WATER-QUALITY ASSESSMENT AND WASTEWATER-MANAGEMENT ALTERNATIVES FOR DARDENNE CREEK IN ST. CHARLES COUNTY, MISSOURI

By Wayne R. Berkas and John R. Lodderhose

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DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
1400 Independence Road, Mail Stop 200
Rolla, Missouri 65401

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CONVERSION FACTORS

Inch-pound units in this report may be expressed as metric by use of the following conversion table:

To convert inch-pound unit	Multiply by	To obtain metric unit
foot	0.3048	meter
cubic foot per second	0.02832	cubic meter per second
mile	1.609	kilometer
square mile	2.590	square kilometer
million gallons per day	0.04381	cubic meter per second

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F=9/5°C + 32.

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By

Wayne R. Berkas, U.S. Geological Survey
and
John R. Lodderhose, Missouri Department of Natural Resources

ABSTRACT

The quality of water in the 15-mile downstream reach of Dardenne Creek in St. Charles County, Missouri, was assessed to determine if it met the Missouri water-quality standards. Concentrations of dissolved-oxygen and total ammonia as N failed to meet water-quality standards downstream from the Harvester-Dardenne and St. Peters Wastewater-Treatment Plants.

Management alternatives using current, design-capacity, and future expansion wastewater discharges from the St. Peters Wastewater-Treatment Plant were evaluated by using the QUAL-II/SEMCOG model, which was calibrated and verified using two independent data sets from Dardenne Creek. Results of computer simulation indicate that a nitrification-type advanced-treatment facility installed at the plant would protect the stream's beneficial uses. This type of facility would produce a 5-day carbonaceous biochemical-oxygen demand of 10 milligrams per liter and a total ammonia as N concentration of 2.0 milligrams per liter. An effluent limit of 5.0 milligrams per liter of 5-day carbonaceous biochemical-oxygen demand would further improve the water quality of Dardenne Creek; however, an additional treatment process, such as sand filtration, would be needed to achieve this criterion.

INTRODUCTION

The development and implementation of wastewater-treatment and stream water-quality management plans were mandated by Public Law 92-500, Federal Water Pollution Control Act Amendments of 1972. To fulfill a requirement of this law, the Missouri Department of Natural Resources (1976) developed a water-quality management plan in accordance with Section 303e of Public Law 92-500. In this plan lower Dardenne Creek was noted as a water-quality limited stream, which required wastewater-treatment plants to use advanced levels of treatment to protect stream water quality. Small dissolved-oxygen and large fecal coliform concentrations were cited as problems caused by multiple wastewater discharges in the basin.

In accordance with Section 208 of Public Law 92-500, areawide plans were developed for selected metropolitan areas (East-West Gateway Coordinating Council and others, 1977). For Dardenne Creek, this plan included a recommendation for consolidation of all wastewater discharge in the downstream part of the basin to a regional plant in St. Charles, Missouri, with discharge to the Mississippi River. This recommendation was later modified by the Missouri Clean Water Commission to allow subregional plants that were to be as environmentally sound as the regional plant.

A requirement of Public Law 92-500, Section 201, is the development of a plant that would identify the future wastewater-management needs of municipalities. Sverdrup and Parcel and Assoc. (1984), developed a plan in which the specific wastewater alternatives were determined for lower Dardenne Creek basin. Population growth in the basin is anticipated, and expansion of existing wastewater plants and construction of new wastewater plants are planned.

Purpose and Scope

This study was done as a partial fulfillment of the requirements of Public Law 92-500. The objectives were to:

1. Collect water-quality data in lower Dardenne Creek for comparison to the Missouri water-quality standards.

2. Evaluate wastewater-management alternatives by simulating water-quality conditions of Dardenne Creek during various wastewater discharges to determine the minimum level of treatment that would be required to protect stream water quality.

This report presents data collected during two 48-hour studies. The data from both studies were used to determine if there were any violations of the Missouri water-quality standards. The first set of data was used to calibrate the QUAL-II/SEMCOG water-quality model (Roesner and others, 1981), and the second set was used to verify the model. The model was then used to simulate dissolved-oxygen and total ammonia-nitrogen concentrations in Dardenne Creek using various wastewater discharges to determine the management alternatives that would meet the Missouri water-quality standards.

Study-Area Description

Lower Dardenne Creek is located in St. Charles County, Missouri (fig. 1). The creek predominately flows northeast and discharges into the Mississippi River. South of Interstate Highway 70, Dardenne Creek flows through an area of steep upland to slightly sloping topography. The soils in this area are deep, well-drained to moderately well-drained, loamy and overlain by loess on the ridge tops and side slopes (Allgood and Persinger, 1979). The creek is characterized by a deep U-shaped channel with silt and clay sides, and sand and gravel bottom. During low flow, the creek consists of long, shallow pools with occasional short riffles. The channel slope averages 0.000806 foot per foot.

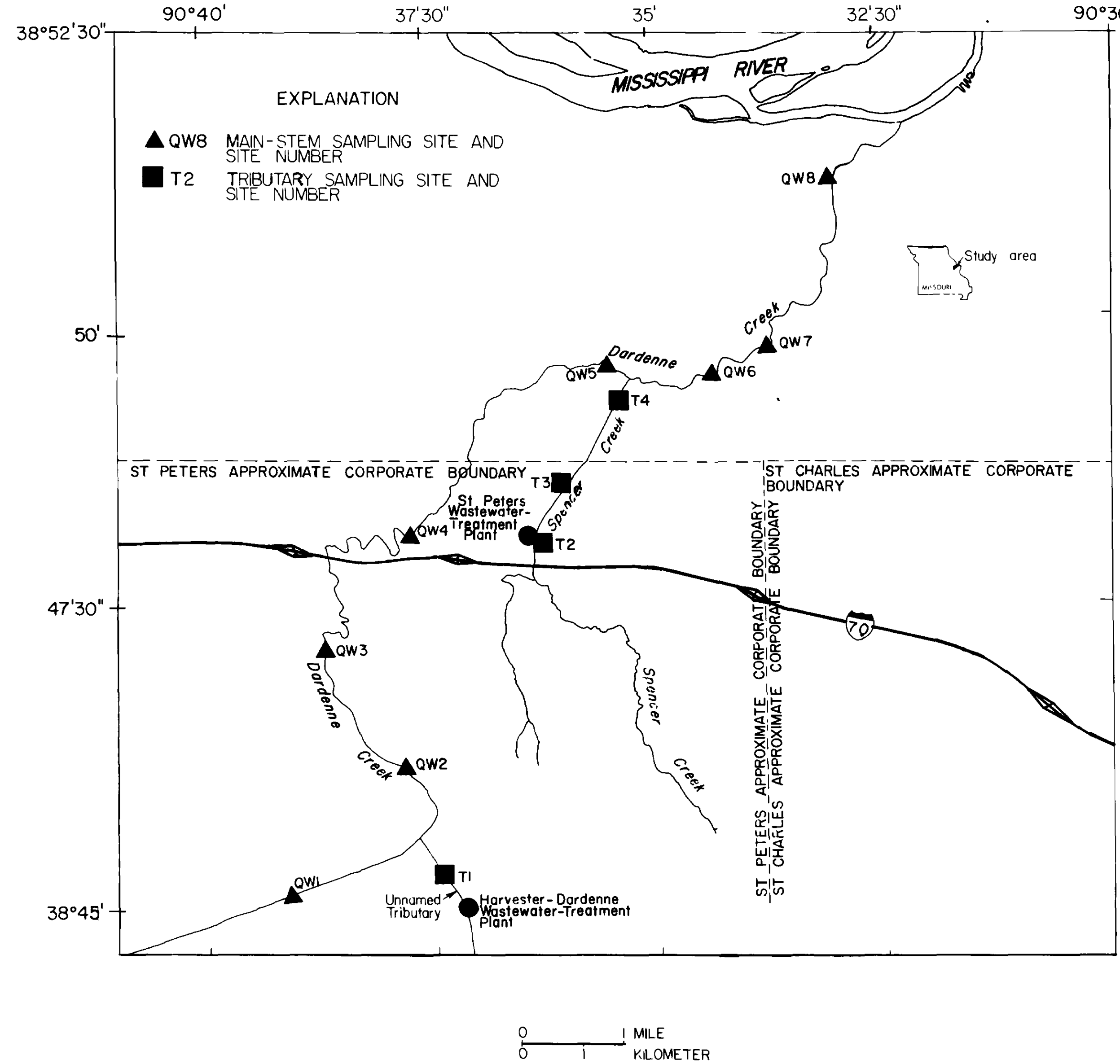

Figure 1.--Water-quality sampling sites on Dardenne Creek and its tributaries.

North of Interstate Highway 70, Dardenne Creek flows through the flood plain of the Mississippi River. The soils in this area are moderately well-drained to poorly drained loam and clay (Allgood and Persinger, 1979). The creek is characterized by a deep U-shaped channel with silt and clay comprising the sides and bottom. During low flow, the creek is made up of a long, deep, slow-moving pool. The channel slope in this area averages 0.000252 foot per foot.

Population in St. Charles County increased from 92,954 during 1970 to 143,455 during 1980 (U.S. Department of Commerce, 1981). The population of St. Peters increased from 484 during 1970 to 15,700 during 1980. Much of this population increase has been along the south side of Interstate Highway 70.

Two municipal wastewater-treatment plants discharge into Dardenne Creek (fig. 1). The Harvester-Dardenne Wastewater-Treatment Plant discharges into a small, unnamed tributary that flows for 0.75 mile before entering Dardenne Creek, 13.4 miles upstream from its mouth. This plant consists of two 0.5 million gallons per day contact-stabilization package plants. The flow at the plant is rapidly approaching design capacity, and it will be taken completely off-line during 1985. The wastewater will then be pumped to another treatment plant that will discharge into the Missouri River. The city of St. Peters has a wastewater-treatment plant and a water-treatment plant on Spencer Creek. Effluent from both plants, which are at the same location, enters Spencer Creek and flows for 2.0 miles before entering Dardenne Creek 5.0 miles upstream from its mouth. St. Peters Wastewater-Treatment Plant consists of a 3.0 million gallons per day aerated lagoon with two final clarifiers and aerobic sludge digestion. The water-treatment plant discharges from lime sludge ponds that typically have large settleable-solids concentrations.

The most downstream 7 miles of Dardenne Creek are classified by the Missouri Department of Natural Resources (1981) as a backwater area of the Mississippi River. The wastewater outflow from the St. Peters Wastewater Treatment Plant enters this backwater area via Spencer Creek. This study was done during low-flow conditions when the backwater from the Mississippi River was observed approximately 2 miles upstream from the mouth of Dardenne Creek.

DATA COLLECTION

Data were collected during two 48-hour periods in the 15-mile downstream reach of Dardenne Creek and its major tributaries. Hydraulic and water-quality data were collected August 1-3, 1983, and were used to define the water quality in Dardenne Creek and to calibrate the digital model. Hydraulic and water-quality data also were collected September 26-28, 1983, and were used to verify the model.

Hydraulic data consisted of measurements of stream velocity and channel geometry, which included stream width, and cross-sectional area. Average velocities in selected reaches also were measured using dye-tracer techniques described by Wilson (1968).

All water-quality data were analyzed by the Missouri Department of Natural Resources, Division of Environmental Quality. Their laboratory used procedures recommended by the American Public Health Association and others (1980). The complete set of water-quality data is tabulated in the "Supplemental Data" section at the end of this report.

