 1970 (flow - cfs)	5.0 mg/1 1970 (flow - cfs)
Summer (June 15 - Sept. 15)	90	160
Fall (sept. 15 - Dec. 15)	35	45
Winter (Dec. 15 - Mar. 15)	60	70
Spring (Mar. 15 - June 15)	35	45

When flows at Brandon are less than those indicated for 4 mg/1 D.O., the "Intermittent Stream" category (7) applies.

THIS SECTION ADDED BY AMENDMENT 12-11-70

APPENDIX B

IOWA WATER QUALITY STANDARDS

(Portion applicable to Big Sioux River Basin)

IOWA WATER POLLUTION CONTROL COMMISSION
RULES AND REGULATIONS
WATER QUALITY STANDARDS

Pursuant to the authority of sections 455B.9 and 455B.13, Code of Iowa, 1971, as amended by S.F. 402, Acts of the 64th G.A., rules appearing in July 1967 Supplement, Iowa Departmental Rules, pages 38-39, are rescinded and the following adopted in lieu thereof.

Section 1.2 (455B) Surface water quality criteria

1.2(1) General policy considerations. Surface waters are to be evaluated according to their ability to support the legitimate (beneficial) uses to which they can feasibly be adapted, and this specific designation of quality areas shall be done by the Iowa Water Pollution Control Commission.

Sampling to determine conformance to these criteria shall be done at sufficient distances downstream from waste discharge points to permit adequate mixing of waste effluents with the surface waters.

1.2(2) General Criteria. The following criteria are applicable to all surface waters at all places and at all times:

a. Free from substances attributable to municipal, industrial, or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits;

b. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges in amounts sufficient to be unsightly or deleterious;

c. Free from materials attributable to municipal, industrial, or other discharges producing color, odor, or other conditions in such degree as to be detrimental to legitimate uses of water;

d. Free from substances attributable to municipal, industrial, or other discharges in concentrations or combinations which are detrimental to human, animal, industrial, agricultural, recreational, aquatic, or other legitimate uses of the water.

1.2(3) Specific criteria for designated water uses.

The following criteria are applicable at flows greater than the lowest flow for seven consecutive days which can be expected to occur at a frequency of once every ten years.

b. Aquatic life. The following criteria are designated for the maintenance and propagation of a well-balanced fish population. They are applicable to any place in surface waters but cognizance will be given to opportunities for admixture of waste effluents with such waters.

(1) Warm water areas: Dissolved oxygen: Not less than 5.0 mg/l during at least 16 hours of any 24-hour period and not less than 4.0 mg/l at any time during the 24-hour period.

pH: Not less than 6.8 nor above 9.0

Temperature:

Mississippi River -- Not to exceed an 89°F maximum temperature from the Minnesota border to the Wisconsin border and a 90°F maximum temperature from the Wisconsin border to the Missouri border nor a 5°F change from background or natural temperature in the Mississippi River.

Missouri River -- Not to exceed a 90°F maximum daily temperature nor a 5°F increase over background or natural temperature.

Interior streams -- Not to exceed a 90°F maximum temperature nor a maximum 5°F increase over background or natural temperature.

Lakes and reservoirs -- Not to exceed a 90°F maximum temperature nor a maximum 3°F inc case over background or natural temperature.

Chemical constituents: Not to exceed the following concentrations:

Specific constituents (mg/l)

Ammonia Nitrogen (N)	2.0	*Copper	0.02
*Arsenic	1.0	Cyanide	0.025
*Barium	5.0	*Lead	0.10
*Cadmium	0.05	*Zinc	1.0
*Chromium (hexavalent)	0.05	Phenols (Other than natural sources)	0.001
*Chromium (trivalent)	1.0		

*A maximum of 5.0 mg/l for the entire heavy metal group shall not be exceeded.

All substances toxic or detrimental to aquatic life shall be limited to nontoxic or non-detrimental concentrations in the surface water.

c. Recreation. The following criteria are applicable to any waters used for recreational activities involving whole body contact such as swimming and water skiing:

(1) Bacteria: Waters shall be considered to be of unsatisfactory bacteriological quality for the above recreational use when:

A sanitary survey indicates the presence or probability of the presence of sewage or other objectional bacteria-bearing wastes or

Numerical bacteriological limits of 200 fecal coliforms per 100 ml for primary contact recreational waters are exceeded during low flow periods when such bacteria can be demonstrated to be attributable to pollution by sewage.

1.2(4) Disinfection.

Continuous disinfection shall be provided for all municipal waste treatment effluents and for all other wastes which may be sources of bacterial pollution throughout the year where such wastes are discharged into waters designated for public water supplies and throughout the recreational season (April 1 to October 31) where such wastes are discharged into waters used or classified for recreational use and at all other times as necessary to prevent bacterial pollution which may endanger the public health or welfare.

1.2(5) Non-degradation.

Waters whose existing quality is better than the established standards as of the date on which such standards become effective will be maintained at high quality unless it has been affirmatively demonstrated to the State that a change is justifiable as a result of necessary economic or social development and will not preclude present and anticipated use of such waters. Any industrial, public or private project or development which would constitute a new source of pollution or an increased source of pollution to high quality waters will be required to provide the necessary degree of waste treatment to maintain high water quality. (In implementing this rule, the appropriate agency of the Federal Government will be kept advised and will be provided with such information as it will need be provided with such information as it will need to discharge its responsibilities under the Federal Water Pollution Control Act, as amended.)

1.2(6) Interstate waters.

(1) The Mississippi river, Missouri river, Fox river, Des Moines river, East Fork of the Des Moines river, West Fork of the Des Moines river, Iowa river, Cedar river, Shellrock river, Winnebago river, Wapsipinicor river, Upper Iowa river, Chariton river, Middle Fork Medicine river, Weldon river, Little river, Thompson river, East Fork of the Big river, Grand river, Platte river, East Fork of the 102 river, Middle Fork of the 102 river, Hedaway river, West Tarkio river, Tarkio river, Nishnabotna river, Little Sioux river, Rock river and Kanaranzi Ditch are hereby designated as interstate waters.

(2) Treatment: All municipal wastes discharged into the interstate waters of the Mississippi river and the Missouri river shall receive a minimum of ninety percent (90) reduction of BOD prior to discharge, no later than dates fixed by order of the Iowa Water Pollution Control Commission. All industrial wastes discharged into such interstate waters shall receive equivalent treatment prior to discharge, no later than dates fixed by order of the Iowa Water Pollution Control Commission.

TABLE 11

WATER POLLUTION CONTROL NEEDS AND DESIGNATED WATER USES
(Revised June 1, 1968)

STREAM AND TRIBUTARY	MUNICIPALITY OR INDUSTRY	POPULATION	PRESENT TREATMENT	TREATMENT NEEDS	COMPLIANCE SCHEDULE	WATER USE
*Big Sioux River	Akron	1351	AE			4
	Hawarden	2544	None	New Plant	July 1, 1968	4
Indian Creek	Ireton	510	IT-TF			4
*Rock River	Rock Valley	1693	ST-SF	Replacement	July 1, 1969	2
	Rock Rapids	2780	PC-TF			2,3
Burr Oak Creek	Hull	1289	PC-TF	Expansion	July 1, 1972	4
Little Rock River	Doon	430	IT	Replacement	July 1, 1972	4
	George	1200	ST-SF	Replacement	July 1, 1968	4
	Little Rock	564	IT-TF			4
Otter Creek	Ashton	615	L			4
	Sibley	2852	PC-TF	Expansion	July 1, 1969	4
Mud Creek	Alvord	238	L			4
	Lester	239	L			4
*Kanaranzi Ditch	Inwood	638	L			4

APPENDIX C

MINNESOTA WATER QUALITY STANDARDS

(Portion applicable to Big Sioux River Basin)

POLLUTION CONTROL AGENCY

CHAPTER FIFTEEN: WPC 15

CRITERIA FOR THE CLASSIFICATION OF THE INTERSTATE WATERS OF THE STATE AND THE ESTABLISHMENT OF STANDARDS OF QUALITY AND PURITY

WPC 15 The official policy and purpose of the State of Minnesota in regard to these matters is set forth in the Minnesota Water Pollution Control Statutes:

Sec. 115.42. It is the policy of the state to provide for the prevention, control and abatement of pollution of all waters of the state, so far as feasible and practical, in furtherance of conservation of such waters and protection of the public health and in furtherance of the development of the economic welfare of the state . . . .It is the purpose of Laws 1963, Chapter 874, to safeguard the waters of the state from pollution by: (a) preventing any new pollution; and (b) abating pollution existing when Laws 1963, Chapter 374, become effective, under a program consistent with the declaration of policy above stated.

Section. 115.44 Subd. 2. In order to attain the objectives of Laws 1963, Chapter 874, the commission* after proper study, and after conducting public hearing upon due notice, shall, as soon as practicable, group the designated waters of the state into classes and adopt classifications and standards of purity and quality therefor. Such classification shall be made in accordance with considerations of best usage in the interest of the public and with regard to the considerations mentioned in subdivision 3 hereof.

Sec. 115.44 Subd. 8. . . .The commission* may classify waters and adopt criteria and standards in such form and based on such evidence as it may deem necessary and sufficient for the purposes of meeting requirements of such federal laws, notwithstanding any provisions in Chapter 115 or any other state law to the contrary. . . .Notwithstanding the provisions of subdivision 4, wherever advisable and practicable the commission* may establish standards for effluent of disposal systems entering waters regardless of whether such waters are or are not classified.

(a) INTRODUCTION

(1) Defintions: The terms "waters of the state" for the purposes of this regulation shall be construed to mean interstate waters as herein below defined, and the terms "sewage," "industrial wastes," and other wastes," as well as any other terms for which definitions are given in the Water Pollution Control Statutes, as used herein have the meanings ascribed to them in Minnesota Statutes, Sections 115.01 and 115.41, with the exception that disposal systems or treatment works

* Laws of 1967, Chapter 882, abolished the Water Pollution Control Commission and transferred its powers and duties to the Minnesota Pollution Control Agency.

operated under permit of the Agency shall not be construed to be "waters of the state" as the term is used herein. The current requirements of applicable federal laws which must be met are set forth in the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.). Interstate waters are defined in Section 13(c) thereof as including all rivers, lakes, and other waters that flow across or form a part of state boundaries. Other terms and abbreviations used herein which are not specifically defined in the law shall be construed in conformance with the context, and in relation to the applicable section of the statutes pertaining to the matter at hand, and current professional usage.

(2) Uses of the Interstate Waters: The classifications are listed separately in accordance with the need for interstate water quality protection, considerations of best use in the interest of the public and other considerations, as indicated in Minnesota Statutes, Section 115.44. The classifications should not be construed to be an order of priority, nor considered to be exclusive or prohibitory of other beneficial uses unless so stated in regard to discharge or disposal of sewage, industrial wastes or other wastes commonly associated with such other uses, where such discharges may adversely affect the specified uses. Only the uses of the interstate waters of the state as a medium for disposal of sewage, industrial wastes or other wastes is subject to regulation by the Agency, not their appropriation or other use such as for navigation or recreation. Where more than one of the listed uses may occur without reasonable separation in distance on the same interstate waters, appropriate adjustments will be made in the classifications and standards to take into account such intermingling of uses.

(3) Determination of Compliance: In making tests or analyses of the interstate waters of the state, sewage, industrial wastes or other wastes to determine compliance with the standards, samples shall be collected in such manner and place, and of such type, number and frequency as may be considered satisfactory by the Agency from the viewpoint of adequately reflecting the condition of the interstate waters, the composition of the effluents, and the effects of the pollutants upon the specified uses. Reasonable allowance will be made for dilution of the effluents in relation to the uses of the interstate waters into which they are discharged or other interstate waters which may be affected. The samples shall be preserved and analyzed in accordance with procedures given in the 1965 edition of Standard Methods for the Examination of Water and Waste-Water, by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation, and any revisions or amendments thereto, or other methods acceptable to the Agency.

(4) Natural Interstate Water Quality: The interstate waters may, in a state of nature, have some characteristics or properties approaching or exceeding the limits specified in the standards. The standards

shall be construed as limiting the addition of pollutants of human origin to those of natural origin, where such be present, so that in total the specified limiting concentrations will not be exceeded in the interstate waters by reason of such controllable additions; except that where the background level of the natural origin is reasonably definable and normally is higher than the specified standard the natural level may be used as the standard for controlling the addition of pollutants of human origin which are comparable in nature and significance with these of natural origin, but where the natural background level is lower than the specified standard and where reasonable justification exists for preserving the quality of the interstate waters as nearly as possible to that found in a state of nature, the natural level may be used instead of the specified standard as the maximum limit on the addition of pollutants. In the adoption of standards for individual interstate waters, the Agency will be guided by the standards set forth herein but may make reasonable modifications of the same on the basis of evidence brought forth at a public hearing if it is shown to be desirable and in the public interest to do so in order to encourage the best use of the interstate waters or the lands bordering such interstate waters.

Waters which are of quality better than the established standards will be maintained at high quality unless a determination is made by the State that a change is justifiable as a reasult of necessary economic or social development and will not preclude appropriate beneficial present and future uses of the waters. Any project or development which would constitute a source of pollution to high quality waters will be required to provide the highest and best practicable treatment to maintain high water quality and keep water pollution at a minimum. In implementing this policy, the Secretary of the Interior will be provided with such information as he requires to discharge his responsibilities under the Federal Water Quality Act, as amended.

(5) Variance From Standards: In any case where, upon application of the responsible person or persons, the Agency finds that by reason of exceptional circumstances the strict enforcement of any provision of these standards would cause undue hardship; that disposal of the sewage, industrial waste or other waste is necessary for the public health, safety or welfare; and that strict conformity with the standards would be unreasonable, impractical or not feasible under the circumstances; the Agency in its discretion may permit a variance therefrom upon such conditions as it may prescribe for prevention, control or abatement of pollution in harmony with the general purpose of these classifications and standards and the intent of the applicable state and national laws. The Federal Water Pollution Control Administration will be advised of any permits which may be issued under this clause together with information as to the need therefor.

(b) WATER USE CLASSIFICATIONS ALL INTERSTATE WATERS OF THE STATE

Based on considerations of best usage in the interest of the public and in conformance with the requirements of the applicable statutes, the interstate waters of the state shall be grouped into one or more of the following classes:

1. Domestic Consumption (to include all interstate waters which are or may be used as a source of supply for drinking, culinary or food processing use or other domestic purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

2. Fisheries and Recreation (to include all interstate waters which are or may be used for fishing, fish culture, bathing or any other recreational purposes, and for which quality control is or may be necessary to protect aquatic or terrestrial life, or the public health, safety or welfare.)

3. Industrial Consumption (to include all interstate waters which are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

4. Agricultural and Wildlife (to include all interest waters which are or may be used for any agriculture purposes, including stock watering and irrigation, or by waterfowl or other wildlife, and for which quality control is or may be necessary to protect terrestrial life or the public health, safety or welfare.)

5. Navigation and Waste Disposal (to include all interstate waters which are or may be used for any form of water transportation or navigation, disposal of sewage, industrial waste or other waste effluents, or fire prevention, and for which quality control is or may be necessary to protect the public health, safety or welfare.)

6. Other Uses (to include interstate waters which are or may serve the above listed uses or any other beneficial uses not listed herein, including without limitation any such uses in this or any other state, province, or nation of any interstate waters flowing through or originating in this state; and for which quality control is or may be necessary for the above declared purposes, or to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such interstate waters, or any other considerations the Agency may deem proper.)

(c) GENERAL STANDARDS APPLICABLE TO ALL INTERSTATE WATERS OF THE STATE

(1) No untreated sewage shall be discharged into any interstate waters of the state. No treated sewage, or industrial waste or other wastes containing viable pathogenic organisms, shall be discharged into interstate waters of the state without effective disinfection. Effective disinfection of any discharges, including combined flows of sewage and storm water, will be required where necessary to protect the specified uses of the interstate waters.

(2) No raw or treated sewage, industrial waste or other wastes shall be discharged into any interstate waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, oil slicks, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, or other offensive or harmful effects.

(3) Existing discharges of inadequately treated sewage, industrial waste or other wastes shall be abated, treated or controlled so as to comply with the applicable standards. Separation of sanitary sewage from natural run-off may be required where necessary to ensure continuous effective treatment of sewage.

(4) The highest possible levels of water quality, including dissolved oxygen, which are attainable in the interstate waters by continuous operation at their maximum capability of all units of treatment works discharging effluents into the interstate waters shall be maintained in the interstate waters in order to enhance conditions for the specified uses.

(5) Means for expediting mixing and dispersion of sewage, industrial waste, or other waste effluents in the receiving interstate waters shall be provided so far as practicable when deemed necessary by the Agency to maintain the quality of the receiving interstate waters in accordance with applicable standards.

(6) It is herein established that the Agency will require secondary treatment or the equivalent as a minimum for all municipal sewage and biodegradable, industrial or other wastes to meet the adopted water quality standards and a comparable high degree of treatment or its equivalent also will be required of all non-biodegradable industrial or other wastes unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses and a variance is granted under the provisions of the variance clause. Secondary treatment facilities are defined as works which will provide effective sedimentation, biochemical oxidation, and disinfection, or the equivalent, including effluents conforming to the following:

Substance or Characteristic	Limiting Concentration or Range
5-Day biochemical oxygen demand	25 milligrams per liter
Total coliform group organisms	1,000 MPN/100 ml
Total suspended solids	30 milligrams per liter
Oil	Essentially free of visible oil
Turbidity	25
pH range	6.5 - 8.5

(7) Allowance shall not be made in the design of treatment works for low stream flow augmentation unless such flow augmentation of minimum flow is dependable under applicable laws or regulations.

(8) In any instance where it is evident that natural mixing or dispersion of an effluent is not effective in preventing pollution, or that it may not be feasible to provide by other means for effective mixing or dispersion of an effluent, or if at the applicable stream flows meantioned in the sections on specific standards of interstate water quality and purity it is evident that the specified stream flow may be less than the effluent flow, the specific standards may be interpreted as effluent standards for control purposes, where applicable. The period of record for determining the specific flow for the stated recurrence interval, where records are available, will include at least the most recent 10 years of record, including flow records obtained after establishment of flow regulation devices, if any. Such calculations will not be applied to lakes and their embayments which have no comparable flow recurrence interval. Where stream flow records are not available, the flows may be estimated on the basis of available information on the watershed characteristics, precipitation, run-off and other pertinent data. In addition, the following effluent standards may be applied without any allowance for dilution where stream flow or other factors are such as to prevent adequate dilution, or where it is otherwise necessary to protect the interstate waters for the stated uses:

Item	Limits
5-day biochemical oxygen demand	20 milligrams per liter
Total phosphorus	1 milligram per liter
Total suspended solids	20 milligrams per liter

It is the intention of the Agency to require removal of nutrients from all sources to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially inimical to preservation or enhancement of the designated water uses.

(9) In any case where, after a public hearing, the Agency finds it necessary for conservation of the interstate waters of the state, or protection of the public health, or in furtherance of the development of the economic welfare of the state, it may prohibit or further limit the discharge to any designated interstate waters of any sewage, industrial waste, or other waste effluents, or any component thereof, whether such effluents are treated or untreated, or existing or new, notwithstanding any other provisions of classification or specific standards stated herein which may be applicable to such designated interstate waters.

(10) In any proceeding where specific standards have been adopted which are directly or indirectly applicable to named interstate waters of the state, it shall be incumbent upon all persons responsible for existing or new sources of sewage, industrial wastes or other wastes which are or will be discharged to such interstate waters, to treat or control their wastes so as to produce effluents having a common level or concentration of pollutants of comparable nature and effect as may be necessary to meet the specified standards or better, and in no case shall the concentration of polluting substances in any individual effluent be permitted to exceed the common concentration or level required of the other sources of comparable nature and effect discharging to the same classified and named interstate waters, regardless of differences in the amount of pollutional substances discharged, or degree of treatment involved.

(11) Liquid substances which are not commonly considered to be sewage or industrial wastes but which could constitute a pollution hazard shall be stored in accordance with Regulation WPC 4, and any revisions or amendments thereto. Other wastes as defined by law or other substances which could constitute a pollution hazard shall not be deposited in any manner such that the same may be likely to gain entry into any interstate waters of the state in excess of or contrary to any of the standards herein adopted, or cause pollution as defined by law.

(12) No sewage, industrial waste or other wastes shall be discharged into the interstate waters of the state in such quantity or in such manner alone or in combination with other substances as to cause pollution thereof as defined by law. In any case where the interstate waters of the state into which sewage, industrial wastes or other waste effluents discharge are assigned different standards than the interstate waters into which such receiving interstate waters flow, the standards applicable to the interstate waters into which such sewage, industrial waste or other wastes discharge shall be supplemented by the following:

The quality of any waters of the state receiving sewage, industrial waste or other waste effluents shall be such that no violation of the standards of any interstate waters of the state in any other class shall occur by reason of the discharge of such sewage, industrial waste or other waste effluents.

(13) Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish or other biota shall be resolved in accordance with the methods specified by the National Technical Advisory Committee of the Federal Water Pollution Control Administration, U. S. Department of the Interior. The Committee's recommendations also will be used as official guidelines in other aspects where the recommendations may be applicable.

(14) All persons operating or responsible for sewage, industrial waste or other waste disposal systems which are adjacent to or which discharge effluents to these waters or to tributaries which affect the same, shall submit regularly every month a report to the Agency on the operation of the disposal system, the effluent flow, and the characteristics of the effluents and receiving waters. Sufficient data on measurements, observations, sampling and analyses, and other pertinent information shall be furnished as may be required by the Agency to in its judgment adequately reflect the condition of the disposal system, the effluent, and the waters receiving or affected by the effluent.

(d) SPECIFIC STANDARDS OF QUALITY AND PURITY FOR DESIGNATED CLASSES OF INTERSTATE WATERS OF THE STATE

The following standards shall prescribe the qualities or properties of the interstate waters of the state which are necessary for the designated public use or benefit and which, if the limiting conditions given are exceeded, shall be considered indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental or injurious with respect to such designated uses or established classes of the interstate waters:

(1) Domestic Consumption

Class A The quality of this class of the interstate waters of the state shall be such that without treatment of any kind the raw waters will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards - 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to underground waters with a high degree of natural protection. The basic requirements are given below:

Substance or Characteristic	Limit or Range
Total coliform organisms	1 most probable number per 100 mililiters
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 milligram per liter
Arsenic (As)	0.01 milligram per liter
Chlorides (Cl)	250 milligrams per liter
Copper (Cu)	1 milligram per liter
Carbon Chloroform extract	0.2 milligram per liter
Cyanides (CN)	0.01 milligram per liter
Fluorides (F)	1.5 milligrams per liter
Iron (Fe)	0.3 milligram per liter
Manganese (Mn)	0.05 milligram per liter
Nitrates (NO_3)	45 milligrams per liter
Phenol	0.001 milligram per liter
Sulfates (SO_4)	250 milligrams per liter
Total dissolved solids	500 milligrams per liter
Zinc (Zn)	5 milligrams per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Hexavalent, Cr)	0.05 milligram per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter

Class B The Quality of this class of the interstate waters of the state shall be such that with approved disinfection, much as simple chlorination or its equivalent, the treated water will meet in all resepcts both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards - 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Total coliform organisms	50 most probable number per 100 milliliters

Class C The quality of this class of the interstate waters of the state shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet in all respects both in mandatory and recommended requirements of the Public Health Service Drinking Water Standards - 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where interstate water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Total coliform organisms	4,000 most probable number per 100 milliliters
Turbidity value	25

Class D The quality of this class of the interstate waters of the state shall be such that after treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, plus additional pre, post, or intermediate stages of treatment, or other equivalent treatment processes, the treated water will meet in all respects the recommended requirements of the Public Health Service Drinking Water Standards - 1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U. S. Department of Health, Education, and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where water is obtained from mechanical fractures, joints, etc., with surface connections, and course gravels subjected to surface water infiltration.

