EVERYONE CAN'T LIVE UPSTREAM

A CONTEMPORARY HISTORY OF THE WATER QUALITY PROBLEMS
ON THE MISSOURI RIVER
(SIOUX CITY, IOWA TO HERMANN, MISSOURI)

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAMS
911 WALNUT, KANSAS CITY, MISSOURI

APRIL, 1971

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REGION VII

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In December 1970, the Environmental Protection Agency (EPA) officially came into being and the Federal Water Quality Administration (FWQA) became the Office of Water Quality within EPA. This report is based on work completed prior to the formation of EPA by many organizational segments of the FWQA and is acknowledged as such. The overall field effort was coordinated by the Missouri Basin Region, FWQA, Mr. John M. Rademacher, Regional Director. The National Field Investigations Center, Cincinnati, Ohio, Mr. A. D. Sidio, Director, contributed generously of manpower, equipment, and consultation. Dr. Robert Bunch and Dr. Gerald Berg of the Advanced Waste Treatment group provided sophisticated laboratory assistance and consultation. Their efforts along with the understanding of Dr. Francis Middleton, their supervisor, is gratefully acknowledged. Finally, Mr. Kenneth M. Mackenthun, now Director of Technical Services, Office of Water Quality, EPA, served as the Washington, D. C. coordinator for the field efforts and his dedicated support eased the administrative burden enabling the cooperative effort to be completed. The report was developed by Mr. Carl M. Walter of the Missouri Basin Region Staff.

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INTRODUCTION

The title of this report was carefully chosen to depict a major dilemma of modern society. That is, the growth of the country has placed man in the position of regarding water, both in quantity and quality, as a limited resource and of developing a workable means to protect this resource. "Everyone Can't Live Upstream" is directly concerned with the quality aspects. It is a factual document showing what happens to a major river as metropolitan areas develop along the stream banks and in essence is a description of the plight of the downstream user.

This report documents the history of water quality problems on the Missouri River beginning with the first Federal enforcement actions, describing the development of water quality standards, and some of the attendant controversy involved, and finally presenting the results of two years of water quality investigations of the river to develop the technical support for stringent water quality standards.

BACKGROUND AND ENFORCEMENT ACTIONS

On July 9, 1956, Congress approved Public Law 84-660, an Act to extend and strengthen the Federal Water Pollution Control activities. Section 9 of this 1956 legislation empowered the Federal government with specific enforcement capability against pollution of interstate waters. Beginning in 1957, a series of enforcement actions were instituted on the Missouri River.

During the period of 1957 to 1966, as these enforcement conferences, hearings and court action progressed, the Federal law was further strengthened by Congressional amendments. The most significant of these amendments was the Water Quality Act of 1965 which called for Federal Water Quality Standards on interstate waters. These Standards were to be developed by the individual states, reviewed and approved by the Federal government, and then accepted as both the State and Federal Standard of quality for the body of water concerned.

Along with the Standards requirement, the Water Quality Act of 1965 introduced the concept of enhancement of quality. The old approach of attempting to solve the problem after damage had occurred was replaced by a program of prevention and control.

The institutional pathways to achieve the goals set forth in the legislation were tortuous. The never ending argument of Federal intervention in States' rights was heard time and again. And, finally the pollution control effort by the states and the cities was one of expediency in order to placate the Federal government. This is demonstrated by the history of water pollution actions on the Missouri

River which are summarized on the following pages.

MISSOURI RIVER - SIOUX CITY, IOWA AREA

An enforcement conference was convened by the Public Health Service on July 24, 1958, at Sioux City involving the municipalities of Yankton, Vermillion and Elk Point, South Dakota; Sioux City, Iowa; South Sioux City, Dakota City, Ponca and Blair, Nebraska; and their associated industries which were discharging their wastes into and causing pollution of the Missouri River. The conferees agreed that pollution of the Missouri River, principally by the municipal and industrial wastes from Sioux City, Iowa, interfered with water uses in Nebraska. A time schedule calling for the awarding of contracts for remedial works by January 1, 1961, was established.

The failure of Sioux City, Iowa, to make suitable progress in providing abatement facilities resulted in the calling of a hearing by the Secretary of Health, Education, and Welfare. This hearing was held in Sioux City, Iowa, on March 23-27, 1959. The Hearing Board found Sioux City, Iowa, and 10 meat packing firms were discharging matter causing pollution of the interstate waters of the Missouri River so as to endanger the health and welfare of persons in Nebraska. Sioux City, Iowa, and its 10 associated industries were then directed to cease and desist and to provide what at that time was considered adequate collection and disposal facilities (primary treatment) by March 1, 1963. Although this schedule, as recommended by the Hearing Board, has been met substantially, new industries, such as Iowa Beef Packers at Dakota City, Nebraska, have located in the area increasing the waste loads discharged. This industry has agreed to provide secondary treatment of their wastes by August 1971.

Water quality standards established by the State of Iowa in accordance with Section 10(c)(1) of the Federal Water Pollution Control Act were determined in part not to be consistent with protection of the public health and welfare, the enhancement of water quality, and the purpose of the Federal Water Pollution Control Act. As a result, a Conference to Consider the Establishment of Water Quality Standards for the Missouri River Basin Interstate Waters--State of Iowa was convened April 15, 1969. As a result of the Conference, Secretary of the Interior Walter J. Hickel proposed standards for Iowa in the Federal Register November 1, 1969, calling for, among other things, secondary treatment plus bacterial control for domestic wastes (90 percent reduction of BOD) and equivalent treatment by industry by December 31, 1973. These standards were adopted by the Secretary of the Interior on May 12, 1970. On June 2, 1970, Governor Ray of Iowa petitioned for a hearing on the matter.

Subsequently, the State of Iowa conducted studies in the Sioux City Area and found evidence of pollution which confirmed our findings. Sioux City was then ordered to procede with the design and construction of secondary treatment facilities.

MISSOURI RIVER - OMAHA, NEBRASKA, COUNCIL BLUFFS, IOWA AREA

The first session of the enforcement conference on the Missouri River, Omaha Area, was held on June 14, 1957, in Omaha, Nebraska. The conferees concluded that pollution did exist and that the major cause of this pollution was Omaha, Nebraska. The schedule set by the conferees was not followed. Progress at Omaha had proceeded on the assumption that the industries would provide pretreatment of the wastes prior to discharge to the City's sewers. A sewage treatment plant was designed on this assumption. By January 1964, the Public Health Service learned that the packinghouses had made an agreement with the City to have the City treat their wastes; however, the municipal sewage treatment plant was not designed to handle this loading of paunch manure and grease. Several proposals to provide pretreatment of the packinghouse wastes either did not meet with the Omaha City officials' approval or the approval of the packing industry. Since it was evident that adequate progress was not going to be provided according to the time schedule set by the first conference, the second session of this conference was called for July 21, 1964, in Omaha, Nebraska. The main recommendations and conclusions from this conference established a new timetable for the planning, financing, and construction of a pretreatment complex. In addition, an Omaha Technical Committee, established by the conferees, continued to meet after the formal conference to work out a technically sound proposal for pretreating the packinghouse wastes. A survey of packinghouse wastes was conducted under the auspices of the Omaha Technical Committee during December 1964.

The findings of this study were presented at a Progress Evaluation Meeting of the Conferees held on February 11-12, 1965, at Omaha, Nebraska.

The findings and recommendations of the Technical Committee, which were endorsed by the conferees unanimously, agreed upon a new time schedule calling for the completion of the pretreatment complex by December 15, 1966.

When it did not appear that the new time schedule would be met, the conferees were again in session on January 27 and March 28, 1966. The conferees reestablished the completion dates set forth at the earlier meeting and set certain limits on grease and suspended solids to be met by the pretreatment facilities.

A follow-up evaluation meeting in Omaha on March 8, 1967, saw the City officials again pledge to complete the pretreatment complex. It was finally completed and put into operation September 2, 1969. Recently, the system has been experiencing operating difficulties, causing a bypassing of wastes to the Missouri River via the Monroe Street sewer. After negotiations with Federal and State officials the City assumed responsibility for operation of pretreatment.

The Omaha City Council, on February 3, 1970, resolved to provide secondary treatment at its Papillion Creek plant by the end of 1975, and by 1978 at the Missouri River plant. Advancing the 1978 date is subject to improvement in the availability of Federal-State funds.

On October 9, 1970, the Nebraska Water Pollution Control Council amended Nebraska Water Quality Standards by requiring secondary treatment of all municipal and industrial waste sources discharging to the Missouri River by December 31, 1975. This amendment stated "To protect and enhance the quality of productivity of the waters, all municipal wastes shall receive at least secondary treatment plus such additional treatment as is required to maintain Water Quality Criteria.

All industrial wastes shall receive an equivalent degree of treatment or control consistent with waste characteristics, uses and quality of receiving waters."

On May 4, 1970, the Council Bluffs, Iowa, City Council passed a resolution to provide secondary treatment by December 31, 1973, or any subsequent date reached jointly by State and Federal governments.

MISSOURI RIVER - ST. JOSEPH, MISSOURI AREA

A conference was held by the Public Health Service on June 11, 1957, in St. Joseph, Missouri. The conferees agreed on a time schedule for the installation of remedial facilities. The main recommendation was that the contract award for the construction of sewage treatment plant to serve the City of St. Joseph and its 18 associated industries be made by January 1, 1959. Since the City of St. Joseph and its electorate were not responsive to the recommendation by the conferees, a public hearing was called by the Secretary of Health, Education and Welfare on July 27-30, 1959, and on August 12, 1959, the Secretary issued a notice directing St. Joseph and 18 industries to cease and desist and to provide remedial work by July 1, 1963.

The St. Joseph Stockyards Company and related meat packing interests formed a sewer district on the south side of St. Joseph which proceeded to build a primary treatment plant in response to the recommendations of the conferees and the cease and desist order of the Secretary following the hearing.

The City of St. Joseph, however, did not respond to the cease and desist order, and an action was instituted in Federal Court which, following a favorable vote for a bond issue in St. Joseph, resulted in a Court Order of October 31, 1961, setting forth completion dates and provisions whereby the City of St. Joseph could make semiannual reports to the Court with provisions for reopening the case by the Government or the City. This case was dismissed without prejudice in U. S. District Court on March 16, 1970.

The municipal primary sewage treatment plant at St. Joseph is complete and operative, although only treating approximately 70 percent of the City's wastes. Remaining interceptor work is proceeding with an anticipated June 1971 completion date.

On November 25, 1969, St. Joseph Mayor Merrifield committed the City to a July 1, 1974, date for the completion of secondary treatment facilities.

The Missouri Water Pollution Board at its regular meeting on February 27, 1970, advanced the Statewide date for secondary treatment of all municipal and industrial wastes to December 31, 1975.

On January 8, 1971, the Kansas Board of Health amended the Kansas Water Quality Standards with a requirement for secondary treatment of all municipal and industrial wastes by December 31, 1975.

KANSAS CITYS AREA

On December 3, 1957, a conference was convened which determined that pollution of interstate waters subject to abatement under the Federal Water Pollution Control Act was occurring in the Missouri River-Kansas Citys Area. The conferees found the major sources of pollution to be the untreated and inadequately treated sewage and industrial wastes from Kansas City, Kansas; Kansas City, Missouri; and North Kansas City, Missouri, and local industrial establishments. They recommended that adequate waste treatment facilities (primary) for Kansas City, Kansas; Kansas City, Missouri; and North Kansas City, Missouri, be completed and in operation by March 1, 1962, with the understanding that the complete separation of storm and sanitary sewage from Kansas City, Kansas, may not be effectuated until January 1, 1963.

In addition, the conferees recommended that industry in the Kansas City Metropolitan Area either connect with a municipal waste disposal system or complete and put into operation adequate treatment works for disposal of domestic and industrial wastes not later than March 1, 1962.

Because effective progress toward pollution abatement was not being made by any of the municipalities cited, a hearing was called and convened June 13-17, 1960. The Hearing Board recommended that on or before January 1, 1963, all remedial facilities (primary) should be placed under contract for construction to be completed and placed in operation within a reasonable time. North Kansas City completed its primary treatment facilities and sewerage system in 1964.

With implementation of recommendations lagging for the two Kansas Citys, a Progress Evaluation Meeting was convened April 21, 1965. The Federal and State conferees unanimously recommended "...that all municipal and industrial wastes originating in the Kansas City Area, the Kansas and Missouri Rivers and the tributaries thereof, be collected adequately through the municipal systems in accordance with the requirements of the State agencies, and that all these works be completed and in operation by January 1, 1967."

Subsequent to the Progress Evaluation Meeting, the City of Kansas City, Missouri, placed its primary treatment facilities and sewerage system collecting domestic and industrial wastes into operation during 1966. As previously mentioned, the Missouri Water Pollution Board advanced the date for secondary treatment facilities to 1975. In response to this decision, the Council of Kansas City, Missouri, issued a resolution stating that Kansas City, Missouri, would comply with this schedule.

The City of Kansas City, Kansas, placed its primary treatment facilities into operation in 1968 and to date has not fully completed construction of its sewerage system. The City still discharges some untreated wastes to streams in the area, and numerous industries discharge untreated wastes to the Missouri River via the Fairfax Drainage District outfall. On May 19, 1970, the Secretary of Interior, Walter J. Hickel, issued a 180-day notification of the violation of established water quality standards to the Fairfax Drainage District and called a hearing for July 7, 1970. As a result of this hearing, the District has submitted an abatement schedule which is being reviewed by EPA pending further enforcement action.

On February 19, 1970, the Board of Commissioners of the City of Kansas City, Kansas, adopted a resolution calling for completion of secondary waste facilities by December 31, 1975.

As previously mentioned, the Kansas Board of Health requires a minimum of secondary treatment or its equivalent of wastes for all sources with an outside date of December 31, 1975.

The case histories make it rather evident that water pollution control was and still is not a popular movement. Then as now rhetoric outweighed actions even with considerable Federal involvement.

WATER QUALITY STANDARDS

Water Quality Standards are comprised of three separate parts. These are the quality criteria, the implementation plan showing time schedules, and the enforcement plan including the monitoring scheme. The intent of the Federal legislation was to have the states formulate and adopt the standards. Then these standards were to be submitted to the Secretary of the Interior for his approval and when approved would become both Federal and State Standards. If not approved, the Secretary of the Interior, after due process of law, would establish the Standards.

The policy guidelines for developing standards provided insight into the purpose and intent of the standards. These guidelines were based on the premise that the waters belong to the people, and therefore, no one entity has a right to pollute. Since this concept had not been followed in the past, the standards were to be designed ultimately to enhance the quality of water through prevention and control.

The first building block of the standard package was the quality criteria. Here it was intended for all existing and potential water uses to be delineated, then the appropriate quality criteria would be established to protect these uses. The mechanism of public meetings was utilized to develop the spectrum of public use desires. The quality criteria necessary to protect these uses were developed by a national technical advisory committee comprised of well known experts in all fields and published in a report entitled "Water Quality Criteria." 1/

The implementation portion of the standards was for the purpose of describing the nature of actions to be taken to achieve compliance and the time frame for completion. In doing so, all relevant pollutional sources were to be considered including municipal and industrial wastes, cooling water discharges, irrigation return flows, and combined sewer overflows. It was clearly stated that no standard would be approved which allows any wastes amenable to treatment or control to be discharged into any interstate water without treatment or control regardless of the water quality criteria and water uses adopted. It was also stated that no standard would be approved which recognized waste transport as the only use.

The enforcement and monitoring aspect of the standards was expected to outline the enforcement authority for ensuring compliance as well as the surveillance program for determining compliance. It should be pointed out, the Standards were not designed primarily as an enforcement device. It was anticipated the orderly implementation of the Standards would provide a mechanism for improvement of the quality of water resources without the necessity of adversary hearings.

The status of Water Quality Standards for the states of Iowa, Nebraska, Kansas and Missouri is shown in Table 1.

1/ U. S. Department of the Interior, Federal Water Pollution Control Administration, Water Quality Criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, D. C., April 1968.

TABLE 1

STATUS OF WATER QUALITY STANDARDS

State	Date of Initial Approval	Federal Exceptions	Present Status January 1971
Iowa	Partial Approval 1/16/69	Excepted temperature criteria for interior streams; Secondary treatment plus disinfection on Missouri and Mississippi; phenol criteria on Missouri.	All issues resolved except Secondary treatment for one community on the Mississippi; State petitioned for hearing 6/2/70 to protest the standards promulgated by Federal Government.
Nebraska	12/19/68	None	State has amended standards to include a December 31, 1975, compliance date for Secondary treatment on Missouri River.
Kansas	Partial Approval 4/25/69	Bacterial criterion, dissolved oxygen criterion, temperature criterion, Secondary treatment date.	Standards have been amended to resolve exceptions and are awaiting approval of EPA
Missouri	7/30/70	None	State on own volition adopted a December 31, 1975, compliance date for Secondary treatment. Standards fully approved.

WATER QUALITY STUDIES

The Missouri Basin, which comprises one-sixth of the land area of the United States, is undergoing a new era of growth stimulated by control, conservation and development of its water resources. The development program is essentially that proposed in the Pick-Sloan Plan and authorized by Congress in the Flood Control Act of 1944. The result of this development has been a system of dams, levees and irrigation projects throughout the Basin.

On the Mainstem of the Missouri six large reservoirs have been created between the headwaters and Yankton, South Dakota. Much of the 811 mile reach downstream from Yankton has been leveed for flood control and channelized for navigation but the River is in a free-flowing state.

The last major dam on the Missouri was closed in the early 1960's, providing almost 76 million acre-feet of storage in the system. Consequently, the flow downstream from Yankton is almost completely regulated. Two distinct flow conditions prevail, approximately 9 months of navigation flows at 30,000 cfs or more and about 3 months of winter flows between 10,000 and 15,000 cfs with the upper reaches subject to periods of ice cover and ice jams.

There had not been any comprehensive water quality investigations since the advent of this hydraulic control of the river until the FWQA investigations of 1968-1970. The past Federal involvement of enforcement actions combined with the preparation and approval of water quality standards, necessitated the accumulation of data defining the quality of the River. This was doubly important because of the major population centers located on the lower portion of the Missouri River and their unknown quality impact of the Missouri River.

A two-part baseline survey was conducted in the fall of 1968 and the winter of 1969 covering the reach of river from Gavins Point Dam upstream from Yankton, South Dakota, to Hermann, Missouri, a river distance of about 700 miles.

The fall 1968 survey was conducted by boat during the navigational period. The actual field efforts were completed in two parts; the first encompassing the area from Sioux City, Iowa to St. Joseph, Missouri, and the second covering St. Joseph, Missouri to Hermann, Missouri. Twenty-nine sample stations were located in the upper reach from Gavins Points Dam to St. Joseph, Missouri and were sampled from October 7 to October 18, 1968 (first autumn survey period). Twenty-one of these stations were located on the main stem of the Missouri River, five stations were on tributary streams and threee stations were waste sources.

In the lower reach from St. Joseph to Hermann, twenty-eight stations were sampled in the period of October 28 to November 8, 1968 (second autumn survey period). Twenty-one of these stations were on the main stem, five were tributary streams, and two were waste sources. One main stem station at St. Joseph, Missouri, of the upstream section was repeated.

The winter 1969 survey was designed to reexamine water quality near urban areas with less extensive coverage at intervening, less accessible areas. Because of reduced flows and ice in the river, samples during this survey were collected from the stream banks at locations accessible by automobile. Thirty-one sampling stations were established on the 700-mile reach during the period of January 20 to February 2, 1969 (winter survey period). Twenty-four of these were on the main stem, two were on tributary streams and five were waste sources.

Stations sampled during the winter survey were located as closely as possible to the October 1968 locations. Where locations were not identical, a letter symbol was added to the station number in the summary tables to distinguish this difference.

Many analyses were necessary to determine the water quality in the Missouri River. In addition to the biological examinations, 45 chemical, biochemical, and bacteriological examinations were included in the analysis series. Not all analyses were performed on daily discrete samples from each station. At selected stations composites were made from the five daily samples and preserved for analysis of other constituents. Sample compositing was used to keep the required number of analyses within manageable limits. The sampling interval for each analysis is shown in Table No. 2. Results of analyses are summarized in Appendix B.

Biological features studied were bottom-inhabiting invertebrate organisms and suspended algae (phytoplankton). Bottom sampling was at approximately 20 river mile intervals except in areas affected by waste discharges where additional stations were established. Forty stations on the Missouri River and one station on each of the major tributaries were sampled. Stations are designated with the same number

TABLE 2

Frequency of Chemical Analyses
MISSOURI RIVER
(Gavins Point Dam to Hermann, Missouri)
OCT.-NOV., 1968 & JAN.-FEB., 1969 SURVEYS

CONSTITUENT OR ANALYSIS	DAILY	5-day Composite Sample	5-day Composite of Filtrate	2-4 Times per Survey Period	1 Time per Survey Period
ALL STATIONS					
Temperature	X				
Dissolved Oxygen (D.O.)	X(1)				
2- and 5-day Biochemical Oxygen Demand (B.O.D.)	X				
Total Alkalinity	X				
Specific Conductance	X				
Turbidity	X				
Chlorides	X(2)				
Sulfates	X(2)				
Total Dissolved Solids	X(2)				
Total Suspended Solids	X(2)				
Total Coliform Bacteria	X				
Fecal Coliform Bacteria	X				
Fecal Streptococci Bacteria	X(3)				
pH	X				
Magnesium		X			
Calcium		X			
Total Phosphorus		X			
Ammonia Nitrogen		X			
Nitrate Nitrogen		X			
Organic Nitrogen		X			
Total Organic Carbon		X			
SELECTED STATIONS					
20-day Biochemical Oxygen Demand (B.O.D.)				X(4)	
Sodium		X			
Potassium		X			
Fluoride		X			
Boron		X			
Arsenic			X		
Iron			X		
Barium			X		
Manganese			X		
Cadmium			X		
Chromium			X		
Copper			X		
Lead			X		
Nickel			X		
Zinc			X		
Phenol				X	
Cyanide				X	
Total Organic Chlorine					X
Chloroform Extract					X
Uranium (U^{235} & U^{238})		X			
Radium-226		X			
Thorium-232		X			
Total Alpha Thorium		X			
Strontium-90		X			

NOTES:
(1) Dissolved oxygen was not performed on waste effluents but only on stream samples.
(2) Analyses were performed 3 times per week during the October-November, 1968 Survey; daily during the winter survey.
(3) Performed during the winter survey only.
(4) Performed twice during autumn survey; once during winter survey.

as the closest chemical and bacteriological station where possible or as Corps of Engineers river miles measured upstream from the Missouri River confluence with the Mississippi River.

All chemical analytical methods conformed to "FWPCA Official Interim Methods for Chemical Analysis of Surface Waters." 2/ Except for modifications required for automated chemistry, methods contained in this volume are essentially the same as those contained in the 12th Edition of "Standard Methods for the Examination of Water and Wastewater." 3/ Most of the heavy metal analyses were performed by atomic absorption spectroscopy.

Bacterial examinations were performed in accordance with "Standard Methods." In this report, the term "total coliform bacteria" refers to bacteria identified as the "Coliform Group" in Standard Methods.

Bottom animal sampling was restricted to pile dikes and adjacent backwater areas because of river channelization and a shifting sand bottom. Pile dikes were examined to determine the representative kinds of benthic animals inhabiting a reach of river. Backwater areas were sampled for bottom organisms with either a Petersen or Ekman dredge. Dredgings were washed and strained through a U. S. Standard No. 30 sieve, and organisms remaining in the sieve were preserved for laboratory identification.

Suspended algal (phytoplankton) samples of one liter were collected at predetermined sampling stations and were preserved with five

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2/ "FWPCA Official Interim Methods for Chemical Analysis of Surface Waters," Federal Water Pollution Control Administration, September 1968.

3/ "Standard Methods for the Examination of Water and Wastewater," 12th Edition, APHA, AWWA, WPCF, 1965.

percent formalin for later identification.

Just prior to the completion of the winter 1969 field work, the Secretary of the Interior took exception to certain portions of the State of Iowa's water quality standards. Data from the 1968 and 1969 surveys were compiled and partially analyzed to provide a technical basis for these exceptions and presented in a standards setting conference in Arpil 1969. The State and the Federal Governments could not come to agreement and the Secretary of the Interior promulgated standards for the State. The State took issue with these standards and requested a hearing to resolve these differences.

In preparation for this more or less adversary confrontation, the FWQA conducted additional studies to evaluate further the pollution of the Missouri River. These studies were initiated in the Fall of 1969 and continued through the Spring of 1970. The primary objective of these studies was to ascertain the degree of water quality degradation in the Missouri River that could be controlled through waste treatment.

The Fall 1969 - Winter 1970 investigations were specifically oriented toward bacteriological and biological aspects of water quality. Separate investigations were conducted to demonstrate the effect of waste discharges on (1) the flavor of fish harvested from the Missouri River; (2) the periphyton crop; (3) the densities of total and fecal coliform groups and of fecal streptococci; (4) the presence of enteric virus and salmonella; and (5) the presence of sterol compounds unique to fecal material.

The fish flesh tainting study was conducted to demonstrate the effects of pollutants on fish flavor. To accomplish this, channel catfish, an important resident species, were exposed to the river both upstream and downstream from all known significant waste discharges. After a period of four days the fish were removed from the water, dressed, quick frozen and submitted to a food flavor test panel.

Periphyton studies were conducted to examine the assemblage of organisms that grow on surfaces of submerged objects in water. For these studies glass slides were exposed both in the vertical and horizontal position to provide a calibrated surface for organism attachment. The periphyton slides were then taken to the laboratory where the organisms were enumerated, identified and tests of organic carbon and chlorophyll were conducted to determine the community balance in terms of the ratio of bacterial slimes to plant organisms.

The bacterial populations utilize organic nutrients while the plants organisms require inorganic nutrient materials. Normally high densities of bacteria indicate the presence of organic waste such as sewage which these organisms convert to inorganic food for the plant cells. High densities of plant cells are indicative of sufficient quantities of inorganic nutrients in the proper environment to support plant growth.

Analyses were made for the total and fecal coliform groups and the fecal streptococcus group of indicator micro-organisms including differentiation of a random selection of fecal streptococci colonies by biochemical procedures. Fecal coliform to fecal streptococci ratios were calculated to indicate the probable source of the wastes, that is, whether of human or animal origin.

Special studies were conducted to determine if pathogenic organisms, such as salmonella and enteric virus, were present in the river at the major use points, and if so, the probable source. These data were desirable to firmly establish the presence of human fecal pollution and to demonstrate the hazard potential.

The last part of the stream quality evaluation program was a study to isolate a specific sterol compound in the waste sources and in the river water. This fecal sterol is a unique solid cyclic alcohol found in the feces of man and higher animals. The presence of this compound in water is positive confirmation of fecal contamination, and since this sterol is biodegradable, it is indicative of relatively recent fecal pollution. Studies at the Advanced Waste Treatment Research Laboratory in Cincinnati have shown this sterol is biodegradable and effectively removed by secondary treatment.

The process for isolating and identifying the fecal sterol involves solvent extraction, thin layer chromatography and positive identification by gas-liquid chromatography. The thin layer identification is a highly positive presumptive test which is confirmed by the gas-liquid chromatography.

The sampling scheme for the Fall 1969 - Winter 1970, field effort is shown in Table 3. When possible, all sample analyses were performed in conformance with either "FWQA Official Methods for Chemical Analyses of Surface Water," or "Standards Methods, 12th Edition." Those analyses not covered by either of the above methods references, were performed by the best procedures available from the FWQA research efforts.

A complete list and description of all stations sampled is appended to this report as Appendix A. A map of the River showing sampling stations and a description of study area is contained in Appendix B.

TABLE 3

SAMPLING SCHEME
MISSOURI RIVER STUDY
FALL 1969 - WINTER 1970

Item	Sampling Reach: Sioux City to Omaha	Omaha to St. Joseph	St. Joseph to Kansas City	Kansas City to Waverly
Fish Flesh Tainting				
Date of Survey	9/29-10/18/69			9/29-10/18/69
No. of Stations Sampled	16	20	11	25
Periphyton				
Date of Survey	9/7-10/7/69			9/7-10/7/69
No. of Samples	12	9	2	15
Bacteriological (Coliform and Streptococcus Groups)				
Date of Survey	8/8-12/69	9/3-7/69	9/18-22/69	9/25-29/69
No. of Stream Stn.	3	4	3	3
No. of Stream Samples per Stn.	28 to 30	28 to 30	28 to 30	28 to 30
No. of Waste Source or Tributary Stn.	6	13	10	8
No. of Samples/Source	2-5	2-5	2-5	2-5
Salmonella				
Date of Survey	9/8-12/69	11/3-7/69	9/18-22/69	
No. of Swabs Exposed	10	16	9	12
Virus				
Date of Sampling	9/9/69			1/20/70
No. of Samples	14	13	14	12
Fecal Sterols				
Dates of Sampling	1/20-3/4/70 3/17-24/70	1/27-2/23/70 3/10-31/70	2/4-4/7/70 4/21-5/5/70	2/11-4/14/70 4/28/70
No. of River Stations Samples	3	4	3	3
No. of Waste Source or Tributary Stn.	2	4	4	5

WATER QUALITY BY METROPOLITAN AREA

In 1961 the Missouri River Public Water Supplies Association comprised of representatives of water utilities using the Missouri River as their source of supply was formally established. This Not-For-Profit Corporation includes representatives from the following communities:

1. Omaha, Nebraska
2. Council Bluffs, Iowa
3. St. Joseph, Missouri
4. Leavenworth, Kansas
5. Atchison, Kansas
6. Kansas City, Missouri
7. Lexington, Missouri
8. Booneville, Missouri
9. Jefferson City, Missouri
10. St. Louis, Missouri
11. St. Louis County Water Company

The water supplied to over 3,000,000 people in these communities represents, by far, the most important use of the river.

Each of these communities has a vested interest in the quality of the Missouri and each is concerned with the fate of the wastes discharge upstream from their intake. For this reason the quality of the River was examined from the viewpoint of the impact of waste discharges from the upstream major metropolitan areas on the nearest major downstream water supply intake. The major areas discussed are:

1. Gavins Point to Omaha, Nebraska, including Sioux City, Iowa
2. Omaha, Nebraska to St. Joseph, Missouri
3. St. Joseph, Missouri to Kansas City, Missouri
4. Kansas City, Missouri to Waverly, Missouri

Appendix B of this report is the complete document prepared after completion of the Fall 1968 - Winter 1969 survey. Only the more significant findings are reported in this text to provide continuity in relating the total scope of work completed.

Gavins Point Dam to Omaha, Nebraska

The water discharged from Gavins Point Dam is of fairly good quality. Data from the 1968-1969 baseline survey are shown in Table 4. For the major use of water supply the only quality characteristics which approach the recommended limits of the Public Health Service are the total dissolved solids and sulfate concentrations which are both from natural sources.

Wastes discharged from the Sioux City metropolitan area have an impact on the quality of the Missouri River. There are approximately 18 known waste discharges in this area. However, during the FWQA surveys, only the tributary streams, the Big Sioux and the Floyd River and the wastes from the Sioux City sewage treatment plant and the Iowa Beef Packers Plant at Dakota City, Nebraska were sampled. In particular, the data from the Fall 1968 - Winter 1969 survey showed an increase in the densities of the bacterial indicator organisms. Since the preponderance of data collected during that survey was representative of normal dry weather flow conditions, 32,400 cfs at Sioux City,

TABLE 4

MISSOURI RIVER WATER QUALITY AT GAVINS POINT DAM

Item	Oct. 7-18, 1968	Jan. 20-Feb. 2, 1969
Turbidity (JU) *	14	1.5
Total Suspended Solids mg/l	45	1.5
Total Dissolved Solids mg/l	474	518
Chloride mg/l	12	11
Alkalinity (as $CaCO_8$) mg/l	169	-
Hardness (as $CaCO_8$) mg/l	238	-
Total Phosphorus mg/l	0.04	-
NH_3 as N mg/l	0.08	-
NO_3 as N mg/l	0.2	-
Organic N as N mg/l	0.4	-
Total N mg/l	0.7	-
Total Organic Carbon mg/l	5	-
Ca mg/l	66	40
Mg mg/l	21	21
Ba mg/l	< 1.0	< 1.0 **
Cd mg/l	< 0.02	< 0.02 **
Fe mg/l	< 0.30	< 0.1 **
Mn mg/l	< 0.05	0.04 **
Cr mg/l	< 0.05	< 0.02 **
As mg/l	< 0.01	< 0.01 **
Cu mg/l	< 0.05	< 0.05 **
Pb mg/l	< 0.05	< 0.05 **
Ni mg/l	< 0.05	< 0.1 **
Zn mg/l	< 0.05	0.03 **
B mg/l	0.12	0.09 **
Na mg/l		75 **
K mg/l		6.0 **
F mg/l		0.6 **
Total Organic Chlorine mg/l	126.0	46.2
Chloroform Extracts	5.5	
Sulfate mg/l	208	206
Fecal Coliform MPN/100 ml	<125 ***	<20 ***

* Unless noted otherwise, results are for 5-day composite samples.

** These results for station 60 miles downstream from Gavins Points Dam.

*** Average of two discrete grab samples.

it is most probable that these organisms were for waste discharges.

The Fall 1969 - Winter 1970 survey provided additional information on the water quality downstream from Sioux City. These date are summarized in Tables 5-11.

Table 5 is a summary of the fecal coliform and fecal streptococci data. This table clearly shows the impact of the Sioux City Area in terms of fecal coliform contributions with the most significant source being the Sioux City waste treatment plant effluent. In total numbers of organisms per day the waste treatment, on the average, discharges twice as many as are found in the river ten miles downstream. The ratio of fecal coliform to fecal streptococci clearly indicate a predominately human or domestic source and the organisms persist from Sioux City to Omaha in densities greater than those recognized by the FWQA as being safe for water supply source use.

Figure 1 is a plot of the numbers of bacteria observed in the river and in the observed outfalls. It is significant to note that the Iowa Beef Packers Company plant was on stirke at the time of the investigation and the data only reflect about 15% of normal production.

Table 6 shows the recovery of salmonella from the Missouri River. Although no salmonella were isolated from the sewage treatment plant effluents at Sioux City during this brief sampling period, it is important to note the persistance of these organisms in the River. Salmonella are known pathogens to humans and their presence indicates a real hazard. Table 7 shows a frequency of occurrence of the salmonella serotypes isolated from humans and farm animals. In addition to bacterial enumeration, laboratory tests were conducted to demonstrate the

TABLE 5

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
SIOUX CITY TO OMAHA
SEPTEMBER 8-12, 1969

Station		River Mile	Geometric Mean		F.C./F.S.	Source	Average Flow cfs	Fecal Coliform Number Per Day Trillion
Number	Location		Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml				
M-52	Missouri River Upstream From the Big Sioux River	736.0	85	160	-	-	53760	110.6
BS-51	Big Sioux River	734.0	120	48	-	-	345	1.0
F-50.5	Floyd River	731.2	3700	2200	-	-	103	9.2
SC-49	Sioux City STP	729.7	32×10^6	5×10^6	6.4	Domestic	24.36	18864.4
IBP-48.5	Iowa Beef Packers	726.2	2×10^6	4×10^6	0.5	Animal	.27	13.1
M-48	Missouri River	717.4	6900	3800	-	-	53960	9010.2
LS-45.5	Little Sioux River	669.2	2100	790	-	-	1194	60.7
S-45	Soldier River	664.0	5500	2900	-	-	58	7.7
B-43	Boyer River	635.1	3500	1200	-	-	125	10.6
M-42	Missouri River at Omaha Water Treatment Plant Intake	626.2	2000	700	-	-	54890	2656.7

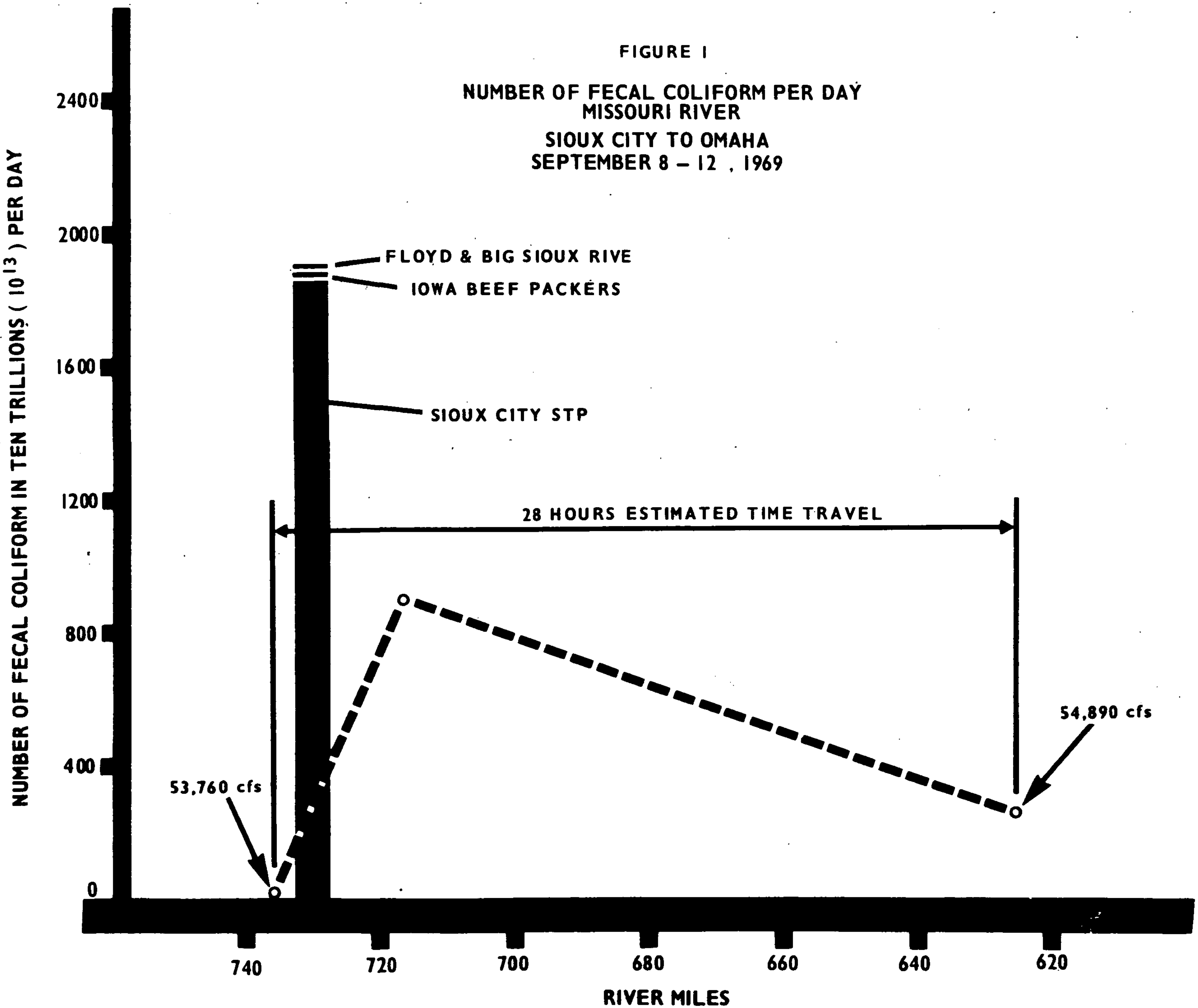


FIGURE I

NUMBER OF FECAL COLIFORM PER DAY
MISSOURI RIVER
SIOUX CITY TO OMAHA
SEPTEMBER 8 – 12 , 1969

TABLE 6

MISSOURI RIVER SALMONELLA ISOLATIONS
SIOUX CITY TO OMAHA
SEPTEMBER 8-12, 1969

Number	Location	Salmonella Isolated
M-52	Missouri River Upstream from the Big Sioux River	*S. enteritidis* ser. Newport *S. enteritidis* ser. Norwich
M-48.5	Iowa Beef Packers Effluent	*S. enteritidis* ser. Sieburg *S. enteritidis* ser. Binza
M-48	Missouri River Downstream from Sioux City	*S. enteritidis* ser. Anatum *S. enteritidis* ser. Derby
M-42	Omaha Water Treatment Plant Intake	*S. enteritidis* ser. Anatum

TABLE 7

SUMMARY OF SALMONELLA SEROTYPES ISOLATED FROM MISSOURI RIVER

Serotypes Isolated from River	Frequency of Serotype Occurrence in 1968*	
	Human**	Farm Animal***
S. Typhi-Murium	26.1 %	16.2 %
S. Newport	6.3	3.0
S. Infantis	4.8	5.7
S. Thompson	3.8	4.7
S. Derby	2.1	3.6
S. Oranienburg	1.5	0.4
S. Montevideo	1.4	2.5
S. Panama	1.2	1.0
S. Anatum	1.1	3.3
S. Muenchen	1.1	0.4
S. Java	1.0	0.2
S. Bredeney	0.9	1.0
S. Poona	0.4	0.02
S. Schwartzengrund	0.3	0.9
S. Give	0.3	0.4
S. Cubana	0.3	0.1
S. Norwich	0.2	0.02
S. Sieburg	0.04	0.4
S. Eimsbuettel	0.03	0.7
S. Binza	0.03	0.3

* Annual Summary 1968: Salmonella Surveillance, National Communicable Disease Center

** Total Human Strains Classified by NCDC - 19,723

*** Total Farm Animal Strains Classified by NCDC - 4,422 ability of bacterial cultures to survive in waste effluent and stream samples. The "Survival Study" procedure involved filtering the original sample through a 0.22 mμ membrane filter. This sterile sample was divided into aliquots which were inocculated individually with pure cultures of indicator bacteria. The number of bacteria remaining were enumerated at intervals of 1, 2, 3, 7 and 14 days. Table 8 summarizes these data.

These survival data demonstrate the availability of nutrient material in the waste effluents to support bacterial growth and the persistance of these organisms in the river water. Considering that the maximum flow time from Sioux City to Omaha is less than 40 hours, the potential hazard from bacterial growth and persistance is aptly demonstrated, especially with the *S. typhimurium* data.

Specialized biological studies were conducted concurrently with the intensive sampling program. These studies including the placing of glass slides to collect periphyton and the exposure of caged channel catfish to the river above and below metropolitan areas to determine the degree of fish flesh tainting caused by waste discharges. The nature of these biological investigations permitted continuous coverage of the entire reach of stream from Sioux City, Iowa to Waverly, Missouri.

The results of the periphyton study are inconclusive. Further study is necessary to evaluate all of the variables influencing the periphyton communities. The periphyton data are presented in the appendix.

The fish flesh tainting investigations demonstrated one form of

TABLE 8

BACTERIAL SURVIVAL STUDIES
SIOUX CITY TO OMAHA

Station		Per Cent Remaining					
Number	Location	Initial Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Fecal Coliform Group				
M-52	Missouri River Upstream from Big Sioux River	50,000	56	15	11	20	<1
SC-49	Sioux City, Iowa STP Effluent	70,000	214	R**	R**	<1	<1
IBP-48A	Iowa Beef Packers Effluent	33,000	112	255	R**	<1	<1
M-48	Missouri River Downstream from Sioux City, Iowa River Mile 717.4	67,000	106	122	3	<1	<1
M-42	Missouri River at Omaha Water Treatment Plant Intake	68,000	84	19.1	18	1	<1
			Fecal Streptococcus Group				
M-52	Missouri River Upstream from Big Sioux River	15,000	53	30	23	<1	<1
SC-49	Sioux City, Iowa STP Effluent	6,800	97	59	72	<1	<1

TABLE 8 (Continued)

BACTERIAL SURVIVAL STUDIES
SIOUX CITY TO OMAHA

Station		Per Cent Remaining					
Number	Location	Initial Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Fecal Streptococcus Group (Cont.)				
IBP-48A	Iowa Beef Packers Effluent	22,000	<1	<1	<1	<1	<1
M-48	Missouri River Downstream from Sioux Ciry, Iowa River Mile 717.4	8,000	30	6	5	1	<1
M-42	Missouri River at Omaha Water Treatment Plant Intake	8,200	48	<1	<1	<1	<1
			Salmonella Typhimurium				
M-52	Missouri River Upstream from Big Sioux River	200,000	34	19	125	7	4
SC-49	Sioux City, Iowa STP Effluent	93,000	R**	215	194	<1	<1
IBP-48A	Iowa Beef Packers Effluent	400.000	17	48	1	<1	<1
M-48	Missouri River Downstream from Sioux City, Iowa River Mile 717.4	110,000	73	26	33	12	<1

TABLE 8 (Continued)

BACTERIAL SURVIVAL STUDIES
SIOUX CITY TO OMAHA

Station		Per Cent Remaining					
Number	Location	Initial Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Salmonella Typhimurium (Cont.)				
M-42	Missouri River at Omaha Water Treatment Plant Intake	130,000	100	73	108	85	176

* Initial count of sample after inoculation with bacterial culture,
** R indicates regrowth or a greater than ten-fold increase,

direct impact of waste discharges on the aquatic system. The results for the Gavins Point Dam to Omaha, Nebraska reach show that fish placed in the River above Sioux City, Iowa had an acceptable flavor as did the fish from the Big Sioux River. The great number of fishermen observed in those areas also attests to their popularity as fishing sites. Numerous slaughterhouses in Sioux City discharge their waste water into the Missouri River between River Mile 732 and 731. Fish held in cages at River Mile 731.5, 731.0 and 730.5 acquired an unacceptable flavor. Pieces of meat and fat collected on the baskets and could be seen floating in the water for several more miles downstream. The fish exposed at River Mile 730.5, downstream from the slaughterhouses and other industries in Sioux City received the lowest flavor score of fish tested in this area.

Wastes discharged into the Missouri River at Sioux City caused an unacceptable flavor in caged fish in at least one mile of the Missouri River bordering Iowa. No unacceptable flavor occurred in test fish placed along either side of the Missouri River from Dakota City, Nebraska, downstream to River Mile 628.0 near the Omaha, Nebraska Water Treatment Plant intake.

During the intensive survey activities in the Fall of 1969, exploratory sampling was conducted to determine the feasibility of the isolation of a fecal sterol and enteric virus. This fecal sterol, coprostanol, is a compound unique to the feces of man and other higher animals. The sterol compound is biodegradable and consequently its isolation confirms unequivocally the presence of relatively fresh excreta. Virus are pathogens that will reproduce only in fairly specific host cells. Isolation of enteric virus is positive proof of human wastes and is a potential health hazard.

Table 9 shows the concentrations of the fecal sterol, coprostanol, observed in the Missouri River.

There is no doubt about the additions of fecal pollution in the Sioux City Area nor of the persistence of this pollution to the Omaha Water Treatment Plant intake at River Mile 626.2.

Fecal coliform densities determined from the same samples are shown in Table 10. The absolute numbers are not completely correct because the samples were held for periods up to 48 hours. Even so, there is a close trend correlation with the Coprostanol concentrations.

The fecal sterol isolations leave no doubt as to the presence of fecal material at the downstream water intake. The dissolved nature of coprostanol combined with the biodegradability shows conclusively that it is possible for any of the many dissolved constituents in waste discharges to impact downstream water users.

Virus samples were collected from three locations in the Sioux City study reach. The analysis of these samples provided the data shown in Table 11.

These data were obtained using rather inefficient techniques and should be on the conservative side. The important factor is that a continuous source of virus is discharging into the river and these organisms represent a potential hazard.

TABLE 9

FECAL STEROL CONCENTRATIONS

Sampling Area	Sampling Point	River Mile	Concentration of Coprostanol in μg/liter — Date of Sampling: 1-20-70	3-4-70	3-17-70	3-24-70	Mean
Missouri River Upstream from Sioux City	M-52	736.0	4	6	10	3	6
Sioux City STP	SC-49	729.0	636	723	684	793	709
Missouri River Downstream from Sioux City	M-48	717.4	98	105	93	109	101
Boyer River	B-43	631.1	64	66	60	57	62
Missouri River at Omaha Water Treatment Plant	M-42	626.2	21	16	23	20	20

TABLE 10

FECAL COLIFORM DENSITIES ISOLATED FROM WATER SAMPLES USED FOR FECAL STEROL ANALYSES

Sampling Area	Sampling Point	River Mile	Number of Fecal Coliforms per 100 ml of Sample — Date of Sampling: 1-20-70	3-4-70	3-17-70	3-24-70	Mean
Missouri River Upstream from Sioux City	M-52	736.0	-	360	8	44	140
Sioux City STP	SC-49	729.0	-	26×10^6	20×10^6	12×10^6	19×10^6
Missouri River Downstream from Sioux City	M-48	717.4	-	1.4×10^4	0.8×10^4	1.6×10^4	1.3×10^4
Boyer River	B-43	635.1	-	1.0×10^4	380	705	3,500
Missouri River at Omaha Water Treatment Plant	M-42	626.2	-	-	930	600	770

TABLE 11

VIRUS ISOLATIONS
SIOUX CITY TO OMAHA

Date of Sampling	Station Number and River Mile	Station Description	Virus Recovered PFU*	Virus Types Recovered
12/11/69	M-52A (732.7)	Missouri River at Thacker Marina Sioux City	0	
12/11/69	SC-49	Sioux City Sewage Treatment Plant	96	
12/11/69	M-48 (717.4)	Missouri River	4	Polio virus 3

*PFU - Plague Forming Units

Omaha-Council Bluffs to St. Joseph, Missouri

This reach includes the 174 river miles between the upstream control station at the Omaha water treatment plant intake and the downstream use-point station at the St. Joseph water treatment plant intake. At the control station the flow primarily is comprised of releases from Gavins Point Dam. Significant tributary inflows from a quantity standpoint are limited to those from the Platte River. From a quality standpoint this reach receives heavy waste loads from the Omaha-Council Bluffs area and lesser loads from other communities located on the stream banks downstream from Omaha.

The quality data for the control station as developed by the Fall 1968-Winter 1969 survey are shown in Table 12. The differences in

TABLE 12

MISSOURI RIVER WATER QUALITY
OMAHA WATER TREATMENT PLANT INTAKE 1/

Item	Oct. 7-18, 1968	Jan. 20-Feb. 2, 1969
Turbidity (JU)	36	9
Total Suspended Solids mg/l	91	25
Total Dissolved Solids mg/l	532	629
Chloride mg/l	13	15
Sulfate mg/l	185	224
Alkalinity as $CaCO_3$ mg/l	172	192
Hardness as $CaCO_3$ mg/l	237	-
Total Phosphorus mg/l*	0.12	0.06
NH_3 as N mg/l*	0.07	0.34
NO_3 as N mg/l*	0.3	0.4
Organic N as N mg/l*	0.9	0.8
Total Organic Carbon mg/l*	6	6
Ca mg/l*	65	44
Mg mg/l*	20	25
Ba mg/l*	1.0	1.0
Cd mg/l*	0.02	0.02
Fe mg/l*	0.30	0.1
Mn mg/l*	0.05	0.3
Cr mg/l*	0.05	0.02
As mg/l*	0.01	0.02
Cu mg/l*	0.05	0.05
Pb mg/l*	0.05	0.05
Ni mg/l*	0.10	0.1
Zn mg/l*	-	0.07
B mg/l*	0.11	0.10
Na mg/l*	13	81
K mg/l*	8.0	6.6
F mg/l*	0.66	0.6
Total Organic Chlorine ug/l**	138.2	40.1
Chloroform Extracts mg/l**	26.1	-
Fecal Coliform MPN/100	8300	4900

1/ Unless otherwise noted, values represent averages of eight to ten discrete samples.

* Values for 5-day composite samples.

** Results of single grab sample.

quality as depicted by the data in Tables 4 and 12 demonstrate the effects of waste discharges from the Sioux City metropolitan area, especially in the observed fecal coliform densities. Again the baseline data were collected during near normal flow conditions and are considered to be representative of periods of minimum uncontrolled runoff.

The Fall 1969-Winter 1970 investigation provided more detailed information on the impact of waste discharges on the quality of the Missouri River downstream from Omaha. During this investigation, samples were collected from 18 stations comprised of 4 Missouri River stations and 14 waste source or tributary stations.

The fecal coliform and fecal streptococcus data are listed in Table 13. These data clearly show an increase in bacterial densities down below the waste sources and mean densities in the river in excess of recognized limits for drinking water supply. The measured fecal coliform contributions from the waste sources between the control station and the next downstream river station account for over 50% of the observed increase in the river. Figure 2 is a plot of the fecal coliform masses observed in the river and contributed by waste sources, Again it is readily apparent that the preponderance of fecal coliform organisms observed in the river is from point source discharges and that the resulting mean river densities are in excess of recognized limits for a raw drinking water supply.

The primary reason for measuring the densities of fecal coliform indicators is to provide some basis for judging the probability of the existence of pathogens in the water. In most instances, the higher

TABLE 13

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
OMAHA TO ST. JOSEPH
NOVEMBER 3-7, 1969

Station			Geometric Mean					
Number	Location	River Mile	Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml	F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform Number Per Day Trillions
M-42	Missouri River at Omaha Water Treatment Plant Intake	626.2	3,700	2,500	-	-	43950	3,900
M-212	Quaker Oats Company	615.2	2,400	2,400	-	-	4	0.23
M-211	Pacific Fruit Express	615.1	2,400	1,200	-	-	0.24	0.01
CB-40B	Council Bluffs STP	614.0	$12x10^6$	$1x10^6$	12.0	Domestic	7.9	2,236
TC-210	Twin Cities Plaza STP	613.6	$3x10^6$	$0.13x10^6$	23.1	Domestic	0.39	28
OM-40A	Omaha, Nebraska STP	611.5	$6x10^6$	$8x10^6$	0.8	Mix	26.9	3,906
OM-208	Monroe Street Sewer Omaha	611.2	$3x10^6$	$10x10^6$	0.3	Animal	4.8	349
M-38	Missouri River Upstream from Bellevue	601.7	15,000	11,000	-	-	45756	16,600
M-206	Bellevue STP	601.5	$4x10^6$	$0.78x10^6$	5.1	Domestic	0.9	87

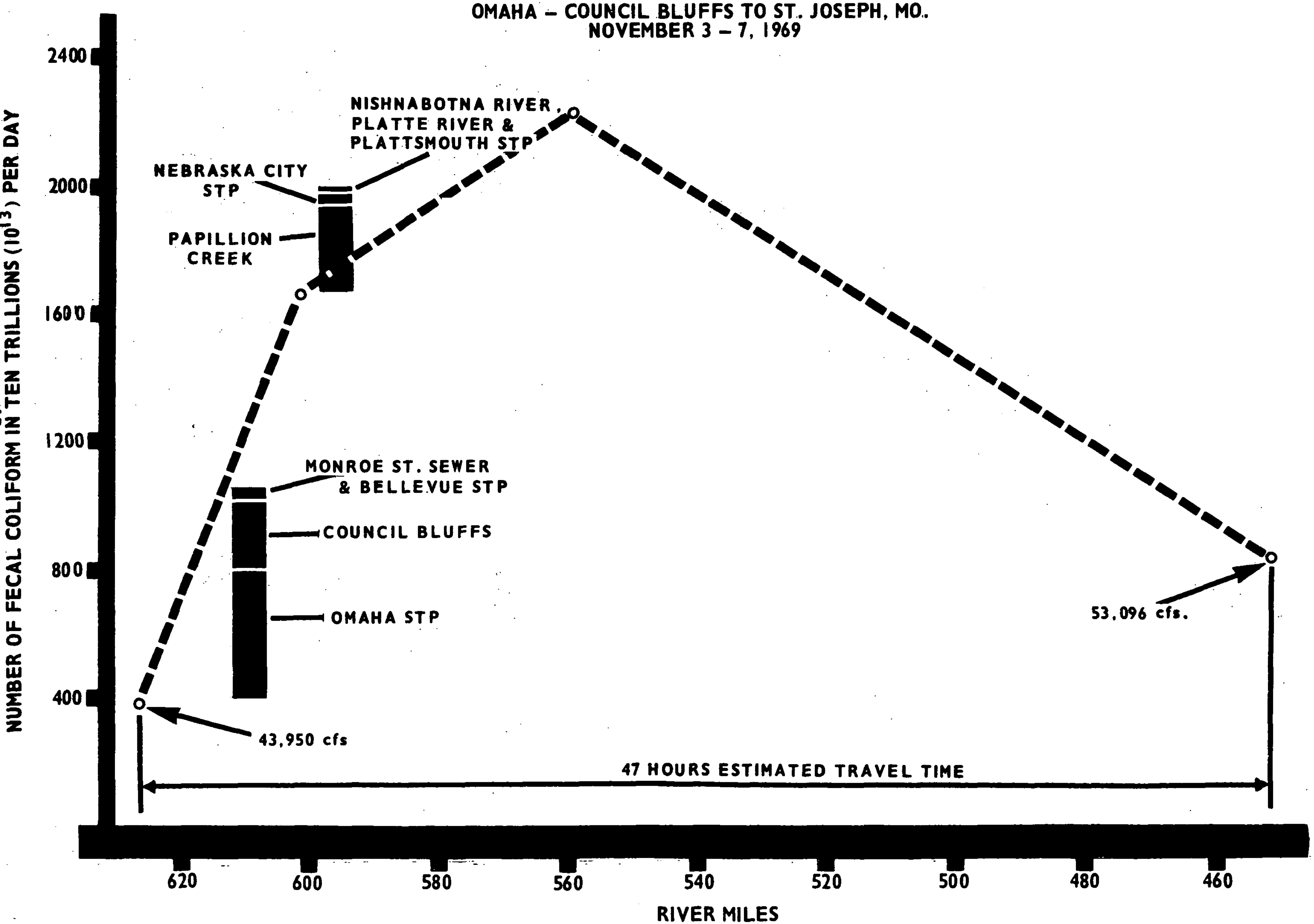
TABLE 13 (Continued)

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
OMAHA TO ST. JOSEPH
NOVEMBER 3-7, 1969

Station		River Mile	Geometric Mean		F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform Number Per Day Trillions
Number	Location		Fecal Coliform MF/100 ml	Fecal Streptococci MF/100 ml				
M-205	Papillion Creek Downstream from Offut	596.6	1.4×10^6	0.25×10^6	-	-	84	2,848
P-37	Platte River	594.8	650	720	-	-	475	7.5
M-201	Plattsmouth STP	591.2	5×10^6	0.59×10^6	8.5	Domestic	0.65	79
M-200	Nebraska City STP	563.3	7×10^6	6×10^6			2.24	380
M-34	Missouri River Downstream from Nebraska City	559.7	18,000	12,000			51028	22,200
N-199	Nishnabotna River	542.0	710	840	-	-	390	7.9
T-198	Tarkio River	507.6	920	1,500	-	-	68	1.5
N-196	Nodaway River	462.4	1,800	3,200	-	-	153	6.7
M-28	Missouri River at St. Joseph Water Treatment Plant Intake	452.3	6,500	3,200	-	-	53096	8,400

FI[redacted]RE 2

NUMBER OF FECAL COLIFORM PER DAY
MISSOURI RIVER
OMAHA – COUNCIL BLUFFS TO ST. JOSEPH, MO.
NOVEMBER 3 – 7, 1969



the densities of fecal coliform, the greater the possibility of pathogens being present. The results of the salmonella tests are shown in Table 14. The isolation of these known pathogens confirms the significance of the high densities of fecal coliforms.

Salmonella are present throughout the entire reach from Omaha-Council Bluffs to St. Joseph. Their presence, particularly at the water treatment plant intakes, is a potential hazard to all water consumers.

The significance of the existence of salmonella in the river and the waste discharges is further emphasized by the results of the survival studies as shown in Table 15. Normally the bacterial indicators are expected to die off at a rate of somewhere between 70-90% in two days. When more than 50% survive after 24 hours, the organisms are persisting, and when there is over a ten-fold increase in numbers, the organisms are undergoing regrowth. The survival data show the ability of the river water and the wastes to sustain bacterial persistence and regrowth.

Specialized biological studies were conducted in this are to examine the periphyton community and to document the possibility of fish flesh tainting.

The periphyton data were somewhat equivocal but did show the presence of bacterial slimes about 50 miles downstream from Omaha-Council Bluffs indicating some organic enrichment.