Water samples were collected every 12 hours and analyzed for:

1. 5-day carbonaceous biochemical-oxygen demand, in milligrams per liter.
2. Total ammonia as N, in milligrams per liter.
3. Total nitrate as N, in milligrams per liter.
4. Dissolved orthophosphate as P, in milligrams per liter.
5. Suspended solids, in milligrams per liter.

Water samples were collected twice daily during each sampling period and analyzed for:

1. Chlorophyll "a", in micrograms per liter.
2. Fecal coliform, in colonies per 100 milliliters.
3. Fecal streptococci, in colonies per 100 milliliters.
4. Chloride, in milligrams per liter.
5. Total-recoverable mercury, in micrograms per liter.
6. Selected pesticides (dieldrin, chlordane, lindane, toxaphene), in micrograms per liter.
7. Total-recoverable iron, in micrograms per liter (August samples only).
8. Chemical-oxygen demand, in milligrams per liter (August samples only).

Analysis in the field for the following was made every 4 hours during each of the data-collection periods at each sampling site:

1. Dissolved oxygen, in milligrams per liter.
2. pH, in units.
3. Temperature, in degrees Celsius.
4. Specific conductance, in microsiemens per centimeter at 25 °C.

During the August sampling period, the U.S. Geological Survey collected and analyzed streambed-oxygen demand using procedures described by Nolan and Johnson (1979), and Terry and others (1983). Reaeration coefficients also were calculated using procedures described by Rathbun and others (1975). A qualitative sampling for macroinvertebrates was made during August by the Missouri Department of Natural Resources, Division of Environmental Quality. During August and September sampling periods, discharge measurements were made by the U.S. Geological Survey using procedures described by Buchanan and Somers (1969). Twenty-four hour composite samples also were collected at the Harvester-Dardenne and St. Peters Wastewater-Treatment Plants for 48 hours during both sampling periods.

WATER QUALITY IN DARDENNE CREEK

The Missouri Department of Natural Resources (1981) classifies Dardenne Creek as a perennial stream beginning 22 miles upstream from its mouth. The water-quality standards for perennial streams require that contaminants shall not cause or contribute to exceedance of maximum specific limitations for designated use of the water. Exceptions are granted by the Clean Water Commission when the flow in perennial streams is less than the average minimum flow for 7 consecutive days that has a recurrence interval of 10 years (7-day Q_{10}) and may be granted when the effluent constitutes a majority of the streamflow. The Clean Water Commission has not granted any exceptions in Dardenne Creek prior to this study (1985). The Missouri water-quality standards and average values of selected water-quality constituents collected August 1-3, 1983, and September 26-28, 1983, are shown in table 1.

The water-quality standards for dissolved oxygen in Dardenne Creek specify that water-quality contaminants shall not cause dissolved-oxygen concentrations to be less than 5.0 milligrams per liter at any time. The wastewater effluent from the Harvester-Dardenne plant caused violations of water-quality standards in Dardenne Creek by decreasing the dissolved-oxygen concentration of 7.1 milligrams per liter at QW1 to 2.2 milligrams per liter at QW2 for the August period, and decreasing the concentration of 7.1 milligrams per liter at QW1 to 1.8 milligrams per liter at QW2 for the September period (see fig. 1). The wastewater effluent from the St. Peters plant caused a violation of water-quality standards in Dardenne Creek, decreasing the dissolved-oxygen concentration of 6.1 milligrams per liter at QW5 to 4.4 milligrams per liter at QW6 for the September period.

When combined with water, ammonia exists in the ionized form (NH_4^+) and the un-ionized or free form (NH_3). The percentage of ammonia in each form is dependent on temperature and pH. For conditions of low temperature and pH, most of the ammonia is in the form of NH_4^+. For conditions of high temperature and pH, most of the ammonia is in the form of NH_3. Thurston and others (1974) give a detailed table listing the percent NH_3 at each temperature and pH. The un-ionized ammonia present in streams is important because it can be toxic to fish.

The water-quality standard for un-ionized ammonia in Dardenne Creek specifies that water-quality contaminants shall not cause un-ionized ammonia concentration to be greater than 0.1 milligram per liter. This would be equivalent to a total ammonia as N concentration of 1.9 milligrams per liter at a temperature of 25 °C and a pH value of 8.0. Discharge from the Harvester-Dardenne plant caused violations of the un-ionized ammonia standard in Dardenne Creek by increasing the total ammonia as N concentration from 0.2 milligram per liter at QW1 to 6.1 milligrams per liter at QW2 for the August period, and increasing the concentration from 0.1 milligram per liter at QW1 to 7.1 milligrams per liter at QW2 for the September period. Discharge from the St. Peters plant caused a violation in the un-ionized ammonia standard by increasing the total ammonia as N concentration from 1.4 milligrams per liter at QW5 to 6.6 milligrams per liter at QW6 for the August period.

Table 1.--Average values of discharge and selected water-quality properties and constituents, August 1-3 and September 26-28, 1983, and Missouri water-quality standard

[--, missing data; ND, none dectected]

Property or constituent	Sampling period	Number of samples	QW1	T1	QW2	QW3	QW4	QW5	T2	T3	T4	QW6	QW7	QW8	Missouri water-quality standard
			Water-quality sampling sites (figure 1)												
Discharge, in cubic feet per second	August	1	3.14	--	6.38	6.68	6.42	--	0.71	4.48	4.45	10.6	--	--	None
	September	1	1.85	3.12	5.40	3.59	5.14	--	0.47	3.62	--	--	--	--	
Temperature, in degrees Celsius	August	12	26.7	24.0	25.7	25.0	26.7	27.8	25.0	23.0	23.5	26.0	27.4	--	32.2, maximum
	September	12	18.4	21.7	19.2	18.2	18.3	19.5	17.8	19.0	19.4	19.1	19.6	17.8	
pH, in units	August	12	7.9	7.4	7.6	7.6	7.7	8.3	8.1	8.0	8.1	8.2	8.2	--	6.5 to 9.0
	September	12	7.8	7.5	7.6	7.5	7.7	7.8	8.0	8.6	8.6	8.2	7.9	7.8	
Dissolved oxygen, in milligrams per liter	August	12	7.1	0.4	2.2	3.2	4.5	12.0	7.8	2.8	3.1	8.2	7.8	--	5.0, minimum
	September	12	7.1	0.4	1.8	3.1	4.0	6.1	8.0	5.0	3.5	4.4	4.0	3.7	
Total ammonia as N, in milligrams per liter	August	4	0.2	13.5	6.1	4.6	3.4	1.4	0.05	15.0	16.0	6.6	6.5	--	1.9 at 25° Celsius and pH equal to 8.0
	September	4	0.1	14.0	7.1	5.2	6.4	4.0	0.1	0.3	0.4	2.0	2.2	1.9	
Dissolved orthophosphate, as P, in milligrams per liter	August	4	0.05	7.2	2.6	1.5	1.0	0.5	0.06	3.4	4.4	1.2	1.2	--	
	September	4	0.2	9.1	3.0	2.8	2.2	1.0	0.11	3.1	4.1	2.7	2.1	1.2	
Total-recoverable iron, in micrograms per liter	August	2	2,000	--	--	2,500	--	4,100	--	--	--	--	6,100	--	1,000
Pesticides, in micrograms per liter	August	2	ND	--	--	ND	--	--	--	--	--	--	ND	--	0.0
	September	2	ND	--	--	ND	--	--	--	--	--	--	ND	--	

The water-quality standard for iron specifies that water-quality contaminants shall not cause the toxic fraction of the total iron concentration in Dardenne Creek to exceed 1,000 micrograms per liter. There is some uncertainty about the meaning of toxic fraction of iron. The toxic fraction is somewhere between the total iron and the dissolved iron concentrations. For this study total-recoverable iron concentrations were measured, which involved using a mild extraction technique in determining the concentration. The authors believe that this extraction technique is too strong and that the concentrations measured are greater than the toxic fraction.

The total-recoverable iron concentrations measured during August at four sites were greater than 1,000 micrograms per liter (see table 1). This constituent shows a significant increase in a downstream direction from QW1, but because samples were not collected at the wastewater plants, and because of the uncertainty as to what fraction is toxic, it cannot be stated that discharge from the wastewater-treatment plants caused a violation of the iron standard.

DESCRIPTION OF WATER-QUALITY MODEL

The computer model used in this study was the QUAL-II/SEMCOG version, developed by Water Resources Engineers, Inc., for the Southeast Michigan Council of Governments (SEMCOG). Details of model formulation and operation are documented by Roesner and others (1981). The model is based on the assumption that the stream is well-mixed and the major transport mechanisms, advection and dispersion, are significant only along the main direction of flow. It allows for multiple-waste discharges, withdrawals, tributary inflows, and incremental flows.

In this study the model was used in a steady-state mode with constant temperature. The following constituents were simulated:

1. Dissolved oxygen.
2. 5-day carbonaceous biochemical-oxygen demand.
3. Algae as chlorophyll "a".
4. Ammonia as N.
5. Nitrate as N.

Model Inputs

The input data required for the QUAL-II model can be grouped into three general classifications: hydraulic data, reaction-rate constants, and water-quality data for headwater and point-source elements. The determination of reaction-rate coefficients basically is the calibration process and is discussed in the "Calibration Results" section. A schematic representation of Dardenne Creek showing subreaches, headwater input locations, and wastewater input locations is shown in figure 2.

The hydraulic data are used by the model to compute time of travel of the water through each computational element in a subreach. The hydraulic data used in this study (table 2) were the channel side slope (run/rise), bottom width of channel, average channel slope, and Manning's roughness coefficient (n). Manning's "n" was determined from the average velocity and channel-geometry data collected throughout Dardenne and Spencer Creeks.

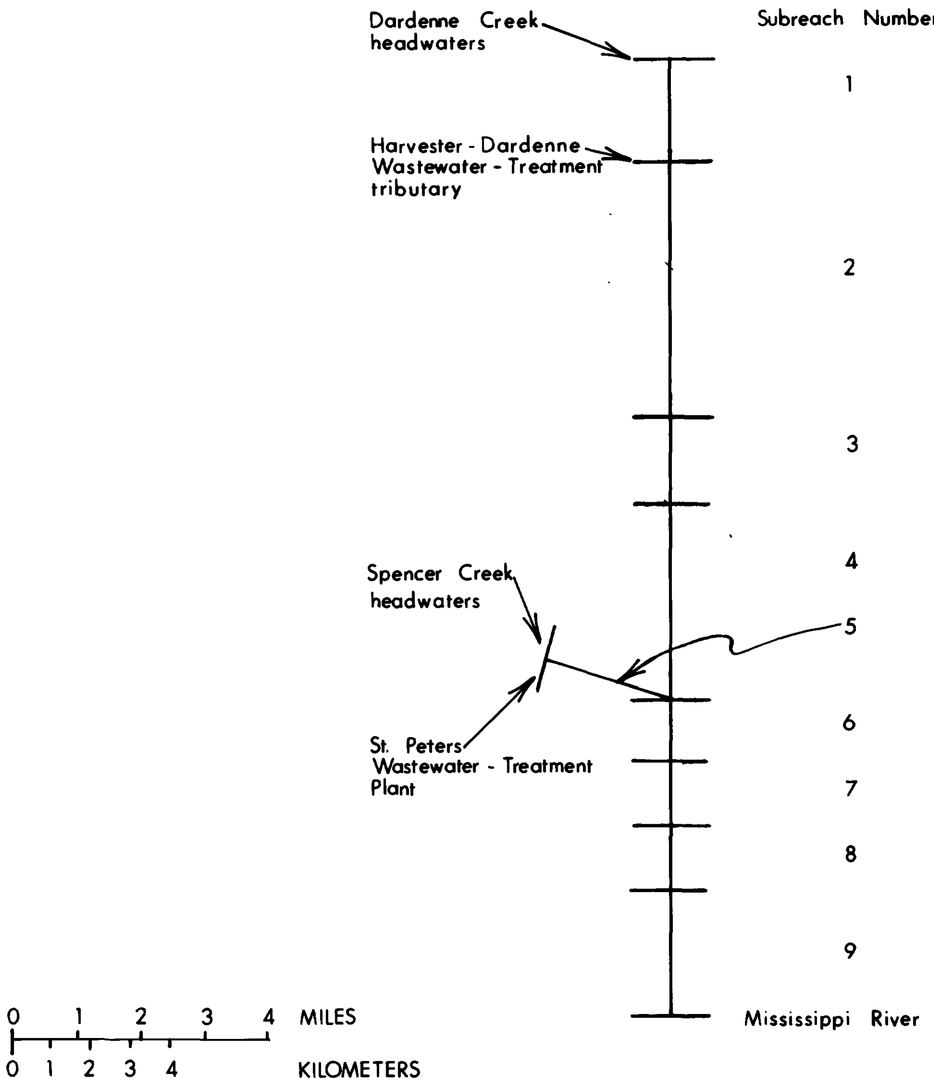

Figure 2.--Model input locations and subreaches on Dardenne and Spencer Creeks.

