EPA/600/3-85/005
January 1985

Site-Specific Water Quality Studies of the Straight River, Minnesota: Complex Effluent Toxicity, Zinc Toxicity, and Biological Survey Relationships

by

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1 REPORT NO EPA/600/3-85/005	2	3 RECIPIENT'S ACCESSION NO. PB85 160703 /AS
4 TITLE AND SUBTITLE Site-Specific Water Quality Studies of the Straight River, Minnesota: Complex Effluent Toxicity, Zinc Toxicity, and Biological Survey Relationships		5 REPORT DATE January 1985 6 PERFORMING ORGANIZATION CODE
7 AUTHOR(S) A.R. Carlson and T.H. Roush		8 PERFORMING ORGANIZATION REPORT NO
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Environmental Research Laboratory-Duluth 6201 Congdon Boulevard Duluth, Minnesota 55804		10 PROGRAM ELEMENT NO. 11 CONTRACT/GRANT NO
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development Environmental Research Laboratory U.S. Environmental Protection Agency Duluth, Minnesota 55804		13 TYPE OF REPORT AND PERIOD COVERED 14 SPONSORING AGENCY CODE EPA-600/03

15 SUPPLEMENTARY NOTES

16 ABSTRACT

Comparative laboratory toxicity tests using Ceriodaphnia reticulata and the fathead minnow Pimephales promelas were conducted to establish relationships between the toxicity of a sewage treatment plant effluent containing high concentrations of zinc, toxicity of the effluent in the receiving water, toxicity of zinc added to the receiving water and a reference water, and receiving water biota survey data. Water and biota were sampled under summer (3 times), fall (once) and winter (once) conditions over a one year period. The relationships were used in evaluating the protectiveness of a site-specific water quality criterion derived for zinc. A strong correlation between the effluents toxicity to daphnids was established, however, toxicity correlation with adverse impact on river biota could not be established.

It was concluded that the effluent did not adversely affect taxa composition and abundance at 2 miles (3.2 km) below the discharge to the river. At 2 miles the zinc concentrations ranged from 100 to 154 g/l and averaged 144 g/l on 3 of 4 sampling dates indicating that a site-specific criterion average concentration of 145 g/l, approximately 3 times greater than the national average concentration, would be protective of river biota.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group

18 DISTRIBUTION STATEMENT Release to public	19 SECURITY CLASS (This Report) Unclassified	21 NO. OF PAGES 59
	20 SECURITY CLASS (This page) Unclassified	22 PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

INTRODUCTION

The physical and/or chemical characteristics of water in a natural system may alter the biological availability and/or toxicity of a material such as zinc. Guidelines for deriving site-specific water quality criteria which take these factors into account have been published by the U.S. Environmental Protection Agency (hereafter referred to as the site-specific guidelines) (U.S. EPA, 1983A). One guideline approach is to simply test a prescribed number of resident species in site water to meet minimum data requirements from which a site criterion is calculated. Another approach is to test sensitive "indicator or surrogate species" from the same population in both clean reference water, hereafter referred to as laboratory water, and site water at the same time (except for water characteristics) under similar conditions. The ratio of site water toxicity value/lab water toxicity value is used to modify the national criteria value to a site-specific value. Both of these criteria derivation approaches are based on the assumptions: (1) that differences in the toxicity values of a specific material determined in laboratory water and site water may be attributed to chemical (e.g., complexing ligands) and/or physical (e.g., adsorption) factors that alter the biological availability and/or toxicity of a material and (2) that selected test species directly integrate differences in the biological availability and/or toxicity of the material and provide a direct measure of the capacity of a site water to increase or decrease toxicity values relative to values obtained in laboratory water. Such single chemical criteria address effects of pollutants on aquatic life in the absence of other pollutants in the water column, a condition which seldom occurs. A chemical of interest is usually one component of many components in an effluent which may affect the chemicals biological availability and/or toxicity.

The objectives of this research project were (1) to evaluate the use of sublethal toxicity test endpoints (effects on survival, growth, and reproduction of selected species) obtained in effluent dilution and receiving water tests for predicting impacts on resident biota; and (2) to determine if site-specific water quality criteria are protective under complexed ambient conditions caused by a point source effluent.

The objectives were approached by conducting aquatic toxicity tests to establish relationships between the toxicity of a sewage plant effluent (STP) containing high concentrations of zinc, toxicity of the effluent in the receiving water, toxicity of zinc added to receiving water and a laboratory water, and biological survey data.

MATERIALS AND METHODS

Site Selection

The Straight River near Owatonna, Minnesota, was selected for study because site monitoring data (Minnesota Pollution Control Agency, 1979) indicated that zinc concentrations below the Owatonna STP discharge were in excess of the national water quality criteria average concentration of 47 µg/l (U.S. EPA, 1980). The Owatonna STP receives both municipal and industrial wastes. The industrial wastes include effluents from several metal plating operations.

The Straight River is a part of the Cannon River watershed. Approximately 465 square miles (1,200 km^2) of south central Minnesota are drained by this river and its tributaries. The specific river reach studied was from just upstream of the city of Owatonna STP outfall at river mile 24.8 (43.1 km) downstream to river mile 20.1 (32.3 km). Water and biota sampling stations were established within this reach of the river: station 1 (reference station) was located 100 yds (91.4 m) upstream from the STP outfall (bridge on North Street), station 2 at river mile 23.6 (38.0 km) (bridge on Steele County Highway 34), station 3 at river mile 22.1 (35.6 km) (bridge on Clinton Falls Township road in sections 28 and 23, T108N R20W), and station 4 at river mile 20.1 (bridge on Steele County Highway 9). These stations correspond to those used by the State in a previous "Load Allocation Study" of the river (Minnesota Pollution Control Agency, 1979). Not all of the stations were sampled on each date, also, several stations in addition to station 1 through 4 were sampled. Station 1A, located approximately 5 miles (8.0 km) upstream from station 1 off county highway 18, was sampled on 7-27-83. Station 1B, located approximately 1 mile (1.6 km) upstream from station 1, was sampled on 2-15-83. This station was located several hundred yards downstream from a small reservoir. Station 1C was located about 20 feet (6.1 m) upstream from the STP effluent discharge to the river and station 2A was downstream about 20 ft in the discharge plume. Both 1C and 2A were sampled on September 10, 1982. Station 2B was located approximately 3/4 mile (1.2 km) downstream from the discharge and was sampled only for fish on 7-28-83. Station 5 was approximately 5 miles downstream from station 1 and was sampled only for plankton on 7-27-83.

Effluent and Stream Water Sampling

Grab samples of the effluent and receiving water were collected in 19 liter polyethylene jugs and transported within 5 hr to the Environmental Research Laboratory-Duluth (ERL-D) where they were used immediately in toxicity tests or stored at ~10 C prior to use in toxicity tests. Samples for testing were collected on 8-17-82, 9-10-82, 2-16-83, 6-27-83 and 7-28-83. An exception was that a 7 hr composite sample of the effluent was collected between 9:00 a.m. and 4:00 p.m. on 7-28-83.

Toxicity Testing

Several toxicity tests were conducted for criteria development and comparative purposes. Daphnids Ceriodaphnia reticulata and larval fathead minnows Pimephales promelas were exposed to zinc added to clean laboratory water (Lake Superior), upstream water (station 1), and downstream "no effect" water (station 3). Effluent dilution and receiving stream water toxicity tests were also conducted to acertain whether or not the effluent was toxic and if it had a measurable impact on biota in the stream after mixing. Toxicity endpoints measured were effects on survival and growth of fathead minnow larvae and survival and reproductive effects on the daphnids.

Test waters were usually warmed on a hot plate or in a water bath to room temperature and then aerated to bring dissolved oxygen concentration to or near air saturation. The effluent dilution concentrations were made by measuring effluent and stream water (from station 1) using graduated cylinders of various sizes and mixing each concentration in one-gallon (3.8 liters) polyethylene or glass beakers. Enough was mixed for both the fathead minnow and daphnid test at one time. All samples were at or near dissolved oxygen saturation when solutions were made up.

The daphnids, from the ERL-D culture unit maintained in Lake Superior water, were usually placed one animal to each of ten 30-ml glass beakers for each effluent concentration, receiving water sample, or zinc addition sample tested. Test duration was usually 7 days. Fifteen ml of test water were placed in each beaker and a daphnid, less than 6 hr old, was added. One drop of water containing 250 μg of yeast was added to each beaker daily. When young were present, they were counted and discarded. Temperatures were maintained at 23-25 C. In tests using water collected on 9-10-82 and 2-16-82 the animal was moved on day 2 and 4 of the test to a new 15 ml volume with an eye dropper and yeast again added. In tests using water samples collected on 9-10-83, only 5 daphnids were used per treatment and the tests were ended after four days of exposure. In tests using water collected on 6-27-83 and 7-28-83 the animals were moved daily. For details of the procedures used see Mount and Norberg (1984).

The 7 day fathead survival and growth tests were started by placing 40 larvae (>24-hr-old), from the ERL-D culture unit maintained in Lake Superior water, to glass tanks containing 2.5 liters of water at each treatment. The larvae were equally divided among 4 compartments of the tanks. Each compartment was separated by a screen on one side which allowed the draining and renewal of test solution. Approximately 2 liters of the solutions was changed daily. Larvae were offered food 3 times a day and tanks were cleaned after the last feeding. Temperatures were maintained at 23-25 C. For details of the procedure used see Norberg and Mount (in press).

Acute toxicity tests were conducted using daphnids (<6-hr-old) and fathead minnows (<24-hr-old) at 23-25 C. Ten animals were tested at each concentration. Five animals were placed into duplicate test containers at each treatment. Daphnids were tested in 30 ml glass beakers containing 15 ml of water and exposed for 48 hr under static water conditions. Fathead minnows were tested in 500 ml glass beakers containing 200 ml of water and exposed for 96 hr under static or daily renewal water conditions.

Chemical-Physical Conditions

Selected physical and chemical characteristics of the test water samples are presented in Tables 1 and 2.

Methods of analysis used for total hardness, total alkalinity, conductivity, pH, dissolved oxygen, chlorine, ammonia, nitrate, nitrite, total solids and suspended solids are described by the American Public Health Association et al. (1980). Dissolved oxygen concentrations of the water in selected treatments of all tests were measured at the end of a test or just before a water change in order to estimate minimum occurring values. Minimum dissolved oxygen concentrations in the daphnid and fathead minnow tests were greater than 6 or 5 mg/l, respectively. An exception was in fathead minnow test tanks containing 100 and 30% effluent collected on 6-27-83. Dissolved oxygen concentrations of 4.8 mg/l in 100% effluent and 4.5 mg/l in 30% were measured on the fourth day of the test and lower concentrations of 2.9 in 100% effluent and 4.0 in 30% effluent were measured the fifth day.