The fish flesh tainting presented a vivid picture of the direct impact of waste discharges between the Omaha-Council Bluffs area and the confluence of the Missouri and Platte Rivers. Caged catfish

TABLE 14

MISSOURI RIVER SALMONELLA ISOLATIONS
OMAHA TO ST. JOSEPH
OCTOBER 9-14, 1969

Station Number	Station Location	Salmonella Isolated
M-42	Missouri River at Omaha Water Treatment Plant	*S*. Anatum
M-211	Pacific Fruit Express Outfall	*S*. Derby *S*. Infantis *S*. Bredeney
TC-210	Twin Cities Plaza STP	*S*. Infantis
OM-209	Missouri River Omaha STP Bypass	*S*. Anatum
OM-40A	Monroe St. Sewer Omaha	*S*. Derby
OM-208	Omaha Missouri River STP Combined Sample Below the Three Outfalls	*S*. Java *S*. Eimsbuettel
M-206	Bellevue STP Outfall	*S*. Muenchen *S*. Schwartzengrund *S*. Derby
M-38	Missouri River Upstream from Bellevue STP	*S*. Muenchen
M-205	Papillion Creek	*S*. Oranienburg
M-34	Missouri River at Nebraska City	*S*. Derby
M-28	St. Joseph Water Treatment Plant Intake	*S*. Montevideo *S*. Derby

TABLE-15

BACTERIAL SURVIVAL STUDIES
OMAHA TO ST. JOSEPH

Station		Initial	Percent Remaining				
Number	Location	Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
				Fecal Coliform			
M-42	Missouri River at Omaha Waterworks	108,000	87	72	130	47	33
M-212	Quaker Oats Outfall	78,000	99	123	154	R**	R**
M-211	Pacific Fruit Express	91,000	102	62	52	12	3
CB-40B	Council Bluffs STP	105,000	86	81	229	R**	R**
OM-40A	Omaha STP	102,000	R**	R**	R**	R**	R**
M-38	Missouri River at Bellevue	104,000	72	87	83	50	29
M-205	Big Papillion Creek	101,000	81	59	59	19	47
P-37	Platte River	90,000	83	53	34	14	5
M-34	Missouri River near Nebraska City	90,000	91	53	52	27	7

TABLE 15 (Continued)

BACTERIAL SURVIVAL STUDIES
OMAHA TO ST. JOSEPH

Station		Initial	Percent Remaining				
Number	Location	Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Fecal Streptococci				
M-42	Missouri River at Omaha Waterworks	55,000	124	126	100	78	73
M-212	Quaker Oats Outfall	50,000	104	38	30	4	<1
M-211	Pacific Fruit Express	56,000	73	96	70	77	70
CB-40B	Council Bluffs STP	55,000	89	113	96	151	R**
OM-40A	Omaha STP	57,000	263	R**	R**	R**	R**
M-38	Missouri River at Bellevue	56,000	91	98	89	77	80
M-205	Big Papillion Creek	56,000	71	98	80	96	79
P-37	Platte River	48,000	83	110	98	110	110
M-34	Missouri River near Nebraska City	50,000	88	94	78	96	72

TABLE 15 (Continued)

BACTERIAL SURVIVAL STUDIES
OMAHA TO ST. JOSEPH

Station		Initial	Percent Remaining				
Number	Station	Count/100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Salmonella Typhimurium				
M-42	Missouri River at Omaha Waterworks	34,000	44	44	26	11	2
M-212	Quaker Oats Outfall	25,000	21	17	14	17	4
M-211	Pacific Fruit Express	26,000	81	65	32	12	4
CB-40B	Council Bluffs STP	32,000	59	50	23	18	750
OM-40A	Omaha STP	25,000	R**	R**	R**	R**	680
M-38	Missouri River at Bellevue	26,000	50	46	32	8	5
M-205	Big Papillion Creek	80,000	41	21	19	5	<1
P-37	Platte River	80,000	43	20	16	6	<1
M-34	Missouri River near Nebraska City	84,000	33	23	14	5	2

* Initial count of sample after inoculation with bacterial culture.

** R indicates regrowth or a greater than ten-fold increase over the initial count.

exposed in river downstream from the Council Bluffs and Twin Cities Plaza sewage discharges acquired an unacceptable flavor. Downstream from the Omaha sewage treatment plant discharge the fish acquired the most unacceptable flavor of any tested. However, in the reach between the Platte River and St. Joseph all exposed fish had acceptable flavors.

Fecal sterol and virus investigations were conducted during and after the intensive survey activities. The fecal sterol is a rather unique indicator of fecal contamination, and its presence leaves no doubt concerning fecal and non-fecal pollution. Table 16 is a presentation of the fecal sterol data that were collected. These data were again confirmed by fecal coliform determinations which are shown in Table 17.

The data in Tables 16 and 17 clearly show the presence of fecal contamination at the water intakes. They also show the major point sources which are amenable to control. The presence of fecal material at the water intake is not a practice either condoned by recognized public health authorities nor one within the best public interest.

The virus data for this reach are shown in Table 18. Here is positive proof of the presence of pathogens in the waste effluents and in the River.

The most significant of these data is the isolation of human enteric virus from the St. Joseph water supply intake.

TABLE-16

FECAL STEROL CONCENTRATIONS
OMAHA TO ST. JOSEPH

Sampling Area	Sampling Point	River Mile	Concentration of Coprostanol in ug/liter				
			Date of Sampling				Mean
			1-27-70	2-23-70	3-10-70	3-31-70	
Missouri River at Omaha Water Treatment Plant	M-42	626.2	9	20	26	28	21
Council Bluffs STP	CB-40B	614.0	743	864	766	815	797
Omaha STP	OM-40A	611.5	250	300	362	335	312
Missouri River Below Omaha	M-38	601.7	73	71	76	67	72
Papillion Creek	M-205	596.6	177	200	295	166	210
Platte River	P-37	594.8	17	21	13	15	16
Missouri River at Nebraska City	M-34	559.7	60	73	76	72	70
Missouri River at St. Joseph Water Treatment Plant	M-28	452.3	31	34	31	37	33

TABLE 17

FECAL COLIFORM DENSITIES ISOLATED FROM WATER SAMPLES USED FOR FECAL STEROL ANALYSIS

Sampling Area	Sampling Point	River Mile	Number of Fecal Coliforms per 100 ml				
			Date of Sampling				
			1-27-70	2-23-70	3-10-70	3-31-70	Mean
Missouri River at Omaha Water Treatment Plant	M-42	626.2	-	1,200	800	1,000	1,000
Council Bluffs STP	CB-40B	614.0	-	$2.9x10^6$	$1.7x10^6$	$4.0x10^6$	$2.9x10^6$
Omaha STP	OM-40A	611.5	-	$1.0x10^6$	$0.8x10^6$	$4.0x10^6$	$1.9x10^6$
Missouri River Below Omaha	M-38	601.7	-	3,000	3,000	6,700	4,200
Papillion Creek	M-205	596.6	-	$3.1x10^5$	$4.1x10^5$	$4.1x10^5$	$3.8x10^5$
Platte River	P-37	594.8	-	340	540	730	540
Missouri River at Nebraska City	M-34	559.7	-	1,800	3,700	5,800	3,800
Missouri River at St. Joseph Water Treatment Plant	M-28	452.3	-	2,400	1,800	1,900	2,100

TABLE 18

VIRUS ISOLATIONS
OMAHA TO ST. JOSEPH

Date of Sampling	Station No. (River Mile)	Station Location	Virus Isolated PFU	Virus Identification
10/16/69	OM-40A	Omaha STP	241	-
10/23/69	CB-40B	Council Bluffs STP	421	-
10/23/69	OM-208	Omaha - Monroe St. Bypass	296	-
10/23/69	TC-210	Twin Cities STP	12	-
10/28/69	M-38 (601.3)	Missouri River - Near Bellevue, Neb.	4	Polio virus 12 & 3 Echo virus 1 & 7
1/20/70	M-28 (452.3)	Missouri River at St. Joseph Water Intake	3	

St. Joseph to Kansas City

The quality of the Missouri River at the St. Joseph water intake reflects the natural self-purification capacity of the river to a small degree by the reduction in non-conservative constituents. The baseline data collected in Fall 1968-Winter 1969 in Table 19 show the continuing trend in quality degradation due to increases in concentrations of conservative materials. Again from the major water use standpoint - water supply - the items of concern are the high fecal coliform densities, which are in excess of recognized limits for this use, and the total dissolved solids concentrations which approach the 500 mg/l

TABLE 19

MISSOURI RIVER WATER QUALITY AT ST. JOSEPH, MISSOURI
WATER TREATMENT PLANT INTAKE 1/

Item	Oct. 7-18, 1968	Jan. 20-Feb. 2, 1969
Turbidity (JU)	48	12
Total Suspended Solids mg/l	131	28
Total Dissolved Solids mg/l	472	510
Chloride mg/l	17	23
Sulfate mg/l	170	177
Alkalinity (as $CaCO_3$) mg/l	163	174
Hardness (as $CaCO_3$) mg/l	254	-
Total Phosphorus mg/l*	0.26	0.06
NH_3 as N mg/l*	0.18	0.34
NO_3 as N mg/l*	0.4	0.4
Total N mg/l*	2.9	1.4
Total Organic Carbon mg/l*	7	6
Ca mg/l*	69	44
Mg mg/l*	20	25
Ba mg/l*	<1.0	<1.0
Cd mg/l*	<0.02	<0.02
Fe mg/l*	<0.30	<0.1
Mn mg/l*	<0.05	0.04
Cr (Total) mg/l*	<0.05	<0.02
As mg/l*	<0.01	<0.01
Cu mg/l*	<0.05	<0.05
Pb mg/l*	<0.05	<0.05
Ni mg/l*	<0.10	<0.1
Zn mg/l*	<0.05	<0.025
B mg/l*	0.10	<0.12
Na mg/l*	13	55
K mg/l*	8.6	7.5
F mg/l*	0.78	0.6
Total Organic Chlorine µg/l**	32.8	73.1
Chloroform Extracts mg/l**	3.7	-
Fecal Coliform MPN/100 ml	6500	2800

1/ Represents the mean of daily discrete samples.

* Represents results of one or two five-day composites.

** Represents results of one grab sample.

maximum recommended concentration in the PHS Drinking Water Standards.

The Fall 1969-Winter 1970 investigation provided additional data showing the presence of fecal contamination added by St. Joseph and other downstream communities. The emphasis of this work again was to show the existence of a potential health hazard that could be mitigated by better waste treatment.

Table 20 is a summary of the fecal coliform and fecal streptococcus data collected during the intensive investigation. These data indicate a significant contribution of both animal and human wastes and show that 50% of the fecal coliform mass observed in the river is attributable to those discharges that were sampled. The densities of fecal coliform organisms increase from 4,300 organisms per 100 ml at the St. Joseph water intake (River Mile 452.3) to 8,800 organisms per 100 ml at River Mile 440. The densities decrease to 3,800 per 100 ml at the Kansas City, Missouri water intake, River Mile 370.5.

Figure 3 is a graphical display of the numbers per day of fecal coliform discharge to the River and the profile in the River. Of particular concern is the occurence of high densities during high flows not involving storm runoff.

The salmonella data shown in Table 21 show the existence of pathogens in the River. The gauze swabs recovered from the Missouri River at Mile 440 and Mile 370, the Kansas City, Missouri water intake resulted in the positive isolation of salmonella, as did those swabs recovered from the listed waste sources.

Here again the potential survival characteristics of the bacteria in the River are of concern. Laboratory tests were conducted using

TABLE 20

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
ST. JOSEPH TO KANSAS CITY
SEPTEMBER 18-22, 1969

Station			Geometric Mean					
Number	Location	River Mile	Fecal Coliform 100 ml	Fecal Streptococci	F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform No./Day Trillions
M-28	St. Joseph Waterworks Intake	452.3	4,300	4,300	1	-	57900	5931
SJ-3	Black Snake Creek	452.3	2x10^{6}	0.96x10^{6}	2.1	-	-	-
SJ-5	Charles St. Sewer	452.3	3x10^{6}	1x10^{6}	3.0	Domestic	2.6	189
SJ-9	Mitchell St. Sewer	452.3	2x10^{6}	0.79x10^{6}	2.5	Mix	-	-
SJ-15	St. Joseph STP	446.4	4x10^{6}	2x10^{6}	2.0	Mix	6.68	647
SJ-17	Brown's Ditch	446.4	0.17x10^{6}	52,000	3.3	-	6.5	27
SJ-18	South St. Joseph Industrial Sewer District STP	445.6	7x10^{6}	37x10^{6}	0.2	Animal	11.29	1913
M-27	Missouri River Palermo Landing	440.3	7,800	8,800	0.9	-	59680	11265
A-25.5	Atchison STP	421	2x10^{6}	250,000	8.0	Domestic	1.64	79

TABLE 20 (Continued)

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
ST. JOSEPH TO KANSAS CITY
SEPTEMBER 18-22, 1969

Station		River Mile	Geometric Mean		F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform No./Day Trillions
Number	Location		Fecal Coliform 100 ml	Fecal Streptococci				
L-24.5	Leavenworth STP	395.6	$4x10^6$	270,000	14.8	Domestic	9.07	878
P-23.5	Platte River	391.2	420	550	-	-	124.6	1
M-101	Line Creek	372.2	10,000	2,700	-	-	2.4	-
M-23	Kansas City, Missouri Water Intake	370.5	3,800	2,400	-	-	63120	5805

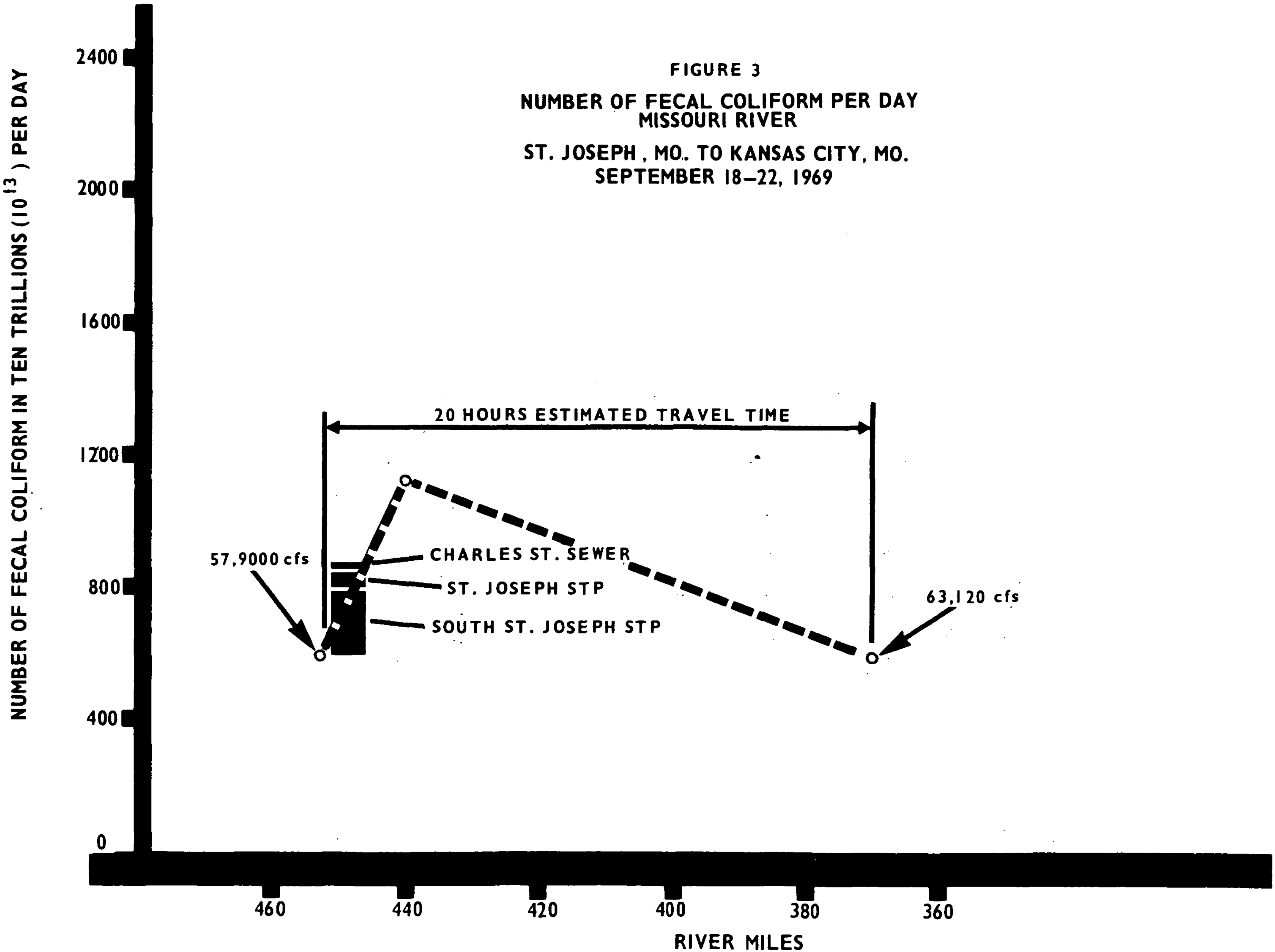


FIGURE 3

NUMBER OF FECAL COLIFORM PER DAY
MISSOURI RIVER

ST. JOSEPH, MO. TO KANSAS CITY, MO.
SEPTEMBER 18–22, 1969

TABLE 21

MISSOURI RIVER SALMONELLA ISOLATIONS
ST. JOSEPH TO KANSAS CITY
SEPTEMBER 18-22, 1969

Station Number	Station Location	Salmonella Isolated
SJ-15	St. Joseph STP (RM 447.4)	S. Schwartzengrund S. Oranienburg
SJ-17	Brown's Branch Ditch (RM 446.4)	S. Panama S. Infantis S. Java S. Eimsbuettel
SJ-18	St. Joseph Industrial STP (RM 445.6)	S. Derby S. Give S. Panama
M-27	Missouri River at Palermo Landing (RM 440.3)	S. Panama S. Infantis
L-24.5	Leavenworth STP (RM 395.6)	S. Bredeney S. Infantis
P-23.5	Platte River (RM 391.2)	S. Typhimurium Var. Copenhagen
M-23	Missouri River at Kansas City, Missouri Water Intake (RM 370.5)	S. Newport S. Give S. Infantis S. Poona

both filtered river and filtered waste samples inoculated with pure bacterial cultures to develop time concentration histories. The results of these tests are shown in Table 22. Since St. Joseph is about 24 hours flow time from Kansas City, the ability of these organisms to persist and regrow has significant importance.

The specialized biological investigations, fish flesh tainting and periphyton, did not indicate any severely polluted areas between St. Joseph and Kansas City. The caged catfish exposed in this reach all had acceptable flavoring and the attached organism community was normal. Bottom dwelling organisms collected during the Fall 1968-Winter 1969 operation were representative of a relatively clean water population.

The special virus and fecal sterol studies initiated during the Fall of 1969 and Winter of 1970, reconfirmed the presence of fecal pollution and pathogenic organisms. The results of the fecal sterol analyses are shown in Table 23. These data clearly show the accretion of the sterol, coprostanol, between the control station at the St. Joseph Waterworks intake and the downstream impact station at the Kansas City, Missouri waterworks intake. The coprostanol data are further verified in significance by the fecal coliform determinations made on the same samples and shown in Table 24.

Virus data are listed in Table 25. These data clearly demonstrate the source and persistence of the pathogens through isolation from both waste source and river samples.

TABLE 22

BACTERIAL SURVIVAL STUDIES
ST. JOSEPH TO KANSAS CITY

Station Number	Station Location	Initial Count Per 100 ml*	Percent Remaining 24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
			Fecal Coliform				
M-28	Missouri River at St. Joseph Intake	98,000	112	92	102	91	68
SJ-15	St. Joseph STP	100,000	R**	R**	R**	R**	R**
SJ-18	St. Joseph Industrial STP	110,000	R**	R**	R**	R**	664
M-27	Missouri River at Palermo Landing	99,000	83	80	59	55	43
M-23	Missouri River at Kansas City Intake	82,000	84	100	82	70	R**
			Fecal Streptococcus				
M-28	Missouri River at St. Joseph Intake	49,000	86	69	94	76	25
SJ-15	St. Joseph STP	52,000	98	44	39	6	7
SJ-18	St. Joseph Industrial STP	52,000	R**	58	73	27	1
M-27	Missouri River at Palermo Landing	83,000	91	68	59	66	59

TABLE 22 (Continued)

BACTERIAL SURVIVAL STUDIES
ST. JOSEPH TO KANSAS CITY

Station		Initial Count	Percent Remaining				
Number	Location	Per 100 ml*	24 Hrs	48 Hrs	72 Hrs	7 Day	14 Day
M-23	Missouri River at Kansas City Intake	52,000	83	90	100	79	44
			Salmonella Typhimurium				
M-28	Missouri River at St. Joseph Intake	76,000	68	40	55	62	13
SJ-15	St. Joseph STP	94,000	R**	R**	R**	R**	R**
SJ-18	St. Joseph Industrial STP	81,000	R**	370	222	103	<1
M-27	Missouri River at Palermo Landing	90,000	40	29	33	19	18
M-23	Missouri River at Kansas City Intake	75,000	44	3	33	2	2

* Initial count of sample after inoculation with bacterial culture.

** R indicates "regrowth" or a greater than ten-fold increase over the initial number.

TABLE 23

FECAL STEROL CONCENTRATIONS
ST. JOSEPH TO KANSAS CITY

Sampling Area	Sampling Point	River Mile	Coprostanol Concentration in μg/1 Date of Sampling 2-4-70	4-7-70	4-21-70	5-5-70	Mean
Missouri River at St. Joseph Water Treatment Plant	M-28	452.3	37	31	35	28	33
St. Joseph STP	SJ-15	446.4	391	418	484	452	436
St. Joseph Industrial STP	SJ-18	445.6	573	465	503	493	508
Missouri River at Palermo Landing	M-27	440.3	56	49	48	43	49
Atchison STP	A-25.5	421.0	365	451	498	389	424
Leavenworth STP	L-24.5	395.6	424	519	486	535	491
Missouri River at Kansas City Water Treatment Plant	M-23	370.5	63	46	54	60	56

TABLE 24

FECAL COLIFORM DENSITIES ISOLATED FROM WATER SAMPLES USED FOR FECAL STEROL ANALYSES

Sampling Area	Sampling Point	River Mile	Fecal Coliform Density Organisms/100 ml — Date of Sampling: 2-4-70	4-7-70	4-21-70	5-5-70	Mean
Missouri River at St. Joseph Water Treatment Plant	M-28	452.3	1,600	1,400	2,600	560	1,800
St. Joseph STP	SJ-15	446.4	1.6×10^6	6.8×10^6	0.7×10^6	7.8×10^6	4.2×10^6
St. Joseph Industrial STP	SJ-18	445.6	1.4×10^6	4.2×10^6	22×10^6	17×10^6	11×10^6
Missouri River at Palermo Landing	M-27	440.3	5,200	1,800	3,700	450	2,800
Atchison STP	A-25.5	421.0	0.97×10^6	5.0×10^6	0.27×10^6	4.9×10^6	2.8×10^6
Leavenworth STP	L-24.5	375.6	4.4×10^6	5.8×10^6	1.9×10^6	11×10^6	5.7×10^6
Missouri River at Kansas City Water Treatment Plant	M-23	370.5	6,200	2,400	3,000	1,000	3,150

TABLE 25

VIRUS ISOLATIONS
ST. JOSEPH TO KANSAS CITY

Date of Samples	Station Number and River Mile	Station Description	Virus Isolated PFU	Virus Identified
1/22/70	SJ-15	St. Joseph STP	93	-
1/22/70	SJ-18	St. Joseph Industrial Effluent	10	-
4/23/70	M-27 (440.3)	Missouri River at Palermo Landing	3	-
9/24/69	A-25.5 (421.0)	Atchison, Kansas STP	402	-
9/24/69	L-24.5 (395.6)	Leavenworth, Kansas STP	57	-

Kansas City to Waverly

The Kansas City Metropolitan Area is the largest in terms of population and diversified industry of those areas considered in these studies. The nature of wastes generated in the Kansas City Area varies from straight domestic to complex organic chemicals from industrial sources. The majority of this waste load is discharged to the Kansas and Blue Rivers which are tributaries to the Missouri.

Baseline data for the Kansas City, Missouri, water intake are presented in Table 26. These data collected during the Fall 1968-Winter 1969 investigation show the river to be approaching marginal quality levels for water supply use on the basis of Environmental

TABLE 26

MISSOURI RIVER WATER QUALITY AT KANSAS CITY, MISSOURI WATER TREATMENT PLANT INTAKE 1/

Item	Oct. 28-Nov. 8, 1968	Jan. 20-Feb. 2, 1969
Turbidity (JU)	61	29
Total Suspended Solids mg/l	173	73
Total Dissolved Solids mg/l	497	485
Chloride mg/l	17	22
Sulfate mg/l	198	185
Alkalinity (as $CaCO_3$) mg/l	179	174
Hardness (as $CaCO_3$) mg/l	261	-
Total Phosphorus mg/l*	0.32	0.24
NH_3 as N mg/l*	0.12	0.75
NO_3 as N mg/l*	1.1	0.7
Organic N as N mg/l*	0.6	0.9
Total Organic Carbon mg/l*	9	7
Ca mg/l*	72	40
Mg mg/l*	20	19
Ba mg/l*	<1.0	<1.0
Cd mg/l*	<0.02	<0.02
Fe mg/l*	<0.03	<0.2
Mn mg/l*	<0.05	<0.06
Cr (Total) mg/l*	<0.05	<0.02
As mg/l*	<0.01	<0.01
Cu mg/l*	<0.05	<0.05
Pb mg/l*	<0.05	<0.05
Ni mg/l*	<0.10	<0.1
Zn mg/l*	<0.05	0.11
B mg/l*	0.32	0.08
Na mg/l*	12	66
K mg/l*	9.0	7.6
F mg/l*	0.5	0.8
Total Organic Chlorine mg/l**	45.9	42.1
Chloroform Extracts mg/l**	0.0	-
Fecal Coliform MPN/100 ml	6500	8300

1/ Represents the mean of daily discrete samples.

* Represents results of one or two five-day composites.

** Represents results of one grab sample.

Protection Agency criteria. The total dissolved solids approach the recommended maximum concentration contained in the Public Health Service drinking water standards and the fecal coliform densities exceed recognized criteria for a raw water source.

The bacterial contamination is demonstrated in greater detail in Table 27 in which the results from the Fall 1969-Winter 1970 survey are listed. These data show the high densities at the control station the large increase due to discharges from the metropolitan area and the persistence of the indicator organisms as far as Waverly, some 87 miles downstream or approximately 26 hours travel time.

Figure 4 is a plot of the numbers of bacteria discharged to the River in the Kansas City Area and the resulting downstream profile. The flat slope of the curve demonstrates the persistence of these indicator organisms in the River.

Salmonella were isolated from many of the waste sources discharging into this reach of the Missouri. Table 28 is a list of the salmonella serotypes identified.

One of the better indices of the quality of a stream is derived from an examination of the invertebrate animals living on the stream bed. The numbers and kinds of bottom dwelling organisms in a specific aquatic environment indicates within a fairly narrow range the quality of that environment.

The Missouri River is rather unique from the biological standpoint. The high flow combined with the intense channelization by flow control structures have limited the development of invertebrate communities to the rock flow control structures and the quiescent areas behind these

TABLE 27

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
KANSAS CITY TO WAVERLY
SEPTEMBER 25-29, 1969

Station		River Mile	Geometric Mean		F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform No./Day Trillions
Number	Location		Fecal Coliform 100 ml	Fecal Streptococcus Per 100 ml				
M-23	Kansas City, Missouri Water Intake	370.5	3,800	4,600	-	-	63,000	5,793
M-102	Fairfax Industrial Sewer	367.6	$0.56x10^6$	$0.23x10^6$	-	-	-	-
KR-22	Kansas River	367.4	1,600	630		-	2,234	24
M-103	Kansas City, Kansas STP	367.2	$5x10^6$	$5x10^6$	1.0	Mix	15.35	1,857
M-104	Kansas City, Missouri Westside STP	367.19	$1x10^6$	$1x10^6$	1.0	Mix	23.99	581
M-105A	Corn Products International (Major Effluent)	365	1,700	18,000	-	-	24.4	1
M-105B	Corn Products International (Minor Effluent)	364.8	2,600	30,000	-	-	2.0	0.1
M-106	Rock Creek, North Kansas City STP	362.7	$0.3x10^6$	$15x10^6$			4.44	32

TABLE 27 (Continued)

MISSOURI RIVER BACTERIOLOGICAL DENSITIES
KANSAS CITY TO WAVERLY
SEPTEMBER 25-29, 1969

Station			Geometric Mean					
Number	Location	River Mile	Fecal Coliform 100 ml	Fecal Streptococcus Per 100 ml	F.C./F.S.	Probable Source	Average Flow CFS	Fecal Coliform No./Day Trillions
M-19	Kansas City Blue River STP	358	3×10^6	0.58×10^6	5.2	Domestic	87.96	6,386
M-107B	Blue River	358	$.99 \times 10^6$	$.15 \times 10^6$	6.2	-	19.2	460
M-108	Rock Creek STP Independence	356.9	2×10^6	1×10^6	2.0	-	8.22	398
M-18	Missouri River near Missouri City	345.5	9,000	54,000	-	-	63,270	13,780
M-109	Little Blue River	339.5	4,100	2,900	-	-	11.6	1.2
M-15	Missouri River near Waverly	293	8,700	12,000	-	-	63,600	13,390

FIGURE 4
NUMBER OF FECAL COLIFORM PER DAY
MISSOURI RIVER
KANSAS CITY, MO. TO WAVERLY, MO.
SEPTEMBER 25-29, 1969

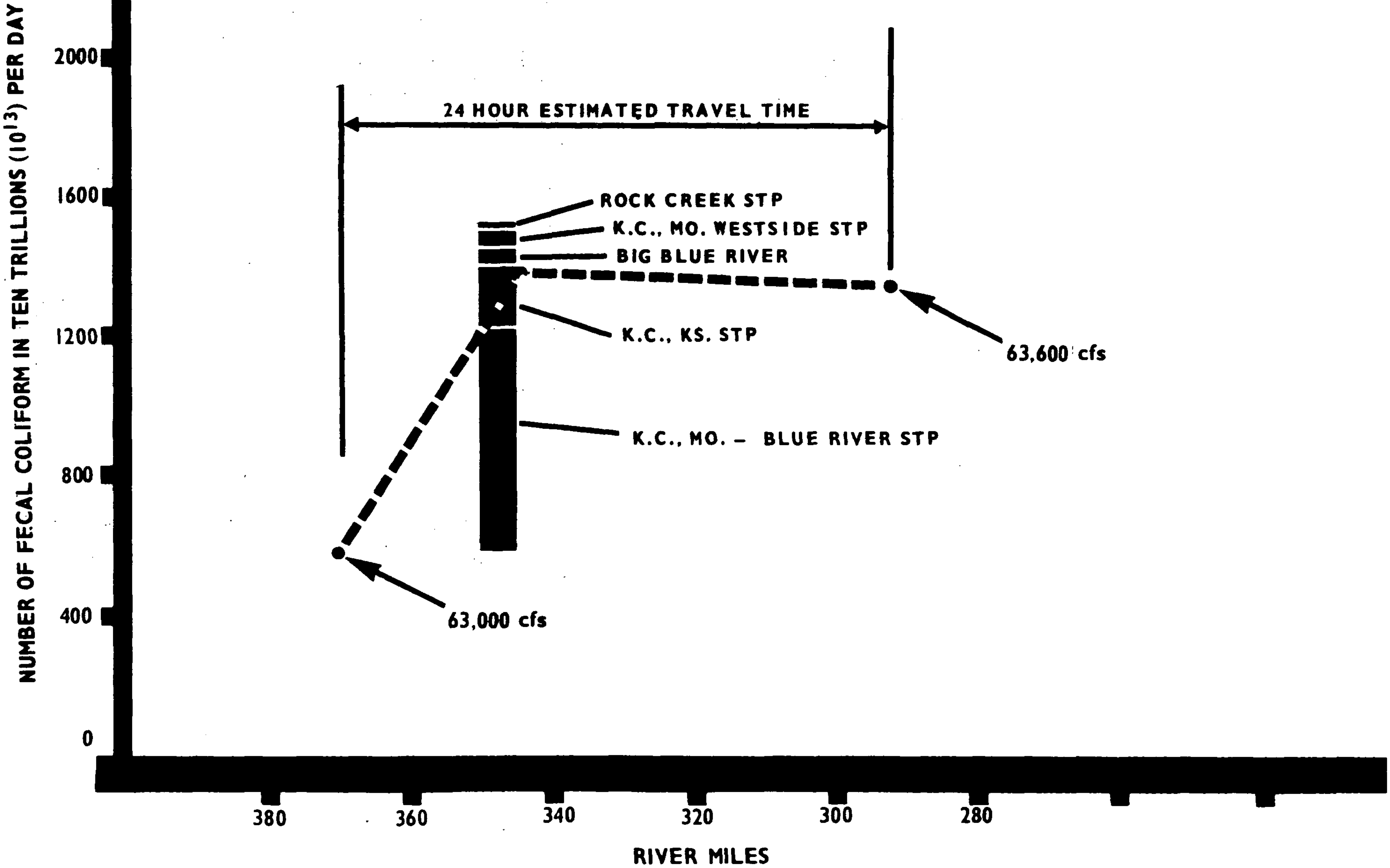


TABLE 28

MISSOURI RIVER SALMONELLA ISOLATIONS
KANSAS CITY TO WAVERLY

Station Number	Station Location	Salmonella Isolated
M-101	Line Creek	*S.* Infantis
M-102	Fairfax Industrial Outfall	*S.* Binza *S.* Typhimurium
M-107B	Big Blue River	*S.* Montevideo *S.* Cubana *S.* Tompson
M-109	Little Blue River	*S.* Muenchen

structures.

The bottom dwelling organism communities were sampled intensively during the Fall 1968 field study. At the control station near the Kansas City, Missouri water intake the organisms found were indicativ- of relatively clean water. There was an assemblage of 7 pollution sensitive and 1 pollution tolerant form.

Approximately 11 miles downstream, most of the pollution sensitive organisms were replaced by pollution tolerant forms indicating degraded water quality. Downstream from the Blue River confluence, 14 miles from the control station, all pollution sensitive organisms were absent and only the more tolerant forms were present. Between the con- fluence of the Blue River, R.M. 356, and Waverly, Missouri, R.M. 293, the accumulation of organic sludge on the pile dikes and in backwater areas limited the available habitat to tolerant forms.

The major tributary streams in this reach, the Kansas and the Big Blue Rivers were both found to be grossly polluted. Bottom dwelling organisms in the Kansas were limited to the most tolerant kinds such as sludge worms, while the Blue River was so severely polluted that the bottom samples were devoid of animals.

The specialised biological studies during the Fall 1969-Winter 1970 reconfirmed the 1968 findings. The fish flesh tainting studies demonstrated that wastes discharged to the Missouri River caused unacceptable flavors in caged catfish for a distance of 22 miles downstream from the Kansas City Area. In addition, fish placed in the Big Blue River, the old channel of the Blue River and Sugar Creek died within 24 hours.

The periphyton studies indicated polluted conditions in a six-mile reach (R.M. 362-R.M. 356) downstream from the Kansas River. Large reductions in numbers of attached organisms were observed in comparison with upstream stations indicating an unfavorable environment. Some recovery was observed downstream from R.M. 356 in numbers of organisms, but the communities included pollution tolerant blue-green algae and protozoans which feed on organic materials.

The fecal sterol isolations represented another index of recent fecal pollution in the Missouri River. Table 29 shows the coprostanol concentrations from samples taken in this reach.

Table 30 is a listing of the fecal coliform densities in the fecal sterol samples. The correlation between the fecal coliform and fecal sterols is quite good even though the samples were between 48 and 72

TABLE 29

FECAL STEROL CONCENTRATIONS
KANSAS CITY TO WAVERLY

Sampling Area	Sampling Point	River Mile	Concentration of Coprostanol in ug/liter				
			Date of Sampling				
			2-11-70	4-14-70	4-28-70	5-13-70	Mean
Missouri River at Kansas City Water Treatment Plant	M-23	370.5	80	68	98	-	82
Kansas River	K-22	367.4	78	70	83	-	77
Kansas City, Kansas STP	M-103	367.20	522	496	587	-	535
Kansas City, Missouri West-Side Plant	M-104	367.19	259	319	298	-	290
Blue River	M-107B	358.0	92	110	92	-	95
Kansas City, Missouri Blue River STP	M-19	358.0	328	419	396	-	381
Missouri River at Missouri City	M-18	345.4	86	75	98	-	87
Missouri River at Waverly	M-15	293.0	66	79	58	-	70

TABLE 30

FECAL COLIFORM DENSITIES ISOLATED FROM WATER SAMPLES
USED FOR FECAL STEROL ANALYSES
KANSAS CITY TO WAVERLY

Sampling Area	Sampling Point	River Mile	Number of Fecal Coliforms per 100 ml of Sample: Date of Sampling 2-11-70	4-14-70	4-28-70	5-13-70	Mean
Missouri River at Kansas City Water Treatment Plant	M-23	370.5	880	2,100	700	18,500	5,500
Kansas River	KR-22	367.4	6,200	1,300	7,400	1,800	4,200
Kansas City, Kansas STP	M-103	367.20	$20x10^6$	$13x10^6$	$5.9x10^6$	$13x10^6$	$13x10^6$
Kansas City, Missouri West-Side Plant	M-104	367.19	$1.3x10^6$	$0.3x10^6$	$0.4x10^6$	$1.6x10^6$	$0.9x10^6$
Blue River	M-107B	358.0	80	500	400	32,000	8,300
Kansas City, Missouri Blue River STP	M-19	358.0	$1.9x10^6$	$2.6x10^6$	$2.2x10^6$	$4.1x10^6$	$2.7x10^6$
Missouri River at Missouri City	M-18	345.4	1,600	1,600	2,100	19,000	6,100
Missouri River at Waverly	M-15	293.0	770	1,800	1,600	11,800	4,000

hours old.

These data again confirm the presence of fecal pollution in the River. For the bacteriological, viral, and fecal sterol data, the upstream control station provides the datum and the downstream observations show a positive increase above this base. The waste discharges that were sampled showed contributions which accounted for almost 60% of the increase in fecal coliform densities. The presence of the fecal sterol, coprostanol, reinforces the significance of the fecal coliform as an indicator and the isolation of salmonella and virus confirms the existence of a potential hazard. Combining these observations with the results of the fish flesh tainting studies, the periphyton studies and the earlier bottom dwelling organism investigation, a rather complete spectrum of pollution is produced.

The virus data as shown in Table 31 provide the final confirmation of the nature of the waste discharges. The total number of virus from waste sources in the Kansas City Area, based on the data in Table 31, averages about 264 virus per gallon of sewage. When it is considered that the Kansas City Area discharges almost 100 million gallons per day into the river, the viral hazard potential is placed in a rather staggering perspective.

TABLE 31

VIRUS ISOLATIONS
KANSAS CITY TO WAVERLY

Date of Samples	Sampling Station Number	Sampling Station Description	Virus Isolated PFU/Liter	Virus Identification
9/26/69	M-102	Fairfax Industrial Sewer	63	-
	M-103	Kansas City, Kansas STP	75.5	-
	M-104	Kansas City, Missouri Westside STP	71.5	-
	M-106	Rock Creek - North Kansas City STP	3.0	-
	M-108	Rock Creek - Independence STP	94	-
	M-19	Kansas City Blue River STP	114	-

OTHER FACTORS

The field investigations conducted between 1968 and 1970 have provided more knowledge of the quality of the Missouri River than heretofore available. These studies were unique in that they included the exotic as well as the standard tests of water quality. And in the end, this uniqueness further emphasized the relationships in the overall body of data.

One of the most significant findings of these investigations is the relative importance of point source discharges and of land runoff. A 2-day portion of the 1968-1969 baseline survey was conducted during a heavy rainstorm. These data are contrasted against the 8-day dry weather data in Table 32, to show the effect of runoff.

It is readily apparent that storm runoff adds a significant waste load to the river. There is an increase in the 5-day 20°C BOD and an attendant decrease in the dissolved oxygen concentrations. The densities of fecal coliform indicator organisms show an increase of several orders of magnitude due to wet weather flow.

However, it is equally important to realize the frequency of occurrence of wet weather flows. Flow hydrographs for five of the more significant streams were plotted to estimate the frequency of runoff peaks that might contribute pollution to the Missouri River. The number and duration of runoff peaks were determined using an arbitrary flow increase with a 2-3 day peak definition. Table 33 summarizes these findings.

Based on these the Missouri could be free from uncontrolled runoff

TABLE 32

A COMPARISON OF WET AND DRY WEATHER
WATER QUALITY AT SELECTED STATIONS
MISSOURI RIVER
1968

Station No.	Station Location	Dissolved Oxygen mg/l		5-Day 20°C BOD mg/l		Suspended Solids mg/l		Fecal Coliform MPN/100 ml	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
M-52	Upstream from Confluence of Missouri River and Big Sioux River	9.5	10.0	0.9	1.2	55	-	220	30,300
M-42	Omaha Water Treatment Plant	9.1	8.0	1.9	4.9	91	1020	8300	210,000
M-28	St. Joseph Water Treatment Plant	8.6	5.6	3.0	-	131	2780	6500	230,000

TABLE 33

SUMMARY OF RUNOFF DURATION AND FREQUENCY
FOR SELECTED MISSOURI RIVER TRIBUTARIES

Stream	Location	Record Length Yrs	Affected % Time	Runoff Peak Duration Days/Yr			Runoff Peaks Number/Yr		
				Avg	Min	Max	Avg	Min	Max
Kansas	Bonner S.	13	16	60	20	92	12	6	18
Platte (Iowa)	Agency	13	14	53	22	86	14	8	24
Nishnabotna	Hamburg	13	11	39	16	64	10	5	17
Little Sioux	Turin	9	12	42	14	79	6	4	9
Big Sioux	Akron	13	9	35	10	82	4	1	10

84 or more percent of the time from any particular tributary. No attempt to modify this for combination of tributaries seems feasible.

Table 34 is a list of all of the significant tributaries and their average flow contribution. The tributaries are listed in descending geographical order. It is expected that the individual stream flow characteristics would be similar to those shown in Table 33.

In addition to the investigation of the significance of point sources, an industrial waste survey was conducted to determine the character of the discharges other than municipal. The metropolitan areas of Kansas City and St. Joseph, Missouri; Omaha and Dakota City, Nebraska; and Council Bluffs and Sioux City, Iowa were included in this survey. All identifiable industries were contacted by letter, phone or personal visit to collect available data on their waste discharges. The entire industrial waste survey effort was under the sponsorship of the respective State Water Pollution Control Agency.

In the Sioux City area, the wastes being discharged to the Floyd River and the Missouri River consist primarily of domestic wastes, industrial wastes associated with the food processing industry -- particularly the meat packing industry, and wastes from large ammonium nitrate and insecticide manufacturing plants. Except for periods during storm runoff, all wastes discharged to the Sioux City municipal sanitary sewer system receive primary treatment. This includes all industrial wastes produced in Sioux City except those from the stockyards and cooling and condensate waters from various industries. Reportedly, a small percentage of the domestic wastes in the Sioux City area are discharged into the municipal storm sewer system.

TABLE 34

SUMMARY OF MISSOURI RIVER TRIBUTARIES

USGS Gage	Stream - Gage		Avg. Dischg. cfs (1967)	Rank
6-4785	James River	Scotland	366	13
6-4855	Big Sioux	Akron	830	9
6-6005	Floyd	James	174	16
6-6075	Little Sioux	Turin	1,003	7
6-6085	Soldier	Pisgah	128	18
6-6095	Boyer	Logan	301	14
6-8055	Platte	South Bend	5,503	3
6-8100	Nishnabotna	Hamburg	970	8
6-8130	Tarkio	Fairfax	186	15
6-8150	Little Nemaha	Falls City	598	11
6-8175	Nodaway	Burlington, Mo.	508	12
6-8205	Platte (Mo.)	Agency, Mo.	827	10
6-8925	Kansas	Bonner Springs	6,583	2
6-8935	Big Blue	Kansas City	137	17
6-8940	Little Blue	Lake City	108	
6-9020	Grand	Summer	3,683	4
6-9055	Chariton	Prairie Hill	1,071	6
6-9265	Osage	St. Thomas	9,604	1
6-9335	Gasconade	Jerome	2,486	5
6-4860	Missouri	Sioux City	31,680	
6-6100	Missouri	Omaha	27,680	
6-8930	Missouri	Kansas City	54,350	

Based upon the findings of this survey there are six major wastewater outlets in the Sioux City area. These are the outlets from a packing plant in Dakota City, Nebraska, the primary effluent from the Sioux City municipal wastewater treatment plant, the effluent from the detention ponds serving the chemical plants, at Port Neal, and three major outlets serving the Sioux City stockyards.

In Council Bluffs, the municipal wastewater treatment plant provides treatment for the domestic and industrial wastes. The major sources of industrial wastes are two food processors and one meat packer.

The packing plant is a large beef slaughtering facility designed to handle 250 head of beef per hour. Some treatment facilities are being provided and supported by an EPA Research and Demonstration Grant.

The industry in Omaha is oriented heavily toward agriculture, including livestock slaughtering, rendering, and hide processing industries; meat processing (breaking, boning, sausage manufacture, etc.); and food processing industry; particularly the frozen-prepared dinner industry, the potato chip industry, and the ice cream and other milk product industry. In the milk product category, cheese manufacturing is minimal.

Another important industrial source of liquid wastes in Omaha is livestock receiving facilities, the largest facility being the Union Stockyards Company. At Union Stockyards, livestock is received and marketed for slaughter or for further feeding. Manure in the cattle pens is removed in the semi-solid form, dehydrated, bagged and sold as soil conditioner. Manure from the swine and sheep pens is washed to the sewer. All runoff resulting from rainfall flows to the sewer.

Associated with the animal handling wastes are the livestock transport trucks. Several truck washing businesses within the city specialize in cleaning manure and bedding from trucks and washing the interior and exterior of the truck. These washwaters enter the sewer carrying considerable quantities of the semi-solid manure removed from the trucks.

Another class of industry, which may be of importance as a source of pollutants having public health significance, is the pharmaceutical industry. One products, diethyl stilbestrol, is widely used as a feed additive for stimulating animal growth. In general, the pharmaceutical industries in Omaha are careful to minimize the loss of product to the sewer. However, the significance of the quantities of hormones and other pharmaceuticals discharged to the sewer from pharmaceutical manufacturing, as compared to other potential sources of the same chemicals, such as from livestock slaughtering operations, cannot be quantified from this survey.

Other classes of industry in Omaha, such as metal plating, textiles, pulp and paper wastes, plastics, and machinery manufacturing, are minimal or non-existent.

Only a superficial survey was made of St. Joseph, Missouri. The domestic waste is processed through two primary treatment plants. Slaughterhouse and insecticide waste are combined in one STP with some domestic sewage to handle the only exotic chemical problem existing in the area.

During the Lower Missouri Survey effort the chemical plant was shut down and no waste other than domestic/slaughterhouse was entering the river.

The industrial background of North Kansas City, Missouri is characterized by a heavy concentration of storage and packaging operations. Few industries are process in nature. Most organizations work the daylight shift with the resultant loading on the sewage treatment plant going from 7,000 PE at night to 70,000 PE in the day.

There are a few light metal fabrication operations where etching, cleaning and plating, produce waste which could be harmful to secondary treatment processing. Those companies not treating wastes in plant can be identified.

Three industries are potential sources of trouble. One produces a large amount of organic loading resulting from the refining of sugar from corn. Some of these wastes are discharged to city sewer while others are allowed to go direct into the Missouri River.

A second industry, a repair shop for railroad tank cars allows the steamings from the car-cleaning operation to escape by seepage into the ground. This is an undefined route of disposal and within a few yards of the river levee and water's edge. Some oils have been seen in storm sewer outfalls into the Missouri River near this installation.

The third industry manufactures copper powder and one of the wastes is a copper ammonium carbonate complex. This material is believed to be adequately disposed of; however, unexplained copper color has been seen in a storm sewer outfall to the Missouri River.

A small creek flows through North Kansas City and into the Missouri which carries the primary treated effluent from the North Kansas City STP and miscellaneous industrial wastes.

Kansas City, Missouri is a transportation terminal for finished and semi-finished goods. Numerous warehouses and assembly plants exist in the area. Industrial waste from these operations is primarily dry in character and very little of an exotic nature.

The City is on a sewer system with localized areas being served by package treatment plants. Most all industries are handled through the City's central treatment plant.

There are numerous food processors throughout the City, such as potato chip manufacturers, dairies, bottling works in addition to restaurants in the retail trade. These high organic waste sources are not a problem source.

An industrial complex centered around a steel mill with attendant etching, plating, cleaning, painting operations exists on the Blue River in the east part of Kansas City. This group of companies discharge much of their wastes into the Blue River making the quality of the stream far below State Standards. The State of Missouri has issued compliance orders in hopes to improve this stream.

Two chemical companies near the steel mill complex could be the source of exotic organo-phosphorus insecticides. One firm reclaims various types of wastes and employs a series of sealed lagoons on the river side of the levee. The other firm, a large manufacturer of agricultural chemicals, is constructing a treating plant to handle its industrial waste. Their wastes are being lagooned and neutralized prior to disposal into the City sanitary sewer.

Table 35 summarizes the results of the industrial waste survey and the basic data are contained in Appendix G.

Based on the analyses of significance and frequency it is readily apparent that point source discharges are responsible for the observed water quality degradation for about 85% of the time. It is also apparent that the pathogenic hazard is high because of the domestic or agri-industry origin of the wastes. Then it is only a matter to determine what feasible means are available to solve this problem.

The problem in the most basic terms is the addition of organic materials, bacteria and virus to the river. Some of the organic materials cause the tainting of fish flesh. Others serve as necessary nutrients to sustain the persistence or regrowth of bacteria. Specific organic compounds such as the fecal sterols show the ability of these biodegradable organic compounds to persist in the water environment and also indicate the presence of recent fecal contamination.

The bacterial indicator organisms also show the presence of material of fecal origin and indicate a possibility of the existence of pathogenic organisms. Isolation of salmonella and virus confirms this premise.

In summary the Missouri River represents a potential hazard to anyone using it as a source of drinking water or for recreation. Mitigation of this hazard through a higher level of waste treatment with adequate bacterial control is technically feasible and well within the public interest.

A properly operated secondary treatment plant will remove between 85 and 95 percent of the five-day biochemical oxygen demand. This rep-

TABLE 35

SUMMARY OF INDUSTRIAL WASTE SURVEY

Metropolitan Area	Number of SIC Code Groups	Total No. of Companies	Number of Companies: With Significant Inplant Treatment	Number of Companies: With Discharge to Municipal Sewers
Sioux City, Iowa	9	74	13	66
Council Bluffs, Iowa	9	35	3	31
Omaha, Nebraska	14	172	10	159
North Kansas City, Missouri	9	30	6	26
Kansas City, Missouri	12	80	14	72

resents a reduction in readily available carbonaceous material which is susceptible to biological oxidation or stabilization. This also removes a substantial portion of the nutrient material necessary for bacterial persistence or regrowth and many of the compounds that taint fish flesh.

Properly operated secondary treatment will remove on the average about 50 percent of the nitrogen which is another nutrient necessary for bacterial growth or persistence.

And, last but not least, properly operated secondary treatment will reduce significantly the bacterial and virus densities. Bacterial removals between 90 and 98% can be obtained. The secondary effluent is more easily disinfected due to greater removals of solids and oxidizable substances. The bacterial reductions that can be obtained with disinfection of secondary effluent depend upon disinfection technique. With chlorination, efficiencies of 99% can be reached.

Insofar as the removal of virus is concerned, properly operated activated sludge treatment will remove up to 90% of the virus. These virus are removed either by adsorption onto the suspended or colloidal material or by inactivation from toxic substances. Additional virus removal can be obtained with proper chlorination, that is requisite free chlorine residuals and proper contact time.

CONCLUSIONS

A minimum of secondary sewage treatment is needed to protect water uses that exist now, as well as in the future, in the Missouri River. The time is past when this Nation can ask itself how much pollution can be added to the environment instead of how much environmental pollution can be prevented. We can no longer afford to take the risk of relying on our reckoning of the assimilative capacity of the receiving waters and minimum acceptable quality as the basis for designing minimum level of waste treatment. This concept has not protected us in the past from polluting most of the Nation's waters, and it is less valid today when the volume and complexity of waste discharges continue to increase at a rapid rate. We subscribe to a concept of water quality enhancement through adequate waste treatment.

There are many valuable and tangible attributes associated with secondary waste treatment other than its capacity to remove oxygen-demanding wastes. Most of these are affected little, if at all, by primary treatment. These attributes include up to 95 percent suspended solids reduction and the removal of substantial quantities of bacteria, pathogenic organisms, viruses, heavy metals, and nutrients including 30 percent or greater phosphorus removal and 50 percent nitrogen reduction. The receiving waters of efficiently treated wastes are kept aesthetically clean. A very important factor is that secondary treatment provides the basis for efficient, effective disinfection through the removal of most of the solid particles that harbor bacteria and by destruction of fecal organic matter in which they multiply. To strive for less than secondary waste treatment or its equivalent is to strive towards mediocrity when something far superior is attainable, technically realistic and needed to protect water uses.

Data collected during investigations made of the Missouri River and its tributaries by the FWQA over the past two years demonstrate conditions of serious pollution. Wastes discharged by the major communities, using only primary treatment, cause measurable increases in bacterial indicator organisms, virus and fecal sterols. These wastes also cause water quality degradation as reflected by the structure of the periphyton communities and the tainting of fish flesh. Each measured pollutional characteristic or observed effect is attributable to constituents that can be substantially removed from waste waters by properly operated secondary treatment facilities with bacterial control.

This investigation also provided specific knowledge on a number of pollutants that should be prevented from entering the Missouri River and that can be controlled by secondary treatment with disinfection. For example, the treatment of public water supplies is based on a concept of multiple barriers against the invasion of pathogenic organisms. One of these barriers is adequate disinfection of municipal wastes that may enter the waterway from which the supply is drawn. There are a number of organisms present in sewage that threaten the health of persons drinking or swimming in the water that is so contaminated. These include: *Salmonella*; *Shigella*; *Leptospira*; *Mycobacterium*; and the enteric viruses, such as polio and hepatitis.

The FWQA investigations on the Lower Missouri River resulted in the isolation of a number of constituents that can be removed by secondary treatment. These included 19 Salmonella serotypes, many of these were pathogenic human strains. Pathogenic Salmonella were demonstrated in three water supply intakes. Bacterial regrowth was found to be significant in the receiving waters. Viruses were isolated from water supply intake areas. It was demonstrated that viruses could survive in Missouri River water for a period of 25 hours or longer, which would permit them to reach most water supply intakes from the pollution source. In laboratory experiments, they survived in large numbers.

Fecal sterols were isolated from water intake areas during the survey. The isolation of fecal sterols confirmed independently with a chemical test rather than a bacteriological one that fecal pollution does occur. These are biodegradable and would be removed in a secondary treatment process.

The Fish-tainting study was not a unique or alternate approach to a comprehensive water quality investigation, but one that has been used on a number of occasions to successfully identify taste and odor problems in water. The presence of unacceptable flavors in fish flesh from caged fish confined downstream from metropolitan areas in the Lower Missouri River is a significant indication of the existence of a problem and of the presence of taste and odor producing compounds in the water. Secondary treatment removes ketones that occur in paint solvents, phenols, hydrocarbons and coal tar wastes that produce disagreeable taste in fish flesh. Water quality standards adopted by the States specify that water quality should be such that off flavors are not produced in fish flesh.

In the case of the Missouri River where the principal use is as a water supply source for approximately three million people, the obligation of upstream communities is readily apparent. Their sewage treatment plants serve as the first of the multiple barriers between the upstream wastewater and downstream water user.

Although it is now technically feasible to produce drinking water from sewage, it is not economically practicable. The water utilities constantly search for the best quality raw water source to provide the general public with a safe potable water supply. The water treatment systems of today are probably capable of removing 99.9% of the virus present. But there is still a chance of the 0.1% slipping through. Since virus were isolated at the water intakes, and since it may take as little as one viral particle to cause infection, the average man dependent on the Missouri River municipal water systems could be subjected to a viral infection. The implementation of higher levels of waste treatment can mitigate this threat. It must be remembered, not everybody can live upstream.

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APPENDIX A

SAMPLING STATION DESCRIPTION

STATION DESCRIPTIONS

Station Number	River Mile	
M-52	736.0	Two miles upstream from mouth of Big Sioux River at I-29 Bridge.
BS-51	734.0	Big Sioux River upstream from confluence with Missouri River at Sioux City, Iowa.
F-50.5	731.2	Floyd River new channel at Dace Avenue Bridge, Sioux City, Iowa.
SC-49	729.7	At Sioux City STP effluent.
IBP-48.5	726.2	Iowa Beef Packers, Inc., Dakota City, Nebraska. Plant effluent at second manhole downstream of package STP on company property south of Sioux City.
M-48	717.4	Below Sioux City STP outfall at power cable crossing.
LS-45.5	669.2	Little Sioux River at Highway I-29 Bridge near River Sioux, Iowa.
S-45	664.0	Soldier River upstream from confluence with Missouri River.
B-43	635.1	Boyer River one mile upstream from confluence with Missouri River.
M-42	626.2	At Omaha, Nebraska water works intake 0.3 Mile below State Highway 36 bridge.
M-52A	732.7	Approximately one mile South of Elk Point, South Dakota, 0.5 mile upstream from U. S. Highway 73 bridge.
M-212	615.2	Quaker Oats Company effluent at concrete box (covered with steel grill) on levee about 100 feet from Missouri River at Pierce Street, Omaha, Nebraska.
M-211	615.1	Pacific Fruit Express outfall off 35th Street at Council Bluffs, Iowa.
CB-40B	614.0	Council Bluffs STP primary effluent at the plant, 35th Street and 23rd Avenue.

Station Number	River Mile	
TC-210	613.6	Twin Cities Plaza STP effluent at plant.
OM-40 OM-40A	611.5	Omaha, Nebraska STP effluent.
OM-208	611.2	At Omaha, Nebraska 10th and Monroe Street sewer effluents in ditch below twin-tube outfall structure, about 100 feet west of Missouri River.
M-38	601.7	At Bellevue, Nebraska 0.1 mile below State Highway 370 bridge.
M-206	601.5	At Bellevue, Nebraska STP Number 1 primary effluent at plant clarifier outfall (upstream of STP secondary digester overflow and water plant lime sludge waste) State Road 370.
M-205	596.6	Papillion Creek at one-lane steel truss and wooden bridge, approximately one mile downstream from U. S. Highway 73 and 75 bridge and Offutt Air Force Base secondary STP outfall, Sarpy County, Nebraska.
P-37	594.8	Platte River 3 miles upstream from confluence with Missouri River at U. S. Highway 73 and 75 bridge south of La Platte, Nebraska.
M-201	591.2	At Plattsmouth, Nebraska STP primary effluent at plant.
M-200	563.3	At Nebraska City, Nebraska STP primary effluent at plant.
M-34	559.7	Downstream from Nebraska City, Nebraska, 0.2 mile above Fraziers Light.
N-199	542.0	Nishnabotna River at Southeast edge of Hamburg at confluence with Missouri River, U. S. Highway 275 bridge.
T-198	507.6	Tarkio River near Corning, Missouri at State Highway 111 bridge.
N-196	462.4	Nodaway River north of Nodaway, Missouri at U. S. Highway 59 bridge on November 3, 1969 and at County Road T Bridge on November 4 - 7, 1969.

Station Number	River Mile	
M-28	452.3	Missouri River at St. Joseph water works intake 0.3 miles downstream from daymark right bank.
OM-209	611.9	Missouri River - Omaha STP By-Pass.
SJ-3	452.3	Blacksnake Creek sewer at mouth of pipe to sink hole aside the Missouri River at St. Joseph, Missouri.
SJ-5	452.3	Charles Street Sewer at manhole in Second Street intersection, St. Joseph, Missouri.
SJ-9	452.3	Mitchell Street sewer at manhole located approximately 30 feet west of Sixth Street curbline, St. Joseph, Missouri.
SJ-15	446.4	St. Joseph, Missouri, Municipal STP primary effluent at outfall to ditch, approximately 150 feet East of Missouri River edge.
SJ-17	446.4	Brown Branch Ditch approximately 400 feet from Missouri River confluence and 10 feet upstrem of South St. Joseph Industrial STP emergency by-pass outfall and downstream of St. Joseph Power & Light Company power plant waste discharge.
SJ-18	445.6	South St. Joseph, Missouri Industrial Sewer District Treatment Plant effluent at mouth of outfall pipe at bank of Missouri River.
M-27	440.3	Missouri River at Palermo Landing 1.3 miles upstream from Palermo Light, left bank about 4 miles west of St. Joseph, Missouri
A-25.5	421.0	Missouri River at Atchison, Kansas STP primary effluent at the plant outfall weir.
L-24.5	395.6	Missouri River at Leavenworth, Kansas STP primary effluent at the collection box for the two clarifier streams.
P-23.5	391.2	Platte River south of Farley, Missouri at State Highway 45 bridge.
M-101	372.2	Line Creek at CB&Q Railroad Bridge approximately 0.4 mile upstream of mouth.

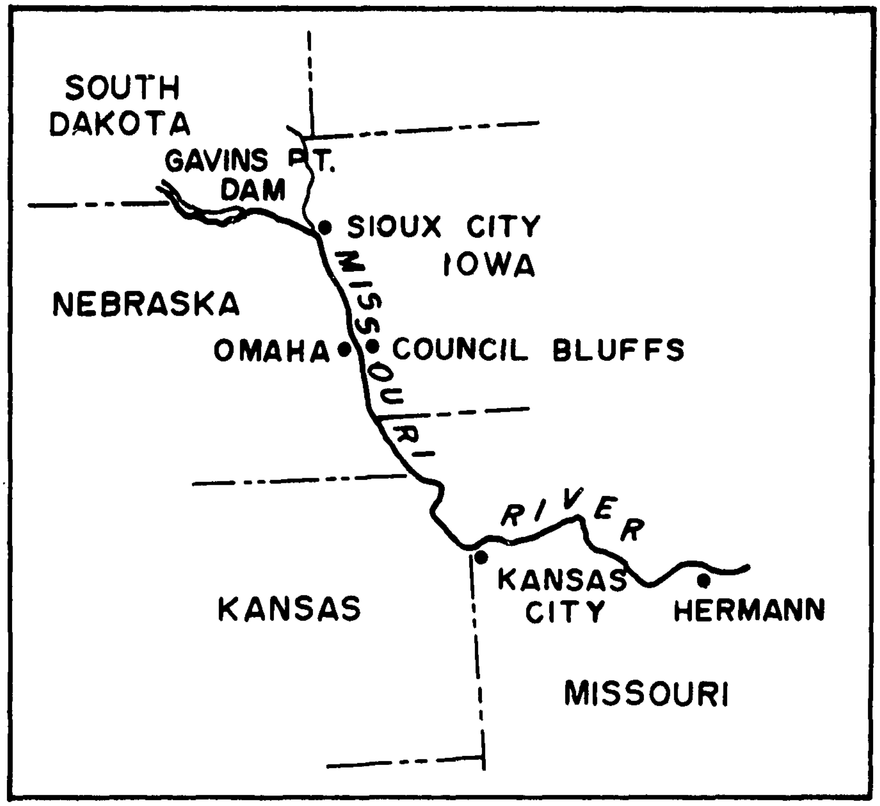
Station Number	River Mile	
M-23	370.5	Missouri River at Kansas City, Missouri Water works Intake (opposite Fairfax Airport).
M-102	367.6	Missouri River at Kaw Valley Drainage District, Fairfax District, Kansas City, Kansas Industrial sewer at outfall structure on Kansas bank of Missouri River.
KR-22	367.4	Kansas River 3 miles from confluence with Missouri River at Missouri Pacific Railroad Bridge, Kansas City, Kansas.
M-103	367.2	Kansas City, Kansas STP.
M-104	367.19	Kansas City, Kansas west side STP.
M-105A	365.0	Corn Products Corporation hot waste effluent at the outfall mouth to ditch (the major discharge to Missouri River).
M-105B	364.8	Howell Street Sewer outfall. Corn Products Corporation minor discharge at floodgate upstream of ditch approximately 200 feet from Missouri River.
M-106	362.7	North Kansas City STP primary effluent at outfall mouth to Rock Creek, Missouri.
M-19	358.0	Big Blue River at Blue River STP, Kansas City, Missouri about 3 miles upstream from confluence with Missouri River.
M-107B	358.0	Big Blue River new channel approximately 100 feet upstream from the mouth, Missouri.
M-108	356.9	Rock Creek STP, Independence, Missouri raw sewage by-pass line from September 25 through September 28, 1969, and primary effluent on September 29, 1969.
M-18	345.5	Missouri River 1 mile upstream of Missouri City, Missouri, N. W. Electric Power Plant Co-op.
M-109	339.5	Little Blue River at U. S. Highway 24 bridge.
M-15	293.5	Missouri River at Waverly, Missouri U. S. Highway 24 and 65, USGS 6-8955.