Table 2.--Hydraulic data used in model calibration and verification

Model subreach (fig. 2)	River mile at upstream end of subreach[1]	Channel side slope (run/rise), in foot per foot	Bottom width of channel, in feet	Average channel slope, in foot per foot	Manning's roughness coefficient (n)
1	15.0	2.0	15.0	0.000806	0.23
2	13.4	2.0	15.0	.000806	.23
3	9.4	2.0	15.0	.000806	.23
4	8.0	1.0	25.0	.000252	.17
5	2.0	1.0	6.0	.001000	.09
6	5.0	1.0	25.0	.000252	.17
7	4.0	1.0	25.0	.000252	.17
8	3.0	1.0	25.0	.000252	.17
9	2.0	1.0	25.0	.000252	.17

[1]River miles upstream from the Mississippi River, except for subreach 5 which is river miles upstream from Dardenne Creek.

Water-quality data are entered into the headwater and point-source elements of the model and routed downstream where they are affected by the hydraulic conditions and the reaction rates of the stream. The data that were entered at these elements were discharge, water temperature, dissolved oxygen, 5-day carbonaceous biochemical-oxygen demand, chlorophyll "a", ammonia as N, and nitrate as N (table 3).

Calibration Results

The process of calibrating the QUAL-II model involves determining the reaction-rate constants, which are 5-day carbonaceous biochemical-oxygen demand ($CBOD_5$) decay rates, reaeration coefficients, chlorophyll "a"-to-algae ratios, algae settling rates, rate coefficients for ammonia oxidation, streambed-oxygen demands, and light-extinction coefficients for each subreach (table 4). The data used in determining these rates were collected during 48 hours from August 1 to 3, 1983.

The carbonaceous biochemical-oxygen demand decay rates were determined by plotting the carbonaceous biochemical-oxygen demand against time on natural-log paper (U.S. Environmental Protection Agency, 1981). The slope of the resulting curve is the decay rate. The data indicate that the decay rate at all locations in the stream were approximately the same, so the decay rate of 0.4 per day was used for all subreaches (see table 4).

Reaeration coefficients were determined using the modified tracer techniques developed by Rathbun and others (1975), at sampling sites QW4 through QW7 on Dardenne Creek, and T3 and T4 on Spencer Creek (see fig. 1). Results of various reaeration predictive equations were compared to the measured values to determine if an equation could be used to compute reaeration in Dardenne Creek, but none of the predictive equations were adequate to portray conditions in Dardenne Creek. However, because the channel geometry of the creek was relatively constant, reaeration coefficients for the unmeasured reaches were estimated from the measured reaches. The reaeration coefficients used for each subreach are listed in table 4.

The chlorophyll "a"-to-algae ratio, the algae settling rate, and the light-extinction coefficient were initially calculated using procedures outlined in the QUAL-II user's manual (Roesner and others, 1981). A ratio of 60.0 was used for the chlorophyll "a"-to-algae ratio, and the rate of 0.2 foot per day was used for algae settling for all subreaches. The light-extinction coefficient varied for the subreaches (see table 4).

The rate coefficients for ammonia oxidation were determined using average velocity measured throughout the study area. The average velocity was used to determine the time interval between sampling locations. The measured ammonia concentrations were plotted against this time interval on natural-log paper (U.S. Environmental Protection Agency, 1981). The slopes of the resulting curves were the corresponding oxidation rates. The data indicated that the oxidation rates for ammonia remained relatively constant at all locations in the stream. A rate coefficient of 0.4 per day was determined after model calibration for ammonia for all subreaches (see table 4).

Table 3.--Water-quality inputs at the headwater and point-source locations that were used in model calibration and verification

[CAL, calibration; VER, verification]

Model input location (fig. 2)	Model run	Discharge, in cubic feet per second	Water temperature, in degrees Celsius	Dissolved oxygen, in milligrams per liter	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Chlorophyll "a", in micrograms per liter	Total ammonia as N, in milli-grams per liter	Total nitrate as N, in milli-grams per liter
Dardenne Creek headwaters	CAL	3.2	25.0	7.0	2.0	8.0	0.2	0.6
	VER	1.9	19.0	7.0	2.0	5.0	.1	1.2
Harvester-Dardenne Wastewater-Treatment Plant tributary	CAL	3.2	25.0	.5	16.0	32.0	13.5	.4
	VER	3.2	19.0	.5	15.0	32.0	12.5	.4
Spencer Creek headwaters	CAL	.7	25.0	8.0	1.0	12.0	.1	.6
	VER	.5	19.0	8.0	1.0	12.0	.1	.8
St. Peters Wastewater-Treatment Plant	CAL	3.3	25.0	3.0	18.0	9.0	20.0	.4
	VER	3.6	19.0	3.0	17.5	9.0	1.6	5.6

Table 4.--Reaction-rate constants determined in model calibration

[all rates expressed at 20° Celsius, in units of $days^{-1}$]

Model subreach (fig. 2)	River mile at upstream end of subreach[1]	Carbonaceous biochemical-oxygen demand (5-day) decay rate in base e	Reaeration coefficient in base	Chlorophyll "a" to algae ratio, in micrograms to milligrams	Algae settling rate, in feet	Rate coefficient for ammonia oxidation, in base e	Streambed-oxygen demand, in milligrams per foot	Light extinction coefficient, in per foot
1	15.0	0.4	3.0	60.0	0.2	0.4	1,500	2.50
2	13.4	.4	3.0	60.0	.2	.4	3,000	2.50
3	9.4	.4	3.0	60.0	.2	.4	2,500	2.50
4	8.0	.4	2.5	60.0	.2	.4	2,000	.30
5	2.0	.4	6.0	60.0	.2	.4	700	.25
6	5.0	.4	2.0	60.0	.2	.4	2,500	.20
7	4.0	.4	2.0	60.0	.2	.4	2,500	.15
8	3.0	.4	2.0	60.0	.2	.4	2,000	.10
9	2.0	.4	2.0	60.0	.2	.4	2,000	.05

[1]River miles upstream from the Mississippi River, except subreach 5 which is river miles upstream from Dardenne Creek.

A streambed sample was collected at each sampling site and analyzed in the laboratory for streambed-oxygen demand using procedures described by Terry and others (1983), and Nolan and Johnson (1979). These values are given in the "Supplemental Data" section at the end of this report. Estimates of the streambed-oxygen demand in each subreach (see table 4) were made using these data.

Obtaining a good calibration of ammonia and nitrate is important because: (1) The oxidation of ammonia can be a significant part of the consumed oxygen in a stream, especially if there are large ammonia concentrations being discharged to the stream; and (2) ammonia is one of the constituents regulated by the Missouri water-quality standards. Comparisons of the calculated and measured total ammonia as N and total nitrate as N concentrations are shown in figures 3 and 4. The model adequately simulated the total ammonia as N and total nitrate as N concentration.

Model calibration was completed for measured concentrations of dissolved oxygen and CBOD, However, at sites QW5, QW6, and QW7 (fig. 1), the model did not adequately simulate the measured dissolved-oxygen concentrations and CBOD (figs. 5 and 6). For the data collection in August, water-quality samples were obtained from one point on the creek at each site. Depth-integrated samples from several locations in the creek cross section would have given more representative values and possibly avoided problems in model calibration.

The simulated and measured $CBOD_5$ concentrations did not adequately compare (fig. 5), possibly because of algae effects (Bingham and others, 1983). The calibration results are as close as the $CBOD_5$ data could be simulated, and the more representative sampling for verification indicated that the $CBOD_5$ rates were acceptable.

If the calibration of total ammonia as N, total nitrate as N, and $CBOD_5$ were accurate, then the model should approximate the observed dissolved-oxygen profile. An adequate comparison of dissolved oxygen occurs from QW1 to QW4 (fig. 6), but inadequate comparisons occurred at QW5, QW6, and QW7 in a pattern similar to ammonia as N, total nitrate as N, and $CBOD_5$.

Verification Results

Before a model can be used to simulate water-quality conditions with various streamflow and wasteload conditions it should be verified with an independent data set. If there is an acceptable match between the model-computed concentrations and the measured concentrations, then the model can be used to predict future conditions.

The data used to verify the model were collected during the 48-hour period from September 26 to 28, 1983. The discharge and temperature in Dardenne Creek, and the total ammonia as N concentration in the effluent from the St. Peters Wastewater-Treatment Plant changed between August and September sampling periods (see table 3).