Procedures for sampling and flame and flameless atomic absorption spectrophotometry analysis of zinc, chromium, copper, lead and cadmium were taken from "Methods for Chemical Analyses of Water and Wastes (U.S. EPA, 1979).

The zinc exposure stock solutions were prepared using Fisher reagent grade zinc-chloride dissolved in deionized water.

The trimmed Spearman-Karber Method (Hamilton et al., 1977) was used for estimating median lethal concentration (LC50s). One way analysis of variance and Dunnett's procedure (Steel and Torrie, 1960) for comparing all treatments with a control (P=0.95) was used to identify significant differences in endpoints measured in the 7 day daphnid and fathead minnow tests.

Biological Survey Methods

Surveys of the Straight River biota were conducted in the immediate vicinity of the water sampling stations. They were completed within 24 hrs of the time water samples were withdrawn for toxicity testing. These surveys were designed to determine the distribution of aquatic organisms in relationship to the Owatonna STP effluent for correlation with effluent dilution and receiving stream water toxicity test results. Only macroinvertebrate populations were sampled on 8-17-82 and 9-10-82. On 2-15-83 plankton sampling was added and on 6-27-83 and 7-28-83 fish sampling was added.

Plankton were sampled by holding a Wisconsin type sampler (80 μ mesh) in the stream for 2 minutes. Two samples were taken at each location. The rate of stream flow was estimated by timing the passage of a floating object over a distance of 10 feet (3.05 m) during the 7-27-83 sampling. Plankton were identified to the lowest convenient taxon using a Sedgewick-Rafter counting cell and a compound microscope at 100x. The 2-15-83 and 6-27-83 sample results are reported as total numbers collected per sample and the 7-27-83 results are reported as density (mean number/liter).

Benthic macroinvertebrates were sampled (one sample at stations 1 and 2) with a Surber sampler (1024 μ mesh) on 8-17-82. Sampling, on 9-10-82 was qualitative and was done with a hand held dip net (508 μ mesh). On 6-27-83 (3 replicates at each station) and 7-27-83 (5 replicates at each station) quantitative sampling was done with a standard Hess sampler (800 x 900 μ mesh) and qualitative sampling was done with dip nets. The dip nets were used in an attempt to sample as many habitats as possible at each station. All samples were preserved in 10% formalin and later sorted using sugar flotation and magnification. Identification was generally made to genus. The quantitative Hess samples are reported as the mean number per square meter. The qualitative dip net samples and Surber samples are reported as total number collected at each station.

On 6-27-83 and 7-28-83, shoreline seining using a 15' (4.6 m) x 4' (1.2 m) seine with 3/16" (0.88 cm) mesh and a backpack electrofishing unit were used to collect fish. The fish were either identified on site and released or preserved in 10% formalin for later identification. On 7-28-83 an intensive fish seining effort was undertaken between the effluent discharge and station 2. Periodic seine hauls were made as the collectors moved down the river from station 2B which was established approximately 1/4 mile (0.4 km) upstream from station 2.

Quality Assurance

Coordination of the various studies was completed by the authors. Details of sampling, transfer of samples, storage of samples, specific sampling sites, dates of collections and measurements to be made on each sample was delineated. We were responsible for all quality assurance related decisions onsite or in the laboratory.

All instruments were calibrated by methods provided by the manufacturers. Methods in the referenced published reports were followed. For quality control data see Appendix 1.

RESULTS AND DISCUSSION

Effluent Toxicity

Daphnid -- All STP effluent samples were toxic to the daphnids. On 8-17-82, all of the daphnids died within 24 hr of exposure to 100% effluent collected before and after chlorination. The chlorinated and non-chlorinated samples contained 4,565 and 4,765 μg/l zinc, respectively. At the 25% effluent concentrations, with nominal zinc concentration of 1,141 in chlorinated samples and 1,191 μg/l in the non-chlorinated samples, all daphnids were dead within the 48 hr test period. At 1% effluent concentrations, the chlorinated sample (nominal 46 μg/l zinc) killed all of the daphnids while 90% survived in the non-chlorinated sample (nominal 48 μg/l zinc). Also, 90% survived in a 1% effluent concentration of aerated subsample of the chlorinated effluent. Apparently, chlorination contributed to the effluents toxicity. Survival of daphnids for 48 hr was not affected in upstream control water (<44 μg/l zinc) (station 1), however, no daphnids survived in downstream water containing effluent (300 μg/l zinc) and collected from station 2. Daphnids responded similarly when exposed in water samples collected on 9-10-82. No daphnids survived in 100% effluent (2,850 μg/l zinc). Survival was not affected in station 1 water (<10 μg/l zinc) and each test animal produced young (1 brood). Survival and young production was affected in water collected downstream from the effluent discharge. No daphnids survived to produce young in water (100 μg/l zinc) from station 2, and 60% survived but did not reproduce in water (<100 μg/l zinc) collected from station 3. Exposure to a 3% effluent concentration of the STP sample (192 μg/l zinc) collected on 2-16-83 killed 100% of the daphnids (Table 3). Survival for 7 days and young production were not affected at a 1% effluent concentration when compared to the control (12 μg/l zinc) (station 1 water).

All daphnids survived in the control water from station 1 (Table 4). No daphnids survived in the water from station 2 (211 µg/l zinc) and only 20% survived in the water from station 3 (136 µg/l zinc) resulting in a large reduction in the young produced per original female when compared to the control (Table 4). Exposure to 10% effluent concentrations of the STP samples collected on 6-27-83 (nominal 282 µg/l zinc) and 7-28-83 (223 µg/l zinc) killed 100% of the daphnids (Table 3). Survival and young production were not affected at 3 and 1% effluent concentrations (≤ nominal 85 µg/l zinc) when compared to the control. No differences in daphnid survival and young production were evident between upstream (4-6 mg/l zinc) and downstream (107-200 µg/l zinc) water exposures (Table 4).

Based on percentage effluent, the 2-16-83 effluent sample was the most toxic to the daphnids when compared to the 6-27-83 and 7-28-83 samples. This difference in toxicity appears to be related to the zinc component of the effluent (Table 3). The range between the highest non-effect and lowest effect effluent dilutions in the 7 day tests on 2-16-83, 6-27-83, and 7-28-83 were 1-3% (43-192 µg/l zinc), 3-10% (nominal 85-282 µg/l zinc), and 3-10% (68-225 µg/l zinc), respectively. Although less of the effluent collected on 2-15-83 was needed to cause a toxic response, noneffect and effect zinc concentration determined for the effluent overlapped those determined for samples collected on the other dates. This difference in effluent toxicity and similarity in effect zinc concentrations are also reflected in the acute toxicity values calculated from the data obtained in the first 48 hr of the 7 day tests (Table 5).

Fathead Minnow -- Survival and growth data (Table 6) for the fathead minnows exposed for 7 days to the STP effluent samples collected on 6-27-83 and 7-28-83 demonstrated that the fathead minnows were not as sensitive as the daphnids to the STP effluent. The range betwen the highest non-effect and lowest effect effluent dilution was 30-100% in each test for the fatheads compared to 3-10% for the daphnids. Specifically, no fish survived in the 6-27-83 100% effluent sample (2,825 µg/l zinc). Survival at this concentration may have been affected by the effluents biological oxygen demand which resulted in low dissolved oxygen concentrations in the test chamber during the last 3 days of testing. Survival was not affected but mean weight was reduced by 30% in the 7-28-83 100% effluent sample (2,395 µg/l zinc) when compared to the control (6 µg/l zinc) (station 1 water). For both dates at 30% (nominal 847 µg/l zinc) or less effluent dilutions, mean survival and weight values were similar to that obtained in the controls. No differences in 7 day survival or growth were evident between upstream (4-6 µg/l zinc) and downstream (107-200 µg/l zinc) water exposures (Table 7).

The STP effluent sample collected on 8-27-82 was toxic to fathead minnows at the 100% effluent concentration. In the chlorinated sample, fish died within the first 2 hr of exposure. In the non-chlorinated sample all were alive within this time frame but were dead when checked 12 hr later. This difference in time to death indicates that the chlorine was contributing to toxicity. No effluent dilution of this effluent sample were tested, however, in tests conducted using upstream control water (station 1) and downstream (station 2) water containing the effluent, all fish survived.

Zinc Addition

Daphnid -- In zinc addition tests using dilution water collected from station 1 on 2-16-83, daphnid survival for 7 days and young production were not affected at zinc concentrations ranging from 24 to 58 µg/l (Table 8). At the 101 µg/l zinc concentration, a 45% reduction in the mean number of young per original female when compared to the control was observed. None survived to produce young at the 198 μg/l zinc exposure. In a similar test with water collected on 7-28-83 (Table 8) survival and growth were not demonstrably affected at zinc concentrations ranging from 18 to 140 μg/l. At 618 μg/l none survived to produce young. Unexplained control mortality was observed near the end of the test resulting in reduced young production. Such mortality was not observed in the 18 to 140 μg/l treatments and in a replicate control set-up at approximately the same time for the STP effluent and receiving water tests. The ranges between the highest non-effect and lowest effect zinc concentrations of 58-101 μg/l and 140-618 μg/l for water collected on 2-16-83 and 7-28-83, respectively, indicate that zinc was less biologically available and/or toxic in water collected on 7-28-83 than in water collected on 2-16-83. Acute toxicity values obtained for daphnids during the first 48 hr of these tests differed by two-fold and support this trend (Table 9).

The toxicity of receiving water collected at station 3 on 2-16-83 was directly attributed to the zinc component of the effluent. The range of 58-101 μg/l zinc between the highest non-effect and lowest effect zinc concentrations using water collected from station 1 (Table 8) was within the 43-192 μg/l range determined for zinc in the effluent dilution test (Table 3). Similar acute toxicity values (48 hr LC50) of 114 and 91 μg/l were calculated from the zinc addition and effluent tests, respectively (Tables 9 and 5). In both of these treatments water collected from station 1 served as dilution water and the control. This control water contained 12 μg/l zinc and was not toxic to the daphnids. Station 2 water, which contained 211 μg/l directly attributable to the effluent, killed all of the exposed daphnids (Table 4) within the first 48 hr of the 7 day test period. Station 3 water, which contained 136 μg/l zinc killed only 60% of the daphnids within the first 48 hrs (Table 4). This mortality in station 3 water is essentially equivalent to the 50% mortality predicted based on the zinc addition and effluent dilution LC50 values (Tables 9 and 5).