APPENDIX B

REPORT ON THE 1968-1969 BASELINE SURVEY

WATER QUALITY OF THE MISSOURI RIVER
GAVINS POINT DAM TO HERMANN, MISSOURI

OCTOBER NOVEMBER, 1968 AND JANUARY FEBRUARY, 1969
SURVEYS



DEPARTMENT OF THE INTERIOR
FEDERAL WATER QUALITY ADMINISTRATION
NATIONAL FIELD INVESTIGATIONS CENTER
CINCINNATI, OHIO
JUNE, 1970

WATER QUALITY OF THE MISSOURI RIVER
(Gavins Point Dam to Hermann, Missouri)

OCTOBER-NOVEMBER 1968
AND
JANUARY-FEBRUARY 1969
SURVEYS

by

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DEPARTMENT OF THE INTERIOR
FEDERAL WATER QUALITY ADMINISTRATION
NATIONAL FIELD INVESTIGATIONS CENTER
CINCINNATI, OHIO

JUNE 1970

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INTRODUCTION

This report is based on field surveys conducted by personnel from the National Field Investigations Center of the Federal Water Pollution Control Administration(FWPCA),* Cincinnati, Ohio in cooperation with the Missouri Basin Region, FWPCA, Kansas City, Missouri.

The purpose of the surveys was to determine Missouri River water quality along the 700-mile reach from Gavins Point Dam near Yankton, South Dakota, to Hermann, Missouri (Figure 1) which includes parts of the borders of South Dakota, Nebraska, Iowa, Missouri, and Kansas.

* throughout this report reference is made to the Federal Water Pollution Control Administration (FWPCA) which is now the Federal Water Quality Administration (FWQA).

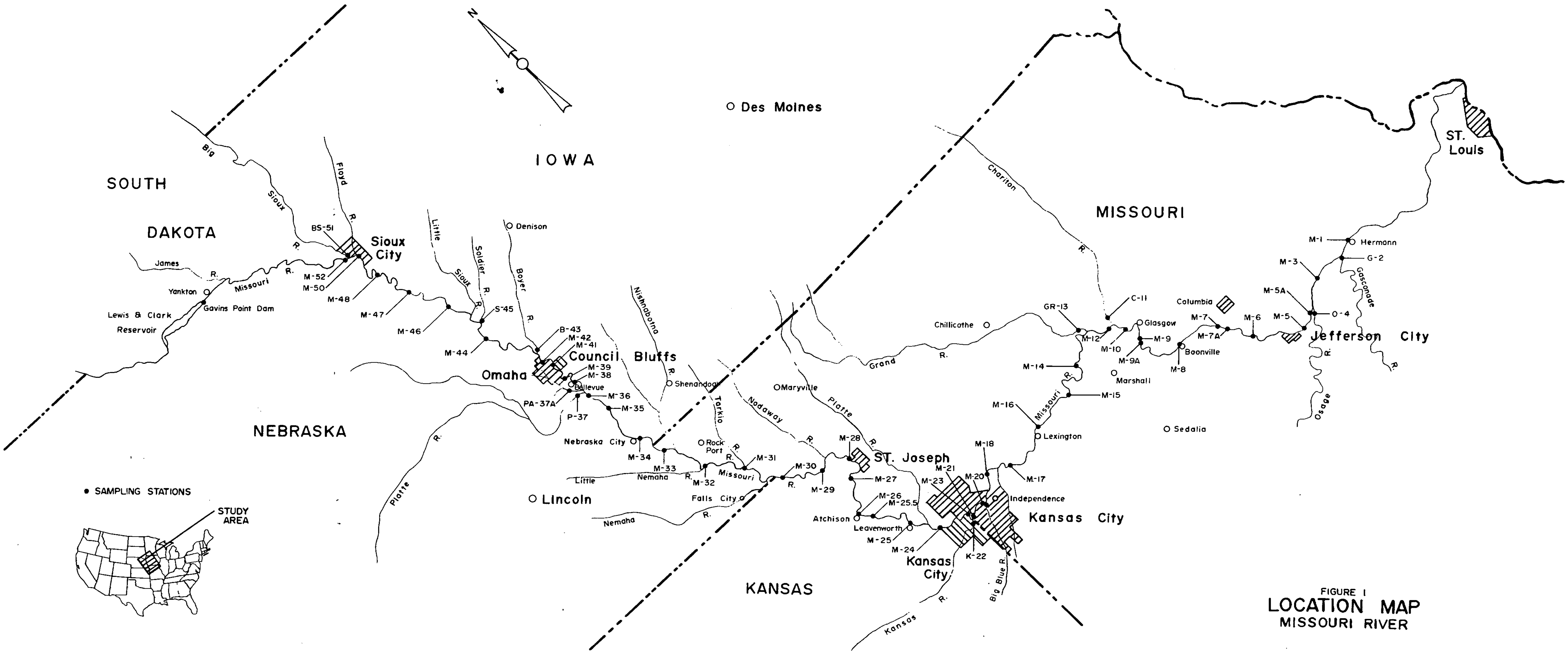

FIGURE 1
LOCATION MAP
MISSOURI RIVER

SUMMARY

1. The subject of this report is the water quality in the 700-mile reach of the Missouri River from Gavins Point Dam near Yankton, South Dakota, to Hermann, Missouri. Major metropolitan areas include: Sioux City, Iowa; Omaha, Nebraska-Council Bluffs, Iowa; St. Joseph, Missouri; and Kansas City, Missouri.

2. Two chemical and bacteriological surveys were conducted. The first was from October 7 to November 8, 1968; the second from January 20 to February 2, 1969. An aquatic biological survey was conducted from October 7 to October 16, 1969.

3. Forty-five physical, chemical, biochemical, and bacteriological examinations were made on samples from 56 locations for the autumn (October-November, 1968) survey and 31 sampling locations for the winter (January-February, 1969) survey.

4. Three hydrologic conditions were encountered during the two surveys:

    a. "Normal" weather and navigational flows for the first eight sampling days of the first autumn survey between Gavins Point Dam and St. Joseph, Missouri (average flow 36,600 cfs), and for the second autumn survey between St. Joseph and Hermann, Missouri (average flow 55,600 cfs).

    b. Two days of heavy rainfall in the basin which caused nearly double normal navigational flows between Omaha, Nebraska and St. Joseph, Missouri for the last

two days of the first autumn survey. The flow averaged 70,400 cfs at St. Joseph.

c. Winter weather and non-navigational flows combined with river stages affected by ice jams were encountered during the winter survey. Flow at St. Joseph averaged 20,800 cfs.

5. At all stations, coliform bacteria densities exceeded by several times the National Technical Advisory Committee Criteria for sources of public water supply and for recreation.

Specifically:

a. During the normal weather periods of the autumn survey, the highest geometric mean total and fecal coliform bacteria densities were 256,000 MPN/100 ml and 61,200 MPN/100 ml respectively, downstream from Omaha-Council Bluffs; and 189,000 MPN/100 ml and 15,000 MPN/100 ml respectively, downstream from Kansas City, Missouri.

b. The coliform densities increased greatly during the autumn 2-day, rain-affected period. Both total and fecal coliform bacteria exceeded 100,000 MPN/100 ml at 19 of 21 river stations sampled with the highest 2-day densities of 1,440,000 MPN/100 ml and 1,120,000 MPN/100 ml respectively, occurring downstream from Nebraska City, Nebraska.

c. The winter survey bacterial densities were generally lower than those of the autumn survey. The highest geometric mean densities occurred downstream from the major metropolitan areas. Total coliform, fecal coliform, and fecal streptococci bacterial densities were 53,800 MPN/100 ml, 14,200 MPN/100 ml, and 61,100 respectively, downstream from Omaha-Council Bluffs, and 128,000 MPN/100 ml, 23,900 MPN/100 ml, and 26,600 MF/100 ml respectively downstream from Kansas City, Missouri.

6. Dissolved oxygen (D.O.) concentrations were greater than 8.3 mg/l during the autumn survey in the Gavins Point Dam to St. Joseph reach and were greater than 9 mg/l in the St. Joseph to Hermann, Missouri reach. Concentrations during the winter survey exceeded 9.0 mg/l in the total 700-mile reach. The lowest dissolved oxygen concentrations occurred during the 2-day, rain-affected period when the lowest average was 5.2 mg/l near St. Joseph.

7. A lead concentration of 0.085 mg/l for the average of two 5-day composite samples and cyanide concentrations of 6 µg/l downstream from Sioux City indicated potential toxicity in the Missouri River.

8. The total dissolved solids concentrations exceeded the recommended limit of 500 mg/l contained in the Public Health Service Drinking Water Standard at six of twenty stations during the first autumn survey upstream from St. Joseph. During the winter survey, twelve of twenty stations exceeded this criterion in the Gavins Point Dam to Hermann reach.

9. Radionuclide concentrations were much less than NTAC permissible criteria in the main stem of the Missouri River and in tributary streams. Concentrations were indicative of natural background levels for uranium, radium-226, and thorium-232. When calculated as gross alpha, the total concentrations, were 2.5 pc/l. Strontium-90 concentrations averaged about 1.8 pc/l during the autumn surveys.

10. A study of bottom-associated animal populations in 638 miles of the Missouri River downstream from Sioux City, Iowa, indicated at least 117 miles were severely degraded by organic pollution and an additional 99 miles were moderately degraded by pollution. Specifically:

    a. From Sioux City, Iowa to Omaha, Nebraska, and Council Bluffs, Iowa, stream bed animals reflected unpolluted conditions with the exception of localized degradation in the Sioux City area.

    b. Severe degradation of the bottom-associated organisms occurred for 54 miles downstream from the Omaha and Council Bluffs area. Objectionable floating solids (grease and chunks of animal fat) were evident from the Omaha and Council Bluffs area downstream past the St. Joseph, Missouri water supply intake a distance of approximately 166 miles.

c. Wastes from the Kansas City area and the Blue and Kansas Rivers produced adverse conditions for aquatic life for 66 river miles downstream as indicated by the absence of pollution-sensitive (clean water) bottom organisms.

d. Increasing numbers of pollution-sensitive bottom organisms occurred in farther downstream reaches which indicated recovery from severe pollution.

11. Biological studies indicated degraded water in tributaries to the Missouri River including the Big Sioux, Floyd, Soldier, Boyer, Kansas and Blue rivers.

12. Suspended algae in the Missouri River increased in numbers from 1,000 cells/ml to 6,000 cells/ml downstream from Omaha, Nebraska - Council Bluffs, Iowa.

METHOD OF STUDY

SAMPLE STATIONS

The autumn survey was designed to give more extensive river coverage when the river was readily accessible because of sustained navigational flows and sampling could be accomplished from boats. The winter survey was designed to reexamine water quality near urban areas with less extensive coverage at intervening, less accessible areas. Because of reduced flows and ice in the river, samples during this survey were collected from the stream banks at locations accessible by automobile.

Fifty-six sample stations were selected in the Gavins Point Dam to Hermann, Missouri river reach for the autumn survey (Appendix A). Twenty-nine sample stations were located in the upper reach from Gavins Point Dam to St. Joseph, Missouri and were sampled from October 7 to October 18, 1968 (first autumn survey period). Twenty-one of these stations were located on the main stem of the Missouri River, five stations were on tributary streams and three stations were waste sources.

In the lower reach from St. Joseph to Hermann, twenty-eight stations were sampled in the period of October 28 to November 8, 1968 (second autumn survey period). Twenty-one of these stations were on the main stem, five were tributary streams, and two were waste sources. One main stem station (M-27) of the upstream section was repeated.

Thirty-one sampling stations were established on the 700-mile reach during the period January 20 to February 2, 1969 (winter survey period). Twenty-four of these were on the main stem, two were on tributary streams and five were waste sources.

Stations sampled during the winter survey were located as closely as possible to the October 1968 locations. Where locations were not identical, a letter symbol was added to the station number in the summary tables to distinguish this difference (Appendix A).

ANALYSES

Many analyses were necessary to determine the water quality in the Missouri River. In addition to the biological examinations, 45 chemical, biochemical, and bacteriological examinations were included in the analysis series. Not all analyses were performed on daily discrete samples from each station. At selected stations composites from five daily samples were made and preserved for analysis of other constituents. Sample compositing was used to keep the required number of analyses within manageable limits. The sampling interval for each analysis is shown in Table No. 1; results of analyses are summarized in Appendix B.

Biological features studied were bottom-inhabiting invertebrate organisms and suspended algae (phytoplankton). Bottom sampling was at approximately 20 river mile intervals except in areas affected by waste discharges where additional stations were established. Forty stations on the Missouri River and one station on each of the major tributaries were sampled. Stations are designated with the same number as the closest chemical and bacteriological station where possible or as Corps of Engineer river miles measured upstream from the Missouri River confluence with the Mississippi River (Appendix A).

ANALYTICAL METHODS

All chemical analytical methods conformed to "FWPCA Official Interim Methods for Chemical Analysis of Surface Waters."* Except for modifications required for automated chemistry, methods contained in this volume are essentially the same as those contained in the 12th Edition of "Standard Methods for the Examination of Water and Wastewater."** Most of the heavy metal analyses were performed by atomic absorption spectroscopy.

Bacterial examinations were performed in accordance with "Standard Methods." In this report, the term "total coliform bacteria" refers to bacteria identified as the "Coliform Group" in Standard Methods.

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* "FWPCA Official Interim Methods for Chemical Analysis of Surface Waters," Federal Water Pollution Control Administration, September, 1968.

** "Standard Methods for the Examination of Water and Wastewater," 12th Edition, APHA, AWWA, WPCF, 1965.

TABLE 1

Frequency of Chemical Analyses
MISSOURI RIVER
(Gavins Point Dam to Hermann, Missouri)
OCT.-NOV., 1968 & JAN.-FEB., 1969 SURVEYS

CONSTITUENT OR ANALYSIS	DAILY	5-day Composite Sample	5-day Composite of Filtrate	2-4 Times per Survey Period	1 Time per Survey Period
ALL STATIONS					
Temperature	X				
Dissolved Oxygen (D.O.)	X[1]				
2- and 5-day Biochemical Oxygen Demand (B.O.D.)	X				
Total Alkalinity	X				
Specific Conductance	X				
Turbidity	X				
Chlorides	X[2]				
Sulfates	X[2]				
Total Dissolved Solids	X[2]				
Total Suspended Solids	X[2]				
Total Coliform Bacteria	X				
Fecal Coliform Bacteria	X				
Fecal Streptococci Bacteria	X[3]				
pH	X				
Magnesium		X			
Calcium		X			
Total Phosphorus		X			
Ammonia Nitrogen		X			
Nitrate Nitrogen		X			
Organic Nitrogen		X			
Total Organic Carbon		X			
SELECTED STATIONS					
20-day Biochemical Oxygen Demand (B.O.D.)				X[4]	
Sodium		X			
Potassium		X			
Fluoride		X			
Boron		X			
Arsenic			X		
Iron			X		
Barium			X		
Manganese			X		
Cadmium			X		
Chromium			X		
Copper			X		
Lead			X		
Nickel			X		
Zinc			X		
Phenol				X	
Cyanide				X	
Total Organic Chlorine					X
Chloroform Extract					X
Uranium (U^{235} & U^{238})		X			
Radium-226		X			
Thorium-232		X			
Total Alpha Thorium		X			
Strontium-90		X			

NOTES:
(1) Dissolved oxygen was not performed on waste effluents but only on stream samples.
(2) Analyses were performed 3 times per week during the October-November, 1968 Survey; daily during the winter survey.
(3) Performed during the winter survey only.
(4) Performed twice during autumn survey; once during winter survey.

Bottom animal sampling was restricted to pile dikes and adjacent backwater areas because of river channelization and a shifting sand bottom. Pile dikes were examined to determine the representative kinds of benthic animals inhabiting a reach of river. Backwater areas were sampled for bottom organisms with either a Petersen or Ekman dredge. Dredgings were washed and strained through a U. S. Standard No. 30 sieve, and organisms remaining in the sieve were preserved for laboratory identification.

Suspended algal (phytoplankton) samples of one liter were collected at predetermined sampling stations and were preserved with five percent formalin for later identification.

MISSOURI RIVER AND TRIBUTARY FLOWS AND HYDROLOGY

Water released from Gavins Point Dam is the major controlling factor affecting Missouri River flows during dry weather periods. During periods of heavy rainfall the hydrology of tributary streams can greatly affect flows in the main stem of the Missouri River. Ice jams in the river during cold, winter weather can also interfere with normal stages and flow rates.

AUTUMN SURVEY

The Gavins Point Dam to St. Joseph, Missouri reach was sampled from October 7 to 18, 1968. For the period October 7 to 16, 1968, which included the first 8 days of sampling, river flows reflected normal weather conditions. An average of 31,300 cubic feet per second (cfs) was released from Gavins Point Dam (Table No. 2 and Appendix E.) Tributary inflows increased the flow to an average of 36,600 cfs at St. Joseph, Missouri, 360 miles downstream. Rainfall for this period was recorded at 0.46 inches at Omaha, Nebraska (Table No. 3).

Beginning late in the day on October 15, 1968, and continuing for the next two days, heavy rainfall occurred in the upstream reaches of the basin (Table No. 3). The average water released from Gavins Point Dam was reduced to 28,500 cfs for the period October 17 to 18, 1968. However, flows increased to 45,900 cfs (139 %) at Omaha; and to 70,400 cfs (192 %) at St. Joseph (Table No. 2). The ratio of rain-affected flows to dry weather flows generally increased in the downstream direction.

Tributary streams in this reach of the Missouri River exhibited even greater percentage flow increases between the normal weather period and the rain-affected period (Table No. 2). The greatest was the Soldier River which increased from 30 cfs to 1,050 cfs (3,500%). The October 7 to 18 survey period, therefore, reflects two distinctly different river conditions. Samples from the October 7 to 16 period reflect river conditions during "normal" autumn weather; samples from the October 17 to 18, 1968 period reflect river conditions warped by extremely heavy rains.

TABLE NO. 2

Summary of Average Daily Discharges[1]

MISSOURI RIVER
Gavins Pt. Dam to St. Joseph, Missouri
October 7-18, 1968 and January 20-31, 1969 Surveys

STATION Name	River Mileage[2]	1968 DISCHARGES cu.ft./sec. Oct. 7-16 Normal Fall	1968 DISCHARGES cu.ft./sec. Oct. 17-18 Extremely Wet	Flow Ratio Wet/Normal	1969 DISCHARGES cu.ft./sec. Jan. 20-31 Non-Navigation	Flow Ratio 1969/1968 Normal
MISSOURI RIVER:						
Gavins Pt. Dam[3], S. Dak.	811.0	31,300	28,500	0.91	16,900	0.54
Sioux City, Iowa	732.3	32,400	34,000	1.05	16,800	0.52
Omaha, Nebraska	615.9	33,100	45,900	1.39	15,000	0.45
Nebraska City, Nebraska	562.6	35,600	57,300	1.61	18,300	0.51
Rulo, Nebraska	498.0	36,300	[illegible],600	1.94	19,200	0.53
St. Joseph, Missouri	448.2	36,600	70,400	1.92	20,800	0.57
TRIBUTARIES:						
Big Sioux River at Akron, Iowa	734.0	170	700	4.15	113	0.66
Soldier River at Pisgah, Iowa	664.0	30	1,050[4]	35.00	35	1.12
Boyer River at Logan, Iowa	635.1	310	1,720	5.55	112	0.36
Platte River near South Bend, Nebr.	594.8	3,450	17,100	4.96	3,350[3]	0.97
WASTE SOURCES:[5]						
Sioux City, Iowa - STP	729.0	25.1 (16.2 mgd)		-	22.6 (14.6 mgd)	-
Council Bluffs, Iowa - STP	614.0	7.7 (5.0 mgd)[6]		-	8.0 (5.2 mgd)	-
Omaha, Nebraska - Missouri R. STP	611.5	0[7]		-	24.8 (16 mgd)	-
Monroe St. Sewer Omaha, Nebraska	611.5	53.1(34.3 mgd)	87.0 (56.2 mgd)[4]	1.64	-	-

TABLE NO. 2
(contd)

Summary of Average Daily Discharges[1/]
(contd)
MISSOURI RIVER
St. Joseph to Hermann, Missouri
October 27-November 8, and January 20-February 2 Surveys

STATION Name	River Mileage[2/]	1968 DISCHARGES cu.ft./sec. Oct. 28-Nov. 8 Normal Fall	1969 DISCHARGES cu.ft./sec. Jan. 20-Feb. 2 Non-Navigation	Flow Ratio 1969/1968 Normal
MISSOURI RIVER:				
St. Joseph, Missouri	448.2	38,800	20,600	0.53
Kansas City, Missouri	366.1	46,300	28,100	0.61
Waverly, Missouri	293.4	45,500	29,300	0.64
Boonville, Missouri	196.6	48,500	46,700[8/]	0.96
Hermann, Missouri	97.9	55,600	92,700[8/]	1.67
TRIBUTARIES:				
Kansas River at Bonner Springs, Kansas	367.4	6,500	14,000	2.15
Grand River near Sumner, Missouri	250.0	167	5,500[8/]	33.10
Chariton River near Price Hill, Missouri	238.8	54	1,770[8/]	32.80
Osage River near St. Thomas, Missouri	130.0	5,380	21,000[8/]	3.90
Gasconade River near Jerome, Missouri 8/	104.4	2,170	9,000[8/]	4.15
WASTE SOURCES:[5/]				
Kansas City, Kansas STP	367.20	12.1(7.81 mgd)	-	-
Kansas City, Missouri WEST SIDE STP	367.19	-	26.8 (17.3 mgd)	-
BLUE RIVER STP	356.9	65.9(42.6 mgd)	91.3 (59 mgd)[9/]	1.39

1/ Average flows based on provisional U. S. Geological Survey data except for waste sources, Gavins Point Dam releases, and Platte River in January, 1969.
2/ River Mileage refers to location of Missouri River USGS gage or to point where tributary or waste source enters Missouri River.
3/ Average flows based on U. S. Army Corps. of Engineers data.
4/ Average includes daily flow on 10/16/68.
5/ Waste source flows are averages for sample days only and may be precipitation-affected.
6/ Flow estimated from information provided by plant personnel.
7/ No flow due to shutdown for system repairs. All sewage was by-passed raw from many outfalls along the Omaha waterfront.
8/ Discharges are for period from January 20-31, 1969.
9/ Average includes a daily raw sewage bypass of 43 mgd.

TABLE NO. 3

Weather Summary
For the Survey Periods
MISSOURI RIVER

LOCATION	Inclusive Periods Normal	Inclusive Periods Wet	Rainfall Inches Normal	Rainfall Inches Wet	Air Temp. °F Avg. Max.	Air Temp. °F Avg. Min.
	Oct.	Oct.				
Sioux City, Ia.	7-14	15-18	0.48	4.12	66.2	48.8
Omaha, Nebraska	7-15	16-18	0.46	3.61	69.8	51.7
Auburn, Nebraska	7-15	16-18	0.08	3.90	70.8	52.2
St. Joseph, Mo.	7-15	16-18	1.29	1.32	74.7	54.5
St. Joseph, Mo.	Oct. 28-Nov. 8		0.69		60.3	36.2
Kansas City, Mo.	"		0.57		58.3	39.8
Jefferson City, Mo.	"		1.67		61.7	36.3
Hermann, Mo.	"		1.73		-	-
Sioux City, Ia.	Jan. 20-31		0.61		18.1	2.6
Omaha, Nebraska	"		0.46		22.6	6.0
Auburn, Nebraska	"		0.50		26.5	10.8
St. Joseph, Mo.	Jan. 23-Feb. 2		0.55		32.7	15.3
Kansas City, Mo.	"		0.53		33.2	17.6
Jefferson City, Mo.	Jan. 20-31		3.69		37.3	21.2
Hermann, Mo.	"		2.94		-	-

The St. Joseph, Missouri to Hermann, Missouri reach was sampled during the period October 28 to November 8, 1968. River flow rates had subsided from the peak of the previous period. Flows averaged 38,800 cfs at St. Joseph and 55,600 cfs 350 miles downstream at Hermann. Approximately 84 percent of the flow increase in this reach during the survey period was contributed by three tributaries: the Kansas River (6,500 cfs), Osage River (5,380 cfs) and Gasconade River (2,170 cfs).

Precipitation during this period was recorded as 0.57 inches at Kansas City, Missouri (Table No. 3).

WINTER SURVEY

Flows during the January to February, 1969 survey were affected by ice jams in the river upstream from Kansas City and by rain downstream. For much of the survey period, river stages were higher than normal summer navigational levels in the reaches upstream from St. Joseph. Flow rates were affected by the damming effect of the ice jams downstream. At Omaha, flows averaged about 1,800 cfs less than that released from Gavins Point Dam (Table No. 2). The flow at St. Joseph averaged 20,800 cfs. Upstream and immediately downstream from the ice jams flows were reduced during the second week of the survey. The flow at Kansas City was composed of 64.5% Missouri River water the first week but only 30.0% the second week (Table No. 2). Approximately two-thirds of the flow at Kansas City was composed of Kansas River water during the second week.

The flow increased slightly to 29,300 cfs at Waverly, Missouri; to 46,700 cfs at Boonville, Missouri 97 miles farther downstream; and to 92,700 cfs at Hermann, another 100 miles downstream. These flows ranged from 53% of the October 28 to November 8 flows at Kansas City to 167% at Hermann. Tributary flows increased from 215% to 3,310% of the earlier period.

Precipitation during the winter survey was 0.46 inches at Omaha, 0.53 inches at Kansas City and 3.69 inches at Jefferson City. These data indicate the large amount of precipitation downstream from Kansas City.

Most of the precipitation was in the form of snow upstream from St. Joseph. Precipitation downstream occurred as a combination of snow, sleet, and rain.

WATER QUALITY

BACTERIAL POLLUTION

Total and fecal coliform bacteria enumeration analyses were performed during the two autumn survey periods of the Missouri River. Fecal streptococci bacteria were enumerated in addition to the coliform analyses during the winter survey.

The report of the National Technical Advisory Committee to the Secretary of the Interior (NTAC Report)[**] has numeric bacterial criteria for natural waters used for public water supplies and for recreation. The permissible criterion for a source of public water supply is a "...monthly arithmetic average based upon an adequate number of samples..."[**] of 10,000/100 ml total coliform bacteria and 2,000/100 ml fecal coliform bacteria. The criteria for recreation is divided into three classifications. These classifications and numerical limits are: General recreational use of surface waters,"... average not to exceed 2,000 fecal coliforms per 100 ml..."[**]; waters designated for recreation uses other than primary contact recreation," ... should not exceed a log mean[***] of 1,000/100 ml..."[**] fecal coliform bacteria; and primary contact recreation,"...shall not exceed a log mean of 200/100 ml..."[**]fecal coliform bacteria.

Geometric mean[***] bacterial densities and the 80% confidence limits for the autumn surveys versus time-of-water travel and river mile are presented graphically in Figures 2 and 3. The time-of-water travel analysis for the autumn survey is included as Appendix D. The winter survey bacterial densities versus river mile are presented in Figure 4. Ice jams affected river stage-discharge relationships making accurate time-of-water travel calculations difficult upstream from Kansas City, Missouri. An unstable hydrograph downstream from Kansas City affected time-of-water travel such that only an average of a wide interval could be calculated. Thus, time-of-water travel is not meaningful for the winter survey period.

[**] Anon. 1968. Water Quality Criteria. Report of the National Technical Advisory Committee for the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C.

[***] Log mean and geometric mean are equivalent terms, i.e., the antilogarithm of the average of the logarithms of a set of numbers.

Gavins Point Dam - St. Joseph, Missouri

Water released from Gavins Point Dam contained low densities of coliform bacteria during the upstream autumn sampling period. Total and fecal coliform bacteria had been increased from mean* densities of 250 MPN/100 ml and less than 120 MPN/100 ml, respectively to 1,380 MPN/100 ml and 220 MPN/100 ml respectively, at Station M-52 (R.M. 736.0) upstream from Sioux City.

Waste from the Sioux City area increased total and fecal coliform densities to 62,800 MPN/100 ml and 14,300 MPN/100 ml respectively, at Station M-48, located 4.5 hours time-of-water travel downstream from the Sioux City sewage treatment plant (STP) discharge. A major cause of this increase in bacterial densities was the unchlorinated discharge from the Sioux City primary sewage treatment plant (Table 7). Another major waste source is the Iowa Beef Packers plant at Dakota City, Nebraska. This plant, providing minimal waste treatment, was not sampled during these surveys.

Coliform densities decreased downstream from the Sioux City area. The trend lines in Figure 2 illustrate the indicated decrease. At the Omaha Metropolitan Utility District (M.U.D.) water intake (Station 42, R.M. 626.2), 34 hours time-of-water travel downstream from the Sioux City STP discharge, the mean total and fecal coliform bacteria densities were 52,300 MPN/100 ml and 8,320 MPN/100 ml, respectively. These densities were 5.2 times and 4.1 times respectively, the NTAC criteria for sources of supply for public drinking water.

Wastes from the Omaha, Nebraska-Council Bluffs, Iowa area increased the mean bacterial densities to 256,400 MPN/100 ml and 61,200 MPN/100 ml total and fecal coliform bacteria respectively, at Station M-39 (R.M. 610.5),** 0.2 hours time-of-water travel downstream from the Monroe Street sewer outfall. The major causes of this increase were the wastes from Omaha including the 34.3 million gallons per day (MGD) of untreated packing house wastes plus an estimated 16 MGD of raw sewage bypassed because of a pumping station outage; and 5 MGD of unchlorinated effluent from the Council Bluffs, Iowa primary sewage treatment plant.

Downstream from Omaha-Council Bluffs coliform bacteria densities decreased. At the St. Joseph, Missouri Water Company intake, mean total and fecal coliform densities had decreased to 57,700 MPN/100 ml and 6,500 MPN/100 ml, respectively. These levels are respectively 5.8 times and 3.2 times the drinking water criteria in the NTAC report.

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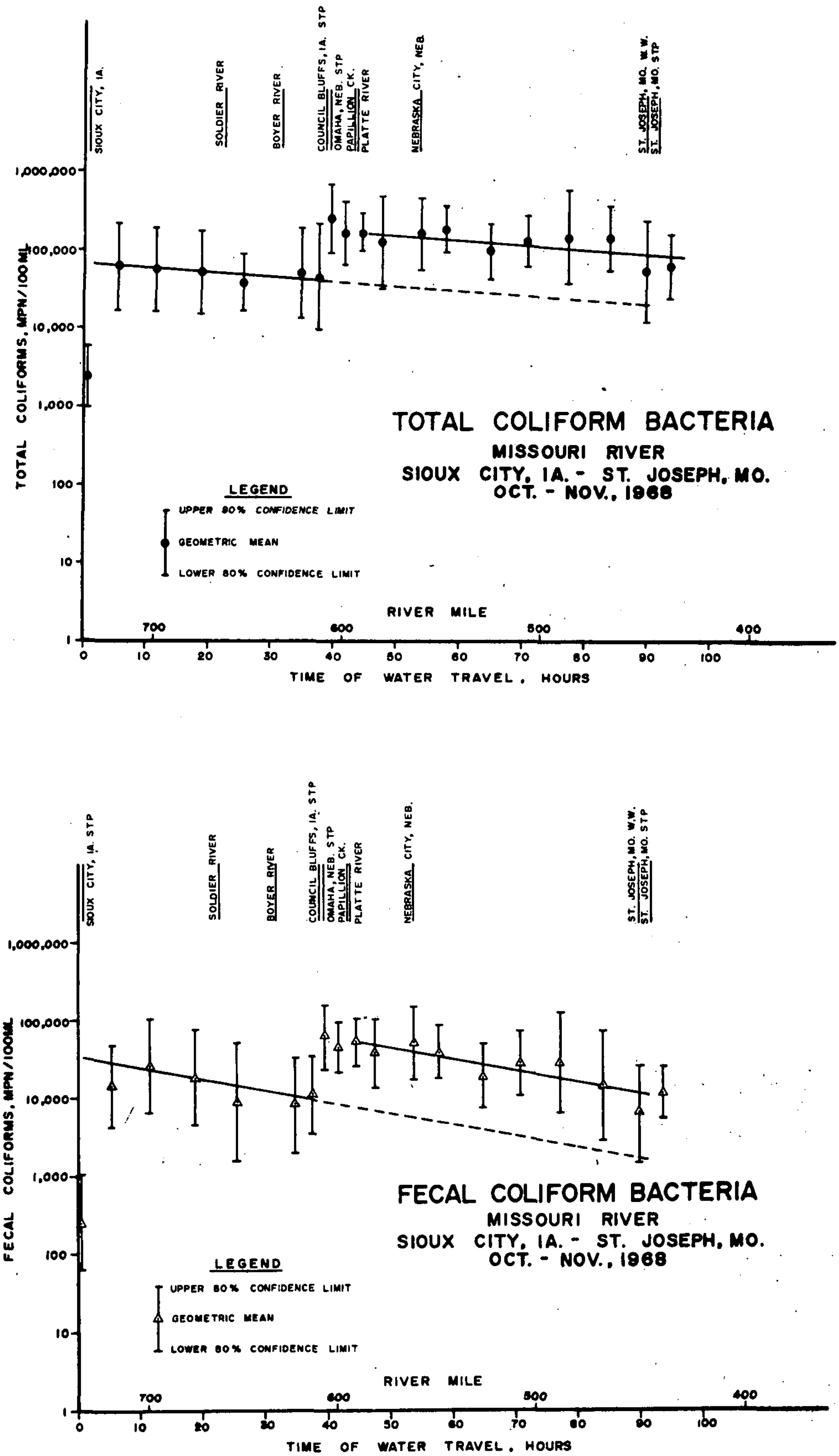
*In discussion of bacteria densities, "mean" refers to geometric mean throughout this report.

**Laboratory composited sample made from quarter point samples (3 samples per station cross-section).

FIGURE 2


SIOUX CITY, IA.
SOLDIER RIVER
BOYER RIVER
COUNCIL BLUFFS, IA. STP
OMAHA, NEB. STP
PAPILLION CK.
PLATTE RIVER
NEBRASKA CITY, NEB.
ST. JOSEPH, MO. W.W.
ST. JOSEPH, MO. STP
TOTAL COLIFORMS, MPN/100ML
TOTAL COLIFORM BACTERIA
MISSOURI RIVER
SIOUX CITY, IA. - ST. JOSEPH, MO.
OCT. - NOV., 1968
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT
RIVER MILE
TIME OF WATER TRAVEL, HOURS
SIOUX CITY, IA. STP
SOLDIER RIVER
BOYER RIVER
COUNCIL BLUFFS, IA. STP
OMAHA, NEB. STP
PAPILLION CK.
PLATTE RIVER
NEBRASKA CITY, NEB.
ST. JOSEPH, MO. W.W.
ST. JOSEPH, MO. STP
FECAL COLIFORMS, MPN/100ML
FECAL COLIFORM BACTERIA
MISSOURI RIVER
SIOUX CITY, IA. - ST. JOSEPH, MO.
OCT. - NOV., 1968
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT
RIVER MILE
TIME OF WATER TRAVEL, HOURS

Graphical extrapolation of the trend lines in Figure 2 indicates that of the bacterial contamination at the St. Joseph Water Company intake about 24% of the total coliform bacteria and 15% of the fecal coliform bacteria were from sources upstream from Omaha-Council Bluffs (primarily from the Sioux City area). The remainder of the contamination was introduced from the Omaha-Council Bluffs area.

During the 2-day rain-affected period, coliform bacteria increased to very high densities throughout the entire reach. Nineteen of the 21 sampling stations had both total and fecal coliform bacterial densities that exceeded 100,000 MPN/100 ml. The highest densities were at Station M-34 (R.M. 559.7) downstream from Nebraska City, Nebraska where densities were 1,440,000 MPN/100 ml and 1,120,000 MPN/100 ml total and fecal coliform bacteria, respectively.

Comparison of the column in Table B-4 entitled "fecal coliform bacteria as a percent of total coliform bacteria" for the 8-day normal period and the 2-day wet period showed a much higher ratio at most stations during the wet period. This large increase in percent fecal coliform bacteria indicates that the coliform bacteria from land runoff were largely from fecal sources. Such areas as feedlots and pastures are heavily contaminated and yield large numbers of fecal coliform bacteria.

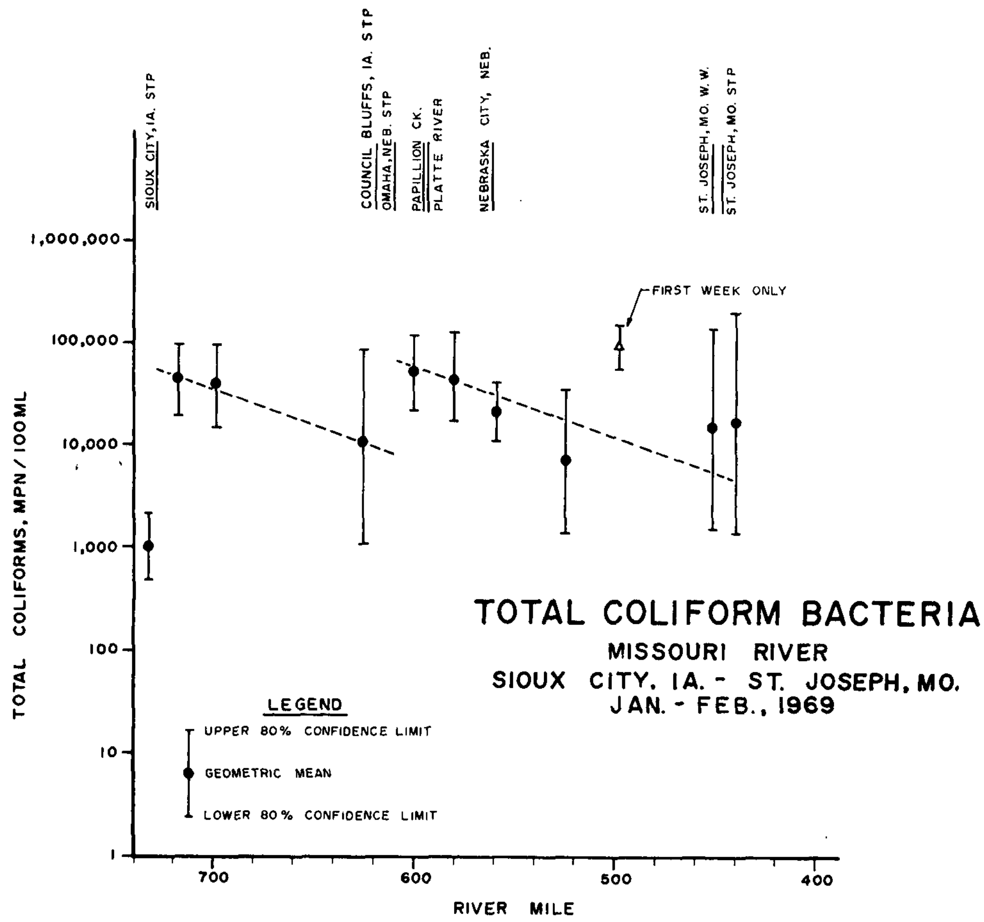
Coliform bacterial densities during the winter survey were substantially less than during the 8-day normal weather period in October 1968 even though stream flow was reduced by about 50% (Figure 3, Appendix Tables B-4 and B-6). The decrease in the winter densities within the Sioux City-Omaha reach was partially caused by the reduced densities in the waste flow from the Sioux City STP discharge (Table No. 7). Reductions in bacterial densities also occurred in portions of the wastes discharged in Omaha. Municipal wastes bypassed during the autumn study received treatment during the winter study.

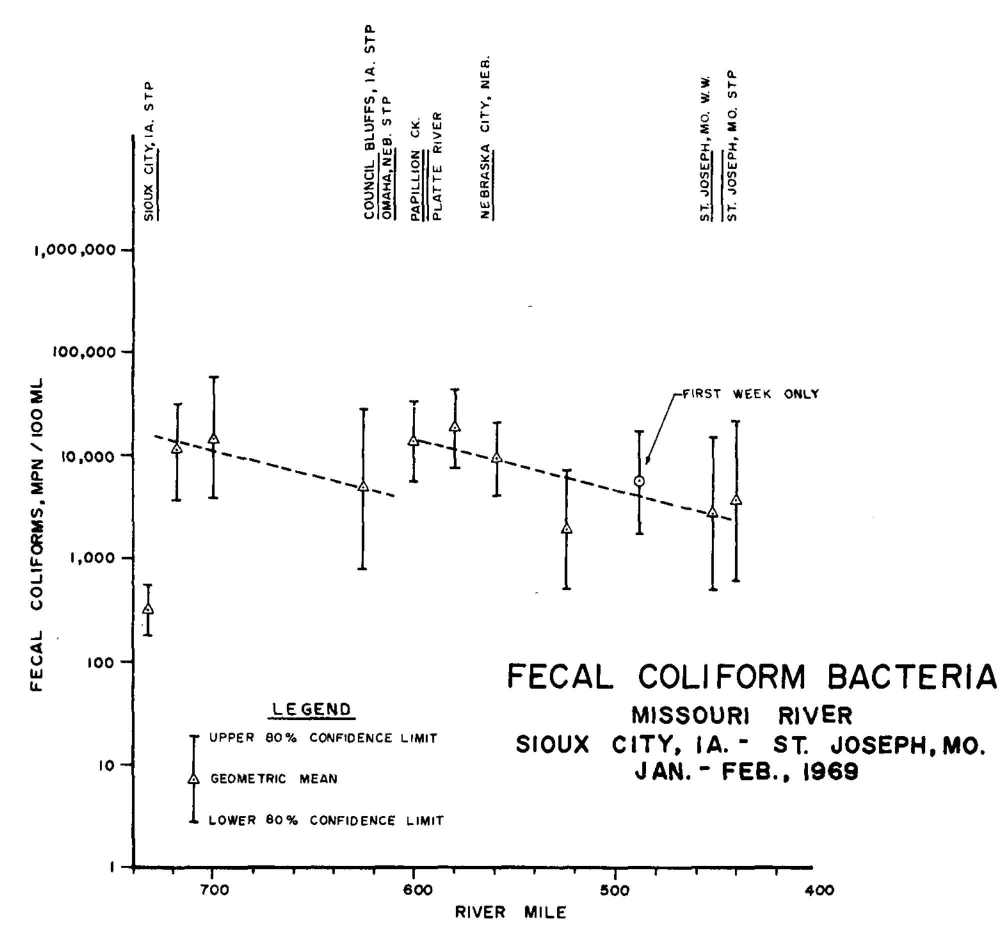
Downstream from the Sioux City area at Station M-48A (R.M. 718.3) bacterial densities increased to 44,300 MPN/100 ml and 11,200 MPN/100 ml total and fecal coliform bacteria, respectively, and 16,500 MF/100 ml fecal streptococci bacteria. Both fecal coliform and fecal streptococci bacteria had higher densities downstream at Station M-47 (R.M. 699.5).

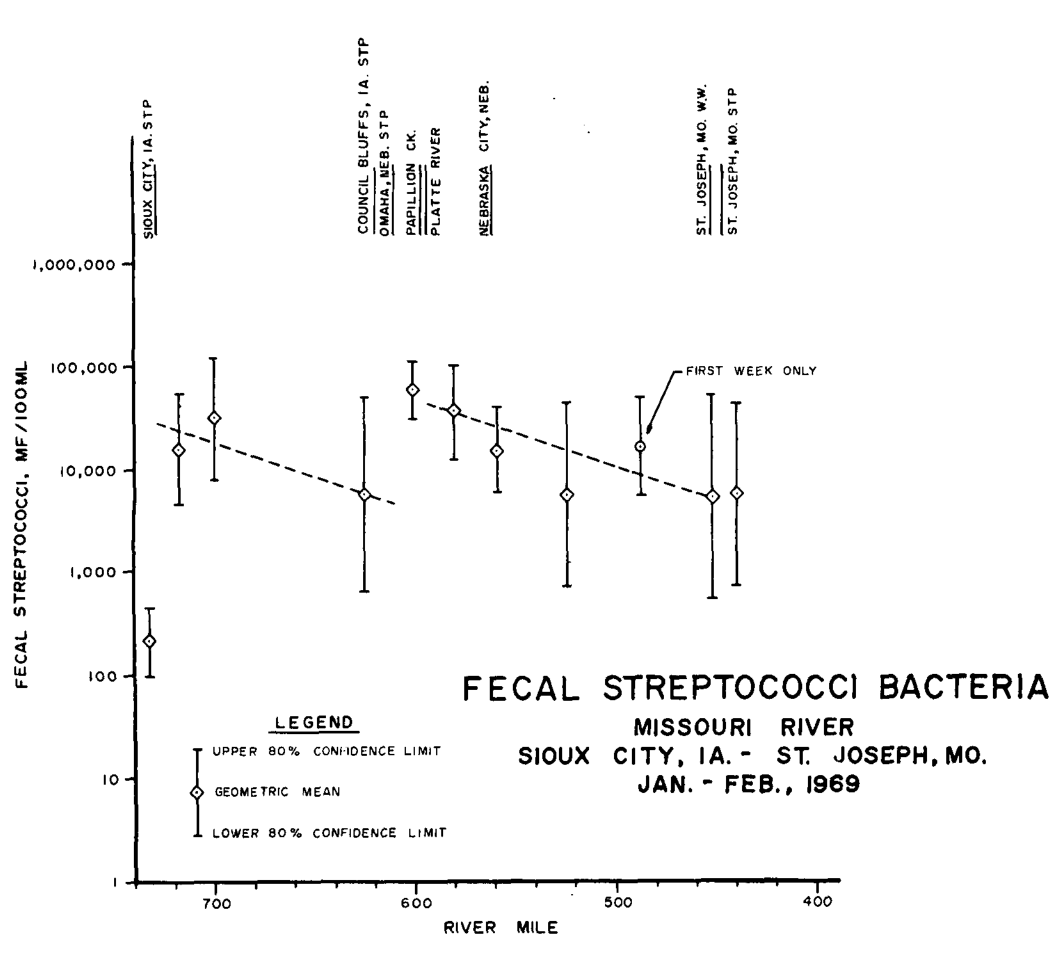
At the Omaha M.U.D. Water Intake (Station M-42, R.M. 626.2) bacterial densities were reduced from upstream levels. The total coliform densities were approximately equal to the NTAC report criteria for sources of public drinking water supplies; however, fecal coliform densities were 2.9 times the criteria.

Bacterial densities increased following the introduction of wastes from Omaha and Council Bluffs. Bacterial densities at

FIGURE 3


SIOUX CITY, IA. STP
COUNCIL BLUFFS, IA. STP
OMAHA, NEB. STP
PAPILLION CK.
PLATTE RIVER
NEBRASKA CITY, NEB.
ST. JOSEPH, MO. W.W.
ST. JOSEPH, MO. STP
FIRST WEEK ONLY
TOTAL COLIFORMS, MPN / 100 ML
1,000,000
100,000
10,000
1,000
100
10
1
700
600
500
400
RIVER MILE
TOTAL COLIFORM BACTERIA
MISSOURI RIVER
SIOUX CITY, IA. - ST. JOSEPH, MO.
JAN. - FEB., 1969
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT


SIOUX CITY, IA. STP
COUNCIL BLUFFS, IA. STP
OMAHA, NEB. STP
PAPILLION CK.
PLATTE RIVER
NEBRASKA CITY, NEB.
ST. JOSEPH, MO. W.W.
ST. JOSEPH, MO. STP
FIRST WEEK ONLY
FECAL COLIFORMS, MPN / 100 ML
1,000,000
100,000
10,000
1,000
100
10
1
700
600
500
400
RIVER MILE
FECAL COLIFORM BACTERIA
MISSOURI RIVER
SIOUX CITY, IA. - ST. JOSEPH, MO.
JAN. - FEB., 1969
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT


SIOUX CITY, IA. STP
COUNCIL BLUFFS, IA. STP
OMAHA, NEB. STP
PAPILLION CK.
PLATTE RIVER
NEBRASKA CITY, NEB.
ST. JOSEPH, MO. W.W.
ST. JOSEPH, MO. STP
FIRST WEEK ONLY
FECAL STREPTOCOCCI, MF / 100 ML
1,000,000
100,000
10,000
1,000
100
10
1
700
600
500
400
RIVER MILE
FECAL STREPTOCOCCI BACTERIA
MISSOURI RIVER
SIOUX CITY, IA. - ST. JOSEPH, MO.
JAN. - FEB., 1969
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT

Station M-38 (R.M. 601.3) increased to 53,800 MPN/100 ml and 14,200 MPN/100 ml total and fecal coliform bacteria respectively, and 61,100 MF/100 ml fecal streptococci bacteria. The mean fecal coliform density was larger downstream at Station M-35 (R.M. 580.9).

Bacterial densities decreased farther downstream. However, the effect of the increased time-of-water travel caused by the ice jams downstream exaggerated the apparent rate of decrease.

St. Joseph, Missouri-Hermann, Missouri

Station M-27 (R.M. 440.3), located about 2 hours time-of-travel downstream from the St. Joseph sewage treatment plant (STP) outfall, was sampled during both the upstream and downstream autumn surveys. Coliform densities were similar during each survey with means of 67,000 MPN/100 ml and 8,100 MPN/100 ml total and fecal coliforms respectively, during the latter St. Joseph-Hermann survey (Figure 4) and 65,300 MPN/100 ml and 11,800 MPN/100 ml respectively, during the upstream autumn survey.

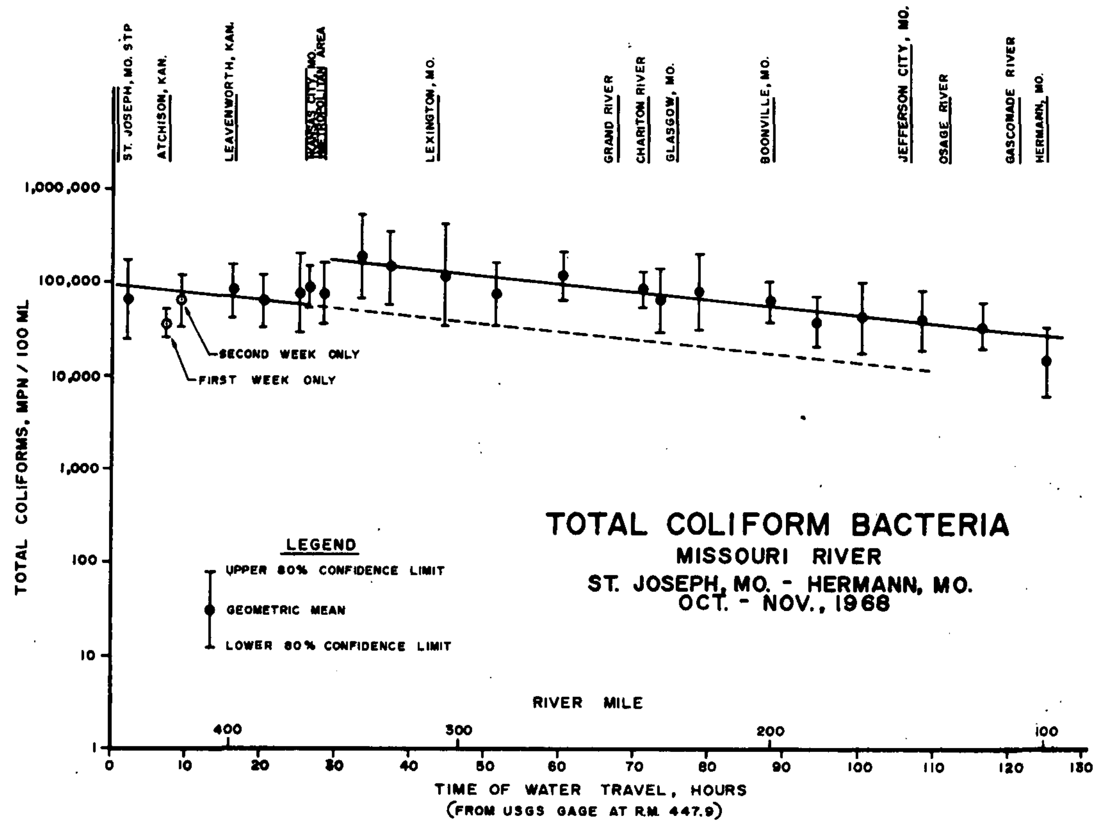
In the reach between St. Joseph and Kansas City, wastes from the Kansas communities of Atchison and Leavenworth enter the Missouri River. The bacteriological effects of wastes from these communities are not readily discernible in Figure 4. This is the result of high residual densities from upstream sources, a large amount of variation in the data as indicated by the 80 % confidence limits, and the dilution afforded by river flows in excess of 38,800 cfs.

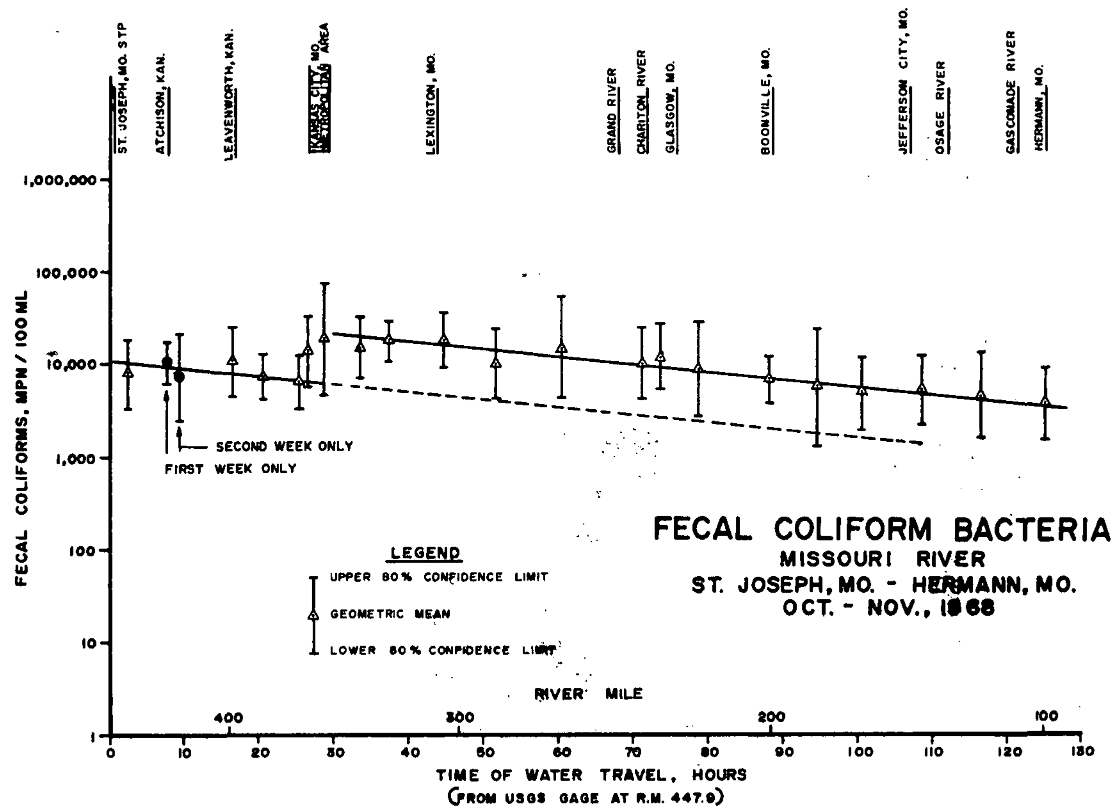
Densities upstream from the Kansas River at Station M-23 (R.M. 370.5) located at the Kansas City, Missouri Water Works Intake, were 77,000 MPN/100 ml and 6,500 MPN/100 ml total and fecal coliform bacteria, respectively. These levels are 7.7 times and 3.2 times respectively, criteria recommended by the NTAC report for sources of public water supplies.

Bacterial densities in the Missouri River were increased by the inflow of: the Kansas River; the Kansas City, Kansas sewage treatment plant; the Kansas City, Missouri west side sewage treatment plant; and the Blue River which contained the Kansas City, Missouri, Blue River sewage treatment plant effluent (Appendix Table B-2). Densities were increased to 189,000 MPN/100 ml and 15,000 MPN/100 ml total and fecal coliform bacteria at Station M-18 (R.M. 345.4) 3.9 hours time-of-water travel downstream from the Blue River.

Coliform densities decreased downstream from the Kansas City area but were greater than recommended water use criteria. At Station M-16 (R.M. 313.2) located within 1 hour time-of-travel from the Lexington, Missouri water intake, total and fecal coliform densities were 11.9 times and 9.0 times the NTAC report criteria for a

FIGURE 4


ST. JOSEPH, MO. STP
ATCHISON, KAN.
LEAVENWORTH, KAN.
KANSAS CITY, MO. METROPOLITAN AREA
LEXINGTON, MO.
GRAND RIVER
CHARITON RIVER
GLASGOW, MO.
BOONVILLE, MO.
JEFFERSON CITY, MO.
OSAGE RIVER
GASCONADE RIVER
HERMANN, MO.
TOTAL COLIFORMS, MPN / 100 ML
1,000,000
100,000
10,000
1,000
100
10
1
SECOND WEEK ONLY
FIRST WEEK ONLY
TOTAL COLIFORM BACTERIA
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
OCT. - NOV., 1968
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT
RIVER MILE
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
TIME OF WATER TRAVEL, HOURS
(FROM USGS GAGE AT R.M. 447.9)


ST. JOSEPH, MO. STP
ATCHISON, KAN.
LEAVENWORTH, KAN.
KANSAS CITY, MO. METROPOLITAN AREA
LEXINGTON, MO.
GRAND RIVER
CHARITON RIVER
GLASGOW, MO.
BOONVILLE, MO.
JEFFERSON CITY, MO.
OSAGE RIVER
GASCONADE RIVER
HERMANN, MO.
FECAL COLIFORMS, MPN / 100 ML
1,000,000
100,000
10,000
1,000
100
10
1
SECOND WEEK ONLY
FIRST WEEK ONLY
FECAL COLIFORM BACTERIA
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
OCT. - NOV., 1968
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT
RIVER MILE
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
TIME OF WATER TRAVEL, HOURS
(FROM USGS GAGE AT R.M. 447.9)

source of public water supply. These same criteria were also exceeded at the water supply intakes for the Missouri communities of Glasgow (approximately 7 and 4.4 times the criteria respectively), Boonville (approximately 5.7 and 3.4 times the criteria respectively), and Jefferson City (approximately 4 and 2.4 times the criteria respectively).

Graphical extrapolation of the trend lines in Figures 4A and 4B indicate that about 34% of the total coliform bacteria and 30% of the fecal coliform bacteria at Jefferson City were from sources upstream from Kansas City. The remainder of the coliforms were principally from the Kansas City area.

During the winter survey, bacterial densities downstream from the St. Joseph area were affected by flow phenomena. Calculations indicate that only a fraction of the Missouri River water at St. Joseph reached Kansas City during this period (see Flow Section for discussion). The character of the river water changed downstream from the Kansas River as it furnished an average of one-half the flow of the Missouri River during the study period. Bacterial densities in the Kansas River were not determined during the winter survey.

Densities at Station M-17 downstream from Kansas City (R.M. 334.5) were 128,000 MPN/100 ml and 23,900 total and fecal coliform bacteria respectively, and 26,600 MF/100 ml fecal streptococci bacteria. Bacterial densities exhibited a decreasing trend in the downstream direction even though rains caused tributaries to flow at several times the November, 1968 rates (Figure 5).