Comparisons between computed and measured total ammonia as N and total nitrate as N concentrations for the verification run are shown in figures 7 and 8. The total ammonia as N concentration discharged into Spencer Creek was much smaller during the verification run (1.6 milligrams per liter) than during the

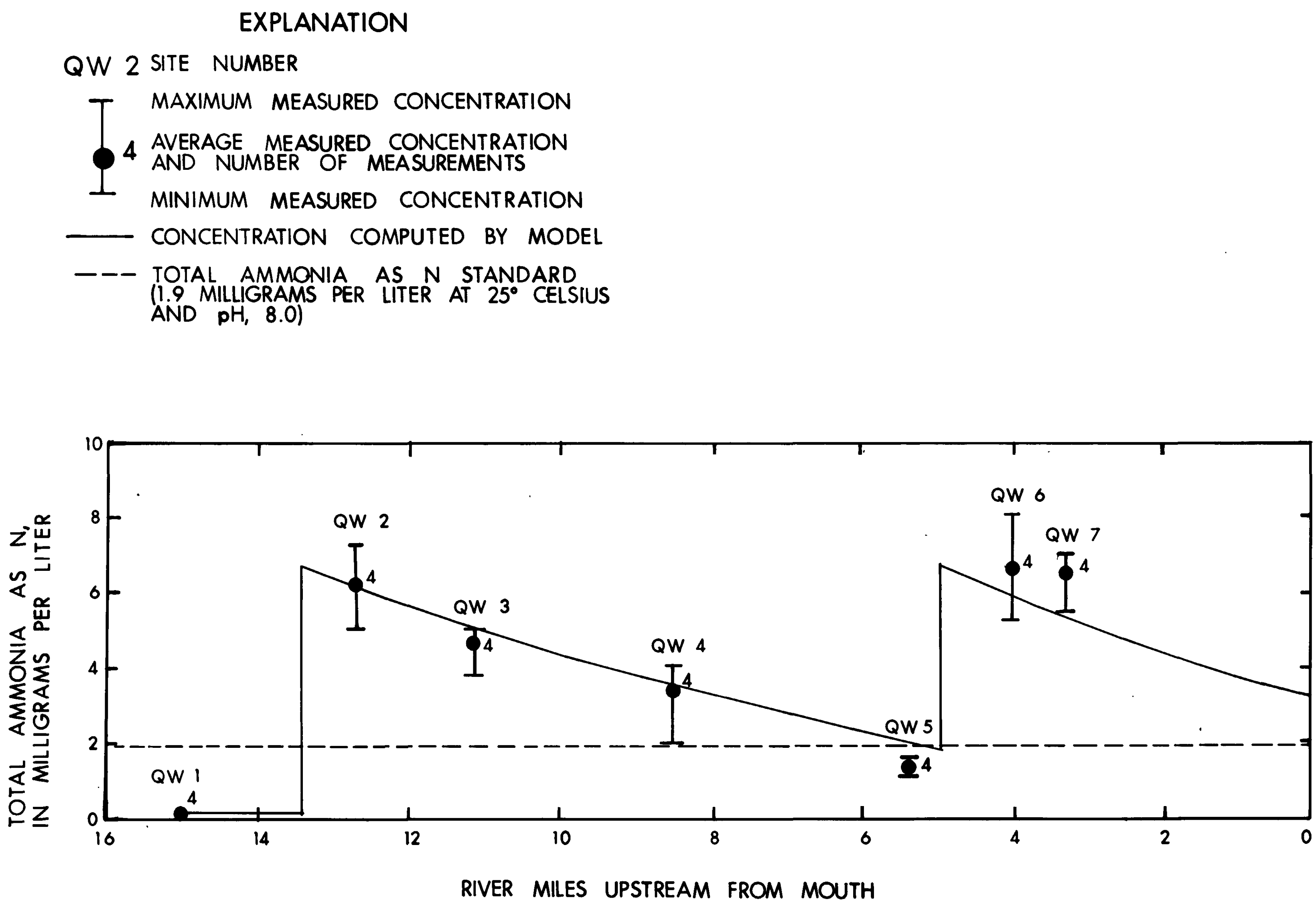

Figure 3.--Computed and measured concentrations of total ammonia as N, Dardenne Creek, August 1983 (calibration).

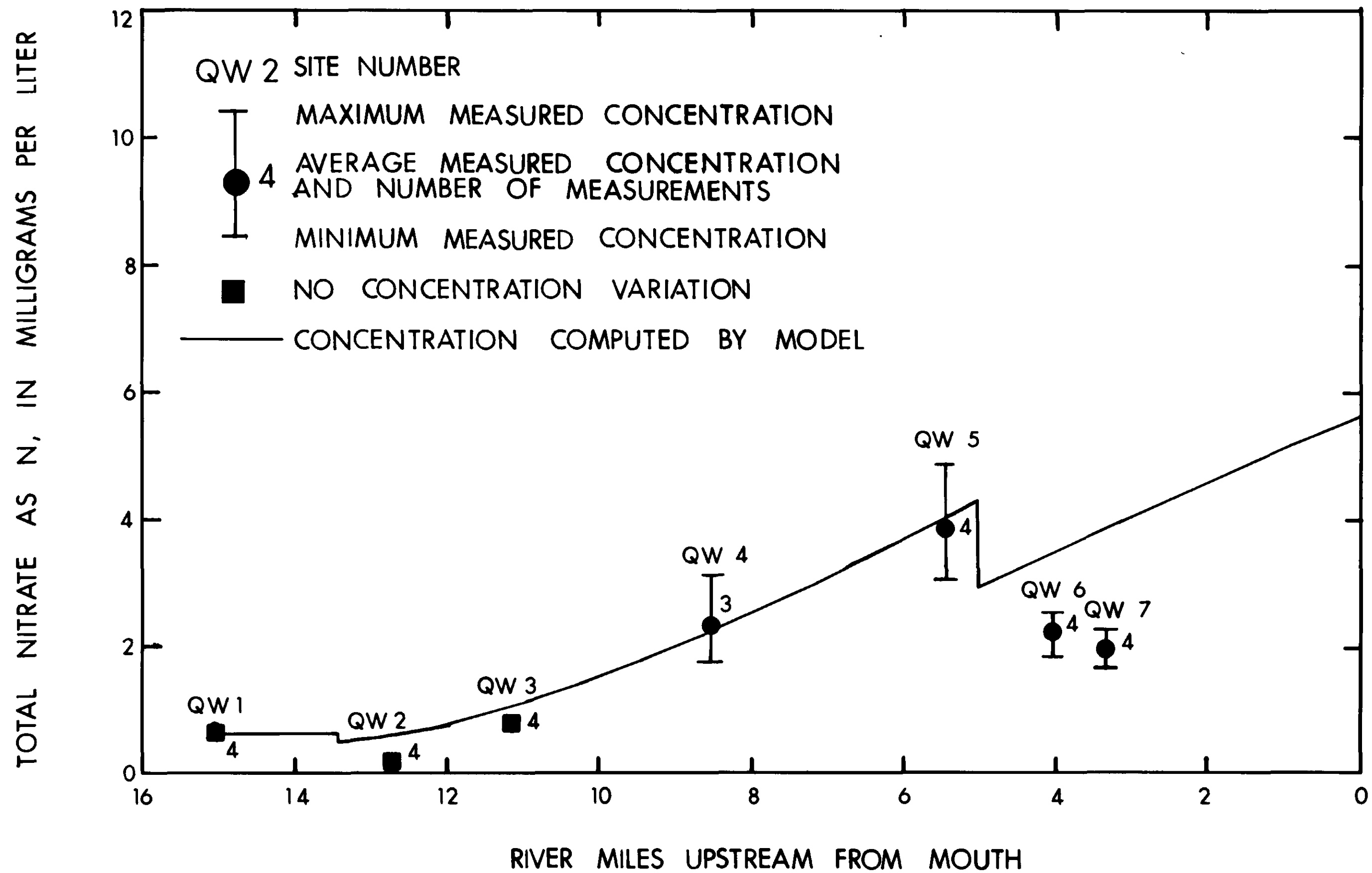

Figure 4.--Computed and measured concentrations of total nitrate as N, Dardenne Creek, August 1983 (calibration).

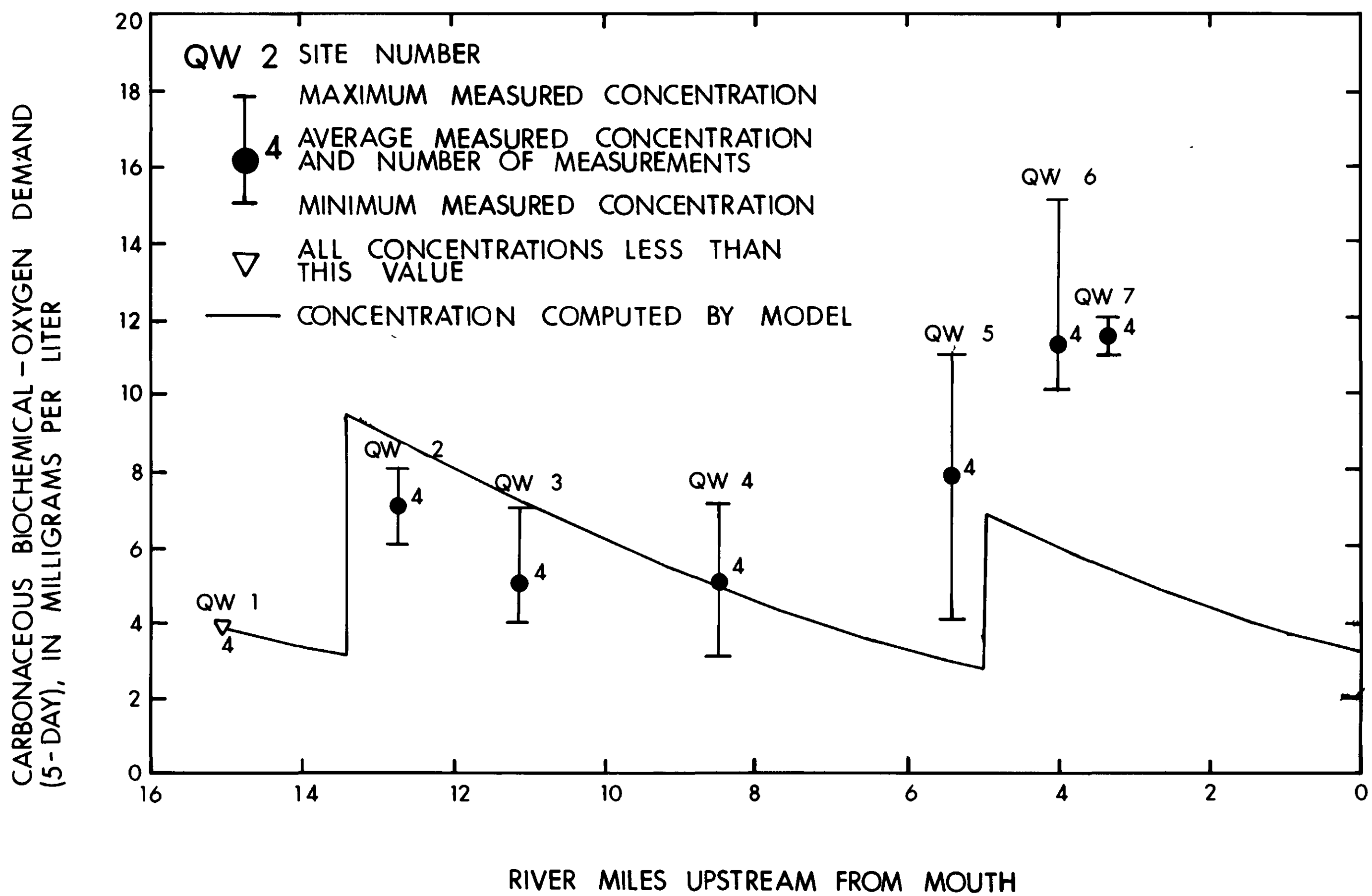

Figure 5.--Computed and measured concentrations of 5-day carbonaceous biochemical-oxygen demand, Dardenne Creek, August 1983 (calibration).