The zinc component of the effluent sample collected on 6-27-83 apparently was not as biologically available and/or toxic to daphnids as was the zinc added to station 1 water. A nominal 48 hr LC50 of 134 µg/l zinc (Table 5) was calculated from the effluent test results. Station 2, 3, and water which contained 107, 150, and 149 µg/l were not toxic. All of these zinc concentrations are higher than the 48 hr LC50 of 96 µg/l (Table 9) resulting from zinc addition to station 1 water. In station 3 water, to which zinc was added, a 48 hr LC50 of 195 µg/l was obtained and indicates a two-fold reduction in zinc biological availability and/or toxicity when compared to the station 1 LC50 value (Table 9). This value is directly comparable to the station 1 LC50 value because it was obtained from a test conducted at the same time under similar conditions.

The zinc component of the effluent collected on 7-28-83 appeared to be more biologically available and/or toxic when diluted with station 1 water than zinc added to station 1 water. Although the ranges of zinc concentrations between the highest non-effect and lowest effect concentration in the 7 day daphnid tests overlapped, the 48 hr LC50 of 134 calculated from the effluent dilution data was about two-fold less than the zinc addition 48 hr LC50 of 264 µg/l (Tables 5 and 9). The station 2 and 3 samples were not toxic but contained 200 and 150 mg/l zinc, respectively (Table 3). Both of these zinc concentrations were in excess of the effluent dilution LC50 value but less than the zinc addition LC50 value. These data indicate that another component(s) of the effluent may have been contributing to the toxicity of the effluent, and that toxicity of the component(s) did not persist but was ameliorated by river conditions by the time the effluent reached station 2.

Site Water vs. Lab Water

Acute toxicity data obtained in concurrent zinc addition tests in Lake Superior (lab water) and Straight River water (site water) indicate that zinc was less biologically available and/or toxic in site water (Table 9). Daphnid water effect ratios (site water LC50/lab water LC50) of 5.5 and 3.0 were calculated from tests on site water collected from station 1 on 8-17-82 and 6-27-83. A daphnid water effect ratio of 6 was calculated for station 3 water collected on 6-27-83. For site waters collected on 6-27-83 the data indicates that the fathead minnow water-effect ratio was greater than 6.7. Tests of each species at the same time in lab and site water collected on 7-28-83 were unsuccessful because of procedural problems in the lab water tests, however, site water tests were completed. These tests differed from the previous tests in that the daphnids were fed and the fathead minnow test solutions were renewed daily. If the previously measured lab LC50 values for these species determined for water collected on 6-27-83 are used in calculating zinc water effect ratios, ratios of 8.2 for daphnids and 5.5 for fathead minnows result.

Biological Survey

Macroinvertebrate -- A 50% reduction in benthic macroinvertebrate taxa composition was evident between stations 1 (reference station) and 2 on 8-17-82 (Table 10). No marked difference in taxa composition was evident in samples collected from stations 1, 2, and 3 on 9-10-82. The greatest difference in composition was between station 1B and station 1. Taxa compositions of samples collected on 2-15-83 were more diverse (Table 11). Total taxa in each sample ranged from 17 to 19. Station 1B and 3 samples (station 2 was ice covered) contained only 11 taxa each in common with the station 1 sample. Taxa composition of station 1 and 2 samples collected on 6-27-83 differed markedly (Table 11). Station 1 samples contained 27 taxa while station 2 samples contained only 15 with 8 of them in common with station 1. Six taxa (Batis, Ephron, Hydropsyche, Stenelnus, and Chironomid pupae) with densities greater than 10 per square meter at station 1 were not found at station 2. At station 3 a more diverse taxa was evident; 39 taxa were identified in the samples, of which 18 were in common with those found at station 1. Five of the six taxa not found in station 2 samples were present in station 3 samples at approximately the same or greater density than at station 1. The mayfly taxon Ephron was absent. Total organism density was 11.6 times less at station 2 and 3.1 times greater at station 3 when compared to station 1. On 7-27-83 the differences in macroinvertebrate taxa composition between stations 1, 2 and 3 were not as evident as in June, however, a similar trend in organism density was evident. When compared to station 1, total organism density was 2.3 times greater at station 1A, 3.4 times less at station 2, 7.2 times greater at station 3 and 2.4 times greater at station 4.

Plankton -- Zooplankton taxa were found in low numbers at each station (Tables 12 and 13). Phytoplankton were more numerous but present mostly as diatoms which were not identified to lower taxa. Stations 1B and 3 samples collected on 2-15-83 each contained 7 taxa with 5 and 4 respectively in common with the station 1 sample. On 6-27-83 station 1 samples contained 12 taxa all of which were found in station 2 samples which contained 14 taxa. On this date markedly less taxa were found in station 3 samples which contained only 3 taxa in common with station 1 samples. This trend in taxa composition at stations 1, 2 and 3 was not evident on 7-27-83. Stations 1, 2 and 3 samples contained 13, 14 and 12 taxa, respectively, with station 2 and 3 samples containing 12 and 10 taxa, respectively, in common with station 1 samples. Station 1A samples (5 miles upstream) contained 7 taxa all found at station 1. The difference in station 1A taxa when compared to station 1 is thought to be reflective of the reservoirs influence on taxa composition. For example, daphnids were not found above the reservoir but were present below the reservoir. Station 4 samples contained 11 taxa of which 10 were in common with station 1. Station 5 (5 miles downstream) contained 8 taxa with only 4 in common with station 1.

Fish -- Fish species composition differences at stations 1, 2 and 3 are apparent in the data obtained from collections made on 6-27-83 (Table 14). Thirteen species were collected at station 1 while 7 and 11 were collected at station 2 and 3, respectively. The station 2 and 3 samples contained 5 and 8 species, respectively, in common with the station 1 sample. Species composition differences between samples collected at stations 1, 2 and 3 on 7-28-83 were evident but less diverse when compared to samples collected at these stations on 6-27-83. Station 1 samples contained 12 species while station 2 samples contained only 8 species, 7 of which were in common with the station 1 sample, however, the station 2B sample contained 11 species, 10 in common with the station 1 sample. On this date periodic seine hauls, made as the collectors moved down the river from station 1 to a point approximately 1/4 mile above station 2, produced only a few fish (sand shiners). Most hauls were empty. Sampling station 2B was established at this point and approximately the same seining effort was expended as at a regular station. The station 3 samples contained 12 species with 8 in common with the station 1 sample. Station 4 samples contained 14 species with 10 in common with the station 1 sample. The station 1A (located 5 miles upstream) sample diverged the most from station 1 composition, it contained 9 species with only 4 in common with the station 1 sample. This sample also contained larval catostomids which were not found at any other station.

Toxicity and Effluent Impact

Under the conditions of this study strong correlations between the Owatonna STP effluent toxicity to daphnids and adverse impacts on the Straight River biota could not be made, however, the biological survey data indicates that the effluent at times may affect taxa distribution and abundance. The daphnid tests indicated that water at station 2 was toxic on 8-17-82. Based on zinc concentration the station 2 water sampled was approximately 5% effluent by volume. Concurrent benthic macroinvertebrate sampling indicated a marked reduction in taxa composition at this station when compared to reference station 1. This data is of limited use in making toxicity vs impact correlations because only a small area of the stream was sampled. However, the mean water discharge of the river was 49 cfs on this date and had been declining from 451 cfs on 7-17-83 (Appendix 2) indicating that prior exposure of resident biota to effluent concentrations toxic to the daphnids was possible. River discharge increased from 42 cfs on 8-21-82 to 553 cfs on 9-2-82 from which it declined to 152 cfs on 9-10-82. On 9-10-82, water sampled at station 2 was estimated to be 3% effluent by volume based on zinc concentration. Intensive qualitative sampling with dip nets on this date indicated that there was very little difference between taxa composition at stations 1, 2 and 3 even though the daphnid tests indicated that the water was toxic at stations 2 and 3. Also at this time very little difference in taxa composition was evident between 3 upstream stations and a station located within the effluent plume. On 2-15-83 station 3 water, estimated to be 4% effluent by volume based on zinc concentration, was also toxic to daphnids. Toxicity to daphnids would have been expected at 3% effluent based on the effluent dilution toxicity tests. The mean water discharge of the river for this date was 138 cfs and had decreased from 205 to 133 cfs over the previous 40 days indicating long-term exposure at concentrations which were toxic to daphnids was possible, however, during this period the river was under winter conditions of low water temperature (1 C on 2-15-83) which is known to markedly reduce the toxicity of many substances including zinc (U.S. EPA, 1980) to aquatic life. At this time station 3 benthic macroinvertebrate and plankton taxa composition differed markedly from station 1, however, taxa composition at station 1B, located approximately 1 mile upstream also differed markedly from station 1. This upstream-downstream variation in taxa composition relative to the reference station indicates that effluent caused impacts cannot be inferred from this data. Water collected from station 1, 2, 3 and 4 on 6-27-83 was not toxic to daphnids, however, macrobenthic invertebrate, zooplankton, and fish populations appeared to be adversely affected by the effluent. At this time six of the most numerous macro-benthic taxa at station 1 were not found at station 2 and organism density at station 2 was 65 fold less than at station 1. Five of the six taxa missing at station 2 were found at station 3 where organism density was 3.1 fold greater than at station 1. The plankton taxa composition at stations 1 and 2 was similar but markedly different at station 3 where only 3 of 12 taxa common to station 1 were found. Fish species composition also differed markedly between station 1 and station 2. The zinc concentrations at station 2 indicated that the effluent concentration was about 3.4% of the water volume. This effluent concentration would not be expected to be toxic to daphnids based on the effluent dilution test results.

The mean river discharge on this date was 159 cfs and had declined from spring and early summer high flow conditions indicating that exposure to resident biota to effluent concentrations toxic to the daphnids was even less probable, however, the occurrence and effects of slug doses of zinc cannot be ruled out and will be discussed in the following zinc site specific criteria section. Stream flow remained relatively stable until 7-1-83. On this day mean river discharge increased to 4,420 cfs from which it declined to 121 cfs on 7-28-83. Water collected from the downstream stations on 7-28-83 again was not toxic to daphnids. The station 2 water sample was approximately 10% effluent by volume based on zinc concentration and would have been predicted to be toxic based on the effluent dilution test results. Apparently the effluents toxicity was ameliorated by the river. At this time the composition of the benthic macroinvertebrate taxa, plankton taxa, and fish species at stations 1, 2, 3 and 4 were not markedly different. Five out of the six benthic macroinvertebrate taxa not found at station 2 on 6-27-83 were present at this time. The benthic macroinvertebrate densities were 3.3-fold less and 7.2-fold greater at stations 2 and 3, respectively, when compared to station 1. Comparison of these data to those obtained on 6-27-83 indicated that the stream was recovering from an adverse impact below the STP effluent discharge. The absence of fish encountered in the intensive seining effort made on 7-28-83 between the STP effluent discharge to the river and station 2A approximately 3/4 mile downstream was also indicative of the STP effluent affecting fish distribution.