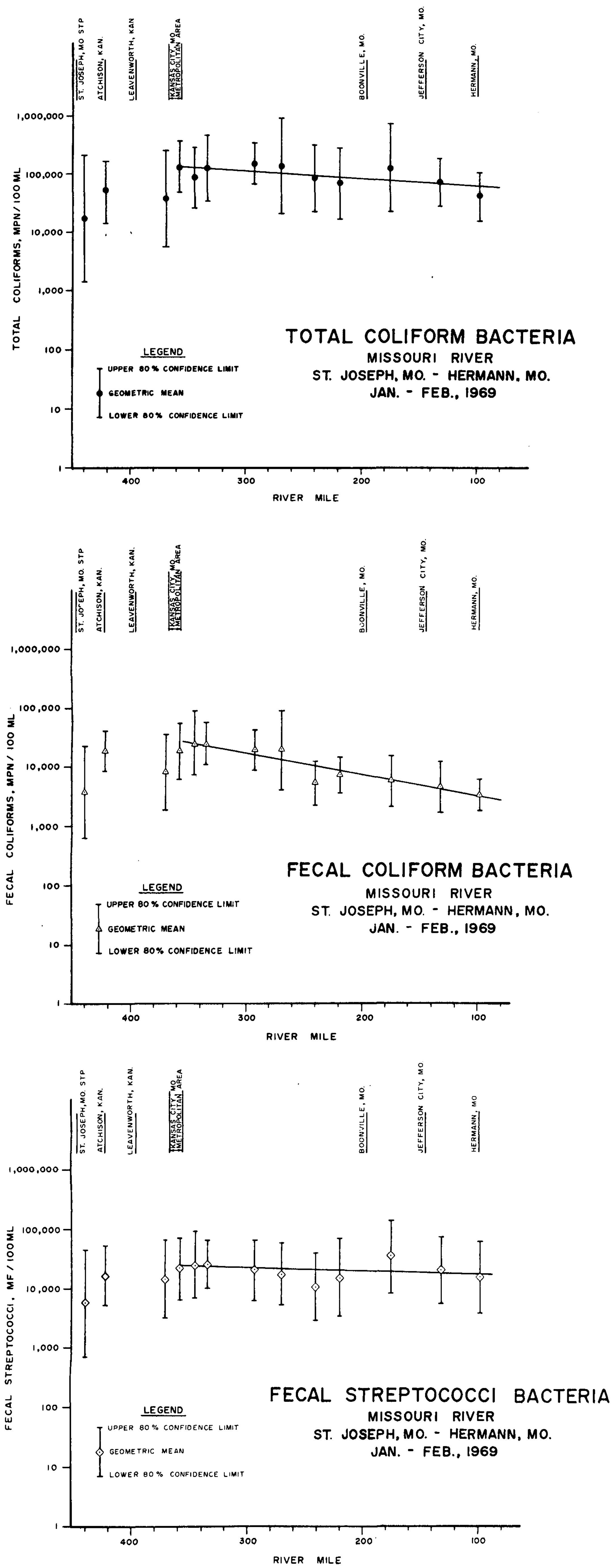
The NTAC report criteria for sources of public drinking water supplies of 10,000/100 ml total coliform bacteria and 2,000/100 ml fecal coliform bacteria was again exceeded at all water supply withdrawal points in this reach.

BIOCHEMICAL OXYGEN DEMAND (BOD)

Wastes containing oxygen demanding organic materials, such as municipal sewage, remove dissolved oxygen from the aquatic environment in the process of the biochemical decomposition and stabilization of these materials. A principal function of waste treatment is the removal of such oxygen-demanding materials. A common measure of the strength of these materials is the 5-day, 20° C. biochemical oxygen demand (BOD_5).

In these surveys, 2-day and 5-day BOD analyses were performed. The use of both analyses permitted estimation of the reaction rates of BOD satisfaction. A detailed analysis of the BOD data is presented in Appendix C.

FIGURE 5


ST. JOSEPH, MO STP
ATCHISON, KAN.
LEAVENWORTH, KAN
KANSAS CITY, MO METROPOLITAN AREA
BOONVILLE, MO.
JEFFERSON CITY, MO.
HERMANN, MO.
TOTAL COLIFORMS, MPN/100 ML
1,000,000
100,000
10,000
1,000
100
10
1
LEGEND
UPPER 80% CONFIDENCE LIMIT
GEOMETRIC MEAN
LOWER 80% CONFIDENCE LIMIT
TOTAL COLIFORM BACTERIA
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
JAN. - FEB., 1969
400
300
200
100
RIVER MILE
FECAL COLIFORMS, MPN/100 ML
FECAL COLIFORM BACTERIA
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
JAN. - FEB., 1969
FECAL STREPTOCOCCI, MF/100ML
FECAL STREPTOCOCCI BACTERIA
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
JAN. - FEB., 1969

Gavins Point Dam-St. Joseph, Missouri

The BOD_5 for the 8-day normal weather period during the upstream autumn survey reflected the waste discharges from the major metropolitan areas (Figure 6). From background concentrations upstream from Sioux City (< 1.0 mg/l) the BOD_5 was increased to 1.6 mg/l at Station M-47 (R.M. 699.5) by wastes from that area. Waste discharges from the Omaha-Council Bluffs area increased the BOD_5 to 5.8 mg/l at Station M-39 (R.M. 610.5). The concentration decreased irregularly downstream to the St. Joseph Water Company Intake.

The average BOD_5 concentrations for the 2-day, rain-affected period increased substantially throughout the entire survey reach. Increases ranged from 1.3 times (0.9 mg/l to 1.2 mg/l) at Station M-52 (R.M. 736.0) to 2.2 times (3.4 mg/l to 7.6 mg/l) at Station M-29 (R.M. 469.0). As was indicated by increases in the bacterial densities, much of this increase was from organic material transported by surface runoff from feedlots and pastures tributary to the river.

The winter survey data indicated concentration increases similar to the normal weather period of the autumn survey for the Sioux City and Omaha metropolitan areas. BOD_5 concentrations were reduced downstream from Omaha-Council Bluffs partially because of the increased time-of-water travel caused by the ice jams and resultant sedimentation of suspended organic material.

St. Joseph, Missouri-Hermann, Missouri

The average BOD_5's remained relatively constant between St. Joseph and Kansas City with averages of approximately 3 mg/l. Wastes from Kansas City increased the BOD_5 to 3.5 mg/l at Station M-21 (R.M. 365.6). The concentration decreased downstream from Kansas City and reached the lowest average of 1.7 mg/l at Station M-9 (R.M. 221.0). Downstream from this point the BOD_5 increased irregularly.

The average BOD_5 concentration trend between St. Joseph and Kansas City was affected by the hydraulic interferences of the ice jams during the winter survey. Downstream from the Kansas City area waste discharges increased the BOD_5 to 5.4 mg/l at Station M-17 (R.M. 334.5). The concentration was slightly reduced to 5.0 mg/l at Station M-12 (R.M. 241.2).

BOD_5 concentrations farther downstream were affected by the large amounts of rain and irregular main stem and tributary hydrographs.

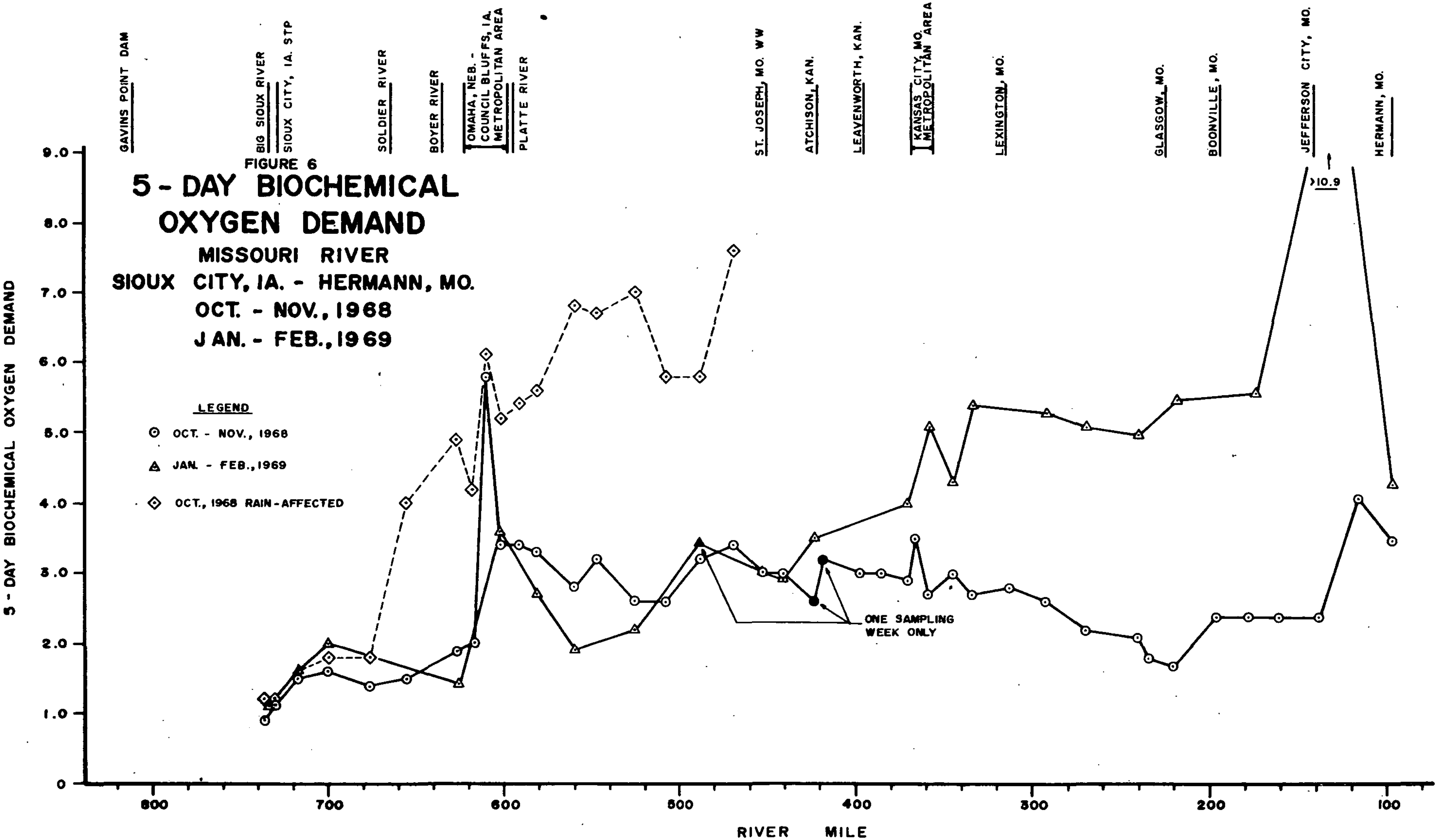


FIGURE 6
5 - DAY BIOCHEMICAL OXYGEN DEMAND
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969

DISSOLVED OXYGEN (D.O.)

The D.O. of a flowing stream or a body of water is an important, necessary constituent to maintain desirable fish and other aquatic life, and to maintain pleasing aesthetic conditions by avoiding obnoxious odors associated with septic conditions.

D.O. Criteria

For sources of public water supply, the NTAC criterion for D.O. is a monthly mean equal to or greater than 4 mg/l with individual samples equal to or greater than 3 mg/l. The NTAC report states, "Criteria for dissolved oxygen are included, not because the substance is of appreciable significance in water treatment or in finished water, but because of its use as an indicator of pollution by organic wastes." NTAC criteria for fish and other aquatic life applicable to the Missouri River is stated, "For a diversified warm-water biota, including game fish, the D.O. concentration should be above 5 mg/l,...however, they may range between 5 and 4 mg/l for short periods during any 24-hour period,..."

Gavins Point Dam - St. Joseph, Missouri

D.O. concentrations averaged 8.3 mg/l or greater in the main stem of the Missouri River for the first 8 sampling days of the October 7-18, 1968 survey (Figure 7 and Appendix Table B-1). The highest average D.O. concentration was 9.5 mg/l and occurred at Station M-52 (R.M. 736) upstream from Sioux City, Iowa.

The rain-affected, 2-day average D.O. concentrations generally decreased from Sioux City to St. Joseph. D.O. concentrations varied inversely with river flows; as the ratio of wet weather flows to dry weather flows increased, D.O. concentrations generally decreased. Two-day average D.O. concentrations had a low of 5.2 mg/l at Station M-29 (R.M. 469.0) upstream from St. Joseph.

During the January-February, 1969 survey, D.O. concentrations showed the effects of an ice cover which was formed by blockage of floating ice by an ice jam upstream from St. Joseph. As additional floating ice was trapped, the ice cover was backed-up past Omaha during the second week of the survey. Upstream from the ice cover and Omaha-Council Bluffs, D.O. concentrations exceeded 12.5 mg/l.

With the introduction of wastes from the Omaha-Council Bluffs area and with the ice cover reducing reaeration, the D.O. concentrations decreased steadily to the lowest average of 9.1 mg/l at Station M-30 (R.M. 488.3) near White Cloud, Kansas (Figure 7). Downstream from St. Joseph and the ice cover, the D.O. concentration increased.

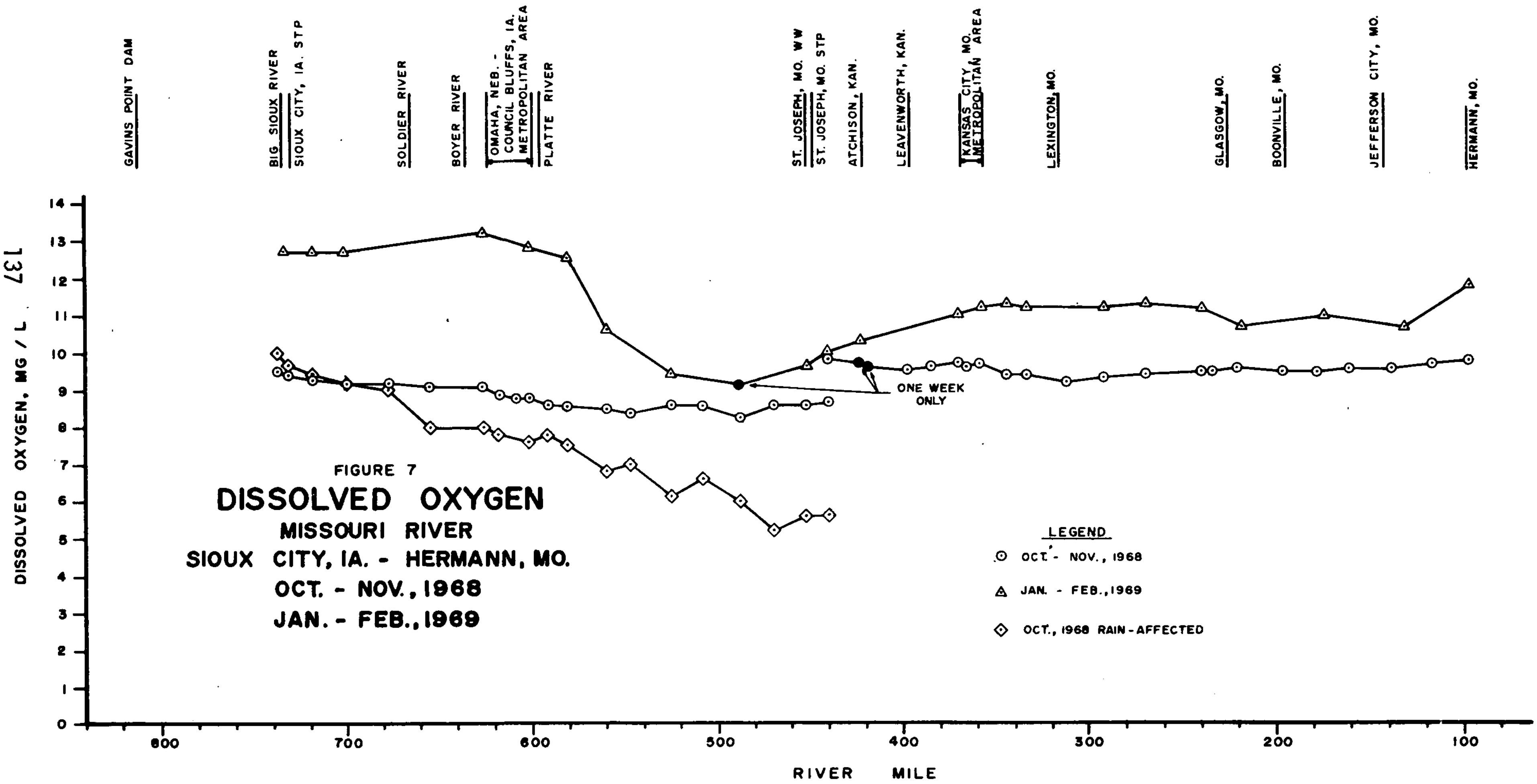


FIGURE 7
DISSOLVED OXYGEN
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969

St. Joseph, Missouri - Hermann, Missouri

Average D.O. concentrations at Station M-27 (R.M. 440.3) were 1.1 mg/l greater during the second autumn survey than during the first autumn survey. This difference is partially accounted for by the lower average water temperature (16° C. vs 9° C.) in the latter survey period. This decrease in temperature increased oxygen saturation from 10.0 mg/l to 11.6 mg/l, a difference of 1.6 mg/l.

D.O. concentrations decreased slightly downstream from St. Joseph but exceeded 9.5 mg/l at all stations upstream from the Kansas City, Missouri water works intake. Downstream from the waste discharges in the Kansas City area, D.O. concentrations decreased to the lowest average of 9.2 mg/l at Station M-16 (R.M. 313.2) approximately 15 hours time-of-water travel downstream. D.O. concentrations recovered further downstream and averaged 9.8 mg/l at Station M-1 (R.M. 98.0) at Hermann.

During the winter survey, D.O. concentrations downstream from St. Joseph increased from 9.6 mg/l at Station M-28 (R.M. 452.3) to 11.2 mg/l at Station M-20A (R.M. 358.3). The warped flow conditions did not adversely affect D.O. concentrations. Downstream from the waste discharges in the Kansas City area, D.O. concentrations decreased slightly to 10.7 mg/l at Station M-9A (R.M. 219.2). The D.O. concentration exceeded this level at the remaining stations in the reach.

The D.O. criteria recommended in the NTAC report were exceeded at all stations during both survey periods.

TOTAL SUSPENDED SOLIDS

The total suspended solids concentration is a measure of the organic and inorganic particulate matter in water. The organic fraction consists of constituents such as, organic material from sewage, meat-packing waste, and suspended algae. The inorganic fraction consists of clays and silts washed from the land and carried by the river. The total suspended solids concentration is an indirect indicator of water clarity.

Gavins Point Dam - St. Joseph, Missouri

Water released from Gavins Point Dam (R.M. 811.0) averaged 45 mg/l total suspended solids (Figure 8). The concentration increased to 55 mg/l at Station M-52 (R.M. 736.0) upstream from Sioux City and remained relatively uniform at this level for 60 miles farther downstream. The total suspended solids increased irregularly downstream from Station M-46 until the highest average concentration in the reach of 278 mg/l occurred at Station M-32 (R.M. 525.1).

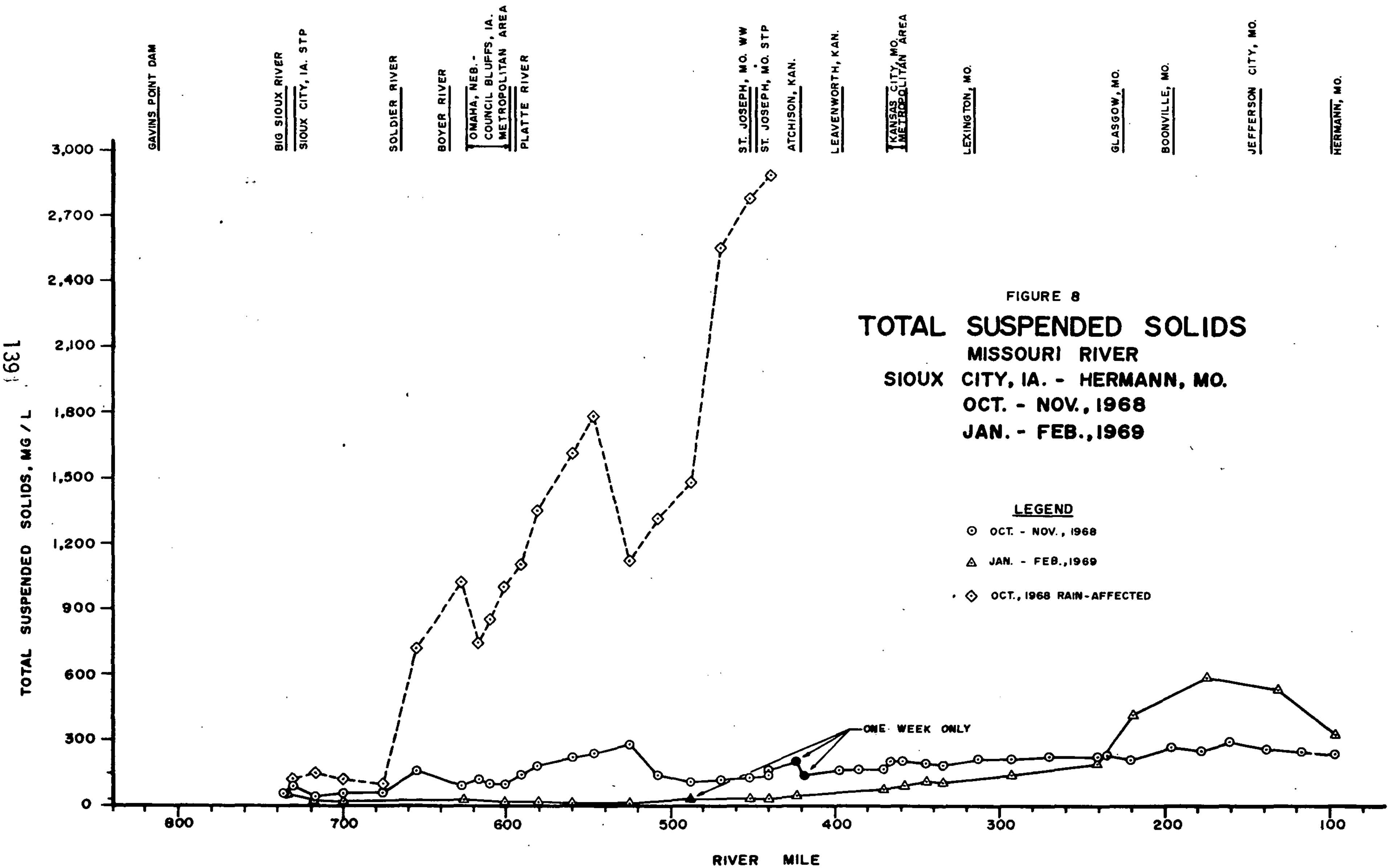


FIGURE 8
TOTAL SUSPENDED SOLIDS
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969

The rain-affected two-day average total suspended solids concentrations were several times greater than the 8-day normal weather concentrations which averaged 715 mg/l at Station M-44 (R.M. 654.6) downstream from the Soldier River. The concentrations followed an irregular, although generally upward trend for the remaining stations in the reach. Beginning at the Omaha Metropolitan Utilities District (M.U.D.) water intake (Station M-42, R.M. 626.2), all of the remaining 13 downstream stations exceeded 700 mg/l total suspended solids, 10 stations exceeded 1,000 mg/l and two stations exceeded 2,000 mg/l. The highest average for the 2-day period was 2,780 mg/l at the St. Joseph Water Company intake (Station M-28, R.M. 452.3).

Upstream from the ice jams, the total suspended solids concentrations during the winter survey were quite low when compared with the autumn results. Water released from Gavins Point Dam (R.M. 811.0) contained only 2 mg/l which increased to 48 mg/l upstream from the major waste discharges in Sioux City. The nine remaining main stem stations in the reach had concentrations between 9 and 28 mg/l.

The clarity of the Missouri River during the winter survey when compared with the autumn survey is attributed to the frozen condition in the drainage basin. Tributary runoff carrying clay and silt particles was small. The damming effect of the ice jams reduced water velocity allowing sedimentation which contributed to water clarity.

St. Joseph, Missouri - Hermann, Missouri

The total suspended solids concentrations in this reach gradually increased in the downstream direction during the autumn survey. The average concentrations increased from 161 mg/l at Station M-27 (R.M. 440.3) downstream from St. Joseph, to the highest average of 297 mg/l at Station M-6 (R.M. 162.0). The concentration decreased slightly at Hermann.

Downstream from the ice jams during the winter survey, the total suspended solids concentrations increased. Concentrations increased from 29 mg/l at Station M-27 (R.M. 440.3) at the St. Joseph water intake to 233 mg/l at Station M-14 (R.M. 270.0). With the heavy rainfall and high runoff in the lower basin, concentrations reached the highest average of 596 mg/l at Station M-7A (R.M. 174.8).

NITROGEN(N)

Total nitrogen consists primarily of ammonia, nitrate, and organic forms. Nitrites are generally insignificant in streams and are not usually determined. Ammonia and nitrate forms of nitrogen are important nutrients required for green plant growth while ammonia and organic nitrogen (from protein-containing organic compounds) compose most of the second stage or nitrogenuous BOD. Ammonia can be a problem at water treatment plants because of its high chlorine demand. Sources of nitrogen include waste discharges, runoff from chemically fertilized agricultural lands and feedlots, and to a minor extent, fixation of atmospheric nitrogen by certain biota.

Gavins Point Dam to St. Joseph, Missouri

During the normal weather survey, total nitrogen concentrations increased in the reach from Gavins Point Dam to Sioux City, decreased between Sioux City and Station M-44 (R.M. 654.6), but exhibited an increasing trend downstream from Omaha (Figure 9). The highest average concentration was 3.3 mg/l at Station M-27 (R.M. 440.3) at the lower end of the reach downstream from St. Joseph.

The composite samples from the rain-affected portion of the survey exhibited an erratic trend in total nitrogen concentrations but generally increased in the downstream direction. Total nitrogen concentrations were less than the 8-day normal-weather data for the Gavins Point Dam to Sioux City reach; approximately the same from Sioux City to the Soldier River; and greater than the normal weather concentrations downstream from the Soldier River. The highest total nitrogen concentration was 4.1 mg/l at Station M-29 (R.M. 469.0). Five of the main stem stations had concentrations of 3.0 mg/l or greater.

During the winter survey total nitrogen concentrations followed a similar pattern although concentrations were greater than during the autumn survey. The highest average concentration in the reach was 2.2 mg/l which occurred both at Sioux City and near St. Joseph.

St. Joseph, Missouri - Hermann, Missouri

During the autumn survey, total nitrogen concentrations generally increased downstream from St. Joseph. The average concentration increased to 2.3 mg/l at Station M-8 (R.M. 197.2) at Boonville, Missouri. Following an apparently aberrant increase at Station M-7 (R.M. 179.0), the concentration decreased to 1.9 mg/l at Hermann.

Average concentrations during the winter survey followed a similar pattern with concentrations increasing downstream from St. Joseph. The highest average concentration was 3.3 mg/l at Station M-15 (R.M. 293.4) at Waverly, Missouri.

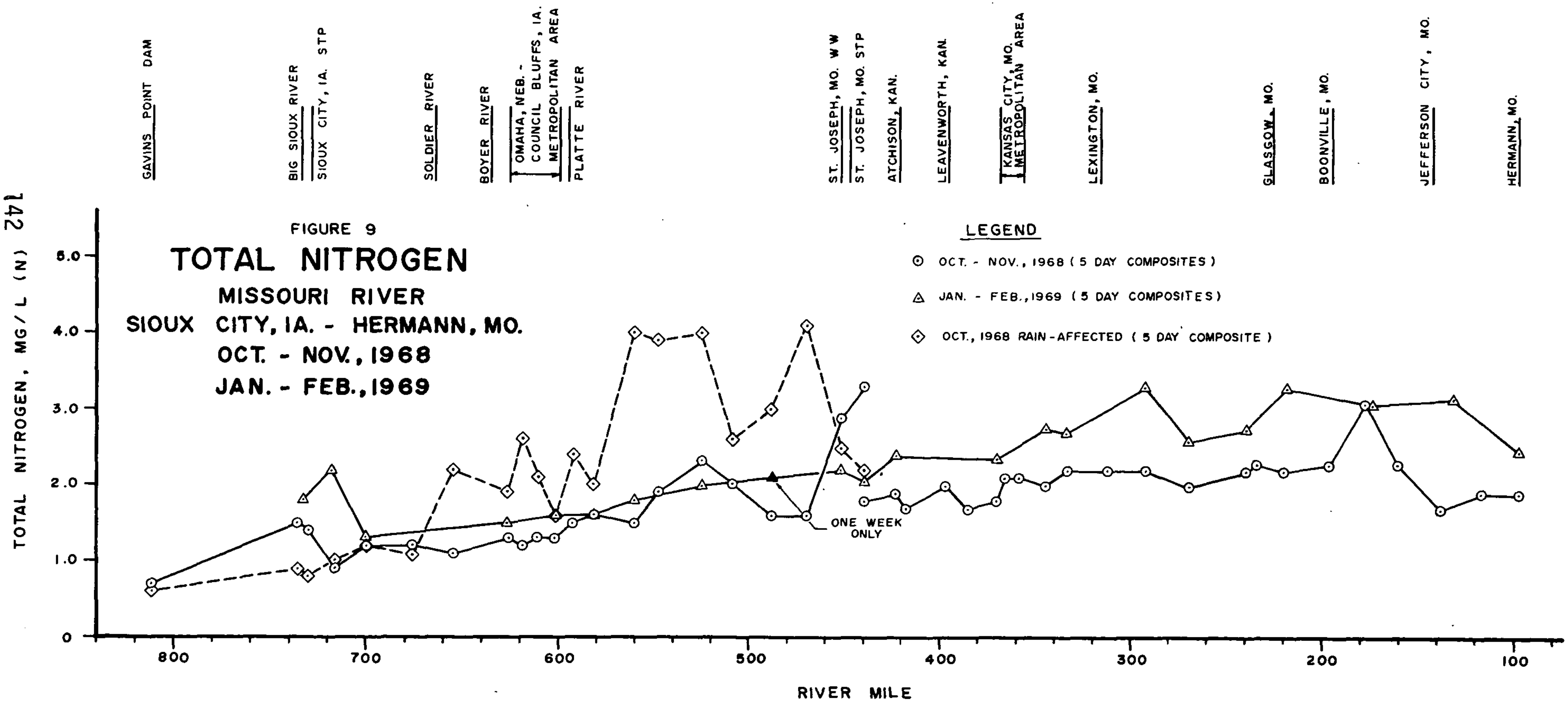
PHOSPHORUS(P)

Phosphorus is an important constituent in chemical fertilizers because of its requirement for plant growth. In streams, phosphorus can contribute to excessive algal growths which cause obnoxious tastes and odors in water supplies. Major sources of phosphorus include detergents in waste discharges and runoff from chemically fertilized agricultural lands.

FIGURE 9

TOTAL NITROGEN

MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969



Gavins Point Dam - St. Joseph, Missouri

Average total phosphorus concentrations were 0.04 mg/l in water released from Gavins Point Dam (R.M. 811.0) during the October 1968 survey (Figure 10).

Downstream from the Omaha-Council Bluffs area, total phosphorus ranged from 0.24 mg/l to 0.30 mg/l. This concentration includes significant contributions from Papillion Creek* and the Platte River (0.80 mg/l). The concentration remained essentially unchanged during the remainder of the reach.

Total phosphorus concentrations increased greatly at most stations in the composite samples collected during the rain-affected period which reflected runoff from agricultural lands. Concentrations increased irregularly downstream from Gavins Point Dam and reached the highest average of 0.92 mg/l at Station M-29 (R.M. 469.0).

During the winter survey, average total phosphorus concentrations had an irregular but generally increasing trend downstream from Sioux City (Figure 10). Concentrations were less than the autumn samples because of reduced contributions from tributaries and the frozen watershed.

St. Joseph, Missouri - Hermann, Missouri

Total phosphorus increased downstream from St. Joseph during the fall survey. Concentrations at 21 of the 22 stations ranged from 0.22 mg/l to 0.40 mg/l. One station had a concentration of 0.62 mg/l.

The winter survey results exhibited a similar pattern. Winter survey phosphorus concentrations were reduced upstream from Lexington, Missouri, but greater downstream. The large amount of rainfall and subsequent land runoff caused the increase downstream. The highest average concentration in the reach was 0.56 mg/l at Station M-5A (R.M. 132.0), two miles upstream from the Osage River.

WATER TEMPERATURE

During the upstream autumn survey period, average water temperatures during the 8-day normal period ranged from 14° C. upstream from Sioux City to 16° C. near the St. Joseph water intake (Appendix Table No. B-1). Average temperatures decreased during the 2-day rain-affected period in the upper reach. The temperature decreased to 10° C. at Sioux City.

Temperatures were reduced during the downstream autumn survey period. Temperatures ranged from 9° C. downstream from St. Joseph to 12° C. at Hermann. Sixteen of the 22 stations averaged 10° C.

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*Papillion Creek is composed primarily of sewage treatment plant effluent. The total phosphorus concentration during the winter survey was 6.45 mg/l. A similar concentration would be estimated for the autumn survey.

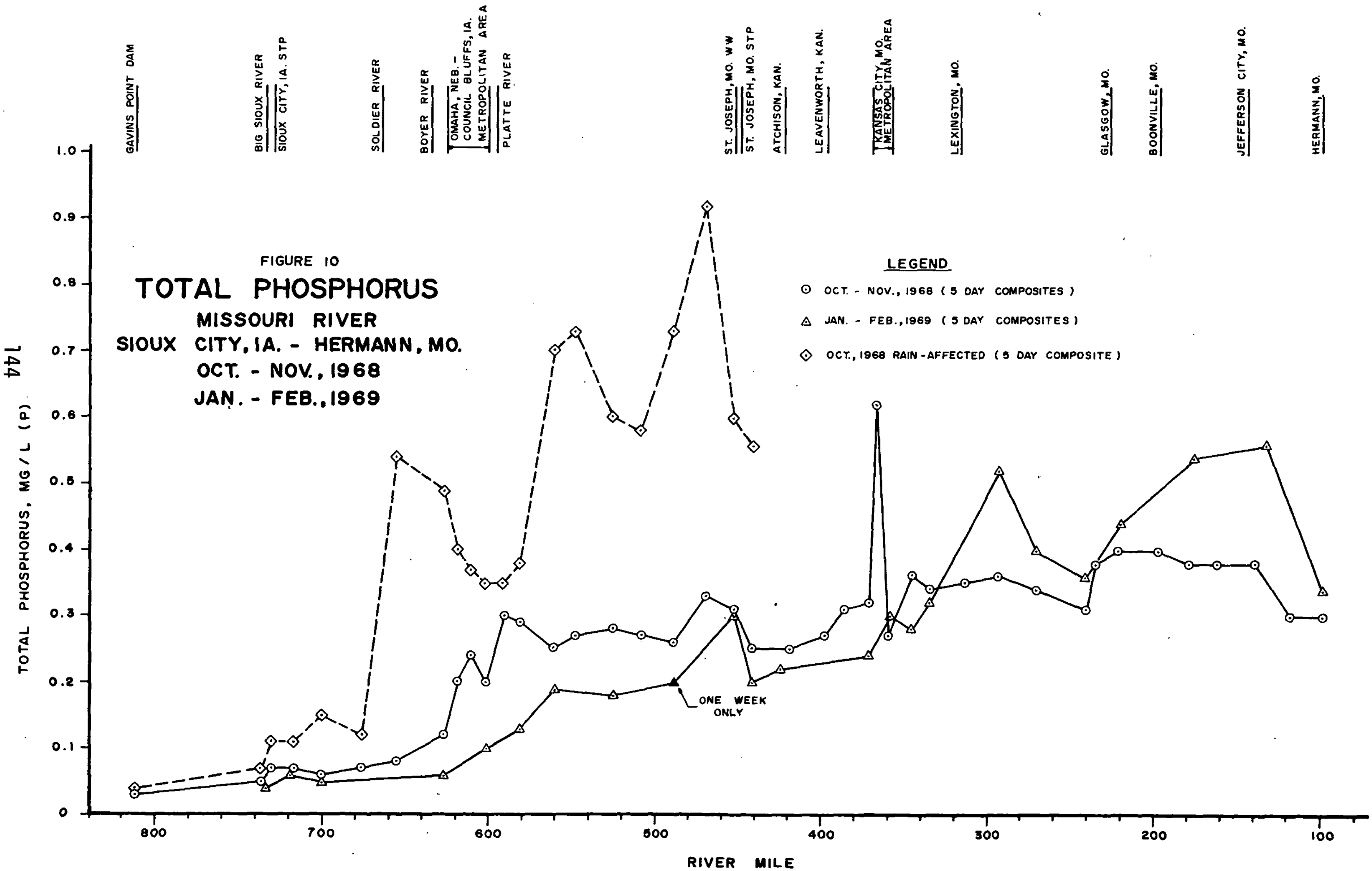

FIGURE 10
TOTAL PHOSPHORUS
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969

Average water temperatures in the entire 700-mile reach were near 0° C. and reflected the low air temperatures and floating ice in the river during the winter survey. Four stations on one sampling run had a 1° - 2° C. difference in temperature (Stations M-26A, M-27, M-28 and M-30) from adjacent upstream and downstream stations. Eighteen of the remaining nineteen stations averaged 0° C. Station M-1 (R.M. 98.0) at Hermann averaged 1°C.

HYDROGEN ION CONCENTRATION(pH)

The NTAC Report on Water Quality Criteria recommends pH levels between 6.0 and 9.0 for maintenance of fish and other aquatic life. The waters of the Missouri River were within these limits.

The pH of the Missouri River was approximately 8.3 for most stations in the upstream reach during the autumn normal weather period(Appendix Table B-1). Average pH's varied from 8.1 to 8.6.

The pH decreased slightly at several stations during the 2-day rain-affected period. The lowest average pH during this period in the main stem Missouri River was 7.8 at Station M-30 (R.M. 488.3).

Downstream from St. Joseph the pH was generally 8.2 during the autumn survey. Average values ranged from 8.1 to 8.3 but 19 of the 22 main stem stations averaged 8.2.

Average pH's were generally lower during the winter survey than during the autumn 8-day normal weather period. In the reach from Sioux City to Atchison, Kansas, average pH values decreased from 8.1 (M-52A, R.M. 732.8) to 7.8 (Station M-26A, R.M. 422.5). After an increase to 8.0 at Station M-23 (R.M. 370.5) at the Kansas City, Missouri water intake, the pH generally decreased downstream to the lowest average of 7.6 at Station M-7A (R.M. 174.8).

ALKALINITY

The alkalinity of natural waters is primarily composed of bicarbonates, carbonates and hydroxide ions and is a measure of the buffer capacity (i.e., resistance to pH change with addition of either acid or base) of a water. It is generally reported as equivalent $CaCO_3$. The NTAC report recommends alkalinities greater than 20 mg/l for maintenance of fish and other aquatic life, and between 30 to a maximum of 400-500 mg/l for sources of public water supplies.

Alkalinity concentrations ranged from 160 mg/l to 197 mg/l in the upstream reach during the normal autumn weather period (Appendix Table No. B-1). Fourteen of 20 stations averaged between 160 - 170 mg/l. Concentrations decreased during the 2-day rain-affected period with a range of 114 mg/l to 130 mg/l. Sixteen of 19 stations averaged between 140 - 160 mg/l. During the autumn survey downstream from St. Joseph, alkalinities averaged between 162 mg/l and 181 mg/l with 20 to 22 stations between 170 - 181 mg/l.

Alkalinities during the winter survey averages between 165 mg/l and 192 mg/l from Sioux City to Station M-12 (R.M. 241.2). Fifteen of the 19 main stem stations averaged between 170 - 185 mg/l. Farther downstream, heavy rains and high flows resulted in a reduced alkalinity concentration of 116 mg/l at Hermann.

TOTAL DISSOLVED SOLIDS

Total dissolved solids are a measure of the inorganic salts present in a water although some soluble organic material may also be included. Excessive total dissolved solids are objectionable because of physiological effects, mineral tastes and economic effects such as corrosion.

The NTAC criteria and the PHS Drinking Water Standards* recommend that total dissolved solids not exceed 500 mg/l for sources of public drinking water supply. Several stations on the Missouri River exceeded this concentration.

Total dissolved solids concentrations during the normal autumn weather period ranged from 468 mg/l to 645 mg/l upstream from St. Joseph (Appendix Table No. B-1). Of the 20 main stem stations sampled, fourteen stations averaged less than 500 mg/l and 19 stations less than 552 mg/l. Concentrations were reduced during the 2-day rain-affected period when results ranged from 198 mg/l to 516 mg/l. Eleven of 16 stations averaged less than 400 mg/l.

Total dissolved solids concentrations ranged from 375 mg/l to 504 mg/l downstream from St. Joseph during the autumn survey. Twenty-one of 22 stations averaged less than 500 mg/l with 14 between 450 mg/l and 500 mg/l.

During the winter survey, the concentration of total dissolved solids ranged from 480 mg/l to 653 mg/l except at the four most downstream stations (M-9A, M-7A, M-5A and M-1). Of the 20 stations sampled, eight ranged from 480 mg/l to 500 mg/l, seven exceeded the 500 mg/l criterion and ranged between 500 mg/l and 550 mg/l. Concentrations at the lower four stations were less than upstream and ranged from 403 mg/l to 254 mg/l. The decrease was caused by the heavy rains and high runoff.

SULFATES

The significance of the sulfate ion in drinking water is essentially the same as total dissolved solids. The Public Health Service Drinking Water Standards recommend limiting sulfate concentrations to 250 mg/l. Average concentrations did not exceed this standard

* Anon. Public Health Service Drinking Water Standards, DHEW, Public Health Service Publ. No. 956 (1962).

in the Missouri River although concentrations in excess of 200 mg/l occurred.

Sulfate concentrations ranged from 164 mg/l to 220 mg/l in the upper reach during the autumn normal weather period (Appendix Table No. B-1). Nine of the 20 stations in this reach averaged over 200 mg/l. Concentrations were similarly distributed during the 2-day rain-affected period although 7 stations had higher results than during the normal period.

Sulfate concentrations ranged from 113 mg/l to 203 mg/l downstream from St. Joseph during the autumn survey. Fifteen stations averaged less than 190 mg/l. Concentrations had a generally decreasing pattern downstream from Kansas City.

During the winter survey, sulfate concentration trends were similar to those of the autumn survey upstream from Station M-9A (R.M. 219.2). Concentrations ranged from 150 mg/l to 224 mg/l. A downward trend occurred between Stations M-9A and M-1 because of dilution from heavy tributary runoff.

TOTAL ORGANIC CARBON

The total organic carbon test is a measure of the total organic matter in water and comprises the theoretical, maximum carbonaceous oxygen demand. The test measures organic carbon in materials contained in waste discharges, naturally occurring organic materials such as lignins, and living organisms such as algae and bacteria, all of which are transported by a stream.

The total organic carbon concentrations were less than 10 mg/l* during the autumn normal weather period in the upstream reaches (Figure 11). Concentrations increased irregularly from 5 mg/l at Gavins Point Dam to concentrations of 8 - 9 mg/l near St. Joseph. Concentrations downstream from Sioux City were approximately two times greater during the rain-affected period when compared to the normal weather period. Two stations had concentrations greater than 20 mg/l and seven stations exceeded 15 mg/l.

Downstream from St. Joseph during the autumn survey, total organic carbon concentrations ranged from 8 mg/l to 11 mg/l with no definite trend evident. Five stations averaged 8 mg/l, 9 stations averaged 9 mg/l, 7 stations averaged 10 mg/l and 1 station averaged 11 mg/l.

Total organic carbon concentrations during the winter survey ranged from 5 mg/l at Sioux City (Station M-52A, R.M. 732.8) to 7 mg/l at the Kansas City, Missouri water intake (Station M-23, R.M. 370.4). Downstream from the Kansas River and the Kansas City area, concentrations generally increased. The highest average of 16 mg/l occurred at Station M-5A (R.M. 132.0).

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* Except for an aberrant concentration of 135 mg/l at Station M-48.

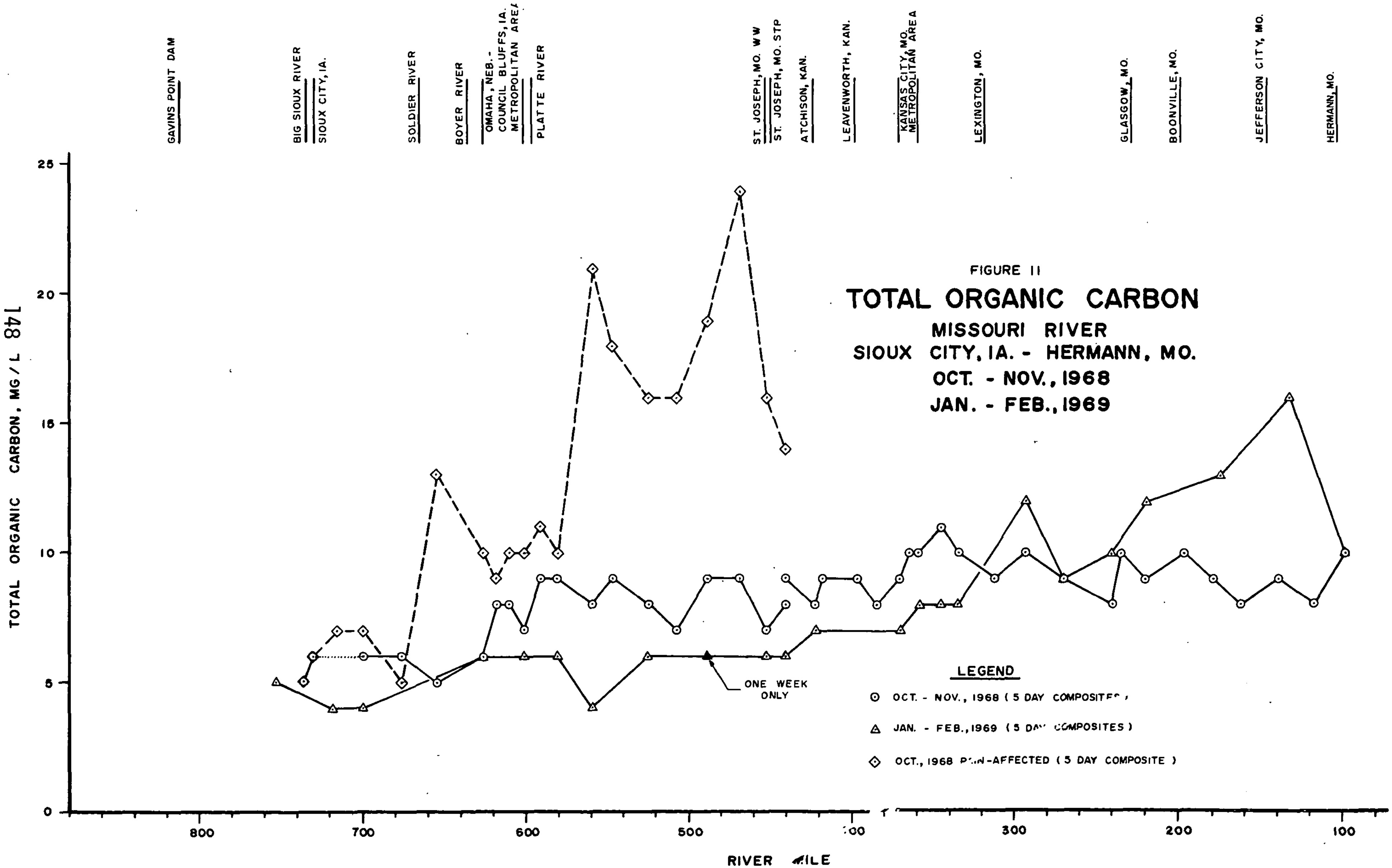

FIGURE 11
TOTAL ORGANIC CARBON
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968
JAN. - FEB., 1969

SOLUBLE METALS

Eleven different metal analyses were performed during the surveys of the Missouri River. All determinations were on the filtrate from samples and thus indicate soluble concentrations. Of these metals, several were absent at all sample stations in detectable concentrations: barium (< 1.0 mg/l), cadmium (< 0.02 mg/l), total chromium (< 0.02 mg/l), copper (< 0.05 mg/l), and nickel (< 0.10 mg/l) (Appendix Table No. B-10).

During the autumn survey, detectable concentrations of boron and iron occurred. Approximately 0.12 mg/l of boron occurred upstream from St. Joseph. Downstream concentrations decreased from 0.34 at Station M-24 (R.M. 384.9) to less than 0.02 mg/l at Hermann (Station M-1 - R.M. 98.0). A soluble iron concentration of 0.60 mg/l for the second 5-day composite was detected at Station M-39 (R.M. 610.5) just downstream from the Missouri River STP discharge in Omaha.

Detectable concentrations of iron, manganese, boron, lead, and arsenic occurred during the winter survey. Soluble iron concentrations ranged from < 0.1 mg/l to 0.3 mg/l. Five of 12 stations had measurable concentrations. Manganese concentrations ranged from < 0.02 mg/l to 0.10 mg/l. Eleven of the 12 stations sampled had positive results. Boron concentrations were detected at all stations selected for analysis. Concentrations ranged from 0.08 mg/l to 0.12 mg/l. The average concentration of lead at Station M-48A (R.M. 718.3) was 0.085 mg/l which exceeded the PHS Drinking Water Standard of 0.05 mg/l. The source of lead was not determined. The largest arsenic concentration in a discrete sample was 0.035 mg/l and occurred upstream from Sioux City at Station M-42 (R.M. 626.2). Detectable concentrations also occurred at Station M-23 (R.M. 370.5) and M-38 (R.M. 601.3).

CYANIDE

Cyanides are synthetic organic compounds which have acute toxicity. The PHS Drinking Water Standards have established a limit of 200 µg/l for cyanides. Since there are no naturally occurring cyanides, their presence indicates a waste source containing the constituent.

Positive cyanide results (more than 1.0 µg/l) were obtained at six of the seven stations sampled between Sioux City and St. Joseph during the autumn survey (Appendix Table No. B-13). Samples from three of eight stations were positive downstream from St. Joseph.

Maximum concentrations during the autumn surveys occurred during the 2-day rain-affected period when the highest single result was 15.2 µg/l at Station M-33 (R.M. 546.7). Four stations in this reach exceeded 10 µg/l during this wet period. Downstream from St. Joseph, the highest single concentration of 7.0 µg/l occurred downstream from the Kansas River at Station M-20.

During the winter survey measurable cyanide results were obtained at 10 of the 12 stations sampled. The maximum concentration was 7.7 µg/l at the Omaha M.U.D. water intake.

TOTAL ORGANIC CHLORINE

Total organic chlorine indicates the presence of organic chlorine-bearing compounds which are principally chlorinated hydrocarbon pesticides in the absence of chlorinated waste discharges. Although the test is non-specific as to which pesticides or other compounds are present, it does indicate the presence of the general group.

Total organic chlorine concentrations were generally higher upstream from St. Joseph than downstream during the autumn surveys (Appendix Table No. B-13). The highest concentration was 264.3 µg/l downstream from the Omaha area waste discharges. Downstream from St. Joseph concentrations ranged from 30.6 µg/l to 98.7 µg/l.

The cause of the higher concentrations of organic chlorine upstream may be related to pesticide use on the extensive farmland in this area (also irrigation upstream from study area) as well as use for insect vector control in feedlot operations.

Total organic chlorine concentrations exhibited no definite pattern during the winter survey. Tributary runoff for most of the basin was small (upstream from Jefferson City, Missouri) because of the frozen conditions of the watershed. Pesticides, also, had not been applied for several months. These levels would represent concentrations in upstream storage reservoirs of both the Missouri and Kansas Rivers. Concentrations ranged from 22.2 µg/l to 74.4 µg/l.

GREASE

The determination of grease by the Standard Methods procedure includes fats, waxes, oils and other non-volatile materials which are soluble in hexane. Grease is an obnoxious compound in water because of the unsightly surface scum formed, and because it causes problems in water supplies.

Because of previous difficulties reported by water supplies downstream from the Omaha area (principally, St. Joseph), grease concentrations were determined for waste discharges in the Omaha area and Sioux City. Downstream from the Omaha area and continuing past the St. Joseph water intake "grease balls" were observed floating on the water surface during the autumn survey. Measurement of grease from the Iowa Beef Packers Plant in Dakota City, Nebraska was determined at a later time by the Missouri Basin Region. Results of these analyses (Table No. 4) indicate grease concentrations in packinghouse waste and in primary treated effluent.

TABLE 4

GREASE

MISSOURI RIVER SURVEYS

Monroe St.- S. Omaha Sewer Composite mg/l	Missouri R. Sewg. Trmnt. Plt. mg/l	Council Bluffs Iowa STP Effluent mg/l	Sioux City Iowa STP Effluent mg/l	Ia. Bf.Pkrs. Dakota City Nebraska mg/l
		OCTOBER-NOVEMBER		
299	-	-	17	-
		JANUARY-FEBRUARY		
-	26	31	38	263 (1)

(1) Average of 3 samples collected on March 27-28, 1969 when Grease removal was not in operation.

Average Grease concentrations in untreated packinghouse waste ranged from 260 - 300 mg/l; that from primary treated effluents ranged from 15 - 40 mg/l.

RADIOACTIVITY LEVELS

Radiological analyses were performed only during the autumn surveys. The naturally occurring radionuclides uranium (U-235 and U-238), radium -226, thorium -232 and total alpha thorium; and the "fission" product strontium-90 were determined. Although not an inclusive list of analyses, this series of naturally occurring nuclides allows an estimate of the natural background levels. Strontium-90 occurs because of past atmospheric nuclear weapons testing and is significant for physiological reasons because its chemical properties are similar to calcium.

As shown in Table No. 5, dissolved radionuclide concentrations in the Missouri River and selected tributaries were substantially lower than the permissible criteria recommended by NTAC for sources of water supply. In the main stem of the Missouri River, at the four stations sampled, uranium concentrations varied from 2.5 µg/l to 4.3 µg/l; radium -226 concentrations from 0.02 pc/l to 0.07 pc/l; and strontium-90 concentrations from 1.5 pc/l to 2.2 pc/l. Thorium -232 concentrations were less than the detection limits of the analytical method.

Gross alpha concentrations for various stream locations in the country are reported in Radiological Health Data and Reports (RHD&R). For the period July to December, 1968 concentrations averaged 2.9 pc/l for the Missouri River at the Missouri City and St. Joseph, Missouri stations. Total alpha concentrations during the autumn survey were calculated from the uranium (after conversion to pc/l*) and radium - 226 concentrations. The concentration calculated by this method was 2.5 pc/l which is very close to the value reported in RHD&R. Thus, the naturally-occurring radionuclides are primarily responsible for the observed autumn concentrations.

The headwaters of the Platte River drain the uranium enriched areas of Colorado and transport higher concentrations of uranium than other Missouri River tributary streams. The uranium concentration was 6.4 µg/l but still much less than the NTAC criterion (Table No. 5).

The strontium-90 concentrations averaged about 1.8 pc/l during the autumn surveys. Strontium-90 concentrations in water have declined with the reduction in atmospheric nuclear testing. In the period from July to September, 1967 RHD&R reported concentrations of 3.0 pc/l and 3.2 pc/l respectively for Missouri City and St. Joseph. The autumn data reflect the decline in the intervening time period.

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* For uranium, 1 µg equals 0.668 pc assuming U-234 equilibrium.

TABLE NO. 5

National Technical Advisory Committee

Recommended Surface Water Radiological Criteria
for
Public Water Supplies

Constituent	Permissible[1] Criteria	Desirable[2] Criteria
Uranium	4.4 mg/l	Absent[3]
Radium-226	3 pc/l	< 1 pc/l
Strontium-90	10 pc/l	< 2 pc/l

(1) Concentrations in raw surface waters which allow the production of a safe, clear, potable, aesthetically pleasing, and acceptable public water supply which meets the limits of the Public Health Service Drinking Water Standards.

(2) Concentrations in raw surface waters that represent high quality water in all respects for use as public water supplies.

(3) Not detectable by the most sensitive analytical procedure in "Standard Methods" or other approved procedure.

BOTTOM ANIMALS*

Many invertebrate animals are found living on the beds of rivers. In a clean water environment, this community includes numerous kinds of pollution-sensitive animals which serve as food organisms for desirable game fish. Pollution-tolerant organisms are present but are few in number. As the environment receives increasing amounts of organic pollution, clean water animals are reduced or eliminated from the community in the order of their sensitivity to degraded water quality. This adverse change in the bottom-associated community is indicative of the extent of pollution. Further evidence of organic pollution is indicated by increases in floating solids and in the formation of sludge deposits in slack water areas behind man-made or naturally occurring obstructions. The sludge may decompose and produce obnoxious gases and remove dissolved oxygen from the overlying flowing water.

The river upstream from Sioux City at Station M-52 (R.M. 736) and downstream to the Omaha, Missouri River waste treatment plant (R.M. 612), supported a stream bed animal community indicative of unpolluted water (Figures 12 and 13, and Table 6). Clean-water stoneflies, mayflies, and caddisflies were the predominant kinds of bottom organisms throughout most of this reach (Appendix Table No. B-16). The number of pollution tolerant forms remained proportionately lower than sensitive kinds except in the reach bordered by Sioux City, Iowa and Dakota City, Nebraska at Station M-50 (R.M. 730). Floating solids consisting of manure, chopped garbage and similar materials were observed. These were found upstream from the municipal waste treatment plants, and thus, originate from untreated waste sources.

Tributaries examined in this reach indicated polluted conditions. Flows from these streams were low in volume and the degraded water entering had no observable effect on the Missouri River.

Downstream from Omaha-Council Bluffs, adverse effects of discharged wastes were discernible for more than 166 miles. Floating solids were evident and unsightly globular masses of grease, chunks of animal fat, and paunch manure accumulated in eddy areas. Clean-water animals were destroyed for 54 miles downstream to Station M-33 (R.M. 547) except at Barlett, Iowa at Station M-35 (R.M. 581) where an aberrant increase in kinds of sensitive and tolerant forms occurred (Figure 13). At Bartlett, available evidence indicated that the animals found were from the Platte River. The Platte River enters upstream, and could have carried invertebrates into the Missouri River. The community found at Station M-35 (R.M. 581) was composed

*The bottom animal community was sampled from locations behind rock jetties and other backwater areas. The bottom animal identifications discussed are for these areas only and are not intended to represent conditions for the entire channel cross sections. (See the Section on Methods.)

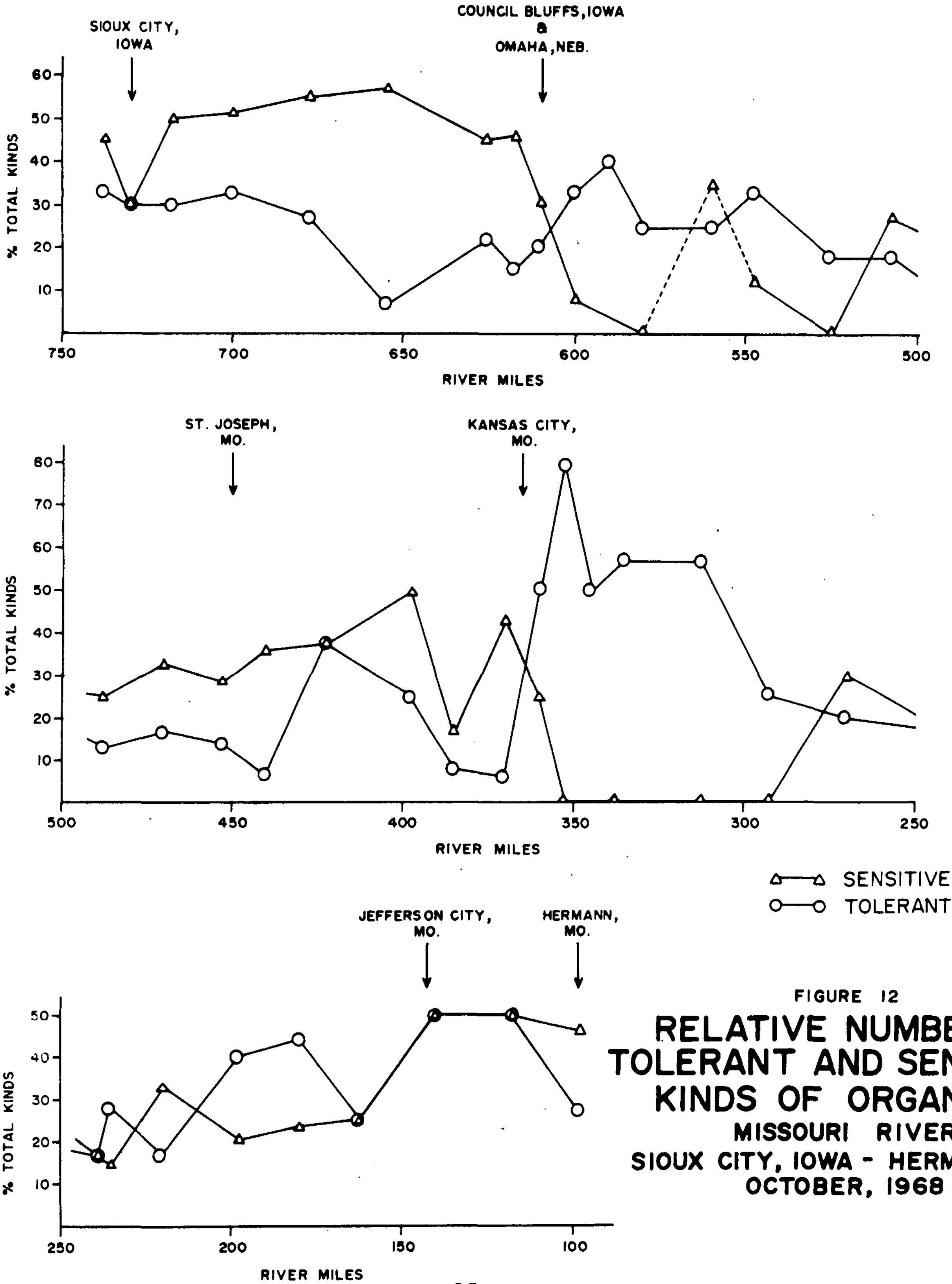


FIGURE 12

RELATIVE NUMBER OF TOLERANT AND SENSITIVE KINDS OF ORGANISMS

MISSOURI RIVER

SIOUX CITY, IOWA - HERMANN, MO.