The concentrations or ranges given below shall not be exceeded in raw waters before treatment:

Substance or Characteristic	Limit or Range
Total coliform organisms	4,000 most probable number per 100 milliliters
Arsenic (As)	0.05 milligram per liter
Barium (Ba)	1 milligram per liter
Cadmium (Cd)	0.01 milligram per liter
Chromium (Cr + 6)	0.05 milligram per liter
Cyanide (CN)	0.2 milligram per liter
Fluoride (F)	1.5 milligrams per liter
Lead (Pb)	0.05 milligram per liter
Selenium (Se)	0.01 milligram per liter
Silver (Ag)	0.05 milligram per liter

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the interstate waters for use as a source of drinking water.

(2) Fisheries and Recreation

Class A The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and Not less than 5 milligrams per liter at other times
Temperature	No material increase
Ammonia (N)	Not to exceed a trace
Chlorides (Cl)	50 milligrams per liter
Chromium (Cr)	Not to exceed a trace
Copper (Cu)	Not to exceed a trace

Cyanides (CN)	Not to exceed a trace
Oil	Not to exceed a trace
pH value	6.5 - 8.5
Phenols	Not to exceed a trace
Turbidity value	10
Color value	30
Total coliform organisms	1,000 most probable number per 100 milliliters
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Discharges of sewage, industrial waste or other waste effluents shall be controlled so that the standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the seven consecutive daily average flows of record (the lowest weekly flow with a once in ten year recurrence interval) for the critical month(s).

Class B The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of sport or commercial fishers and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 6 milligrams per liter from April 1 through May 31, and Not less than 5 milligrams per liter at other times.
Temperature	86° F in July and August, 80° F in June and September, 67° F in May and October, 55° F in April and November, 43° F in March and December, and 37° F in Jan. and February. Or 5°F above ambient, whichever is greater, except that in no case shall it exceed 90°F.

Ammonia (N)	1 milligram per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.2 milligram per liter
Cyanides (CN)	0.02 milligram per liter
Oil	Not to exceed a trace
pH value	6.5 - 9.0
Phenols	0.01 milligram per liter
Turbidity	25
Total coliform organisms	1,000 most probable number per 100 milliliters
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Discharges of sewage industrial waste or other waste effluents shall be controlled so that the standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the 7 consecutive daily average flows of record (the lowest weekly flow with a once in 10 year recurrence interval for the critical month.

Class C The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of fish of species, commonly inhabiting waters of the vicinity under natural conditions, and be suitable for boating and other forms of aquatic recreation not involving prolonged intimate contact with the water for which the interstate waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 5 milligram per liter from April 1 through May 31, and Not less than 3 milligrams per liter at other times.
	90° F in July and August, 87° F in June and September, 75° F in May and October, 63° F in April and November, 51° F in March and December, and

	45° F in January and Feb.)Or 5°F above ambient, whichever is greater, except that in no case shall it exceed 90°F.
Ammonia	2 milligrams per liter
Chromium (Cr)	0.05 milligram per liter
Copper (Cu)	0.2 milligram per liter
Cyanides (CN)	0.02 milligram per liter
Oil	None in such quantities as to (1) produce a visible color film on the surface, (2) impart an oily odor to water or and oil taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse or taint any of the associated biota, or (4) become effective toxicants according to the criteria recommended.
pH value	6.0 - 9.5
Phenols	None that could impart odor or taste to fish flesh or or other freshwater edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aqua products, bioassays and taste ponds will be required to determine whether tainting is likely.
Turbidity value	25
Total coliform organisms	5,000 most probable number per 100 milliliters
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Discharges of sewage, industrial waste or other waste effluents shall be controlled so that the standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the 7 consecutive daily average flows of record (the lowest weekly flow with a once in 10 year recurrence interval) for the critical month.

The aquatic habitat, which includes the interstate waters and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste or other waste effluents to be interstate waters.

No sewage, industrial waste or other wastes shall be discharged into any of the interstate waters of this category so as to cause any material change in any other substances or characteristics which may impair the quality of the interstate waters or the aquatic biota of any of the above-listed classes or in any manner render them unsuitable or objectionable for fishing, fish culture or recreational uses. Additional selective limits or changes in the discharge bases may be imposed on the basis of local needs.

(3) Industrial Consumption

Class A The quality of this class of the interstate waters of the state shall be such as to permit their use without chemical treatment, except softening for ground water, for most industrial purposes, except food processing and related uses, for which a high quality of water is required. The quality shall be generally comparable to Class B waters for domestic consumption, except for the following:

Substance or Characteristic	Permissible Limit or Range
Chlorides (Cl)	50 milligrams per liter
Hardness	50 milligrams per liter
pH value	6.5 - 8.5
Temperature	75° F in July and August, 70° F in June and September, 60° F in May and October, (Surface) 50° F in April and November,

	40° F in March and December, and 35° F in January and February
	55° F (Ground)
Total coliform organisms	5,000 most probable number per 100 milliliters

Class B The quality of this class of the interstate waters of the state shall be such as to permit their use for general industrial purposes, except food processing, with only a moderate degree of treatment. The quality shall be generally comparable to Class D interstate waters used for domestic consumption, except for the following:

Substance or Characteristic	Permissible Limit or Range
Chlorides (Cl)	100 milligrams per liter
Hardness	250 milligrams per liter (Surface) 350 milligrams per liter (Ground)
pH value	6.0 - 9.0
Temperature	65° F (ground) 86° F (surface)
Total coliform organisms	5,000 most probable number per 100 milliliters

Class C The quality of this class of the interstate waters of the state shall be such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling, or other unsatisfactory conditions. The following shall not be exceeded in the interstate waters:

Substance or Characteristic	Limit or Range
Chlorides (Cl)	250 milligrams per liter
Hardness	500 milligrams per liter
pH value	6.0 - 9.5
Temperature	65° F (ground) 90° F (surface)
Total coliform organisms	5,000 most probable number per 100 milliliters

Additional selective limits may be imposed for any specific interstate waters as needed.

STATE OF MINNESOTA
WATER POLLUTION CONTROL COMMISSION

Classifications and Criteria for The Interstate Waters of Minnesota(1)

WATERS	REACH OR AREA INVOLVED	CLASSIFICATION(2)
	Missouri River Basin	
Rock River	Source to Iowa border	2C, 3B
Kanaranzi Creek	Source to Iowa border	2C, 3B
Little Rock River	Source to Iowa border	2C, 3B
Medary Creek	Source to South Dakota border	2C, 3B
Flandreau Creek	Source to South Dakota border	2C, 3B
Pipestone Creek	Source to South Dakota border	2C, 3B
Split Rock Creek	Source to Split Rock Lake outlet	2B, 3B
Split Rock Creek	Split Rock Lake to South Dakota border	2C, 3B
Beaver Creek	Source to South Dakota border	2C, 3B
Mud Creek	Source to Iowa border	2C, 3B

(1) All interstate waters are included, although some minor water courses such as unnamed streams or interconnecting waters and/or intermittently flowing creeks, ditches, or draws, etc. are not listed individually herein. The requirements for previously classified waters are given in Regulations WPC 1 through 3, inclusive, and 5 through 13, inclusive.

(2) Includes known present uses and/or uses which may be made of the waters in the future. In addition to the classification(s) given below, the interstate waters are also included in Classes 3C, 4, 5 and 6 for all reaches or areas where such uses are possible. Where specific criteria are common to two or more listed classes the more restrictive values shall apply. For additional information refer to the Criteria for Classification and Establishment of Standards (Regulation WPC 15).

MINNESOTA POLLUTION CONTROL AGENCY
Division of Water Quality

Priority of Interstate Waters
Enforcement Projects[1]

System Name and Project Designation	Reach or Area Affected, and Adjacent States or Provinces	Specific Waters Involved, and Counties in or Through Which They flow[1]	Enforcement Hearing to be Scheduled By[15]
Rock River (Rock)	Hendricks-Hills Jackson (South Dakota and Iowa)	Flandreau Creek Lincoln County Pipestone County Pipestone Creek Pipestone County Split Rock Creek Pipestone County Rock County Beaver Creek Rock County Mud Creek Rock County Rock River Pipestone County Rock County Kanaranzi Creek Nobles County Rock County Little Rock Creek Nobles County	October 1, 1970

NOTE: Lakes or reservoirs which are an integral part of the main stem of the named river, such as Winnibigoshia Lake in the case of the Mississippi River, or Okamanpeedan Lake in the case of the East Fork of the Des Moines River, are usually not listed separately but are considered to be included as part of the river system. In the same manner, some lakes which lie on a border, such as Iowa Lake, although not named are considered to be part of the interstate stream by which they are drained. Named bays are usually considered to be part of the lake to which they are connected, but in some cases, such as St. Louis and Superior Bays of Lake Superior, may be included as part of a river system.

MINNESOTA POLLUTION CONTROL AGENCY
Division of Water Quality

Major Actual or Potential Sources of Sewage or Industrial Wastes
(Source Categories I and 2) Which Discharge to
and/or May Affect Interstate Waters

March 1969

WATERS	SOURCES	REMAINING CONTROL AND/OR TREATMENT NEEDS	SCHEDULED COMPLETION BY
		Missouri River Basin	
Rock River	Luverne	Sewer separation Expand sewage works	June 18, 1978(rec) Dec. 18, 1971(rec)
	Iowa Beef Packers Inc., Luverne	Coliform reduction	
	Edgerton	Coliform reduction Sewer separation	 June 18, 1978(rec)
	Holland	Coliform reduction Sewer separation	 June 18, 1978(rec)
Kanaranzi Cr.	Adrian	- - -	- - -
Little Rock R.	Rushmore	Treatment works	Dec. 18, 1971(rec)
Pipestone Cr.	Pipestone	Sewer separation	June 18, 1978(rec)
	Pawnee Packing Co., Pipestone	Waste disposal facilities concurrently with plant construction	
Split Rock Cr.	Jasper	- - -	- - -
Mud Creek	Hills	- - -	- - -

(rec) - means the completion date has only been recommended, not established formal order

APPENDIX D

METHODS OF ANALYSIS

METHODS OF ANALYSIS

A. BACTERIOLOGY

Bacteriological analyses of total and fecal coliform bacteria and fecal streptococci were performed according to standard techniques,[1/] employing the membrane filter procedure. To prevent contamination, all samples were collected in sterile bottles prepared by the accepted procedure.[1/]

Salmonella sampling involved placement of sterile gauze pads at selected stream locations for a three-to-five-day period. The pads were retrieved, placed in sterile plastic bags, chilled, and transported to the laboratory within one hr for analyses. There is no standard procedure for detection of *Salmonella* in surface waters. The method employed by NFIC-Denver is the elevated temperature technique of Spino[2/] with modifications. Selective enrichment media included dulcitol-selenite broth and tetrathionate broth. Incubation temperature was 41.5°C. On each of four successive days the growth in each of the enrichment media containing the pads was streaked onto selective plating media that consisted of brilliant green and xylose-lysine-deoxycholate agars. Colonies with characteristics typical of *Salmonella* were picked and subjected to biochemical identification. *Salmonella* were identified serologically, and representative serotypes from each location were sent to the National Center for Disease Control, Atlanta, Georgia, for confirmation.

B. CHEMISTRY

BOD and DO tests were conducted according to standard techniques[1/] using the azide modification of the Winkler method.

All other laboratory analyses and field measurements were conducted in accordance with accepted standard techniques.[3/]

The following analytical Quality Control values are attendant to the data released for the subject survey:

Accuracy

Parameter	Range of Values (mg/l)	Range of % Recovery	Avg Δ% Recovery	Standard Deviation (mg/l)
NH_3-N	28-117	89-109	6	±5.78
NH_3-N	1.54-5.34	86-106	6	±0.23
$NO_3 + NO_2$-N	1.81-2.73	99-114	4	±0.095
TKN	57-170	91-115	6	±6.6
TKN	9.0-12.6	97-115	11	±0.42
Total P	0.50-11.98	91-117	7	±0.70
Total P	22-35	86-121	8	±2.6
TOC	18.2-72.4	94-105	2	±1.02
COD	249-307	98-112	5	±13.2
COD	292-1,551	89-106	4	±26

NOTE: Avg Δ% Recovery equals 100% ± (Observed % Recovery).

Precision

Parameter	Range of Values (mg/l)	Range of % Precision	Avg Precision (%)	Standard Deviation (mg/l)
BOD	300-1,200	±12	±5	±50
BOD	425-2,420	± 8	±3	±46
NH_3-N	23.4-85.3	± 8	±3	± 1.97
NH_3-N	0.35-3.43	±10	±5	± 0.12
NO_3 + NO_2-N	0.80-1.62	± 7	±3	± 0.05
TKN	0.81-6.6	± 5	±3	± 0.13
TKN	41-188	±10	±4	± 6.9
TOC	155-384	± 5	±3	±11.2
TOC	9.0-37.90	± 7	±4	± 0.85
COD	224-1,711	±17	±5	±26
COD	78-152	± 9	±5	± 5.3
Total Solids	1,870-5,090	± 4	±1	±71
Total Solids	398-989	± 1	±1	± 3

Precision calculations in this report are based upon results of replicate analyses conducted regularly during each series of samples.

Similarly calculated are accuracy data based upon percent recovery of standard additions to previously analyzed samples in a series of analyses. It should be emphasized that standard deviations calculated in this regard serve only as an indicator of precision or accuracy limits for the particular series of analyses under consideration. Standard-deviation values calculated in this manner can be used for inter-laboratory or literature comparisons in order to indicate the ability of a particular laboratory to perform a given analysis. It is not, however, a quantitative value that defines maximum or minimum limits for any specific item of data.

C. BIOLOGY

Fall Survey

Benthos — Bottom-dwelling invertebrates were quantitatively sampled, with a Petersen grab, at four sites (cross-stream transects) per station. In addition, qualitative samples were taken at each sampling location by two methods: (1) between 10 September and 3 October 1972, Hester-Dendy artificial substrates were exposed for 24-day periods; (2) available habitats were sampled by screening sediments and manually removing organisms from beneath rocks and on debris, etc. Organisms collected only in qualitative samples were arbitrarily assigned values of one per square foot* of stream bed and were counted with the quantitative samples. In the laboratory, the alcohol-preserved samples were separated from debris, identified, and counted. Results of quantitative sampling were expressed as numbers of organisms per square foot* of stream bed.

In order to determine species diversity the information theory method of Lloyd, Zar, and Karr[6/] was employed. Diversity has at least two meanings: (1) It refers to the species richness in terms of numbers of species in an area (equals species diversity), and (2) it is based on the relative composition of the individuals in an area (equals

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* The number of organisms per square meter is obtained by multiplying No./ft^2 by a factor of 10.76.

dominance diversity). The species-diversity concept, as used in this report, measured the mathematical relationship of the species collected to a theoretical maximum for a given community under the conditions found at a given station. Calculated diversity values fall into three categories: 0-1.0 indicates gross organic pollution; 1.1-3.0 indicates moderate pollution or enrichment; and greater than 3.0 indicates clean water.

Primary Productivity --

A. *In Situ* Measurement

1. Periphyton: Periphyton growth in the Big Sioux River and its tributaries was assessed using artificial substrates containing five 5.08 x 7.62-cm (2 x 3-in.) glass microscope slides. A substrate was placed near each bank at the biological sampling stations [Table K-2]. After 24-day exposures, between 10 September and 3 October 1972, the glass-slide substrates, together with the attached organisms, were recovered, disassembled, and stored on dry ice, in the dark -- for transport to the NFIC-Denver laboratory.

   At the laboratory the periphyton samples were analyzed for chlorophyll a concentrations per unit area, according to accepted procedures.[1/]

2. Primary Production: Dark and light bottles filled with river water were incubated four hr (0800 to 1200) at River Miles

106.2, 113.0, 127.0, 134.5, 141.2, 143.2, and 162.2. Net and gross photosynthesis, respiration, and carbon fixation were calculated using available formulas.[1/] During the dark-light bottle incubation period, dissolved oxygen in the river was measured hourly, from 0600 (1 hr before sunrise) until 1200.

B. Algal Assays

Algal assay tests were conducted as outlined in "Algal Assay Procedure-Bottle Test," August 1971.[4/]

Two specific algal assay tests were conducted at the NFIC-Denver laboratory using the receiving water (Big Sioux River immediately upstream of the Sioux Falls WWTP) as dilution water.

1. Sewage Effluent Additions: Unchlorinated effluent from the final clarifier of the Sioux Falls WWTP was collected on the same day (9/13/72) as the dilution water. The effluent was added in triplicate to effect 0, 0.1, 1.0, 5, 10, 20, 40, 60, 80, and 100-percent concentrations. An inoculum of algae, *Selenastrum capricornutum* (standard test organisms obtained from the EPA Pacific Northwest Water Laboratory), was added to each flask. The initial culture volume was adjusted to 100 ml per 250 ml Erlenmeyer flask in order to allow maximum aeration. Initial *in vivo* fluorescence readings were made employing a modified, high-sensitivity Turner Fluorometer. Fluorescence readings were converted to chlorophyll-a

concentrations, and algal growth was then expressed as changes in chlorophyll-a concentrations (μg/l). The test cultures were incubated in a 24°C water bath mounted on a shaker platform. Light at mid-flask level was adjusted to 432 lm/m^2 (400 ft-c i.e., 24-hr light), and the shaker set at 100 oscillations/min. Daily *in vivo* fluorescence readings were made of each culture until the first exponential phase of growth was completed. The algal cultures were subsampled periodically for cell identification.

2. Phosphorus and Nitrogen Additions: Various concentrations of phosphorus and nitrogen (0, 0.01, 0.10, 1.0, and 10.0 mg/l) were added to receiving water in order to determine the amounts of phosphorus or nitrogen that were algal-growth limiting in the Big Sioux River at the time of the Fall 1972 EPA Survey. Test conditions were as outlined above.

Winter Survey

Algal Assays -- On 24 January 1973, samples were collected, for algal assays, from the Sioux Falls WWTP main effluent and by-pass discharge and from the Big Sioux River (dilution water). Test conditions were identical to those employed for the fall investigations, with the following exception: One of the triplicate tests was conducted using 500 ml of sample in 1,000 ml flasks in a static water bath.

Additional algal assays were performed using nutrient-stripped WWTP effluent. Nutrient stripping was accomplished by precipitation. Effluent samples were heated with 400 mg/l $Ca(OH)_2$ for two hr; the heated supernatant was then aerated for two additional hr. During precipitation and aeration, the pH was maintained at 11. After stripping was completed, the pH was adjusted to 9. Phosphorus-removal efficiency was 95 percent (from 13.9 to 0.69 mg/l) for the WWTP final effluent and 94 percent (from 25.4 to 1.4 mg/l) for the by-pass effluent. The receiving (dilution) water contained 0.48 mg/l total phosphorus. Ammonia-nitrogen removal from the final effluent was 95 percent (from 36 to 1.7 mg/l); 63 percent of the ammonia nitrogen (from 48 to 18 mg/l) was stripped from the by-pass effluent. The receiving water contained 0.55 mg/l NH_3-N. Waters tested for algal-growth potential contained 0, 0.1, 1, 5, 10, 20, 40, 60, 80, and 100-percent stripped effluent. Also, 0.1, 1, 10, and 50 percent dilutions of stripped effluent with combinations of 0.1, 1, and 10 mg/l additions of nitrogen and phosphorus were tested.

Fish Assays -- Channel catfish (*Ictalurus punctatus*) approximately 7.6 cm (3 in.) in total length were received from the U.S. Fish and Wildlife Service National Fish Hatchery, Senecaville, Ohio, and transferred into acclimation tanks filled with 9-10°C water of pH 7.7±0.2.

After four to five days of acclimation, fish were used to evaluate the toxic effects of the effluent from the Sioux Falls, South Dakota, WWTP. Fish testing included flow-through bioassays and *in situ* survival studies.

The flow-through bioassay system consisted of an effluent diluter (modified from Mount and Brungs[7/]) and epoxy-coated wooden test tanks.

The diluter was constructed and calibrated to provide a series of seven dilutions [100, 52, 36, 27, 16, and 8 percent effluent and 100 percent dilution water (control)]. Test water was obtained from the final effluent of the Sioux Falls WWTP, and dilution water was obtained from the diversion canal 0.4 km (0.25 mi) upstream of the treatment plant. Effluent and dilution-water reservoirs were refilled on an average of every six hr.

To maintain a satisfactory, dissolved-oxygen level, test water was aerated using finely dispersed air bubbles. This aeration procedure caused no measurable loss of NH_3 from the test water. All other test conditions were ambient.

Diluter cycles delivered 500 ml of water to test chambers in approximately four hr.

Test chambers were duplicated and placed in random order to minimize external environmental influences; all were monitored twice daily for NH_3, DO, pH, and temperature. Mortality was recorded at the end of each 24-hr period. Data from the bioassays were analysed statistically by the probit method of Litchfield and Wilcoxon.[5/]

In situ fish-survival studies were initiated after a four-day acclimation period. Catfish were placed in 10-liter plastic buckets. Numerous 0.5-cm holes in the buckets permitted the stream water to flow through, yet retain the fish. Two buckets with ten fish each were suspended in the river at each station, and one bucket was placed in the effluent from the main outfall of the Sioux Falls, South Dakota, WWTP. Following a 96-hr exposure, the cages were removed and the percent fish survival was determined. During this period, dissolved oxygen, water temperature, pH, and ammonia were monitored in the Big Sioux River at the fish cage sites [RM 142.95, 142.85, 128.5, and the diversion channel, Table K-11].

REFERENCES

1/ M. J. Tarus, A. E. Greenberg, R. D. Hoak, and M. C. Rand, *Standard Methods for the Examination of Water and Wastewater* 13th Edition, American Public Health Association. New York, New York 1971.

2/ Donald F. Spino, *Elevated-Temperature Technique for the Isolation of Salmonella from Streams,* Applied Microbiology, Vol. 14, No. 4 July 1966. Amer. Soc. for Microbiology.

3/ *Methods for Chemical Analysis of Water and Wastes,* Environmental Protection Agency, National Environmental Research Center, Analytical Quality Control Laboratory Cincinnati, Ohio. July 1971.

4/ *Algal Assay Procedure Bottle Test,* National Eutrophication Research Program, Environmental Protection Agency. 82 p. (1971).

5/ J. T. Litchfield and F. Wilcoxon. *A Simplified Method of Evaluating Dose-Effect Experiments.* Jour. Pharmacal Exp. Ther., 96:99-113. (1949).

6/ N. Lloyd, J. H. Zar, and J. R. Karr. *On the Calculation of Information - Theoretical Measures of Diversity.* Amer. Midland Naturalist. 79:257-272. (1968).

7/ D. T. Mount and W. A. Brungs. *A Simplified Dosing Apparatus for Fish Toxicity Studies.* Water Res., 1:21-29. (1967).

APPENDIX E

SOURCES OF POLLUTION

MUNICIPAL WASTE SOURCES

[Tables E-1 to E-3 list the municipal waste sources discharging to the Big Sioux River Basin.]

INDUSTRIAL WASTE SOURCES

[Table E-4 lists the industrial waste sources with direct discharges to the Big Sioux River Basin.]

AGRICULTURAL SOURCES OF POLLUTION

General

The Big Sioux River Basin is fertile and rich farmland. As a result, various agricultural activities contribute pollutants to the Big Sioux River. These pollutants include sediments, pecticides, fertilizers, animal wastes, and other organic materials. Most of the pollutants reach surface waters in runoff following rainfall or during the spring thaw. As a result, agricultural sources of pollution are intermittent in nature and difficult to quantify. They are also, with the exception of animal feedlots, diffuse sources adding to the difficulties of identification.

The magnitude of agricultural pollution problems in the Big Sioux River Basin is not well defined. Average water-quality conditions only partially reflect the impact of such pollution as slugs of pollutants during runoff events can cause short-term, water-quality degradation not reflected in monitoring data. It is known, however, that agricultural sources contribute to increased turbidity and nutrient levels in the Big Sioux River.

Animal Feedlots

The trend in livestock production is toward confined feeding. As a result, a vast increase in the number of feedlots has occurred over the last decade. The water-pollution hazard from feedlots is greater than from open grazing because the animal wastes have a greater tendency to run off than to become incorporated in the soil.

Most of the previous studies of feedlot runoff in the Big Sioux River Basin have concluded that the problem, when considered on the basis of a daily or yearly average pollution load, is not of major significance. There is, however, a significant potential for short term water quality problems as most of the feedlot runoff reaches a water course in slug discharges. State water-pollution-control agencies have initiated efforts to control wastes from feedlots. [Table E-5 is a list of applications for wastewater disposal permits from South Dakota operators of feedlots with possible drainage to the Big Sioux River or its tributaries.] A South Dakota State University Masters Thesis* lists feedlots observed, during a September 1967 Aerial Survey, adjacent to the Big Sioux River. More than fifty feedlots are tabulated in this list, thus indicating that many South Dakota feedlot operators have not yet applied for wastewater-disposal permits.