The lack of strong correlations between effluent toxicity to daphnids and biological impact in the stream may have been due to not sampling and testing the effluent and receiving water over a sufficient number of days to get a measure of the duration of exposure of the resident biota to conditions toxic to the test animals. Often river flow had been higher prior to sampling indicating that susceptible biota may not have time to react to adverse conditions. The higher flow may also have contributed to biota recolonization which may have masked effluent impact.

Site-Specific Zinc Criteria

To use the indicator species procedure of the site-specific guidelines to derive a site criterion for zinc, the resident species range of sensitivity for the chemical of interest should be similar to that for species in the national criteria document (U.S. EPA, 1980). Daphnia magna was identified in this document as the most sensitive species tested based on acute toxicity and among the two most sensitive species tested based on chronic toxicity. Because Daphnidae were also found at the study site it was assumed that the range of resident species sensitivity to zinc was similar to that for species used to establish national criteria. The indicator species Ceriodaphnia reticulata used in this study and Daphnia magna have also been shown to be equally sensitive to zinc in 48 hr toxicity tests (Mount and Norberg, 1984).

A water quality criterion consists of two concentrations: the criterion maximum concentration and the criterion average concentration. To protect aquatic life and its uses in the Straight River, in each 30 consecutive days the site-specific average and maximum concentrations for zinc should not be exceeded; and the concentration may be between the average concentration and the maximum concentration for up to 96 hr.

Since daphnids were markedly more sensitive to zinc than the fathead minnows, the daphnid data was used to calculate a site-specific water quality criterion. Data for water collected on 6-27-83 was the only set that met all but one of the requirements of the indicator species procedure of the site-specific guidelines (U.S. EPA, 1983). The exception was that LC50 values used in calculating the daphnid water effect ratio for zinc could not be shown to be statistically different using recommended procedures. For the site water, 96 µg/l zinc LC50, a 95% confidence interval could not be calculated using the Trimmed Spearman-Karber method because of the nature of the mortality data; 100% died at 140 µg/l zinc, the highest concentration tested, and none died at 60 µg/l zinc. However, for the lab water LC50 of 32 µg/l, the 95% confidence interval of 26-40 µg/l does not overlap the above 60 µg/l site water no-effect concentration indicating that the water effect ratio of 3 calculated from this data is a valid estimate of the difference between waters in the biological availability and/or toxicity of zinc to the daphnids. This water effect ratio was used to calculate a site-specific maximum concentration for zinc in the following equation:

Site-Specific Maximum Concentration = Water Effect Ratio x National Maximum Concentration (at lab water hardness)

Site-Specific Maximum Concentration = 3 x 145 µg/l zinc = 435 µg/l zinc

The national maximum concentration used in the calculation and those hereafter discussed were derived according to the revised national guidelines (U.S. EPA, 1983) using the data presented in the national criteria document (U.S. EPA, 1980). This site-specific maximum concentration is more restrictive than a national maximum concentration of 801 µg/l zinc derived for the Straight River at a water hardness of 353 mg/l. The site-specific average concentration of 145 mg/l was obtained by dividing the site-specific maximum concentration by the national acute-chronic ratio of 3. The site-specific average concentration is less restrictive than the national average concentration of 47 µg/l for all waters.

Analysis of STP monitoring data for metals as reported to the Minnesota Pollution Control Agency by the City of Owatonna, U.S. Geological Survey flow data (Appendix 2), and data obtained in this study demonstrate that zinc concentrations at and below station 2 exceeded the site-specific average (145 µg/l) and maximum (435 µg/l) concentration under low flow conditions in the Straight River during the one year period of this study. For the five water samples collected at station 2, zinc concentrations averaged 236 µg/l and ranged from 100 to 380 µg/l (Table 1). For station 3, zinc concentrations ranged from <100 to 154 µg/l and averaged 144 µg/l on 3 of 4 sampling dates. On these dates the effluent samples averaged 2.6 mg/l zinc and the average discharge of the Straight River system was 140 cfs and ranged from 49 cfs on 8-17-82 to 159 cfs on 6-27-83. The average discharges for the months of August and January were below 140 cfs indicating that even higher 30 day average zinc concentrations were possible. Relatively high effluent zinc concentrations of 17.0 and 20.5 mg/l for samples analyzed on 9-16-82 and 9-30-82, respectively, were reported by the city. The other 21 effluent zinc concentrations reported within the one year time frame of this study ranged from 0.04 to 5.32 mg/l and averaged 2.32 mg/l with a standard deviation of 1.28 mg/l. From 9-26-82 to 9-30-82 the daily average river discharge ranged from 126 to 158 cfs. High concentration of zinc in the effluent during this period of time would undoubtably have resulted in a zinc concentration higher than the site-specific maximum concentration at and below station 2. This conclusion is supported by reported measured concentration of 830 µg/l zinc in water collected from station 2 on 2-2-78 (Minnesota Pollution Control Agency, 1979).

The apparent adverse effluent impact on biota at station 2 could not be attributed to the zinc component of the STP effluent. The effluent contained many other potential toxic components besides zinc, several of which were measured (Tables 1 and 2). Because it contained domestic wastes, it also contained dissolved and solid forms of nutrients that contribute to increased biological activity in the receiving stream. For example, increased bacterial nitrification is evident when ammonia, nitrite, and nitrate concentrations from station 2 are compared to station 1 (Table 2). Increased biological activity at station 2 coupled with seasonal variability in the flow and other physical, chemical and biological conditions all affect the distribution and abundance of the species inhabiting this station. Because of this inherent variability it was not possible to sort out possible intermittant zinc toxicity effects on biota using information obtained from this study.

Under the conditions of this study the distribution of benthic-macroinvertebrates and fish did not appear to be adversely impacted by the STP effluent or its zinc component at station 3. At this station, zinc concentrations ranged from <100 to 154 µg/l on the 4 sampling dates and averaged 144 µg/l on 3 of 4 sampling dates. The total number of benthic-macroinvertebrate taxa (Figure 1) found at this station were similar or greater than found at station 1 on the four sampling dates. The total number of fish species were similar (Figure 2) between station 1 and 3 on the two dates they were sampled. The total number of plankton taxa were markedly less, when compared to station 1, on 1 of the 3 dates they were sampled (Figure 3). This difference could have been due to upstream effluent impacts causing plankton death and sedimentation and/or predation. Nevertheless, if the assumption of the national (U.S. EPA, 1983B) and site-specific guidelines that the protection of site-species all of the time is not necessary because aquatic life can tolerate some stress and occasional adverse effects is taken into consideration, these data indicate that the site-specific criterion average concentration of 145 μg/l would be protective of Straight River biota.

ACKNOWLEDGMENTS

We thank Donald Mount, Nelson Thomas, Scott Heinritz, Dean Hammermeister, and Carol Church for their contributions to this study.

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Table 1. Total hardness, total alkalinity, conductivity, and selected metal concentrations of the Owatonna STP and receiving water samples used in toxicity testing.

Test Water Source	Date Sampled	Total Hardness (mg/l as $CaCO_3$)	Total Alkalinity (mg/l as $CaCO_3$)	Conductivity (μmho)	pH	Total Zn (μg/l)	Total Cu (μg/l)	Total Cr (μg/l)	Total Pb (μg/l)	Total Cd (μg/l)
Station 1	8-17-82	353	268	-	7.9	<44	<6	<3	1.2	<0.1
(~100 yds above STP)	9-10-82	-	-	-	-	<100	-	-	-	-
	2-16-83	376	-	388	7.9	12	<3	2	-	<0.1
	6-27-83	394	-	320	7.9	4	-	-	-	-
	7-28-83	362	276	720	7.7	6	9 (<1)[a]	15 (14)[a]	5 (1)[a]	1.0 (0.3)[a]
Station 2	8-17-82	376	-	-	7.3	380 (180)[a]	<6	5 (<3)[a]	0.53 (<0.03)[a]	<0.1
(~1.2 miles below STP)	9-10-82	-	-	-	-	100	-	-	-	-
	2-16-83	378	-	428	7.9	211	<3	6 (4)[a]	-	<0.1
						183 (156)[a]				
	6-27-83	392	-	350	7.8	107	8	18	3.5	0.1
	7-28-83	376	278	825	7.6	200 (90)[a]	7 (2)[a]	21 (12)[a]	4.0 (1.0)[a]	0.5 (0.4)[a]
Station 3	9-10-82	-	-	-	-	<100	-	-	-	-
(~2.7 miles below STP)	2-16-83	380	-	425	8.0	128	<3	4	-	<0.1
	6-27-83	380		350	7.9	154	4.0	11	3.1	0.2
	7-28-83	374	277	825	7.6	150 (95)[a]	5 (3)[a]	14 (7)[a]	3.0 (1)[a]	0.6 (0.6)
Station 4	6-27-83	-	-	340	7.9	149	-	-	-	-
(~5 miles belowSTP)	7-28-83	374	275	740	7.6	86 (29)[a]	12 (1)[a]	- (4.8)	9 (1)	1.4 (0.5)
STP Effluent	8-17-82	339	-	-	7.2	4,565[a](4,207)[b]	28 (20)[a]	72 (48)[a]	0.03 (<0.03)[a]	0.3 (0.2)[a]
					-	4,765[c](4,436)[a]	20 (<6)[a]	67 (42)[a]	0.03 (<0.03)[a]	0.21 (<0.11)[a]
	9-10-82	-	-	-	-	2,850	-	-	-	-
	2-16-83	359	-	1,400	7.6	2,967	17 (6)[a]	94 (73)[a]	-	0.8
						2,509 (2,255)				
	6-27-83	284		750	7.5	2,825	59	879	5.8	0.9
	7-28-83	274	219	1,910	7.2	1,900[d](1,650)[a]	34 (26)[a]	920 (860)[a]	2.6 (2.3)[a]	1.5 (1.1)[a]
						2,395[e](998)	-	-	-	-

[a] Dissolved measurement (0.45 μ filtrate).

[b] Chlorinated sample.

[c] Prechlorination sample.

[d] Measurement of 1 subsample taken on the day of collection.

[e] Measurements of subsample several days after collection and just prior to testing.

Table 2. Turbidity, total solids, total suspended solids, ammonia, nitrate, nitrite and total chlorine concentrations of the Owatonna STP and receiving water samples collected on 7-28-83.