OCTOBER, 1968

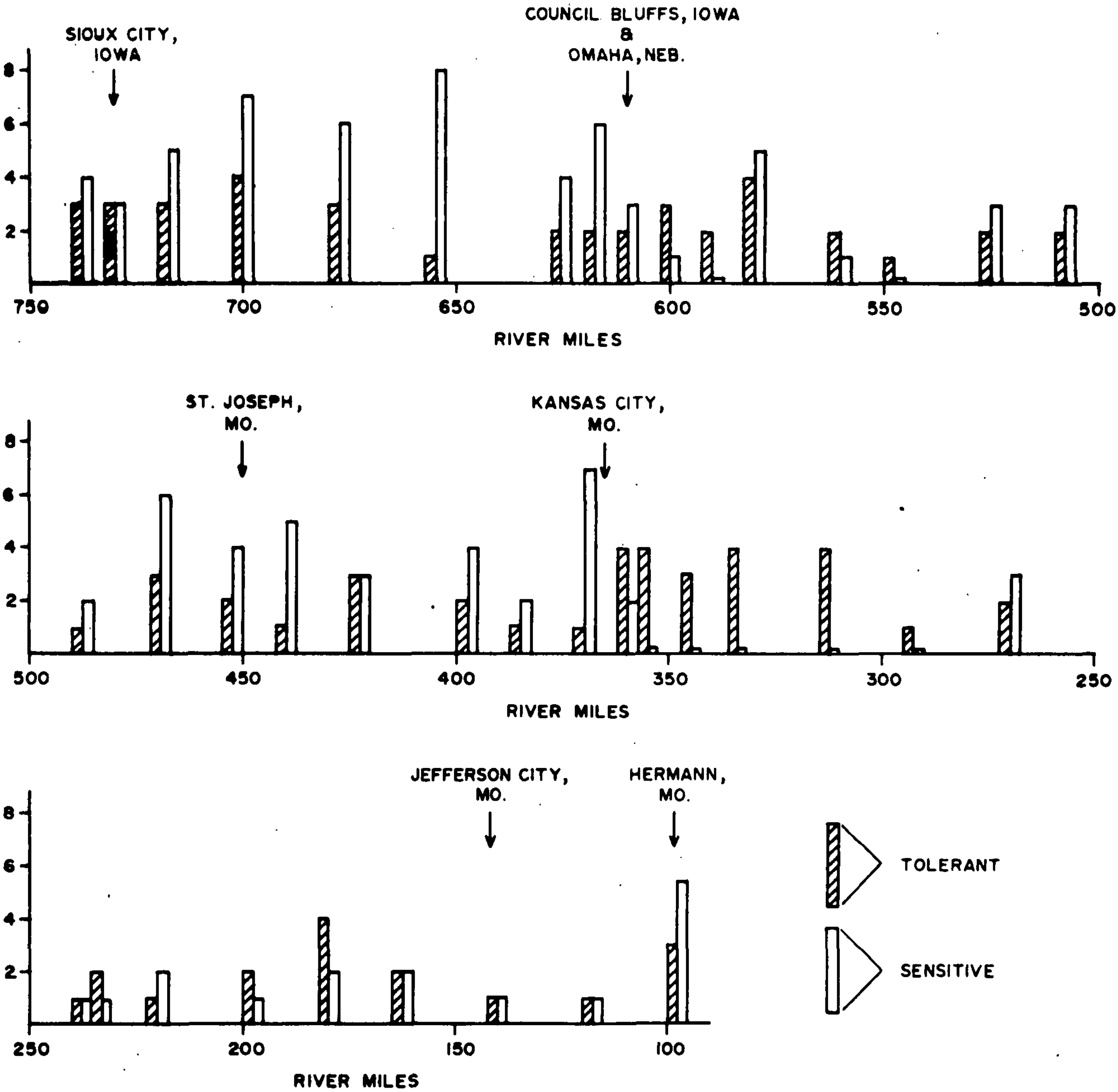


FIGURE 13

NUMBER OF KINDS OF BOTTOM ORGANISMS

MISSOURI RIVER
SIOUX CITY, IOWA - HERMANN, MO.
OCTOBER, 1968

of nearly the same kinds as found in the Platte River. These particular forms were not found at adjacent Missouri River stations and thus would not be indicative of Missouri River water quality at this station.

Downstream from Brownville, Nebraska, at Station M-32 (R.M. 525), the number of pollution sensitive kinds of bottom animals were proportionately greater than pollution tolerant animals (Figure 13). This increase resulted from water quality improvement caused by natural removal of organic settleable solids contained in upstream wastes so that backwater bottom conditions improved. The river continued to support a community of benthic animals indicative of good quality water downstream to Kansas City. Slowly decomposing grease globs remaining in these waters did not induce changes sufficient to affect the aquatic life but were aesthetically objectionable for recreation and water supply uses.

Pile dikes at Station M-23 (R.M. 370) immediately upstream from the Kansas City area supported a diverse bottom fauna. The community contained an assemblage of 7 pollution sensitive and 1 pollution tolerant form. The number of animal kinds present and the composition of the bottom-associated organisms was indicative of unpolluted water (Table 6).

Approximately 11 river miles downstream at Station M-20 (R.M. 359), the number of pollution sensitive forms decreased from 7 to 2 kinds and the tolerant forms increased from 1 to 4. Pollution tolerant sludgeworms, pulmonate snails and leeches predominated which indicated degraded water quality. Sensitive forms such as, mayflies were reduced in number of kinds; caddisflies were eliminated. Large quantities of floating and suspended material and oil were observed at this station.

Downstream from the Blue River confluence, all pollution sensitive organisms were eliminated and replaced by more pollution tolerant forms (R.M. 356). Restriction of the diversity of forms to those that are most tolerant indicated gross organic pollution. The accumulation of organic sludge on the pile dikes, and in the backwater areas, limited the available habitat to tolerant forms. This condition persisted for approximately 63 miles downstream to Waverly, Missouri at Station M-15 (R.M. 293).

Downstream from Waverly from Station M-14 (R.M. 270) to Station M-8 (R.M. 197), the appearance of pollution sensitive forms indicated slight recovery from pollution. However, this portion of the river contained animal communities comprised of near equal varieties of pollution sensitive and tolerant animals. This is indicative of moderate pollution when compared to upstream clean-water areas where the variety of sensitive forms were four to five times as numerous as the tolerant ones.

From Lupus, Missouri, at Station M-7 (R.M. 179) downstream to Hermann, Missouri, at Station M-1 (R.M. 98), large numbers of pollution sensitive burrowing mayflies were collected. The presence of these clean water organisms was an indication of improved water quality in this reach.

SUSPENDED ALGAE

The suspended algal community, phytoplankton, in large flowing streams originate in lakes and backwaters associated with the streams. This community is affected by environmental factors characteristic of each stream such as: turbidity, water velocity, and available inorganic nutrients. Turbidity restricts the amount of light that penetrates the water and thus restricts algal photosynthesis.

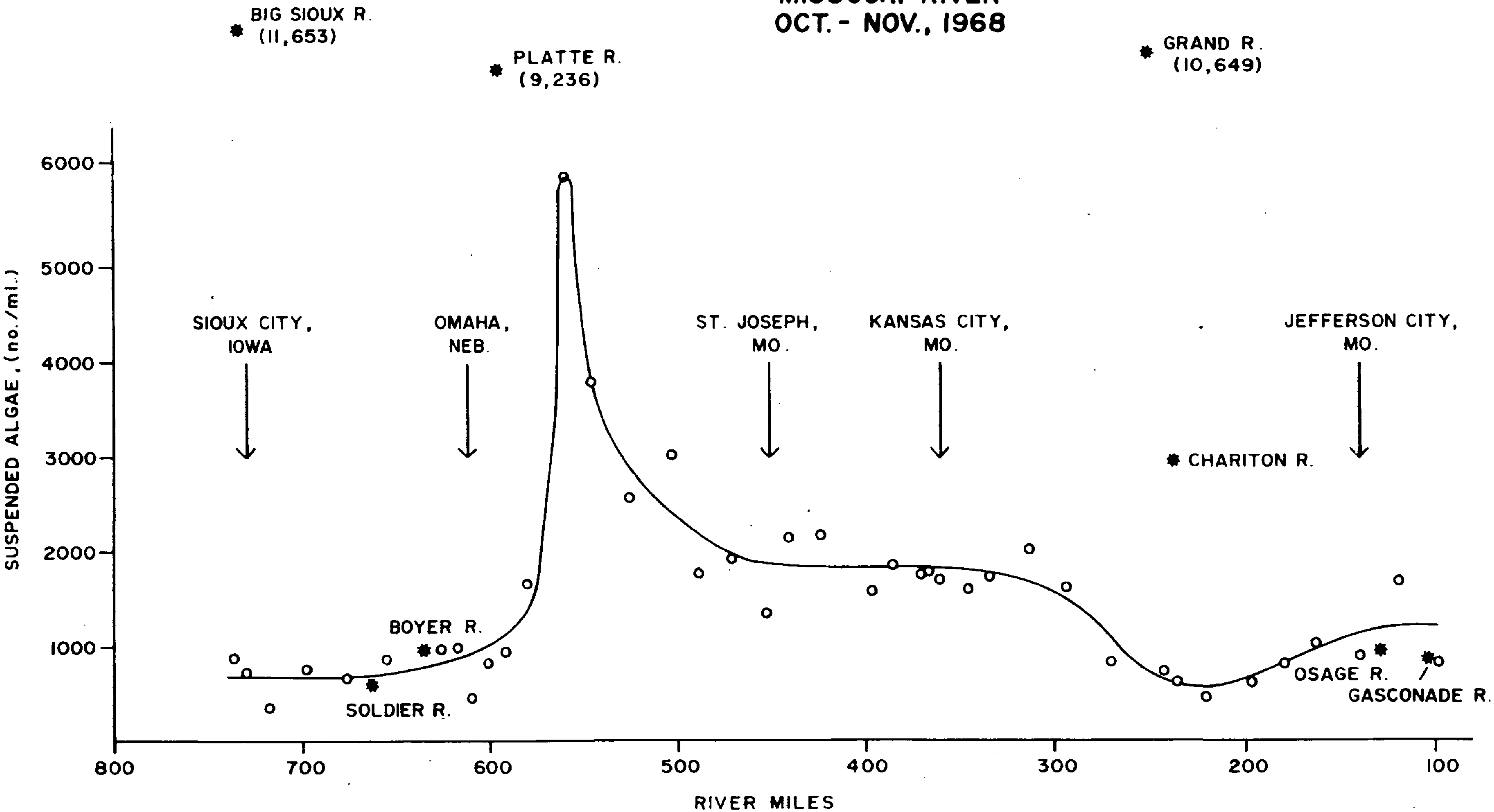
Water velocity also affects phytoplankton which are principally static water organisms. Their presence in flowing water results from facultative adaptation. Swift turbulent currents are detrimental to many of these fragile organisms because of the abrasive action of suspended solids and because the organism is prevented from maintaining a position for optimum light. Increased inorganic nutrients may produce increases in numbers and change the kinds of algae present, unless physical factors are limiting.

In the Missouri River, a combination of a swift current, high turbidity, and lack of adjoining still water environments (due to channelization of the river), tend to limit the phytoplankton community to low numbers.

Suspended algae ranged in numbers from 870 cells per milliliter (ml) to 1,000 cells per ml in the river reach from Station M-52 (R.M. 736.0) at Sioux City to Omaha-Council Bluffs at Station M-41 (R.M. 618.3) (Figure 14). Downstream from Omaha-Council Bluffs, beginning at Station M-38 (R.M. 601.3), the algal population started to increase and attained a high of 6,000 cells per ml at Station M-34 (R.M. 559.7) which was approximately a sixfold increase. This increase is attributed to nutrients being discharged to the river. Downstream from this point to St. Joseph, Missouri, at Station M-28 (R.M. 452.3), the population of algae gradually declined. From Station M-28 at St. Joseph, Missouri to a point downstream from Kansas City at Station M-15 (R.M. 293.4), the algal population ranged from 1300 to 2000 cells per ml. The algal population of 2,000 per ml in this reach would have declined to numbers equal to, or less than, those noted upstream from Omaha except for the nutrients discharged from cities adjoining the river. Downstream, the effects of current, turbidity and suspended solids reduced the population to 500 cells per ml at Station M-9 (R.M. 221). The algal population increased slightly to 1,000 cells per ml farther downstream at Station M-6 (R.M. 162.0).

FIGURE 14

SUSPENDED ALGAE
(number per ml.)
MISSOURI RIVER
OCT.- NOV., 1968



Tributary streams contained high populations of phytoplankton but stream flows were too small to contribute significant quantities of algae to the Missouri River algal populations.

TRIBUTARY STREAMS

Twelve tributary streams were sampled either for chemical and bacteriological analyses or biological analyses, or both, near their confluences with the Missouri River during the autumn survey (Table 6, 7 and Appendix B). Two of these (Papillion Creek and the Platte River) were again sampled during the winter survey.

Big Sioux River

This stream flows into the Missouri River just upstream from Sioux City, Iowa, and forms the South Dakota-Iowa state line. Only four kinds of pollution tolerant and one kind of pollution sensitive animals were found. The bottom contained deposits of organic material and oil. During the two-day, rain-affected period, DO's decreased by fifty percent (from 12.0 mg/l to 6.0 mg/l) and fecal coliform bacteria increased from 110 MPN/100 ml to 4,000 MPN/100 ml.

Floyd River

The bottom of this stream was covered with organic solids, including manure, and exuded the rotten egg odor of hydrogen sulfide. Water quality was degraded so severely that only one kind of pollution tolerant bottom animal could inhabit these waters.

Soldier River

The water quality in this stream was greatly affected by rainfall. During the rain-affected period, geometric mean fecal coliform bacterial densities increased from 4,000 MPN/100 ml to 2,000,000 MPN/100 ml, and suspended solids from 10 mg/l to 3,530 mg/l. The stream supported only two kinds of pollution tolerant bottom organisms and no clean water kinds.

Boyer River

The water quality of the Boyer River was also adversely affected during the rainy period. Fecal coliform densities increased from a mean of 20,500 MPN/100 ml to 1,500,000 MPN/100 ml, and the BOD_5 increased to 14 mg/l. The sandy bottom of the stream supported only one kind of sensitive clean water organism, and three kinds of tolerant bottom organisms.

Papillion Creek

A primary source of flow in this stream is the treated sewage discharges from Omaha's Papillion Creek sewage treatment plant,

TABLE 6

NUMBER OF KINDS OF

BOTTOM-ASSOCIATED ANIMALS

MISSOURI RIVER

OCTOBER, 1968

LOCATION	Corresponding Water Quality Station	River Mile	Pollution Sensitive Organisms	Pollution Intermediately Sensitive Organisms	Pollution Tolerant Organisms	Total Number of Kinds
			MISSOURI RIVER			
	M-52	736	4	2	3	9
	M-50	730	3	4	3	10
	M-48	717	5	2	3	10
	M-47	699	7	2	4	13
	M-46	676	6	2	3	11
	M-44	655	8	5	1	14
	M-42	626	4	3	2	9
	M-41	618	6	5	2	13
	M-39	610	3	4	2	9
	M-38	601	1	9	3	13
	M-36	591	0	3	2	5
	M-35	581	5	7	4	16
	M-34	560	1	5	2	8
	M-33	547	0	2	1	3
	M-32	525	3	6	2	11
	M-31	507	3	6	2	11
	M-30	488	2	4	1	7
	M-29	469	6	9	3	18
	M-28	452	4	8	2	14
	M-27	440	5	8	1	14
	M-26	423	3	2	3	8
	M-25	397	4	1	2	7
	M-24	385	2	9	1	12
	M-23	370	7	8	1	16
	M-20	359	7	2	4	8
	-	356	0	1	4	5
	M-18	345	0	3	3	6
	M-17	334	0	3	4	7
	M-16	313	0	3	4	7
	M-15	293	0	3	1	4
	M-14	270	3	5	2	10
	M-12	238	1	4	1	6
	M-10	235	1	4	2	7
	M- 9	221	2	3	1	6
	M- 8	197	1	2	2	5
	M- 7	179	2	3	4	9
	M- 6	162	2	4	2	8
	M- 5	139	1	0	1	2
	M- 3	118	1	0	1	2
	M- 1	98	5	3	3	11
			TRIBUTARY STREAMS			
BIG SIOUX RIVER	BS-51		1	2	4	7
FLOYD RIVER	-		0	0	1	1
SOLDIER RIVER	S-45		0	9	2	11
BOYER RIVER	B-43		1	5	3	9
PLATTE RIVER	P-37		4	4	2	10
KANSAS RIVER	Kr-22		0	3	2	5
BLUE RIVER	-		0	0	0	0
GRAND RIVER	Gr-13		2	5	2	9
OSAGE RIVER	O-4		1	3	3	7
GASCONADE RIVER	G-2		1	4	1	6

NOTE: Bottom organism identifications are in Appendix Table No. B-16.

TABLE 7

SUMMARY OF TRIBUTARY STREAM DATA

MISSOURI RIVER

TRIBUTARY STREAM	Enters Missouri River at R.M.	5-Day Biochemical Oxygen Demand 8-Day Normal	2-Day Wet	Winter	Dissolved Oxygen 8-Day Normal	2-Day Wet	Winter	8-Day Normal Total	Fecal	2-Day Wet Total	Fecal	Winter Total	Fecal	Total Suspended Solids 8-Day Normal	2-Day Wet	Winter
Big Sioux River(BS-51)	734.0	9.1	6.0	-	12.0	6.0	-	1,130	110	17,000	4,000	-	-	55	71	-
Soldier River(S-45)	664.0	2.3	6.9	-	9.9	6.6	-	14,700	4,000	2,400,000	2,000,000	-	-	10	3,530	-
Boyer River(B-43)	635.1	9.2	14.0	-	8.2	5.7	-	114,400	20,500	> 2,000,000	1,500,000	-	-	729	999	-
Papillion Creek(PA-37A)	596.5	-	127	84	-	-	3.9	-	-	16,000,000	11,000,000	4,040,000	591,200	-	-	100
Platte River(P-37)	594.8	7.9	8.2	2.1	9.2	7.8	10.0	27,700	11,200	620,000	290,000	36,000	18,700	763	-	32
Kansas River(KR-22)	367.4	3.1			9.6			116,000	6,800					284		
Grand River(GR-13)	250.0	3.3			9.3			4,000	< 460					59		
Chariton River(C-11)	238.8	3.4			10.4			> 10,700	2,340					54		
Osage River(O-4)	130.0	1.6			9.4			5,000	1,100					55		
Gasconade River(G-2)	104.4	3.2			9.7			2,600	570					66		

Offutt Air Force Base, and the community of Bellevue, Nebraska. This small creek was sampled during both the fall and winter surveys. Sampling was confined to three days, all of which were affected by rain, during the autumn survey. Water quality approached that of untreated sewage with a BOD_5 of 127 mg/l and a fecal coliform density of 11,000,000 MPN/100 ml. Water quality was only slightly better during the winter survey when the BOD_5 was 84 mg/l and the fecal coliform density was 591,000 MPN/100 ml.

Platte River

The Platte River is the largest tributary to the Missouri River in the reach from Gavins Point Dam to St. Joseph, Missouri. This stream was sampled for chemical and bacteriological analyses during both the autumn and winter surveys. Biological sampling was conducted during the autumn period only.

During the autumn and winter surveys, the fecal coliform densities were quite similar with densities of 11,200 MPN/100 ml and 18,700 MPN/100 ml, respectively. However, the densities increased to 290,000 MPN/100 ml during the 2-day, rain-affected period.

The average concentration of suspended solids during the winter survey was only four percent (32 mg/l) of that during the autumn survey (763 mg/l). The frozen condition of the watershed, and low runoff, accounted for this reduction.

The bottom animal community during the autumn survey was composed of predominately clean water forms. Four pollution sensitive and two pollution tolerant animal kinds were found.

Kansas River

Bottom materials from the Kansas River were composed primarily of paunch manure and organic sludges, and emanated a distinct rotten egg odor during the autumn survey. Bubbling gases from these bottom deposits, oil and floating solids such as, animal fat, clotted blood, and hair were observed in this stream. Only pollution tolerant sludgeworms, mothflies and midge larvae were found in the bottom animal community.

The fecal coliform bacterial density was 6,800 MPN/100 ml near the stream mouth. Total suspended solids averaged 284 mg/l.

Blue River

The Blue River was severely polluted by wastes discharged from the Kansas City Blue River sewage treatment plant, and industrial wastes including that from steel processing. Bottom samples collected from the Blue River were devoid of bottom animals which indicated gross organic pollution and possibly, the presence of toxic materials. Bottom sediments were composed of a gray-black organic sludge that had a strong hydrogen sulfide odor. The water was colored gray and pockmarked by bubbles of decomposition gases.

Grand River

When sampled during the autumn survey, this stream had low flows averaging 167 cfs. (Winter flows averaged 5,500 cfs.) The bottom animal community was composed of two pollution sensitive, and two pollution tolerant forms. Two-thirds of the population density were tolerant sludgeworms. Mean fecal coliform densities were < 460 MPN/100 ml during this low flow period.

Chariton River

This stream had a mean flow of only 54 cfs during the autumn sampling period. Fecal coliform bacteria had a geometric mean of 2,340 MPN/100 ml which exceeded the NTAC contact and non-body contact recreation criteria. The average D.O. of 10.4 mg/l was near saturation and satisfactory for aquatic life.

Osage River

The Osage River is a large tributary to the lower Missouri River. The flow averaged 5,380 cfs during the autumn survey, and 21,000 cfs during the winter survey. During the autumn survey, fecal coliform bacteria had a geometric mean of 1,100 MPN/100 ml which exceeded the NTAC contact and non-body contact recreation criteria. The bottom organism community was composed of one pollution sensitive and three pollution tolerant forms. However, more than one-half the population density was composed of the pollution sensitive variety.

Gasconade River

Waters of this stream had geometric mean fecal coliform densities of 570 MPN/100 ml which exceeded the NTAC primary contact recreation standard of 200 MPN/100 ml. However, land runoff from the 1-2/3 inches of rain during the two-week autumn survey may have increased the densities. The bottom animal community was composed of one pollution sensitive and one pollution tolerant form. One-third of the population density was composed of tolerant sludgeworms.

MUNICIPAL WASTE SOURCES

Seven of the larger municipal waste discharges were sampled during the Missouri River surveys (Table 8). Six of the discharges were final effluents from primary waste treatment plants; one reported discharge was a composite of two separate Omaha sewers which discharged untreated wastes to the Missouri River: the Monroe Street and South Omaha interceptor sewers.

TABLE 8

MUNICIPAL WASTE SOURCES

MISSOURI RIVER

WASTE DISCHARGE	Sampling Period	FLOW MGD	BOD_5 mg/l	Total Suspend. Solids mg/l	BACTERIAL DENSITIES TOTAL COLI MPN/100ml	FECAL COLI MPN/100ml	FECAL STREP MF/100ml	Total(2) Organic Carbon mg/l	Total(2) Phos-Phorus mg/l	Total(2) Nitro-gen mg/l	Grease mg/l
Sioux City, Iowa STP	Oct. 7-18, 1968	16.2	247	109	75,200,000	20,200,000	-	97	10.6	78.8	17
	Jan.20-31, 1969	14.6	340	130	19,460,000	5,150,000	8,760,000	65	14.2	73.2	38
Omaha, Nebraska:											
Composite: Monroe St. & So. Omaha Sewers	Oct. 7-18, 1968	34.3	985	891	18,600,000	7,760,000	-	212	11.4	67.2	299
Missouri River Sewage Treatment Plant	Jan.20-24, 1969	16.0(3)	256	91	11,180,000	3,000,000	16,650,000	30	6.9	26.8	26
Council Bluffs, Iowa	Oct. 1968(1)	5(3)	-	-	160,000,000	35,000,000	-	-	-	-	
Sewage Treatment Plant	Jan.27-31, 1969	5.2	335	99	22,540,000	4,330,000	1,320,000	61	16.5	57.0	31
Kansas City, Missouri:											
Blue River Sewage Treatment Plant	Oct.28-Nov. 1, 1968	42.6	171	87	46,000,000	4,500,000	-	49	9.8	32.6	-
	Jan.20-24, 1969	59.0	136	78	40,440,000	7,930,000	7,880,000	31	8.7	30.4	-
West Side Sewage Treatment Plant	Jan.27-31, 1969	17.3	123	58	8,940,000	2,760,000	5,050,000	28	5.6	24.4	-
Kansas City, Kansas: Sewage Treatment Plant	Nov. 4-8, 1968	7.8	277	267	46,000,000	9,700,000	-	82	12.0	43.7	-

NOTES: (1) Single grab sample.

(2) Weekly composite made from 5 daily composite samples.

(3) Estimated by plant personnel.

Secondary treatment of these discharges as well as other smaller municipal treatment plants, and industrial waste discharges would substantially reduce concentrations of BOD; total organic carbon; settleable and suspended solids; grease and other floatable materials; and bacteria and viruses discharged to the Missouri River from these controllable sources. Resulting water quality improvement in the Missouri River would be both aesthetic through removal of obnoxiously appearing suspended and floatable material which forms scum on pile dikes and settles to form sludge in backwater areas; and bacteriologically by affording a safer water for recreation and for municipal water supply.

Future water quality studies will be designed to quantitate these and additional water quality improvements.

APPENDIX B-1

STATION DESCRIPTIONS
(by Missouri River Mile)

APPENDIX B-1

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River (1) Mile	Sample (2) Type	DESCRIPTION
M-1	98.0	A	Missouri River at State Highway 19 bridge, Hermann, Missouri.
G-2	104.4	A	Gasconade River at State Highway 100 - 1 mile upstream from confluence.
M-3	118.0	A	Missouri River at Chamois. Missouri (0.2 miles upstream from Kishmar Light).
O-4	130.0	A	Osage River at Bonnots Mill Landing, Missouri.
M-5A	132.0	C	Missouri River at small boat dock - off Missouri State Highway 94.
M-5	139.0	A	Missouri River - 3 miles downstream from Jefferson City, Missouri (at Moreau River light).
M-6	162.0	A	Missouri River at Wilton, Missouri (0.2 miles upstream from Wilton light).
M-7A	174.8	C	Missouri River at Lupus, Missouri.
M-7	179.0	A	Missouri River at Searcys Bend - 4 miles upstream from Lupus, Missouri (at Searcys Bend light).

(1) Biology stations may not coincide exactly with chemical and bacteriological sampling stations; usually they were ± 0.2 mile.

(2) Sample type: A - Chemical, bacteriological and biology sample station.
B - Biology sample station only.
C - Chemical and bacteriological sampling station only.

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River Mile (1)	Sample Type (2)	DESCRIPTION
M-8	197.2	A	Missouri River at M.K.T. RR bridge, Boonville, Missouri.
M-9A	219.2	C	Missouri River at limestone quarry, downstream from Bluffport, Missouri.
M-9	221.0	A	Missouri River at Fish Creek Bend - 5 miles downstream from Glasgow, Missouri (at Brockway Island Light - 221.0).
M-10	235.1	A	Missouri River at Gilliam Bend - 6 miles downstream from New Frankfort, Missouri (at light).
C-11	238.8	A	Chariton River upstream from confluence. For October 28-30 at a point approximately 1 mile upstream. For October 31-November 8 at Price Bridge, Highway VV south of Keytesville, Missouri.
M-12	241.2	A	Missouri River at New Frankfort Landing, Missouri.
GR-13	250.0	A	Grand River upstream from confluence. For October 28-30 at Brunswick. For October 31-November 8 at U.S. Highway 24 Bridge, Missouri.
M-14	270.0	A	Missouri River at Ray-Carrol County, Grain Growers, Inc., loading dock, east of Wakenda, Missouri.

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River Mile (1)	Sample Type (2)	DESCRIPTION
M-15	293.4	A	Missouri River at U. S. Highway 24 & 65 - Waverly, Missouri.
M-16	313.2	A	Missouri River - 4 miles downstream from Lexington, Missouri (at Ray-Carrol G.G., Inc. loading dock).
M-17	334.5	A	Missouri River at Fishing River Landing via gravel road south from Orrick, Missouri.
M-18	345.4	A	Missouri River at N. W. Electric (Co-operative) Power Plant near Missouri City, Missouri.
-	356 ±	B	Missouri River downstream from confluence with Blue River.
K-19	358.0	C	Kansas City Blue River Sewage Treatment Plant (effluent to Big Blue River).
-	358.0	B	Big Blue River.
M-20A	358.3	C	Missouri River at Kansas City Power and Light Company - Hawthorne Plant water intake structure.
M-20	359.3	A	Missouri River at C.R.I. & P. RR bridge.
M-21	365.6	A	Missouri River A.S.B. Highway & RR bridge.
K-19B	367.19	C	Kansas City, Missouri West Side Sewage Treatment Plant effluent.
K-19A	367.20	C	Kansas City, Kansas Sewage Treatment Plant effluent.

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River Mile (1)	Sample Type (2)	DESCRIPTION
KR-22	367.4	A	Kansas River at Central Avenue bridge.
M-23	370.5	A	Missouri River at Kansas City, Missouri Waterworks Intake opposite Fairfax Airport.
M-24	384.9	A	Missouri River upstream from Kansas City (at Weavers light).
M-25	397.4	A	Missouri River at Leavenworth, Kansas (0.2 miles downstream from Highway bridge).
M-25.5	418.0	C	Missouri River - approximately 4 miles downstream from Atchison, Kansas.
M-26A	422.5	C	Missouri River at Atchison and Eastern Railroad Company bridge.
M-26	422.6	A	Missouri River at Atchison, Kansas (0.1 miles upstream from RR bridge).
M-27	440.3	A	Missouri River at Palermo landing (1.3 miles upstream from Palermo light).
M-28	452.3	A	Missouri River at St. Joseph Water Company Waterworks Intake.
M-29	469.0	A	Missouri River - 0.5 miles upstream from Charleston landing (Daymark).
M-30	488.3	A	Missouri River at White Cloud, Kansas (at power cable crossing).
M-31	507.5	A	Missouri River - 9.5 miles upstream from Rulo, Nebraska.

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River Mile [1]	Sample Type [2]	DESCRIPTION
M-32	525.1	A	Missouri River (at Upper Morgan Bend, upper light).
M-33	546.7	A	Missouri River at Peru Sportsman Club ramp.
M-34	559.7	A	Missouri River downstream from Nebraska City (0.2 miles upstream from Frazers light).
M-35	580.9	A	Missouri River at Bartlett, Iowa (at Shenandoah Boat Club ramp).
M-36	591.2	A	Missouri River at Plattsmouth, Nebraska (0.2 miles downstream from Pollock light).
P-37	594.8	A	Platte River at U.S. Highway 75 bridge, Nebraska.
PA-37A	596.5	C	Big Papillion Creek at Offutt Air Force Base Road to Capehart, Nebraska - off U.S. Highway 75.
M-38	601.3	A	Missouri River at Bellevue, Nebraska (0.1 miles downstream from State Highway 370 bridge).
M-39	610.5	A	Missouri River downstream from Omaha STP outfall (at power cable crossing).
OM-40	611.5	C	Composite sample of 7 parts Monroe St. Sewer effluent and 1 part South Omaha Sewer, Omaha, Nebraska (approximate river mileage).
OM-40A	611.5	C	Omaha, Missouri River Sewage Treatment Plant effluent (approximate river mileage).

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River[1] Mile	Sample[2] Type	DESCRIPTION
CB-40B	614.0	C	Council Bluffs Sewage Treatment Plant effluent (approximate river mileage).
M-41	618.3	A	Missouri River at I.C. RR bridge.
M-42	626.2	A	Missouri River at Omaha Waterworks Intake (0.3 miles downstream from Highway 36 bridge).
B-43	635.1	A	Boyer River at I-29 Highway bridge, Iowa.
M-44	654.6	A	Missouri River upstream from Blair, Nebraska (at Tyson Boat Marina).
S-45	664.0	A	Soldier River at I-29 Highway bridge, Iowa.
M-46	676.5	A	Missouri River at Upper Sioux Reach, upper light.
M-47	699.5	A	Missouri River at Lighthouse Marina (also called Don Ruth Marina - 6 miles from Whiting, Iowa).
M-48	717.4	A	Missouri River downstream from Sioux City STP outfall (at power cable crossing).
M-48A	718.3	C	Iowa Power and Light Co. Power Plant.
SC-49	729.0	C	Sioux City Sewage Treatment Plant effluent (approximate river mileage).
M-50	730.0	A	Missouri River downstream from Floyd River confluence - Sioux City, Iowa (at power cable crossing).
-	731	B	Floyd River 0.1 miles upstream from the confluence.

APPENDIX B-1
(Contd.)

STATION DESCRIPTIONS
(by Missouri River Mile)

MISSOURI RIVER BASIN SURVEYS

STATION	River Mile(1)	Sample Type(2)	DESCRIPTION
M-52A	732.8	C	Missouri River 0.5 miles upstream from U.S. 73 Highway bridge.
BS-51	734.0	A	Big Sioux River upstream from confluence (at I-29 Highway bridge).
M-52	736.0	A	Missouri River - 2 miles upstream from Sioux River confluence.
Gavins Pt. Dam	811.0	C	Lewis and Clark Reservoir Dam upstream from Yankton, South Dakota (Corps of Engineers).

APPENDIX B-2

DATA SUMMARY

TABLE NO. B-1

Summary of 8- & 2-Day Averages[1] for Discrete Samples
MISSOURI RIVER
OCTOBER 7-18, 1968 SURVEY

STATION Name	River Mileage	TEMPERATURE °C 8-Day	2-Day	DISSOLVED OXYGEN mg/l 8-Day	2-Day	2-DAY BOD mg/l 8-Day	2-Day	5-DAY BOD mg/l 8-Day	2-Day	pH Units 8-Day	2-Day	ALKALINITY $CaCO_3$ mg/l 8-Day	2-Day	HARDNESS $CaCO_3$ mg/l 8-Day	2-Day
MISSOURI RIVER:															
Gavins Pt. Dam	811.0	-	-	-	-	-	-	-	-	8.3[2]	-	169[2]	-	238[2]	-
M-52	736.0	14	10	9.5	10.0	0.4	0.6	0.9	1.2	8.3	8.4	166	160	258	254
M-50	730.0	14	10	9.4	9.7	0.4	0.6	1.1	1.2	8.3	8.3	165	160	249	275
M-48	717.4	14	11	9.3	9.4	0.8	0.8	1.5	1.6	8.3	8.3	167	160	252	258
M-47	699.5	15	12	9.2	9.2	0.8	0.9	1.6	1.8	8.3	8.3	174	154	257	254
M-46	676.5	15	11	9.2	9.0	0.7	1.0	1.4	1.8	8.3	8.3	160	158	254	258
M-44	654.6	15	13	9.1	8.0	0.8	1.9	1.5	4.0	8.3	8.2	197	156	264	254
M-42	626.2	14	12	9.1	8.0	1.1	2.6	1.9	4.9	8.2	8.2	172	168	237	271
M-41	618.3	14	14	8.9	7.8	1.2	2.2	2.0	4.2	8.2	8.2	169	154	263	238
M-39	610.5	14	13	8.8	-	3.6	3.2	5.8	6.1	8.3	8.1	164	114	254	238
M-38	601.3	15	13	8.8	7.6	1.9	2.6	3.4	5.2	8.6	8.1	168	147	250	238
M-36	591.2	15	12	8.6	7.8	1.9	2.9	3.4	5.4	8.2	8.1	167	154	249	242
M-35	580.9	15	12	8.6	7.5	1.8	2.9	3.3	5.6	8.1	8.0	168	180	272	258
M-34	559.7	14	14	8.5	6.8	1.3	3.3	2.8	6.8	8.3	8.0	169	148	262	226
M-33	546.7	15	14	8.4	7.0	1.7	3.9	3.2	6.7	8.3	8.0	170	146	256	246
M-32	525.1	15	14	8.6	6.1	1.3	2.8	2.6	7.0	8.2	8.0	174	158	258	246
M-31	507.5	15	14	8.6	6.6	1.3	2.5	2.6	5.8	8.2	8.0	165	160	253	258
M-30	488.3	15	15	8.3	6.0	1.9	2.6	3.2	5.8	8.2	7.8	170	152	258	258
M-29	469.0	15	15	8.6	5.2	2.1	3.0	3.4	7.6	8.2	7.8	173	145	261	242
M-28	452.3	16	16	8.6	5.6	1.8	-	3.0	-	8.3	8.0	163	158	254	246
M-27	440.3	16	15	8.7	5.6	1.6	2.9	3.0	5.6	8.2	7.8	171	143	263	242
TRIBUTARIES:[5]															
BS-51[3]	734.0	14	11	12.0	6.0	4.6	3.4	9.1	6.0	8.4	8.0	214	177	388	385
S-45[3]	664.0	-	10	9.9	6.6	1.3	5.2	2.3	6.9	8.3	7.8	255	149	350	246
B-43	635.1	14	10	8.2	5.7	5.0	8.1	9.2	14.0	8.1	7.8	251	174	340	242
PA-37A[4]	596.5	-	10	-	-	-	55	-	127	-	-	-	-	-	-
P-37	594.8	16	11	9.2	7.8	4.2	3.8	7.9	8.2	8.2	7.7	158	130	199	184
WASTE SOURCES:[5]															
SC-49[3]	729.0	-	-	-	-	152	160	247	260	7.4	8.0	412	374	439	344
OM-40[3]	611.5	-	-	-	-	554	551	985	847	7.3	7.7	249	225	263	293
CB-40B	614	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE NO. B-1
(contd)

Summary of 8- & 2-Day Averages1/ for Discrete Samples
MISSOURI RIVER
OCTOBER 7-18, 1968 SURVEY

STATION Name	River Mileage	TURBIDITY Units 8-Day	TURBIDITY Units 2-Day	TOTAL SUSP. SOLIDS mg/l 8-Day	TOTAL SUSP. SOLIDS mg/l 2-Day	TOTAL DISSOL. SOLIDS mg/l 8-Day	TOTAL DISSOL. SOLIDS mg/l 2-Day	SPEC. CONDUC. µmhos/cm at 25°C. 8-Day	SPEC. CONDUC. µmhos/cm at 25°C. 2-Day	CHLORIDE mg/l 8-Day	CHLORIDE mg/l 2-Day	SULFATE mg/l 8-Day	SULFATE mg/l 2-Day
MISSOURI RIVER:													
Gavins Pt. Dam	811.0	14 2/	-	45 2/	-	474 2/	-	800 2/	-	12 2/	-	208 2/	-
M-52	736.0	22	30	55	-	471	-	800	750	11	13	203	212
M-50	730.0	21	34	62	87	484	497	820	880	12	14	214	245
M-48	717.4	24	48	44	147	494	365	790	720	12	14	209	188
M-47	699.5	24	46	61	114	552	341	800	730	11	15	191	245
M-46	676.5	24	39	58	102	496	398	790	740	12	13	210	212
M-44	654.6	44	255	155	715	533	287	790	720	12	19	199	188
M-42	626.2	36	231	91	1020	532	330	800	680	13	13	185	182
M-41	618.3	47	245	120	740	540	326	790	710	12	17	180	158
M-39	610.5	39	250	95	850	478	469	790	680	13	17	216	172
M-38	601.3	37	350	95	998	493	313	790	770	16	17	210	170
M-36	591.2	46	300	136	1100	485	327	790	770	15	18	187	198
M-35	580.9	50	325	185	1340	490	-	790	640	15	18	172	330
M-34	559.7	67	470	220	1610	493	500	790	640	19	27	164	185
M-33	546.7	114	440	238	1780	482	-	780	650	17	27	187	180
M-32	525.1	59	492	278	1120	645	245	780	660	20	32	220	128
M-31	507.5	64	560	142	1310	480	516	800	640	18	28	209	-
M-30	488.3	52	810	110	1480	512	449	700	600	22	16	194	162
M-29	469.0	46	985	123	2550	468	312	790	580	21	21	166	145
M-28	452.3	48	1120	131	2780	472	198	780	600	17	20	170	165
M-27	440.3	47	1120	142	2890	458	174	780	600	17	21	186	130
TRIBUTARIES:5/													
BS-51	734.0	20	30	55	71	547	422	1040	900	45	52	169	142
S-45 3/	664.0	6	1670	10	3530	423	3670	660	340	13	13	40	26
B-43	635.1	245	1850	729	999	392	2860	700	400	45	22	78	37
PA-37A 4/	596.5	-	-	-	-	-	-	-	-	-	-	-	-
P-37	594.8	175	538	763	-	504	-	810	620	69	69	68	72
WASTE SOURCES:5/													
SC-49	729.0	61	94	109	170	1330	1020	2230	1900	243	300	236	140
OM-40 3/	611.5	178	297	891	840	1650	1690	2370	2110	481	499	234	188
CB-40B	614	-	-	-	-	-	-	-	-	-	-	-	-

1/ 8-day average is for typical Fall weather, where total precipitation was 0.46" in Omaha; 2-day average is for extremely wet weather, where precipitation was 3.61.
2/ Average of two 5-day composite samples (Gavins Pt. Dam only).
3/ Averages for 7 days of typical Fall and 3 days of extremely wet weather.
4/ Average for 3 days of extremely wet weather.
5/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-2

Summary of Averages for Discrete Samples
MISSOURI RIVER
OCTOBER 28-NOVEMBER 8, 1968 SURVEY

STATION Name	River Mileage	TEMPERATURE °C	DISSOLVED OXYGEN mg/l	2-DAY BOD mg/l	5-DAY BOD mg/l	pH Units	ALKALINITY as $CaCO_3$ mg/l	HARDNESS as $CaCO_3$ mg/l
MISSOURI RIVER:								
M-27	440.3	9	9.8	1.5	3.0	8.2	179	257
M-26[1]	422.6	10	9.7	1.4	2.6	8.2	181	248
M-25.5[2]	418.0	9	9.6	1.6	3.2	8.2	179	263
M-25	397.4	9	9.5	1.4	3.0	8.2	179	248
M-24	384.9	10	9.6	1.5	3.0	8.3	186	258
M-23	370.5	9	9.7	1.5	2.9	8.2	179	261
M-21	365.6	10	9.6	1.7	3.5	8.2	180	243
M-20	359.3	10	9.7	1.4	2.7	8.2	181	242
M-18	345.4	10	9.4	1.4	3.0	8.2	180	243
M-17	334.5	10	9.4	1.5	2.7	8.2	181	242
M-16	313.2	10	9.2	1.3	2.8	8.2	181	246
M-15	293.4	10	9.3	1.3	2.6	8.2	180	244
M-14	270.0	10	9.4	1.0	2.2	8.2	176	244
M-12	241.2	10	9.5	0.9	2.1	8.2	177	237
M-10	235.1	10	9.5	1.0	1.8	8.2	174	239
M- 9	221.0	10	9.6	0.9	1.7	8.2	174	241
M- 8	197.2	10	9.5	1.3	2.4	8.1	174	242
M- 7	179.0	10	9.5	1.4	2.4	8.2	174	250
M- 6	162.0	10	9.6	1.2	2.4	8.2	174	254
M- 5	139.0	10	9.6	1.2	2.4	8.2	174	239
M- 3	118.0	12	9.7	2.4	4.1	8.2	161	208
M- 1	98.0	12	9.8	1.9	3.5	8.1	162	210
TRIBUTARIES:[3]								
KR-22	367.4	11	9.6	1.6	3.1	8.2	182	213
GR-13	250.0	11	9.3	1.9	3.3	8.1	182	193
C-11	238.8	9	10.4	1.8	3.4	8.2	168	196
O-4	130.0	13	9.4	1.0	1.6	8.1	112	154
G-2	104.4	12	9.7	2.0	3.2	8.2	167	179
WASTE SOURCES:[3]								
K-19A[2]	367.20	19	-	147	277	7.6	301	292
K-19[1]	356.9	-	-	127	171	7.2	188	229

TABLE NO. B-2
(contd)

Summary of Averages for Discrete Samples
MISSOURI RIVER
OCTOBER 28-NOVEMBER 8, 1968 SURVEY

STATION Name	River Mileage	TURBIDITY Units	TOTAL SUSP. SOLIDS mg/l	TOTAL DISSOL. SOLIDS mg/l	SPEC. CONDUC. µmhos/cm at 25°C.	CHLORIDE mg/l	SULFATE mg/l
MISSOURI RIVER:							
M-27	440.3	55	161	485	7[illegible]0	17	174
M-26 1/	422.6	61	200	490	710	16	203
M-25.5 2/	418.0	53	141	496	720	16	192
M-25	397.4	58	165	494	710	16	194
M-24	384.9	60	165	504	7[illegible]0	16	201
M-23	370.5	61	173	497	710	17	198
M-21	365.6	102	202	464	670	20	176
M-20	359.3	86	204	468	680	18	190
M-18	345.4	99	194	471	680	19	190
M-17	334.5	100	188	469	680	18	186
M-16	313.2	101	214	459	680	19	179
M-15	293.4	103	213	452	670	18	188
M-14	270.0	71	229	466	680	19	154
M-12	241.2	74	227	466	680	19	156
M-10	235.1	73	238	445	670	19	153
M- 9	221.0	72	215	458	690	19	154
M- 8	197.2	75	276	448	680	19	152
M- 7	179.0	79	257	446	680	19	150
M- 6	162.0	81	297	434	670	19	152
M- 5	139.0	81	265	449	660	19	152
M- 3	118.0	68	250	373	580	17	122
M- 1	98.0	78	241	375	570	16	113
TRIBUTARIES: 3/							
KR-22	367.4	135	284	312	500	29	103
GR-13	250.0	31	59	266	450	12	41
C-11	238.8	36	54	285	470	10	63
O- 4	130.0	28	55	174	390	5	22
G- 2	104.4	34	66	194	330	4	5
WASTE SOURCES: 3/							
K-19A 2/	367.20	87	265	741	1260	123	241
K-19 1/	356.9	64	87	656	940	85	229

1/ Result for 5 discrete samples, 10/28 - 11/1/68.
2/ Result for 5 discrete samples, 11/4 - 11/8/68.
3/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-3

Summary of Averages for Discrete Samples
MISSOURI RIVER
January 20-February 2, 1969

STATION Name	River Mileage	TEMPERATURE °C	DISSOLVED OXYGEN mg/1	2-DAY BOD mg/1	5-DAY BOD mg/1	pH Units	ALKALINITY Ca CO_3 mg/1
MISSOURI RIVER:							
Gavins Pt. Dam 1/	811.0	-	-	-	-	-	-
M-52A	732.8	0	12.7	0.4	1.1	8.1	175
M-48A	718.3	0	12.6	0.8	1.6	8.1	174
M-47	699.5	0	12.7	1.0	2.0	8.1	176
M-42	626.2	0	13.2	0.8	1.4	8.1	192
M-38	601.3	0	12.8	2.2	3.6	8.1	187
M-35	580.9	0	12.5	1.7	2.7	8.0	188
M-34	559.7	0	10.6	1.1	1.9	8.0	185
M-32	525.1	0	9.4	1.1	2.2	7.9	182
M-30 2/	488.3	2	9.1	1.7	3.4	7.8	165
M-28	452.3	2	9.6	1.5	3.0	7.8	174
M-27	440.3	2	10.0	1.3	2.9	7.8	175
M-26A	422.5	2	10.3	1.6	3.5	7.8	176
M-23	370.5	0	11.0	2.2	4.0	8.0	174
M-20A	358.3	0	11.2	2.7	5.1	7.9	181
M-18	345.4	0	11.3	2.1	4.3	7.9	183
M-17	334.5	0	11.2	3.1	5.4	7.9	183
M-15	293.4	0	11.2	2.7	5.3	7.9	186
M-14	270.0	0	11.3	2.5	5.1	7.9	179
M-12	241.2	0	11.2	2.8	5.0	7.8	178
M-9A	219.2	0	10.7	3.2	> 5.5	7.7	144
M-7A	174.8	0	11.0	3.0	> 5.6	7.6	132
M-5A	132.0	0	10.7	7.7	> 10.9	7.6	136
M-1	98.0	1	11.8	2.3	4.3	7.7	116
TRIBUTARIES: 3/							
PA-37A	596.5	1	3.9	41	84	7.8	289
P-37	594.8	0	10.0	1.1	2.1	7.9	181
WASTE SOURCES: 3/							
SC-49	729.0	17	-	207	340	7.6	472
CB-40B 4/	.614	-	-	172	335	7.3	213
OM-40A 2/	611.5	-	-	162	256	7.9	208
K-19B 4/	367.19	-	-	71	123	7.4	158
K-19 2/	356.9	-	-	88	136	7.4	206

TABLE NO. B-3
(contd)

Summary of Averages for Discrete Samples
MISSOURI RIVER
January 20-February 2, 1969

STATION Name	River Mileage	TURBIDITY Units	TOTAL SUSP. SOLIDS mg/l	TOTAL DISSOL. SOLIDS mg/l	SPEC. CONDUC. µmhos/cm at 25°C.	CHLORIDE mg/l	SULFATE mg/l
MISSOURI RIVER:							
Gavins Pt. Dam 1/	811.0	1.5	1.5	518	-	11	206
M-52A	732.8	19	48	546	800	12	214
M-48A	718.3	10	23	553	810	13	213
M-47	699.5	9	18	554	8[illegible]	14	213
M-42	626.2	9	25	629	860	15	224
M-38	601.3	8	17	570	810	16	221
M-35	580.9	8	17	653	790	18	206
M-34	559.7	7	12	525	760	25	175
M-32	525.1	6	9	527	750	22	173
M-30 2/	488.3	17	27	486	710	22	170
M-28	452.3	12	28	510	740	23	177
M-27	440.3	12	29	517	730	23	179
M-26A	422.5	16	42	506	740	23	175
M-23	370.5	29	73	485	730	22	185
M-20A	358.3	35	91	489	730	25	178
M-18	345.4	41	115	491	720	26	162
M-17	334.5	44	102	494	730	27	173
M-15	293.4	60	141	496	7[illegible]0	27	181
M-14	270.0	70	233	480	710	28	173
M-12	241.2	66	197	489	680	26	150
M-9A	219.2	144	423	403	560	20	120
M-7A	174.8	211	596	337	480	17	95
M-5A	132.0	219	543	371	520	19	109
M-1	98.0	138	331	254	360	9	55
TRIBUTARIES: 3/							
PA-37A	596.5	41	100	646	1000	106	80
P-37	594.8	16	32	455	700	56	81
WASTE SOURCES: 3/							
SC-49	729.0	55	130	1482	2270	334	200
CB-40B 4/	614	55	99	908	1370	113	242
OM-40A 2/	611.5	52	91	1132	1650	291	238
K-19B 4/	367.19	40	58	1428	2290	538	232
K-19 2/	356.9	50	78	836	1230	145	217

1/ Result for the average of two 5-day composite samples.
2/ Result for five discrete samples, 1/20 - 1/24/69.
3/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.
4/ Result for five discrete samples, 1/27 - 1/31/69.

TABLE NO. B-4

Summary of Bacterial Densities

MISSOURI RIVER
October 7-18, 1968 Survey

STATION Name	River Mileage	Time-of-Water Travel Hours 5/	TOTAL COLIFORM BACTERIA MPN/100 ml Normal 8-Day Mean	Upper 80% Conf. Limit	Lower 80% Conf. Limit	Wet 2-Day Mean	FECAL COLIFORM BACTERIA MPN/100 ml Normal 8-Day Mean	Upper 80% Conf. Limit	Lower 80% Conf. Limit	Wet 2-Day Mean	FECAL COLIFORM BACTERIA as a % of TOTAL COLIFORM BACTERIA Normal 8-Day	Wet 2-Day
MISSOURI RIVER:												
Gavins Pt. Dam	811.0	-	250 1/	-	-	-	< 125 1/	-	-	-	< 50.0	-
M-52	736.0	- 1.6	1,380	3,940	490	74,800	220	710	70	30,300	15.9	40.5
M-50	730.0	0.5	2,420	6,050	970	74,800	240	1,080	60	47,000	9.9	62.8
M-48	717.4	5.2	62,800	224,400	17,600	265,000	14,300	48,900	4,210	116,000	22.8	43.8
M-47	699.5	11.3	57,100	197,200	16,500	230,000	26,600	109,500	6,460	108,000	46.6	47.0
M-46	676.5	18.8	53,000	178,000	15,800	213,000	18,900	77,900	4,590	149,000	35.7	70.0
M-44	654.6	25.2	39,500	91,400	17,100	852,000	9,030	50,600	1,610	278,000	22.9	32.6
M-42	626.2	34.7	52,300	192,900	14,200	414,000	8,320	34,100	2,030	207,000	15.9	50.0
M-41	618.3	37.3	46,600	223,100	9,750	802,000	11,200	34,600	3,630	207,000	24.0	25.8
M-39	610.5	39.3	256,400	708,000	92,800	330,000	61,200	164,600	22,800	230,000	23.9	69.7
M-38	601.3	41.6	165,200	421,800	64,700	460,000	45,200	96,400	21,200	330,000	27.4	71.7
M-36	591.2	44.2	174,200	306,200	99,100	790,000	53,500	107,600	26,600	490,000	30.7	62.0
M-35	580.9	47.3	130,400	495,600	34,300	790,000	38,400	104,100	14,200	330,000	29.4	41.8
M-34	559.7	53.8	166,800	474,400	58,600	1,440,000	50,800	150,000	17,200	1,120,000	30.4	77.8
M-33	546.7	57.7	189,400	377,600	94,900	> 727,000	38,500	82,400	18,000	460,000	20.3	< 63.3
M-32	525.1	64.7	100,400	232,900	43,300	767,000	19,000	50,400	7,130	352,000	18.9	45.9
M-31	507.5	70.6	133,800	294,500	60,800	838,000	28,000	70,200	11,200	435,000	21.0	51.9
M-30	488.3	77.1	154,400	614,000	38,800	-	28,400	128,100	6,310	-	18.4	-
M-29	469.0	83.9	147,800	392,700	55,600	-	14,600	73,400	2,900	-	9.9	-
M-28	452.3	89.8	57,700	252,900	13,200	852,000	6,480	26,900	1,560	232,000	11.2	27.2
M-27	440.3	93.6	65,300	168,900	25,300	790,000	11,800	26,200	5,320	330,000	18.1	41.8
TRIBUTARIES:												
BS-51	734.0	- 0.8	1,130	6,730	190	17,000	110	440	30	4,000	9.7	23.5
S-45	664.0	22.5	14,700	96,100	2,250	2,400,000	4,000	63,100	240	2,000,000	27.2	83.3
B-43	635.1	31.6	114,400	1,011,000	12,900	> 2,000,000	20,500	376,700	1,110	1,500,000	17.9	< 75.0
PA-37A	596.5	43.0	-	-	-	16,000,000 2/	-	-	-	11,000,000 2/	-	68.8
P-37	594.8	43.3	27,700	259,800	2,950	620,000	11,200	82,700	1,500	290,000	40.4	46.8
WASTE SOURCES: 4/												
SC-49	729.0	0.7	75,200,000	151,500,000	37,300,000	49,000,000	20,200,000	53,300,000	7,680,000	49,000,000	26.9	100.0
CB-40B	614.0	38.4	160,000,000 3/	-	-	-	35,000,000 3/	-	-	-	21.9	-
OM-40	611.5	39.1	18,600,000	42,500,000	8,160,000	30,000,000	7,760,000	19,400,000	3,100,000	11,000,000	41.7	36.7

1/ Average of two discrete samples.
2/ Average for 3 samples which were influenced by extremely wet weather.
3/ Single sample during normal weather period.
4/ River Mileage refers to point where tributary or waste source enters Missouri River.
Samples were collected on tributary or waste source upstream from confluence.
5/ Time-of-water travel from USGS Gage at Sioux City, Iowa.

TABLE NO. B-5

Summary of Bacterial Densities

MISSOURI RIVER
October 28-November 8, 1968 Survey

STATION		Time-of-Water[4/]	TOTAL COLIFORM BACTERIA MPN/100 ml			FECAL COLIFORM BACTERIA MPN/100 ml			Fecal Coliform Bacteria as a % of
Name	River Mileage	Travel Hours	Geom. Mean	Upper 80% Conf. Limit	Lower 80% Conf. Limit	Geom. Mean	Upper 80% Conf. Limit	Lower 80% Conf. Limit	Total Coliform Bacteria
MISSOURI RIVER:									
M-27	440.3	2.3	67,000	183,400	24,700	8,100	19,400	3,390	12.1
M-26[1/]	422.6	7.7	37,000	51,900	27,000	11,000	18,400	6,270	29.7
M-25.5[2/]	418.0	9.3	65,000	125,900	33,600	7,300	21,400	2,510	11.2
M-25	397.4	16.3	82,000	164,000	41,100	11,000	25,100	4,440	13.4
M-24	384.9	20.4	64,000	124,200	33,300	7,500	13,500	4,220	11.7
M-23	370.5	25.2	77,000	208,300	28,500	6,500	12,900	3,300	8.4
M-21	365.6	26.6	88,000	151,000	51,300	14,000	33,300	5,780	15.9
M-20	359.3	28.8	79,000	169,800	36,900	19,000	74,200	4,760	24.0
M-18	345.4	33.5	189,000	537,300	66,700	15,000	33,200	7,220	7.9
M-17	334.5	37.3	150,000	382,700	57,200	18,000	29,500	10,600	12.0
M-16	313.2	44.7	119,000	412,100	34,200	18,000	35,800	9,170	15.1
M-15	293.4	51.6	77,000	173,600	34,100	10,000	24,400	4,280	13.0
M-14	270.0	60.2	119,000	221,900	64,200	15,000	55,100	4,200	12.6
M-12	241.2	71.1	88,000	140,900	54,600	10,000	25,400	4,260	11.4
M-10	235.1	73.5	67,000	149,600	30,000	12,000	28,000	5,570	17.9
M- 9	221.0	78.7	80,000	206,300	31,200	8,900	29,200	2,700	11.1
M- 8	197.2	88.1	65,000	106,700	39,800	7,000	12,800	3,800	10.8
M- 7	179.0	94.4	39,000	72,800	20,700	5,700	23,900	1,350	14.6
M- 6	162.0	100.4	44,000	104,900	18,200	5,000	12,400	2,000	11.4
M- 5	139.0	108.5	41,000	87,500	19,500	5,400	12,700	2,300	13.2
M- 3	118.0	116.4	36,000	64,400	20,400	4,700	13,700	1,580	13.1
M- 1	98.0	124.7	15,000	35,000	6,100	3,800	9,250	1,570	25.3
TRIBUTARIES:[3/]									
KR-22	367.4	26.2	116,000	315,200	42,900	6,800	12,600	3,700	5.9
GR-13	250.0	67.8	4,000	36,900	430	< 460	< 6,470	< 30	< 11.5
C-11	238.8	71.9	> 10,700	> 110,600	> 1,030	2,340	22,400	240	< 21.9
O- 4	130.0	112.1	5,000	61,300	410	1,100	14,500	80	22.0
G- 2	104.4	121.5	2,600	39,300	170	570	10,700	30	21.9
WASTE SOURCES:[3/]									
K-19A	367.2	26.2	46,000,000	88,200,000	24,400,000	9,700,000	21,300,000	4,390,000	21.1
K-19	356.9	29.6	46,000,000	59,000,000	36,100,000	4,500,000	7,360,000	2,810,000	9.8

1/ Results for five discrete samples, 10/28 - 11/1/68.
2/ Results for five discrete samples, 11/4 - 11/8/68.
3/ River Mileage refers to point where tributary or waste source enters the Missouri River. Samples were collected on tributary or waste source upstream from confluence.
4/ Time-of-water travel from USGS Gage at St. Joseph, Missouri.