Iowa has also initiated registering feedlots. [The registered feedlots in the Big Sioux River Basin in Iowa are listed in Table E-6.]

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* John Edward Foley, *The Pollution Potential of Feedlots Along the Main Stem of the Big Sioux River* - A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science Major in Civil Engineering. South Dakota State University, Brookings, South Dakota. (1968)

TABLE E-1

SOUTH DAKOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Alcester	Brule Creek	627	223	(0.059)	Secondary (Trickling Filters)
Arlington	b/	954	314	(0.083)	Secondary (Trickling Filters)
Aurora	Tributary of Medary Creek	200			Stabilization Pond
Baltic	Big Sioux River	360		No Flow	Secondary (Stabilization Ponds)
Bradley	b/	157			None
Brandon	Big Sioux River	656	174	(0.046)	Secondary (Stabilization Ponds)
Bristol	b/	470	300	(0.08)	Secondary (Trickling Filter & Discharge to Landlocked Lake)
Brookings	Six-Mile Creek	13,860	3,785	(1.000)	Secondary (Trickling Filter & Stabilization Ponds)
Bryant	b/	500	151	(0.040)	Secondary (Stabilization Ponds & Discharge to Landlocked Slough)
Canton	Big Sioux River	2,660	806	(0.213)	Secondary (Stabilization Ponds)
Castlewood	Big Sioux River	520	185	(0.049)	Secondary (Stabilization Ponds)

TABLE E-1 (Cont.)

SOUTH DAKOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Chester	Skunk Creek	277	72	(0.019)	Secondary (Stabilization Ponds)
Clear Lake	Hidewood Creek	1,135	386	(0.102)	Secondary (Stabilization Ponds-Normally Do Not Discharge)
Colman	Bachelor Creek	456	151	(0.040)	Secondary (Stabilization Ponds-Normally Do Not Discharge)
Colton	Skunk Creek	600	159	(0.042)	Secondary (Stabilization Ponds)
Corson	Split Rock Creek	100	26.5	(0.007)	Secondary (Stabilization Ponds)
Crooks Sanitation District	Big Sioux River	202			Secondary (Stabilization Pond)
Dell Rapids	Big Sioux River	1,990	492	(0.130)	Secondary (Trickling Filter)
DeSmet	Silver Lake[b/]	1,336	405	(0.107)	Primary (Imhoff Tank)
Eden	b/	132	34	(0.009)	Primary (Imhoff Tank)
Egan	Big Sioux River	300			None
Elkton	Spring Creek	500	178	(0.047)	Primary (Imhoff Tank)

TABLE E-1 (Cont.)

SOUTH DAKOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Estelline	Big Sioux River	720	189	(0.05)	Secondary (Stabilization Ponds)
Flandreau	Big Sioux River	2,027	681	(0.18)	Secondary (Trickling Filter)
Flandreau (BIA)					Secondary (Trickling Filter)
Florence	b/	257	1,160	(0.308)	Secondary (Stabilization Ponds)
Garden City	b/	126			None
Garretson	Split Rock Creek	840	257	(0.068)	Secondary (Stabilization Ponds)
Hartford	Skunk Creek	800		(0.6)	Secondary (Trickling Filter)
Hayti	Marsh Lake[b/]	420	114	(0.030)	Secondary (Stabilization Ponds)
Hudson	Big Sioux River	360	110	(0.029)	None
Humboldt	Skunk Creek	440	110	(0.029)	Secondary (Stabilization Ponds)
Lake Kampeska Sanitary District		1,400			None
Lake Norden	Lake St. John[b/]	330	223	(0.059)	Secondary (Stabilization Ponds)

TABLE E-1 (Cont.)

SOUTH DAKOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m³/day	(mgd)	Type of Treatment
Lake Preston	Lake Preston[b/]	812	246	(0.065)	Secondary (Stabilization Ponds)
Madison	Lake Madison	6,315	8,330	(2.2)	Secondary (Trickling Filter & Stabilization Pond)
North Sioux City		860			None
Oldham	b/	244	64	(0.017)	Secondary (Stabilization Ponds)
Ramona	b/	227			None
Roslyn	b/	250	132	(0.035)	Primary (Imhoff Tank)
Sinai	b/	165	42	(0.011)	Secondary (Stabilization Ponds)
Sioux Falls	Big Sioux River	74,000	37,800	(10.000)	Secondary (Activated Sludge)
Summit	b/	332	87	(0.023)	Secondary (Stabilization Ponds)
Tea	Nine-Mile Creek	300	79	(0.021)	Secondary (Stabilization Ponds)
Trent	Big Sioux River	177			Secondary (Stabilization Pond)
Valley Springs	Beaver Creek	550	151	(0.040)	Secondary (Stabilization Ponds)

TABLE E-1 (Cont.)

SOUTH DAKOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Volga	Big Sioux River	900	900	(0.238)	Secondary (Stabilization Ponds)
Watertown	Big Sioux River	14,000	11,100	(2.920)	(Trickling Filters, Stabilization Ponds)
Waubay	Slough to Bitter Lake[b/]	696	185	(0.049)	Primary (Imhoff Tank)
Webster	Waubay Lake	2,252	681	(0.180)	Secondary (Stabilization Ponds)
Wentworth		196			None
Toronto	Deer Creek	200			Secondary (Stabilization Ponds)
White	Six-Mile Creek	410	114	(0.030)	Secondary (Trickling Filter)
Willow Lake	Willow Lake[b/]	353	151	(0.040)	Primary (Imhoff Tank)
Worthing	Snake Creek	294	79	(0.021)	Secondary (Stabilization Ponds)

a/ This includes industrial wastes discharged to municipal plants.
b/ This is a non-contributing part of the basin.

TABLE E-2

IOWA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Akron	Big Sioux River	1,300	265	(0.070)	Secondary (Activated Sludge)
Alvord	Mud Creek	200	64	(0.017)	Secondary (Stabilization Ponds)
Ashton	Otter Creek		114	(0.030)	
Doon	Little Rock River	420	167	(0.044)	Primary (Imhoff Tank)
George	Little Rock River	1,140	265	(0.070)	Secondary (Stabilization Ponds)
Hawarden	Big Sioux River	2,415	378	(0.1)	Secondary (Activated Sludge)
Hull	Unnamed Tributary of Rock River	1,289	322	(0.085)	Secondary (Trickling Filter)
Inwood	Unnamed Tributary of Big Sioux River	600	114	(0.030)	Secondary (Stabilization Ponds)
Ireton	Indian Creek	800	151	(0.040)	Secondary (Trickling Filter)
Larchwood	Unnamed Tributary of Big Sioux River	450	114	(0 030)	Secondary (Stabilization Ponds)
Lester	Mud Creek	230	57	(0.015)	Secondary (Stabilization Ponds)
Little Rock	Little Rock River	535	91	(0.024)	Secondary (Trickling Filter)
Rock Rapids	Rock River	2,000	609	(0.161)	Secondary (Trickling Filter)
Rock Valley	Rock River	1,610	409	(0.108)	Secondary (Septic Tank & Sand Filter)
Sibley	Otter Creek	2,750	10,900	(2.879)	
Westfield	Big Sioux River		98	(0.026)	

a/ This includes industrial wastes discharged to municipal plants.

TABLE E-3

MINNESOTA MUNICIPAL WASTE SOURCES[a/]
BIG SIOUX RIVER BASIN

Source	Receiving Water	Population Served	Flow m^3/day	Flow (mgd)	Type of Treatment
Adrian	Kanaranzi Creek	1,350			Secondary (Stabilization Ponds)
Beaver Creek	Beaver	231			(Stabilization Ponds)
Edgerton	Chanarambie Creek	1,119			Secondary (Trickling Filter)
Ellsworth	Tributary of Kanaranzi Creek	588			Secondary (Trickling Filter)
Hatfield	Rock River	86			Secondary (Imhoff Tank and Lagoon)
Hills	Mud Creek	514	742	(0.196)	Secondary (Stabilization Ponds)
Holland	Tributary of Rock River	237			Secondary (Trickling Filter)
Jasper	Split Rock Creek	452	326	(0.086)	Secondary (Trickling Filter)
Lake Benton	Flandreau Creek	683			Secondary (Stabilization Ponds)
Luverne	Rock River	4,233	2,930	(0.774)	Secondary (Trickling Filter)
Pipestone	Pipestone Creek	4,795	1,360	(0.360)	Secondary (Trickling Filter)
Rushmore	Little Rock River	394			Stabilization Ponds

a/ This includes industrial wastes discharged to municipal plants.

TABLE E-4

INDUSTRIAL WASTE SOURCES[a/]
(DIRECT DISCHARGES) BIG SIOUX RIVER BASIN

Source	Manufacturing Process	Flow m^3/day	Flow (mgd)	Receiving Water	Type of Treatment
Concrete Materials Co., Inc. Sioux Falls, S. Dak.	Crushed aggregate (April-Nov.)	1,060	(0.28)	Big Sioux River	Screening, Sedimentation
Concrete Materials Summit, S Dak.	Gravel washing			Tributary to Big Sioux River	Settling Ponds-closed system
DeSmet Rendering Co. DeSmet, S Dak	Rendering activities	265	(0 07)	b/	Grease removal
EROS Sioux Falls, S. Dak.	Photofinishing			No Discharge until Spring of 1975	
Hallett Construction Co. Watertown, S. Dak	Gravel washing			Willow Creek	Settling pond
Iowa Beef Processors, Inc. Luverne, Minn.	Meat Packing	3,780	(1.0)	Rock River	Sedimentation, anaerobic lagoon, aerobic lagoon[c/]
L. G Everist, Inc. Dell Rapids, S. Dak.	Gravel washing and quarrying (April-Nov.)	5,300	(1.40)	Big Sioux River	Settling Ponds
Northern States Power Co. (Lawrence Plant) Sioux Falls, S Dak.	Power generation	908	(0.24)	Big Sioux River	Cooling towers, screening, lime precipitation
Northern States Power Co. (Pathfinder Plant) Sioux Falls, S Dak.	Power generation	2,200	(0.58)	Big Sioux River	Cooling towers, settling basin
F J McLaughlin Construction Co Watertown, S Dak.	Gravel washing			Big Sioux River	Settling basin (closed system)
Rock River Gravel Co. Pipestone, Minn	Gravel washing			Pipestone Creek	
Watertown Rendering Co Watertown, S Dak	Rendering activities	189	(0.05)	Big Sioux River	Settling ponds

a/ The data were taken from various sources Refuse Act Permit Applications, Interim Plan-Big Sioux River Basin-South Dakota, Correspondence-Iowa Water Pollution Control Commission, NFIC-D Reconnaissance of Big Sioux River Basin-Minnesota.
b/ This is a non-contributing part of the basin.
c/ The firm is installing a spray-irrigation system with complete retention during the irrigation season.

TABLE E-5

APPLICATIONS FOR WASTEWATER DISPOSAL PERMITS FROM
OPERATORS OF FEEDLOTS IN SOUTH DAKOTA WITH POSSIBLE DRAINAGE
TO THE BIG SIOUX RIVER OR ITS TRIBUTARIES.
AUGUST 1972

Number	County	Owner	Drainage	Animal Units c/
a/ 1	Brookings	L.S. Barrnet	Big Sioux River	100 C, 500 S
2	"	SDSU	Six Mile Cr.	11,000 P
3	"	SDSU	Six Mile Cr.	300 C
4	"	SDSU	Six Mile Cr.	370 C
5	"	SDSU	Six Mile Cr.	500 S
6	"	C.E. Nelson	Medary Cr.	800 C & S
a/ 7	"	A.J. Vanderwal	Big Sioux River	1,000 C
8	"	Steven Goodfellow	Oakwood Lake	300 C & S
b/ 9	"	Alvin Johnson	N. Deer Cr.	300 C, 500 S
10	"	Stanley Hesby	Lake Sinani	225 C, 200 S
b/ 11	"	M.V. Kleinjan	Trib. Big Sioux R.	150 C, 450 S
b/ 12	"	Arthur Vanderwal	Big Sioux River	135 C
b/ 13	"	Leland Schlimmer	Trib. Big Sioux R.	300 C, 400 S
a/ 14	"	Earnest Telkamp	Medary Creek	5,000 C & S & Sh
15	"	Lloyd Minor	Medary Creek	490 C
b/ 16	"	D. W. Harvey	Medary Creek	200 C
b/ 17	"	Richard Jenson	Trib. Big Sioux R.	100 C, 250 S
b/ 18	"	Lyle Telkamp	Medary Creek	250 C
b/ 19	Minnehaha	Howard Johnson	Split Rock Creek	600 C & S
20	"	Paul Rooney	Split Rock Creek	3,000 C
21	"	Henry Sieps	Split Rock Creek	150 C
22	"	Wayne Burkhurt	Pipestone Creek	1,000 C & S
23	"	Roger Skallard	Split Rock Creek	200 C
24	"	Herbert Ranschau	Skunk Creek	500 C
25	"	C.J. Delbridge	Trib. Big Sioux R.	844 C
26	Lincoln	Gerhard Sweeter	Beaver Creek	800 C
27	"	Ronald Larson	Beaver Creek	100 S, 300 Sh
28	"	Robert Roetzel	Beaver Creek	400 C
29	"	Lowell Larson	Trib. Big Sioux R.	150 C
30	Union	Andrew Quam	Trib. Big Sioux R.	450 C
31	Union	Larry L. Nilson	Trib. Big Sioux R.	1,000 C

a/ The feedlot has been inspected.
b/ This feedlot has been inspected and needs waste control facilities. (Of the eleven feedlots inspected, eight need control.)
c/ C refers to cow;
S refers to swine;
Sh to sheep;
P to poultry; and
C & S to combined cows & swine.

TABLE E-6

REGISTERED FEEDLOTS IN THE BIG SIOUX RIVER BASIN IN IOWA

Owner	County	Location	Capacity[a/]
Ralph L. Kooiker	Lyon	E 1/2, Sec. 10, Cleveland T.[b/]	3,500
Vertis Garnmeister	"	NE 1/4, Sec. 8, Wheeler T.	2,500
Alfred TeSlaa	"	Sec. 5, Rock T.	1,500
Walter Jansma & Son	"	Sec. 6 & 7, Rock T.	
Howard P. Mogler	"	SE 1/4, Sec. 12, Logan T.	800
John Colenbrander	Sioux	SW 1/4, Sec. 30, Welcome T.	1,000
Ken Aulstein	"	SE 1/4, Sec. 18, Welcome T.	1,000
Lawrence Ter Horst	"	SW 1/4, Sec. 28, Center T.	1,600
Theodore Port	Plymouth	SE 1/4, Sec. 8, Sioux T.	300 Hogs
J. Thomas Kenney	"	NE 1/4, Sec. 12, Westfield T.	600

a/ Except where otherwise denoted numbers refer to cattle.
b/ The letter "T" denotes the township.

APPENDIX F

SUMMARY TABLES FROM STREAM AND PLANT STUDY DATA

TABLE F-1
SUMMARY OF BACTERIOLOGICAL ANALYSES
BIG SIOUX RIVER
FEBRUARY, 1973

Station Description*	Total Coliforms Count/100 ml Maximum	Total Coliforms Count/100 ml Log Mean	Total Coliforms Count/100 ml Minimum	Fecal Coliforms Count/100 ml Maximum	Fecal Coliforms Count/100 ml Log Mean	Fecal Coliforms Count/100 ml Minimum	Fecal Streptococci Count/100 ml Maximum	Fecal Streptococci Count/100 ml Log Mean	Fecal Streptococci Count/100 ml Minimum
Big Sioux River at U S. Highway 14, 3.2 km east of Volga, S. D. (RM 243.9)	16,000	820	120	1,300	100	50	30,000	650	100
Big Sioux River 16.2 km S.E. of Brookings, S.D ; 0.8 km downstream from I-29 Bridge (RM 232.6)	84,000	3,000	800	350	170	20	3,900	1,500	950
Big Sioux River at S D Highway 34, 4.8 km S.W Flandreau, S.D. (RM 206 1)	29,000	7,600	1,100	980	150	50	50,000	3,600	550
Big Sioux River 1.6 km west of Renner, S.D. (RM 162.2)	12,000	2,200	820	320	200	100	10,000	2,100	660
Meilman Food Industries Lagoon System Effluent (RM 154.2)	360,000	210,000	120,000	140,000	57,000	37,000	8,600,000	3,300,000	1,000,000
Skunk Creek at Marion Road W. Sioux Falls, S.D. (RM 152 8/1.1)	10,000	670	20	100	<24	<4	9,500	1,500	230
Big Sioux River at Western Avenue S W. Sioux Falls, S D (RM 150.6)	10,000	1,300	320	490	210	100	99,000	42,000	22,000
Big Sioux River opposite Morrell Condenser 0.2 km upstream of Diversion Canal, Sioux Falls, S D. (RM 143 2)	19,000	1,700	600	2,200	240	43	3,100	1,200	390
Sioux Falls, S D. WWTP Effluent (RM 143.0)	>8,000,000	>1,300,000	470,000	>600,000	>180,000	23,000	53,000,000	2,000,000	120,000

TABLE F-1 (Cont.)

SUMMARY OF BACTERIOLOGICAL ANALYSES
BIG SIOUX RIVER
FEBRUARY, 1973

Station Description*	Total Coliforms Count/100 ml Maximum	Total Coliforms Count/100 ml Log Mean	Total Coliforms Count/100 ml Minimum	Fecal Coliforms Count/100 ml Maximum	Fecal Coliforms Count/100 ml Log Mean	Fecal Coliforms Count/100 ml Minimum	Fecal Streptococci Count/100 ml Maximum	Fecal Streptococci Count/100 ml Log Mean	Fecal Streptococci Count/100 ml Minimum
Sioux Falls, S D , WWTP By-pass Effluent (RM 142 9)	54,000,000	16,000,000	1,500,000	30,000,000	4,300,000	150,000	540,000,000	>82,000,000	2,800,000
Big Sioux River at Highway 77 (Cliff Avenue) 0.5 km downstream from Sioux Falls, S.D., Wastewater Treatment Plant (RM 142.7)	210,000	70,000	17,000	17,000	5,900	2,200	390,000	110,000	7,100
Big Sioux River downstream from I-229 2.9 km downstream from Sioux Falls, S D. , Wastewater Treatment Plant (RM 141.2)	280,000	120,000	51,000	50,000	13,000	1,300	>1,000,000	>14,000	1,900
Big Sioux River at Brandon Road, west of Brandon, S.D. (RM 134 5)	540,000	100,000	9,900	56,000	12,000	680	1,400,000	74,000	1,200
Split Rock Creek at U S. Highway 16, 2.4 km east of Brandon, S D. (RM 130 1/5 3)	9,900	2,200	390	68	39	10	7,000	1,900	730
Big Sioux River at Highway 38 Bridge, approximately 2.4 km upstream of Iowa-South Dakota state boundary (RM 128 5)	36,000	13,000	3,900	3,900	1,400	170	91,000	11,000	2,100
Big Sioux River at Highway 18 4.8 km east of Canton, S D. (RM 106 2)	3,700	1,500	270	480	130	10	3,100	760	260
Rock River 4.8 km east of Hudson, S D. on South Dakota Spur #46 (RM 76.2/5.8)	10,000	4,700	1,600	1,000	630	390	31,000	5,800	1,100

TABLE F-1 (Cont.)

SUMMARY OF BACTERIOLOGICAL ANALYSES
BIG SIOUX RIVER
FEBRUARY, 1973

Station Description*	Total Coliforms Count/100 ml Maximum	Total Coliforms Count/100 ml Log Mean	Total Coliforms Count/100 ml Minimum	Fecal Coliforms Count/100 ml Maximum	Fecal Coliforms Count/100 ml Log Mean	Fecal Coliforms Count/100 ml Minimum	Fecal Streptococci Count/100 ml Maximum	Fecal Streptococci Count/100 ml Log Mean	Fecal Streptococci Count/100 ml Minimum
Big Sioux River 1.6 km east of Hudson, S.D Spur #46 (RM 80.9)	1,900	560	190	170	<55	<10	3,100	930	540
Big Sioux River at Iowa Highway 10, 6.4 km north of Hawarden, Iowa (RM 66.9)	3,600	2,100	1,000	490	240	120	4,300	3,200	1,700
Big Sioux River at South Dakota Highway 48, Akron, Iowa (RM 46 8)	3,300	1,200	600	260	170	80	24,000	7,400	3,700
Big Sioux River at U.S. 77 Northwest Sioux City, Iowa (Military Road) (RM 5.0)	3,200	910	250	200	100	40	9,400	5,100	2,800

* Under individual station descriptions, metric unit equivalents are made as 1 km = 0.62 miles.

TABLE F-2
SUMMARY OF BACTERIOLOGICAL ANALYSES
ROCK RIVER
FEBRUARY, 1973

Station Description*	Total Coliforms Count/100 ml			Fecal Coliforms Count/100 ml			Fecal Streptococci Count/100 ml		
	Maximum	Log Mean	Minimum	Maximum	Log Mean	Minimum	Maximum	Log Mean	Minimum
Rock River 0.8 km upstream of Luverne, Minnesota, Wastewater Treatment Plant (RM 76 2/52 5).**	<100	<84	70	12	11	10	390	350	320
Rock River at Minnesota-Iowa State Line Bridge, 7.2 km north of Rock Rapids, Iowa (RM 76 2/40 8)**	2,500	2,500	2,500	590	410	280	2,300	1,600	1,100
Little Rock River at Highway 75 Bridge, 4.8 km east of Doon, Iowa (RM 76 2/23 1/4 0)**	170	130	100	32	31	30	2,700	1,900	1,300
Rock River at Lyon, Colorado Road K42 Bridge, 1.6 km north of Doon, Iowa (RM 76.2/25 7)**	3,100	2,800	2,600	1,200	690	400	2,700	2,400	2,100
Rock River 4.8 km east of Hudson, S D. on South Dakota Spur #46 (RM 76 2/5 8)**	10,000	4,700	1,600	1,000	630	390	31,000	5,800	1,100

* Under individual station descriptions metric unit equivalents are made as 1 km = 0.62 mile.
** Summary of 2 samples.
*** Summary of 10 samples.