Test Water Source	Turbidity (NTU)	Total Solids (mg/l)	Total Suspended Solids (mg/l)	NH_3N (mg/l)	NO_3N (mg/l)	NO_2N (mg/l)	Cl_2 (mg/l)
Station 1 (~100 yds above STP)	30	866	51	0.10	3.18	<0.025	<0.020
Station 2 (~1.2 miles below STP)	31	606	46	0.32	3.71	0.025	<0.020
Station 3 (~2.7 miles below STP)	31	877	47	0.19	3.60	<0.025	-
Station 4 (~5 miles below STP)	29	554	43	0.04	3.64	<0.025	-
STP effluent	38	902	32	2.5	9.50	<0.025	<0.020[a] 0.190[b]

[a] Composite sample.

[b] Sample collected at the end of the discharge pipe.

Table 3. Young production and percentage survival of daphnids, *Ceriodaphnia reticulata* (N=10) in Owatonna STP effluent and several dilutions made with receiving water, and corresponding zinc concentrations.

STP Effluent			
Percentage Effluent (v/v)	Total Zinc Concentration µg/l	Young/Female	Percentage Survival
	Grab Sample (2-16-83)		
100	2,967	0.0[a]	0[a]
30	1,440	0.0[a]	0[a]
10	267	0.0[a]	0[a]
3	192	0.0[a]	0[a]
1	43	9.9 (3.6)[b]	100
Control	12	9.7 (2.3)[b]	100
	Grab Sample (6-27-83)		
100	2,825	0.0[a]	0[a]
30	847[c]	0.0[a]	0[a]
10	282[c]	0.0[a]	0[a]
3	85[c]	16.9 (11.4)[b]	80
1	28[c]	18.2 (12.7)[b]	80
Control	4	20.0 (11.0)[b]	80
	Composite Sample (7-28-83)		
100	2,395	0.0[a]	0[a]
30	665	0.0[a]	0[a]
10	225	0.0[a]	0[a]
3	68	13.6 (5.0)[b]	80
1	-	19.4 (4.3)[b]	100
Control	6	14.3 (6.2)[b]	90

[a] Significantly different than the control (P=0.95)

[b] One standard deviation in parenthesis.

[c] Nominal values.

Table 4. Young production and percentage survival of daphnids <u>Ceriodaphnia reticulata</u> (N=10) in receiving water collected from above and below the Owatonna STP discharge.

Station	River Mile	Date of Water Collection	Total Zinc Concentration (μg/l)	Young/ Female	Standard Deviation	Percentage Survival
1 (Above STP)	24.8	2-16-83	12	9.7	2.2	100
		6-27-83	4	20.0	11.0	80
		7-28-83	6	14.3	6.2	90
2 (Below STP)	23.6	2-16-83	211	0[a]	-	0[a]
		6-27-83	107	22.7	5.7	100
		7-28-83	200 (90)[b]	10.0	2.6	70
3 (Below STP)	22.1	2-16-83	128	1.6[a]	3.4	20[a]
		6-27-83	154	19.6	10.0	80
		7-28-83	150 (95)[b]	12.7	5.2	90
4 (Below STP)	19.8	6-27-83	149	26.1	2.5	100
		7-28-83	86 (29)[b]	16.3	7.0	100

[a] Significantly different than station 1 (P=0.95).

[b] Dissolved zinc concentration (μg/l).

Table 5. Acute toxicity values (LC50s) obtained during the first 48 hr of the 7 day exposures of daphnid *Ceriodaphnia reticulata* and fathead minnow *Pimephales promelas* in Owatonna STP effluent dilutions.

Test Water Source	Date Sampled	Total Hardness (µg/l)	Daphnid 48 hr LC50 % Effluent	Daphnid 48 hr LC50 Total Zinc (µg/l)	Daphnid 48 hr LC50 Dissolved Zinc (µg/l)	Fathead Minnow 96 hr LC50 % Effluent	Fathead Minnow 96 hr LC50 Total Zinc (µg/l)	Fathead Minnow 96 hr LC50 Dissolved Zinc (µg/l)
STP effluent	2-16-83	359	1.7	91	-	-	-	-
	6-27-83	380	4.7	134[a]	-	76 (58-99)	2,148[a] (1,653-2,793)	-
	7-28-83	274	5.5	124	79	-	>2,395	>998

[a] Nominal value based on measured zinc concentrations in 100% effluent.

Table 6. Survival and growth data for larval fathead minnows *Pimephales promelas* exposed to Owatonna STP effluent and several dilutions made with receiving water, and corresponding zinc concentrations.

Percentage Effluent (v/v)	Total Zinc Concentration (µg/l)	Mean Percentage Survival	Mean Dry Weight (mg)
	Grab Sample (6-27-83)		
100	2,825	0[a]	-
30	847[b]	92	.34 (.06)
10	282[b]	90	.36 (.09)
3	85[b]	97	.36 (.06)
1	28[b]	95	.39 (.05)
Control	4	97	.36 (.05)
	Composite Sample (7-28-83)		
100	2,395	75	.28 (.03)[a]
30	665	75	.49 (.14)
10	225	85	.46 (.07)
3	68	95	.44 (.05)
1	-	92	.39 (0.9)
Control	6	82	.41 (.10)

[a] Significantly different than the control (P≐0.95).

[b] Estimated zinc concentration based on the measured concentration in 100% effluent.

Table 7. Survival and growth data for larval fathead minnows *Pimephales promelas* exposed in receiving waters collected from above and below the Owatonna STP effluent discharge and corresponding zinc concentrations.

Station	River Mile	Date of Water Collection	Total Zinc Concentration (µg/l)	Mean Percentage Survival	Mean Dry Weight (mg)
1 (Above STP)	24.8	6-27-83	4	97	.36 (.06)[b]
		7-28-83	6	82	.41 (.10)[b]
2 (Below STP)	23.6	6-27-83	107	92	.40 (.04)[b]
		7-28-83	200 (90)[a]	87	.50 (.09)[b]
3 (Below STP)	22.1	6-27-83	151	90	.37 (.05)[b]
		7-28-83	150 (95)[a]	87	.54 (.08)[b]
4 (Below STP)	19.8	6-27-83	-	97	.40 (.06)[b]
		7-28-83	86 (29)[a]	90	.43 (.09)[b]

[a] Dissolved zinc concentration.

[b] One standard deviation.

Table 8. Young production and percent survival of daphnids *Ceriodaphnia reticulata* (N=10) obtained from 7 day zinc addition toxicity tests in upstream water (Station 1). Grab samples of dilution water were obtained on 2-16-83 and 7-28-83.

Zinc Concentration (μg/l) Total	Dissolved	Young/Female	Standard Deviation	Percentage Survival
		2-16-83 Dilution Water		
198	-	0[a]	-	0[a]
101	-	8.8[a]	7.7	80
58	-	12.3	4.6	90
41	-	20.4	6.2	100
24	-	15.5	6.8	100
11 (Control)	-	15.8	4.9	100
		7-28-83 Dilution Water		
618	460	0[a]	-	0[a]
140	90	5.7	5.9	100
59	31	11.4	4.0	90
37	9	10.7	3.5	90
18	5	13.3	5.8	100
6 (Control)	8	9.3 (14.3)[b]	8.7 (6.2)[b]	50 (90)[b]

[a] Signficantly different than the control (P = 0.95).

[b] Values for daphnids reared under similar conditions as controls in the effluent dilution tests.

Table 9. Acute toxicity values (LC50s) obtained from static tests in which zinc was added to receiving water (collected from above and below the STP outfall) and Lake Superior water.

Test Water Source	Date Sampled	Total Hardness (μg/l as $CaCO_3$)	Daphnid 48 hr LC50 (μg/l zinc)		Fathead Minnow 96 hr LC50 (μg/l zinc)	
			Total	Dissolved	Total	Dissolved
Station 1 (Above STP)	8-17-82	353	224[a] (146-343)	-	-	-
	2-16-83	376	114[b]	-	-	-
	6-27-83	392	96[c]	-	<2,660[c]	<1,960
	7-28-83	362	264[b] (206-367)	180 (136-238)	2,159[d,e] (1,277-3,649)	1,857 (1,091-3,158)
Station 3 (Below STP)	6-27-83	392	195[c] (176-216)	-	<2,930[c]	<2,360
	7-28-83	374		-	2,000[d,e] (1,542-2,592)	1,545 (1,205-1,983)
Lake Superior		45	41[a] (32-52)		-	-
			32[c] (26-40)		396 (315-497)	

[a] Nominal values obtained in tests conducted at the same time under similar conditions.

[b] Test organisms were fed. Data obtained during the first 48 hr of the 7 day daphnid tests.

[c,d] Values for each species obtained in tests conducted at the same time under similar conditions.

[e] Test water was renewed every 24 hr. In these tests 20% mortality occurred in the controls.

Table 10. Total number of benthic macroinvertebrates sampled. A Surber sampler was used on August 17, 1982 and a dip net "kick method" was used on September 10, 1982 to make the collections.

	Station							
	August		September					
	1	2	1B	1	1C	2A	2	3
Diptera								
Rhagionidae - Atherix	1		1	2	3			3
Simulidae	3	1						
Chironomidae	4	8	2	8	6	6	4	13
Tabanidae								2
Trichoptera								
Hydropsychidae								
Hydropsyche	4		14	5	1		1	
Cheumatopsyche	3				2	1		1
Ephemeroptera								
Heptageniidae								
Stenonema	17	3	53	12	4	3	19	22
Heptagenia	3		16					
unidentifiable	7		1				1	
Baetidae								
Isonichia	3		10	1		1		
Baetis	3		57	4	10	10	2	3
Caenidae								
Tricorythodes	4	1	8	8	3	10	1	
Ephemeridae								
Ephoron			1		1			
Potomanthus			2					
Coleoptera								
Elmidae (adults)	1	3	5	2	2	2	2	2
(larvae)	8	3	6	17	6	6	4	3
Megaloptera								
Sialidae - Sialis						1		
Other								
Clam			1					
Limpet				1			1	
Snail							1	
Planaria			1					
Oligochaetes				10	1	3	3	1
Leech						1		
Number of taxa	12	6	14	11	11	11	10	9
Taxa in common with Station 1	-	6	9	-	8	7	9	7

Table 11. Results of quantitative (D) and qualitative (Q) benthic aquatic macroinvertebrate sampling of the Straight River near Owatonna, Minnesota on February 15, 1983, June 27, 1983 and July 27, 1983. Quantitative results are expressed as the mean number per m^2. Qualitative results are expressed as total number collected.