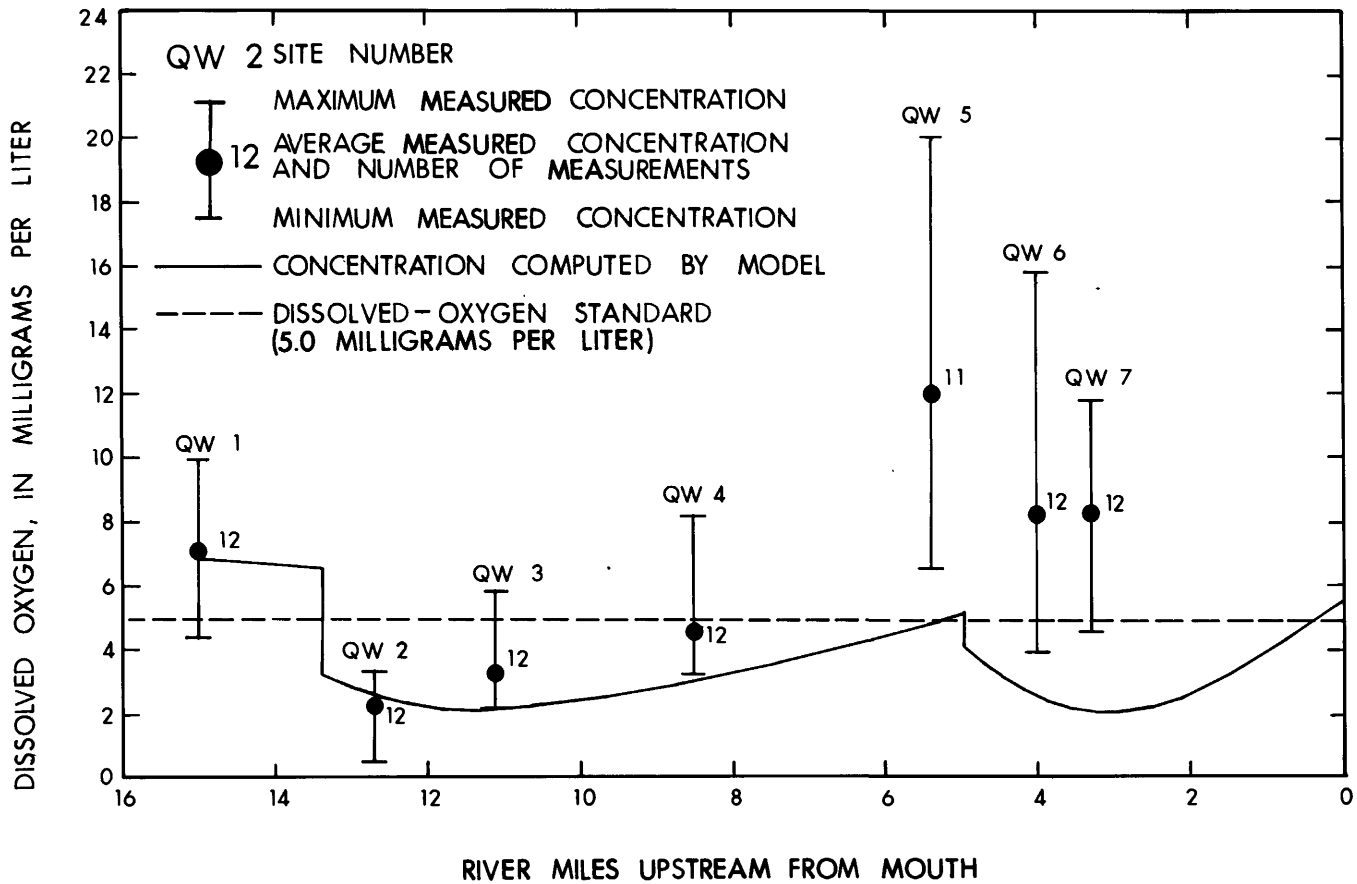

Figure 6.--Computed and measured concentrations of dissolved oxygen, Dardenne Creek, August 1983 (calibration).

calibration run (20.0 milligrams per liter). Simulated concentrations compare closely to measured concentrations for total ammonia as N, but the comparison was not as good for total nitrate as N concentrations. Modeling the nitrogen cycle is complex and some of the chemical reactions do not take place in the same way as they are presented in a mathematical model.

Computed and measured CBOD concentrations compared closely (fig. 9), especially downstream from QW5. Good samples were obtained and algae did not significantly affect the sample as it did for the calibration data.

The dissolved-oxygen verification is the ultimate verification test, because virtually all the constituents simulated by the model affect the dissolved-oxygen concentration. A good match occurred between the model-computed and measured data, indicating that the model calibration was good (fig. 10).

WASTEWATER-MANAGEMENT ALTERNATIVES

The final objective of this study was to determine the necessary level of wastewater treatment before discharge to Dardenne Creek. The management alternatives considered were secondary treatment and advanced treatment. The alternatives were evaluated by simulating water quality resulting from each type of treatment. The elimination of the Harvester-Dardenne Wastewater-Treatment Plant also was evaluated.

In evaluating the type of treatment necessary to meet the standards in Dardenne Creek, it was necessary to simulate the worst quality-of-water conditions that were expected to occur during low-flow periods. Normally, the 7-day Q_{10} is considered an acceptable low-flow condition for simulation purposes. According to Skelton (1976), the 7-day Q_{10} for streams in the Dardenne Creek area with drainage areas less than 250 square miles will almost always be 0.0 cubic foot per second. The drainage area of Dardenne Creek at QW1 is 72.1 square miles, so the 7-day Q_{10} should be 0.0 cubic foot per second. It is desirable to have some flow when running the model; therefore, a flow of 0.1 cubic foot per second was used as input to Dardenne Creek headwaters.

In the "201" facilities plan (Sverdrup and Parcel and Assoc., 1984), estimates of future expansions of the St. Peters Wastewater-Treatment Plant were made that will meet the needs of the area by 2000. A plant discharge of 5.4 cubic feet per second was estimated. For this study, the plant was evaluated using the existing average discharge of 3.3 cubic feet per second, the design-capacity discharge of 4.5 cubic feet per second, and the anticipated future expansion discharge of 5.4 cubic feet per second.

Secondary Treatment

For this study, secondary treatment is defined as producing a 5-day CBOD concentration of 30.0 milligrams per liter and a total ammonia as N concentration of 20.0 milligrams per liter. The simulated ammonia as N concentration resulting from a wastewater discharge of 3.3 cubic feet per second is shown in figure 11. There would be a violation of the ammonia standard on Dardenne Creek downstream from Spencer Creek for all discharges greater than 3.3 cubic feet per second from the St. Peters Wastewater-Treatment Plant. The simulated dissolved-oxygen concentration resulting from a wastewater discharge of 3.3 cubic feet per second is shown in figure 12. The dissolved-oxygen concentration in Dardenne Creek would be completely depleted downstream from Spencer Creek for all discharges greater than 3.3 cubic feet per second from the St. Peters Wastewater-Treatment Plant.

Advanced Treatment

For this study, advanced treatment consists of a nitrification process that produces a 5-day CBOD concentration of 10.0 milligrams per liter or less and a total ammonia as N concentration of 2.0 milligrams per liter or less.

The simulated ammonia as N concentration resulting from a wastewater discharge of 5.4 cubic feet per second is shown in figure 13. The simulation indicates that nitrification would decrease the ammonia as N concentration in the wastewater discharges from the St. Peters Wastewater-Treatment Plant for effluent discharges less than the anticipated future expansion discharge of 5.4 cubic feet per second.

The simulated dissolved-oxygen concentration resulting from a wastewater discharge of 3.3 and 5.4 cubic feet per second is shown in figure 14. The smallest predicted dissolved-oxygen concentration is 4.3 milligrams per liter resulting from a wastewater discharge of 5.4 cubic feet per second. This value is slightly less than the dissolved-oxygen standard of 5.0 milligrams per liter. Further analysis indicated that decreasing the CBOD concentration to 5.0 milligrams per liter for a wastewater discharge of 5.4 cubic feet per second would result in dissolved-oxygen concentrations in Dardenne Creek greater than 5.0 milligrams per liter. To achieve this, an addition to the nitrification process, such as sand filtration, is needed.

SUMMARY AND CONCLUSIONS

Chemical, physical, and biological data were collected in the 15-mile downstream reach of Dardenne Creek from August 1 to 3, 1983, and were used to characterize the water-quality conditions in the creek. Downstream from the Harvester-Dardenne and St. Peters Wastewater-Treatment Plants dissolved-oxygen and total ammonia as N concentrations in Dardenne Creek did not meet the Missouri water-quality standards of 5.0 milligrams per liter and 1.9 milligrams per liter (at 25 °C and pH, 8.0).

The Qual-II/SEMCOG model was selected to simulate dissolved-oxygen and total ammonia concentrations in Dardenne Creek so that different management objectives could be evaluated at the St. Peters Wastewater-Treatment Plant. The model was calibrated using data collected during August 1-3, 1983. The model was then verified using data collected during September 26-28, 1983. The calibrated model was run using the current wastewater discharge of 3.3 cubic feet per second, the design-capacity wastewater discharge of 4.5 cubic feet per second, and the anticipated future expansion wastewater discharge of 5.4 cubic feet per second from the St. Peters Wastewater-Treatment Plant. The management alternatives of secondary treatment and advanced treatment were evaluated at each wastewater discharge. The St. Peters Wastewater-Treatment Plant needs a nitrification-type advanced-treatment facility that would produce a CBOD concentration of 10 milligrams per liter and a total ammonia as N concentration of 2.0 milligrams per liter to meet the dissolved-oxygen and ammonia standards for wastewater discharges less than the anticipated future expansion discharge of 5.4 cubic feet per second. Decreasing the CBOD concentrations discharged from the plant to 5.0 milligrams per liter would result in dissolved-oxygen concentrations in Dardenne Creek greater than 5.0 milligrams per liter. This would require an addition to the nitrification process, such as sand filtration.

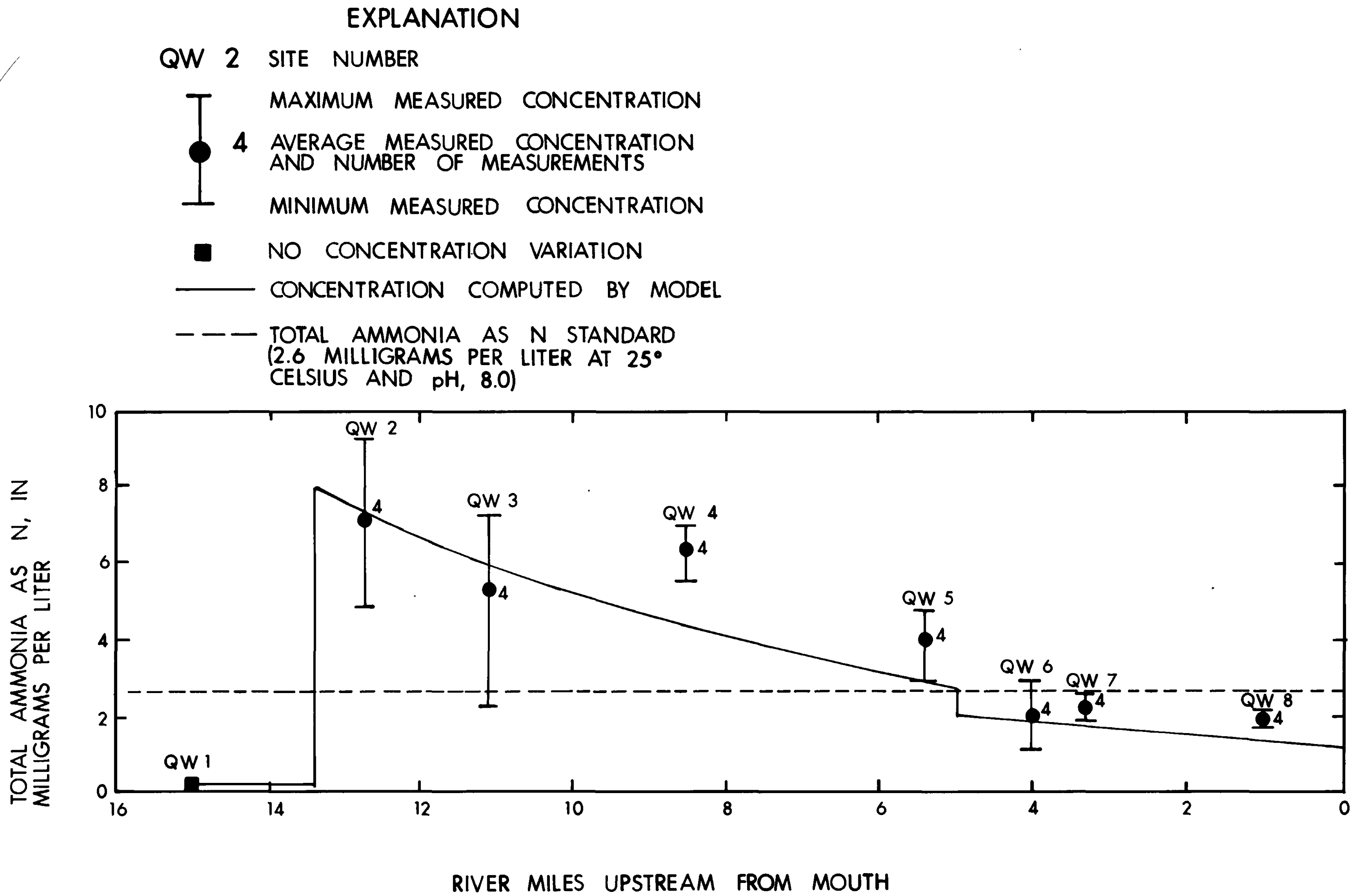

Figure 7.--Computed and measured concentrations of total ammonia as N, Dardenne Creek, September 1983 (verification).