TABLE NO. B-6

Summary of Bacterial Densities

MISSOURI RIVER
January 20-February 2, 1969 Survey

STATION Name	River Mileage	TOTAL COLIFORM BACTERIA MPN/100 ml Geom. Mean	Upper 80% Conf.Limit	Lower 80% Conf.Limit	FECAL COLIFORM BACTERIA MPN/100 ml Geom. Mean	Upper 80% Conf.Limit	Lower 80% Conf.Limit	FECAL STREPTOCOCCI BACTERIA MPN/100 ml Geom. Mean	Upper 80% Conf.Limit	Lower 80% Conf.Limit	Fecal Coli. Bact. as a % of Tot. Coli. Bact.	RATIO Fecal Coli. Bact. / Fecal Strep. Bact.
MISSOURI RIVER:												
Gavins Pt. Dam 1/	811.0	< 30	-	-	< 20	-	-	20	-	-	-	-
M-52A	732.8	1,040	2,200	500	320	550	180	220	470	100	30.8	1.45
M-48A	718.3	44,300	98,900	19,800	11,200	32,900	3,780	16,500	56,600	4,800	25.3	0.68
M-47	699.5	39,000	98,200	15,400	15,300	58,800	3,990	31,700	124,800	8,030	39.2	0.48
M-42	626.2	10,100	88,300	1,160	4,910	29,600	810	5,920	53,700	650	48.6	0.83
M-38	601.3	53,800	125,400	23,100	14,200	34,800	5,830	61,100	119,500	31,200	26.4	0.23
M-35	580.9	45,100	113,900	17,800	19,100	45,900	7,950	37,700	105,400	13,500	42.4	0.51
M-34	559.7	21,600	41,600	11,200	9,510	21,800	4,150	16,300	43,300	6,130	44.0	0.58
M-32	525.1	7,280	37,300	1,420	1,930	7,600	520	5,940	47,400	740	27.2	0.33
M-30 2/	488.3	95,200	161,600	56,100	5,830	18,300	1,860	17,300	51,500	5,840	6.1	0.34
M-28	452.3	15,800	158,800	1,580	2,830	15,900	500	5,590	57,200	550	17.9	0.51
M-27	440.3	17,300	201,400	1,480	3,760	22,800	620	5,960	46,800	760	21.7	0.63
M-26A	422.5	51,500	177,900	14,900	18,900	41,600	8,600	16,600	53,400	5,170	36.7	1.14
M-23	370.5	37,400	251,200	5,560	8,320	36,000	1,920	15,000	69,500	3,220	22.2	0.55
M-20A	358.3	136,500	374,700	49,700	18,600	56,700	6,100	22,000	73,800	6,530	13.6	0.84
M-18	345.4	87,400	297,400	25,700	24,200	94,900	6,190	25,700	95,300	6,920	27.7	0.94
M-17	334.5	128,000	477,700	34,300	23,900	56,600	10,100	26,600	69,100	10,200	18.7	0.90
M-15	293.4	150,300	342,500	66,000	19,500	43,000	8,870	20,900	69,300	6,300	13.0	0.93
M-14	270.0	140,500	942,300	20,900	19,700	94,500	4,110	18,500	62,600	5,450	14.0	1.06
M-12	241.2	87,300	323,600	23,600	5,560	13,600	2,280	11,200	42,500	2,950	6.4	0.50
M-9A	219.2	70,000	285,400	17,200	7,520	15,600	3,620	16,200	72,200	3,640	10.7	0.46
M-7A	174.8	129,500	736,100	22,800	5,970	16,300	2,190	35,000	142,400	8,590	4.6	0.17
M-5A	132.0	73,400	191,500	28,200	4,700	12,900.	1,710	20,900	76,600	5,730	6.4	0.22
M-1	98.0	42,800	110,200	16,600	3,380	6,290	1,820	15,900	64,600	3,940	7.9	0.21
TRIBUTARIES: 3/												
PA-37A	596.5	4,040,000	9,570,000	1,710,000	591,200	1,130,000	310,100	534,200	1,570,000	182,100	14.6	1.11
P-37	594.8	36,000	143,600	9,000	18,700	60,600	5,750	8,060	63,900	1,020	51.9	2.32
WASTE SOURCES: 3/												
SC-49	729.0	19,460,000	57,930,000	6,540,000	5,150,000	20,000,000	1,330,000	8,760,000	37,670,000	2,040,000	26.5	0.59
CB-40B 4/	614.0	22,540,000	42,190,000	12,040,000	4,330,000	9,630,000	1,950,000	1,320,000	2,930,000	597,000	19.2	3.28
OM-40A 2/	611.5	11,180,000	33,730,000	3,700,000	3,000,000	14,990,000	600,300	16,650,000	62,120,000	4,460,000	26.8	0.18
K-19B 4/	367.2	8,940,000	26,630,000	3,000,000	2,760,000	5,220,000	1,460,000	5,050,000	11,310,000	2,260,000	30.9	0.55
K-19 2/	356.9	40,440,000	111,980,000	14,610,000	7,930,000	12,340,000	5,100,000	7,880,000	49,790,000	1,750,000	19.6	1.01

1/ Result for two discrete samples, 1/24 and 1/31/69.
2/ Result for 5 discrete samples, 1/20 - 1/24/69.
3/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.
4/ Results for 5 discrete samples, 1/27 - 1/31/69.

TABLE NO. B-7

Summary of 5-Day Composite Samples

MISSOURI RIVER
October 7-18, 1968 Survey

STATION Name	River Mileage	TOT. PHOSPHORUS mg/l Normal 5-Day	TOT. PHOSPHORUS mg/l Wet 5-Day	NH_3 as N mg/l Normal 5-Day	NH_3 as N mg/l Wet 5-Day	NO_3 as N mg/l Normal 5-Day	NO_3 as N mg/l Wet 5-Day	ORG. N as N mg/l Normal 5-Day	ORG. N as N mg/l Wet 5-Day	TOT. NITROGEN mg/l Normal 5-Day	TOT. NITROGEN mg/l Wet 5-Day	TOT. ORG. CARBON mg/l Normal 5-Day	TOT. ORG. CARBON mg/l Wet 5-Day	Ca mg/l Avg. of Two 5-Day Samples	Mg mg/l Avg. of Two 5-Day Samples
MISSOURI RIVER:															
Gavins Pt. Dam 1/	811.0	0.04	0.03	0.08	0.06	0.2	0.3	0.4	0.2	0.7	0.6	5	6	66 1/	21 1/
M-52	736.0	0.05	0.07	0.09	0.12	0.2	0.4	1.2	0.4	1.5	0.9	5	5	69	20
M-50	730.0	0.07	0.11	0.20	0.16	0.2	0.2	1.0	0.4	1.4	0.8	6	6	70	20
M-48	717.4	0.07	0.11	< 0.01	0.20	0.2	0.2	0.7	0.6	0.9	1.0	135	7	70	20
M-47	699.5	0.06	0.15	0.20	0.28	0.2	0.3	0.8	0.6	1.2	1.2	6	7	68	22
M-46	676.5	0.07	0.12	0.15	0.18	0.2	0.2	0.9	0.7	1.2	1.1	6	5	67	20
M-44	654.6	0.08	0.54	0.24	0.27	0.3	0.4	0.6	1.5	1.1	2.2	5	13	68	22
M-42	626.2	0.12	0.49	0.07	0.19	0.3	0.4	0.9	1.3	1.3	1.9	6	10	65	20
M-41	618.3	0.20	0.40	0.12	0.17	0.3	0.4	0.8	2.0	1.2	2.6	8	9	92	6
M-39	610.5	0.24	0.37	0.17	0.22	0.3	0.4	0.8	1.5	1.3	2.1	8	10	68	20
M-38	601.3	0.20	0.35	0.09	0.15	0.3	0.4	0.9	1.1	1.3	1.6	7	10	68	20
M-36	591.2	0.30	0.35	0.07	0.47	0.4	0.4	1.0	1.5	1.5	2.4	9	11	63	22
M-35	580.9	0.29	0.38	0.14	0.52	0.3	0.4	1.2	1.1	1.6	2.0	9	10	70	23
M-34	559.7	0.25	0.70	0.19	0.51	0.3	0.6	1.0	2.9	1.5	4.0	8	21	68	20
M-33	546.7	0.27	0.73	0.13	1.13	0.4	0.6	1.4	2.2	1.9	3.9	9	18	70	20
M-32	525.1	0.28	0.60	0.13	1.55	0.3	0.5	1.9	1.9	2.3	4.0	8	16	66	22
M-31	507.5	0.27	0.58	0.14	0.18	0.4	0.6	1.5	1.8	2.0	2.6	7	16	66	22
M-30	488.3	0.26	0.73	0.25	0.26	0.3	0.7	1.0	2.0	1.6	3.0	9	19	68	22
M-29	469.0	0.33	0.92	0.17	0.28	0.3	1.0	1.1	2.8	1.6	4.1	9	24	68	21
M-28	452.3	0.26	0.60	0.18	0.21	0.4	0.7	2.3	1.6	2.9	2.5	7	16	69	20
M-27	440.3	0.25	0.56	0.19	0.27	0.4	0.6	2.7	1.3	3.3	2.2	8	14	72	19
TRIBUTARIES: 2/															
BS-51	734.0	0.29	0.32	0.39	0.62	0.2	1.3	1.9	1.2	2.5	3.1	13	9	94	37
S-45	664.0	0.17	3.00	0.10	0.72	0.5	1.6	0.7	7.4	1.3	9.7	5	56	72	32
B-43	635.1	2.10	2.85	0.64	0.52	3.0	3.5	5.7	4.9	9.3	8.9	40	37	72	36
PA-37A	596.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P-37	594.8	0.80	1.50	0.43	0.59	0.5	0.5	2.1	3.4	3.0	4.5	19	23	61	11
WASTE SOURCES: 2/															
SC-49	729.0	10.6	9.60	66.80	60.00	< 0.1	< 0.1	12.0	13.7	78.8	73.8	97	82	113	34
OM-40	611.5	11.4	12.0	36.8	39.8	0.5	< 0.1	30.0	160	67.2	199.8	212	278	70	21
CB-40B	614	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ 5-Day Composite for typical Fall weather period 10/7-11/68.
2/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-8

Average of Two 5-Day Composite Samples

MISSOURI RIVER
October 28-November 8, 1968 Survey

STATION Name	River Mileage	TOTAL PHOSPHORUS as P mg/l	NH_3 as N mg/l	NO_3 as N mg/l	ORGANIC N as N mg/l	TOTAL NITROGEN mg/l	TOTAL ORGANIC CARBON mg/l	Ca mg/l	Mg mg/l
MISSOURI RIVER:									
M-27	440.3	0.25	0.16	1.0	0.6	1.8	9	-	-
M-26 1/	422.6	0.22	< 0.01	1.4	0.5	1.9	8	-	-
M-25.5 2/	418.0	0.25	0.11	1.0	0.6	1.7	9	-	-
M-25	397.4	0.27	0.12	1.1	0.8	2.0	9	-	-
M-24	384.9	0.31	0.12	1.0	0.6	1.7	8	69	21
M-23	370.5	0.32	0.12	1.1	0.6	1.8	9	72	20
M-21	365.6	0.62	0.19	1.0	0.9	2.1	10	67	18
M-20	359.3	0.32	0.20	1.1	0.8	2.1	10	67	18
M-18	345.4	0.36	0.23	1.1	0.7	2.0	11	68	22
M-17	334.5	0.34	0.24	1.2	0.8	2.2	10	-	-
M-16	313.2	0.35	0.26	1.2	0.7	2.2	9	-	-
M-15	293.4	0.36	0.22	1.2	0.8	2.2	10	-	-
M-14	270.0	0.34	0.12	1.2	0.7	2.0	9	66	20
M-12	241.2	0.31	0.12	1.2	0.9	2.2	8	66	18
M-10	235.1	0.38	0.10	1.3	0.9	2.3	10	64	19
M- 9	221.0	0.40	0.10	1.3	0.8	2.2	9	63	20
M- 8	197.2	0.40	0.16	1.3	0.8	2.3	10	66	18
M- 7	179.0	0.38	0.16	1.2	1.7	3.1	9	71	18
M- 6	162.0	0.38	0.16	1.2	0.9	2.3	8	62	20
M- 5	139.0	0.38	0.14	0.8	0.8	1.7	9	64	18
M- 3	118.0	0.30	0.09	1.0	0.8	1.9	8	56	16
M- 1	98.0	0.30	0.10	1.0	0.8	1.9	10	56	17
TRIBUTARIES: 3/									
KR-22	367.4	0.46	0.23	1.2	0.8	2.2	11	-	-
GR-13	250.0	0.16	0.05	< 0.1	0.32	0.5	8	60	10
C-11	238.8	0.22	0.09	0.2	0.6	0.9	9	59	12
O- 4	130.0	0.08	0.10	0.4	0.4	0.90	6	46	10
G- 2	104.4	0.11	0.04	0.2	0.4	0.64	5	38	20
WASTE SOURCES: 3/									
K-19A 2/	367.20	12.0	33.0	1.2	9.5	43.7	82	-	-
K-19 1/	356.9	9.75	26.2	< 0.1	6.2	32.6	49	-	-

1/ Result of one 5-Day Composite for 10/28 - 11/1/68.
2/ Result of one 5-Day Composite for 11/4 - 11/8/68.
3/ River Mileage refers to point where tributary or waste source enters Missouri River.
Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-9

Average of Two 5-Day Composite Samples

MISSOURI RIVER
January 20-February 2, 1969 Survey

STATION Name	River Mileage	TOTAL PHOSPHORUS as P mg/l	NH_3 as N mg/l	NO_3 as N mg/l	ORGANIC N as N mg/l	TOTAL NITROGEN mg/l	TOTAL ORGANIC CARBON mg/l	SPECIFIC CONDUC. µmhos/cm at 25° C.	Ca mg/l	Mg mg/l
MISSOURI RIVER:										
Gavins Pt. Dam	811.0	-	-	-	-	-	-	700	40	21
M-52A	732.8	0.04	0.14	0.4	1.2	1.8	5	800	41	23
M-48A	718.3	0.06	0.87	0.6	0.6	2.2	4	790	40	23
M-47	699.5	0.05	0.37	0.4	0.6	1.3	4	780	40	23
M-42	626.2	0.06	0.34	0.4	0.8	1.4	6	860	44	25
M-38	601.3	0.10	0.40	0.6	0.6	1.6	6	790	42	24
M-35	580.9	0.13	0.48	0.4	0.6	1.6	6	800	42	24
M-34	559.7	0.19	0.63	0.6	0.6	1.8	4	750	40	20
M-32	525.1	0.18	0.75	0.6	0.7	2.0	6	750	40	21
M-30 1/	488.3	0.20	0.75	0.5	0.8	2.1	6	690	38	19
M-28	452.3	0.30	0.81	0.6	0.8	2.2	6	720	41	20
M-27	440.3	0.20	0.78	0.4	0.8	2.0	6	710	41	20
M-26A	422.5	0.22	0.82	0.7	0.8	2.4	7	720	39	20
M-23	370.5	0.24	0.75	0.7	0.9	2.4	7	700	40	19
M-20A	358.3	0.30	0.87	0.6	1.2	2.7	8	710	41	19
M-18	345.4	0.28	0.82	0.9	1.0	2.8	8	710	40	19
M-17	334.5	0.32	0.80	0.8	1.2	2.7	8	700	40	19
M-15	293.4	0.52	0.94	0.8	1.6	3.3	12	700	40	19
M-14	270.0	0.40	0.82	0.7	1.1	2.6	9	700	40	19
M-12	241.2	0.36	0.78	0.8	1.2	2.8	10	690	37	19
M- 9A	219.2	0.44	0.74	0.9	1.6	3.3	12	550	30	16
M- 7A	174.8	0.54	0.60	0.8	1.8	3.1	13	490	25	14
M- 5A	132.0	0.56	0.64	0.7	1.8	3.2	16	520	26	15
M- 1	98.0	0.34	0.31	0.8	1.4	2.4	10	360	23	14
TRIBUTARIES: 2/										
PA-37A	596.5	6.45	27.0	1.0	3.8	31.8	22	990	43	22
P-37	594.8	0.32	0.41	0.8	0.6	1.9	5	690	26	14
WASTE SOURCES: 2/										
SC-49	729.0	14.2	59.2	< 0.01	14	73.2	65	2,280	52	36
CB-40B 3/	614	16.5	45.0	0.03	12	57.0	61	1,320	18	12
OM-40A 1/	611.5	6.90	20.2	0.7	5.9	26.8	30	1,580	38	22
K-19B 3/	367.19	5.55	19.5	0.3	4.6	24.4	28	2,360	42	10
K-19 1/	356.9	8.70	25.5	0.07	4.8	30.4	31	1,220	45	14

1/ Result of one 5-Day Composite for 1/20 - 1/24/69.
2/ Result of one 5-Day Composite for 1/27 - 1/31/69.
3/ River Mileage refers to point where tributary or waste source enters Missouri River.
Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-10

Summary of Soluble Metals
Average of Two 5-Day Composite Samples

MISSOURI RIVER
October 7-18, 1968 Survey

STATION Name	River Mileage	Ba mg/l	Cd mg/l	Fe mg/l	Mn mg/l	Cr mg/l	As mg/l	Cu mg/l	Pb mg/l	Ni mg/l	Zn mg/l	B mg/l	Na mg/l	K mg/l	F mg/l
MISSOURI RIVER:															
Gavins Pt. Dam	811.0	< 1.0 1/	< 0.02 1/	< 0.30 1/	< 0.05 1/	< 0.05 1/	< 0.01	< 0.05 1/	< 0.05 1/	< 0.10 1/	< 0.05 1/	0.1[illegible]	-	-	-
M-52	736.0	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	0.06	0.11	15	7.7	0.57
M-50	730.0	-	-	-	-	-	-	-	-	-	-	-	14	7.5	0.59
M-48	717.4	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.1[illegible]	-	-	-
M-44	654.8	-	-	-	-	-	-	-	-	-	-	-	14	7.6	0.74
M-42	626.2	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	-	0.11	13	8.0	0.66
M-39	610.5	< 1.0	< 0.02	< 0.45	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.11	-	-	-
M-38	601.3	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.1[illegible]	14	8.0	0.62
M-36	591.2	-	-	-	-	-	-	-	-	-	-	-	14	8.7	0.64
M-33	546.7	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.15	-	-	-
M-28	452.3	< 1.0	0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	0.10	< 0.05	0.1[illegible]	13	8.6	0.7[illegible]
M-27	440.3	< 1.0	< 0.02	< 0.03	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.10	-	-	-

1/ 5-Day composite for typical Fall weather period 10/7-11/68 (Gavins Point Dam only).

TABLE NO. B-11

Summary of Soluble Metals
Average of Two 5-Day Composite Samples

MISSOURI RIVER
October 28-November 8, 1968 Survey

STATION Name	STATION River Mileage	Ba mg/l	Cd mg/l	Fe mg/l	Mn mg/l	Tot. Cr mg/l	As mg/l	Cu mg/l	Pb mg/l	Ni mg/l	Zn mg/l	B mg/l	Na mg/l	K mg/l	F mg/l
MISSOURI RIVER:															
M-24	384.9	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.10	0.34	-	-	-
M-23	370.5	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.32	12	9.0	0.5
M-21	365.6	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.31	-	-	-
M-20	359.3	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	≤ 0.05	0.24	-	-	-
M-18	345.4	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.27	-	-	-
M-12	241.2	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.06	-	-	-
M- 7	179.0	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.05	-	-	-
M- 1	98.0	< 1.0	< 0.02	< 0.30	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	< 0.10	< 0.05	0.02	-	-	-

TABLE NO. B-12

Summary of Soluble Metals
Average of Two 5-Day Composite Samples

MISSOURI RIVER
January 20-February 2, 1969 Survey

STATION Name	River Mileage	Ba mg/l	Cd mg/l	Fe mg/l	Mn mg/l	Tot. Cr mg/l	As mg/l	Cu mg/l	Pb mg/l	Ni mg/l	Zn mg/l	B mg/l	Na mg/l	K mg/l	F mg/l
MISSOURI RIVER:															
M-52A	732.8	< 1.0	< 0.02	< 0.1	0.04	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.03	0.09	75	6.0	0.6
M-48A	718.3	< 1.0	< 0.02	< 0.1	0.05	< 0.02	< 0.01	< 0.05	0.085	< 0.1	0.07	-	-	-	-
M-42	626.2	< 1.0	< 0.02	0.1	0.03	< 0.02	< 0.02	< 0.05	< 0.05	< 0.1	0.07	0.10	81	6.6	0.6
M-38	601.3	< 1.0	< 0.02	< 0.1	0.04	< 0.02	< 0.02	< 0.05	< 0.05	< 0.1	0.08	0.10	70	6.2	0.6
M-28	452.3	< 1.0	< 0.02	< 0.1	0.04	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.025	0.12	55	7.5	0.6
M-27	440.3	< 1.0	< 0.02	< 0.2	0.04	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.055				
M-23	370.5	< 1.0	< 0.02	< 0.2	0.06	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.110	0.08	66	7.6	0.8
M-20A	358.3	< 1.0	< 0.02	0.1	0.04	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.115	-	-	-	-
M-18	345.4	< 1.0	< 0 02	0.3	0.07	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	0.105	-	-	-	-
M-12	241.2	< 1.0	< 0.02	< 0.1	0.06	< 0.02	0.01	< 0.05	< 0.05	< 0.1	< 0.02	-	-	-	-
M-7A	174.8	< 1.0	< 0.02	0.2	0.10	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	< 0.02	-	-	-	-
M-1	98.0	1.0	< 0.02	0.2	< 0.02	< 0.02	< 0.01	< 0.05	< 0.05	< 0.1	< 0.02	-	-	-	-

TABLE NO. B-13

Summary of Organic and Radioactive Constituents

MISSOURI RIVER
October 7-18, 1968 Survey

STATION Name	River Mileage	CYANIDE, µg/1 Avg.1/	Max.	PHENOL, µg/1 Avg.2/	Max.	TOT.3/ ORG. CHLORINE µg/1	CHLOROFORM3/ EXTRACTS mg/1	URAN-IUM4/ µg/1	Ra-226 4/ pc/1	THORIUM4/ µg/1	TOT.4/ α THORIUM pc/1	SOLUBLE4/ Sr-90 pc/1
MISSOURI RIVER:												
Gavins Pt. Dam	811.0	-	-	-	-	126.0	5.5	-	-	-	-	-
M-52	736.0	< 4.3	12.2	< 1.5	2.0	-	-	4.3	0.02	< 4	< 0.52	2.2
M-48	717.4	6.2	14.0	< 1.5	2.0	56.5	0.0	-	-	-	-	-
M-42	626.2	< 2.7	5.4	-	-	138.2	26.1	-	-	-	-	-
M-39	610.5	< 5.1	8.4	< 1.5	2.0	-	-	-	-	-	-	-
M-38	601.3	< 1.0	< 1.0	< 1.5	2.0	264.3	9.4	-	-	-	-	-
M-36	591.2	-	-	-	-	-	-	2.5	0.07	< 4	< 0.67	1.9
M-33	546.7	5.6 5/	15.2	< 1.5	2.0	-	-	-	-	-	-	-
M-28	452.3	4.7	11.2	< 1.5	2.0	32.8	3.7	-	-	-	-	-
M-27	440.3	< 2.7	5.4	< 1.5	2.0	-	-	-	-	-	-	-
TRIBUTARIES:6/												
BS-51	734.0	-	-	-	-	-	-	4.3	0.07	< 4	0.19±0.16 7/	1.2
S-45	664.0	-	-	-	-	-	-	3.9	0.07	< 4	< 0.18	1.0
B-43	635.1	-	-	-	-	-	-	4.1	0.19	< 4	< 0.18	1.8
P-37	594.8	-	-	-	-	-	-	6.4	0.12	< 4	0.30±0.22 7/	0.8
WASTE SOURCES:6/												
OM-40	611.5	-	-	-	-	-	133.5	-	-	-	-	-

1/ Average of 3 to 4 grab samples during typical Fall and wet weather.
2/ Average of 2 grab samples during typical Fall weather.
3/ Single grab sample during typical Fall weather.
4/ Composite for 8 samples collected both during typical Fall weather and extremely wet weather.
5/ Includes a maximum discrete value of 15.2 µg/1.
6/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.
7/ Counting error is expressed at the 95% confidence level.

TABLE NO. B-14

Summary of Organic and Radioactive Constituents

MISSOURI RIVER
October 28-November 8, 1968 Survey

STATION Name	River Mileage	CYANIDE, µg/l Avg.1/	CYANIDE, µg/l Max.	PHENOL, µg/l Avg.2/	PHENOL, µg/l Max.	TOT.3/ ORG. CHLORINE µg/l	CHLOROFORM3/ EXTRACTS mg/l	URANIUM4/ µg/l	Ra-226 4/ pc/l	SOLUBLE4/ Sr-90 pc/l
MISSOURI RIVER:										
M-24	384.9	< 1.0	< 1.0	< 10	< 10	-	-	-	-	-
M-23	370.5	< 2.4	6.4	< 10	< 10	45.9	0.0	-	-	-
M-21	365.6	< 1.0	< 1.0	< 10	< 10	-	-	-	-	-
M-20	359.3	< 3.6	7.0	< 10	< 10	-	-	-	-	-
M-18	345.4	< 1.0	< 1.0	< 10	< 10	30.6	25.5	-	-	-
M-14	270.0	-	-	-	-	-	-	4.3	0.07	1.7
M-12	241.2	< 1.0	< 1.0	1.2	1.4	-	-	-	-	-
M- 7	179.0	3.6	5.0	0.6	0.6	-	-	-	-	-
M- 3	118.0	-	-	-	-	98.7	3.6	-	-	-
M- 1	98.0	< 1.0	< 1.0	1.7	2.6	-	-	3.0	0.04	1.5
TRIBUTARIES:5/										
KR-22	367.4	-	-	-	-	52.1	15.0	-	-	-
GR-13	250.0	-	-	-	-	-	-	2.0	0.03	1.5
C-11	238.8	-	-	-	-	-	-	1.6	0.02	1.4
O- 4	130.0	-	-	-	-	-	-	0.5	< 0.02	1.2
G- 2	104.4	-	-	-	-	-	-	0.5	0.03	-

1/ Average of 4 grab samples.
2/ Average of 2 grab samples.
3/ Single grab sample on 11/1/68.
4/ Composite of 5 grab samples, daily from 11/4 - 11/8/68.
5/ River Mileage refers to point where tributary or waste source enters Missouri River. Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-15

Summary of Organic Constituents

MISSOURI RIVER
January 20-February 2, 1969 Survey

STATION Name	River Mileage	CYANIDE, µg/l Avg.[1]	CYANIDE, µg/l Max.	PHENOL, µg/l Avg.[1]	PHENOL, µg/l Max.	TOT.[2] ORG. CHLORINE µg/l
MISSOURI RIVER:						
Gavins Pt. Dam	811.0	-	-	-	-	46.2
M-52A	732.8	< 1.2	2.0	< 1.2	1.6	-
M-48A	718.3	1.9	3.8	< 1.2	1.6	22.2
M-42	626.2	≤ 2.7	7.7	< 1.9	4.0	40.1
M-38	601.3	< 1.8	2.6	< 1.0	< 1.0	33.0
M-28	452.3	< 1.9	3.6	< 2	< 2	73.1
M-27	440.3	< 1.7	3.2	< 2	< 2	-
M-23	370.5	< 1.2	1.6	< 2.7	4.0	42.1
M-20A	358.3	< 1.0	< 1.0	5.0	9.0	-
M-18	345.4	< 3.0	7.0	8.7	16.0	36.1
M-12	241.2	< 1.6	2.8	< 1.3	2.2	-
M- 7A	174.8	< 1.2	1.6	< 1.2	1.6	-
M- 1	98.0	< 1.0	< 1.0	< 1.2	1.6	74.4
TRIBUTARIES:[3]						
P-37	594.8	-	-	-	-	72.0

1/ Average of 3 to 4 grab samples.
2/ Single grab sample.
3/ River Mileage refers to point where tributary or waste source enters Missouri River.
Samples were collected on tributary or waste source upstream from confluence.

TABLE NO. B-16

Bottom Associated Animals

MISSOURI RIVER
October 1968

Organism	Station (River Mile) 736	730	717	699	676	655	626	618	Big Sioux River 734-1	Floyd River 731-.01	Soldier River 664-1	Boyer River 635-3
Sensitive Organisms												
Stoneflies												
Perlodidae	-	-	-	-	Q	-	-	-	-	-	-	-
Acroneuria	-	-	-	Q	-	Q	-	-	-	-	-	-
Mayflies												
Ameletus	-	-	-	-	-	Q	Q	-	-	-	-	4
Caenis	-	-	-	-	-	-	-	Q	-	-	-	-
Heptagenia	-	-	Q	Q	-	Q	Q	Q	-	-	-	-
Hexagenia	-	-	-	Q	-	-	-	-	-	-	-	-
Isonychia	Q	Q	Q	Q	Q	Q	-	-	-	-	-	-
Stenonema	Q	-	Q	Q	Q	Q	-	Q	-	-	-	-
Tricorythodes	-	-	-	-	-	-	-	Q	-	-	-	-
Caddisflies												
Cheumatopsyche	-	-	-	-	-	Q	-	-	-	-	-	-
Hydropsyche	Q	Q	Q	Q	Q	Q	Q	Q	Q	-	-	-
Neureclipsis	Q	Q	Q	Q	-	Q	Q	Q	-	-	-	-
Potamyia	-	-	-	-	Q	-	-	-	-	-	-	-
Psychomyia	-	-	-	-	Q	-	-	-	-	-	-	-
Subtotal/sq. ft.	-	-	-	-	-	-	-	-	-	0	0	4
Subtotal/kinds	4	3	5	7	6	8	4	6	1	0	0	1
Intermediate Organisms												
Midges												
Cricotopus	-	Q	-	Q	-	-	Q	Q	-	-	-	-
Glyptotendipes	Q	-	Q	-	-	-	-	-	Q	-	Q	-
Orthocladius	-	-	-	-	-	Q	-	-	-	-	-	-
Polypedilum	-	-	-	-	-	Q	Q	Q	-	-	8	Q
Procladius	-	-	-	-	-	-	Q	-	-	-	-	-
Psectrocladius	-	Q	-	-	-	-	-	Q	-	-	Q	-
Pseudochironomus	-	-	-	-	-	-	-	-	-	-	Q	-
Tanytarsus	-	-	-	-	-	-	-	Q	-	-	-	-
Craneflies												
Eriootera	-	-	-	-	-	-	-	-	-	-	-	Q
Blackflies												
Simulium	-	-	-	-	-	-	-	-	-	-	Q	-
Damselflies												
Amphiagrion	-	-	-	-	-	-	-	-	-	-	Q	-
Argia	-	-	-	-	-	Q	-	-	-	-	Q	-
Scuds												
Gammarus	-	Q	-	-	-	-	-	-	-	-	-	Q
Hyalella	Q	-	-	-	Q	Q	-	Q	Q	-	-	Q
Limpets												
Ancylidae	-	-	-	-	-	-	-	-	-	-	Q	Q
Clams												
Sphaeriidae	-	-	-	-	-	-	-	-	-	-	4	-
Sow Bugs												
Asellus	-	Q	Q	Q	Q	Q	-	-	-	-	-	-
Subtotal/sq. ft.	-	-	-	-	-	-	-	-	-	0	12	-
Subtotal/kinds	2	4	2	2	2	5	3	5	2	0	9	5
Tolerant Organisms												
Snails												
Physa	-	Q	Q	Q	Q	-	-	Q	Q	-	-	-
Leeches												
Hirudidae	Q	-	Q	Q	Q	Q	Q	-	Q	-	-	Q
Bloodworms												
Chironomus	Q	Q	Q	Q	Q	-	Q	-	Q	-	4	Q
Sludgeworms												
Tubificidae	Q	4	-	Q	-	-	-	Q	280	6	8	304
Subtotal/sq. ft.	-	-	-	-	-	-	-	-	280	6	12	304
Subtotal/kinds	3	3	3	4	3	1	2	2	4	1	2	3
Grand Total/sq. ft.	-	-	-	-	-	-	-	-	280	6	24	308
Number of Kinds	9	10	10	13	11	14	9	13	7	1	11	9

Q = Organisms collected qualitatively.

TABLE NO. B-16
(contd)
1

Bottom Associated Animals

MISSOURI RIVER
October 1968

Organisms	Station (River Mile) 610	601	591	581	560	547	525	507	488	469	452	440	423	397	385	Platte River 595-.5
Sensitive Organisms																
Mayflies																
Ameletus	Q	-	-	Q	-	-	-	-	-	Q	Q	Q	-	-	-	-
Baetis	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-
Heptagenia	-	-	-	Q	-	-	-	Q	-	Q	Q	Q	Q	-	-	Q
Isonychia	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-
Stenonema	Q	-	-	Q	Q	-	Q	Q	Q	Q	Q	Q	-	Q	Q	Q
Paracloeodes	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-
Caddisflies																
Cheumatopsyche	Q	Q	-	-	-	-	Q	-	2	Q	-	-	Q	-	Q	Q
Hydropsyche	-	-	-	Q	-	-	-	Q	-	Q	-	Q	-	Q	-	Q
Neureclipsis	-	-	-	-	-	-	Q	-	-	Q	Q	Q	Q	-	-	-
Subtotal/sq. ft.	-	-	-	-	-	-	-	-	2	-	4	-	-	-	-	-
Subtotal Kinds	3	1	0	5	1	0	3	3	2	6	4	5	3	4	2	4
Intermediate Organisms																
Beetles																
Cymbiodyta	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-
Midges																
Cardiocladius	-	Q	-	-	-	-	-	-	-	Q	Q	-	-	-	-	-
Chironomus	-	-	-	-	-	-	-	-	2	-	-	Q	-	-	2	-
Clinotanypus	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus	Q	Q	-	-	-	-	-	-	-	Q	Q	Q	-	-	Q	-
Glyptotendipes	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-
Orthocladius	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-
Pentaneura	-	-	-	-	Q	-	-	-	-	Q	Q	Q	-	-	-	-
Polypedilum	Q	4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	-	Q	Q	Q
Procladius	-	Q	-	Q	-	-	-	-	-	-	-	-	-	-	-	Q
Psectrocladius	-	Q	-	Q	-	-	Q	-	-	-	-	-	-	-	Q	-
Spaniotoma	Q	Q	-	-	Q	-	Q	-	Q	Q	Q	Q	Q	-	Q	-
Tanytarsus	Q	Q	-	-	-	-	Q	-	-	Q	-	Q	-	-	Q	Q
Tanypus	-	-	-	-	-	-	-	4	-	-	-	-	-	-	Q	-
Psectrotanypus	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-
Craneflies																
Erioptera	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-
Limonia	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-
Blackflies																
Simulium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Damselflies																
Amphiagrion	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	Q	-
Argia	-	-	-	Q	-	-	-	Q	-	-	Q	-	-	-	-	-
Scuds																
Crangonys	-	-	-	-	Q	-	Q	-	Q	Q	-	-	-	-	-	-
Gammarus	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-
Hyalella	-	-	Q	-	Q	Q	-	Q	-	Q	Q	-	-	-	-	-
Sow Bugs																
Asellus	-	Q	-	-	-	-	-	Q	-	Q	-	-	-	-	-	-
Limpet																
Ancylidae	-	-	-	-	-	-	-	-	-	-	-	Q	Q	-	Q	-
Subtotal/sq. ft.	4	12	3	7	5	2	6	9	5	9	8	-	-	-	2	-
Subtotal Kinds	4	9	3	7	5	2	6	6	4	9	8	8	2	1	9	4
Tolerant Organisms																
Snails																
Physa	-	Q	Q	Q	Q	-	-	-	-	-	Q	-	Q	Q	-	-
Leeches																
Hirudidae	Q	Q	-	Q	-	-	Q	-	-	Q	-	-	Q	-	-	Q
Bloodworms																
Chironomus	-	-	-	Q	-	-	-	Q	-	8	-	-	-	Q	-	-
Sludgeworms																
Tubificidae	Q	190	100	Q	200	180	320	120	90	580	Q	Q	10	-	50	Q
Subtotal/sq. ft.	-	190	100	-	200	180	320	120	90	588	-	1	10	-	50	-
Subtotal/kinds	2	3	2	4	2	1	2	2	1	3	2	1	3	2	1	2
Grand Total/sq. ft.	-	194	100	-	00	180	3[illegible]0	124	94	588	-	4	10	-	52	-
Number of Kinds	9	13	5	16	8	3	11	11	7	18	14	14	8	7	12	10

Q = Organisms collected qualitatively.

TABLE NO. B-16
(contd)

Bottom Associated Animals

MISSOURI RIVER
October 1968

Organism	Station (River Mile)																	Kansas River	Blue River	Grand River	Osage River	Gasconade River
	370	359	356	345	334	313	293	270	238	235	221	197	179	162	139	118	98	367-.5	358-.1	250-.5	130-.5	104-.2
Sensitive Organisms																						
Mayflies																						
Ameletus	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caenis	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptagenia	Q	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagenia	4	-	-	-	-	-	-	-	-	-	-	-	8	100	-	24	62	-	-	-	28	24
Isonychia	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-
Paracloeodes	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenonema	Q	Q	-	-	-	-	-	Q	-	Q	Q	Q	-	4	Q	-	Q	-	-	Q	-	-
Tricorythodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-
Caddisflies																						
Cheumatopsyche	Q	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	Q	-	-	-	-	-
Hydropsyche	Q	-	-	-	-	-	-	Q	-	-	Q	-	-	-	-	-	Q	-	-	-	-	-
Potamyia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-
Subtotal/sq. ft.	4	-	-	-	-	-	-	-	-	-	-	-	8	104	-	24	62	-	-	-	28	24
Subtotal/Kinds	7	2	0	0	0	0	0	3	1	1	2	1	2	2	1	1	5	0	0	2	1	1
Intermediate Organisms																						
Beetles																						
Dineutus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Narpus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Midges																						
Alblabesmyia	-	-	-	-	-	-	Q	4	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Chironomus	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus	-	-	4	-	-	-	-	-	Q	-	Q	-	-	-	-	-	-	-	-	-	-	-
Glyptotendipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-
Paralauterborniella	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum	2	Q	-	Q	Q	-	-	Q	Q	Q	Q	Q	Q	-	-	-	-	68	-	Q	-	4
Procladius	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	4	-	-	-	-	-
Psectrocladius	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudochironomus	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spaniotoma	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus	Q	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanypus	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phantom Midges																						
Chaoborus	4	-	-	-	-	-	-	Q	Q	Q	-	-	Q	-	-	-	-	28	-	-	2	-
Mosquitoes																						
Anopheles	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Craneflies	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-
Mothflies																						
Pericoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-
Damselflies																						
Amphiagrion	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Argia	-	-	-	-	Q	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enallagma	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ischnura	-	Q	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	Q	-	-	Q	-	-
Scuds																						
Crangonyx	Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hyalella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-
Limpets																						
Ancylidae	4	-	-	Q	-	2	Q	Q	Q	-	Q	-	-	Q	-	-	-	-	-	-	-	-
Flatworms																						
Turbellaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Biting Midges																						
Bezzia	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	40
Clams																						
Sphaeriidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Sphaerium	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal/sq. ft.	1	-	4	[illegible]	-	[illegible]	-	4	-	-	-	-	4	8	-	-	6	102	-	8	8	60
Subtotal/Kinds	8	2	1	3	3	3	3	5	4	4	3	2	3	4	0	0	3	3	0	5	3	4
Tolerant Organisms																						
Snails																						
Physa	-	Q	Q	Q	4	Q	-	-	-	-	-	-	Q	4	-	-	Q	-	-	-	4	-
Leeches																						
Hirudidae	-	Q	4	Q	Q	Q	-	Q	-	-	-	-	Q	-	-	-	2	-	-	-	-	-
Bloodworms																						
Chironomus	-	Q	Q	-	6	Q	-	-	-	Q	-	Q	Q	-	-	-	-	40	-	4	6	-
Sludgeworms																						
Tubificidae	590	Q	62	552	100	356	120	60	96	56	168	48	292	56	232	252	100	980	-	40	3	40
Subtotal/sq. ft.	590	4	66	[illegible]	[illegible]	[illegible]	120	60	96	56	168	48	[illegible]	60	232	252	102	1020	0	44	13	40
Subtotal/Kinds	1	4	4	3	4	4	1	2	1	2	1	2	4	2	1	1	3	2	0	2	3	1
Grand total/sq. ft.	606	8	70	[illegible]	[illegible]	[illegible]	[illegible]	64	96	56	168	48	[illegible]	[illegible]	[illegible]	276	[illegible]	[illegible]	-	5	49	124
Grand total - Number of kinds	16	8	5	6	7	7	4	10	6	7	6	5	9	8	2	2	11	5	0	9	7	6

Q = Organisms collected qualitatively.

TABLE NO. B-17

Suspended Algae

MISSOURI RIVER
OCTOBER-NOVEMBER, 1968

STATION	River Mile	Number/ ml	Cell Vol. (ppm)
M-52	736.0	872	0.84
M-50	730.0	728	1.34
M-48	717.4	339	1.01
M-47	699.5	749	1.24
M-46	676.5	687	0.93
M-44	654.6	893	1.54
M-42	626.2	966	1.85
M-41	618.3	996	2.23
M-39	610.5	453	0.65
M-38	601.3	817	5.44
M-36	591.2	947	1.92
M-35	580.9	1,654	2.17
M-34	559.7	5,995	5.82
M-33	546.7	3,791	3.53
M-32	525.1	2,584	2.51
M-31	507.5	3,046	2.93
M-30	488.3	1,769	2.63
M-29	469.0	1,905	3.51
M-28	452.3	1,366	1.85
M-27	440.3	2,144	4.65

TABLE NO. B-17
(contd.)
1

Suspended Algae
MISSOURI RIVER
OCTOBER-NOVEMBER, 1968

STATION	River Mile	Number/ ml	Cell Vol. (ppm)
M-26	422.6	2,178	3.21
M-25	397.4	1,584	2.85
M-24	384.9	1,863	5.34
M-23	370.5	1,749	3.83
M-21	365.6	1,798	2.67
M-20	359.3	1,699	4.48
M-18	345.4	1,600	1.67
M-17	334.5	1,727	2.84
M-16	313.2	2,013	1.37
M-15	293.4	1,617	2.32
M-14	270.0	782	0.59
M-12	241.2	765	0.73
M-10	235.1	603	0.58
M- 9	221.0	471	0.64
M- 8	197.2	605	0.90
M- 7	179.0	815	0.86
M- 6	162.0	1,016	1.30
M- 5	139.0	895	0.87
M- 3	118.0	1,593	1.54
M- 1	98.0	826	0.85

TABLE NO. B-17
(contd.)
?

Suspended Algae
MISSOURI RIVER
OCTOBER-NOVEMBER, 1968

STATION	River Mile	Number/ ml	Cell Vol. (ppm)
TRIBUTARY STREAMS			
	BIG SIOUX RIVER		
BS-51	734.0	11,653	11.75
	SOLDIER RIVER		
S-45	664.0	644	0.61
	BOYER RIVER		
B-43	635.1	961	0.88
	PLATTE RIVER		
P-37	594.8	9,236	13.04
	KANSAS RIVER		
Kr-22	367.4	1,815	0.86
	GRAND RIVER		
GR-13	250.0	10,649	6.04
	CHARITON RIVER		
C-11	238.8	2,986	4.76
	OSAGE RIVER		
O- 4	130.0	943	1.16
	GASCONADE RIVER		
G- 2	104.4	851	1.26

APPENDIX B-3

DETERMINATION OF BOD EXERTION RATES

APPENDIX B-3

DETERMINATION OF BOD EXERTION RATES

MISSOURI RIVER

The biochemical oxygen demand (BOD) test is an empirical bioassay-type procedure which measures the oxygen consumed by microbiological organisms during the assimilation of the organic matter present. The BOD can exert a significant influence on water quality by depleting the dissolved oxygen concentration to levels that can damage beneficial water uses. Although no known damages to beneficial water uses because of the BOD depleting the D.O. were known to occur in the Missouri River during these surveys, low dissolved oxygen concentrations did occur during the peak run-off period of October 17 and 18, 1968. The minimum observed D.O. was 4.5 mg/l at Station M-28, near the St. Joseph, Missouri water intake. The corresponding BOD_5 was 8 mg/l. During the January, 1969 survey, the effects of an ice cover significantly reduced reaeration, and D.O.'s were reduced by BOD exertion.

There is only a remote possibility that D.O. could be suppressed to levels that would damage aquatic life in the Missouri River. Such an occurrence would likely occur during heavy run-off from large areas of the watershed, including scouring of organic bottom deposits and hydraulic overflows containing sewage and packinghouse wastes. The Missouri River downstream from Omaha is the reach where the probability is greatest for such an occurrence; the organic loads are greatest, the watershed most subject to erosion, and the climate most appropriate.

The following limited objectives required a more detailed analysis of the BOD data:

1. To calculate BOD's at exactly 2.0 and 5.0 days from nominal values of observed BOD, which were incubated at various times near 2.0 and 5.0 days. All average BOD concentrations at Missouri River stations were found to be within ± 0.1 mg/l of the calculated "exact" results.

2. To determine BOD exertion rate constants(k_1).

3. To discuss the BOD results obtained during this survey which may be helpful in future water quality surveys of the Missouri River.

The primary assumptions for the BOD calculations made were that the kinetics of the BOD reactions observed at all stations were "first-order," and that nitrification (second stage BOD) was not an effect within the 5-day time of incubation. These assumptions were generally confirmed by the 20-day BOD results determined at selected stations.

For each daily sample, the k_1's were computed using the nominal BOD_2 and BOD_5 concentrations and exact incubation times to the nearest 0.001 day. Because of the low precision in the BOD test at low concentrations, the standard deviation about the mean of the daily k_1's at a station commonly equalled one-half the calculated k_1, and occasionally exceeded k_1. The mean of a set of individual k_1's at a station had little meaning when the variability of the individual samples was great. A more meaningful statistical method was used: the daily BOD_2's and BOD_5's and incubation times at each station were averaged for each of the survey periods and using first order kinetics, a value of k_1 was determined. This procedure yielded more significant results.

The reaction rates (k_1) determined for each station were graphed versus time-of-water travel for the autumn survey (Figure C-1 and C-2) and versus river mile for the winter survey (Figure C-3). Trend lines drawn through the graphed points indicate that the rate of BOD satisfaction decreases downstream from the major waste discharges. This effect occurs because the less readily biodegradable compounds remain as the microbiological assimilation and oxidation progresses and thus, dissolved oxygen is consumed at a reduced rate.

At stations where flows were available or could be accurately calculated, the BOD_5 loads (as pounds per day) were computed for the fall navigational period (Figure C-4). Flows are plotted and connected so that the build-up of BOD loads could be shown with respect to river discharge.

Because of hazards to small boats on the Missouri River during high runoff periods, only one sample was obtained for many stations in the period of rain-affected runoff, October 17 and 18, 1968. The k_1 for individual samples and the k_1 from the average of two samples ranged from 0.02 to 0.16 per day during this period. Organic materials ranged from the highly inert to the highly biodegradable such as sewage. Results from the analysis, including k_1, BOD_L, and BOD_5 load for tributaries and waste sources studied, are in Table C-1. The BOD load analysis shows the relative importance of the various waste sources and tributaries contributing oxidizable organic pollution.

TABLE NO. C-1

Summary of BOD Characteristics for Tributaries and Waste Sources
MISSOURI RIVER
Autumn and Rain-affected Period, 1968 and Winter, 1969 Surveys

STATION NAME	SAMPLING PERIOD (Autumn, 1968)	K_1 Base 10 per Day (Autumn, 1968)	BOD_L mg/l (Autumn, 1968)	BOD_5 Load lbs./Day (Autumn, 1968)	SAMPLING PERIOD (Rain-affected Period, 1968)	K_1 Base 10 per Day (Rain-affected Period, 1968)	BOD_L mg/l (Rain-affected Period, 1968)	BOD_5 Load lbs./Day (Rain-affected Period, 1968)	SAMPLING PERIOD (Winter, 1969)	K_1 Base 10 per Day (Winter, 1969)	BOD_L mg/l (Winter, 1969)	BOD_5 Load lbs./Day (Winter, 1969)
TRIBUTARIES:												
BS-51	10/8-16/68	0.10	13.4	8,400	10/17-18/68	0.13	8.1	24,600	-	-	-	-
S-45	10/7-15/68	0.17	2.7	400	10/16-18/68	0.31	7.2	41,300	-	-	-	-
B-43	10/8-16/68	0.09	14.6	18,200	10/17-18/68	0.13	18.5	117,000	-	-	-	-
PA-37A	-	-	-	-	10/16-18/68	0.02	552	119,000[1]	1/20-31/69	0.06	164	22,600[2]
P-37	10/8-16/68	0.08	13.4	158,000	10/17-18/68	0.05	20.9	756,000	1/20-31/69	0.08	3.5	40,300
KR-22	10/28-11/8/68	0.09	4.9	111,000	-	-	-	-	-	-	-	-
GR-13	10/28-11/8/68	0.10	5.0	2,800	-	-	-	-	-	-	-	-
C-11	10/28-11/8/68	0.12	4.4	1,000	-	-	-	-	-	-	-	-
O-4	10/28-11/8/68	0.14	2.1	53,400	-	-	-	-	-	-	-	-
G-2	10/28-11/8/68	0.16	3.8	43,400	-	-	-	-	-	-	-	-
WASTE SOURCES:												
SC-49	10/6-15/68	0.15	303	33,300	10/16-17/68	0.18	305	40,900	1/20-31/69	0.14	421	41,700
CB-40B	-	-	-	-	-	-	-	-	1/27-31/69	0.08	558	14,200
OM-40	10/8-15/68	0.13	1,320	258,000	10/16-18/68	0.20	963	505,000	-	-	-	-
OM-40A	-	-	-	-	-	-	-	-	1/20-23/69	0.12	377	34,200
K-19A	11/4-8/68	0.11	385	18,300	-	-	-	-	-	-	-	-
K-19B	-	-	-	-	-	-	-	-	1/27-31/69	0.13	161	17 800
K-19	10/28-11/1/68	0.28	179	61,900	-	-	-	-	1/20-24/69	0.18	154	66,800

1/ Based on estimated average flow of 150 cfs.

2/ Based on estimated average flow of 50 cfs.

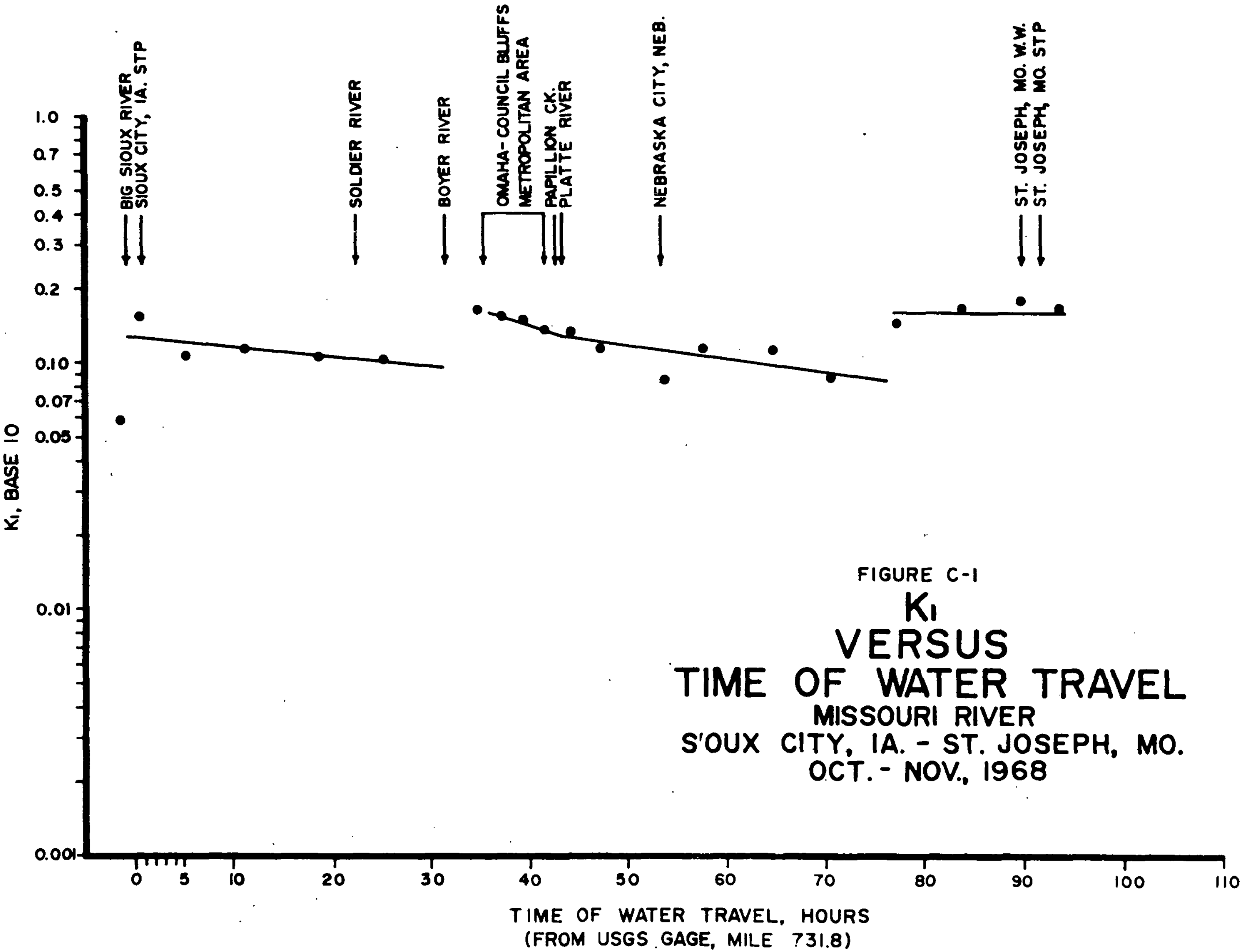


FIGURE C-1
K_1
VERSUS
TIME OF WATER TRAVEL
MISSOURI RIVER
S'OUX CITY, IA. - ST. JOSEPH, MO.
OCT. - NOV., 1968

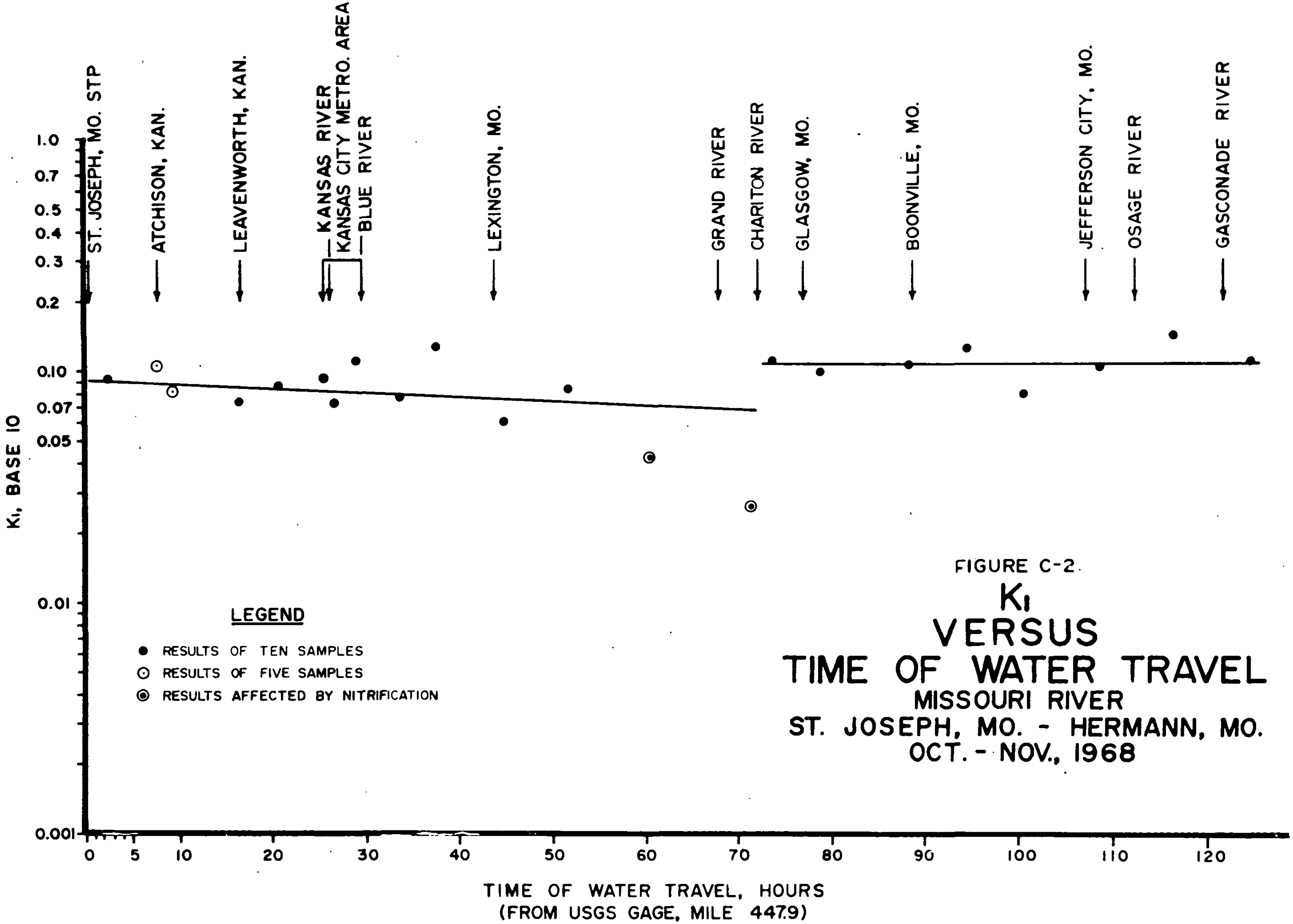


FIGURE C-2
K_1
VERSUS
TIME OF WATER TRAVEL
MISSOURI RIVER
ST. JOSEPH, MO. - HERMANN, MO.
OCT. - NOV., 1968

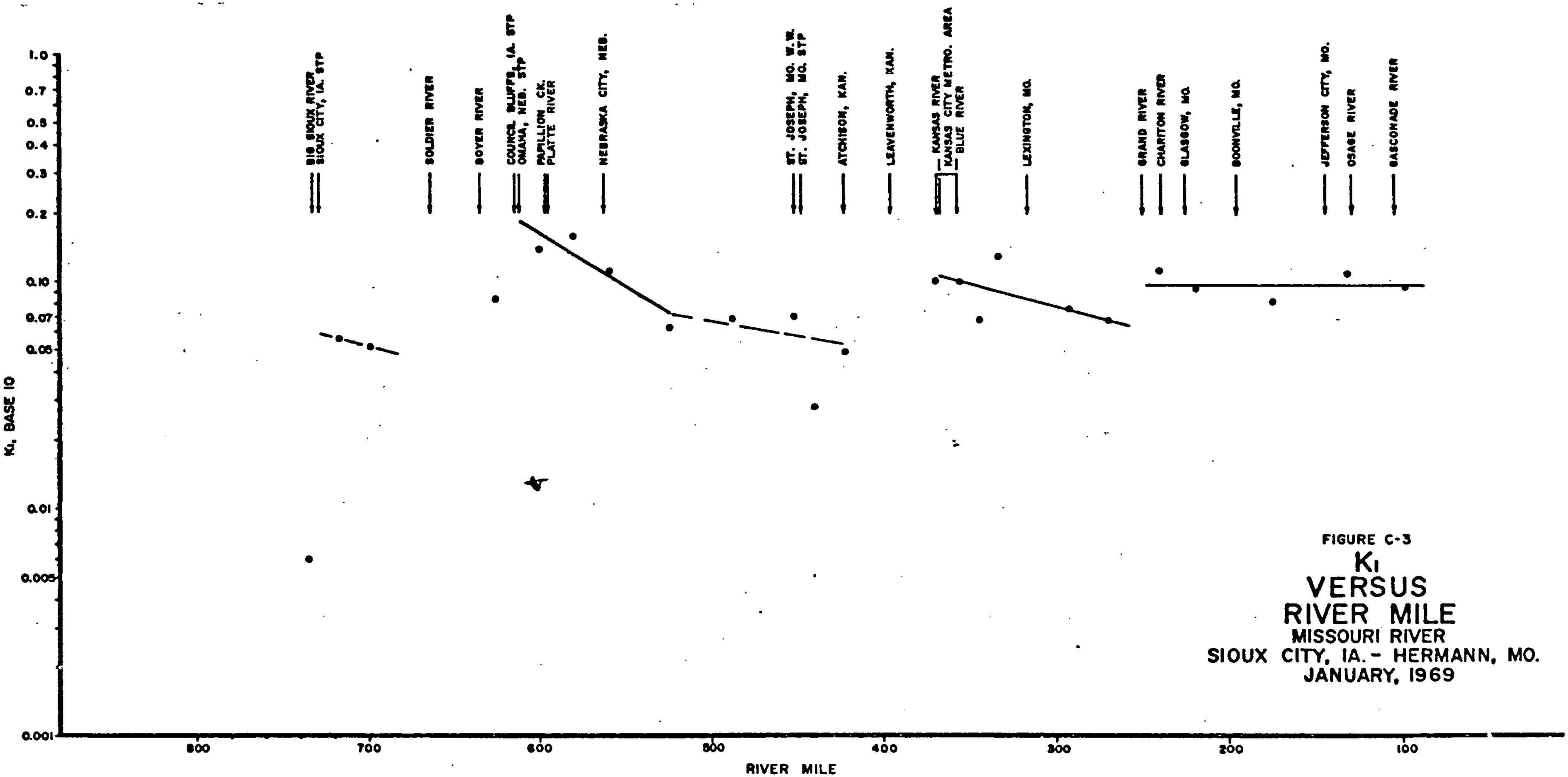
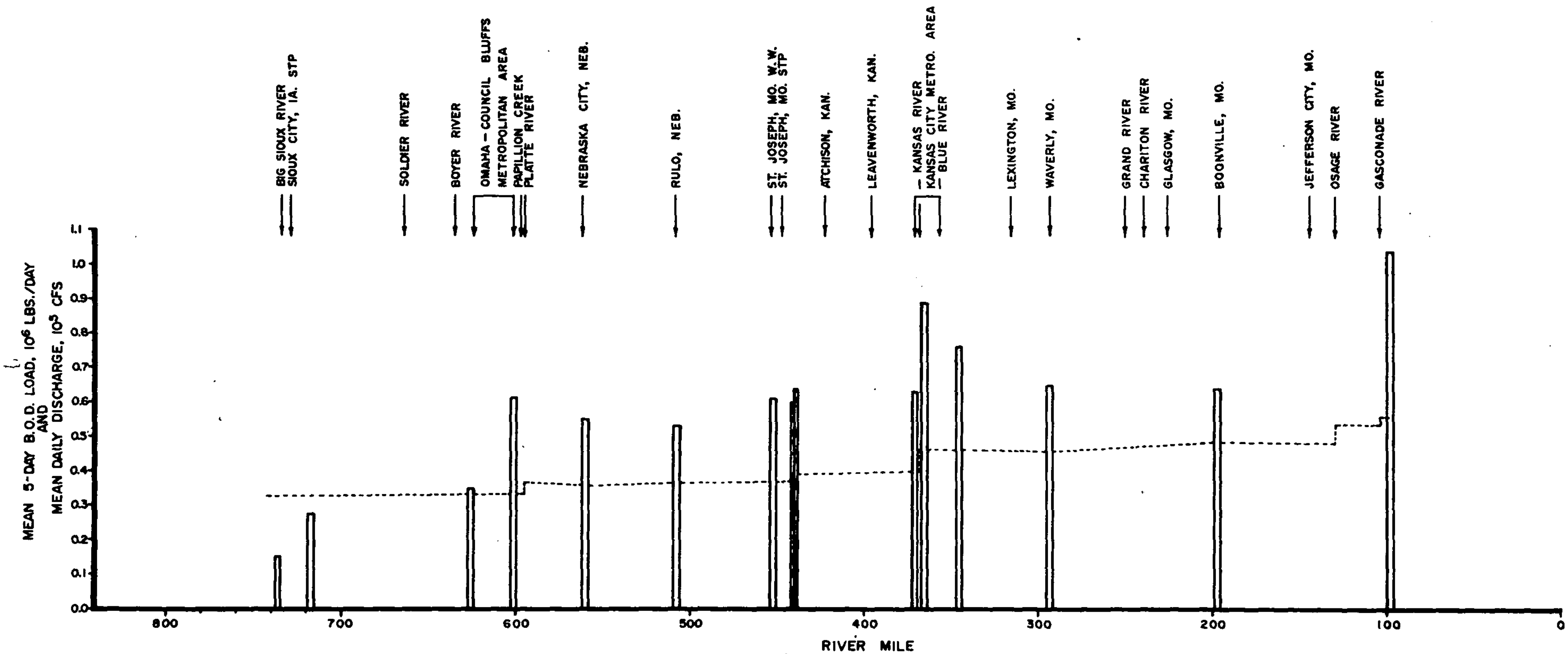


FIGURE C-3
K1
VERSUS
RIVER MILE
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
JANUARY, 1969



LEGEND

-------- MEAN DAILY DISCHARGE

MEAN 5-DAY B.O.D. LOAD

FIGURE C-4

MEAN 5-DAY B.O.D. LOAD AND DISCHARGE VERSUS RIVER MILE

MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968

APPENDIX B-4

TIME-OF-WATER TRAVEL IN THE MISSOURI RIVER

APPENDIX B-4

TIME-OF-WATER TRAVEL IN THE MISSOURI RIVER

The purpose of this analysis was to determine the time-of-water travel that occurred during the autumn of 1968 for the reach from Sioux City, Iowa to Hermann, Missouri. The time-of-water travel of solutes in the Missouri River has been computed for various flow rates in the reach from Yankton, South Dakota, to St. Louis, Missouri. The variations in the main stem flow that occur over this reach require that time-of-water travel be computed separately for several sub-reaches. The reference gage for each sub-reach is the one that measures inflow. For this analysis reference gages considered were the following:

Sioux City, Iowa; Omaha and Nebraska City, Nebraska; St. Joseph, Kansas City, Waverly, Boonville, Jefferson City, and Hermann, Missouri - the upstream gage being the reference gage for each reach.