	Stations (February)						Stations (June)						Stations (July)									
	1B		1		3		1		2		3		1A		1		2		3		4	
	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q
Ephemeroptera																						
Baetis	2						43	49			43	12	14	39	7	39		2	29	16	11	9
Ephoron							65	17					79	10	90	17	50	4	7			
Stenonema		1	15	2	77	7				1	7	5	18	19	39	32		17	47	40	68	14
Heptagenia							118	94	4	1	22	10		3				1	4	3		6
Isonychia							11	20			29			6	4	9		2	25	3	11	8
Tricorythodes							4						4	10	7	16		14	165	16	47	14
Caenis			2				7	3						1				1	11			1
Paraleptophlebia		1																				
Plecoptera																						
Perlesta										2	4			2		1						
Pteronarcys								6			7		7	4	4	2		2	4	1		
Acroneuria													4	5								
Taeniopteryx	2	5	6	1	2	1																
Trichoptera																						
Hydropsyche	2	4	6	1	15	2	36	8			47		373	19	90	13	11	2	215	16	230	43
Cheumatopsyche	28	62	39	2	2	1	4				39	1		1	4	12	4	1			25	
Hydropsyche Pupae													18	1		1			11		4	
Pycnopsyche	2	1																				
Hydroptilidae											11		22	2	11				39		47	4
Leptoceridae														1								
Coleoptera																						
Stenelmis							29	3			57		68	7	32	6	11	2	79	1	36	6
Optioservus											18						4	1	36	1	29	3
Dubiraphia								4			29							3	18			
Elmidae	39	6	34	16	24	1																
Laccophilus																1				1		
Hydroporus										1												
Diptera																						
Probezzia					2			2			18											
Atherix	9		4		9	2					11		43	3	4	2			47	5	50	19
Tipula	11				2														4		4	
Simuliidae	2	7					7	1			97								7		11	4
Hemerodromia											14											
Chironomidae Pupae					4	5	14	5			147	1				1		2	7	1		7
Ablabesmyia					4	1	7	1	4		588	1				6		2	118	2	25	8

Table 11 (continued)

	Stations (February)						Stations (June)						Stations (July)									
	1B		1		3		1		2		3		1A		1		2		3		4	
	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q	D	Q
Diptera (continued)																						
Pentaneuna				2	4						7		4	1					97	1		
C. (Dicrotendipes)											11											
C. (Cryptochironomus)								1			18			2								1
C. (Tribelos)					2						75		29			1		5		2		
Polypedilum							11	24	4		25	1		6		31	4	38	72	14	14	37
Stenochironomus													4									
Tanytarsus					4		36	4	18		75	2	18					2	7	1	4	
Rheotanytarsus							7	3			50				4	1						
Micropsectra			2					1														
Cricotopus	86	17	6	12	155	9	373	20	7		1,130								212	3	47	19
Nanocladius											108								497	2	36	20
Brillia		1	4	1	28	2	4	1			54	3				1		2		2		
Psectrocladius					4				4		50								377		14	18
Trichocladius											25	1	4									
Metriocnemus			2		2						4											
Odonata																						
Ischnura										6	4											
Argia												2										
Anax																1		1		1		
Other																						
Corixidae										2				130		2				1		
Plea														1				1				
Sialis	4								4									2	4	1		
Isopoda			2								7										4	1
Hyalella														4					4			
Hirudinae											61	1							7			
Planeria	4	2	4				4								4							
Ferrissima			11		4												4		11		7	1
Physa			2	1			4	1		1	4	1				2						
Plecepoda		2	4	1			4						4	3	4							
Nematoda											11											
Oligochaete	2		2		4		183	25	22		129		11		4	1	4	1	43	1		1
Decapoda							7	1	18	4	22	6		5		12		13	4	3		3
Total	193		145		348		978		85		3,061		724		308		92		2,207		727	
Number of taxa		17		18		19		27		15		39		30		27		25		36		27
Taxa in common with Station 1		11		-		11		-		8		18		20		-		17		22		20

Table 12. Number of plankton per sample collected from the Straight River, Owatonna, Minnesota, on February 15, 1983 and June 27, 1983.

	Station (February)			Station (June)					
				1		2		3	
	1B	1	3	A	B	A	B	A	B
Cladocera				1		2	2		
Bosmina		1		1	1		2		
Copepods		1		3	9	2	2		
Nauplii	12	9	11	12	16	5	2		
Chironomidae		1			2	4	1		
Nematoda			41	1	1	32	11		
Tardigrada				1					
Branchionus	1	1							
Large Branchionidae		2		1	1	5	0		
Small Branchionidae	6	2	1			6	2		
Bdelloidea	1		8	1	1	37	8		
Polyarthra	4		1						
Keratella	5	7	4	1			1		
Kellicottia			3						
Pediastrum				10	6		1		
Ceratium							1		
Desmids				5	4	5	1		
Solitary Diatoms	8,600	14,675	10,375	24,400	23,550	23,350	5,300	9,350	6,800
Number of taxa	7	9	7	12		14		3	
Taxa in common with Station 1	5		4			12		3	

Table 15. Plankton density (mean number/liter) calculated from samples collected from the Straight River, Owatonna, Minnesota, July 27, 1983.

	Station					
	1A	1	2	3	4	5
Cladocera		0.15	0.16	0.11		
Bosmina		0.12	0.11	0.16		
Copepods	0.04	0.54	0.16		0.19	
Nauplii	0.21	0.77	0.26	0.60	1.34	0.034
Chironomidae		0.05	0.15	0.11	0.13	0.06
Nematoda			0.18	0.60	1.15	0.61
Tardigrada						
Branchionus		0.22	0.16	0.11	0.13	0.17
Large Branchionidae		0.09	0.11	0.06	0.06	
Small Branchionidae	0.09	0.37	0.22	0.28	0.96	0.56
Bdelloidea			2.33	1.46	2.05	0.71
Polyarthra						
Keratella		0.12	0.11	0.22		
Kellicottia						
Pediastrum	0.30	0.05			0.06	
Ceratium	0.18	0.12	0.11	0.11		
Desmids	0.13	0.22	0.17		0.13	
Solitary Diatoms	421.3	697.6	423.0	282.0	393.5	390.8
Number of taxa	7	13	14	12	11	8
Taxa in common with Station 1	7		12	10	10	4

Table 14. Fish collected by seine and electro-fishing from the Straight River, Owatonna, Minnesota, July 28, 1983. Presence (denoted by x) or absence of species was determined in June and total number of each species in July. Station 2B was sampled only with the seine.

	Station (June)			Station (July)					
	1	2	3	1A	1	2B	2	3	4
Northern pike, *Esox lucius*	x	x		3	1	3	1		2
Brook stickleback, *Culaea inconstans*		x							
Mudminnow, *Umbra limi*		x							
Black crappie, *Pomoxis nigromaculatus*			x		21	7	6	9	15
Green sunfish, *Lepomis cyanellis*	x			2	5		9	11	16
Pumpkinseed, *L. gibbosus*					2				
Orangespotted sunfish, *L. humilis*									1
Rock bass, *Ambloplites rupestris*	x	x	x	1					
Iowa darter, *Etheostoma exile*				1		1			
Johnny darter, *E. nigrum*			x	15	1	19	12	3	1
Blackside darter, *Percina maculata*				9				1	
Black bullhead, *Ictalurus melas*	x	x			1	1			1
Stonecat, *Noturus flavus*				1					
Tadpole madtom, *N. gyrinus*									1
Carp, *Cyprinus carpio*	x		x				1	1	1
Creek chub, *Semotilus atromaculatus*	x		x		10	73	5	3	3
Bluntnose minnow, *Pimephales notatus*	x	x	x	4	10	187	10	7	15
Fathead minnow, *P. promelas*	x				15	80		3	10
Sand shiner, *Notropis stramineus*	x		x		1	7		22	23
Emerald shiner, *N. atherinoides*					6				
Redfin shiner, *N. umbratilis*				68		3			
Common shiner, *N. cornutus*	x		x					7	
Spotfin shiner, *N. spilopterus*	x							2	
Blacknose dace, *Rhinichthys atratulus*	x		x						1
Larval cyprinids	x				17	42			
White sucker, *Catostomus commersoni*	x	x	x		6	9	6	8	2
Hog sucker, *Hypentelium nigricans*			x	1					
Larval catastomids				8					
Number of species	13	7	11	9	12	11	8	12	14
Taxa in common with Station 1		5	8	4		10	7	8	10