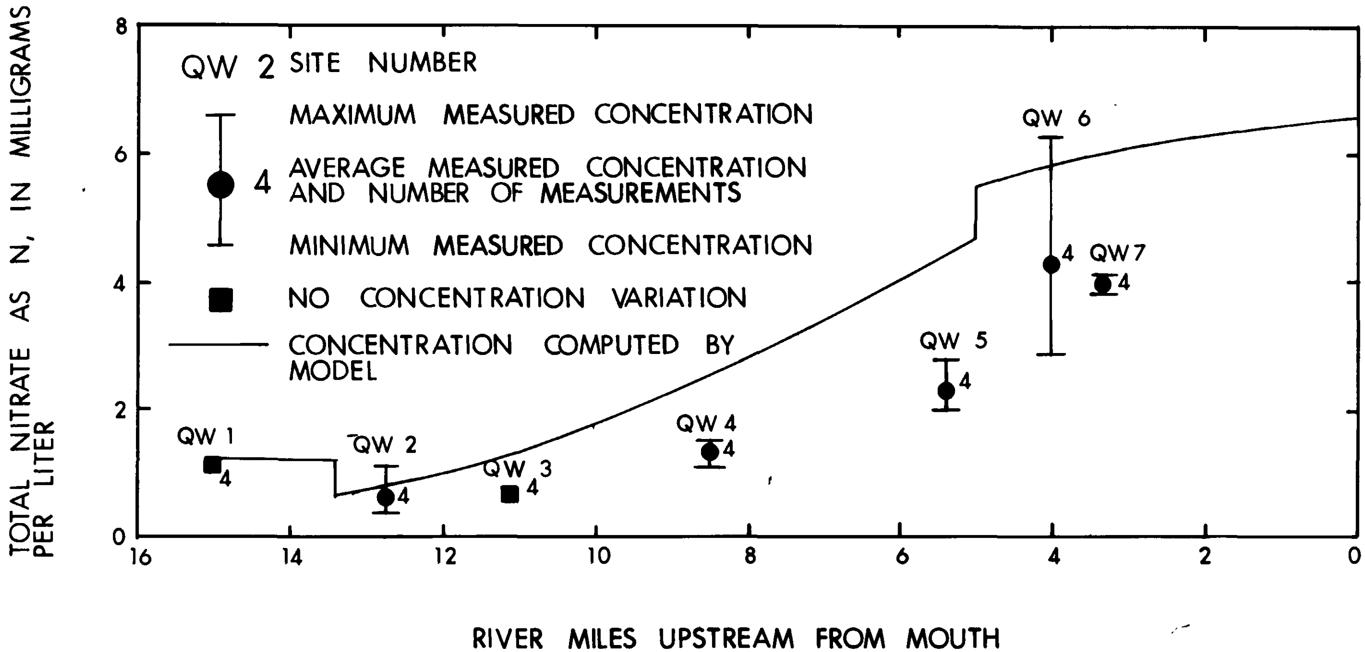

Figure 8.--Computed and measured concentrations of total nitrate as N, in Dardenne Creek, September 1983 (verification).

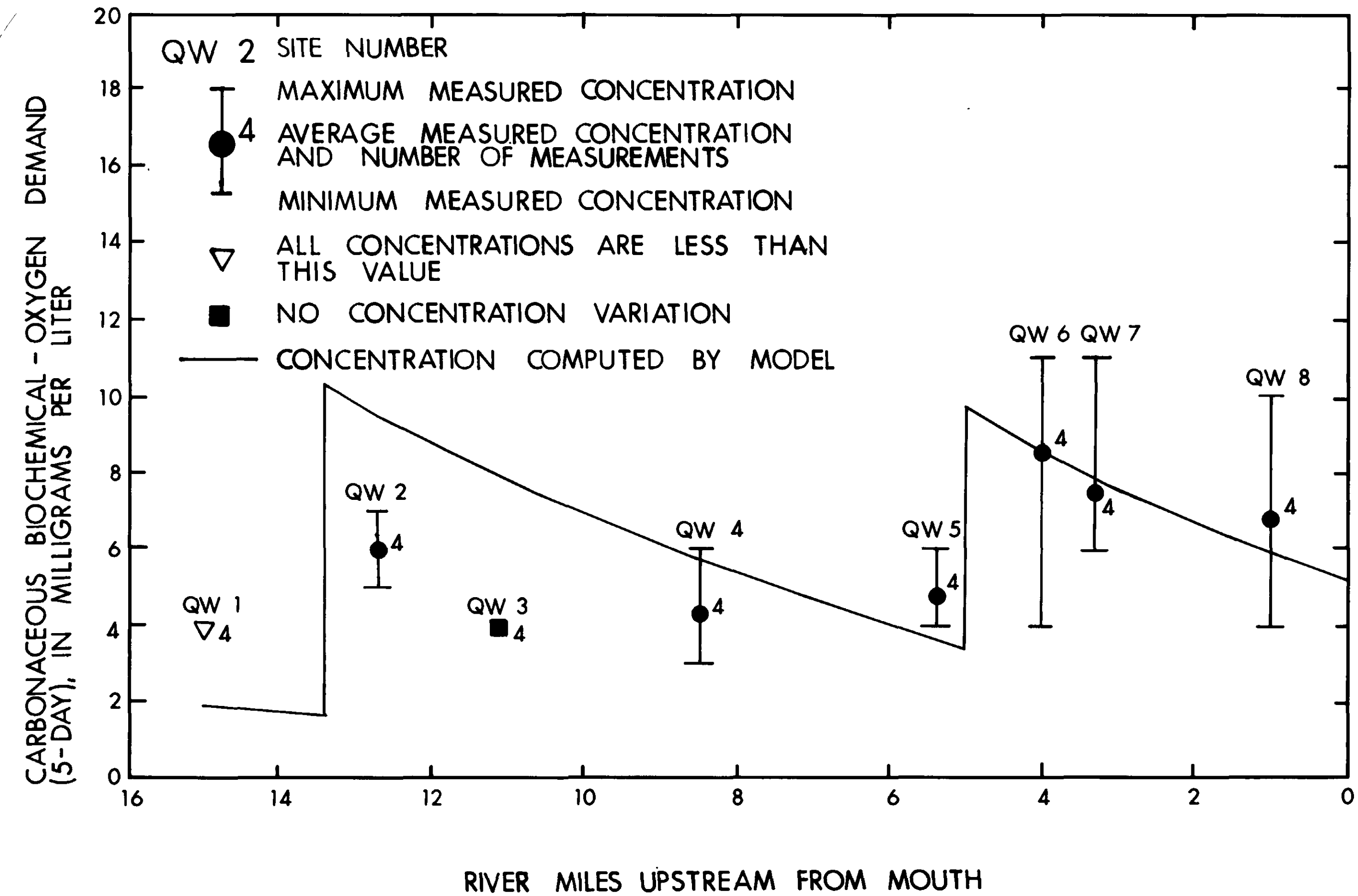

Figure 9.--Computed and measured concentrations of 5-day carbonaceous biochemical-oxygen demand, Dardenne Creek, September 1983 (verification).

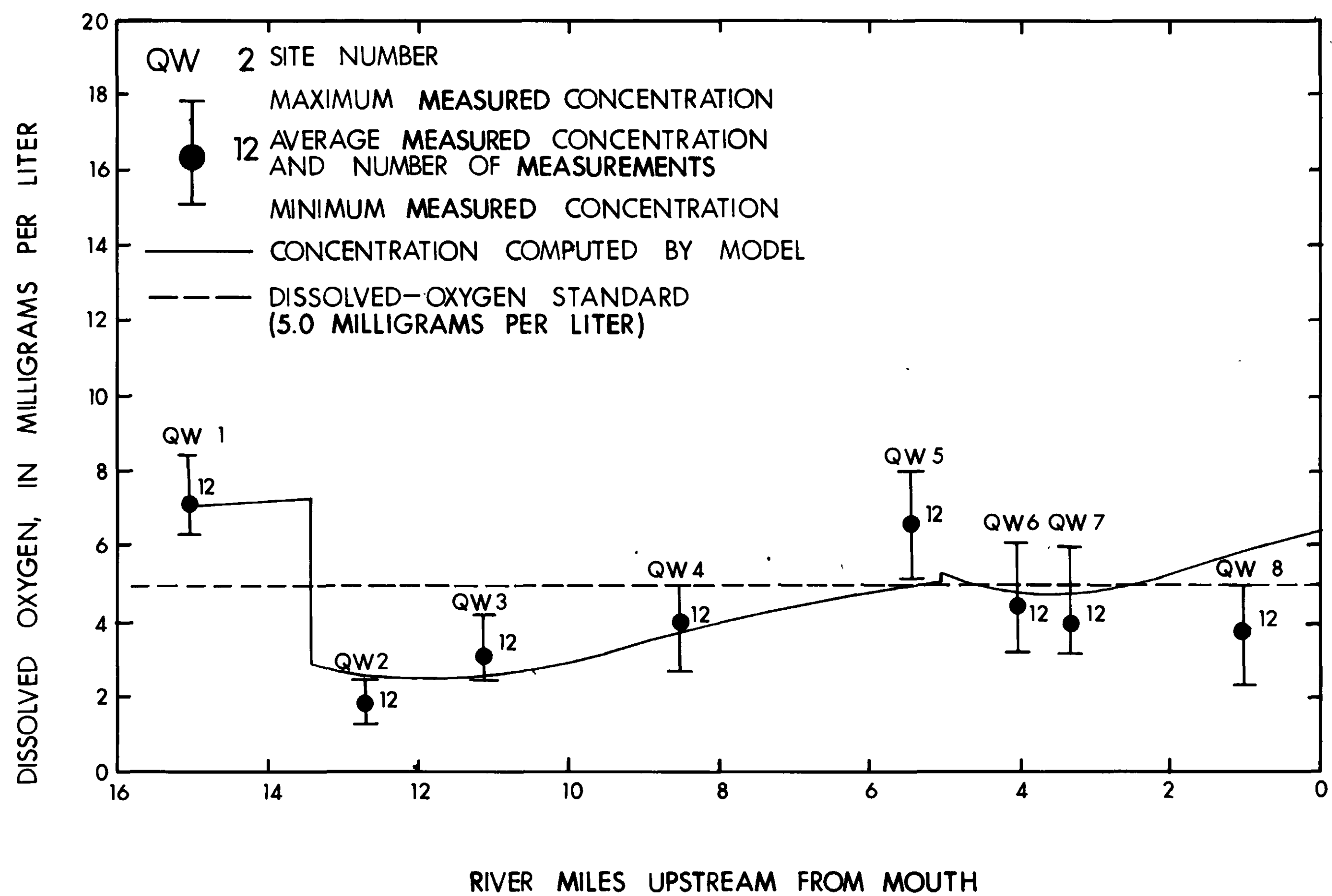

Figure 10.--Computed and measured dissolved-oxygen concentrations, Dardenne Creek, September 1983 (verification).