TABLE F-3

SALMONELLA ISOLATIONS FROM
BIG SIOUX RIVER, FEBRUARY, 1973

River Mile	Station Description	Serotypes Isolated
143/0.2	Diversion Canal 0.3 km (0.2 mi.) upstream of Sioux Falls, South Dakota, Wastewater Treatment Plant.	No *Salmonella* isolated
154.2	Meilman Food Industries Lagoon System Effluent at Point of Discharge to Big Sioux River.	*S. siegberg* *S. tennessee* *S. bareilly*
143.0	Sioux Falls, South Dakota, Wastewater Treatment Plant discharge.	*S. heidelberg* *S. oranienburg*
142.9	Sioux Falls, South Dakota, Wastewater Treatment Plant by-pass discharge.	*S. heidelberg* *S. anatum*
142.7	Big Sioux River at U.S. Highway 77 bridge, 0.5 km (0.3 mi.) downstream from Sioux Falls, South Dakota, Wastewater Treatment Plant.	*S. heidelberg* *S. derby*
134.5	Big Sioux River at Brandon Rd.; west of Brandon, South Dakota.	*S. heidelberg* *S. anatum* *S. derby*
128.5	Big Sioux River at Highway 38 bridge, 2.4 km (1.5 mi.) upstream of Iowa-South Dakota State line.	*S. heidelberg* *S. anatum* *S. eimsbuettel*

TABLE F-4

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average load kg/day	Average load lb/day
RM 263.5 -- Big Sioux River at S.D. Hwy. 28, 2.4 km (1.5 mi) W of Estelline, S.D. (1423)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)			7.6		
Temperature (°C)			0.0		
Conductivity (μmhos/cm)			850		
BOD	1		2.8		
COD	1		62		
TOC	1		14		
Total Solids	1		722		
Suspended Solids	1		21		
NH_3-N	1		0.67		
Total Kjeldahl Nitrogen-N	1		2.01		
Organic-N	1		1.34		
NO_2 + NO_3-N	1		1.08		
Total Phosphorus-P	1		0.40		
Turbidity (JTU)					
Dissolved Oxygen	1		6.8		
RM 243.9 -- Big Sioux River at U.S. Hwy. 14, 3 km (2 mi) E of Volga, S.D. (1422)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.7-7.9			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		650-850			
BOD	8	1.4-6.2	3.9		
COD	8	37-78	56		
TOC	8	9-21	14		
Total Solids	6	560-661	612		
Suspended Solids	6	5-18	9		
NH_3-N	8	0.31-0.42	0.38		
Total Kjeldahl Nitrogen-N	8	1.27-1.75	1.43		
Organic-N	8	0.91-1.33	1.06		
NO_2 + NO_3-N	8	1.13-1.32	1.24		
Total Phosphorus-P	8	0.19-0.39	0.29		
Turbidity (JTU)	8	3-6			
Dissolved Oxygen	8	8.6-12	10.4		
RM 232.6 -- Big Sioux River, 15.2 km (9.5 mi) SE of Brookings, S.D., 0.8 km (0.5 mi) downstream from the I-29 River Crossing at USGS Gaging Station (1421)					
Flow (m^3/sec)	8	1.5-1.8	1.63		
Flow (mgd)	8	34-41	37.2		
pH (standard units)		7.4-7.9			
Temperature (°C)		0.0-1.0			
Conductivity (μmhos/cm)		600-950			
BOD	3	3.4-47	18	2,500	5,510
COD	4	54-120	90	12,500	27,700
TOC	4	10-45	20	2,750	6,060
Total Solids	3	457-637	570		
Suspended Solids	2	b/	8	1,240	2,740
NH_3-N	8	0.38-0.81	0.63	89.3	197
Total Kjeldahl Nitrogen-N	8	1.60-4.36	2.12	29.8	656
Organic-N	8	1.04-3.68	1.49	20.8	458
NO_2 + NO_3-N	8	0.80-1.33	1.21	170	376
Total Phosphorus-P	4	0.37-0.98	0.53	74.3	164
Turbidity (JTU)	4	4-8			
Dissolved Oxygen	8	7.8-11	9.1		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 206.1 -- Big Sioux River at S.D. Hwy. 34, 4.8 km (3 mi) SW of Flandreau, S.D. (1420)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.4-8.0			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		650-800			
BOD	3	7.8-12	10		
COD	3	90-110	97		
TOC	3	16-20	18		
Total Solids	3	479-549	509		
Suspended Solids	3	7-20	12		
NH_3-N	8	0.69-1.03	0.88		
Total Kjeldahl Nitrogen-N	8	2.40-3.73	2.85		
Organic-N	8	1.52-2.75	1.96		
NO_2 + NO_3-N	8	1.09-1.48	1.30		
Total Phosphorus-P	3	0.60-0.67	0.63		
Turbidity (JTU)					
Dissolved Oxygen	8	7.7-10.0	8.9		
RM 162.2 -- Big Sioux River 1.6 km (1 mi) W of Renner, S.D. (1419)					
Flow (m^3/sec)	8	1.97-3.23	2.67		
Flow (mgd)	8	45-74	61		
pH (standard units)		7.4-7.8			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		650-875			
BOD	8	6.8-16	9.5	2,240	4,940
COD	8	62-86	76	17,600	38,800
TOC	8	16-26	20	4,720	10,400
Total Solids	6	449-606	522		
Suspended Solids	6	7-29	14		
NH_3-N	8	0.45-1.14	0.88	203	448
Total Kjeldahl Nitrogen-N	8	2,17-3.64	2.80	648	1,430
Organic-N	8	1.64-2.50	1.92	444	980
NO_2 + NO_3-N	8	1.34-1.51	1.42	327	721
Total Phosphorus-P	8	0.49-0.72	0.57	132	290
Turbidity (JTU)	8	3-18			
Dissolved Oxygen	8	10-12	10.9		
RM 154.2 -- Spencer Foods, Inc. Lagoon Effluent at Point of Discharge to Big Sioux River, 60 M (200 ft) upstream of 12th St. Bridge in W Sioux Falls, S.D. (1425)					
Flow (m^3/sec)	9	965-2,290	1,400		
Flow (mgd)	9	0.255-0.604	0.370		
pH (standard units)		7.3-7.8			
Temperature (°C)		0.0-0.1			
Conductivity (μmhos/cm)		2,000-3,000			
BOD	c/				
COD	9	310-520	420	562	1,240
TOC	9	73-150	103	141	310
Total Solids	9	990-1,750	1,510		
Suspended Solids	9	54-170	90	118	261
Volatile Suspended Solids	9	44-130	73	96.6	213
NH_3-N		28-69	59	77.1	170
Total Kjeldahl Nitrogen-N	9	64-105	94	128	283
Organic-N	9	24-44	35	49.4	109
NO_2 + NO_3-N	9	0.01-0.39	0.11	0.22	0.49
Total Phosphorus-P	9	7.1-14.1	11.6	15.5	34.1
Turbidity (JTU)					
Dissolved Oxygen					

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 152.8/1.1 -- Skunk Creek at Marion Rd., W of Sioux Falls, S.D. (1416)					
Flow (m^3/sec)	10	0.17-0.19	0.18		
Flow (mgd)	10	3.9-4.5	4.1		
pH (standard units)		7.1-7.6			
Temperature (°C)		0.0-0.0			
Conductivity (µmhos/cm)		650-850			
BOD	5	3.2-34	12	197	434
COD	6	40-98	55	857	1,890
TOC	6	8-29	17	265	585
Total Solids	4	399-669	525		
Suspended Solids	4	5-12	8	128	282
NH_3-N	10	0.56-1.38	0.94	14.6	32.3
Total Kjeldahl Nitrogen-N	10	1.65-4.41	2.38	37.3	82.4
Organic-N	10	0.76-3.03	1.44	18.0	39.8
NO_2 + NO_3-N	10	1.02-1.40	1.19	18.4	40.7
Total Phosphorus-P	5	0.19-0.74	0.35	5.58	12.3
Turbidity (JTU)					
Dissolved Oxygen	10	5.2-9.0	7.4		
RM 150.6 -- Big Sioux River at Western Ave., SW Sioux Falls, S.D. (1415)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.5-7.5			
Temperature (°C)		0-0			
Conductivity (µmhos/cm)		960-1,150			
BOD	2	6.8-8.0	7.4		
COD	2	b/	49		
TOC	2	b/	10		
Total Solids	1		802		
Suspended Solids	1		26		
NH_3-N	4	0.57-2.85	1.95		
Total Kjeldahl Nitrogen-N	4	2.11-4.28	3.50		
Organic-N	4	1.33-1.91	1.55		
NO_2 + NO_3-N	4	0.81-0.98	0.89		
Total Phosphorus-P	2	0.60-0.70	0.65		
Turbidity (JTU)					
Dissolved Oxygen	4	7.3-8.3	7.8		
RM 143.2 -- Big Sioux River Opposite John Morrell and Co. Former Discharge, 0.2 km (0.1 mi) upstream of Diversion Canal (1413)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.5-8.2			
Temperature (°C)		0.0-0.0			
Conductivity (µmhos/cm)		380-1,100			
BOD	9	4.2-6.6	5.8		
COD	9	46-66	55		
TOC	9	9-19	13		
Total Solids	7	640-795	702		
Suspended Solids	7	6-27	16		
NH_3-N	10	1.37-2.47	2.04		
Total Kjeldahl Nitrogen-N	10	2.87-3.94	3.57		
Organic-N	10	1.04-2.52	1.52		
NO_2 + NO_3-N	10	1.01-1.16	1.08		
Total Phosphorus-P	10	0.38-0.97	0.54		
Turbidity (JTU)					
Dissolved Oxygen	10	13-15	13.2		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 143.0 -- Sioux Falls, S.D., Wastewater Treatment Plant Effluent (1412)					
Flow (m^3/sec)		24,100-39,400	34,000		
Flow (mgd)	10	6.38-10.4	8.99		
pH (standard units)		7.2-7.8			
Temperature (°C)		9.0-12.0			
Conductivity (µmhos/cm)		2,200-3,000			
BOD	8	72-140	110	3,710	8,190
COD	8	110-210	152	5,310	11,700
TOC	8	24-69	38	1,300	2,860
Total Solids	8	1,450-1,830	1,580		
Suspended Solids	8	16-67	33	1,120	2,460
Volatile suspended solids	8	14-44	24	794	1,750
NH_3-N	8	36-45	40	1,400	3,090
Total Kjeldahl Nitrogen-N	8	41-65	52	1,820	4,010
Organic-N	8	4-25	12	419	924
NO_2 + NO_3-N	8	5.5-12.6	8.7	300	661
Total Phosphorus-P	8	12.4-15.3	13.7	475	1,048
Turbidity (JTU)					
Dissolved Oxygen					
RM 142.9 -- Sioux Falls, S.D., Wastewater Treatment Plant By-pass (1424)					
Flow (m^3/sec)		83.3-435	193		
Flow (mgd)		0.022-0.115	0.051		
pH (standard units)		6.8-7.4			
Temperature (°C)		11.5-16.0			
Conductivity (µmhos/cm)		2,200-5,500			
BOD	10	250-1,300	880	173	382
COD	10	560-1,900	1,450	294	649
TOC	10	130-500	330	68.0	150
Total Solids	10	1,850-3,300	2,600		
Suspended Solids	10	220-640	450	87.5	193
Volatile Suspended Solids	10	200-550	376	74.8	165
NH_3-N	10	40-72	54	10.3	22.8
Total Kjeldahl Nitrogen-N	10	120-180	151	29.4	64.8
Organic-N	10	67-119	97.4	19.0	42.0
NO_2 + NO_3-N	10	0.05-0.67	0.17	0.03	0.06
Total Phosphorus-P	10	16.3-24.9	20.1	4.10	9.05
Turbidity (JTU)					
Dissolved Oxygen					
RM 142.7 -- Big Sioux River at U.S. Hwy. 77 (Cliff Ave.), 0.5 km (0.3 mi) downstream from Sioux Falls, S.D. Wastewater Treatment Plant (1411)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.4-8.0			
Temperature (°C)		<0.0-1.5			
Conductivity (µmhos/cm)		500-1,200			
BOD	5	5-11	7.9		
COD	5	89-100	96		
TOC	5	15-29	19		
Total Solids	4	584-675	611		
Suspended Solids	4	3-18	11		
NH_3-N	10	1.26-6.33	3.34		
Total Kjeldahl Nitrogen-N	10	2.6-8.75	6.13		
Organic-N	10	1.34-4.43	2.78		
NO_2 + NO_3-N	10	1.23-1.40	1.33		
Total Phosphorus-P	6	0.89-1.67	1.28		
Turbidity (JTU)					
Dissolved Oxygen	10	12-13	12.9		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 141.2 -- Big Sioux River downstream from I-229, 2.9 km (1.8 mi) Downstream from Sioux Falls, S.D., Wastewater Treatment Facility (1410)					
Flow (m^3/sec)	10	3.13-3.95	3.45		
Flow (mgd)	10	71.6-90.3	79.1		
pH (standard units)		7.4-7.8			
Temperature (°C)		<0.0-3.5			
Conductivity (μmhos/cm)		600-100			
BOD	10	4.6-11	8.2	2,470	5,440
COD	10	64-94	75	19,600	43,300
TOC	10	15-21	18	5,400	11,900
Total Solids	8	541-722	632		
Suspended Solids	8	7-16	11.4	3,470	7,660
NH_3-N	10	3.26-7.05	4.7	1,400	3,080
Total Kjeldahl Nitrogen-N	10	5.86-11.5	7.53	2,260	4,980
Organic-N	10	1.43-4.32	2.87	862	1,900
NO_2 + NO_3-N	10	1.18-1.45	1.29	386	852
Total Phosphorus-P	10	1.07-1.99	1.52	454	1,000
Turbidity (JTU)					
Dissolved Oxygen	10	12-13	12.6		
RM 134.5 -- Big Sioux River at Brandon Rd. Bridge 0.8 km (0.5 mi) W of Brandon, S.D. (1409)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.3-7.6			
Temperature (°C)		<0.0-3.0			
Conductivity (μmhos/cm)		400-1,300			
BOD	5	6.2-9.9	8.1		
COD	5	65-95	76		
TOC	5	12-22	17		
Total Solids	4	627-801	682		
Suspended Solids	4	7-23	12		
NH_3-N	10	5.17-7.79	6.57		
Total Kjeldahl Nitrogen-N	10	9.18-12.7	10.6		
Organic-N	10	2.80-6.98	4.35		
NO_2 + NO_3-N	10	1.35-1.70	1.58		
Total Phosphorus-P	5	1.71-2.67	2.14		
Turbidity (JTU)					
Dissolved Oxygen	10	11-12	11		
RM 130.1/5.3 -- Split Rock Creek at U.S. Hwy. 16, 2.4 km (1.5 mi) E of Brandon, S.D. (1408)					
Flow (m^3/sec)	10	0.48-1.18	0.63		
Flow (mgd)	10	11-27.1	14.5		
pH (standard units)		7.1-7.7			
Temperature (°C)		0.0-0.5			
Conductivity (μmhos/cm)		375-500			
BOD	5	3.0-12	7.2	476	1,050
COD	5	73-100	86	5,160	11,370
TOC	5	20-43	27	1,740	3,840
Total Solids	4	281-353	323		
Suspended Solids	4	3-18	9	429	947
NH_3-N	9	1.34-1.96	1.74	93.0	205
Total Kjeldahl Nitrogen-N	9	3.50-4.27	3.90	216	477
Organic-N	9	1.73-2.93	2.17	124	273
NO_2 + NO_3-N	9	0.93-1.05	0.99	54.0	119
Total Phosphorus-P	5	0.63-0.86	0.72	43.5	96
Turbidity (JTU)	5	2-13			
Dissolved Oxygen	10	6.4-7.4	6.8		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 128.5 -- Big Sioux River at Hwy. 38 Bridge, approx. 2.4 km (1.5 mi) upstream of Iowa-South Dakota State Boundary (1407)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.1-7.8			
Temperature (°C)		0.0-1.0			
Conductivity (µmhos/cm)		540-850			
BOD	10	4.6-11	7.3		
COD	10	74-98	86		
TOC	10	17-27	21		
Total Solids	8	526-623	574		
Suspended Solids	8	5-31	15		
NH_3-N	10	2.04-6.31	4.85		
Total Kjeldahl Nitrogen-N	10	5.39-9.56	7.33		
Organic-N	10	1.76-3.94	2.48		
NO_2 + NO_3-N	10	1.26-1.49	1.38		
Total Phosphorus-P	5	1.21-1.76	1.58		
Turbidity (JTU)					
Dissolved Oxygen	10	6.6-8.9	7.8		
RM 106.2 — Big Sioux River at U.S. Hwy. 18, 4.8 km (3 mi) E of Canton, S.D. (1406)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.2-7.6			
Temperature (°C)		0.0-0.5			
Conductivity (µmhos/cm)		600-900			
BOD	9	4.6-12	6.3		
COD	9	61-86	77		
TOC	9	17-25	20		
Total Solids	7	506-639	580		
Suspended Solids	7	8-16	11		
NH_3-N	10	2.97-6.61	4.56		
Total Kjeldahl Nitrogen-N	10	5.17-7.94	6.27		
Organic-N	10	0.63-2.20	1.72		
NO_2 + NO_3-N	10	1.38-1.73	1.56		
Total Phosphorus-P	10	1.01-1.62	1.39		
Turbidity (JTU)	9	4-10			
Dissolved Oxygen	10	5.6-7.3	6.5		
RM 80.9 — Big Sioux River 1.6 km (1 mi) E of Hudson, S.D. on S.D. Spur No. 46 (1404)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		6.9-7.5			
Temperature (°C)		0.0-1.0			
Conductivity (µmhos/cm)		700-870			
BOD	5	3.6-9.6	5.7		
COD	5	64-100	84		
TOC	5	18-28	20		
Total Solids	4	555-612	597		
Suspended Solids	4	12-22	16		
NH_3-N	10	2.48-4.10	3.61		
Total Kjeldahl Nitrogen-N	10	4.69-6.64	5.52		
Organic-N	10	1.39-2.75	1.91		
NO_2 + NO_3-N	10	1.49-1.75	1.64		
Total Phosphorus-P	5	0.94-1.37	1.20		
Turbidity (JTU)					
Dissolved Oxygen	10	4.2-5.5	4.8		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 76.2/52.5 -- Rock River, 0.8 km (0.5 mi) upstream of Luverne, Minnesota, Wastewater Treatment Plant (1429)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.2-7.3			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		480-540			
BOD	2	2.0-6.2	4.1		
COD	2	56-72	64		
TOC	2	21-24	22		
Total Solids	2	389-398	394		
Suspended Solids	2	13-14	14		
NH_3-N	2	1.54-1.57	1.56		
Total Kjeldahl Nitrogen-N	2	3.04-3.11	3.08		
Organic-N	2	1.50-1.54	1.52		
NO_2 + NO_3-N	2	1.40-1.44	1.42		
Total Phosphorus-P	2	0.44-0.57	0.50		
Turbidity (JTU)					
Dissolved Oxygen	2	2.2-2.6	2.4		
RM 76.2/40.8 - Rock River at Minnesota-Iowa State Boundary, 8 km (5 mi) N of Rock Rapids, Iowa (1428)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.2-7.3			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		500-580			
BOD	2	6.2-6.3	6.2		
COD	2	53-80	66		
TOC	2	23-18	20		
Total Solids	2	413-440	42		
Suspended Solids	2	20-25	22		
NH_3-N	2	1.66-1.68	1.67		
Total Kjeldahl Nitrogen-N	2	3.32-3.40	3.36		
Organic-N	2	1.66-1.72	1.69		
NO_2 + NO_3-N	2	1.18-1.28	1.23		
Total Phosphorus-P	2				
Turbidity (JTU)					
Dissolved Oxygen	2	3.8-3.8	3.8		
RM 76.2/25.7 - Rock River at Lyon County Road K 42 Bridge, 1.6 km (1 mi) N of Doon, Iowa (1426)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.4-7.5			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		500-580			
BOD	2	3.5-5.6	4.6		
COD	2	58-76	67		
TOC	2	16-22	19		
Total Solids	2	389-405	397		
Suspended Solids	2	4-12	8		
NH_3-N	2	1.59-1.72	1.66		
Total Kjeldahl Nitrogen-N	2	3 44-3.50	3.47		
Organic-N	2	1.78-1.85	1.82		
NO_2 + NO_3-N	2	1.27-1.28	1.28		
Total Phosphorus-P	2	0.52-0.85	0.68		
Turbidity (JTU)					
Dissolved Oxygen	2	6.6-6.6	6.6		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 76.2/23.1/4.0 -- Little Rock River at Hwy 75 Bridge, 4.8 km (3 mi) E of Doon, Iowa (1427)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		7.1-7.1			
Temperature (°C)		0.0-0.0			
Conductivity (μmhos/cm)		650-700			
BOD	2	3.5-5.0	4.2		
COD	2	38-64	51		
TOC	2	13-16	14		
Total Solids	2	457-503	480		
Suspended Solids	2	4-13	8.5		
NH_3-N	2	1.46-1.48	1.47		
Total Kjeldahl Nitrogen-N	2	2.65-2.67	2.66		
Organic-N	2	1.09-1.19	1.14		
NO_2 + NO_3-N	2	1.63-1.65	1.64		
Total Phosphorus-P	2				
Turbidity (JTU)					
Dissolved Oxygen	2	2.4-2.4	2.4		
RM 76.2/5.8 -- Rock River 4.8 km (3 mi) E of Hudson, S.D. on S.D. Spur No. 46 (1405)					
Flow (m^3/sec)	10	b/	5.64		
Flow (mgd)	10	b/	129		
pH (standard units)		7.0-7.6			
Temperature (°C)		0.0-1.0			
Conductivity (μmhos/cm)		420-600			
BOD	5	1.9-9.2	5.9	2,880	6,350
COD	5	45-69	61	29,750	65,600
TOC	5	20-31	24	1,180	26,000
Total Solids	4	348-405	363		
Suspended Solids	4	8-20	15	7,350	16,200
NH_3-N	10	1.89-2.72	2.13	1,040	2,290
Total Kjeldahl Nitrogen-N	10	3.50-4.80	4.13	2,010	4,440
Organic-N	10	1.45-2.79	2.00	975	2,150
NO_2 + NO_3-N	10	1.22-1.44	1.30	635	1,400
Total Phosphorus-P	5	0.65-1.06	0.83	403	888
Turbidity (JTU)	5	5-20			
Dissolved Oxygen	10	1.4-6.0	3.0		
RM 66.9 -- Big Sioux River at Iowa Hwy. 10, 6.4 km (4 mi) N of Hawarden, Iowa (1403)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		6.9-7.6			
Temperature (°C)		0.0-1.0			
Conductivity (μmhos/cm)		520-850			
BOD	4	3.6-5.8	5.1		
COD	4	71-89	80		
TOC	4	18-24	21		
Total Solids	4	445-510	483		
Suspended Solids	4	4-21	12		
NH_3-N	10	2.30-3.45	2.84		
Total Kjeldahl Nitrogen-N	10	4.37-5.44	4.87		
Organic-N	10	1.54-2.51	2.00		
NO_2 + NO_3-N	10	1.37-1.52	1.44		
Total Phosphorus-P	4	0.93-1.18	1.04		
Turbidity (JTU)					
Dissolved Oxygen	10	2.4-5.6	3.3		

TABLE F-4 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
BIG SIOUX RIVER AND TRIBUTARIES
SOUTH DAKOTA-IOWA-MINNESOTA
1-10 FEBRUARY 1973

Parameter[a/]	No. of Samples	Range	Average	Average Load kg/day	Average Load lb/day
RM 46.8 -- Big Sioux River at South Dakota Hwy. 48, Akron, Iowa (1402)					
Flow (m^3/sec)	10	10.0-16.8	12.8		
Flow (mgd)	10	232-384	293		
pH (standard units)		7.0-7.5			
Temperature (°C)		0.0-0.5			
Conductivity (µmhos/cm)		460-690			
BOD	10	3.7-14	7.0	8,340	18,400
COD	10	60-94	84	95,200	210,000
TOC	10	16-27	21	24,900	54,900
Total Solids	7	433-524	478		
Suspended Solids	7	10-43	24	24,900	55,000
NH_3-N	10	2.25-3.07	2.53	27,800	6,140
Total Kjeldahl Nitrogen-N	10	4.22-5.21	4.66	5,220	11,500
Organic-N	10	1.61-2.85	2.13	2,420	5,330
NO_2 + NO_3-N	10	1.34-1.55	1.45	1,590	3,500
Total Phosphorus-P	10	0.74-1.47	1.02	1,170	2,570
Turbidity (JTU)					
Dissolved Oxygen	10	1.8-3.4	2.6		
RM 5.0 -- Big Sioux River at U.S. Hwy. 77 (Military Rd.) NW Sioux City, Iowa (1401)					
Flow (m^3/sec)					
Flow (mgd)					
pH (standard units)		6.9-7.5			
Temperature (°C)		0.0-1.0			
Conductivity (µmhos/cm)		500-650			
BOD	4	5.0-6.8	5.6		
COD	4	67-78	75		
TOC	4	16-23	21		
Total Solids	4	460-518	495		
Suspended Solids	4	21-38	31		
NH_3-N	7	2.19-2.64	2.32		
Total Kjeldahl Nitrogen-N	7	3.96-5 22	4.43		
Organic-N	7	1.82-3.01	2.11		
NO_2 + NO_3-N	7	1.24-1.70	1.34		
Total Phosphorus-P	2	0.71-1.09	0.90		
Turbidity (JTU)					
Dissolved Oxygen	4	1.7-3.0	2.3		

a/ All values are reported as mg/l, except where specified.
b/ All values are the same.
c/ Sample was toxic and no DO depletion occurred.