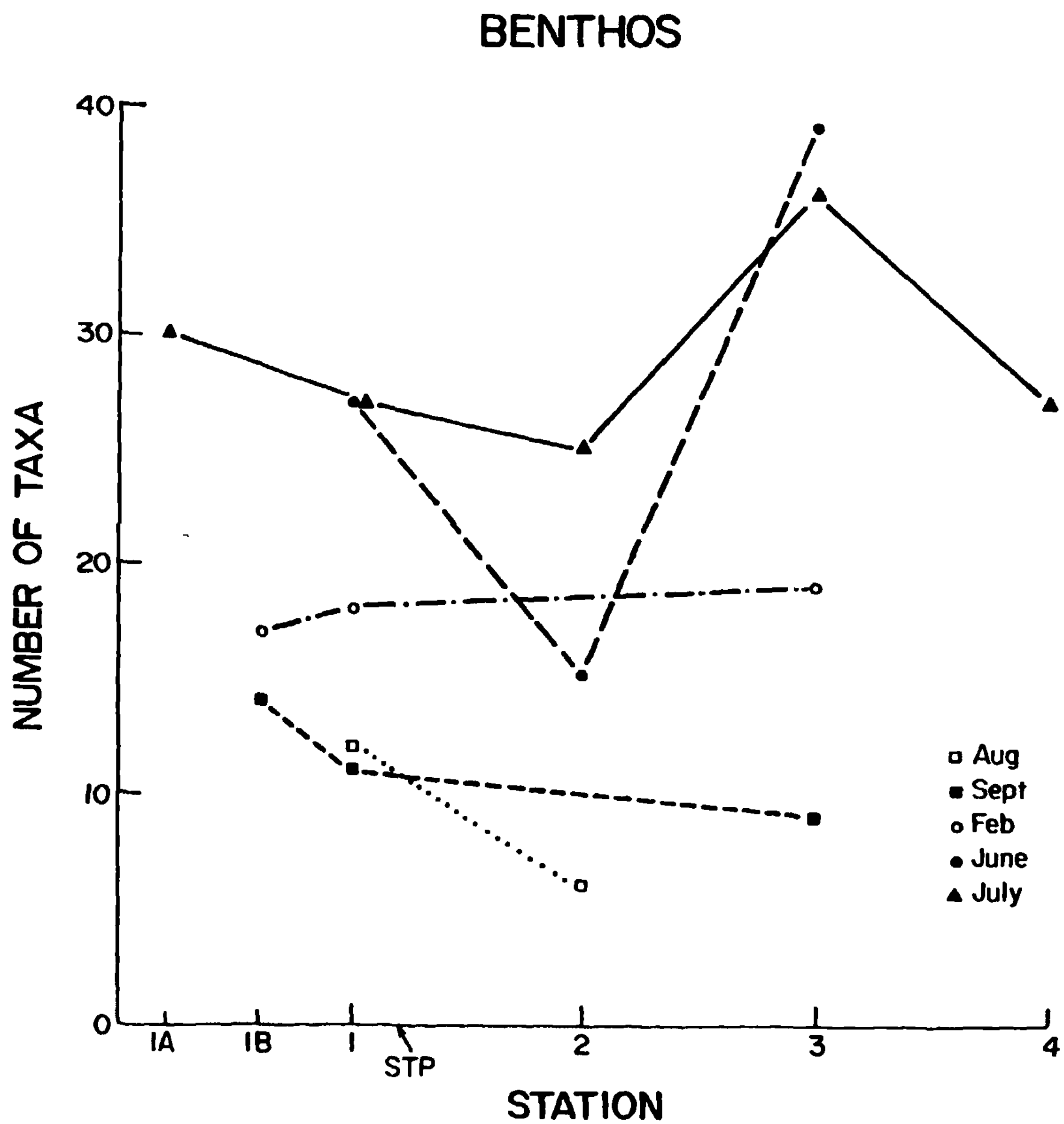

Figure 1. Number of bentho-macroinvertebrate taxa identified at each sampling station.

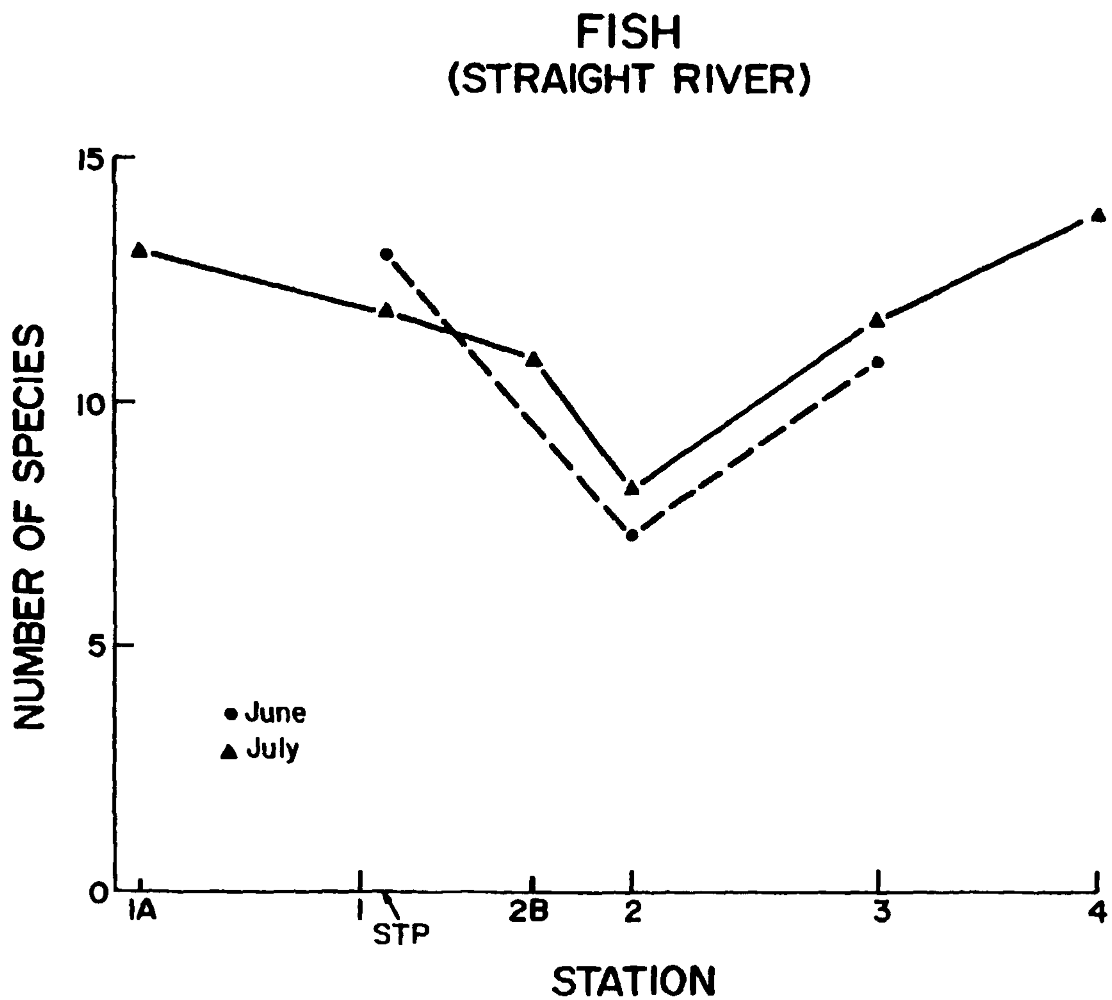

Figure 2. Number of fish species identified at each sampling station.

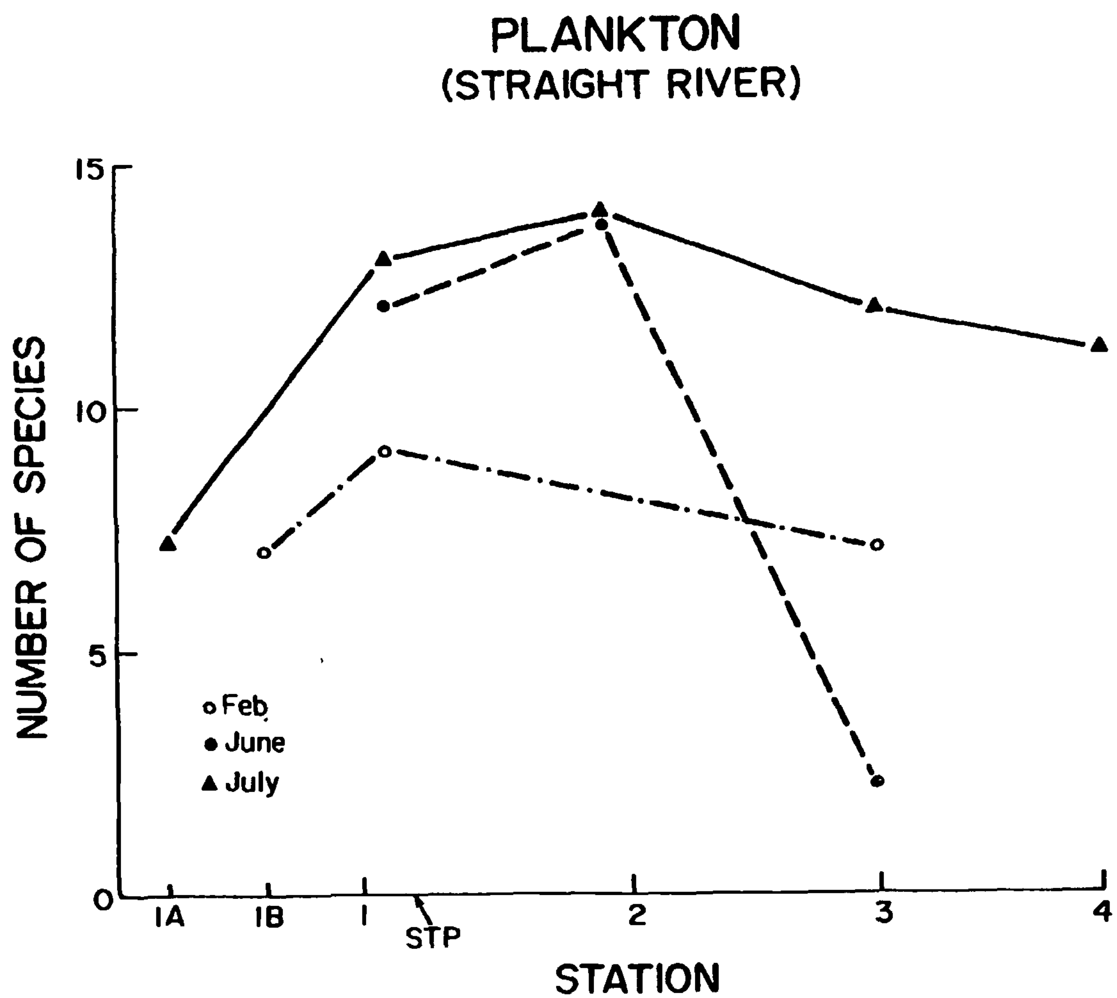

Figure 3. Number of plankton taxa identified at each station.

APPENDIX 1

Quality Control Data

Quality control values for measurement of selected metals in test waters. Values are reported as percentage recovery.

Date of Water Collection	Zinc	Copper	Cadmium	Chromium	Lead
Recovery of U.S. EPA Reference Sample					
8-17-82	100	99	105	93	111
9-10-82	94				
2-17-82	100, 101	95	98	104	-
6-27-82	-	106	94	105	96
Recovery of a Spike					
8-17-82	97	102	101	90	103

Quality control values for measurements of zinc in tests using water collected on 6-27-83.

Sample	% Agreement of Duplicates	% Recovery/Spike Concentration
Daphnia #3 (7/1)	98.0	103.5/200 µg/l
Mount #9 - Initial	100.0	94.1/1,000 µg/l
FHM, LH_2O (6/28)	98.9	100.8/500 µg/l

Reference Sample	Analytical Mean (µg/l)	True Value (µg/l)
EPA W476#1 (N=2)	6.2	6.1
WP475#3 (N=4)	200	200

Quality control values for selected metals in tests using water collected on 7-28-83.