The computed U. S. Geological Survey times-of-travel* were cumulatively summed for each station downstream, beginning with time equal 0 hours at the Sioux City gage. Flows used were 30,000, 40,000, and 50,000 cubic feet per second (cfs). The results were graphed (Figure D-1) versus the Missouri River mileage of the station. These three flow rates encompass the range of flows that occurred in the reach when studied in 1968.

For each sub-reach, the mean discharge (Table D-1) at the reference gage was calculated by linear interpolation and plotted between computed discharges. The flow line was constructed by connecting points within a sub-reach. An example of this procedure is presented for the sub-reach from Boonville to Jefferson City, Missouri. Mean discharge at the Boonville reference gage for the period of study from October 28, to November 8, 1968 was 48,500 cfs. Computed times-of water travel downstream from Sioux City, Iowa, in the sub-reach at bracketing flows were:

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* Bowie, J. E., and Petri, L. R., 1969, Travel of Solutes in the Lower Missouri River, U. S. Geological Survey Hydrol. Inv. Atlas BA-332.

a) Boonville:

174.9 Hours (40,000 cfs)

161.6 Hours (50,000 cfs)

b) Easely:

184.8 Hours (40,000 cfs)

171.1 Hours (50,000 cfs)

c) Jefferson City:

.194.9 Hours (40,000 cfs)

180.3 Hours (50,000 cfs)

Interpolating for a flow equal to 48,500 cfs gave a time-of-water travel from Sioux City of: 163.6 hours at Boonville, 173.2 hours at Easely, and 182.5 hours at Jefferson City. Plotting these times versus the respective Missouri River mile and connecting with a straight line gave the flow line for the sub-reach. The cumulative travel times at the head and tail of each sub-reach were recorded so that the time-of-water travel could be adjusted for a change of flow in each adjacent sub-reach. In the Waverly to Boonville sub-reach, for instance, the time-of-water travel at the tail of the flow line at Boonville was 169.8 hours. This value will be needed to adjust the cumulative time-of-water travel downstream from Sioux City for variations in discharge.

To use the constructed flow lines for the various sub-reaches considered, the graph is entered from the abscissa at each respective station mileage for which the time-of-water travel is to be determined. Pivoting at the interpolated flow line and reading the ordinate gives a nominal time-of-water travel with respect to the Sioux City gage. This value must be corrected because the flow line from sub-reach to sub-reach is discontinuous due to changes in the discharge. In making this correction, use the two values of nominal time-of-water travel at the point of discontinuity - the reference gage. For example, the upstream sub-reach from Waverly to Boonville flow line had a nominaltime of-water travel of 169.8 hours at Boonville. The adjacent downstream sub-reach from Boonville to Jefferson City had a nominal time-of-water travel of 163.6 hours. To make the time-of-water travel continuous, the 6.2 hours must be added to the downstream sub-reach. In this example the correction is additive because the downstream sub-reach discharge exceeded the upstream one. When the mean discharge at the downstream gage is less, the correction is negative. To determine the time-of-water travel from some initial

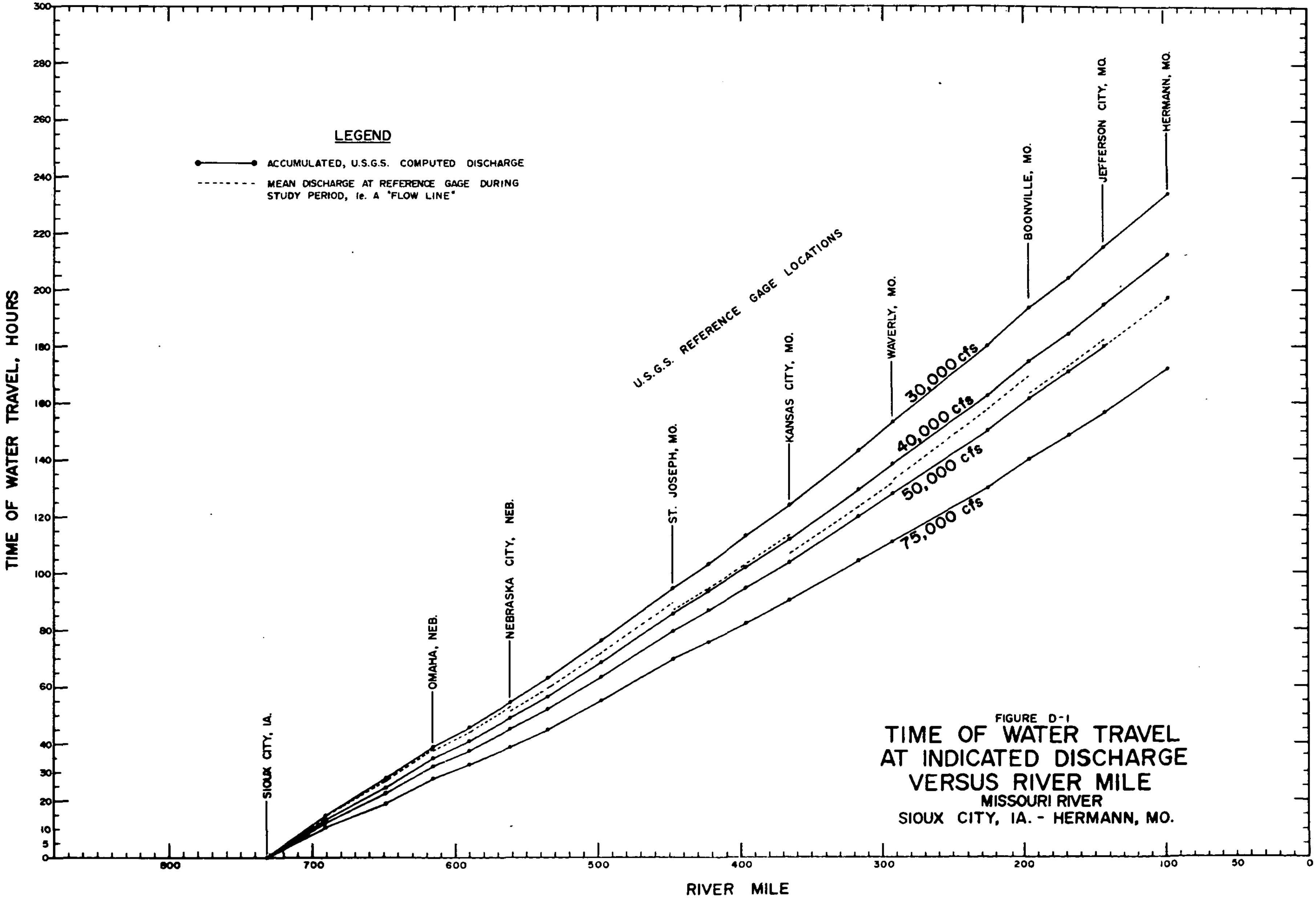

FIGURE D-1
TIME OF WATER TRAVEL AT INDICATED DISCHARGE VERSUS RIVER MILE
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.

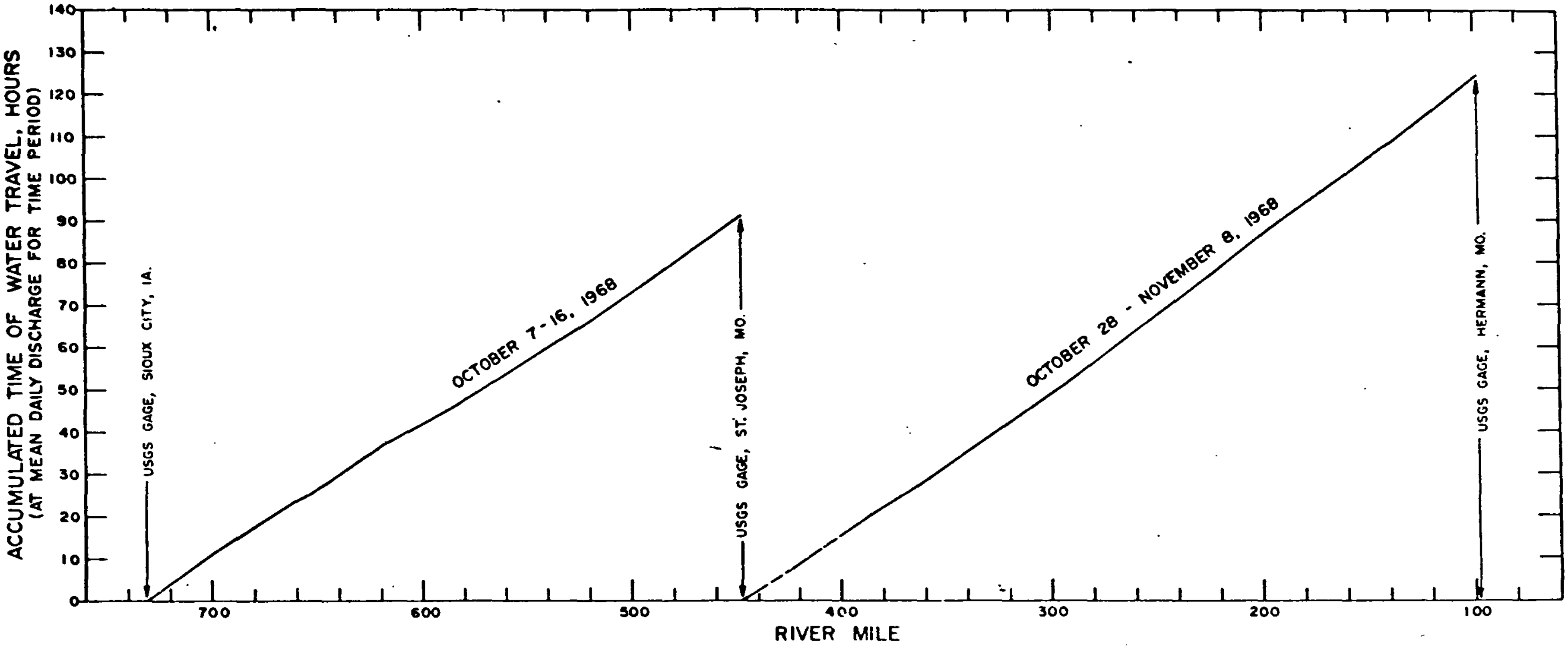

FIGURE D-2
ACCUMULATED TIME OF WATER TRAVEL
VERSUS
RIVER MILE
MISSOURI RIVER
SIOUX CITY, IA. - HERMANN, MO.
OCT. - NOV., 1968

TABLE NO. D-1

Time-of-Water Travel

MISSOURI RIVER
Fall, 1968 Navigation Season Surveys

STATION Name	River Mileage	Reference Gage	Nominal Trav. Time below Sioux City Hours	Correction account of Ref. GageChange Hours	Cumulative Correction Hours	Corrected Trav. Time below Sioux City Hours	Corrected Trav. Time below St. Joseph Hours
MISSOURI RIVER:							
M-52	736.0		-1.6 1/			-1.6 1/	
	731.8	Sioux City, Iowa	0.0			0.0	
M-50	730.0		0.5	0	0	0.5	
M-48	717.4		5.2	0	0	5.2	
M-47	699.5		11.3	0	0	11.3	
M-46	676.5		18.8	0	0	18.8	
M-44	654.6		25.2	0	0	25.2	
M-42	626.2		34.7	0	0	34.7	
M-41	618.3		37.3	0	0	37.3	
	615.8	Omaha, Nebraska					
M-39	610.5		39.0	+0.3	+0.3	39.3	
M-38	601.3		41.3	+0.3	+0.3	41.6	
M-36	591.2		43.9	+0.3	+0.3	44.2	
M-35	580.9		47.0	+0.3	+0,3	47.3	
	561.8	Nebraska City, Nebraska					
M-34	559.7		52.0	+1.5	+1.8	53.8	
M-33	546.7		55.9	+1.5	+1.8	57.7	
M-32	525.1		62.9	+1.5	+1.8	64.7	
M-31	507.5		68.8	+1.5	+1.8	70.6	
M-30	488.3		75.3	+1.5	+1.8	77.1	
M-29	469.0		82.1	+1.5	+1.8	83.9	
M-28	452.3		88.0	+1.5	+1.8	89.8	
	447.9	St. Joseph, Missouri	89.5	+1.5	+1.8	91.3	0.0
M-27	440.3		89.0	+2.8	+4.6	93.6	2.3
M-26	422.6		94.4	+2.8	+4.6	99.0	7.7
M-25.5	418.0		96.0	+2.8	+4.6	100.6	9.3
M-25	397.4		103.0	+2.8	+4.6	107.6	16.3
M-24	384.9		107.1	+2.8	+4.6	111.7	20.4
M-23	370.5		111.9	+2.8	+4.6	116.5	25.2
	365.7	Kansas City, Missouri					
M-21	365.6		106.9	+6.4	+11.0	117.9	26.6
M-20	359.3		109.1	+6.4	+11.0	120.1	28.8
M-18	345.4		113.8	+6.4	+11.0	124.8	33.5
M-17	334.5		117.6	+6.4	+11.0	128.6	37.3
M-16	313.2		125.0	+6.4	+11.0	136.0	44.7
M-15	293.4		131.9	+6.4	+11.0	142.9	51.6
	293.4	Waverly, Missouri					
M-14	270.0		141.4	-0.9	+10.1	151.5	60.2
M-12	241.2		152.3	-0.9	+10.1	162.4	71.1
M-10	235.1		154.7	-0.9	+10.1	164.8	73.5
M- 9	221.0		159.9	-0.9	+10.1	170.0	78.7
M- 8	197.2		169.3	-0.9	+10.1	179.4	88.1
	196.6	Boonville, Missouri					
M- 7	179.0		169.4	+6.2	+16.3	185.7	94.4
M- 6	162.0		175.4	+6.2	+16.3	191.7	100.4
	143.9	Jefferson City, Missouri					
M- 5	139.0		181.3	+2.2	+18.5	199.8	108.5
M- 3	118.0		189.2	+2.2	+18.5	207.7	116.4
M- 1	98.0		197.2	+2.2	+18.5	215.7	124.4

1/ Negative sign denotes upstream from reference gage.

TABLE NO. D-1
(contd)

Time-of-Water Travel

MISSOURI RIVER
NORMAL FALL - Oct. 7-16, and Oct. 28-Nov. 8, 1968
TRIBUTARIES, MUNICIPALITIES AND WASTE SOURCES

STATION Name	River Mileage	Reference Gage	Nominal Trav. Time below Sioux City Hours	Correction account of Ref. GageChange Hours	Cumulative Correction Hours	Corrected Trav. Time below Sioux City 2/ Hours	Corrected Trav. Time below St. Joseph 3/ Hours
Big Sioux River	734.0		-0.8	0	0	-0.8 1/	
	731.8	Sioux City, Iowa	0.0	0	0	0.0	
Sioux City	729.0		+0.7	0	0	+0.7	
Soldier River	664.0		22.5	0	0	22.5	
Boyer River	635.1		31.6	0	0	31.6	
Omaha-Council Bluffs - Metro. Area Upper Boundary	624.0		35.4	0	0	35.4	
	615.8	Omaha, Nebraska					
Council Bluffs	614.0		38.1	+0.3	+0.3	38.4	
So. Omaha - Monroe St. Sewers	611.5		38.8	+0.3	+0.3	39.1	
Omaha-Council Bluffs Metro. Area - Lower Boundary	601.0		41.3	+0.3	+0.3	41.6	
Papillion Creek	596.6		42.7	+0.3	+0.3	43.0	
Platte River	594.8		43.0	+0.3	+0.3	43.3	
Nebraska City	562.0		53.0	+0.3	+0.3	53.3	
	561.8	Nebraska City, Nebraska					
St. Joseph Water Co. Intake	452.3		88.0	+1.5	+1.8	89.8	
	447.9	St. Joseph, Mo.				91.3	0.0
St. Joseph	447.0		87.0	+2.8	+4.6	91.6	0.3
Atchison	422.5		94.4	+2.8	+4.6	99.0	7.7
Leavenworth	396.0		103.3	+2.8	+4.6	107.9	16.6
Kansas City, Kansas - Mo. Metro. Area - Upper Boundary	369.0		112.3	+2.8	+4.6	116.9	25.6
Kansas River	367.4		112.9	+2.8	+4.6	117.5	26.2
Kansas City, Kans.	367.2		113.0	+2.8	+4.6	117.6	26.3
	365.7	Kansas City, Mo.					
Blue River - Kansas City Metro. Area - Lower Boundary	356.9		109.9	+6.4	+11.0	120.9	29.6
Lexington	316		124.0	+6.4	+11.0	135.0	43.7
	293.4	Waverly, Mo.					
Grand River	250.0		149.0	-0.9	+10.1	159.1	67.8
Chariton River	238.8		153.1	-0.9	+10.1	163.2	71.9
Glasgow	226.0		158.0	-0.9	+10.1	168.1	76.8
Boonville	196.6		169.8	-0.9	+10.1	179.9	88.6
	196.6	Boonville, Mo.					
Jefferson City	145.0		181.9	+6.2	+16.3	198.2	106.9
Osage River	130.0		184.9	+2.2	+18.5	203.4	112.1
Gasconade River	104.4		194.3	+2.2	+18.5	212.8	121.5

1/ Negative sign denotes upstream from reference gage.
2/ October 7-16 study period pertains to reach from Sioux City to St. Joseph - River Mile 447.9.
3/ October 28-November 8, 1968 study period pertains to reach from St. Joseph to Hermann, Missouri - River Mile 98.0.

point on the Missouri River, the above procedure must begin at that point and proceed downstream. The corrections for discontinuity in flow are cumulative from sub-reach to sub-reach in downstream order.

The corrected time-of-water travel downstream from Sioux City to St. Joseph is a mean for the study period from October 7-16, 1968; from St. Joseph to Hermann, is for the period from October 28 - November 8, 1968. In addition to the discontinuities mentioned, one further break in the data is caused by the change in study periods at St. Joseph. Flow at the St. Joseph gage in the October 7-16, 1968 survey period averaged 36,600 cfs, in the October 26 - November 8 survey period the flow averaged 38,800 cfs.

Table D-1 presents the nominal and corrected travel times and the correction factors used in this analysis. Figure D-2 shows the time-of-water travel downstream from Sioux City, Iowa, and St. Joseph, Missouri, for the respective periods of study.

As a precaution before using these data, the qualifications cited in the basic data reference should be examined:*

> "The data in this report are for a full conservative soluble contaminant. Contaminants that do not fall into this category such as, low-density oily wastes, might move at rates considerably different from those of a conservative soluble contaminant.
>
> "A contaminant may be introduced into the river in many ways. It might be introduced suddenly or gradually, or it might be introduced along the bank or near midstream. The mode of introduction can affect significantly both the travel time and the maximum concentrations attained."

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*Ibid.

APPENDIX C

DATA FROM PERIPHYTON STUDY

TABLE 1

STATION DESCRIPTIONS BY MISSOURI RIVER MILE

River Mile	Description
737.5	Missouri River - 3.5 miles upstream from Big Sioux River confluence.
734-0.5	Big Sioux River 0.5 miles upstream from confluence.
732.1	Missouri River 1.9 miles downstream from Big Sioux River confluence, Iowa side of river.
731-0.1	Floyd River near I-29 bridge.
729	Downstream 0.1 mile from Sioux City Sewage Treatment Plant effluent, Iowa side of river.
727.9	Missouri River, Sioux City Pipe Line crossing Northern Natural Gas Co., Nebraska side.
723.2	Missouri River, 2.3 miles downstream from Dakota City, Nebraska side of river.
717.7	Missouri River 0.5 miles upstream from Iowa Power and Light cable crossing, Nebraska side of river.
699.0	Missouri River 0.5 miles downstream from Lighthouse Marina, Nebraska side of river.
664.6	Missouri River 0.6 miles upstream from Soldier River confluence, Iowa side of river.
664-0.5	Soldier River approximately 0.5 miles upstream from confluence with Missouri.
627.6	Missouri River 1.4 miles upstream from Omaha Waterworks intake, Iowa side of river.
625.6	Missouri 0.6 miles downstream from Omaha Waterworks intake, Iowa side of river.
613.5	Missouri River 0.5 miles downstream from Council Bluffs Sewage Treatment Plant effluent, Iowa side of river.
608.1	Missouri River 2.4 miles downstream from Omaha STP outfall, Nebraska side.
595-0.5	Platte River 0.5 miles upstream from confluence with Missouri.

TABLE 1 (Cont.)

River Mile	Description
289.8	Missouri River, 3.6 miles downstream from Waverly, Missouri, right bank.
257.6	Missouri River 5 miles downstream from U. S. Highway 41 bridge, right bank.
239-0.1	Chariton River 0.1 miles upstream from confluence with the Missouri.
178.3	Missouri River 35.3 miles upstream from Jefferson City, Missouri, left bank of river.
130-1.0	Osage River 1 mile upstream from confluence with Missouri, left bank.
104-0.1	Gasconade River near railroad bridge 0.1 mile upstream from confluence with Missouri, left bank.

TABLE 1 (Cont.)

River Mile	Description
591.8	Missouri River 0.6 miles upstream from Plattsmouth, Nebraska, Nebraska side.
580	Missouri 0.9 miles downstream from Shennandoah Boat Club Ramp, Nebraska side.
560	Missouri River 2 miles downstream from Nebraska City, Nebraska side.
523.7	Missouri River 4.1 miles downstream from Little Nemaha River confluence, Missouri side of river.
485.6	Missouri River 2.4 miles downstream from White Cloud, Kansas, Kansas side.
451.6	Missouri River 0.7 miles downstream from St. Joseph, Missouri Waterworks intake, Missouri side of river.
417.4	Missouri River approx. 4.6 miles downstream from Atchison, Kansas, Kansas side.
367.5-0.2	Kansas River near 4th bridge, upstream from confluence with Missouri.
362.9	Missouri River approx. 0.7 miles upstream from Chouteau Bridge, right bank.*
358-0.1	Big Blue River 0.1 miles upstream from the confluence with the Missouri.
357-0.1	Big Blue River (Old Channel) 0.1 miles upstream from confluence with the Missouri.
356.2	Missouri River downstream 1.8 miles from confluence with Big Blue River, right bank of river.
356.1	Missouri River downstream 1.9 miles from confluence with Big Blue River, right bank.
347.4	Missouri River 2 miles upstream from N. W. Electric Power Plant, right bank.
326.8	Missouri River 3 miles downstream from Napoleon, Missouri, right bank.

*Convention for right or left is looking downstream with the direction of water flow.

TABLE 2

NUMBERS OF ATTACHED ORGANISMS/SQ. IN. ON VERTICALLY EXPOSED SLIDES

MISSOURI RIVER, SEPTEMBER 7 - OCTOBER 7, 1969

River Mile	Greens	Blue-Greens	Flagellates	Centric Diatoms	Non-Colonial Diatoms	Sheathed Diatoms	Protozoa	Fungi	Nematodes	Misc.	Total
MAIN STEM											
737.5	150,000	325,000	-	150,000	2,275,000	150,000	-	-	-	-	3,050,000
732.1	44,000	162,000	-	9,000	602,000	-	-	-	-	-	817,000
729	200,000	950,000	-	-	2,450,000	-	-	-	-	-	3,600,000
727.9	100,000	175,000	-	75,000	3,550,000	-	-	-	-	-	3,900,000
723.2	325,000	175,000	-	50,000	1,975,000	50,000	-	-	-	-	2,525,000
717.7	275,000	275,000	-	2,300,000	3,525,000	1,825,000	-	-	-	-	8,200,000
699	200,000	825,000	-	100,000	5,825,000	125,000	-	-	-	-	7,075,000
664.6	100,000	-	-	100,000	5,875,000	6,550,000	-	-	-	-	12,625,000
627.6	75,000	250,000	-	1,250,000	3,600,000	8,825,000	100,000	-	-	-	14,100,000
625.6	675,000	500,000	-	50,000	3,425,000	-	-	-	-	-	4,650,000
613.5	75,000	50,000	-	75,000	3,400,000	525,000	-	-	-	*Z	4,125,000
608.1	50,000	50,000	-	600,000	1,400,000	100,000	-	25,000	-	-	2,225,000
591.8	1,000,000	100,000	4,775,000	-	13,825,000	25,000	50,000	-	-	-	19,775,000
580.0	1,550,000	150,000	475,000	125,000	2,425,000	550,000	-	-	-	*Z	5,275,000

TABLE 2 (Cont.)

River Mile	Greens	Blue-Greens	Flagellates	Centric Diatoms	Non-Colonial Diatoms	Sheathed Diatoms	Protozoa	Fungi	Nematodes	Misc.	Total
560.0	-	100,000	50,000	275,000	6,000,000	5,225,000	-	-	-	*Z	11,650,000
523.7	100,000	-	-	650,000	9,500,000	6,675,000	75,000	-	-	-	17,000,000
485.6	25,000	25,000	-	200,000	8,225,000	7,050,000	-	-	-	-	15,525,000
451.6	50,000	-	350,000	25,000	4,975,000	50,000	-	-	-	-	5,450,000
417.4	50,000	25,000	75,000	75,000	1,475,000	325,000	-	-	-	-	2,025,000
362.9	18,000	900	17,000	4,000	92,000	60,000	900	-	-	-	192,800
356.2	22,000	105,000	-	11,000	76,000	346,000	11,000	-	-	-	571,000
356.1	173,000	2,554,000	129,000	151,000	130,000	3,874,000	108,000	-	-	-	7,119,000
347.4	238,000	-	-	43,000	909,000	1,580,000	-	-	-	-	2,770,000
326.8	173,000	346,000	87,000	216,000	390,000	77,318,000	-	-	-	-	78,530,000
289.8	130,000	43,000	-	216,000	1,385,000	2,337,000	-	-	-	-	4,111,000
257.6	541,000	22,000	-	43,000	2,446,000	1,904,000	-	-	-	-	4,956,000
228.4	368,000	22,000	-	130,000	2,445,000	606,000	-	-	-	-	3,571,000
178.3	130,000	87,000	-	22,000	110,000	158,000	-	22,000	-	-	529,000

*Z - Zoogloea sp. present

TABLE 2 (Cont.)

River Mile	Greens	Blue-Greens	Flagellates	Centric Diatoms	Non-Colonial Diatoms	Sheathed Diatoms	Protozoa	Fungi	Nematodes	Misc.	Total
TRIBUTARIES											
734 Big Sioux	75,000	-	-	200,000	575,000	-	-	-	-	-	850,000
731 Floyd	425,000	250,000	625,000	1,000,000	12,075,000	625,000	-	-	-	-	15,000,000
664 Soldier	400	900	1,300	-	13,000	8,000	-	-	400	-	24,000
595 Platte	5,000	2,000	400	-	32,000	-	900	-	-	-	40,300
367.5 Kansas	14,000	53,000	16,000	14,000	209,900	46,000	31,000	900	1,300	-	386,000
358 Big Blue	2,000	12,000	-	500	3,000	-	-	-	-	-	17,500
357 Big Blue (Old Channel)	-	3,000	-	-	3,000	-	-	-	-	-	6,000
239 Chariton	10,000	3,000	900	-	65,000	-	-	1,700	-	-	80,600
130 Osage	43,000	86,000	29,000	72,000	1,529,000	836,000	29,000	29,000	-	-	2,624,000
104 Gasconade	25,000	100,000	-	100,000	1,025,000	-	-	-	-	-	1,250,000

TABLE 3

AMOUNTS OF CHLOROPHYLL a AND ORGANIC CARBON IN THE ORGANISMS ATTACHED TO VERTICALLY SUSPENDED ARTIFICAL SUBSTRATES IN THE MISSOURI RIVER, SIOUX CITY, IOWA, TO HERMANN, MISSOURI

River Mile	Chlorophyll a µg/sq. in.	Organic Carbon mg/sq. in.
MAIN STEM		
737.5	3.1	7.7
732.1	.9	2.6
729	14.4	3.0
727.9	3.1	1.8
723.2	2.3	5.5
717.7	27.7	7.6
699	44.0	6.7
664.6	24.6	6.5
625.6	40.8	2.7
608.1	6.2	13.7
591.8	21.8	1.8
580.0	21.1	10.3
560.0	39.5	3.2
523.7	22.8	4.6
485.6	7.8	2.8
451.6	<.9	1.7
417.4	<.9	2.9
362.9	4.6	3.2
356.2	2.7	0.9

TABLE 3 (Cont.)

River Mile*	Chlorophyll a µg/sq. in.	Organic Carbon mg/sq. in.
356.1	3.4	10.2
347.4	6.8	3.2
327.0	13.4	5.0
326.8	15.7	12.6
289.8	7.8	9.8
257.6	15.7	7.2
228.4	9.1	7.1
178.3	2.8	3.3
TRIBUTARIES		
734 Big Sioux River	2.4	3.4
731 Floyd River	2.1	11.0
664 Soldier River	2.7	4.6
595 Platte River	2.1	2.5
367.5 Kansas River	3.4	2.8
358 Big Blue River	<.9	5.0
357 Big Blue River - Old Channel	1.9	6.4
239 Chariton River	1.0	2.0
130 Osage River	11.9	3.7
104 Gasconade River	15.9	2.7

*River mile of Missouri River at the tributary confluence.

TABLE 4

NUMBER OF ORGANISMS AND DRY WEIGHT OF MATERIALS

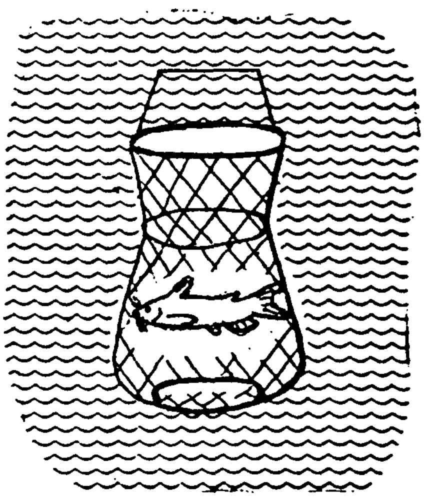
COLLECTED ON VERTICALLY AND HORIZONTALLY ORIENTED SUBSTRATES

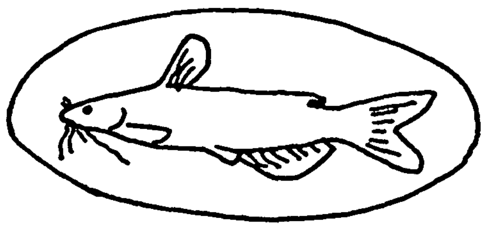
	Numbers of Organisms/sq. in.		Dry Weight of Sample in Grams	
River Mile	Vertical Slide	Horiz. Slide	Vertical Slide	Horiz. Slide
737.5	3,050,000	1,100,000	3.6087	10.4616
732.1	817,000	679,000	0.4642	5.2474
729	3,600,000	3,250,000	0.1366	0.4096
727.9	3,900,000	2,475,000	0.1773	4.9300
723.2	2,525,000	1,700,000	0.1656	0.2764
717.7	8,200,000	3,500,000	1,2132	4.4110
699	7,075,000	3,175,000	0.4752	4.3280
664.6	12,625,000	4,800,000	1.3128	1.0303
657.9	1,125,000	425,000	--	--
627.6	14,100,000	17,450,000	--	--
627.4	4,825,000	7,875,000	0.0468	0.6276
625.6	4,650,000	1,475,000	0.2533	1.5492
613.5	4,125,000	4,125,000	--	--
608.1	2,225,000	3,075,000	6.0893	7.2959

APPENDIX D

REPORT ON FISH FLESH TAINTING INVESTIGATION

THE EFFECTS OF WASTE WATER DISCHARGES ON THE FLAVOR OF FISHES IN THE MISSOURI RIVER, OCTOBER, 1969.





United States Department of the Interior
Federal Water Quality Administration
National Field Investigations Center

1970

EFFECTS OF WASTE WATER DISCHARGES ON THE FLAVOR OF FISHES IN THE MISSOURI RIVER (SIOUX CITY, IOWA, TO WAVERLY, MISSOURI)

OCTOBER 1969

Nelson A. Thomas
and
Delbert B. Hicks

A Study Report for Distribution by the
Director, Missouri Basin Region, FWQA

Prepared by

Water Sciences Section
National Field Investigations Center
Federal Water Quality Administration
United States Department of the Interior
Cincinnati, Ohio

1970

SUMMARY

1. An investigation of effects of pollutants on fish flavor was conducted on the Missouri River from Sioux City, Iowa, downstream to Waverly, Missouri. Test channel catfish were placed upstream and downstream from all known significant waste discharges in this reach. After four days exposure, they were removed, dressed, quick frozen, and submitted to a food-flavor test panel.

2. Fish held in the Missouri River in a one mile reach downstream from slaughterhouses and industrial waste discharges at Sioux City, Iowa, had an unacceptable flavor. Pieces of meat scraps and fat littered the water surface and collected on the baskets containing the fish.

3. Downstream from the Council Bluffs and Twin Cities sewage discharges, caged fish acquired an unacceptable flavor.

4. Downstream from the Omaha sewage treatment plant discharge, fish acquired the most unacceptable flavor of any tested in the study. Wastes from the Omaha sewage treatment plant caused an unacceptable flavor in fish for 2.5 miles of river along the Nebraska shore.

The discharge of inadequately treated wastes from the Omaha sewage treatment plant produced slimes in the river that collected on the cages, another indication of the severity of pollution in this area.

5. Test fish placed in the Missouri River downstream from the confluence of the Platte River to Kansas City, Kansas, had an acceptable flavor.
6. Wastes in runoff from the Fairfax dump at Kansas City, Kansas, caused fish to have an unacceptable flavor.
7. Fish placed in the Kansas River acquired an unacceptable flavor.
8. Wastes in the Kansas River and from the Kansas City, Kansas, and Kansas City, Missouri, sewage treatment plants discharge combined to cause an unacceptable flavor in caged fish in 2.5 miles along the south shore of the Missouri River.
9. Slime growths stimulated by wastes from Corn Products Company plant covered baskets placed 1000 feet downstream from the outfall and suffocated the test fish.
10. Fish placed along the north shore of the river downstream from the North Kansas City, Missouri, sewage treatment plant (Rock Creek) acquired an unacceptable flavor.

11. Fish placed in the Big Blue River and immediately downstream from its confluence with the Missouri River died within 24 hours indicating that these waters were toxic. Fish placed farther downstream in the Missouri River (one-half mile) possessed an unacceptable flavor.

12. The Old Blue River and Sugar Creek waters were toxic to fish. Caustic wastes in Sugar Creek dissolved the meat leaving only skin and bones in the basket. Fish in the Missouri River downstream from Sugar Creek acquired even more of an unacceptable flavor than fish at the next upstream station.

13. Wastes discharged to the Missouri River and its tributaries from the Kansas City area not only caused an unacceptable flavor in test fish for 22 miles, but were toxic to fish.

14. Of the 440 mile reach of the Missouri River studied, unacceptable flavors were found in fish placed at locations bracketing a total of 26 miles of river, all of which were confined to metropolitan areas.

STANDARDS VIOLATIONS

1. The State of Iowa general standard that surface waters be "Free from materials attributable to municipal, industrial or other discharges producing color, odor, or other conditions in such degree to be detrimental to legitimate uses of water" was violated by the discharge of industrial wastewater at Sioux City, Iowa, and the sewage discharges from Council Bluffs and Twin cities, Iowa.
2. The State of Nebraska standard "Concentrations of substances shall be less than that amount which is or may become injurious to the designated uses" was violated by the wastewater discharge from the Omaha sewage treatment plant.
3. The State of Kansas standard "Taste and odor producing substances from man-made sources shall be limited to concentrations in rivers that will not interfere with ... or impart unpalatable flavors to fish ... " was violated by wastes in the runoff from the Fairfax dump at Kansas City, Kansas, and wastewater discharges to the Kansas River.

4. The State of Missouri standard "Taste and odor producing substances from man-made sources shall be limited to concentrations in rivers that will not interfere with ... or impart unpalatable flavors to fish ... " was violated by the discharge of wastewater to the Kansas River and from the Kansas City, Kansas, and Kansas City, Missouri, sewage treatment plant discharges. The standard also was violated by the wastewater from the North Kansas City, Missouri, sewage treatment plant (Rock Creek), the South Kansas City, Missouri, sewage treatment plant (Big Blue River), and industrial wastewater carried by Sugar Creek to the Missouri River.

EFFECTS OF WASTE WATER DISCHARGES ON THE FLAVOR OF FISHES IN THE MISSOURI RIVER (SIOUX CITY, IOWA, TO WAVERLY, MISSOURI)

OCTOBER 1969

At the request of the Regional Director of the Missouri Basin Region, FWPCA, to investigate waste discharges that may effect an unacceptable flavor in fish in the Missouri River from Sioux City, Iowa, to downstream from Kansas City, Kansas, the National Field Investigations Center conducted fish flesh tainting studies from September 29 to October 18, 1969. The study reach extended from Sioux City, Iowa [River Mile (R.M.) 735] to Waverly, Missouri (R.M. 295) (Figure 1).

Fishermen have captured fish which possessed unacceptable flavors from the Missouri River. Because of this, sports fishermen have sought new uncontaminated fishing waters where their catch will be edible. Commercial fishermen have lost dressed fish markets because of consumer rejection of fish with unacceptable flavors and must sell their catches at reduced prices as live fishes for stocking ponds where with time the flavor will improve.

The study was directed to the identification of waste discharges that cause unacceptable flavor in channel catfish

(*Ictalurus punctatus* Rafinesque). This fish is one of the most important commercial and game fish in the Missouri River.

The commercial fishery on the Missouri River is a valuable resource. In 1966, 4.5 million pounds of fish valued at $315,000 were harvested from the Missouri River. In the states of Iowa, Kansas, Missouri and Nebraska, there were 292 Missouri River commercial fishermen. However, the vast majority of people who fish on the Missouri River are sports fishermen. It should be recognized that the Missouri River has both an important sport and commercial fishery and these should be protected and improved.

States bordering the Missouri River have endeavored to protect the Missouri River fishery resources by Water Quality Standards. The State of Nebraska Standards for taste and odor producing substances, state, "Concentrations of substances shall be less than that amount which is or may become injurious to the designated uses."

Water Quality Standards for the State of Missouri state, "Taste and odor producing substances discharged shall be limited to concentrations in the stream that will not interfere with... or impart unpalatable flavor to food fish,..." Water Quality Standards for the State of Kansas state for the Kansas and Missouri rivers that, "Taste and odor producing substances from man-made sources shall be limited to concentrations in rivers that will not interfere with...or impart unpalatable flavor to fish,..." The State of Iowa Standards include the general criteria which provide that surface waters be "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."

METHOD

The method employed on the Missouri River to identify waste sources producing an unacceptable flavor in catfish was to place untainted catfish in cages located upstream and downstream from suspected waste sources. This procedure has been found to successfully relate the unacceptable flavor produced in native fish to particular waste sources.

To ensure uniform taste quality before exposure, all fish were held in 62° F well water for a period of 10 days. After this period, some fish were cleaned and frozen on dry ice as reference fish. After the fish were transferred to the test sites, four fish each were placed in fish cages and suspended approximately two feet beneath the water's surface. Fish were exposed to waters for 96 hours.

The Missouri River was divided into four test reaches:

(1) The Sioux City reach (mile 735 to 691) encompassed 16 test sites.

(2) The Omaha reach (river mile 628 to 562) included 21 test sites.

(3) The St. Joseph reach (river mile 452.4 to 391) had 11 sites.

(4) The Kansas City reach (river mile 378 to 295) had 25 test sites.

After exposure, the fish were dressed and frozen on dry ice. The control and exposed samples were shipped to the Department of Food Science and Technology, Oregon State University, Corvallis, Oregon, where samples were stored at 0° F until testing. For testing, frozen catfish were washed, wrapped in aluminum foil, placed on slotted, broiler-type pans, and cooked in a gas oven at 400° F for 23 to 45 minutes depending on the size of the fish. Each sample was boned and the flesh flaked and mixed to insure a uniform sample. Samples were served in coded cups to judges seated in individual test booths. Known and coded references or control samples were included in each test. The judges scored the flavor and desirability of each sample on a seven point scale ranging from 7, no unnatural flavor or very desirable, to 1, very extreme unacceptable flavor or very undesirable. Fish flesh having scores of 5.0 or higher were considered to have an acceptable flavor.

RESULTS

Fish placed upstream from Sioux City had an acceptable flavor. Test fish from the Big Sioux River also exceeded the acceptable value (5.0). Numerous fishermen observed in these areas attest to the popularity of these areas as fishing sites. Numerous slaughterhouses in Sioux City discharged their waste water into the Missouri River between river mile 732 and 731. Fish held in cages at river mile 731.5, 731.0 and 730.5 acquired an unacceptable flavor (Figure 2). Pieces of meat and fat collected on the baskets and could be seen floating in the water for several more miles downstream. Fish held at river mile 730.5 downstream from the slaughterhouses and other industries in Sioux City received the lowest flavor score of fish tested in this area (Table 1). Wastes discharged into the river at Sioux City caused an unacceptable flavor in caged fish in at least one mile of the Missouri River bordering Iowa.

No unacceptable flavor occurred in test fish placed along either side of the river from Dakota City, Nebraska, downstream to river mile 628.0 near Omaha, Nebraska. Test fish between river miles 628 and 624.6 retained near acceptable flavors (Figure 3). At river mile 622 (Iowa shore), the fish scored 4.3 indicating an unacceptable flavor. At river mile 617, the test fish had a flavor score of 4.9 indicating a near acceptable flavor.

Along the Iowa side of the Missouri River, caged fish had acceptable flavors downstream to river mile 614.0 where the Council Bluffs and Twin Cities sewers discharged to the river and caused an unacceptable flavor in caged fish at river mile 612. Directly across the river on the Nebraska bank, the caged fish were rated with an acceptable flavor score of 5.2 (Figure 3). At river mile 611 (800 ft. downstream from the Omaha sewage treatment discharge), caged fish acquired the most unacceptable flavor (rating of 2.6) of any of the fish tested in 440 miles of the Missouri River studied. The discharge of inadequately treated wastes from the Omaha sewage treatment plant also sufficiently enriched the Missouri River to support slime growths that covered the cages. Slime growths indicate organic pollution which degraded the environment. Flavor of caged fish was still severely degrade 900 feet downstream from the slaughterhouse discharges which entered the river approximately one-half mile downstream from the Omaha sewage treatment plant outfall. Caged catfish from both sides of the Missouri River at river mile 608 were rated with acceptable flavor scores (Figure 3).

Wastes from the Omaha sewage treatment plant degraded the flavor of fish in 2.5 miles of river along the Nebraska shore. Wastes from the Council Bluffs and Twin Cities sewage discharges degraded the flavor in caged fish to make them unacceptable in 2.5 miles of river along the Iowa shore.

The flavor of caged catfish was acceptable from river mile 608 to upstream from Kansas City, Kansas, at river mile 378 (Figure 4). Along the Kansas side of the Missouri River two miles downstream from the Fairfax dump (river mile 372), caged fish had an unacceptable flavor (rating of 3.6). At river mile 367.8, approximately .3 mile upstream from the Kansas River confluence, fish flavor was acceptable indicating dilution of the compounds from the Fairfax dump.

Test fish from the Kansas River (river mile 367.5-0.5) had an unacceptable flavor rating of 2.9. Downstream from river mile 367.5, along the south shore of the Missouri River, the combined effects of the Kansas River and waste water discharged from a Kansas City, Kansas, and a Kansas City, Missouri, sewage treatment plant caused an unacceptable flavor in fish held at river mile 366.6 and 364.2 (Figure 4). Fish placed across the river (north shore) at river mile 365.6, 364.0, and 363.0 did not acquire an unacceptable flavor. However, fish placed in baskets

1000 feet downstream from the Corn Products Company waste discharge (river mile 365, Missouri's north shore) died because of suffocation caused by dense slime growths covering the baskets. These growths did not occur upstream from Corn Products indicating the Corn Products Company was discharging inadequately treated wastes. The growths also covered the rocks of the jettys thus reducing habitat for fish food organisms in at least one mile of the river.

Test fish along the north bank of the river approximately 400 feet downstream from Rock Creek confluence at river mile 362.6 had an unacceptable flavor rating of 3.8. Rock Creek receives wastes from the North Kansas City, Missouri, sewage treatment plant.

Degradation of fish flavor was found along the south bank at river mile 358.2 where fish acquired an unacceptable flavor rating of 4.2. Immediately upstream from this station, either a power or an industrial complex discharged their waste waters to the river.

Test fish in the Big Blue River died within four hours of planting and those fish placed in the Missouri River 200 feet downstream from the Big Blue River confluence died within 24 hours. One-half mile downstream at river mile 357.5, the caged fish acquired an unacceptable flavor rating of 3.0. The Old Blue River was also toxic; however, the unacceptable flavor of fish in this reach of the Missouri River masked any further degradation caused by the Old Blue River. Wastes in Sugar Creek, river mile 356.7 - < 0.1, not only were toxic but also caustic which resulted in fish flesh being dissolved off the bones. After 96 hours, only skin and bones remained in the cages set in Sugar Creek. Approximately 200 feet downstream from the Sugar Creek confluence, the test fish were given even a lower flavor score (3.2) than had been given to the test fish downstream from the Old Blue River at river mile 356.9 (Table 1). Fish placed in baskets three miles downstream still had an unacceptable flavor as a result of wastes from the Big Blue and Old Blue rivers and Sugar Creek. Fish with acceptable flavors were recovered from the station at river mile 345. The fish downstream from the Little Blue River had only a slight unacceptable flavor (4.9). Fifty miles downstream at Waverly, Missouri, the fish scored 5.5 indicating acceptable flavor.

Wastes discharged to the Missouri River from the Kansas City, Kansas, North Kansas City and Kansas City, Missouri, and the Kansas River areas caused unacceptable flavors in fish for 22 miles. Wastes carried in Sugar Creek, the Big Blue and Old Blue rivers were toxic to test fish.

Table 1

Off-Flavor and Desirability Scores of

Caged Catfish, Missouri River, 1969

Missouri River Mile	Bank[1]	Location	Flavor Score	Desirability Score
		Control	5.9	5.3
734.6	R + L	Upstream from Sioux City	5.1	4.4
734.0-[2] 0.5	R	Big Sioux River	5.5	4.7
732.0	R	Upstream from Old Floyd River	5.1	4.4
	R	SLAUGHTERHOUSE WASTE DISCHARGES		
731.5	R	Upstream from New Floyd River	4.7	3.9
	R	SLAUGHTERHOUSE WASTE DISCHARGES		
731.0	R	Downstream from New Floyd River	4.8	3.9
	R	SLAUGHTERHOUSE WASTE DISCHARGES		
730.5	R	Downstream from New Floyd River	4.3	3.3
729.5	R	Upstream from Sioux City Sewage Discharge	5.0	3.8
	R	SIOUX CITY SEWAGE DISCHARGE		
729.0	R	Downstream from Sioux City Sewage Discharge	5.0	4.0
728.1	R	Downstream from Sioux City Sewage Discharge	5.0	4.1

[1]Looking upstream.

[2]Miles upstream in tributary.

Missouri River Mile	Bank[1]	Location	Flavor Score	Desirability Score
728.0	L	Upstream from slaughterhouse waste Discharge	5.2	4.0
	L	SLAUGHTERHOUSE WASTE DISCHARGES		
726.2	L	Downstream from Slaughterhouse Waste Discharges, Dakota City, Nebraska	5.1	4.5
	L	DAKOTA CITY, NEBRASKA, SEWAGE DISCHARGE		
725.2	L	Downstream from Dakota City Sewage Discharge	5.6	4.7
723.5	L	Downstream from Dakota City Sewage Discharge	5.3	4.7
717.5	R	Downstream from Metropolitan Utilities District and Iowa Power and Light Co. Discharge	5.3	4.5
691.0	L	Decatur, Nebraska	5.0	4.3
628.0	R + L	Upstream from Omaha, Nebraska	5.1	4.6
625.0	L	Downstream from Metropolitan Utilities District Power Discharge	4.9	4.6
624.6	L	Upstream from Portland Cement	4.8	4.4
622.0	R	Downstream from Omaha Storm Sewer	4.3	4.0
617.0	R	Upstream from National Co-op Refinery	4.9	5.5
616.4	L	Omaha Municipal Dock and Cargill, Inc.	4.7	4.4
616.2	L	Downstream from Ditch from Railroad Yards	5.4	4.8

Missouri River Mile	Bank [1]	Location	Flavor Score	Desirability Score
615.0	R	Upstream from Council Bluffs Sewage Discharge	5.1	4.2
614.8	L	Downstream from Quaker Oats Waste Discharge	4.9	4.1
		COUNCIL BLUFFS SEWAGE DISCHARGE		
614.0	R	Downstream from Council Bluffs Sewage Discharge	5.0	4.4
	R	TWIN CITIES SEWAGE DISCHARGE		
612.1	R	Downstream from Council Bluffs and Twin Cities Sewage Discharge	4.2	3.4
612.1	L	Upstream from Omaha Sewage Discharge	5.2	5.6
	L	OMAHA SEWAGE DISCHARGE		
611.0	L	Downstream from Omaha Sewage Discharge	2.6	1.6
	L	SLAUGHTERHOUSE WASTE DISCHARGE		
610.0	L	Downstream from Omaha Sewage discharge and Slaughterhouse Waste Discharges	3.8	2.8
608.0	L	Downstream from Omaha Sewage Discharges	5.4	4.6
608.0	R	Downstream from Council Bluffs Sewage Discharges	6.0	5.4
602.0	L	Upstream from Bellevue, Nebraska	5.4	4.7
599.0	L	Downstream from Bellevue Sewage Discharges	5.1	4.1
591.0	L	Plattsmouth, Nebraska	5.5	4.8

Missouri River Mile	Bank[1]	Location	Flavor Score	Desirability Score
562.0	L	Nebraska City, Nebraska	5.3	4.6
452.4	R	Upstream from St. Joseph, Missouri Water Intake	5.6	5.1
449.0	R	Downstream from a St. Joseph, Missouri, Storm Drain	5.7	5.2
447.0	R	Upstream from St. Joseph Sewage Discharge	5.6	4.9
	R	ST. JOSEPH MUNICIPAL STP		
446.0	R	Downstream from St. Joseph Sewage Discharge	5.8	5.4
		SOUTH ST. JOSEPH INDUSTRIAL SEWER DISTRICT STP OUTFALL		
444.0	R	Downstream from St. Joseph, Missouri Industrial Waste Discharge	5.4	4.8
440.0	R	Downstream from St. Joseph, Missouri	5.6	5.3
424.0	L	Upstream from Atchison, Kansas	5.9	5.4
421.0	L	Downstream from Atchison, Kansas	Fish cage lost	
398.0	L	Upstream from Leavenworth, Kansas	5.8	5.3
395.0	L	Downstream from Leavenworth, Kansas	5.4	5.0
391.0	R	Downstream from Platte River Confluence	5.9	5.0
378.0	L	Upstream from Kansas City, Kansas	5.1	4.5
	L	DRAINAGE FROM FAIRFAX DUMP		
370.4	R	Kansas City, Missouri, Water Intake	5.5	4.7
370.0	L	Downstream from Fairfax Dump	3.6	2.3
368.1	L	Kaw Valley Drainage District		
367.8	L	Upstream from Kansas River	5.5	4.7

Missouri River Mile	Bank[1]	Location	Flavor Score	Desirability Score
367.5-0.5	L	Kansas River	2.9	1.7
	L	KANSAS CITY, KANSAS, AND KANSAS CITY, MISSOURI, SEWAGE DISCHARGES		
366.6	L	Downstream from Kansas River confluence and Downstream from Kansas City, Mo., and Kansas City, Kansas, Sewage Discharges	3.9	2.7
365.6	R	Upstream from Corn Products Waste Discharge	5.4	4.4
	R	CORN PRODUCTS WASTE DISCHARGES		
364.2	L	Downstream from Kansas River and Kansas City, Mo., and Kansas City, Kansas, Sewage Discharges	4.6	3.5
364.0	R	Downstream from Corn Products Waste Discharge	5.5	4.[illegible]
363.0	R	Upstream from Rock Cr.	5.3	4.6
	R	NORTH KANSAS CITY, MISSOURI, SEWAGE DISCHARGES		
362.0	R	Downstream from Rock Cr.	3.3	2.6
358.2	L	Upstream from Big Blue River	4.2	3.3
358.0-0.5	L	Big Blue River	Toxic, Fish Died	
	L	KANSAS CITY, MISSOURI, SEWAGE DISCHARGE		
357.9	L	Downstream from Big Blue River	Toxic, Fish Died	
357.5	L	Downstream from Big Blue River	3.0	1.9

Missouri River Mile	Bank[1]	Location	Flavor Score	Desirability Score
357.2	L	Downstream from Big Blue River	3.5	2.2
357.0	L	Upstream from Old Blue River	3.0	1.7
357.0- < 0.1	L	Old Blue River	3.5 Toxic to 3 of 4 test fish	2.1
356.9	L	Downstream from Old Blue River	3.6	2.7
356.7- < 0.1	L	Sugar Cr.	Toxic, Caustic Dissolved Meat	
356.6	L	Downstream from Sugar Cr.	3.2	2.3
354.2	L	Downstream from Cement City, Missouri	4.2	3.1
345.0	R	Downstream from Missouri City Electric Power Discharge	5.4	4.7
339.5	L	Downstream from Little Blue River	4.9	4.0
295.0	L	Waverly, Missouri	5.5	4.7

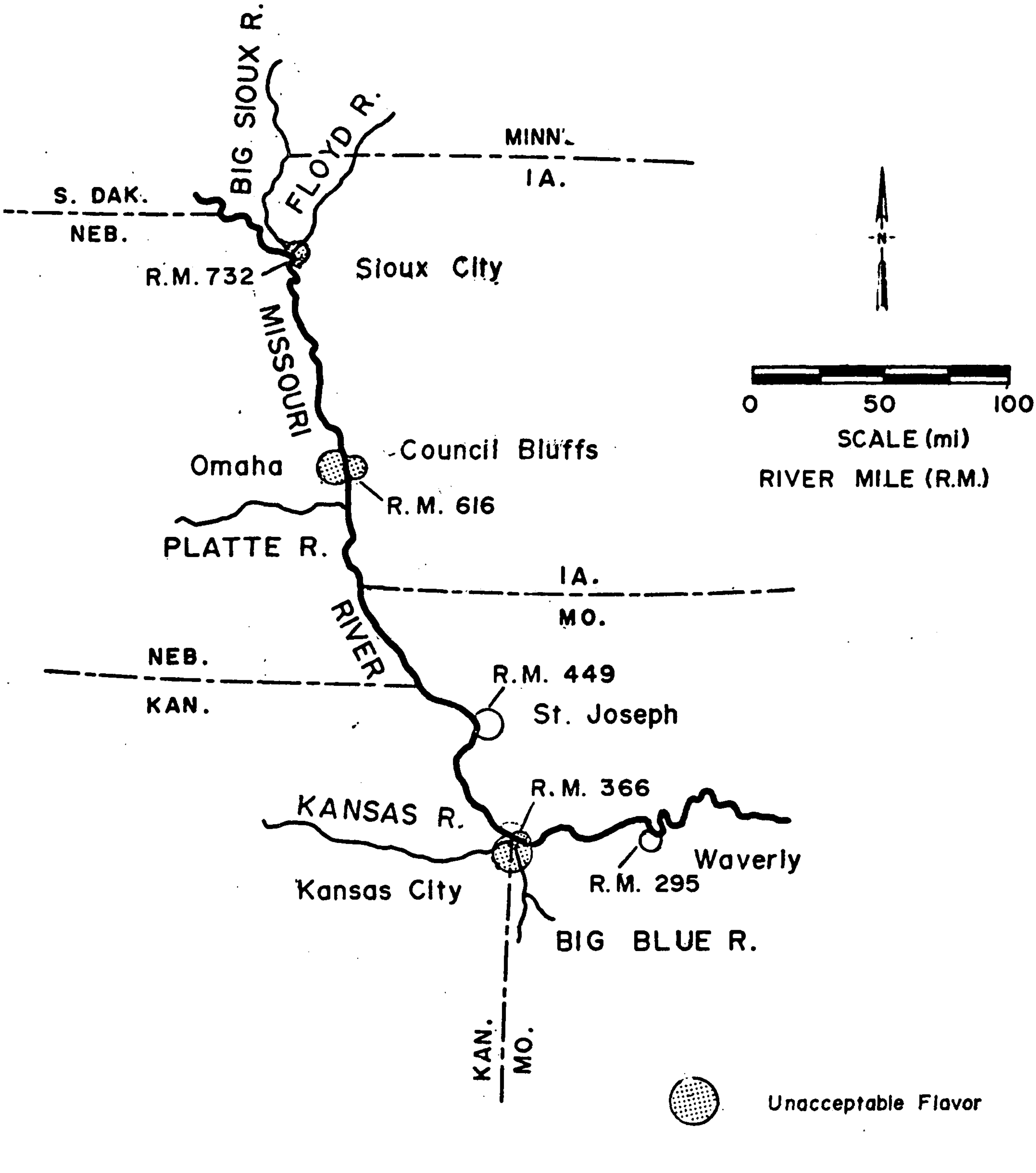


FIGURE 1. FISH FLAVOR STUDY AREA AND REACHES OF UNACCEPTABLE FISH FLAVOR, MISSOURI RIVER, 1969.