TABLE F-5

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1450 -- Industrial Pretreatment Plant - Influent (Combined)

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
S E V E N - D A Y					
Flow (m^3/day)	1	7,120-18,700	14,800		
Flow (mgd)		1.88-4.94	3.91		
pH (standard units)		6.6-8.1			
Temperature (°C)		8.5-25.0			
Conductivity (µmhos/cm)		1,600-5,000			
BOD	7	1,000-3,800	1,700	26,100	57,600
COD	7	1,300-4,700	2,470	38,000	83,800
TOC	7	290-980	593	9,070	20,000
Total Solids	7	2,530-4,520	3,320		
Suspended Solids	7	170-1,900	1,010	15,400	33,900
Volatile Suspended Solids	7	130-1,500	813	12,600	27,800
NH_3-N	7	23-40	30	440	969
Total Kjeldahl Nitrogen-N	7	57-240	121	1,860	4,110
Organic-N	7	30-200	91	1,420	3,140
NO_2 + NO_3-N	7	<0.5	<0.5		
Total Phosphorus-P	7	17.3-31.6	23.3	357	787
W E E K - D A Y					
Flow (m^3/day)		15,900-18,700	17,800		
Flow (mgd)		4.21-4.94	4.71		
pH (standard units)		6.6-8.1			
Temperature (°C)		15.5-25.0			
Conductivity (µmhos/cm)		2,600-5,000			
BOD	5	1,000-3,800	1,920	33,300	73,400
COD	5	2,100-4,700	2,760	48,100	106,000
TOC	5	470-980	648	11,400	25,100
Total Solids	5	2,530-4,520	3,500		
Suspended Solids	5	530-1,900	1,110	19,300	42,600
Volatile Suspended Solids	5	420-1,500	922	16,100	35,600
NH_3-N	5	23-40	30	526	1,160
Total Kjeldahl Nitrogen-N	5	92-240	136	2,370	5,220
Organic-N	5	68-200	106	1,840	4,060
NO_2 + NO_3-N	5	<0.5	<0.5		
Total Phosphorus-P	5	22.4-31.6	25.3	448	988
W E E K - E N D					
Flow (m^3/day)		7,110-7,190	7,150		
Flow (mgd)		1.88-1.90	1.89		
pH (standard units)		6.7-7.6			
Temperature (°C)		8.5-22.0			
Conductivity (µmhos/cm)		1,600-3,100			
BOD	2	1,100-1,200	1,150	8,210	18,100
COD	2	1,300-2,200	1,750	2,500	27,600
TOC	2	290-620	455	3,250	7,160
Total Solids	2	2,790-2,960	2,880		
Suspended Solids	2	170-1,400	785	5,560	12,300
Volatile Suspended Solids	2	130-950	540	3,850	8,480
NH_3-N	2	27-34	30	218	481
Total Kjeldahl Nitrogen-N	2	57-110	84	594	1,310
Organic-N	2	30-76	53	378	833
NO_2 + NO_3-N	2	<0.5	<0.5		
Total Phosphorus-P	2	17.3-19.0	18.2	130	286

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1451 -- Industrial Pretreatment Plant - John Morrell & Company, Inc.
Discharge to City System

S E V E N - D A Y

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
Flow (m^3/day)		5,190-15,400	12,100		
Flow (mgd)		1.37-4.08	3.20		
pH (standard units)		5.9-10.5			
Temperature (°C)		8.0-27 0			
Conductivity (µmhos/cm)		3,000-8,000			
BOD	7	1,000-3,600	1,840	24,300	53,500
COD	7	1,900-6,300	3,830	51,300	113,000
TOC	7	320-1,500	809	10,800	23,900
Total Solids	6	3,250-7,270	5,190		
Suspended Solids	6	820-3,100	1,610	20,100	44,400
Volatile Suspended Solids	6	660-2,600	1,330	17,000	37,500
NH_3-N	7	19-42	26	323	712
Total Kjeldahl Nitrogen-N	7	58-290	146	1,960	4,320
Organic-N	7	34-248	119	1,640	3,610
NO_2 + NO_3-N	7	<1.0	<1.0		
Total Phosphorus-P	7	16.3-46.2	36.4	458	1,010

W E E K - D A Y

Parameter	No. of Samples	Range	Average	kg/day	lb/day
Flow (m^3/day)		13,900-15,400	14,600		
Flow (mgd)		3.67-4.08	3.87		
pH (standard units)		6.3-10.5			
Temperature (°C)		20.0-27.0			
Conductivity (µmhos/cm)		3,100-8,000			
BOD	5	1,700-3,600	2,160	21,500	69,500
COD	5	3,300-6,300	4,560	66,700	147,000
TOC	5	720-1,500	980	14,300	31,500
Total Solids	4	3,890-7,270	6,050		
Suspended Solids	4	1,100-3,100	1,840	26,900	59,400
Volatile Suspended Solids	4	890-2,600	1,580	23,[illegible]00	51,100
NH_3-N	5	19-42	27	[illegible]7	375
Total Kjeldahl Nitrogen-N	5	120-290	178	[illegible]	5,730
Organic-N	5	98-248	151	2,[illegible]00	4,860
NO_2 + NO_3-N	5	<1.0	<1.0		
Total Phosphorus-P	5	35.0-46.2	39.2	572	1,260

W E E K - E N D

Parameter	No. of Samples	Range	Average	kg/day	lb/day
Flow (m^3/day)		5,180-6,430	5,830		
Flow (mgd)		1.37-1.70	1.54		
pH (standard units)		5.9-7.7			
Temperature (°C)		8.0-26.5			
Conductivity (µmhos/cm)		3,000-5,000			
BOD	2	1,000-1,100	1,050	6,080	13,400
COD	2	1,900-2,100	2,000	11,700	25,800
TOC	2	320-440	380	2,170	4,790
Total Solids	2	3,250-3,660	3,460		
Suspended Solids	2	820-1,500	1,160	6,530	14,400
Volatile Suspended Solids	2	660-1,000	830	4,720	10,400
NH_3-N	2	24	24	139	307
Total Kjeldahl Nitrogen-N	2	58-71	65	371	817
Organic-N	2	34-47	41	231	510
NO_2 + NO_3-N	2	<1.0	<1.0		
Total Phosphorus-P	2	16.3-42.5	29.4	179	395

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1452 -- Industrial Pretreatment Plant - Primary Clarifier Overflow

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		7,120-18,700	14,800		
Flow (mgd)		1.88-4.94	3.91		
pH (standard units)		6.5-7.7			
Temperature (°C)		7.5-23.0			
Conductivity (μmhos/cm)		3,100-5,200			
BOD	7	340-1,700	1,010	16,200	35,800
COD	7	560-2,400	1,510	24,400	53,900
TOC	7	140-620	356	5,810	12,800
Total Solids	7	1,900-3,390	2,690		
Suspended Solids	7	360-970	584	8,890	19,600
Volatile Suspended Solids	7	180-700	389	6,120	13,500
NH_3-N	7	37-99	66	894	1,970
Total Kjeldahl Nitrogen-N	7	110-200	131	1,940	4,280
Organic-N	7	30-115	65	1,050	2,310
NO_2 + NO_3-N	7	<0.50	<0.50		
Total Phosphorus-P	7	16.0-26.7	21.6	335	739
WEEK-DAY					
Flow (m^3/day)		15,900-18,700	17,800		
Flow (mgd)		4.21-4.94	4.71		
pH (standard units)		6.5-7.5			
Temperature (°C)		14.0-23.0			
Conductivity (μmhos/cm)		3,100-5,200			
BOD	5	820-1,700	1,200	21,200	46.800
COD	5	1,600-2,400	1,820	32,200	70,900
TOC	5	320-620	436	7,670	16,900
Total Solids	5	2,520-3,390	2,960		
Suspended Solids	5	360-970	634	11,100	24,500
Volatile Suspended Solids	5	180-700	448	7,890	17,400
NH_3-N	5	38-85	57.0	993	2,190
Total Kjeldahl Nitrogen-N	5	110-200	135	2,380	5,240
Organic-N	5	49-115	78	1,380	3,040
NO_2 + NO_3-N	5	<0.5	<0.5		
Total Phosphorus-P	5	21.4-26.7	23.8	423	933
WEEK-END					
Flow (m^3/day)		7,110-7,190	7,150		
Flow (mgd)		1.88-1.90	1.89		
pH (standard units)		6.9-7.7			
Temperature (°C)		7.5-16.0			
Conductivity (μmhos/cm)		3,300-4,100			
BOD	2	340-720	530	3,800	8,370
COD	2	560-880	720	5,120	11,300
TOC	2	140-170	155	1,110	2,450
Total Solids	2	1,900-2,110	2,010		
Suspended Solids	2	400-520	460	3,290	7,260
Volatile Suspended Solids	2	210-270	240	1,710	3,780
NH_3-N	2	80-99	90	639	1,410
Total Kjeldahl Nitrogen-N		110-130	120	857	1,890
Organic-N	2	30-31	31	218	481
NO_2 + NO_3-N	2	<0.50	<0.50		
Total Phosphorus-P	2	16.0	16.0	115	253

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1453 -- Industrial Pretreatment Plant - Intermediate Clarifier Overflow

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		7,120-18,700	14,800		
Flow (mgd)		1.88-4.94	3.91		
pH (standard units)		6.6-7.6			
Temperature (°C)		7.0-20.5			
Conductivity (µmhos/cm)		3,400-5,500			
BOD	7	320-1,800	1,010	16,400	36,100
COD	7	420-2,000	1,290	21,000	46,300
TOC	7	130-500	323	5,170	11,400
Total Solids	7	1,920-3,190	2,530		
Suspended Solids	7	220-800	425	5,990	13,200
Volatile Suspended Solids	7	180-650	331	4,580	10,100
NH_3-N	6	58-100	75	1,010	2,220
Total Kjeldahl Nitrogen-N	6	110-180	133	1,900	4,190
Organic-N	6	27-99	58	898	1,980
NO_2 + NO_3-N	6	<0.50	<0.50		
Total Phosphorus-P	6	17.5-26.3	22.4	326	719
WEEK-DAY					
Flow (m^3/day)		15,900-18,700	17,800		
Flow (mgd)		4.21-4.94	4.71		
pH (standard units)		6.6-7.3			
Temperature (°C)		9.0-20.5			
Conductivity (µmhos/cm)		3,400-5,500			
BOD	5	700-1,800	1,210	21,500	47,300
COD	5	1,200-2,000	1,560	27,600	60,900
TOC	5	330-500	380	6,710	14,800
Total Solids	5	256-500	391	6,940	15,300
Volatile Suspended Solids	5	240-380	297	5,260	11,600
NH_3-N	4	58-81	67	1,180	2,610
Total Kjeldahl Nitrogen-N	4	120-180	138	2,400	5,300
Organic-N	4	54-99	70.3	1,220	2,700
NO_2 + NO_3-N	4	<0.5	<0.5		
Total Phosphorus-P	4	20.2-26.3	23.6	418	922
WEEK-END					
Flow (m^3/day)		7,110-7.190	7,150		
Flow (mgd)		1.88-1.90	1.89		
pH (standard units)		7.0-7.6			
Temperature (°C)		7.0-15.5			
Conductivity (µmhos/cm)		3,500-4,200			
BOD	2	320-690	505	3,610	7,960
COD	2	420-820	620	4,440	9,800
TOC	2	130-230	180	1,290	2,840
Total Solids	2	1,940-2,120	2,020		
Suspended Solids	2	220-800	510	3,660	8,080
Volatile Suspended Solids	2	180-650	415	2,980	6,560
NH_3-N	2	83-100	92	653	1,440
Total Kjeldahl Nitrogen-N	2	110-140	125	894	1,970
Organic-N	2	27-40	34	241	531
NO_2 + NO_3-N	2	<0.50	<0.50		
Total Phosphorus-P	2	17.5-22.5	20.0	143	315

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1454 — Industrial Pretreatment Plant - Secondary Trickling Filter Underflow (i.e., Effluent from Industrial Plant)

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		7,120-18,700	14,800		
Flow (mgd)		1.88-4.94	3.91		
pH (standard units)		6.5-7.7			
Temperature (°C)		7.0-17.5			
Conductivity (μmhos/cm)		3,600-5,200			
BOD	7	140-900	459	7,170	15,800
COD	7	280-1,000	643	10,100	22,200
TOC	7	86-290	177	2,800	6,170
Total Solids	7	1,900-2,710	2,310		
Suspended Solids	7	190-580	380	5,720	12,600
Volatile Suspended Solids	7	84-390	239	3,830	8,450
NH_3-N	7	75-120	94.4	1,370	3,020
Total Kjeldahl Nitrogen-N	7	100-160	126	1,860	4,110
Organic-N	7	20-48	31.3	494	1,090
NO_2 + NO_3-N	7	<10.0	<10.0		
Total Phosphorus-P	7	15.0-23.4	20.7	320	706
WEEK-DAY					
Flow (m^3/day)		15,900-18,700	17,800		
Flow (mgd)		4.21-4.94	4.71		
pH (standard units)		7.1-7.7			
Temperature (°C)		7.0-17.5			
Conductivity (μmhos/cm)		3,600-5,200			
BOD	5	290-900	526	9,210	20,300
COD	5	480-1,000	730	12,900	28,400
TOC	5	150-290	202	3,600	7,930
Total Solids	5	2,120-2,710	2,420		
Suspended Solids	5	190-580	400	7,030	15,500
Volatile Suspended Solids	5	190-390	282	4,990	11,000
NH_3-N	5	75-116	92.4	1,630	3,600
Total Kjeldahl Nitrogen-N	5	100-160	128	2,260	4,990
Organic-N	5	25-48	35.6	630	1,390
NO_2 + NO_3-N	5	<10.0	<10.0		
Total Phosphorus-P	5	21.9-23.4	22.6	403	888
WEEK-END					
Flow (m^3/day)		7,110-7,190	7,150		
Flow (mgd)		1.88-1.90	1.89		
pH (standard units)		6.5-7.7			
Temperature (°C)		7.0-15.0			
Conductivity (μmhos/cm)		3,700-4,400			
BOD	2	140-440	290	2,080	4,590
COD	2	280-570	425	3,040	6,710
TOC	2	86-140	113	812	1,790
Total Solids	2	1,900-2,200	2,050		
Suspended Solids	2	200-460	330	2,370	5,220
Volatile Suspended Solids	2	84-180	132	948	2,090
NH_3-N	2	79-120	100	717	1,570
Total Kjeldahl Nitrogen-N	2	100-140	120	862	1,900
Organic-N	2	20-21	21	147	323
NO_2 + NO_3-N	2	<10.0	<10.0		
Total Phosphorus-P	2	15.0-17.0	16.0	114	252

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1455 -- Domestic and Industrial Plant - Domestic Influent to Plant (Before Combining With Industrial Pretreatment Plant Effluent)

S E V E N - D A Y

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
Flow (m^3/day)		14,800-22,400	18,600		
Flow (mgd)		3.90-5.91	4.91		
pH (standard units)		6.9-8.2			
Temperature (°C)		11.0-14.0			
Conductivity (μmhos/cm)		1,500-3,000			
BOD	7	330-840	520	9,980	22,000
COD	7	400-920	744	14,100	31,100
TOC	7	110-190	151	2,840	6,270
Total Solids	7	1,160-2,420	1,510		
Suspended Solids	7	170-310	227	4,230	9,320
Volatile Suspended Solids	7	100-190	159	2,780	6,570
NH_3-N	7	26-32	28	517	1,140
Total Kjeldahl Nitrogen-N	7	40-45	42	780	1,720
Organic-N	7	13-17	14	264	583
NO_2 + NO_3-N	7	<0.2	<0.2		
Total Phosphorus-P	7	9.06-17.1	14.4	266	587

W E E K - D A Y

Parameter	No. of Samples	Range	Average	kg/day	lb/day
Flow (m^3/day)		17,000-22,400	19,700		
Flow (mgd)		4.50-5.91	5.20		
pH (standard units)		6.9-8.2			
Temperature (°C)		12.0-14.0			
Conductivity (μmhos/cm)		1,800-3,000			
BOD	5	330-840	568	11,400	25,200
COD	5	780-920	842	16,500	36,400
TOC	5	150-190	166	3,260	7,180
Total Solids	5	1,320-2,420	1,640		
Suspended Solids	5	200-310	232	4,580	10,100
Volatile Suspended Solids	5	120-190	170	3,360	7,410
NH_3-N	5	26-28	27	535	1,180
Total Kjeldahl Nitrogen-N	5	40-45	42	821	1,810
Organic-N	5	13-17	15	288	635
NO_2 + NO_3-N	5	<0.2	<0.2		
Total Phosphorus-P	5	9.06-17.1	14.5	282	622

W E E K - E N D

Parameter	No. of Samples	Range	Average	kg/day	lb/day
Flow (m^3/day)		14,800-16,900	15,800		
Flow (mgd)		3.90-4.46	4.18		
pH (standard units)		7.3-8.1			
Temperature (°C)		11.0-12.5			
Conductivity (μmhos/cm)		1,500-2,900			
BOD	2	380-420	400	6,350	14,000
COD	2	2400-600	500	8,030	17,700
TOC	2	110-120	115	1,820	4,020
Total Solids	2	1,160-1,220	1,190		
Suspended Solids	2	170-260	215	3,350	7,390
Volatile Suspended Solids	2	100-160	130	2,020	4,460
NH_3-N	2	28-32	30	472	1,040
Total Kjeldahl Nitrogen-N	2	41-45	43	680	1,500
Organic-N	2	13	13	206	454
NO_2 + NO_3-N	2	<0.2	<0.2		
Total Phosphorus-P	2	13.1-15.3	14.2	226	498

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1457 -- Domestic and Industrial Plant - Primary Clarifier Overflow

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
S E V E N - D A Y					
Flow (m^3/day)		21,900-40,900	33,300		
Flow (mgd)		5.78-10.8	8.81		
pH (standard units)		7.1-7.7			
Temperature (°C)		8.5-14.0			
Conductivity (μmhos/cm)		2,200-3,700			
BOD	7	240-1,700	673	23,200	51,100
COD	7	340-2,300	819	29,500	65,100
TOC	7	89-320	167	5,900	13,000
Total Solids	7	1,430-2,670	1,920		
Suspended Solids	7	100-1,400	389	14,400	31,700
Volatile Suspended Solids	7	90-1,200	311	11,700	25,700
NH_3-N	7	47-72	59	1,970	4,340
Total Kjeldahl Nitrogen-N	7	75-180	105	3,630	8,010
Organic-N	7	25-126	46	1,660	3,660
NO_2 + NO_3-N	7	<2.0	<2.0		
Total Phosphorus-P	7	15.0-20.5	18.1	607	1,340
W E E K - D A Y					
Flow (m^3/day)		35,200-40,900	37,500		
Flow (mgd)		9.30-10.8	9.91		
pH (standard units)		7.1-7.6			
Temperature (°C)		9.0-14.0			
Conductivity (μmhos/cm)		2,400-3,600			
BOD	5	490-1,700	806	29,300	64,600
COD	5	550-2,300	954	36,800	81,200
TOC	5	140-320	190	7,210	15,900
Total Solids	5	1,840-2,670	2,080		
Suspended Solids	5	100-1,400	478	18,600	41,000
Volatile Suspended Solids	5	90-1,200	392	15,300	33,800
NH_3-N	5	49-68	59	2,200	4,860
Total Kjeldahl Nitrogen-N	5	79-180	112	4,270	9,420
Organic-N	5	25-126	53	2,060	4,550
NO_2 + NO_3-N	5	<2.0	<2.0		
Total Phosphorus-P	5	15.6-20.5	18.6	694	1,530
W E E K - E N D					
Flow (m^3/day)		21,900-24,100	23,000		
Flow (mgd)		5.78-6.36	6.07		
pH (standard units)		7.3-7.7			
Temperature (°C)		8.5-12.5			
Conductivity (μmhos/cm)		2,200-3,700			
BOD	2	240-440	340	794.0	17,500
COD	2	340-620	480	11,200	24,700
TOC	2	89-130	110	2,540	5,600
Total Solids	2	1,430-1,630	1,530		
Suspended Solids	2	140-190	165	3,760	8,300
Volatile Suspended Solids	2	100-120	110	2,540	5,600
NH_3-N	2	47-72	60	1,380	3,050
Total Kjeldahl Nitrogen-N	2	75-100	88	2,020	4,460
Organic-N	2	28	28	644	1,420
NO_2 + NO_3-N	2	<2.0	<2.0		
Total Phosphorus-P	2	15.0-19.0	17.0	393	867

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1412 -- Domestic and Industrial - Final Clarifier Overflow
(i.e., Wastewater Treatment Plant Effluent)

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
S E V E N - D A Y					
Flow (m^3/day)		21,900-40,900	33,300		
Flow (mgd)		5.78-10.8	8.82		
pH (standard units)		7.0-7.7			
Temperature (°C)		9.0-14.5			
Conductivity (μmhos/cm)		2,300-3,300			
BOD	7	56-140	99	3,370	7,420
COD	7	95-250	158	5,350	11,800
TOC	7	25-42	34	1,120	2,480
Total Solids	7	1,370-1,700	1,530	51,300	113,000
Suspended Solids	7	21-64	37	1,170	2,590
Volatile Suspended Solids	7	8-42	24	844	1,860
NH_3-N	7	33-56	45	1,470	3,240
Total Kjeldahl Nitrogen-N	7	41-61	51	1,690	3,720
Organic-N	7	5-9	7	219	483
NO_2 + NO_3-N	7	<15			
Total Phosphorus-P	7	12.2-15.4	14.0	472	1,040
W E E K - D A Y					
Flow (m^3/day)		35,200-40,900	37,500		
Flow (mgd)		9.30-10.8	9.91		
pH (standard units)		7.0-7.7			
Temperature (°C)		9.0-14.5			
Conductivity (μmhos/cm)		2,300-3,300			
BOD	5	56-140	103	3,910	8,620
COD	5	98-250	164	6,210	13,700
TOC	5	25-42	34	1,280	2,820
Total Solids	5	1,410-1,700	1,560	58,500	129,000
Suspended Solids	5	21-52	34	1,270	2,790
Volatile Suspended Solids	5	14-42	29	1,070	2,350
NH_3-N	5	33-56	42	1,580	3,490
Total Kjeldahl Nitrogen-N	5	41-61	49	1,840	4,050
Organic-N	5	5-9	7	252	555
NO_2 + NO_3-N	5	<15 (8.8)	<15 (8.8)	293	647
Total Phosphorus-P	5	13.4-15.4	14.4	540	1,190
W E E K - E N D					
Flow (m^3/day)		21,900-24,100	23,000		
Flow (mgd)		5.78-6.36	6.07		
pH (standard units)		7.1-7.6			
Temperature (°C)		9.0-13.0			
Conductivity (μmhos/cm)		2,400-3,200			
BOD	2	74-100	87	2,010	4,440
COD	2	95-190	143	3,310	7,290
TOC	2	27-37	32	739	1,630
Total Solids	2	1,370-1,500	1,440	33,000	72,800
Suspended Solids	2	20-64	42	943	2,080
Volatile Suspended Solids	2	8-18	13	293	646
NH_3-N	2	48-55	52	1,190	2,620
Total Kjeldahl Nitrogen-N	2	54-61	58	1,320	2,920
Organic-N	2	6	6	138	304
NO_2 + NO_3-N	2	<15 (8.8)	<15 (8.8)	293	647
Total Phosphorus-P	2	12.2-13.9	13.1	301	664

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1424 -- Wastewater Treatment Plant Bypass