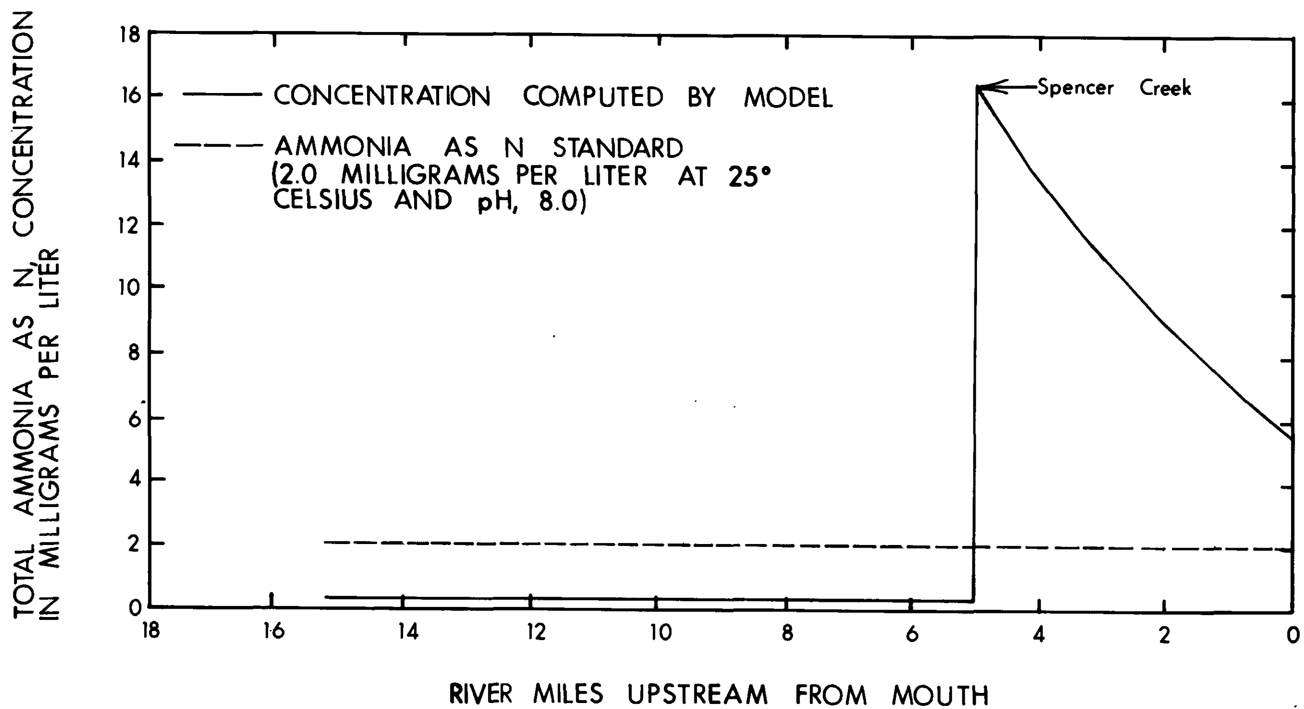

Figure 11.--Results of simulations of total ammonia as N concentrations in Dardenne Creek, with a discharge of 3.3 cubic feet per second of secondary treatment effluent at the St. Peters Wastewater - Treatment Plant.

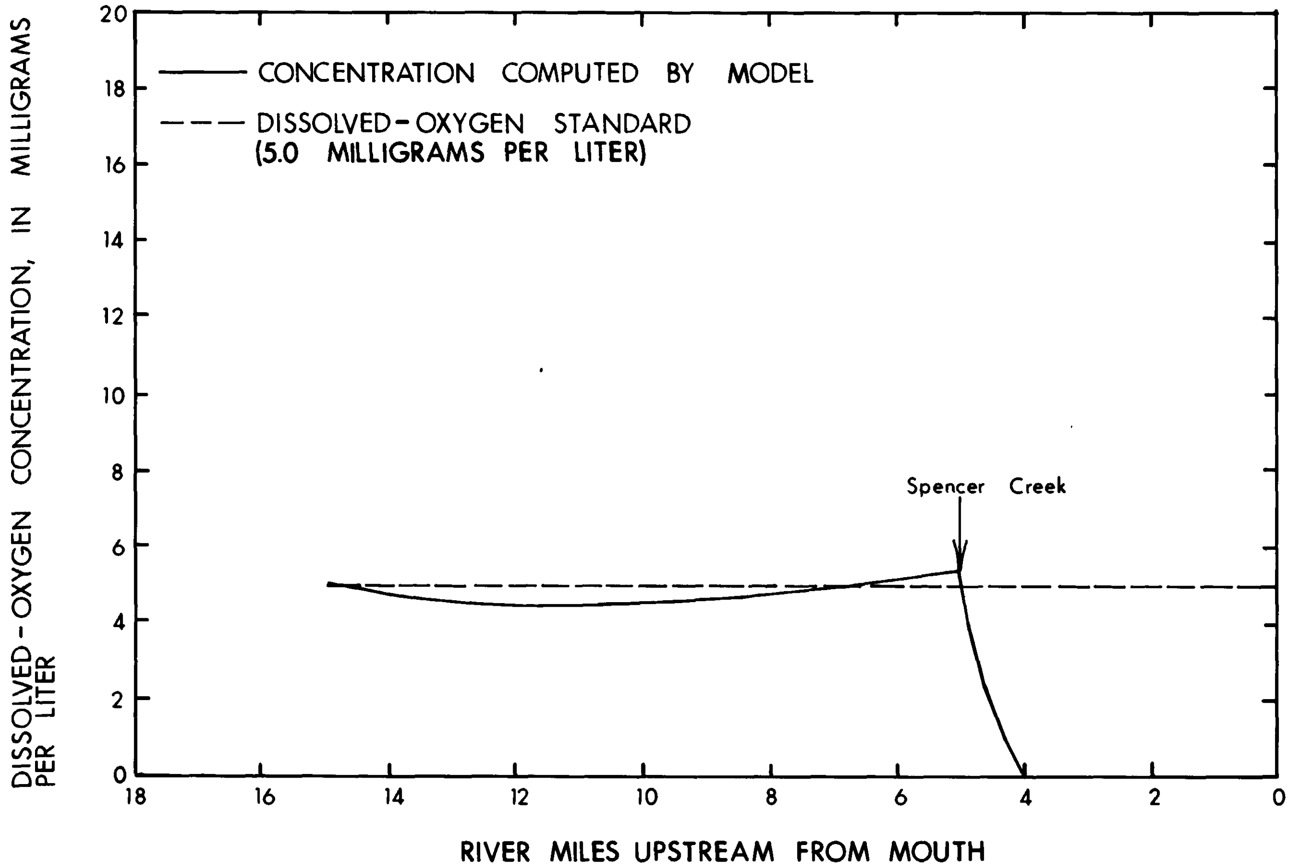

Figure 12.--Results of simulations of dissolved-oxygen concentrations in Dardenne Creek, with a discharge of 3.3 cubic feet per second of secondary treatment effluent at the St. Peters Wastewater-Treatment Plant.

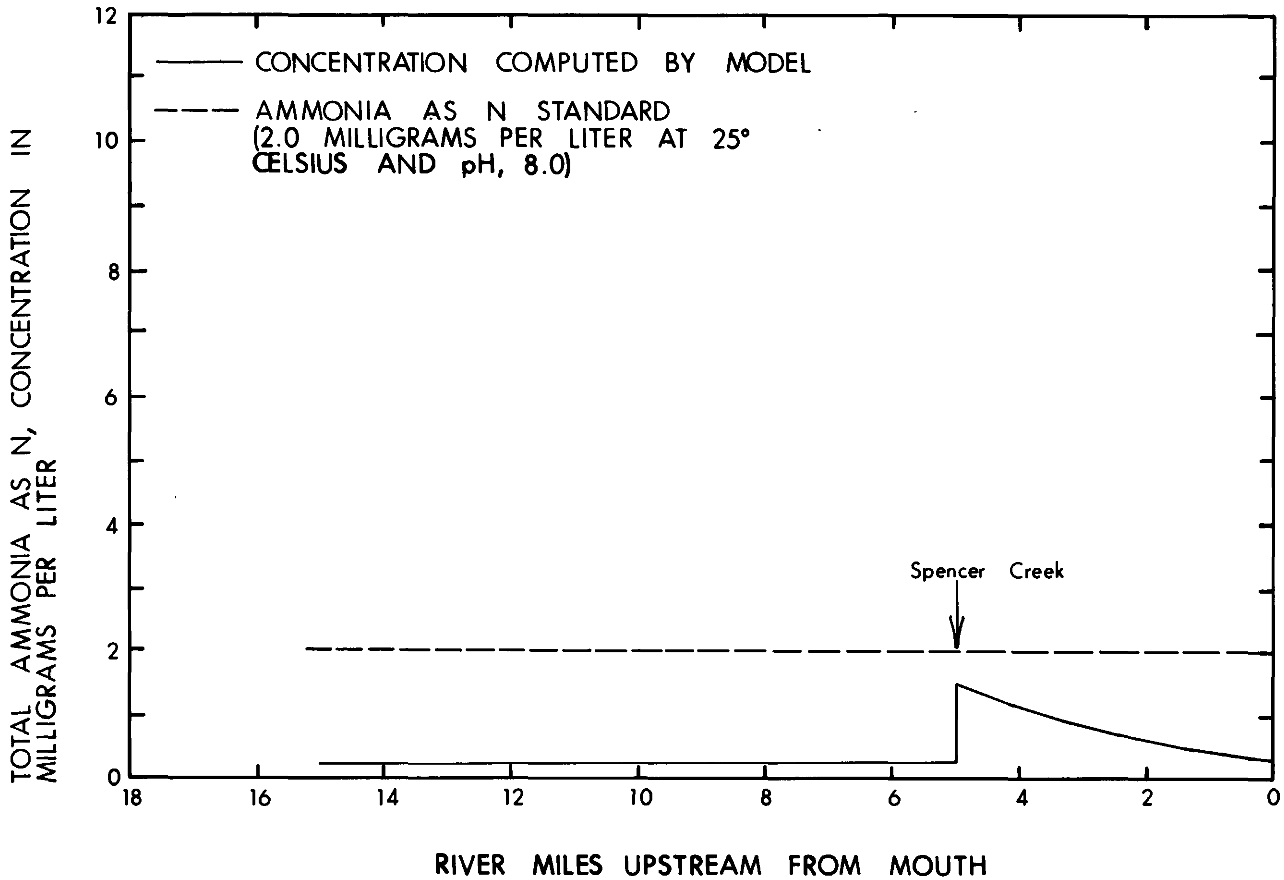

Figure 13.--Results of simulations of total ammonia as N concentrations in Dardenne Creek, with a discharge of 5.4 cubic feet per second of advanced treatment (nitrification) effluent at the St. Peters Wastewater-Treatment Plant.