Sample	% Agreement of Duplicates	% Recovery/Spike Concentration
ZINC - ACID EXCHANGEABLE		
Daphnia metals addition	86.7	88.0/25 µg/1
Daphnia, upstream	91.2	75.0/124 µg/1
Daphnia, upstream	96.7	100.8/245 µg/1
Fathead minnow, upstream	99.6	87.9/481 µg/1
Fathead minnow, upstream	84.2	93.3/481 µg/1
Daphnia, instream, 2A	74.0	84.3/99 µg/1
Daphnia, downstream	42.8	88.0/50 µg/1
Fathead minnow, downstream	87.3	77.0/99 µg/1
Fathead minnow, downstream	89.8	107/99 µg/1
Fathead minnow, effluent dilution	86.7	103.2/124 µg/1
Fathead minnow, effluent dilution	88.6	94.4/124 µg/1
Fathead minnow, Lake Superior water	94.9	86.1/481 µg/1
Fathead minnow, Lake Superior water	96.4	84.6/481 µg/1
Fathead minnow, Lake Superior water	98.5	83.1/1,724 µg/1
COPPER - ACID EXCHANGEABLE		
Fathead minnow, downstream, control composite	none	97.9/8.00 µg/1
Daphnia effluent dilution, 3%	none	98.9/8.00 µg/1
Fathead minnow, effluent dilution, 30%	none	101.2/16.0 µg/1
CADMIUM - ACID EXCHANGEABLE		
Fathead minnow, downstream control composite	100	119/1.50 µg/1
LEAD - ACID EXCHANGEABLE		
Fathead minnow, downstream control	91.4	108/18 µg/1
CHROMIUM - ACID EXCHANGEABLE		
Fathead minnow, downstream control composite	83.3	108/7.0 µg/1

Reference	Concentration (µg/l)	
	Analytical $\bar{x} \pm 1$ SD	True Values
Zinc		
EPA WP475 #2 (N=4)	11.7 ± 1.6	12.5
WP475 #3 (N=13)	210 ± 14.5	200
WP475 #6 (N=3)	414 ± 0.6	400
Copper		
WP475 #1 (N=3)	40.9 ± 0.7	40.0
WP475 #2 (N=2)	8.04 ± 0.2	8
Cadmium		
WP475 #2 (N=1)	1.49	1.5
Lead		
WP475 #2 (N=3)	18.9 ± 1.2	18
Chromium		
WP475 #2 (N=2)	6.64 ± 0.3	7

Quality control values for selected measurements of water samples collected on 7-28-83.

Test	EPA Reference $\bar{x}$ Exp/True	Site	% Agreement of Duplicates	% Recovery/Spike Concentration
Total alkalinity		1	99.6	
		Effluent	99.1	
Total hardness		1	100	
		4A	100	
Turbidity		3	96.9	
Ammonia nitrogen	2/5 strength WP 481 0.608/0.600 mg/l Theory/exp. 98.7% rec	3 Eff	95	97/3.00 mg/l
Nitrite nitrogen				
Nitrate-nitrite nitrogen	*WP481 N=12 0.65/0.64 mg/l		95.1	90.3/2.00 mg/l
Residue, non-filterable		4A	95.4	
Residue, Total		3	97.4	

* Samples were analyzed in conjunction with the Connecticut samples. A cumulative value is given here.

Quality control values for selected metals in tests of water collected on 7-28-83.

Metal	Deionized Water Blank Spike Recovery/Spike Concentration	Site 4A % Agreement of Duplicates	Site 4A % Recovery/Spike Concentration
	Total Recoverable Metals		
Zinc	105.2/160 µg/l	96.5	105.9/160 µg/l
Copper	102/100 µg/l	77.2	101.4/100 µg/l
Cadmium	96.7/26.0 µg/l	97.7	115.4/26 µg/l
Lead	110.8/240 µg/l	91.9	104.9/266 µg/l
Chromium	98.1/160 µg/l	96.7	96.6/160 µg/l

APPENDIX 2

Provisional Record

U.S. Geological Survey

Cannon River Basin

05353800 Straight River Near Faribault, MN

LOCATION -- Lat 44°15'29", long 93°13'51", in W 1/2 SE 1/4 sec. 9, T. 109 N., R. 20 W., Rice County, Hydrologic Unit 07040002, on right bank 15 ft (5 m) downstream from highway bridge, 2.8 mi (4.5 km) upstream from Falls Creek and 3.2 mi (5.1 km) southeast of Faribault.

DRAINAGE AREA -- 442 mi^2 (1,145 km^2).

PERIOD OF RECORD -- October 1965 to current year.

GAGE -- Water-stage recorder. Datum of gage is 1,034.58 ft (315.340 m) National Geodetic Vertical Datum of 1929.

REMARKS -- Records good except those for winter period, which are fair.

AVERAGE DISCHARGE -- 17 years, 237 ft^3/s (6.712 m^3/s), 7.28 in/yr (185 mm/yr).

EXTREMES FOR PERIOD OF RECORD -- Maximum discharge, 5,990 ft^3/s (170 m^3/s) May 1, 1973, gage height, 11.20 ft (3.414 m); maximum gage height, 12.74 ft (3.883 m) Mar. 5, 1974 (backwater from ice); minimum discharge, 10 ft^3/s (0.28 m^3/s) Oct. 27, 1976; minimum gage height, 3.66 ft (1.116 m) Nov. 27, 1976.

Discharge, in cubic feet per second, water year October 1981 to September 1982

Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	121	205	134	67	40	69	905	267	2020	178	79	470
2	109	197	133	64	40	68	749	249	1520	166	77	553
3	107	193	132	62	40	68	709	238	1070	166	75	470
4	144	190	130	59	40	67	569	249	784	157	73	322
5	155	189	128	57	40	66	528	466	632	140	75	227
6	182	187	130	55	40	66	456	654	538	143	73	189
7	191	183	130	52	40	66	433	874	494	238	69	171
8	191	174	120	50	40	66	393	862	442	456	67	154
9	178	200	110	48	40	67	388	737	406	325	63	140
10	173	203	109	47	40	70	363	611	371	256	61	152
11	164	193	111	45	40	100	346	499	338	306	59	145
12	154	181	112	44	40	150	406	489	313	282	55	202
13	152	175	113	43	40	300	494	814	286	221	55	555
14	180	169	114	42	40	600	523	1020	264	198	53	636
15	198	163	114	42	42	800	554	1010	275	201	51	652
16	210	158	113	41	43	900	664	975	271	302	49	600
17	306	151	112	41	45	1200	1100	975	275	451	49	530
18	436	143	111	40	48	1400	1160	1260	294	380	48	438
19	456	155	108	40	53	1640	988	1100	298	275	48	352
20	417	151	105	40	56	1580	874	950	275	217	46	283
21	361	125	100	40	62	1440	737	760	260	194	42	235
22	319	127	97	40	66	1220	621	714	242	182	69	205
23	285	129	94	40	69	1180	538	709	228	160	61	186
24	227	131	91	40	70	1430	480	670	235	140	103	169
25	258	133	88	40	70	1320	428	595	313	126	107	152
26	249	145	85	40	70	1210	388	543	271	121	121	141
27	247	141	82	40	70	1010	350	590	249	115	95	134
28	247	140	79	40	70	850	325	616	228	105	72	126
29	247	138	76	40	--	778	302	579	207	98	130	135
30	242	136	73	40	--	826	282	584	191	93	171	158
31	223	--	70	40	--	982	--	2600	--	88	169	--
Total	7129	4905	3304	1419	1394	21589	17053	23259	13590	6480	2365	8882
Mean	230	164	107	45.8	49.8	696	568	750	453	209	76.3	296
Max	456	205	134	67	70	1640	1160	2600	2020	456	171	652
Min	107	125	70	40	40	66	282	238	191	88	42	126
CFSM	.52	.37	.24	.10	.11	1.58	1.29	1.70	1.03	.47	.17	.67
In.	.60	.41	.28	.12	.12	1.82	1.44	1.96	1.14	.55	.20	.75

Cal Yr 1981 Total 101622 Mean 278 Max 2900 Min 28 CFSM .63 In 8.55
Wtr Yr 1982 Total 111369 Mean 305 Max 2600 Min 40 CFSM .69 In 9.37

Discharge, in cubic feet per second, water year October 1982 to September 1983

Mean Values

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	238	300	310	238	130	1900	1990	622	429	4420	89	276
2	382	282	347	227	130	2740	2080	751	396	4790	83	206
3	492	252	387	220	130	2930	1870	799	382	3380	81	160
4	513	257	398	215	130	2800	1620	745	355	2960	77	131
5	480	244	377	205	130	2530	1410	649	333	2600	73	130
6	457	234	376	195	130	2410	1320	720	320	2170	69	126
7	478	228	386	190	130	2520	1360	1820	308	1760	65	127
8	451	219	379	185	130	2250	1290	1620	298	1460	60	111
9	418	217	319	175	130	1720	1200	1320	293	1220	59	108
10	371	634	310	172	130	1370	1180	1040	285	958	56	95
11	332	1080	300	170	130	1150	1310	837	273	731	54	94
12	304	1360	297	167	130	954	1320	728	264	570	51	88
13	281	1330	280	163	130	835	1910	770	253	475	50	86
14	265	1190	278	160	130	766	2270	731	265	405	48	82
15	252	999	254	157	133	739	2170	662	243	349	47	110
16	232	839	250	152	138	701	2040	582	223	308	46	171
17	216	699	250	150	147	653	1920	526	204	280	46	173
18	209	590	256	150	165	646	1770	489	200	259	45	159
19	216	604	204	150	180	703	1680	568	196	245	43	192
20	630	758	193	150	225	716	1820	691	198	243	41	1780
21	962	772	195	150	390	629	2280	721	196	211	46	1890
22	967	691	199	150	650	547	2540	641	191	187	44	1660
23	852	604	181	150	1000	501	2280	553	179	170	43	1390
24	720	529	215	150	990	477	1880	494	166	154	42	1140
25	604	471	761	147	940	475	1530	450	160	143	391	923
26	508	412	824	144	920	469	1280	414	158	132	240	755
27	442	389	680	140	920	454	1050	448	159	123	323	621
28	396	353	415	135	1360	428	869	461	171	121	321	502
29	372	359	272	130	--	459	766	475	198	117	271	408
30	340	346	270	130	--	484	682	478	292	107	415	335
31	314	--	262	130	--	1100	--	463	--	98	333	--
Total	13694	17242	10425	5147	9978	37056	48687	22268	7588	31146	3652	14029
Mean	442	575	336	166	356	1195	1623	718	253	1005	118	468
Max	967	1360	824	238	1360	2930	2540	1820	429	4790	415	1890
Min	209	217	181	130	130	428	682	414	158	98	41	82
CFSM	1.00	1.30	.76	.38	.81	2.70	3.67	1.62	.57	2.27	.27	1.06
In.	1.15	1.45	.88	.43	.84	3.12	4.10	1.87	.64	2.62	.31	1.18
AC-FT	27160	34200	20680	10210	19790	73500	96570	44170	15050	61780	7240	27830

Wtr Yr 1983 Total 220912 Mean 605 Max 4790 Min 41 CFSM 1.37 In 18.59 AC-FT 438200