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		5.3-2,910	587		
Flow (mgd)		0.0014-0.77	0.155		
pH (standard units)		6.5-7.5			
Temperature (°C)		8.0-21.0			
Conductivity (μmhos/cm)		3,000-6,000			
BOD	7	370-1,800	1,010	735	1,620
COD	7	560-2,200	1,240	821	1,810
TOC	7	160-560	341	207	456
Total Solids	7	1,190-3,260	2,530		
Suspended Solids	7	190-820	429	187	413
Volatile Suspended Solids	7	80-560	296	126	278
NH_3-N	7	48-120	75.1	32.3	71.3
Total Kjeldahl Nitrogen-N	7	110-190	131	67.1	148
Organic-N	7	20-103	56.3	34.7	76.5
NO_2 + NO_3-N	7	<0.5			
Total Phosphorus-P	7	15.6-25.9	21.9	14.0	30.8
WEEK-DAY					
Flow (m^3/day)		5.3-2,910	749		
Flow (mgd)		0.0014-0.77	0.198		
pH (standard units)		6.5-7.5			
Temperature (°C)		11.5-21.0			
Conductivity (μmhos/cm)		3,300-6,000			
BOD	5	720-1,800	1,220	993	2,190
COD	5	780-2,200	1,460	1,100	2,420
TOC	5	320-560	398	275	607
Total Solids	5	2,520-3,260	2,880		
Suspended Solids	5	300-820	508	246	542
Volatile Suspended Solids	5	200-560	368	169	372
NH_3-N	5	48-87	63.6	37.9	83.5
Total Kjeldahl Nitrogen-N	5	110-190	132	84.8	187
Organic-N	5	49-103	68.4	46.7	103
NO_2 + NO_3-N	5	<0.5 (0.16)	<0.5 (0.16)	0.093	0.206
Total Phosphorus-P	5	20.2-25.9	23.9	18.4	40.5
WEEK-END					
Flow (m^3/day)		178	178		
Flow (mgd)		0.047	0.047		
pH (standard units)		7.0-7.4			
Temperature (°C)		8.0-16.0			
Conductivity (μmhos/cm)		3,000-4,500			
BOD	2	370-600	485	86.2	190
COD	2	560-830	695	124	273
TOC	2	160-240	200	35.6	78.4
Total Solids	2	1,190-2,080	1,640	291	641
Suspended Solids	2	190-270	230	41.0	90.3
Volatile Suspended Solids	2	80-150	115	20.5	45.1
NH_3-N	2	88-120	104	18.5	40.8
Total Kjeldahl Nitrogen-N	2	120-140	130	23.1	51.0
Organic-N	2	20-32	26	4.63	10.2
NO_2 + NO_3-N	2	<0.5 (0.16)	<0.5 (0.16)	0.09	0.206
Total Phosphorus-P	2	15.6-18.5	17.1	3.03	6.68

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1459 -- Sludge System - Influent to Sludge Thickeners

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
		SEVEN-DAY			
Flow (m^3/day)		3,970-6,400	5,150		
Flow (mgd)		1.05-1.69	1.36		
pH (standard units)		6.5-7.6			
Temperature (°C)		8.5-18.0			
Conductivity (µmhos/cm)		2,800-4,800			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	7	48-115	86	439	968
Total Kjeldahl Nitrogen-N	7	240-610	417	2,120	4,680
Organic-N	7	181-562	331	1,680	3,710
NO_2 + NO_3-N	7	<0.80	<0.80		
Total Phosphorus-P	7	58-136	88	450	993
		WEEK-DAY			
Flow (m^3/day)		5,030-6,400	5,370		
Flow (mgd)		1.33-1.69	1.42		
pH (standard units)		6.5-7.5			
Temperature (°C)		10.5-18.0			
Conductivity (µmhos/cm)		2,800-4,800			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	5	48-125	82	436	962
Total Kjeldahl Nitrogen-N	5	240-610	430	2,260	4,990
Organic-N	5	181-562	348	1,820	4,020
NO_2 + NO_3-N	5	<0.80	<0.80		
Total Phosphorus-P	5	58-136	95	503	1,110
		WEEK-END			
Flow (m^3/day)		3,970-5,150	4,580		
Flow (mgd)		1.05-1.36	1.21		
pH (standard units)		6.8-7.6			
Temperature (°C)		8.5-15.0			
Conductivity (µmhos/cm)		3,200-4,000			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	2	76-115	96	446	983
Total Kjeldahl Nitrogen-N	2	350-420	385	1,770	3,910
Organic-N	2	274-305	290	1,330	2,930
NO_2 + NO_3-N	2	<0.80	<0.80		
Total Phosphorus-P	2	62-76	69	319	703

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1460 -- Sludge System - Supernatant From Sludge Thickeners

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		3,670-5,680	4,500		
Flow (mgd)		0.97-1.50	1.19		
pH (standard units)		6.3-7.5			
Temperature (°C)		9.0-17.5			
Conductivity (μmhos/cm)		2,900-4,400			
BOD	7	820-2,400	1,340	6,030	13,300
COD	7	1,200-2,600	1,810	8,210	18,100
TOC	7	220-540	416	1,900	4,190
Total Solids	7	1,930-13,200	4,270		
Suspended Solids	7	300-13,000	2,490	13,200	29,200
Volatile Suspended Solids	7	240-9,000	1,750	9,340	20,600
NH_3-N	7	48-96	73	327	720
Total Kjeldahl Nitrogen-N	7	130-210	157	708	1,560
Organic-N	7	52-125	85	380	837
NO_2 + NO_3-N	7	<0.50	<0.50		
Total Phosphorus-P	7	16.3-64.6	32.1	146	321
WEEK-DAY					
Flow (m^3/day)		4,240-5,680	4,650		
Flow (mgd)		1.12-1.50	1.23		
pH (standard units)		6.3-7.4			
Temperature (°C)		10.0-17.5			
Conductivity (μmhos/cm)		2,900-4,400			
BOD	5	1,000-2,400	1,520	6,940	15,300
COD	5	1,600-2,600	2,060	9,520	21,000
TOC	5	450-540	472	2,190	4,830
Total Solids	5	2,730-13,200	5,140		
Suspended Solids	5	660-13,000	3,260	17,700	39,000
Volatile Suspended Solids	5	540-9,000	2,340	12,600	27,800
NH_3-N	5	48-85	67	311	685
Total Kjeldahl Nitrogen-N	5	130-210	160	735	1,620
Organic-N	5	62-125	93	424	936
NO_2 + NO_3-N	5	<0.50	<0.50		
Total Phosphorus-P	5	24.2-64.6	36.9	169	373
WEEK-END					
Flow (m^3/day)		3,670-4,650	4,160		
Flow (mgd)		0.97-1.23	1.10		
pH (standard units)		6.8-7.5			
Temperature (°C)		9.0-15.0			
Conductivity (μmhos/cm)		3,500-4,000			
BOD	2	820-960	890	3,670	8,090
COD		1,200	1,200	4,990	11,000
TOC	2	220-330	275	1,170	2,590
Total Solids	2	1,930-2,220	2,080		
Suspended Solids	2	300-830	565	2,220	4,900
Volatile Suspended Solids	2	240-350	295	1,200	2,650
NH_3-N	2	78-96	87	367	808
Total Kjeldahl Nitrogen-N	2	130-170	150	635	1,400
Organic-N	2	52-74	63	268	590
NO_2 + NO_3-N	2	<0.50	<0.50		
Total Phosphorus-P	2	16.3-24.2	20.3	86.2	190

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1461 -- Sludge System - Influent to Complete Mixed Digesters

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		333-931	6,175		
Flow (mgd)		0.088-0.246	0.163		
pH (standard units)		4.9-7.2			
Temperature (°C)		8.5-19.0			
Conductivity (µmhos/cm)		2,100-5,000			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	7	140-390	268	157	347
Total Kjeldahl Nitrogen-N	7	1,400-1,860	1,660	1,030	2,260
Organic-N	7	1,105-1,540	1,390	866	1,910
NO_2 + NO_3-N	7	<2.0	<2.0		
Total Phosphorus-P	7	168-600	384	230	506
WEEK-DAY					
Flow (m^3/day)		439-931	700		
Flow (mgd)		0.116-0.246	0.185		
pH (standard units)		5.1-7.2			
Temperature (°C)		12.0-19.0			
Conductivity (µmhos/cm)		2,100-5,000			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	5	140-300	238	163	360
Total Kjeldahl Nitrogen-N	5	1,500-1,800	1,670	1,170	2,570
Organic-N	5	1,330-1,540	1,430	998	2,200
NO_2 + NO_3-N	5	<2.0	<2.0		
Total Phosphorus-P	5	188-480	354	243	535
WEEK-END					
Flow (m^3/day)		333-477	405		
Flow (mgd)		0.088-0.126	0.107		
pH (standard units)		4.9-7.1			
Temperature (°C)		8.5-17.5			
Conductivity (µmhos/cm)		2,800-4,600			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	2	295-390	342	142	314
Total Kjeldahl Nitrogen-N	2	1,400-1,860	1,630	676	1,490
Organic-N	2	1,105-1,470	1,290	535	1,180
NO_2 + NO_3-N	2	<2.0	<2.0		
Total Phosphorus-P	2	320-600	460	196	432

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1462 -- Sludge System - Effluent From Digesters

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
S E V E N - D A Y					
Flow (m^3/day)		333-931	617		
Flow (mgd)		0.088-0.246	0.163		
pH (standard units)		7.0-8.9			
Temperature (°C)		10.5-34.0			
Conductivity (μmhos/cm)		5,600-9,500			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	7	465-1,000	866	526	1,160
Total Kjeldahl Nitrogen-N	7	1,770-2,140	1,930	1,180	2,600
Organic-N	7	810-1,415	1,060	653	1,440
NO_2 + NO_3-N	7	<2.0	<2.0		
Total Phosphorus-P	7	250-430	354	211	466
W E E K - D A Y					
Flow (m^3/day)		439-931	700		
Flow (mgd)		0.116-0.246	0.185		
pH (standard units)		7.0-8.9			
Temperature (°C)		10.5-34.0			
Conductivity (μmhos/cm)		5,600-9,500			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	5	465-1,000	843	590	1,300
Total Kjeldahl Nitrogen-N	5	1,770-1,940	1,860	1,310	2,890
Organic-N	5	810-1,415	1,020	726	1,600
NO_2 + NO_3-N	5	<2.0	<2.0		
Total Phosphorus-P	5	250-430	338	231	509
W E E K - E N D					
Flow (m^3/day)		333-477	405		
Flow (mgd)		0.088-0.126	0.107		
pH (standard units)		7.1-7.6			
Temperature (°C)		13.5-32.5			
Conductivity (μmhos/cm)		6,500-9,500			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids					
Volatile Suspended Solids					
NH_3-N	2	920-930	925	374	825
Total Kjeldahl Nitrogen-N	2	2,020-2,140	2,080	844	1,860
Organic-N	2	1,090-1,220	1,060	472	1,040
NO_2 + NO_3-N	2	<2.0	<2.0		
Total Phosphorus-P	2	370-420	395	161	356

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1463 -- Sludge System - Supernatant Return From Sludge Lagoons

Parameter[a]	No. of Samples[b]	Range	Average	Average Load kg/day	Average Load lb/day
SEVEN-DAY					
Flow (m^3/day)		307-2,150	780		
Flow (mgd)		0.081-0.567	0.206		
pH (standard units)		7.1-7.3			
Temperature (°C)		0.0-3.0			
Conductivity (µmhos/cm)		8,000-14,000			
BOD	7	680-1,700	1,160	771	1,700
COD	7	2,000-2,600	2,290	1,740	3,830
TOC	7	300-870	470	336	741
Total Solids	7	3,660-4,290	3,820		
Suspended Solids	7	480-2,000	1,240	984	2,170
Volatile Suspended Solids	7	390-1,200	829	708	1,560
NH_3-N	6	500-990	839	694	1,530
Total Kjeldahl Nitrogen-N	6	660-2,070	1,280	975	2,150
Organic-N	6	110-1,130	428	280	617
NO_2 + NO_3-N	6	<1.0	<1.0		
Total Phosphorus-P	6	50.4-72.0	59.3	46.7	103
WEEK-DAY					
Flow (m^3/day)		306-2,150	844		
Flow (mgd)		0.081-0.567	0.223		
pH (standard units)		7.1-7.3			
Temperature (°C)		0.0-3.0			
Conductivity (µmhos/cm)		8,000-14,000			
BOD	5	680-1,700	1,190	807	1,780
COD	5	2,100-2,600	2,320	1,880	4,150
TOC	5	300-380	354	280	618
Total Solids	5	3,660-4,290	3,870		
Suspended Solids	5	480-1,400	982	907	2,000
Volatile Suspended Solids	5	390-1,200	800	766	1,690
NH_3-N	4	870-990	940	839	1,850
Total Kjeldahl Nitrogen-N	4	1,160-2,070	1,470	1,190	2,630
Organic-N	4	290-1,130	533	351	775
NO_2 + NO_3-N	4	<1.0	<1.0		
Total Phosphorus-P	4	50.4-72.0	58.1	50.8	112
WEEK-END					
Flow (m^3/day)		625	625		
Flow (mgd)		0.165	0.165		
pH (standard units)		7.1-7.3			
Temperature (°C)		0.0-2.0			
Conductivity (µmhos/cm)		9,000-12,000			
BOD	2	990-1,200	1,100	685	1,510
COD	2	2,000-2,400	2,200	1,370	3,030
TOC	2	650-870	760	476	1,050
Total Solids	2	3,700-3,710	3,710		
Suspended Solids	2	1,800-2,000	1,900	1,190	2,620
Volatile Suspended Solids	2	600-1,200	900	562	1,240
NH_3-N	2	500-775	640	399	879
Total Kjeldahl Nitrogen-N	2	660-1,100	880	549	1,210
Organic-N	2	110-325	218	136	299
NO_2 + NO_3-N	2	<1.0	<1.0		
Total Phosphorus-P	2	56.8-66.7	61.8	38.6	85.0

TABLE F-5 (Cont.)

SUMMARY OF FIELD DATA AND ANALYTICAL RESULTS
SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT
24-31 JANUARY 1973

Station No. 1464 — Sludge System - Waste Activated Sludge (Sampled in Return Activated Sludge Channel)

Parameter[a/]	No. of Samples[b/]	Range	Average	Average Load kg/day	Average Load lb/day
S E V E N - D A Y					
Flow (m^3/day)		2,010-3,360	2,630		
Flow (mgd)	7	0.530-0.888	0.696		
pH (standard units)		7.1-7.5			
Temperature (°C)		8.5-14.0			
Conductivity (μmhos/cm)		2,200-3,500			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids	7	3,900-5,400	4,370	11,400	25,200
Volatile Suspended Solids					
NH_3-N	7	53-76	66	174	384
Total Kjeldahl Nitrogen-N	7	320-490	421	1,110	2,440
Organic-N	7	261-421	355	934	2,060
NO_2 + NO_3-N	7	<0.5	<0.5		
Total Phosphorus-P	7	68.5-83.1	76.6	201	444
W E E K - D A Y					
Flow (m^3/day)		2,010-2,720	2,350		
Flow (mgd)		0.530-0.720	0.621		
pH (standard units)		7.1-7.5			
Temperature (°C)		8.5-14.0			
Conductivity (μmhos/cm)		2,200-3,500			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids	5	3,900-5,400	4,500	10,600	23,400
Volatile Suspended Solids					
NH_3-N	5	53-70	64	148	327
Total Kjeldahl Nitrogen-N	5	320-490	420	980	2,160
Organic-N	5	261-421	356	835	1,840
NO_2 + NO_3-N	5	<0.5	<0.5		
Total Phosphorus-P	5	68.5-83.1	77.3	181	400
W E E K - E N D					
Flow (m^3/day)		3,330-3,360	3,340		
Flow (mgd)		0.880-0.888	0.884		
pH (standard units)		7.2-7.4			
Temperature (°C)		9.0-13.5			
Conductivity (μmhos/cm)		2,900-3,200			
BOD					
COD					
TOC					
Total Solids					
Suspended Solids	2	3,800-4,300	4,050	13,600	29,900
Volatile Suspended Solids					
NH_3-N	2	67-76	72	239	528
Total Kjeldahl Nitrogen-N	2	390-460	425	1,420	3,140
Organic-N	2	323-384	354	1,180	2,610
NO_2 + NO_3-N	2	<0.5	<0.5		
Total Phosphorus-P	2	72.1-78.0	75.0	251	554

a/ All values are reported as mg/l, except where otherwise specified.
b/ This refers to number of samples analyzed during seven-day, week-day, or week-end period.

APPENDIX G

DANGERS INHERENT IN INADEQUATELY TREATED DOMESTIC SEWAGE

DANGERS INHERENT IN INADEQUATELY TREATED DOMESTIC SEWAGE

Inadequately treated sanitary or domestic waste contains significant populations of bacteria, viruses, and protozoa that multiply within the gastro-intestinal tract of man and which are excreted in the feces of warm-blooded animals, including humans.

Inadequately treated waste poses a health threat because of the high numbers of pathogenic bacteria and viruses whose presence is indicated by fecal coliform bacteria. Fecal coliform bacteria are that portion of the coliform group of bacteria found in the feces of man and animals.

Among the disease-producing micro-organisms indicated by the presence of fecal coliform bacteria are enteropathogenic *E. coli* (causes acute localized infections such as cystitis, oculitis, colitis, diarrhea, and septicemias which sometimes are fatal for infants and aged), *Leptospira,* (commonly known as Weils disease, characterized by jaundice and kidney hemorrhage), *Salmonella* (which causes gastro-enteritis, typhoid and paratyphoid fevers), *Shigella* (which causes bacterial dysentery), *Brucella* (which causes undulent fever), *Mycobacterium tuberculosis* (which causes tuberculosis), and *vibrio cholera* (which causes cholera). The presence of *Salmonella* also indicates a high probability of the presence of other pathogenic bacteria. Waste may also contain protozoa such as those causing amoebic dysentery.

Enteroviruses are concentrated in particulate fecal matter when waste treatment is insufficient to adequately separate the solids from wastewater. Massive numbers of virus particles can be dispelled in the waste effluent to receiving surface waters.

Enteroviruses are generally transmitted by the fecal-oral route. A very small quantity of viruses are capable of infecting a susceptible individual.

Enteroviruses are pathogenic to humans and cause a variety of diseases, including poliomyelitis, aseptic meningitis (a paralytic disease similar to paralytic polio), herpangina (a throat infection common to children), pleurodyna (an infection which causes excruciating muscular pain), myocarditis (inflammation of the heart valves), coxsackie virus infection (a disease similar to polio but without paralysis), adenovirus infection (causes common colds, respiratory disease, and rashes), and other intestinal disorders such as diarrhea.

Also, the infectious hepatitis virus may be present in sewage and cause serious liver diseases.

Such viruses have a water survival time of many months. This is especially dangerous when they are replaced and supplemented by continued discharges of waste. Additionally, viruses do not lose their virulence, although they may diminish in number.

Enteroviruses, pathogenic bacteria, and protozoa endanger not only the original host of the disease organism, but they also threaten whole communities because the initial host can infect his family and others with whom he comes into contact. Also, these micro-organisms can increase in virulence by host passage.

APPENDIX H

LISTING OF SAMPLING STATIONS

TABLE H-1

LISTING OF SAMPLING STATIONS - BIG SIOUX RIVER STUDY
(STREAM STATIONS AND DIRECT DISCHARGES)
FALL 1972 AND WINTER 1973

River Mile	Sampling Period*	Description
263.5	A, B	Big Sioux River at S.D. Hwy. 28, 2.4 km (1.5 mi) west of Estelline, S.D.
243.9	A, B	Big Sioux River at U.S. Hwy. 14, 3 km (2 mi) east of Volga, S.D.
237.6	A	Big Sioux River at Brookings County Road 12, approx. 3 km (2 mi) downstream from Sixmile Creek confluence -- approx. 5 km (3 mi) SE of Brookings, S.D.
232.6	B	Big Sioux River, 15.3 km (9.5 mi) SE of Brookings, S.D., 0.8 km (0.5 mi) downstream of the I-29 river crossing at USGS gaging station
214.6/0.1	A	Willow Creek 5 km (3 mi) east of Flandreau, S.D.
206.1	A, B	Big Sioux River at S.D. Hwy. 34, 5 km (3 mi) SW of Flandreau, S.D.
186.9	A	Big Sioux River at Minnehaha-Moody County Line Road, 5 km (3 mi) NE of Dell Rapids, S.D.
173.0	A	Big Sioux River at Baltic, S.D.
162.2	A, B	Big Sioux River 1.6 km (1 mi) west of Renner, S.D.
155.4	A	Big Sioux River at Madison St. NW Sioux Falls, S.D., 1.2 km (0.75 mi) upstream of the Spencer discharge
154.2	B	Meilman Food Industries (formerly Spencer Foods, Inc.) lagoon effluent at the point of discharge to Big Sioux River, 61 m (200 ft) upstream of 12th St. Bridge in West Sioux Falls, S.D.

TABLE H-1 (Cont.)

LISTING OF SAMPLING STATIONS - BIG SIOUX RIVER STUDY
(STREAM STATIONS AND DIRECT DISCHARGES)
FALL 1972 AND WINTER 1973

River Mile	Sampling Period*	Description
154.2	A	Big Sioux River at 12th St., NW Sioux Falls, S.D., 91 m (300 ft) downstream from the Meilman discharge
152.8/1.1	A, B	Skunk Creek at Marion Rd., West Sioux Falls, S.D.
150.6	A, B	Big Sioux River at Western Ave., SW Sioux Falls, S.D.
146.8	A	Big Sioux River at 26th St., SE Sioux Falls, S.D.
143.8	A	Big Sioux River at McClellan St., north Sioux Falls, S.D.
143.2	A, B	Big Sioux River opposite John Morrell and Co., former discharge, 0.2 km (0.1 mi) upstream of the diversion canal
143.0	B	Sioux Falls, S.D., WWTP effluent
142.9	B	Sioux Falls, S.D., WWTP by-pass
142.7	A, B	Big Sioux River at U.S. Hwy. 77 (Cliff Ave.), 0.5 km (0.3 mi) downstream from the Sioux Falls, S.D., WWTP
141.2	A, B	Big Sioux River downstream from I-229, 2.9 km (1.8 mi) downstream from the Sioux Falls, S.D., WWTP
134.5	A, B	Big Sioux River at Brandon Rd. Bridge, 0.8 km (0.5 mi) west of Brandon, S.D.
130.1/27.3	A	Split Rock Creek at Minnesota-South Dakota State boundary line, 1.6 km (1 mi) east of Sherman, S.D.

TABLE H-1 (Cont.)

LISTING OF SAMPLING STATIONS - BIG SIOUX RIVER STUDY
(STREAM STATIONS AND DIRECT DISCHARGES)
FALL 1972 AND WINTER 1973

River Mile	Sampling Period*	Description
130.1/5.3	A, B	Split Rock Creek at U.S. Hwy. 16, 2.4 km (1.5 mi) east of Brandon, S.D.
128.5	B	Big Sioux River at Hwy. 38 Bridge, approx. 2.4 km (1.5 mi) upstream of the Iowa-South Dakota State Line
127.0	A	Big Sioux River at the Iowa-South Dakota State Line, 4 km (2.5 mi) SW of Rowena, S.D.
113.0	A	Big Sioux River at Klondike, Iowa
106.2	A, B	Big Sioux River at U.S. Hwy. 18, 5 km (3 mi) east of Canton, S.D.
80.9	A, B	Big Sioux River 1.6 km (1 mi) east of Hudson, S.D., on S.D. Spur No. 46
76.2/52.5	B	Rock River, 0.8 km (0.5 mi) upstream of Luverne, Minnesota, WWTP
76.2/40.8	A, B	Rock River at Minnesota-Iowa State Line, 8 km (5 mi) north of Rock Rapids, Iowa
76.2/25.7	B	Rock River at Lyon County Road K 42 Bridge, 1.6 km (1 mi) north of Doon, Iowa
76.2/23.1/4.0	B	Little Rock River at Hwy. 75 Bridge, 5 km (3 mi) east of Doon, Iowa
76.2/5.8	A, B	Rock River 5 km (3 mi) east of Hudson, S.D., on S.D. Spur No. 46
66.9	A, B	Big Sioux River at Iowa Hwy. 10, 6 km (4 mi) north of Hawarden, Iowa
46.8	A, B	Big Sioux River at South Dakota Hwy. 48, Akron, Iowa

TABLE H-1 (Cont.)

LISTING OF SAMPLING STATIONS - BIG SIOUX RIVER STUDY
(STREAM STATIONS AND DIRECT DISCHARGES)
FALL 1972 AND WINTER 1972

River Mile	Sampling Period*	Description
35.3	A	Big Sioux River at South Dakota Hwy. 50, 3 km (2 mi) west of Westfield, Iowa
16.8	A	Big Sioux River at Union County (S.D.) Road 8, 45 m (50 yd) downstream from confluence with Broken Kettle Creek
5.0	A, B	Big Sioux River at U.S. Hwy. 77 (Military Rd.) NW Sioux City, Iowa
2.2	A	Big Sioux River at Riverside City Park, western Sioux City, Iowa

* The letter "A" refers to the Fall Study and the "B" to the Winter Study.