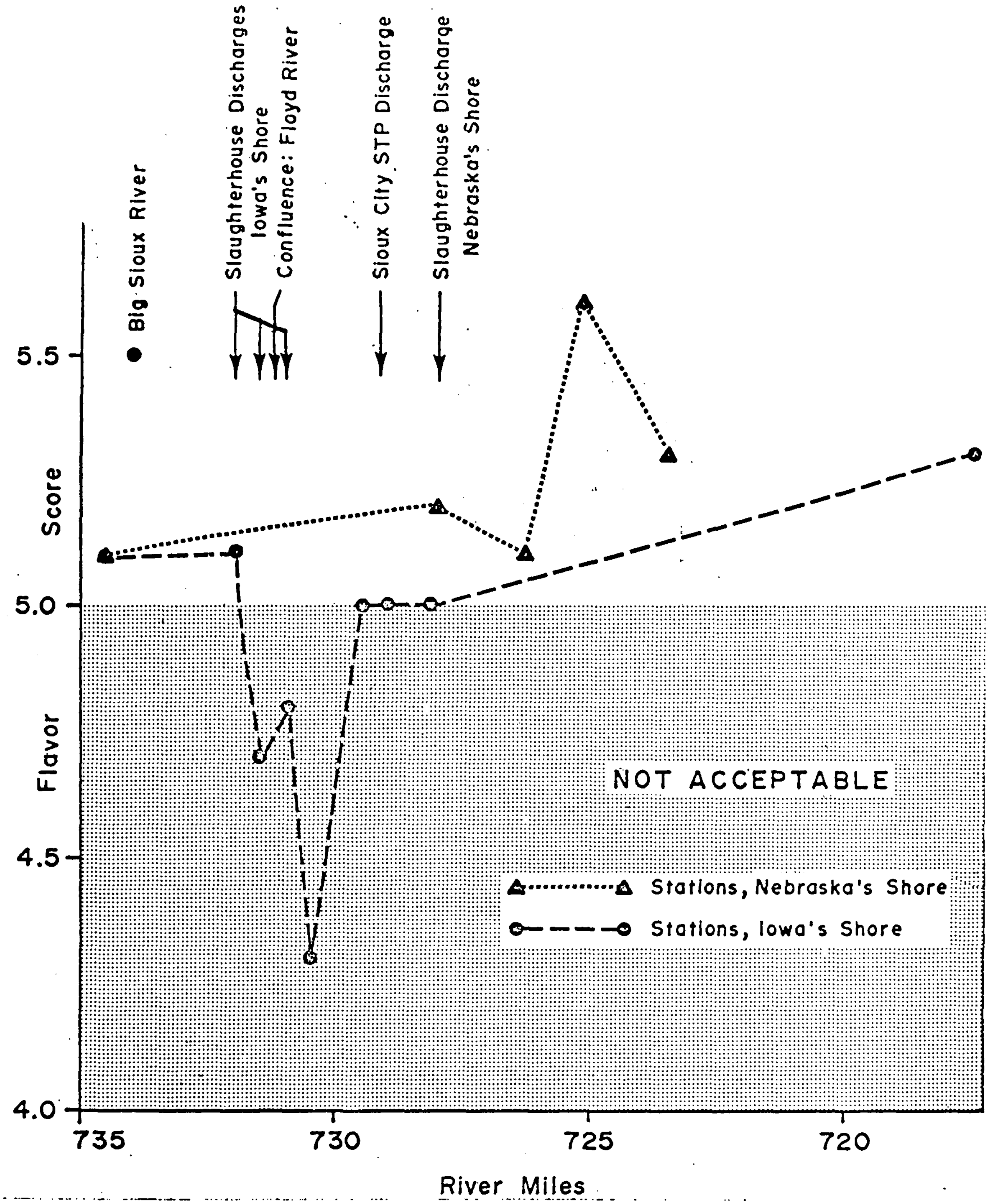


FIGURE 2. FLAVOR OF CAGED CHANNEL CATFISH, MISSOURI RIVER NEAR SIOUX CITY, IOWA 1969

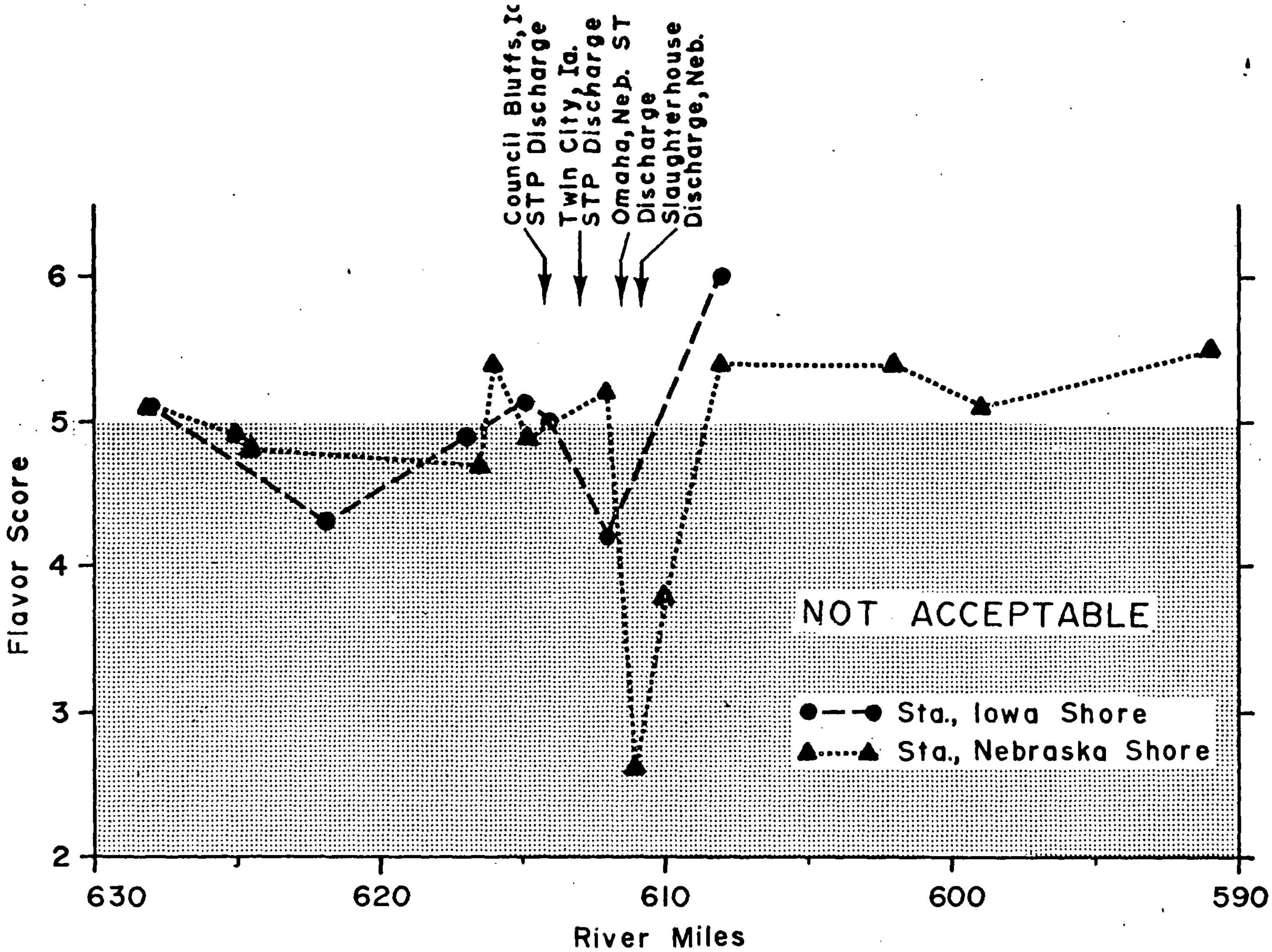


FIGURE 3. FLAVOR OF CAGED CHANNEL CATFISH, MISSOURI RIVER, NEAR OMAHA, NEBRASKA, 1969.

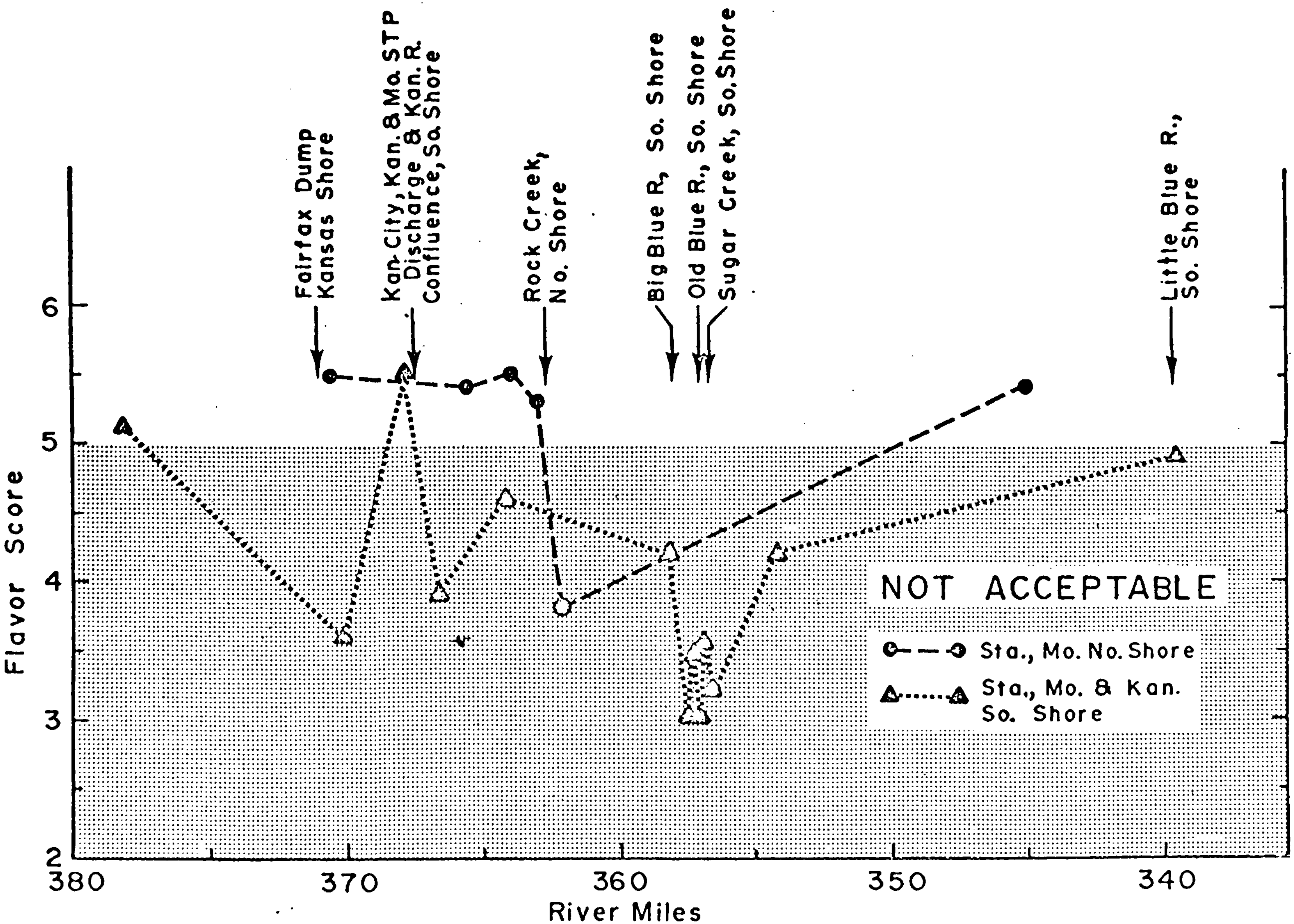


FIGURE 4. FLAVOR OF CAGED CHANNEL CATFISH, MISSOURI RIVER, NEAR KANSAS CITY, MISSOURI & KANSAS, 1969.

APPENDIX E

REPORT ON FECAL STEROL INVESTIGATION

MISSOURI RIVER BASIN STEROL ASSAY PROJECT REPORT

COPROSTANOL, A POSITIVE MARKER OF DOMESTIC AND RUN-OFF POLLUTION

Sterol Assay of Wastewater Plant Effluents and Surface Waters of the Lower Main Stem Missouri

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The specific proof of pollution of natural waters from various sources requires isolation and identification of the specific organic pollutants in these waters. Although contamination of waters by domestic sewage is commonly concluded on the basis of standard coliform organism counts, the use of a specific fecal organic compound that can be correlated quantitatively with this major source of pollution is more desirable. Steroids offer such a class of compounds, since certain steroids are characteristic of wastes from human beings and higher animals.

Coprostanol (coprostan-3-β-ol, 5 β-cholestan-3 β-ol) is one of the principal sterols in feces of human beings and higher animals, and feces are said to be the only source of this compound. The finding of coprostanol in water would therefore indicate excreta from either domestic wastes or run-off from pastures or barnyards. The merits of using this major human fecal sterol as a positive marker of domestic pollution has been recently emphasized (Murtaugh and Bunch, 1967; and Smith and Gouron, 1969). It was shown by the first authors that these compounds are removed by adequate secondary sewage treatment.

This study was undertaken to estimate the extent of human and warm-blooded animal fecal pollution and to pinpoint the main sources of this pollution in the Missouri River. The survey covered 28 sampling stations in the Sioux City, Omaha, St. Joseph and Kansas City area. The sampling stations and their river mileage (RM) are described in appendix I. Each location was sampled four different times at approximately two-week intervals. The samples were iced and flown to this laboratory. They were about one day old when analyzed.

The analytical method used for the estimation of the coprostanol in the river waters and in the wastewaters was based on the methodology which was previously developed in this laboratory (Murtaugh and Bunch, 1967), and proven effective for the recovery of sterols from wastewater as well as from a stream in the Cincinnati area. There was one major change in that a new packing was used for the gas-liquid chromatography column which permitted the free sterols to be run. This eliminated the need for making the trimethylsilyl ether derivatives. The procedure consisted of hexane extraction, mild alkali-alcohol hydrolysis of esters and conjugates to free sterols, cleanup by thin-layer chromatography (TLC) and quantitative measurement by gas-liquid chromatography (GLC). The procedure used is fully described in appendix II.

Simultaneously with the assay for the fecal sterol the number of fecal coliforms were determined utilizing the membrane filter technology.

Results and Discussion

The examination of sewage effluents and surface waters in the Sioux City, Omaha, St. Joseph and Kansas City areas of the lower main stem

Missouri revealed the presence of coprostanol. The chromatographic analyses of all samples from the sampling points show significant variations in the amount of the specific indicator of domestic pollution, coprostanol, as the degree of sewage pollution of the watercourse varied.

The sewage treatment plant (STP) effluents along the Missouri River within the above four sampling areas were shown to have significantly higher concentration of the fecal sterol than the surface water samples taken at points just before the plant sewage effluent discharge area or further down the river away from the treatment plants. The decrease in concentration of coprostanol was demonstrated adequately by analysis of water samples taken further away along the riverfrom the location of treatment plant outfalls.

Table 1 summarizes the analytical data on the concentration of coprostanol in effluent and surface water samples from the 28 sampling points. The treated sewage effluent samples from the Sioux City treatment plant (SC-49) contained a concentration of coprostanol in the range of 636 to 794 μg per liter. The STP effluents of the Omaha area at sampling points CB-40 B and OM-40 A gave values in the range of 743 to 864 and 250 to 362 μg per liter respectively. The range values of coprostanol concentration in samples of sewage effluent from sampling points SJ-15, SJ-18, A-25.5 and L-24.5 of the St. Joseph area were, respectively, 391 to 484, 465 to 573, 365 to 498 and 424 to 535 μg per liter. Kansas City area samples of STP effluent from M-103, M-104, and M-19 sampling points contained concentrations of fecal sterol in the range from 496 to 587, 259 to 319, and 328 to 419 μg per liter, respectively. The surface river water samples contained substantially lower concentrations of coprostanol, particularly at points further away from the treatment plant outfalls.

These conclusions are further substantiated by the microbiological data compiled for the same samples which were subjected to sterol analysis. A resume on the enumeration of fecal coliforms in the treated sewage effluents and surface river samples from the Missouri River is given in Table 2. The treated sewage effluents demonstrate the number of fecal coliforms in the millions per 100 ml of sample, while surface river samples further away from the plant sewage outfall show a progressively lower density of fecal coliforms. Since the same trend was determined for the concentration of coprostanol in the effluent and surface river samples, there seems to be a definite and significant correlation between the concentration of the fecal sterol and the degree of fecal pollution. This is graphically shown in Figure 1 which is a profile of the average density of fecal coliforms and average concentration of coprostanol for the 28 sampling stations.

On an average a hog, a cow or a human being would be expected to excrete 800 to 1,000 mg of coprostanol per day. If this is diluted with 100 gallons of wastewater, the expected concentration would be 210 to 250 µg per liter in raw wastewater. The results as compiled in Table 1 show that all treatment plant effluents exceeded this amount. The river samples are very high considering the dilution the wastewater would receive upon entering the river. The Missouri River samples were more than 10-fold greater in coprostanol than below an outfall of a poorly run secondary treatment plant in the Cincinnati area (Murtaugh and Bunch, 1967).

Summary

Sewage treatment plant effluents and surface river water samples from 28 sampling stations on the lower main stem Missouri were analyzed for the presence of the fecal sterol, coprostanol.

Data compiled on the amounts of coprostanol in the treatment plant effluents and surface waters indicate conclusively that the Missouri River is polluted with fecal matter.

Significant variations in the amount of coprostanol in the effluents and surface waters at sampling points further away from sewage effluent outfalls were clearly demonstrated and these show a correlation to the density of fecal coliforms at the same locations.

The analytical data definitely demonstrate the potential for using the analysis for sterol content to measure fecal pollution and the merit for using coprostanol as a positive marker of fecal pollution. The specific nature of coprostanol and its occurrence in surface waters polluted by domestic and run-off sewage leave little doubt that the presence of this fecal sterol connotes fecal pollution and that it ought to be used as an index of pollution in addition to the standard method for enumeration of fecal coliforms.

Acknowledgements

The authors wish to acknowledge the excellent assistance of the personnel of the Missouri Basin Region of FWQA for the laborious task of furnishing all the samples for this study. The authors express their sincere appreciation to Mr. Robert N. Bloomhuff for his enthusiasm and extremely capable assistance throughout the development of this study and for the photographic work on thin-layer chromatographs. The authors also wish to express their thanks to Mr. Cecil W. Chambers and Mr. Albert D. Venosa for supplying microbiological data of this study.

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TABLE 1. Quantitative Analysis of Coprostanol in Waste Treatment Plant Effluent and Surface Water Samples Taken from Sampling Points of the Lower Main Stem Missouri

Sampling Area	Sampling Point	River Mileage	Concentration of Coprostanol in μg/liter				Mean
			Date of Sampling				
			1-20-70	3-4-70	3-17-70	3-24-70	
Sioux City Area	M-52	736.0	4	6	10	3	6
	SC-49	729.0	636	723	684	793	709
	M-48	717.4	98	105	93	109	101
	B-43	631.1	64	66	60	57	62
	M-42	626.2	21	16	23	20	20
			1-27-70	2-23-70	3-10-70	3-31-70	
Omaha Area	M-42	626.2	9	20	26	28	21
	CB-40 B	614.0	743	864	766	815	797
	OM-40-A	611.5	250	300	362	335	312
	M-38	601.7	73	71	76	67	72
	M-205	596.6	177	200	295	166	210
	P-37	594.8	17	21	13	15	16
	M-34	559.7	60	73	76	72	70
	M-28	452.3	31	34	31	37	33
			2-4-70	4-7-70	4-21-70	5-5-70	
St. Joseph Area	M-28	452.3	37	31	35	28	33
	SJ-15	446.4	391	418	484	452	436
	SJ-18	445.6	573	465	503	493	508
	M-27	440.3	56	49	48	43	49
	A-25.5	421.0	365	451	498	389	424
	L 24.5	395.6	424	519	486	535	491
	M-23	370.5	63	46	54	60	56

TABLE 1. (Continued)

Sampling Area	Sampling Point	River Mileage	Concentration of Coprostanol in μg/liter — Date of Sampling				Mean
			2-11-70	4-14-70	4-28-70	5-13-70	
Kansas City Area	M-23	370.5	80	68	98	--	82
	K-22	367.4	78	70	83	--	77
	M-103	367.20	522	496	587	--	535
	M-104	367.19	259	319	298	--	290
	M-107 B	358.0	92	110	92	--	95
	M-19	358.0	328	419	396	--	381
	M-18	345.4	86	75	98	--	87
	M-15	293.0	66	79	58	--	70

TABLE 2. Enumeration of Fecal Coliforms in Waste Treatment Plant Effluent and Surface Water Samples Taken from Sampling Points at the Lower Main Stem Missouri.

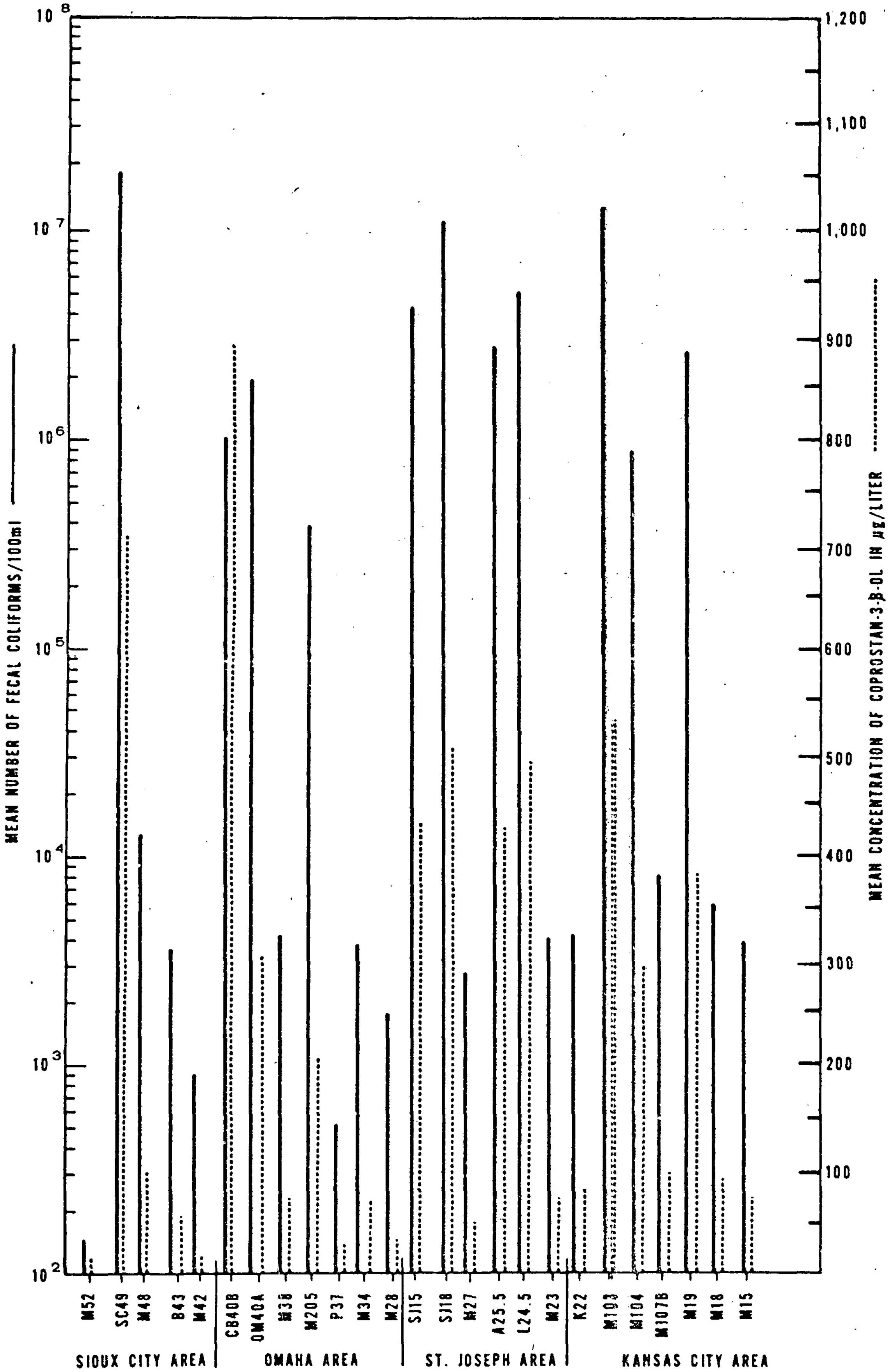
Sampling Area	Sampling Point	River Mileage	Number of Fecal Coliforms per 100 ml of Sample — Date of Sampling				Mean
			1-20-70	3-4-70	3-17-70	3-24-70	
Sioux City Area	M-52	736.0	---	360	8	44	140
	SC-49	729.0	---	26×10^6	20×10^6	12×10^6	19×10^6
	M-48	717.4	---	1.4×10^4	0.8×10^4	1.6×10^4	1.3×10^4
	B-43	635.1	---	1.0×10^4	380	705	3,500
	M-42	626.2	---	---	930	600	770
			1-27-70	2-23-70	3-10-70	3-31-70	
Omaha Area	M-42	626.2	---	1,200	800	1,000	1,000
	CB-40 B	614.0	---	2.9×10^6	1.7×10^6	4.0×10^6	2.9×10^6
	OM-40 A	611.5	---	1.0×10^6	0.8×10^6	4.0×10^6	1.9×10^6
	M-38	601.7	---	3,000	3,000	6,700	4,200
	M-205	596.6	---	3.1×10^5	4.1×10^5	4.1×10^5	3.8×10^5
	P-37	594.8	---	340	540	730	540
	M-34	559.7	---	1,800	3,700	5,800	3,800
	M-28	452.3	---	2,400	1,800	1,900	2,100
			2-4-70	4-7-70	4-21-70	5-5-70	
St. Joseph Area	M-28	452.3	1,600	1,400	2,600	560	1,800
	SJ-15	446.4	1.6×10^6	6.8×10^6	0.7×10^6	7.8×10^6	4.2×10^6
	SJ-18	445.6	1.4×10^6	4.2×10^6	22×10^6	17×10^6	11×10^6
	M-27	440.3	5,200	1,800	3,700	450	2,800
	A-25.5	421.0	0.97×10^6	5.0×10^6	0.27×10^6	4.9×10^6	2.8×10^6
	L-24.5	375.6	4.4×10^6	5.8×10^6	1.9×10^6	11×10^6	5.7×10^6
	M-23	370.5	6,200	2,400	3,000	1,000	3,150

TABLE 2. (Continued)

Sampling Area	Sampling Point	River Mileage	Number of Fecal Coliforms per 100 ml of Sample — Date of Sampling: 2-11-70	4-14-70	4-28-70	5-13-70	Mean
Kansas City Area	M-23	370.5	880	2,100	700	18,500	5,500
	K-22	367.4	6,200	1,300	7,400	1,800	4,200
	M-103	367.20	20×10^6	13×10^6	5.9×10^6	13×10^6	13×10^6
	M-104	367.19	1.3×10^6	0.3×10^6	0.4×10^6	1.6×10^6	0.9×10^6
	M-107 B	358.0	80	500	400	32,000	8,300
	M-19	358.0	1.9×10^6	2.6×10^6	2.2×10^6	4.1×10^6	2.7×10^6
	M-18	345.4	1,600	1,600	2,100	19,000	6,100
	M-15	293.0	770	1,800	1,600	11,800	4,000

FIGURE I

RELATIONSHIP BETWEEN CONCENTRATION OF COPROSTAN-3-β-OL AND NUMBER OF FECAL COLIFORMS



APPENDIX I

SAMPLING LOCATIONS - LOWER MAIN STEM MISSOURI

Sioux City Area

1.	M-52	Missouri River at RM-736 above the mouth of the Big Sioux River
2.	SC-49	Sioux City STP Effluent
3.	M-48	Sioux City mixing zone station - Missouri River at RM 717
4.	M-42	Missouri River at RM 626.2, Omaha Waterworks Intake
5.	B-43	Boyer River at I-29 Highway Bridge above Omaha

Omaha Area

1.	M-42	Missouri River at RM-626.2, Omaha Waterworks Intake
2.	OM-40A	Omaha-Missouri River STP Effluent
3.	CB-4CB	Council Bluffs STP Effluent
4.	M-205	Papillion Creek at CRB 1 mile below US-73
5.	M-38	Missouri River at Bellevue RM-601.6, Omaha area mixing station
6.	M-34	Missouri River at Nebraska City RM-559.7
7.	M-28	Missouri River at St. Joseph Waterworks Intake RM-452.3
8.	P-37	Platte River at US-73 Bridge Junction at RM-594.9L

St. Joseph Area

1.	M-28	Missouri River at St. Joseph Waterworks Intake RM-452.3
2.	SJ-15	St. Joseph Municipal STP effluent
3.	SJ-18	South St. Joseph Industrial STP effluent
4.	M-27	Missouri River at St. Joseph area mixing station RM-440.3

APPENDIX I (continued)

5. A-25.5 Atchison STP effluent

6. L-24.5 Leavenworth STP effluent

7. M-23 Missouri River at Kansas City Waterworks Intake RM-370.5

Kansas City Area

1. M-23 Missouri River at Kansas City Waterworks Intake RM-370.5

2. K-22 Kansas River at Central Avenue Bridge in Kansas City, Kansas

3. M-103 Kansas City, Kansas STP Effluent Westside

4. M-104 Kansas City, Missouri STP Effluent

5. M-19 Kansas City, Missouri-Blue River STP Effluent

6. M-107B Big Blue River at Mouth RM-358.0

7. M-18 Missouri River at Missouri City Power Plant Mixing Zone

8. M-15 Missouri River at Waverly RM-293.0

APPENDIX II

METHODOLOGY

Analysis of Cholesterol and Coprostanol in Rivers and Wastewaters

I. Hexane extraction of sterols and sterol conjugates.

1. To 1 liter samples add 20 ml of conc. HCl and 20 ml of 20% NaCl aqueous solution. Mix thoroughly.
2. Extract three times with 1/5 volumes of prepurified hexane. Extraction is performed in 2 liter capacity separatory funnels on a reciprocal shaker.
3. The pooled hexane fractions are then passed through a column of sodium sulfate to eliminate the water content.
4. The hexane is evaporated in a flash evaporator under vacuum to near dryness.

II. Mild alkali-ethanol hydrolysis of hexane extracted sterols.

1. The near dry residue is transferred to small digestion flasks.
2. Add 3 ml of 25% KOH aqueous solution and mix the contents thoroughly.
3. Add 7 ml of 95% ethyl alcohol and mix the contents thoroughly.
4. Add a few boiling chips to each of the digestion flasks and place them on a hot plate, connect them to the condensers and hydrolyze the contents for 2 hours.
5. After hydrolysis, cool the flasks immediately in an ice bath.

III. Hexane extraction of hydrolysates.

1. To the chilled contents in digestion flasks add 10 ml of distilled water.
2. Transfer the contents to 125 ml capacity separatory funnels.
3. Rinse the digestion flasks thoroughly with 40 ml of prepurified hexane and pour the solvent into the separatory funnels.
4. Extract on reciprocal shaker.
5. Repeat extraction with second 40 ml volume of hexane.
6. The pooled two hexane fractions are rinsed with 10 ml of 2% aqueous NaCl solution, shaken thoroughly, and allowed to stand for 10 minutes.
7. The NaCl layer is drained off and the hexane layer is transferred to evaporation flasks and evaporated in a flash evaporator to almost dryness.

IV. Transfer of hydrolyzed extract to small storage tubes.

1. The near dry residue in evaporation flasks is rinsed 3 times with 2 ml volumes of absolute ethanol, each rinsing facilitated by 10-minute shaking on a reciprocal or rotary shaker.
2. The rinsings are placed into small tubes and the contents are evaporated to dryness under forced prepurified air on a specially designed steam bath.
3. Follow the rinsing of the evaporation flasks with two additional acetone rinsings using 2 ml of acetone for each rinse.
4. Acetone rinsings are evaporated in the tubes, using above method.

V. Preliminary thin layer chromatography of the sterol extracts.

1. 20 by 20 cm glass plates are coated with 0.25 mm layer of Silica Gel G (E. Merck, Darmstadt) and activate for one hour at 110 C.
2. The prepared plates are stored in a vacuum desiccator until used.
3. Standard solutions of the sterols in acetone are prepared as 0.1% solutions, and the reference standards are spotted by means of Hamilton syringes on the Silica Gel G plates, using 5 ug/5 ul twice per each spot.
4. To the hydrolyzed samples of extracted sterols in small tubes are added 0.5 ml volumes of warm acetone. The contents are dissolved in acetone and 10 ul volumes of each of the extract samples are spotted on the same plate next to the reference standards.
5. The drying of the spots is facilitated by the use of infrared lamp.
6. The chromatoplates are developed with a mixture of chloroform and ether in the ratio of 9:1. They are then air dried for 15 minutes and heat dried (110 C) for additional 5 minutes.
7. The chromatoplates are sprayed with a 10% solution of phosphomolybdic acid in 95% ethanol.
8. After heating at 100 C for 15 minutes, the sterols appear as dark spots (violet-blue-indigo) on a yellow background.
9. The Rf values of the standard references are compared with those of the sterol extracts.

VI. Preparative thin layer chromatography for GC chromatography analysis.

1. Reference standards of sterols are spotted on the plate using the same concentrations per spot as above.
2. 0.1 ml volumes of the hydrolyzed samples of extracted sterols in acetone are streaked on the same plates with the standards on the right half portions of each plate.
3. After drying, the chromatoplates are developed with a mixture of $CHCl_3$-ether in the ratio of 9:1, air dried and heat dried.

4. The sterols are located by covering that portion of the plate containing the unknown samples with aluminum foil and spraying the reference standards with 10% solution of phosphomolybdic acid in 95% ethanol.
5. The standard reference spots are visualized after heating at 100 C for 15 minutes.
6. Areas for unknown samples corresponding to locations of reference standards are removed with a micro spatula, placed in prewashed medicine droppers plugged with prewashed glass wool and eluted into micro thistle tubes with 5 ml of acetone.
7. The eluted sterols are concentrated in the thistle tubes to the top level of the thistle on a steam bath with the aid of a gentle stream of clean, dry air.

VII. Gas-liquid chromatography of the silica Gel G eluted sterols.

1. Quantitative determinations are made with an Aerograph gas chromatograph and using a flame ionization detector.
2. A stainless steel column 1/8 in x 6 ft is packed with 60-80 mesh chromasorb Q coated with fluoroalkyl silicone polymer QF-1 (3% by weight) and column temperature is maintained at 235 C.
3. Helium is used as carrier gas, helium pressure adjusted to 25 psi, and the carrier gas flow rate maintained at 48 ml per minute.
4. Hydrogen flow rate to the flame ionization detector is kept at 25 ml/min. and the source of hydrogen is a hydrogen generator.
5. The air flow to the ionization detector is maintained at 200 ml/min.
6. The temperatures of the injector and detector are kept at 240 C.
7. 5 ug/5 ul concentrations of reference standards are injected and standard reference peaks determined for the concentrations of each of the standard sterols injected.
8. The retention time of each of the respective sterol standards is determined for the above set of column and detector conditions used.
9. Quantitative determinations of the unknown sterol extracts are based on peak height compared to a standard curve prepared from known reference standards. Qualitative determinations of unknowns are based on the retention time as compared with that of standards.
10. Internal standards are employed in the analysis of each of the separated (TLC) unknown sterol fractions to definitely categorize the unknown sample.

APPENDIX F

REPORT ON VIRUS ISOLATION INVESTIGATION

THE VIRUS HAZARD ON THE MISSOURI RIVER

Gerald Berg, Daniel R. Dahling, Donald Berman, and Carl Walter

A single infectious virus excreted by a human is capable of infecting other humans who consume that virus (Table 1)(1). The presence of a single such virus in water that people consume, therefore, constitutes a clearcut hazard to health and well-being.

Fecal coliforms always occur in the gastrointestinal tracts of warm blooded animals. Certain viruses and pathogenic bacteria may or may not be present at the same time. Fecal coliforms serve as indicators that viruses or pathogenic bacteria may be present. Thus, evidence of fecal coliforms in water is only an indication that hazardous agents may be present. Evidence constituted by many other biological and chemical indicators of pollution is often equivocal too, because in themselves, these indicators usually cannot be shown to be injurious to health. When no one line of evidence is conclusive, multiple lines of such evidence must be relied upon to support enforcement actions on the premise that the sum of the many such lines of evidence will stand stronger than any one line could stand alone.

Viruses are a different matter. Each virus is capable of producing infection. Each virus is thereby a dangerous pollutant. Thus, the detection of a single virus particle is the detection of a dangerous pollutant.

The detection of a virus in a sewage effluent ejected into a waterway constitutes a clear and present danger to health in the area of the outfall, immediately downstream of the outfall, and in communities well downstream when that virus will survive in the stream long enough to reach the downstream communities. Even when downstream transmission is not in evidence, the presence of viruses in an effluent and in a receiving water a short distance downstream of the outfall from which the effluent is discharged is a hazard, constitutes an adulteration of stream quality in that area, and thereby in itself demands remedial action.

MATERIALS AND METHODS

Collection of samples. All samples were collected by Region personnel. Raw influent and effluent samples were collected in cubitainers from primary treatment plants along the Missouri River and couriered to Cincinnati by air or transported by truck when river water samples were also taken. Samples were kept cold during transport.

Most sewage and effluent samples were processed immediately upon reaching the laboratory, but some were stored at -70 C before processing.

Large samples of water were collected in 55-gallon plastic-lined drums from selected locations on the Missouri River and trucked overnight to Cincinnati. In some instances, field filtrations were achieved with the equipment described below and the filter sandwiches were returned to Cincinnati, along with the silt collected on the pre-filters, for processing.

Recovery of viruses from sewage and treatment plant effluents. Each two-liter sample of sewage or treatment plant effluent was filtered through a Millipore AP 20 fiberglass prefilter and an MF 0.45 μ membrane filter. Prefilters and filters were pretreated with 0.1% Tween-80 to prevent virus adsorption to the filters and then rinsed with distilled water prior to contact with the samples. Ten ml of an $Al(OH)_3$ gel, prepared in McIlvaine's buffer* by procedures described elsewhere (2), was added to each filtered sample and each suspension was stirred with a magnetic stirrer for an hour. The $Al(OH)_3$ precipitates, to which virus had adsorbed, were collected by filtration on MF 0.45 μ membranes and removed with a spatula. The membranes were washed with 10 ml of a cell growth medium, and the washings were added to the corresponding $Al(OH)_3$ precipitates. The suspensions of medium and $Al(OH)_3$ were diluted 1:5 and inoculated onto cell cultures, 1 ml per culture, for assay by the plaque technic.

Five grams of fraction 5 bovine albumin and 100 ml of 1% aqueous protamine sulfate were added to each sample from which the $Al(OH)_3$ had been filtered and the suspensions were stirred for 30 minutes with a magnetic stirrer. The precipitates that formed were then collected on Tween-80-treated Millipore AP 20 fiberglass prefilters, and 1 ml of 1 M NaCl was filtered through each pad to dissolve the precipitates and elute the viruses. Each pad was subsequently washed with 6 ml of distilled water which were added to the corresponding dissolved precipitate, and the total volumes were inoculated onto cell cultures, 1 ml per culture, for assay by the plaque technic (3).

In some tests, the $Al(OH)_3$ and protamine sulfate procedures were applied to separate samples of effluent, because at the time the

* McIlvaine's buffer consisted of 0.05 M Na_2HPO_4 and sufficient citric acid to bring the pH to 6.

studies were done, it was believed that the $Al(OH)_3$ procedure would recover only small viruses and the protamine sulfate procedure would recover only large viruses. Subsequently, it was shown that the $Al(OH)_3$ procedure does recover some large viruses, and the protamine sulfate procedure does recover some small viruses. Thus, the results from the $Al(OH)_3$ procedure and those from the protamine sulfate procedure overlap somewhat and are not additive when separate effluent samples were used for each. Unless otherwise indicated in the table footnote, however, the two procedures were applied in tandem on the same sample, and the total number of viruses recovered reflect the minimum present in the sample. In any event, neither procedure is quantitative. The total amount of viruses in an effluent must exceed by some considerable amount the quantity of viruses detected.

Recovery of viruses from river water. Fifty or 100 gallons of river water were filtered through a 293 mm Tween-80-treated Millipore AP 20 prefilter and then through two 143 mm Tween-80-treated AP 20 prefilters between which were sandwiched 1.8 gm of washed Monsanto PE 60 polyelectrolyte (4). The filter pads were supported in Millipore filter holders of appropriate size connected in tandem. The 293 mm filter clogged frequently with silt and was replaced as necessary. The silt was collected with a spatula and the virus eluted from it with 3% beef extract by a method designed in this laboratory (6). Viruses were eluted from the polyelectrolyte by circulating 60 ml of 0.5% pancreatin through the sandwich three times, and then circulating 60 ml of pH 9 borate buffer containing 10% fetal calf serum through the sandwich three times. The borate buffer consisted of 0.05 M H_3BO_3, 0.05 M KCl, and sufficient NaOH to bring the pH to 9. Each eluate was collected separately, filtered through an MF 0.45 μ membrane filter to remove bacteria and fungi, and inoculated onto cell cultures, 1 ml per culture for assay of viruses.

Cell cultures. All viruses were isolated by the plaque technic in primary cell cultures prepared from rhesus monkey kidney cells.

Identification of viruses. Viruses are being identified under contract with Dr. S. S. Kalter, Southwest Foundation for Research and Education, San Antonio, Texas.

RESULTS AND DISCUSSION

Our first important effort to demonstrate virus pollution of a major stream was undertaken in the late summer of 1969 along the Missouri River. Repeated efforts to demonstrate, with standard pollution indicators [such as depressed dissolved oxygen levels (DO) and 5-day 20 C biochemical oxygen demands (BOD)] deleterious alteration of the stream by communities that discharged primary effluents into it had been essentially unsuccessful. The likelihood of recovering viruses from a stream when other indicators of pollution could not be demonstrated seemed remote: Viruses usually do not reach levels much beyond several thousand plaque-forming units (PFU)* per gallon of sewage, they do not multiply in the effluent or in the stream, and they slowly die off as time progresses. Moreover, once diluted in the stream they become difficult to detect because good quantitative concentration methods have not yet been developed. There did exist, however, the advantage that demonstration of even one virus particle of

* Plaque-forming units are infectious units.

human origin is bonafide evidence of dangerous pollution, whereas small changes in pollution indicator values below cutfalls are difficult to interpret.

Thus, our initial efforts were directed at detecting viruses in effluents discharged into the river. Six times during the months of September and October 1969, samples were taken from sewage treatment plants along stretches of the waterway. Most samples were primary effluent, but some raw sewage and river water samples were also taken. Viruses, often several hundred per gallon, were consistently recovered from municipal treatment plant primary effluents, and from raw sewage (Tables 2-7). Stock yard effluents also yielded hundreds of viruses when tested in calf kidney cells, indicative that animal viruses in large numbers are continuously discharged into the waterway. In itself, all of this was bonafide evidence that the Missouri River was being polluted with infectious agents.

To determine how far downstream these infectious agents constituted a hazard presented a more complex problem, because dilution of the viruses in the stream necessitates a concentration of small numbers of viruses from very large volumes of water. No established methods were available for such studies. As an alternative, viruses of the types present in sewage effluents (enteroviruses and reoviruses) were seeded into Missouri River water and into the effluents as well, and 24-hour viral survivals (long enough to reach major downstream water supplies) were determined. Table 8 shows that large numbers of viruses survived in the Missouri River water, in the sewage, and in the effluents.

after 24 hours. The reovirus, reportedly capable of producing cancers in certain animals when inoculated in very small amounts (5), appeared to increase in numbers in the river water, perhaps the result of clumps breaking up. It was clear, in any event, that viruses ejected into waterways with domestic sewage could reach water intakes many miles downstream.

The detection of viruses at water intakes downstream of a pollution source can demonstrate that the hazard perpetrated in the area of an outfall by the discharge of viruses into that area has extended itself to the downstream community. Good quantitative technics for detecting small amounts of viruses in large volumes of water were not available, but a technic under development, capable of detecting a portion of the viruses present, gave some promise of sufficient sensitivity. This was the polyelectrolyte method. In this method (see Materials and Methods), large volumes of water are filtered through a Monsanto compound designated PE 60 which adsorbs some viruses. Adsorbed viruses subsequently can be eluted and quantified. Thus, an effort was made to recover viruses from large volumes of river water. An attempt was made also to recover viruses from the silt that collected on fiberglass prefilters used to remove suspended material before the water passed through the polyelectrolyte. A number of attempts were made to detect viruses upstream and downstream from outfalls and at some water intakes. These studies are summarized in Table 9.

A 50-gallon water sample taken at Missouri City yielded five viruses, and a sample of similar size taken at Bellevue yielded four viruses. Six more viruses were recovered from the silt in the water sample. At Sioux City, four viruses were recovered from a 50-gallon water sample and its silt five miles below the sewage outfalls, but none were recovered from samples taken above the outfalls. Forty-eight viruses per liter of sample were recovered from Sioux City primary effluent sampled on the same day.

A mid-winter study at St. Joseph yielded interesting results. One virus was recovered from 50 gallons of water taken at Palermo landing, about 10 miles below St. Joseph's sewage treatment outfalls, but 19 viruses were recovered from a sample of similar size taken at the water intake above the outfalls. This is equal to 360,000 viruses per million gallons of water. Recovery of viruses from water intakes during the winter, especially, when transmission of enteric viruses is at a relatively low point, underscores the hazard perpetrated upon downstream communities by upstream communities that discharge viruses in their effluents. St. Joseph primary effluents also yielded considerable quantities of viruses (Table 9). This study was repeated in the spring at which time viruses were again recovered from the water intake, and at Palermo landing also.

All viruses identified thus far are polioviruses and echoviruses, are of human origin, and are capable of infecting humans who consume them.

Since trucking multiple 50-gallon samples to Cincinnati, especially during the winter months, was difficult, a comparative study was set up at the time of the spring sampling at St. Joseph to determine whether filtrations through the polyelectrolyte could be done in the field and virus elution and isolation subsequent to return of the filters to the Cincinnati laboratory. The results of this study show that the same amount of viruses were recovered when filtrations were done in the field as when they were done in the laboratory on trucked-in samples (Table 10). Subsequent studies in our laboratory showed that storage of the filters at 4 C for several days before and after water was filtered through them did not reduce virus recoveries (Table 11), and thus added support to the feasibility of a field filtration technic. The results in Table 11 also demonstrate the inefficiency of the technic as a quantitative method for virus recovery.

Although technical problems occurred in the field that made it impossible to filter much more than half of the 50 gallons that were filtered in the laboratory, these problems were minor and should be easy to resolve.

SUMMARY

A single viable virus excreted by a human is capable of infecting other humans who consume it, and thus constitutes a hazard to health and well-being. Thus, each virus is a dangerous pollutant. Viruses have been detected along the Missouri River in effluents, midstream, and at water intakes, demonstrating a clearcut hazard perpetrated upon downstream communities by those upstream. The methods used to demonstrate the virus pollution were capable of detecting only a portion of the viruses present. Thus, many more viruses were present than we were able to detect. There is clearly an urgent need for developing better methodology for detecting small numbers of viruses in large volumes of water.

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Table 1. Minimal Infective Dose of Viruses for Man

Virus	Dose*	Route of inoculation	No. infected / No. inoculated	% infected
Poliovirus 1 (SM)	2 PFU	Oral (gelatin capsule)	2/3	67
Poliovirus 3 (Fox)	1 TCD_{50}	Gavage	3/10	30
Measles	1 TCD_{50}	Intranasal	8/35	24

* Given in plaque-forming units (PFU) or that amount of virus that will infect 50% of the tissue cultures inoculated (TCD_{50}).

Table 2. Recovery of Viruses from Missouri River Effluents
(Samples of 9/19/69)

Sample	Site of sampling: Place	Site of sampling: River miles	Type of effluent	Laboratory recovery method	Virus recovered (PFU/liter)
A-25.5	Atchison sewage treatment plant	421.0	Primary	$Al(OH)_3$	9.5
L-24.5	Leavenworth sewage treatment plant	395.6	Primary	$Al(OH)_3$	
SJ-15	St. Joseph sewage treatment plant	446.4	Primary	$Al(OH)_3$	8
SJ-18	South St. Joseph industrial sewer district (stock yard)	445.6	Primary	$Al(OH)_3$*	2.5
				Protamine sulfate*	10
				$Al(OH)_3$	0
				Protamine sulfate	4

* Tested in calf kidney cells.

Table 3. Recovery of Viruses from Missouri River Effluents
(Samples of 9/24/69)

Sample	Site of sampling		Type of effluent	Laboratory recovery method	Virus recovered (PFU/liter)
	Place	River miles			
A-25.5	Atchison sewage treatment plant	421.0	Primary	$Al(OH)_3$	128.5
				Protamine sulfate	274
L-24.5	Leavenworth sewage treatment plant	395.6	Primary	$Al(OH)_3$	50
				Protamine sulfate	9
SJ-15	St. Joseph sewage treatment plant	446.4	Primary	$Al(OH)_3$	53
				Protamine sulfate	20.5
SJ-18	South St. Joseph industrial sewer district (stock yard)	445.6	Primary	$Al(OH)_3$*	45.5
				Protamine sulfate*	58
				$Al(OH)_3$	85
				Protamine sulfate	15

* Tested in calf kidney cells.

Table 4. Recovery of Viruses from Missouri River Effluents
(Samples of 9/26/69)

Sample	Site of sampling: Place	Site of sampling: River miles	Type of effluent	Laboratory recovery method+	Virus recovered (PFU/liter)
M-19	Big Blue River sewage treatment plant		Primary	$Al(OH)_3$	96
				Protamine sulfate	18
M-104	Kansas City, Mo. westside sewage treatment plant	367.19	Primary	$Al(OH)_3$	71
				Protamine sulfate	0.5
M-106	Rock Creek below North Kansas City sewage treatment plant	362.7	Primary	$Al(OH)_3$	2.5
				Protamine sulfate	0.5
M-108	Rock Creek at Independence, Mo. raw sewage by-pass line	356.9	Raw sewage	$Al(OH)_3$	85
				Protamine sulfate	9
M-102	Kaw Valley District outfall	367.6L	Primary	$Al(OH)_3$	61
				Protamine sulfate	2
M-103	Kansas City, Kansas sewage treatment plant	367.2L	Primary	$Al(OH)_3$	73
				Protamine sulfate	2.5

+ Separate samples used for tests with $Al(OH)_3$ and protamine sulfate.

Table 5. Recovery of Viruses from Missouri River Effluents
(Samples of 10/1/69)

Sample	Site of sampling: Place	Site of sampling: River miles	Type of effluent	Laboratory recovery method	Virus recovered (PFU/liter)
M-19	Big Blue River sewage treatment plant		Primary	$Al(OH)_3$	109
				Protamine sulfate	0
M-102	Kaw Valley District outfall	367.6L	Primary	$Al(OH)_3$	0
				Protamine sulfate	1
M-103	Kansas City, Kansas sewage treatment plant	367.2L	Primary	$Al(OH)_3$	146
				Protamine sulfate	56
M-104	Kansas City, Mo. westside sewage treatment plant	367.19	Primary	$Al(OH)_3$	92
				Protamine sulfate	6
M-106	Rock Creek below north Kansas City sewage treatment plant	362.7	Primary	$Al(OH)_3$	1.5
				Protamine sulfate	0
M-108	Rock Creek at Independence, Mo. raw sewage by-pass line	356.9	Raw sewage	$Al(OH)_3$	16
				Protamine sulfate	0.5

Table 6. Recovery of Viruses from Missouri River Effluents
(Samples of 10/16/69)

Sample	Site of sampling: Place	Site of sampling: River miles	Type of effluent	Laboratory recovery method*	Virus recovered (PFU/liter)
OM-40A	Omaha-Missouri River sewage treatment plant from Monroe Street by-pass	611.5	Raw sewage	$Al(OH)_3$	19
				Protamine sulfate	222
M-211	Pacific Fruit Express outfall	611.5R	Train car wash raw discharge	$Al(OH)_3$	0
				Protamine sulfate	0
M-212	Quaker Oats Co.	615.2L	Raw process waste outfall	$Al(OH)_3$	0
				Protamine sulfate	0

* Separate samples used for tests with $Al(OH)_3$ and protamine sulfate.

Table 7. Recovery of Viruses from Missouri River Effluents
(Samples of 10/24/69)

Sample	Site of sampling: Place	Site of sampling: River miles	Type of effluent	Laboratory recovery method	Virus recovered (PFU/liter)
M-38	Bellevue, 0.1 miles above State Highway 370 bridge		River water	$Al(OH)_3$*	0
				Protamine sulfate*	0
M-203	Omaha-Papillion Creek sewage treatment plant		2/3 secondary 1/3 primary	$Al(OH)_3$*	41
				Protamine sulfate*	1.5
M-211	Pacific Fruit Express	611.5R	Train car wash raw discharge	$Al(OH)_3$*	0
				Protamine sulfate*	0
M-212	Quaker Oats Co.	615.2L	Raw process waste outfall	$Al(OH)_3$*	0
				Protamine sulfate*	0
OM-40A	Omaha-Missouri River sewage treatment plant	611.5L	Primary	$Al(OH)_3$*	20
				Protamine sulfate*	26
TC-210	Twin Cities Plaza raw sewage discharge	613.6R	Raw sewage	$Al(OH)_3$*	5
				Protamine sulfate*	7
CB-40B	Council Bluffs sewage treatment plant	614.0R	Primary	$Al(OH)_3$*	135
				Protamine sulfate*	286
OM-208	Monroe Street by-pass of raw wastes to Missouri River	611.4L	Raw packing waste	$Al(OH)_3$	95
				Protamine sulfate	201
				$Al(OH)_3$+	0
				Protamine sulfate+	0.5

* Separate samples used for tests with $Al(OH)_3$ and protamine sulfate.

+ Tested in calf kidney cells.

Table 8. Survival of Viruses in Missouri River Water and in Sewage Effluents*

Date samples were collected	Site of sampling Place/River miles		Type of sample	Poliovirus 1 Hours 0	Poliovirus 1 Hours 24	Echovirus 7 Hours 0	Echovirus 7 Hours 24	Reovirus 1 Hours 0	Reovirus 1 Hours 24
10/7/69	River water	354.4	Water	9.6×10^4**	7.1×10^4(74)***	9.5×10^4	4.7×10^4(50)	1.6×10^3	1.07×10^4(167)
	Big Blue River sewage treatment plant		Primary effluent	11.3×10^4	6.0×10^4(53)	8.8×10^4	13.2×10^4(150)	2.4×10^3	2.06×10^3(86)
10/29/69	River water	601.3	Water	1.1×10^5	6.8×10^4(61)	8.7×10^4	8.0×10^4(92)	1.21×10^3	1.65×10^3(136)
	Papillion Creek	596.6	2/3 secondary 1/3 primary	1.12×10^5	4.4×10^4(40)	7.6×10^4	1.04×10^5 (136)	9.4×10^2	2.23×10^3(233)
11/9/69	River water	440.3	Water	1.47×10^5	3.2×10^4(22)	1.44×10^5	7.8×10^4(54)	3.2×10^3	2.15×10^4(672)
	S. St. Joseph ind. sewer dist.	445.6	Primary effluent	1.34×10^5	1.22×10^5(91)	1.2×10^5	9.5×10^4(79)	5.2×10^3	3.39×10^3(65)
11/17/69	River water M-48	718.3	Water	3.12×10^5	5.8×10^4(19)	1.6×10^5	5.6×10^4(35)	1.25×10^4	5.1×10^4(403)
	Sioux City SC-49	729.0R	Primary effluent	1.89×10^5	8.4×10^4(44)	1.34×10^5	6.8×10^4(51)	1.4×10^4	1.52×10^4(109)

* Samples were stored at room temperature (23-26 C).

** PFU per ml.

*** Percent surviving given in parenthesis.

Table 9. Recovery of Viruses from Missouri River Water and Silt

Date of sampling	Site of sampling: Place	River miles	Type of sample	Size of sample	Lab recovery procedure	Virus recovered (PFU/sample)	Virus types recovered*
10/8/69	Missouri City Power Plant Dock	354.4	Water	50 gal	Polyelectrolyte	5	E8, E8, E1, E1, E7
			Silt	from 8.33 gal**	Beef extract	0	
10/30/69	Near Omaha Bellevue Power Plant	601.3	Water	50 gal	Polyelectrolyte	4	P2, E7, P2,
			Silt	from 50 gal**	Beef extract	6	E1, P1, E7, P3
12/11/69	Thacker Marina in Sioux City (above all sewage outfalls)	732.7L	Water	50 gal	Polyelectrolyte	0	
			Silt	from 50 gal**	Beef extract	0	
	Sioux City		Primary effluent	2 liters	$Al(OH)_3$	82	Not yet typed
					Protamine sulfate	14	Not yet typed
	Sioux City (5 miles below all sewage outfalls)	717.0	Water	50 gal	Polyelectrolyte	1	Not yet typed
			Silt	from 50 gal**	Beef extract	3	P3, P3
1/22/70	St. Joseph Water Works intake line (above sewage outfalls)	452.3	Water	50 gal	Polyelectrolyte	19	P3, P2, P2, P2, E7, E33, E33
			Silt	from 50 gal**	Beef extract	0	
	St. Joseph Municipal		Primary effluent	2 liters	$Al(OH)_3$	88	Not yet typed
					Protamine sulfate	5	Not yet typed
	St. Joseph Municipal (meat packing plant)		Primary effluent	2 liters	$Al(OH)_3$	134	Not yet typed
					Protamine sulfate	0	
	Palermo Landing	440.3	Water	50 gal	Polyelectrolyte	1	E33
			Silt	from 50 gal**	Beef extract	0	
4/23/70	St. Joseph Water Works intake (above sewage outfalls)	452.3	Water	50 gal	Polyelectrolyte	3	Not yet typed
			Silt	from 50 gal**	Beef extract	0	
	St. Joseph Municipal sewage treatment plant		Primary effluent	2 liters	$Al(OH)_3$	222	Not yet typed
					Protamine sulfate	66	Not yet typed
	St. Joseph Industrial sewage treatment plant (meat packing plant)		Primary effluent	2 liters	$Al(OH)_3$	10	Not yet typed
					Protamine sulfate	0	
	Palermo Landing	440.3	Water	50 gal	Polyelectrolyte	3	Not yet typed
				from 50 gal**	Beef extract	0	

* Not all viruses recovered have been typed as yet.

** Silt taken from prefilters used in filtration of 50-gallon samples. Sometimes silt from volumes less than the 50 gallons filtered were used.

Table 10. Comparison of Field Filtration and Laboratory Filtration of Water Samples on Efficiency of Recovery of Viruses from Missouri River Water at St. Joseph

Site of sampling: Place	Site of sampling: River miles	Type of sample	Size of sample	Site of filtration	Virus recovered (PFU/sample)	Virus types recovered**
Waterworks Intake	452.3	Water	50 gal	Laboratory	3	
			31 gal	Field	1	E1
		Silt	Silt from 50 gal*	Laboratory	0	
			Silt from 31 gal*	Field	1	E7
Palermo Landing	440.3	Water	50 gal	Laboratory	3	
			21 gal	Field	1	E7
		Silt	Silt from 50 gal*	Laboratory	0	
			Silt from 21 gal*	Field	2	E7

* Silt taken from prefilters used in filtration of corresponding water samples.

** Not all viruses recovered have been typed as yet.

Table 11. Recovery of Viruses from Freshly Prepared and Stored Polyelectrolyte PE 60

Virus	Control	Freshly prepared PE 60	Stored PE 60	Storage (days at 4 C)	
				Before test	After test
Poliovirus 1	75*	38* (51%)	45* (53%)	2	3
Echovirus 7	79	24 (30%)	20 (25%)	2	5
Reovirus 1	105	33 (31%)	9 (8%)	2	5
Reovirus 1	84	14 (17%)	12 (14%)	2	2.5

* Plaque-forming units.

APPENDIX G

INDUSTRIAL WASTE SURVEY SUMMARY DATA

SIOUX CITY, IOWA

a	b	c	d	e	f
SIC Group	Group Name	Number of Companies	With Significant In-Plant Treatment	Discharge to Municipal Sewers	General Character of Wastes
20	Food Products	38	9	36	Food Scrap
26	Paper Products	1	0	1	Cooling Water
27	Printing/Publishing	4	0	4	Photo Engraving-Acids
28	Chemicals & Allied	5	1	1	Process Chemicals
32	Stone-Clay Products	4	0	4	Wash Waters
33	Primary Metals	1	0	1	Plating
34	Fabricated Metals	7	3	5	Plating
36	Electrical/Equipment Supplies	4	0	4	Dilute Acids
50	Wholesale Trade	10	0	10	Wash Water

COUNCIL BLUFFS, IOWA

a	b	c	d	e	f
SIC Group	Group Name	Number of Companies	With Significant In-Plant Treatment	Discharge to Municipal Sewers	General Character of Wastes
20	Food Products	5	1	5	Food Scrap
27	Printing/Publishing	2	2	2	Photo Engraving-Acids
28	Chemicals & Allied	4	0	4	Process Chemicals
33	Primary Metals	2	0	2	Plating
34	Fabricated Metals	1	0	1	Plating
36	Electrical/Equipment Supplies	3	0	3	Dilute Acids
37	Transportation Equipment	2	0	2	Steamed Wash Waters
42	Motor Freight Transportation	5	0	3	Wash Water
50	Wholesale Trade	11	0	9	Wash Water

OMAHA, NEBRASKA

a	b	c	d	e	f
SIC Group	Group Name	Number of Companies	With Significant In-Plant Treatment	Discharge to Municipal Sewers	General Character of Wastes
07	Agricultural Services	2	0	1	Feedlot Runoff
20	Food Products	78	2	78	Food Scrap
27	Printing/Publishing	2	0	2	Photo Engraving-Acids
28	Chemicals & Allied	18	2	15	Process Chemicals
29	Petroleum Refining	2	0	2	Petroleum
33	Primary Metals	2	1	0	Plating
34	Fabricated Metals	8	1	8	Plating
35	Manufacturing	6	0	6	Plating
36	Electrical/Equipment Supplies	2	1	2	Dilute Acids
37	Transportation Equipment	2	0	2	Steamed Wash Waters
42	Motor Freight Transportation	9	1	9	Wash Water
50	Wholesale Trade	32	2	29	Wash Water
73	Miscellaneous Business	4	0	4	Wash Water
75	Auto Repair	5	0	1	Plating

NORTH KANSAS CITY, MISSOURI

a SIC Group	b Group Name	c Number of Companies	d With Significant In-Plant Treatment	e Discharge to Municipal Sewers	f General Character of Wastes
20	Food Products	3	0	3	Food Scrap
26	Paper Products	2	0	2	Cooling Water
27	Printing/Publishing	3	0	3	Photo Engraving-Acids
28	Chemicals & Allied	11	3	8	Process Chemicals
29	Petroleum Refining	4	1	4	Petroleum
33	Primary Metals	2	1	2	Plating
34	Fabricated Metals	2	0	2	Plating
36	Electrical/Equipment Supplies	2	1	2	Dilute Acids
37	Transportation Equipment	1	0	0	Steamed Wash Waters

KANSAS CITY, MISSOURI

a	b	c	d	e	f
SIC Group	Group Name	Number of Companies	With Significant In-Plant Treatment	Discharge to Municipal Sewers	General Character of Wastes
20	Food Products	12	1	11	Food Scrap
26	Paper Products	2	0	2	Cooling Water
27	Printing/Publishing	5	0	5	Photo Engraving-Acids
28	Chemicals and Allied	23	2	20	Process Chemicals
29	Petroleum Refining	5	1	5	Petroleum
31	Leather Products	2	2	2	Hide By-Products
33	Primary Metals	7	1	6	Plating
34	Fabricated Metals	15	3	13	Plating
36	Electrical/Equipment Supplies	4	2	4	Dilute Acids
45	Air Transportation	1	1	0	Plating/ Petroleum
50	Wholesale Trade	3	0	3	Wash Water
78	Motion Pictures	1	1	1	Film Processing

APPENDIX H

BASIC DATA

The data upon which this report is based has been placed in the EPA STORET System for storage and easy retrieval. Arrangements to obtain copies of these data can be made by contacting the Environmental Protection Agency, Office of Water Quality, 911 Walnut, Kansas City, Missouri 64106.