TABLE H-2

LISTING OF SAMPLING STATIONS - SIOUX FALLS
WASTEWATER TREATMENT PLANT STUDY
24 THROUGH 31 JANUARY 1973

Station Numbers	Description
1450	Industrial Pretreatment Plant - influent (combined)
1451	Industrial Pretreatment Plant - John Morrell & Company discharge to city system
1452	Industrial Pretreatment Plant - primary-clarifier overflow
1453	Industrial Pretreatment Plant - intermediate-clarifier overflow
1454	Industrial Pretreatment Plant - secondary trickling-filter underflow (i.e., effluent from Industrial Plant)
1455	Domestic and Industrial Plant - domestic influent to plant (before combining with Industrial Pretreatment Plant effluent)
1457	Domestic and Industrial Plant - primary-clarifier overflow
1412	Domestic and Industrial - final-clarifier overflow (i.e., wastewater treatment plant effluent)
1424	Wastewater Treatment Plant - by-pass
1459	Sludge System - influent to sludge thickeners
1460	Sludge System - supernatant from sludge thickeners
1461	Sludge System - influent to complete mixed digesters
1462	Sludge System - effluent from digesters
1463	Sludge System - supernatant return from sludge lagoons
1464	Sludge System - waste activated sludge (sampled in Return Activated Sludge Channel)

APPENDIX I

STREAM FLOWS DURING WINTER-1973

TABLE I-1

STREAM FLOWS DURING WINTER-1973

Station	Date	Time (hr)	Gage (ft)	Flow (m^3/sec)	Flow (cfs)
Big Sioux River 15.2 km (9.5 mi) East of Brookings S.D.	2/1/73	0845	3.32	1.50	53
	2/2/73	1045	3.32	1.50	53
	2/3/73	1135	3.33	1.53	54
	2/4/73	1235	3.35	1.58	56
	2/5/73	0625	3.40	1.73	61
	2/6/73	1030	3.40	1.73	61
	2/7/73	0950	3.41	1.75	62
	2/8/73	1235	3.43	1.81	64
Big Sioux River 4.8 km (3 mi) S.E. of Dell Rapids on Minnehaha County Rd. 110	3/1/73	1032	3.87	2.66	94
	2/2/73	1207	3.82	2.35	83
	2/3/73	1300	3.77	2.07	73
	2/4/73	1352	3.83	2.41	85
	2/5/73	0745	4.05	3.79	134
	2/6/73	1200	4.16	4.53	160
	2/7/73	1245	4.17	4.58	162
	2/8/73	1350	4.02	3.59	127
Skunk Creek 4.0 km (2.5 mi) upstream of confluence with Big Sioux at Marion Rd. bridge	2/1/73	1135	32.52	0.175	6.2
	2/2/73	1220	32.52	0.170	6.0
	2/3/73	1345	32.52	0.170	6.0
	2/4/73	1435	32.52	0.170	6.0
	2/5/73	0835	32.52	0.198	7 0
	2/6/73	1330	32.50	0.198	7.0
	2/7/73	1150	32.52	0.184	6.5
	2/8/73	1430	32.52	0.184	6.5
	2/9/73	1400	32.53	0.170	6.0
	2/10/73	1120	32.52	0.170	6.0
Diversion Canal - top of spillway in Sioux Falls, S.D.	2/1/73	1200	7.99	2.97	105
	2/2/73	1200	7.93	2.49	88
	2/3/73	1200	7.95	2.69	95
	2/4/73	1200	7.87	1.78	70
	2/5/73	1200	7.92	2.41	85
	2/6/73	1200	7.96	2.69	95
	2/7/73	1200	7.99	2.97	105
	2/8/73	1200	8.02	3.25	115
	2/9/73	1200	8.02	3.25	115
	2/10/73	1200	8.02	3.25	115

TABLE I-1 (Cont.)

STREAM FLOWS DURING WINTER-1973

Station	Date	Time (hr)	Gage (ft)	Flow (m^3/sec)	Flow (cfs)
Big Sioux River at Cliff Ave. North	2/1/73	0900	5.61	3.17	112
Side of Sioux Falls, S.D.	2/1/73	1330	5.63	3.28	116
	2/2/73	0930	5.60	3.11	110
	2/2/73	1355	5.63	3.28	116
	2/3/73	1320	5.63	3.28	116
	2/4/73	1000	5.57	2.94	104
	2/4/73	1550	5.64	3.34	118
	2/5/73	0750	5.64	3.34	118
	2/6/73	1005	5.72	3.79	134
	2/7/73	1000	5.74	3.91	138
	2/8/73	1415	5.75	3.96	140
	2/9/73	0955	5.68	3.57	126
	2/10/73	0735	5.63	3.28	116
Split Rock Creek 5.6 km (3.5 mi)	2/1/73	0845	3.62	1.19	42
upstream of confluence with	2/2/73	1210	3.26	0.736	26
Big Sioux River County Road bridge,	2/3/73	1430	3.16	0.538	19
0.8 km (0.5 mi) east of Corson, S.D.	2/4/73	1620	3.20	0.623	22
	2/5/73	0650	3.19	0.594	21
	2/6/73	0820	3.25	0.736	26
	2/6/73	0920	3.21	0.623	22
	2/7/73	0900	3.15	0.538	19
	2/8/73	1322	3.12	0.481	17
	2/9/73	0855	3.14	0.509	18
	2/10/73	0635	3.54	0.538	19
Rock River at Highway 18 Bridge	2/1/73	1100	6.40		
2.9 km (1.8 mi) west of Rock	2/2/73	1005	6.40		
Valley Iowa	2/3/73	1200	6.40		
	2/4/73	1430	6.38		
	2/5/73	0650	6.37		
	2/6/73	1115	6.37	5.66	200
	2/7/73	1220	6.38		
	2/8/73	1420	6.37		
	2/9/73	1100	6.38		
	2/10/73	0945	6.38		
Rock River at City Park,	2/7/73			2.13	75
Rock Rapids, Iowa	2/9/73	1135	2.07		
	2/10/73	0920	2.08		

APPENDIX J

FLOWS AT
SIOUX FALLS, SOUTH DAKOTA,
WASTEWATER TREATMENT PLANT

TABLE J-1

FLOWS AT SIOUX FALLS, SOUTH DAKOTA, WASTEWATER TREATMENT PLANT

Date*	Industrial Raw		Domestic Raw		Total		Sludge to Thickener		Sludge to Digester		Supernatant Return from Thickener	
	m^3/day	mgd	m^3/day	mgd	m^3/day	mgd	m^3/day	mgd	m^3/day	mgd	m^3/day	mgd
January 24	18,400	4.86	22,400	5.91	40,800	10.77	5,150	1.36	681	0.18	4,470	1.18
25	18,100	4.77	21,100	5.57	39,200	10.34	5,190	1.37	946	0.25	4,240	1.12
26	15,900	4.21	20,700	5.48	36,600	9.69	5,070	1.34	719	0.19	4,350	1.15
27	7,190	1.90	16,900	4.46	24,100	6.36	5,150	1.36	492	0.13	4,660	1.23
28	7,110	1.88	14,800	3.90	21,900	5.78	3,970	1.05	341	0.09	3,630	0.96
29	18,100	4.78	17,100	4.52	35,200	9.30	6,400	1.69	719	0.19	5,680	1.50
30	18,700	4.94	17,000	4.50	35,700	9.44	5,030	1.33	454	0.12	4,580	1.21
31	19,500	5.14	17,900	4.73	37,400	9.87						
February 1	16,500	4.35	20,300	5.37	36,800	9.72						
2	16,500	4.35	16,500	4.35	33,000	8.70						
3	8,670	2.29	18,100	4.79	26,800	7.08						
4	8,140	2.15	19,200	5.08	27,300	7.23						
5	18,600	4.91	19,300	5.10	37,900	10.01						
6	18,700	4.94	20,800	5.50	39,500	10.44						
7	18,200	4.81	17,800	4.69	36,000	9.50						
8	17,600	4.66	19,300	5.10	36,900	9.76						
9	16,100	4.25	18,200	4.80	34,300	9.05						

* Time periods include 8 A.M. of day listed to 8 A.M. of following day.

APPENDIX K

BIOLOGICAL STUDIES DATA - FALL 1972
AND WINTER 1973

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972

Mainstem River Mile	Tributary River Mile	Date	Time	Temp (°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
263.5		9/26	0935	10.0	8.0	ND	10	10.1	93
263.5		9/30	1255	12.0	8.5	ND	11	12.8	123
263.5		10/1	1245	14.0	--	ND	7	12.8	129
243.9		9/26	1055	10.0	8.1	ND	12	11.1	102
243.9		9/30	1210	10.5	8.4	ND	14	11.7	108
243.9		10/1	1205	14.0	--	ND	17	11.3	113
237.6		9/26	1140	10.0	8.2	ND	16	11.5	105
237.6		9/30	1135	10.0	8.3	ND	18	11.1	102
237.6		10/1	1135	13.0	--	ND	14	10.8	106
	214.6/0.1	9/26	1300	12.5	7.8	ND	10	7.7	75
	214.6/0.1	9/30	1050	10.5	8.0	ND	8	9.0	83
	214.6/0.1	10/1	1105	12.0	--	ND	25	12.0	115

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp. (°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
206.1		9/26	1340	13.0	8.2	ND	29	12.4	122
206.1		9/30	1000	10.5	8.4	ND	23	10.3	95
206.1		10/1	1050	12.0	--	ND	25	11.2	107
186.9		9/26	1430	14.0	8.2	ND	25	14.0	140
186.9		9/30	0845	9.5	8.5	ND	23	10.4	94
186.9		10/1	1010	12.0	--	ND	30	11.0	106
173.0		9/26	1505	14.0	8.2	ND	23	11.5	115
173.0		9/30	0815	10.0	8.4	ND	16	10.2	94
173.0		10/1	0950	12.5	--	ND	27	11.0	109
162.2		9/26	1540	15.5	8.4	ND	25	14.2	148
162.2		9/30	0750	8.5	8.4	ND	32	9.7	86
162.2		10/1	0940	11.0	--	ND	30	9.8	93
155.4		9/27	0730	9.0	8.4	ND	14	9.2	82
155.4		9/28	1240	13.0	8.4	ND	12	14.3	143
155.4		9/29	0835	8.0	8.4	ND	15	10.3	90

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp. (°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
154.2		9/27	0755	9.0	8.1	3.0	21	8.0	72
154.2		9/28	1225	12.5	7.9	4.5	27	9.3	90
154.2		9/29	0900	8.0	8.1	2.2	19	8.9	77
	152.8/1.1	9/26	1620	16.5	8.3	ND	16	17.1	175
	152.8/1.1	9/30	0730	8.5	8.2	ND	17	12.2	107
	152.8/1.1	10/1	0930	11.5	--	ND	17	13.2	125
150.6		9/27	0825	10.0	7.9	0.3	20	8.9	82
150.6		9/28	1205	12.0	8.0	<0.1	17	12.1	116
150.6		9/29	0930	9.5	7.9	0.1	15	9.6	87
146.8		9/27	0855	10.0	7.9	ND	15	8.8	80
146.8		9/28	1145	12.5	8.0	ND	15	11.0	107
146.8		9/29	0955	9.5	8.1	ND	10	10.4	94
143.8		9/27	0925	11.0	8.1	<0.1	27	10.4	98
143.8		9/28	1050	11.5	8.5	ND	30	10.0	95
143.8		9/29	1040	11.5	8.2	ND	25	10.7	102

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp.(°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
143.2		9/27	0950	11.5	8.2	<0.1	25	10.4	99
143.2		9/28	1035	11.5	8.2	<0.1	27	9.5	90
143.2		9/29	1055	11.5	8.3	ND	28	11.5	109
142.7		9/27	1020	14.0	8.5	5.2	27	9.8	98
142.7		9/28	1010	13.5	8.1	14.0	30	9.2	91
142.7		9/29	1115	13.0	8.0	9.5	25	9.8	96
142.7		9/30	1425	14.5	8.1	8.4	22	10.1	103
142.7		10/1	0830	14.0	--	1.0	32	9.6	96
142.7		10/2	1330	16.5	7.9	8.0	--	9.3	99
142.7		10/3	1405	18.0	7.6	13.5	--	9.2	100
142.7		10/3	0700	14.5	8.1	3 7	--	9.3	95
141.2		9/27	1105	13.5	8.2	2.7	27	10.3	103
141.2		9/28	0955	12.0	8.2	4.0	32	9.1	87
141.2		9/29	1135	12.0	8.2	2.8	25	10.5	101

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp.(°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
134.5		9/27	1215	13.0	8.0	1.0	27	9.8	97
134.5		9/28	0935	12.0	8.0	5.0	26	7.5	72
134.5		9/29	1155	12.5	8.0	2.1	25	9.5	93
	130.1/27.3	9/27	1330	12.5	8.0	ND	24	11.8	114
	130.1/27.3	9/28	0815	12.0	8.0	ND	25	8.2	78
	130.1/27.3	9/29	1330	12.0	8.3	ND	17	13.6	130
	130.1/5.3	9/27	1245	12.0	8.2	ND	21	11.2	107
	130.1/5.3	9/28	0915	12.5	8.1	ND	22	8.3	80
	130.1/5.3	9/29	1300	11.0	8.3	ND	15	11.8	110
127.0		9/28	1315	14.0	8.9	2.6	24	9.4	94
127.0		9/29	1240	11.5	7.9	2.7	23	9.7	92
127.0		10/1	0800	11.0	7.6	1.0	24	7.6	71
127.0		10/2	1255	15.5	7.9	0.4	--	9.9	103
127.0		10/3	0740	14.5	7.8	2.1	--	6.1	62

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp.(°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat)
106.2		10/1	0935	12.0	8.2	ND	28	10.0	96
106.2		10/2	1130	15.0	8.1	ND	--	11.4	117
106.2		10/3	0910	14.5	8.1	ND	--	9.1	93
80.9		10/1	1055	13.5	8.5	ND	27	11.9	118
80.9		10/2	1040	14.0	8.4	ND	--	11.4	114
80.9		10/3	0950	15.5	8.3	ND	--	10.2	106
	76.2/40.8	10/1	0845	10.5	8.3	ND	20	9.4	87
	76.2/40.8	10/2	1210	14.5	8.4	ND	--	15.0	152
	76.2/40.8	10/3	0820	14.0	8.2	ND	--	8.3	83
	76.2/5.8	10/1	1110	13.5	8.3	ND	15	12.8	127
	76.2/5.8	10/2	1055	14.5	8.2	ND	--	12.5	127
	76.2/5.8	10/3	0935	15.0	8.0	ND	--	9.5	98
66.9		10/1	1145	14.5	8.4	ND	27	12.6	128
66.9		10/2	1010	13.5	8.5	ND	--	10.5	104
66.9		10/3	1045	15.0	8.4	ND	--	10.4	107

TABLE K-1
Field Measurements and Analytical Data.
Big Sioux River and Selected Tributaries,
Minnesota, South Dakota, and Iowa.
September and October, 1972
(Continued)

Mainstem River Mile	Tributary River Mile	Date	Time	Temp.(°C)	pH	NH_3-N (mg/l)	Turb. (J.T.U.)	DO (mg/l)	DO (% sat.)
46.8		10/1	1210	14.5	8.5	ND	32	12.8	130
46.8		10/2	0940	14.0	8.5	ND	--	10.6	106
46.8		10/3	1110	16.0	8.3	ND	--	11.5	121
35.3		10/1	1235	14.5	8.5	ND	27	13.0	132
35.3		10/2	0900	14.0	8.5	ND	--	10.0	100
35.3		10/3	1130	16.5	8.2	ND	--	11.6	124
16.8		10/1	1300	14.5	8.5	ND	22	13.1	134
16.8		10/2	0835	13.5	8.4	ND	--	10.0	99
16.8		10/3	1150	16.0	8.4	ND	--	10.7	112
5.0		10/1	1325	14.5	8.4	ND	19	13.6	138
5.0		10/2	0815	13.5	8.5	ND	--	11.9	118
5.0		10/3	1210	15.5	8.4	ND	--	12.2	126
2.2		10/1	1340	17.0	8.5	ND	20	17.1	175
2.2		10/2	0745	13.5	8.5	ND	--	13.0	129
2.2		10/3	1215	17.5	8.6	ND	--	18.0	180

TABLE K-2

Chlorophyll a from periphyton. Artificial substrates exposed for 24-day periods between 10 September 1972 and 3 October 1972.

	Chlorophyll a	
River Mile	$\mu g/cm^2$	$\mu g/in^2$
263.5	8.71	56.2
243.9	5.52	35.6
237.6	5.92	38.2
214.6/0.1	0.71	4.6
206.1	1.39	9.0
186.9	1.30	8.4
173.0	1.52	9.8
162.2	0.68	4.4
154.2	5.02	32.4
150.6	4.65	30.0
146.8	2.08	13.4
143.2	6.73	43.4
141.2	2.60	16.8
134.5	1.18	7.6
130.1/27.3	4.22	27.2
130.1/5.3	3.91	25.2
127.0	3.98	25.7
106.2	3.01	19.4
80.9	1.52	9.8
76.2/40.8	7.42	47.9
76.2/5.8	6.26	40.4
66.9	6.43	41.5
46.8	2.14	13.8
35.3	4.42	28.5
16.8	3.38	21.8
2.2	2.05	13.2

TABLE K-3

Species diversity ($\bar{d}$) of benthic macroinvertebrates, Big Sioux River and selected tributaries. September and October, 1972.

River Mile	$\bar{d}$	River Mile	$\bar{d}$
263.5	1.15	142.7	3.17
243.9	3.65	141.2	4.52
237.6	2.46	134.5	4.25
214.6/0.1	3.03	130.1/27.3	3.48
206.1	3.69	130.1/5.3	2.02
186.9	3.39	127.0	3.22
173.0	3.51	106.2	1.64
162.2	3.10	80.9	0.94
155.4	2.62	76.2/40.8	2.50
154.2	3.42	76.2/5.8	2.36
152.8/1.1	0.98	66.9	3.91
150.6	1.41	46.8	2.59
146.8	3.99	35.3	3.15
143.8	1.73	16.8	4.14
143.2	3.17	2.2	1.82

TABLE K-4
Results of nitrogen analyses from
selected waste discharges to the Big Sioux River
Sioux Falls, South Dakota.

Location	Date	Time	TKN mg/l	NH_3-N mg/l	Org.-N mg/l	NO_2+NO_3-N mg/l
Meilman Food Industries (formerly Spencer Foods, Inc.) effluent from process-waste lagoons.	10/2/72	1145	35.0	31.0	4.0	<0.05
	10/2/72	1625	38.0	32.0	6.0	0.26
	10/3/72	0830	43.0	33.0	10.0	<0.05
	10/3/72	1230	37.0	36.0	1.0	0.26
John Morrell and Company condenser discharge.	10/2/72	1200	1.8	0.2	1.6	0.79
	10/2/72	1405	1.9	0.2	1.7	1.10
	10/2/72	1600	2.1	0.2	1.9	0.97
	10/2/72	1800	1.9	0.1	1.8	0.92
	10/3/72	0800	12.0	9.8	2.0	0.98
	10/3/72	1200	5.1	3.5	1.6	0.60

TABLE K-5
Dissolved-Oxygen Profiles.
Big Sioux River, Sioux Falls, South Dakota
September, 1972.

River Mile	Date	Time	Temp(°C)	DO (mg/l)	DO (% sat)
162.2	9/26	0600	11.5	9.4	89
	9/26	0610	11.5	9.2	87
	9/26	0700	11.5	9.5	90
	9/26	0800	11.0	10.0	94
	9/26	0900	10.5	10.0	93
	9/26	1000	11.5	10.9	104
	9/26	1100	11.5	11.0	105
	9/26	1200	11.5	12.2	115
	9/27	0600	11.0	9.6	90
	9/27	0700	11.0	9.6	90
	9/27	0800	10.5	9.7	90
	9/27	0900	11.0	9.8	92
	9/27	1000	11.5	10.5	100
	9/27	1100	11.5	11.3	107
	9/27	1200	12.0	12.1	115
143.2	9/26	0605	9.0	8.7	77
	9/26	0700	9.0	8.6	76
	9/26	0800	9.0	8.9	79
	9/26	0900	9.0	9.4	84
	9/26	1000	9.5	10.0	90
	9/26	1100	10.0	10.5	96
	9/26	1200	11.0	11.0	103

TABLE K-5
Dissolved-Oxygen Profiles.
Big Sioux River, Sioux Falls, South Dakota
September, 1972.
(Continued)

River Mile	Date	Time	Temp(°C)	DO (mg/l)	DO (% sat)
141.2	9/26	0610	12.5	9.2	89
	9/26	0700	12.0	9.3	89
	9/26	0805	12.0	9.4	90
	9/26	0908	11.5	9.7	92
	9/26	1000	12.5	9.9	96
	9/26	1103	12.5	9.9	96
	9/26	1200	13.5	10.0	99
134.5	9/26	0615	11.0	7.1	67
	9/26	0705	11.0	7.3	68
	9/26	0805	11.5	7.5	71
	9/26	0900	11.5	7.9	75
	9/26	1000	11.5	8.4	80
	9/26	1100	12.0	9.0	86
	9/26	1200	12.5	9.5	93
134.5	9/27	0605	12.0	7.4	70
	9/27	0700	12.0	7.4	70
	9/27	0800	11.0	7.5	70
	9/27	0900	12.0	8.0	76
	9/27	1000	12.0	8.6	83
	9/27	1100	12.5	9.4	91
	9/27	1200	12.5	9.9	96

TABLE K-5
Dissolved-Oxygen Profiles
Big Sioux River, Sioux Falls, South Dakota
September, 1972.
(Continued)

River Mile	Date	Time	Temp(°C)	DO (mg/l)	DO (% sat)
127.0	9/26	0634	11.5	7.3	69
	9/26	0700	11.5	7.2	68
	9/26	0800	10.0	7.3	66
	9/26	0900	12.0	7.3	70
	9/26	1000	11.5	7.8	74
	9/26	1100	11.5	8.2	77
	9/26	1200	12.0	8.7	84
127.0	9/27	0600	12.0	7.8	75
	9/27	0702	12.0	8.9	85
	9/27	0800	12.0	7.6	73
	9/27	0900	11.5	7.7	73
	9/27	1005	11.5	8.1	76
	9/27	1100	12.0	8.6	83
	9/27	1206	12.5	9.1	84
113.0	9/27	0715	11.5	7.5	71
	9/27	0800	10.0	7.8	72
	9/27	0900	11.0	7.6	71
	9/27	1000	12.0	8.2	79
	9/27	1100	12.0	8.3	80
	9/27	1200	12.0	9.5	91

TABLE K-5
Dissolved-Oxygen Profiles
Big Sioux River, Sioux Falls, South Dakota
September, 1972.
(Continued)

River Mile	Date	Time	Temp(°C)	DO (mg/l)	DO (% sat)
106.2	9/27	0700	10.0	8.4	77
	9/27	0800	10.0	8.7	79
	9/27	0900	10.0	8.8	80
	9/27	1000	10.0	9.1	83
	9/27	1100	10.0	9.4	85
	9/27	1200	10.5	9.7	85

TABLE K-6

Gross and Net Photosynthesis, Respiration, and Carbon Fixation, Big Sioux River - Fall, 1972

River Mile	Date	Photosynthesis (mg/l) Gross	Net	Respiration	Carbon Fixed mg/m^3/day
162.2	9/26	4.9	4.8	0.1	4,950
162.2	9/27	6.4	6.3	0.1	6,500
143.2	9/26	5.9	5.6	0.3	6,050
141.2	9/26	1.7	1.8	- 0.1	1,855
134.5	9/26	1.6	1.9	- 0.3	1,955
127.0	9/26	1.7	2.0	- 0.3	2,060
127.0	9/27	1.8	1.8	0	1,855
113.0	9/27	2.8	2.7	0.1	2,785
106.2	9/26	6.1	5.7	0.4	5,870

TABLE K-7

Algal Growth, Stimulated by Additions of Sioux Falls WWTP Final Clarifier Effluent to Big Sioux River Receiving Water [Expressed as Concentration of Chlorophyll a (µg/l)] Samples Collected 9/13/72; Incubated 9/15 to 9/24/72.

Dilutions	Chlorophyll a (µg/l)		
% Sewage	Initial	Peak	(Day)
0.0	4.9	10.8	(4)
0.1	4.8	26.3	(4)
1.0	4.9	24.4	(4)
5.0	4.7	26.2	(4)
10.0	4.6	9.0	(5)
20.0	4.3	28.6	(7)
40.0	3.5	26.5	(9)
60.0	2.9	34.0	(9)
80.0	2.1	80.8	(9)
100.0	1.5	88.0	(9)

TABLE K-8

Algal Growth, Stimulated by Additions of Nitrogen And Phosphorus to Big Sioux River Water [Expressed as Concentration of Chlorophyll a (µg/1)] Samples Collected 9/13/72, Incubated 9/15 to 9/24/72.

Nitrogen (N) mg/1	Phosphorus (P) mg/1	Chlorophyll a (µg/1) Initial	Peak	(Day)
0.0	0.0	4.9	4.9	(0)
0.01	0.0	4.9	26.4	(4)
0.1	0.0	4.9	29.4	(4)
1.0	0.0	4.8	39.9	(5)
10.0	0.0	4.4	33.0	(4)
0.0	0.01	4.9	19.5	(4)
0.01	0.01	4.8	29.1	(5)
0.1	0.01	4.9	22.8	(4)
1.0	0.01	4.9	30.3	(4)
10.0	0.01	4.4	53.4	(5)
0.0	0.1	4.9	24.9	(4)
0.01	0.1	4.9	22.2	(4)
0.1	0.1	4.9	11.1	(3)
1.0	0.1	4.4	23.1	(5)
10.0	0.1	4.5	48.9	(5)
0.0	1.0	4.9	24.0	(4)
0.01	1.0	4.9	22.2	(4)
0.1	1.0	4.8	6.9	(9)
1.0	1.0	4.9	29.1	(5)
10.0	1.0	4.5	33.0	(5)
0.0	10.0	4.5	8.0	(9)
0.01	10.0	4.5	11.0	(6)
0.1	10.0	4.5	11.2	(6)
1.0	10.0	4.4	27.6	(7)
10.0	10.0	4.1	43.8	(9)

TABLE K-9
BENTHOS, BIG SIOUX RIVER AND SELECTED TRIBUTARIES
SOUTH DAKOTA, IOWA, MINNESOTA
(Numbers per square foot) [a]
September-October, 1972

Organisms / River Mile	2 2	16 8	35 3	46 8	66 9	76 2/8 5	76 2/32 0	80 9	106 2	127 0	130 1/9 3	130 1/27 3	134 5	141 2	142 7	143 2	143 8
Annelida																	
Oligochaeta								1	2					Q [b]			
Tubificidae	42			2		43	354				14	4	Q	Q			
Hirudinea																	
Dina parva												1	Q				
Crustacea																	
Amphipoda																	
Talitridae																	
Hyalella azteca						1				Q		1	Q			Q	
Decapoda																	
Carbarinae																	
Orconectes sp.																	
Insecta																	
Ephemeroptera																	
Leptophlebiidae																	
Paraleptophlebia sp.		Q			Q			Q	Q	Q	1		Q	Q	Q		
Potamanthidae																	
Potamanthus sp										Q	7	29					
Baetiscidae																	
Baetisca sp						5											
Siphlonuridae																	
Isonychia sp					Q			1	Q				Q	Q			
Tricorythidae																	
Tricorythodes sp			Q			1			2								
Caenidae																	
Caenis sp		Q						Q	Q			Q					
Leptophlebiidae																	
Leptophlebia sp.					Q				Q						Q		
Ephemeridae																	
Hexagenia sp	2										1	6			Q		
Brachycercus sp						6	1				Q	1					
Heptageniidae																	
Cinygmula sp				Q			3	Q	Q		Q			Q			
Stenonema sp		Q	Q	Q	Q	84	14	Q	Q	Q	Q	1	Q	Q	Q	Q	1
Heptagenia sp	Q	Q	Q	1	Q		9	9	Q	Q	Q		Q	Q			1
Baetidae																	
Baetis sp		Q	Q	Q	Q	19	78	3	4	Q	5		Q	Q		Q	
Centroptilum sp							544		4		2	21					
Pseudocloeon sp									Q								
Odonata																	
Coenagriidae																	
Enallagma sp		Q						Q			Q	Q					
Argia sp	Q		Q					Q				Q					
Gomphidae																	
Gomphus sp	2	1				Q		1				Q	Q				
Coleoptera																	
Dytiscidae			Q									Q					
Elmidae												Q				Q	1
Stenelmis sp.					Q	1			Q		3	4				Q	

TABLE K-9 (Cont.)
BENTHOS, BIG SIOUX RIVER AND SELECTED TRIBUTARIES
SOUTH DAKOTA, IOWA, MINNESOTA
(Numbers per square foot) [a/]
September-October, 1972
(Continued)

Organisms / River Mile	146 8	150 6	152 8/1 1	154 2	155 4	162 2	173 0	186 9	206 1	214 6/0 1	237 6	243 9	263 5
Tricoptera	18	531	392										
Hydropsychidae													
Hydropsyche sp	19	76	61		5	11	Q [b/]		17	Q	10	Q	130
Cheumatopsyche sp.	18	2		Q	27	1	Q	1	7	1	92	Q	Q
Polycentropidae													
Polycentropus sp.							Q		1				
Diptera													
Tipulidae	3	2				3							
Simuliidae													
Simulium sp		7	8	Q	3	24		2	2		5	Q	2
Ceratopogonidae	1												
Chironomini							Q						
Chironomus	1			Q	5	2	4	Q			7		
Cryptochironomus	Q	7			1		3		3	2			
Dicrotendipes													
Endochironomus					1								
Glyptotendipes		1	1										
Harnischia		2											
Limnochironomus													
Microtendipes				2									
Paratendipes													
Pentapedilum													
Polypedilum	2	3		Q	2		4	3	9		9	Q	2
Pseudochironomus							2						
Tribelos												1	
Xenochironomus		Q					22						
Orthocladiinae	Q												
Corynoneura		Q											
Cricotopus	2	9					Q					Q	2
Eukiefferiella													
Orthocladius	Q				2			Q					
Procladius												Q	
Psectrocladius	Q	2			1						Q		
Thienemanniella	Q						2			Q			Q
Smittia							Q						
Tanypodinae													
Coelotanypus							6	Q	Q		2	Q	2
Podonominae					1		Q						
Tanytarsini													
Tanytarsus								Q					
Pelecypoda													
Sphaeriidae													
Sphaerium	2											1	
Gastropoda													
Pulmonata													
Physidae													
Physa			Q	Q		1							
NUMBER OF KINDS	30	25	11	11	14	15	19	12	16	8	14	16	15
NUMBER/SQ FT [a/]	102	664	471	12	52	51	60	19	57	9	149	21	148

TABLE K-9 (Cont.)
BENTHOS, BIG SIOUX RIVER AND SELECTED TRIBUTARIES
SOUTH DAKOTA, IOWA, MINNESOTA
(Numbers per square foot) [a/]
September-October, 1972

Organisms / River Mile	146 8	150 6	152 8/1 1	154 2	155 4	162 2	173 0	186 9	206 1	214 6/0 1	237 6	243 9	263 5
Annelida													
Oligochaeta													
Tubificidae	7	2	1		Q [b/]			3			17		1
Hirudinea													
Dina parva	3								2				1
Crustacea													
Amphipoda													
Talitridae													
Hyalella azteca	Q	Q	Q	Q									1
Decapoda													
Cambarinae													
Orconectes sp											Q	Q	
Insecta													
Ephemeroptera													
Leptophlebiidae													
Paraleptophlebia sp	2	Q	Q	Q	Q	Q			1		Q	Q	Q
Potamanthidae													
Potamanthus sp	Q					Q							Q
Baetiscidae													
Baetisca sp	5	Q											
Siphlonuridae													
Isonychia sp											Q	Q	
Tricorythidae													
Tricorythodes sp	2				1	1			2				Q
Caenidae													
Caenis sp						1							
Leptophlebiidae													
Leptophlebia sp.	Q	1						Q				Q	
Ephemeridae													
Hexagenia sp	1		Q				6			1		6	Q
Brachycercus sp	Q	Q											
Heptageniidae													
Cinygmula sp				Q							Q	Q	
Stenonema sp	Q	2		1	1	Q	Q	Q	1	Q	Q	Q	Q
Heptagenia sp	2	3	3			Q			Q			Q	
Baetidae													
Baetis sp						Q	Q		Q	Q			
Centroptilum sp	1	1											
Pseudocloeon sp													
Odonata													
Coenagriidae													
Enallagma sp						Q							
Argia sp							Q						
Gomphidae													
Gomphus sp								1					
Coleoptera		4											
Dytiscidae				Q					Q				
Elmidae	Q	1				Q							
Stenelmis sp.								3	6				

TABLE K-9 (Cont.)
BENTHOS, BIG SIOUX RIVER AND SELECTED TRIBUTARIES
SOUTH DAKOTA, IOWA, MINNESOTA
(Numbers per square foot) a/
September-October, 1972
(Continued)

Organisms / River Mile	2.2	16.8	35.3	46.8	66.9	76.2/8.5	76.2/32.0	80.9	106.2	127.0	130.1/9.3	130.1/27.3	134.5	141.2	142.7	143.2	143.8
Tricoptera																	
Hydropsychidae																	
Hydropsyche sp		Q b/	2	5	Q	89	846	287	310		265	1	Q	Q	Q	Q	33
Cheumatopsyche sp		Q	17		Q	236	490		51		1	29	Q	Q	Q		Q
Polycentropidae																	
Polycentropus sp.		Q														Q	2
Diptera																	
Tipulidae						2											
Simuliidae																	
Simulium sp		Q	Q		Q	18	158		19	Q	11		Q	Q			
Ceratopogonidae											3						
Chironomini	Q													Q			
Chironomus	3						4	3		Q	1	1	Q	3			
Cryptochironomus	3		2				2										
Dicrotendipes	Q																
Endochironomus											Q						
Glyptotendipes	Q	Q					9		Q		Q	2		Q	Q	Q	
Harnischia							2							Q			
Limnochironomus							3										
Microtendipes				1							12						
Paratendipes			2														
Pentapedilum																	
Polypedilum		Q	Q		Q		4		9	Q		4	Q	Q			Q
Pseudochironomus														Q			
Tribelos																	
Xenochironomus				13		Q		3			11						
Orthocladiinae																	
Corynoneura								Q									
Cricotopus		Q									Q		Q	Q	Q		Q
Eukiefferiella																	
Orthocladius			Q		Q				Q								
Procladius																	
Psectrocladius		Q							Q			2	Q				
Thienemanniella				Q							Q		Q	Q			Q
Smittia																	
Tanypodinae				Q									Q				
Coelotanypus					Q			Q	3	Q	Q	2		Q			
Podonominae									Q								
Tanytarsini		Q															
Tanytarsus															Q		
Pelecypoda																	
Sphaeriidae																	
Sphaerium	1	2							1			Q					
Gastropoda																	
Pulmonata																	
Physidae																	
Physa									1			Q				Q	
NUMBER OF KINDS	11	17	13	10	14	14	16	16	24	10	24	25	18	21	9	9	9
NUMBER/SQ FT a/	58	18	32	27	14	507	2,521	316	420	10	348	118	18	24	9	9	42

a/ No./m^2 is obtained by multiplying No./ft^2 by a factor of 10.76.
b/ The capital letter, Q, equals organisms collected qualitatively, arbitrarily assigned a value of one for computing.

TABLE K-10
WATER-QUALITY CONDITIONS AND 96-HOUR BIOASSAY RESULTS
SIOUX FALLS, WWTP, JANUARY 30-FEBRUARY 3, 1973

Dilution % Sewage	NH_3	D.O.	pH	Temperature °C	Number of fish alive/dead after 96 hr	Mortality %
100	55.9 mg/1 (54-64)	4.7 mg/1 (4.0-5.8)	7.3-7.5	16.6 (14-18)	0/20	100
52	23.4 mg/1 (18-27)	5.6 mg/1 (3.4-7.0)	7.4-7.6	16.1 (13-18)	19/1	5
36	16.25 mg/1 (14-18)	6.2 mg/1 (5.4-7.3)	7.4-7.7	15.4 (11-18)	20/0	0
27	14.6 mg/1 (11-18)	6.3 mg/1 (4.8-7.3)	7.4-7.7	15 (13-18)	20/0	0%
16	13.7 mg/1 (11-20)	6.0 mg/1 (5.5-7.0)	7.4-7.8	15.9 (12-18)	20/0	0
8	6.5 mg/1 (4-12)	5.6 mg/1 (3.4-7.3)	7.5-7.7	15.5 (13-18)	20/0	0
Control 100% Dilution	0.25 mg/1 (0.0-1.5)	7.4 mg/1 (5.4-8.6)	7.7-7.9	14.8 (11-17)	20/0	0

TABLE K-11

LOCATION OF FISH CAGES IN BIG SIOUX RIVER
SIOUX FALLS, SOUTH DAKOTA
29 January-February 1973

River Mile	Description
--	Diversion canal approximately 1.1 km (0.66 mi) downstream from Big Sioux RM 158.8 (Reference Site).
142.95	Big Sioux River, about 135 m (150 yd) upstream of Sioux Falls, South Dakota, WWTP effluent outfall.
142.85	Big Sioux River, about 135 m (150 yd) downstream from Sioux Falls, South Dakota, WWTP effluent outfall.
128.5	Big Sioux River, Hwy 38 bridge approximately 2.4 km (1.5 mi) upstream of Iowa-South Dakota state line.
142.9	Main outfall, Sioux Falls, South Dakota, WWTP effluent.

TABLE K-12

Algal Growth, Stimulated by Additions of Sioux Falls WWTP
Final Effluent to Big Sioux River Receiving Water
[Expressed as Concentration of Chlorophyll a (μg/1)]
Samples Collected 1/25/73, Incubated 1/31 to 2/9/73

Dilutions % Sewage	Chlorophyll a (μg/1) Initial	Peak	(Day)
0.0	1.1	2.0	(7)
0.1	1.1	1.8	(7)
1.0	1.2	3.5	(9)
5.0	1.3	3.1	(7)
10.0	1.3	3.8	(7)
20.0	1.5	4.9	(8)
40.0	1.7	25.0	(9)
60.0	2.1	80.6	(9)
80.0	2.4	122.9	(9)
100.0	2.6	65.6	(9)

TABLE K-13

Algal Growth, Stimulated by Additions of Sioux Falls WWTP
By-pass to Big Sioux River Receiving Water
[Expressed as Concentration of Chlorophyll a (μg/l)]
Samples Collected 1/25/73, Incubated 1/31 to 2/9/73

Dilutions	Chlorophyll a (μg/l)		
% Sewage	Initial	Peak	(Day)
0.0	1.0	1.3	(7)
0.1	1.2	1.4	(6)
1.0	1.3	2.6	(7)
5.0	1.4	3.1	(7)
10.0	1.8	3.7	(7)
20.0	2.3	4.4	(6)
40.0	3.2	8.0	(9)
60.0	4.0	4.7	(5)
80.0	4.9	4.9	(0)
100.0	6.0	6.0	(0)

TABLE K-14

Algal Growth, Stimulated by Additions of Nitrogen
And Phosphorus to Big Sioux River Water
[Expressed as Concentration of Chlorophyll a (µg/l)]
Samples Collected 1/25/73, Incubated 1/31/73 to 2/9/73

Nitrogen mg/l as N	Phosphorus mg/l as P	Chlorophyll a (µg/l) Initial	Peak	(Day)
0	0	1.2	1.3	(7)
1	0	1.1	1.2	(7)
10	0	1.1	1.1	(0)
30	0	1.0	1.0	(0)
70	0	0.9	0.9	(0)
0	.01	1.3	2.2	(8)
1.0	.01	1.3	2.2	(9)
10	.01	1.1	1.3	(8)
30	.01	1.0	1.0	(0)
70	.01	0.9	0.9	(0)
0	0.1	1.2	2.5	(9)
1	0.1	1.2	1.8	(7)
10	0.1	1.1	2.1	(9)
30	0.1	1.1	1.7	(7)
70	0.1	.9	1.2	(4)
0	1.0	1.2	4.6	(7)
1	1.0	1.1	4.8	(7)
10	1.0	1.1	4.7	(7)
30	1.0	1.1	4.1	(7)
70	1.0	0.8	1.0	(5)
0	10.0	1.3	7.0	(8)
1	10.0	1.3	6.1	(8)
10	10.0	1.2	6.4	(8)
30	10.0	1.0	5.4	(8)
70	10.0	0.8	4.1	(5)

TABLE K-15

Algal Growth, Stimulated by Additions of Stripped Effluent from the Sioux Falls WWTP to Big Sioux River Receiving Water [Expressed as Concentration of Chlorophyll a (µg/l)] Samples Collected 1/25/73, Incubated 2/28 to 3/9/73

Dilutions % Sewage	Chlorophyll a (µg/l) Initial	Peak	(Day)
0.0	2.2	2.2	(1)
0.1	2.2	2.2	(5)
1.0	2.0	2.2	(1)
5.0	2.0	2.1	(1)
10.0	2.1	2.8	(5)
20.0	3.0	5.8	(7)
40.0	3.2	8.8	(8)
60.0	2.6	13.1	(9)
80.0	2.3	53.1	(9)
100.0	2.3	334.6	(9)

TABLE K-16

Algal Growth, Stimulated by Additons of Stripped Effluent from the Sioux Falls WWTP Plus Nitrogen and Phosphorus to Big Sioux River Receiving Water
[Expressed as Concentration of Chlorophyll a (μg/l)]
Samples Collected 1/25/73, Incubated 2/28 to 3/9/73.

Dilutions % Sewage	Nitrogen mg/l as N	Phosphorus mg/l as P	Chlorophyll a (μg/l) Initial	Peak	(Day)
0	0	0	2.2	2.2	(1)
0.1	0.1	0	2.2	2.3	(1)
0.1	0	0.1	2.6	Contaminated	(6)
0.1	0.1	0.1	2.3	5.4	(7)
1.0	0.1	0	2.2	2.4	(1)
1.0	0	0.1	2.3	5.6	(6)
1.0	0.1	0.1	2.3	5.3	(6)
10.0	0.1	0	2.3	3.2	(5)
10.0	0	0.1	2.6	7.3	(9)
10.0	0.1	0.1	2.5	6.9	(9)
50.0	0.1	0	2.9	11.1	(7)
50.0	0	0.1	2.7	12.0	(7)
50.0	0.1	0.1	2.8	11.7	(9)
0.1	1.0	0	2.5	2.5	(1)
0.1	0	1.0	2.5	9.0	(5)
0.1	1.0	1.0	2.4	8.9	(5)
1.0	1.0	0	1.8	1.9	(1)
1.0	0	1.0	2.6	9.0	(6)
1.0	1.0	1.0	2.3	8.9	(6)
10.0	1.0	0	1.9	3.1	(5)
10.0	0	1.0	2.4	11.4	(8)
10.0	1.0	1.0	2.4	11.2	(8)
50.0	1.0	0	2.7	10.8	(9)
50.0	0	1.0	2.4	16.0	(9)
50.0	1.0	1.0	2.4	17.9	(8)
0.1	10.0	0	1.9	2.5	(5)
0.1	0	10.0	2.3	12.3	(6)
0.1	10.0	10.0	2.5	Contaminated	(5)

TABLE K-16 (Cont.)

Algal Growth, Stimulated by Additions of Stripped Effluent From the Sioux Falls WWTP Plus Nitrogen and Phosphorus to Big Sioux River Receiving Water
[Expressed as Concentration of Chlorophyll a (μg/l)]
Samples Collected 1/25/73, Incubated 2/28 to 3/9/73

Dilutions % Sewage	Nitrogen mg/l as N	Phosphorus mg/l as P	Chlorophyll a (μg/l) Initial	Peak	(Day)
1.0	10.0	0.0	1.9	2.6	(6)
1.0	0.0	10.0	2.3	12.2	(5)
1.0	10.0	10.0	2.3	12.5	(5)
10.0	10.0	0.0	2.0	4.0	(6)
10.0	0.0	10.0	2.3	10.6	(5)
10.0	10.0	10.0	2.5	11.1	(5)
50.0	10.0	0.0	2.7	12.8	(5)
50.0	0.0	10.0	2.4	12.8	(6)
50.0	10.0	10.0	2.5	16.5	(7)

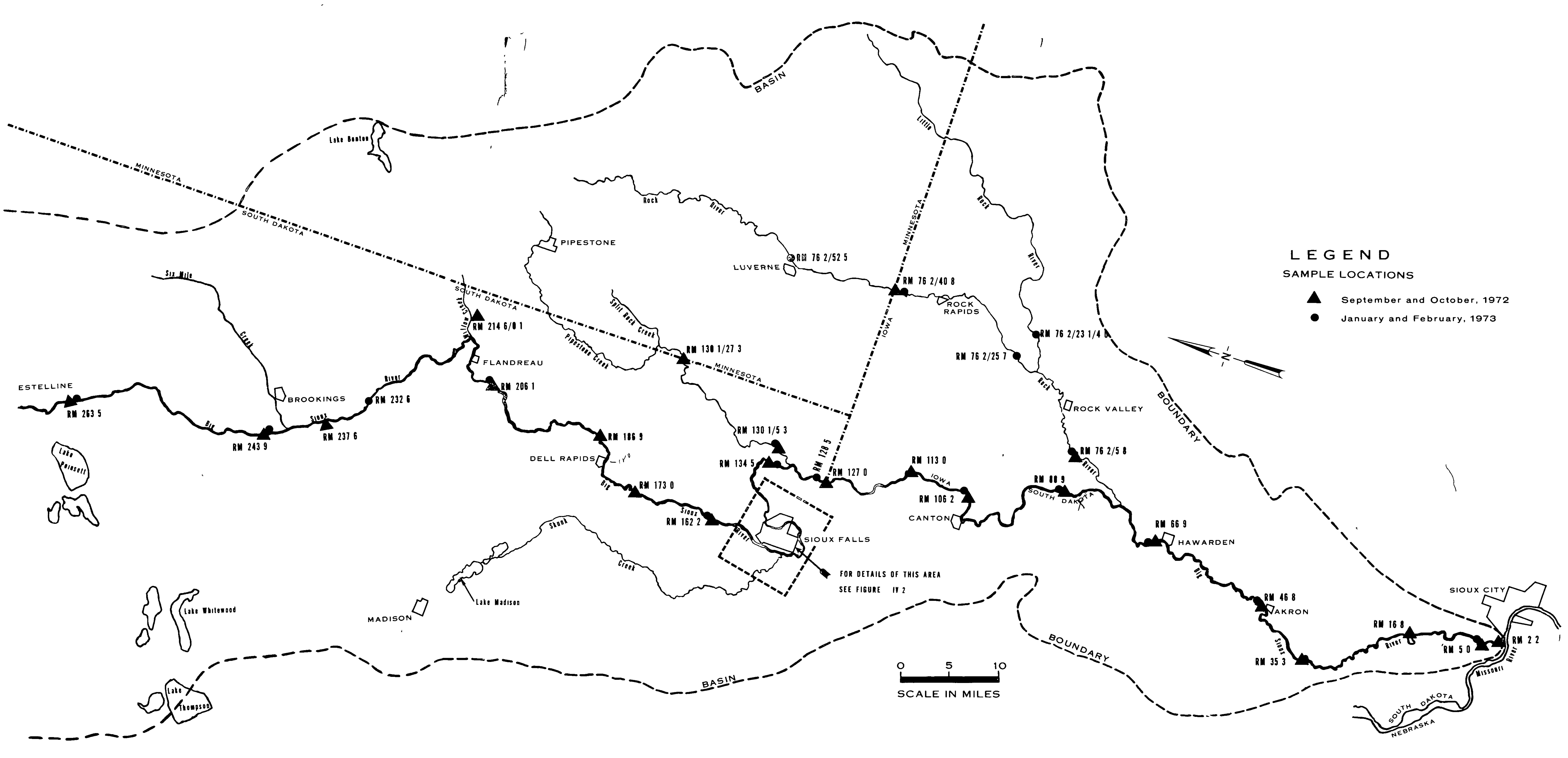

Figure IV-1 Sampling Locations, Big Sioux River and Selected Tributaries, Estelline, South Dakota to Sioux City, Iowa