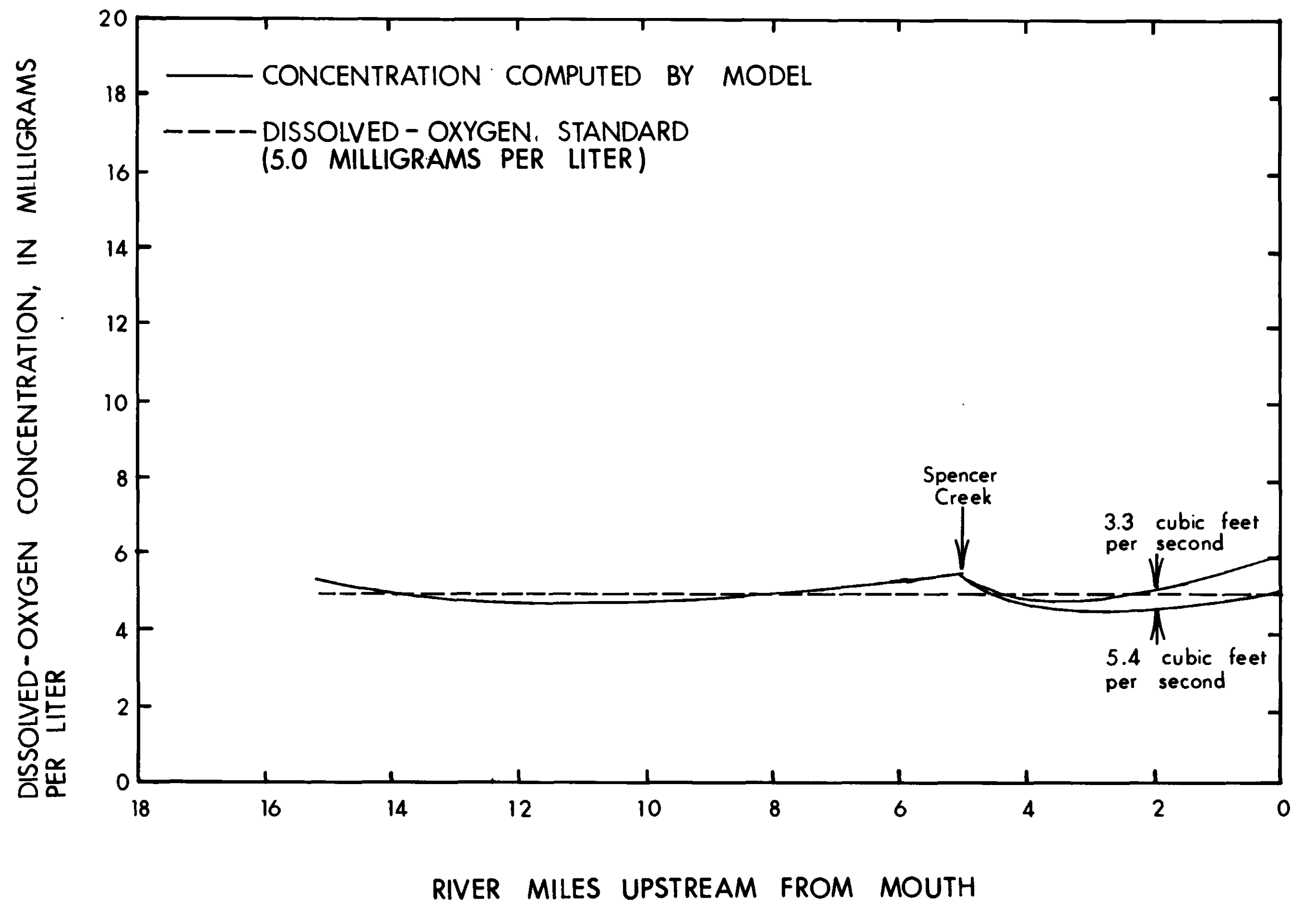

Figure 14.--Results of simulations of dissolved-oxygen concentrations in Dardenne Creek, with a discharge of 3.3 and 5.4 cubic feet per second of advanced treatment (nitrification) effluent at the St. Peters Wastewater-Treatment Plant.

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SUPPLEMENTAL DATA

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983

[--, missing data]

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
QW1	August 1	1800	9.1	8.2	29.0	380
		2200	6.1	7.8	27.0	410
	2	0200	5.4	7.8	25.0	420
		0600	4.4	7.6	24.0	415
		1000	6.7	7.9	25.0	400
		1400	10.0	8.3	28.0	380
		1800	9.8	8.2	29.0	390
		2200	6.3	7.9	28.0	390
	3	0200	5.8	7.6	27.0	390
		0600	5.5	7.9	25.0	400
		1000	6.5	8.0	26.0	395
		1400	9.4	8.0	27.5	395
	September 26	1800	8.0	7.9	18.0	425
		2200	7.1	8.0	17.0	450
	27	0200	6.6	7.3	17.0	440
		0600	6.5	7.6	16.0	450
		1000	6.9	7.9	16.0	445
		1400	8.4	7.7	17.5	450
		1800	8.1	7.8	25.0	445
		2200	6.8	8.0	21.0	430
	28	0200	6.3	8.2	19.0	445
		0600	5.9	7.8	17.0	445
		1000	6.6	7.8	18.0	445
		1400	8.4	7.9	19.5	450
T2	August 1	1800	.3	7.4	25.0	775
		2200	.4	7.3	23.0	750
	2	0200	.4	7.5	24.0	710
		0600	.4	7.6	21.5	730
		1000	1.2	7.5	24.0	780
		1400	.4	7.5	25.5	780
		1800	.3	7.3	25.0	790
		2200	.3	7.2	24.0	765
	3	0200	.3	7.5	24.0	750
		0600	.2	7.6	23.0	730
		1000	.4	7.5	24.0	750
		1400	.3	7.5	24.5	830

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
T2	September 26	1800	0.4	7.8	22.0	800
		2200	.3	7.5	21.0	800
	27	0200	.3	7.3	20.0	755
		0600	.4	7.5	18.0	695
		1000	.7	7.6	21.5	800
		1400	.5	7.2	23.5	850
		1800	.2	7.4	25.0	550
		2200	.5	7.4	22.5	780
	28	0200	.5	7.6	21.0	800
		0600	.1	7.5	20.0	740
		1000	.5	7.6	22.5	810
		1400	.4	7.5	23.0	865
QW2	August 1	1800	2.7	7.4	26.0	525
		2200	3.0	7.5	26.0	540
	2	0200	2.0	7.6	26.0	525
		0600	1.1	7.8	23.5	560
		1000	1.8	7.6	24.5	595
		1400	3.3	7.7	26.0	490
		1800	2.6	7.4	27.0	550
		2200	3.0	7.6	27.0	575
	3	0200	1.8	7.7	26.0	585
		0600	.5	7.6	25.0	575
		1000	1.9	7.6	25.5	570
		1400	2.3	7.6	25.5	520
	September 26	1800	2.4	8.6	18.0	555
		2200	2.2	7.6	19.0	600
	27	0200	2.5	7.3	18.0	590
		0600	1.6	7.5	17.0	620
		1000	1.9	7.7	18.0	575
		1400	2.2	7.3	19.0	630
		1800	1.7	7.4	22.0	550
		2200	1.5	7.5	20.5	615
	28	0200	1.3	7.6	20.0	550
		0600	1.3	7.6	19.0	630
		1000	1.6	7.7	20.0	650
		1400	1.9	7.6	20.0	520

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
QW3	August 1	1800	3.4	7.5	26.0	550
		2200	2.8	7.3	25.0	560
	2	0200	2.5	7.6	24.0	550
		0600	2.1	7.7	23.0	555
		1000	2.5	7.6	24.0	560
		1400	5.8	7.7	27.0	540
		1800	3.9	7.5	27.0	530
		2200	3.1	7.6	25.0	480
	3	0200	2.9	7.2	25.0	560
		0600	2.1	7.6	24.0	500
		1000	2.8	7.6	24.5	545
		1400	5.1	7.7	26.0	550
	September 26	1800	2.7	8.4	18.0	640
		2200	2.6	7.3	17.0	610
	27	0200	4.2	7.3	16.0	605
		0600	2.5	7.3	16.5	580
		1000	3.4	7.3	16.5	580
		1400	3.6	7.3	19.0	575
		1800	3.1	7.4	22.0	560
		2200	3.0	7.4	19.0	600
	28	0200	2.9	7.7	19.0	520
		0600	2.9	7.6	18.0	645
		1000	3.1	7.8	18.0	620
		1400	3.4	7.6	20.0	500
QW4	August 1	1800	4.7	7.5	27.0	590
		2200	3.9	7.6	27.0	575
	2	0200	3.4	7.8	26.0	550
		0600	3.3	7.6	24.5	560
		1000	4.8	7.7	26.5	550
		1400	8.1	7.9	28.5	545
		1800	5.3	7.6	28.0	530
		2200	4.0	7.6	28.0	550
	3	0200	3.5	8.0	27.0	570
		0600	3.2	7.6	25.0	590
		1000	4.6	7.7	26.5	575
		1400	5.4	7.7	26.5	575

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
QW4	September 26	1800	4.7	8.6	17.0	620
		2200	4.3	8.8	16.0	625
	27	0200	2.7	7.3	17.0	580
		0600	4.1	7.4	16.0	630
		1000	4.7	7.4	17.5	650
		1400	5.0	7.4	19.0	650
		1800	3.8	7.5	21.0	600
		2200	3.6	7.5	19.5	610
	28	0200	3.3	7.7	19.0	570
		0600	3.5	7.6	18.0	640
		1000	4.0	7.6	19.0	650
		1400	4.7	7.6	20.5	620
QW5	August 1	1800	16.5	8.8	29.5	495
		2200	13.2	8.6	28.0	500
	2	0200	9.7	8.3	26.5	510
		0600	6.8	8.0	26.0	520
		1000	--	--	--	--
		1400	17.6	8.5	30.0	540
		1800	20.0	8.5	30.5	545
		2200	16.6	8.6	28.5	740
	3	0200	12.0	8.3	27.0	550
		0600	6.9	7.9	26.0	570
		1000	6.5	7.8	27.0	570
		1400	10.7	8.1	27.0	600
	September 26	1800	6.6	8.6	18.0	600
		2200	5.7	8.9	18.0	600
	27	0200	5.2	7.4	17.0	600
		0600	5.1	7.4	17.0	605
		1000	5.8	7.5	19.0	620
		1400	8.0	7.7	22.5	620
		1800	6.6	7.5	21.0	620
		2200	6.3	7.7	20.0	610
	28	0200	5.6	7.9	20.0	610
		0600	5.3	7.8	19.0	620
		1000	6.0	7.8	20.0	645
		1400	7.4	7.9	22.5	605

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
T4	August 1	1800	2.9	8.0	23.5	1090
		2200	2.6	8.4	22.0	1050
	2	0200	2.6	8.3	21.5	1060
		0600	3.4	8.3	20.0	1050
		1000	4.3	8.3	25.0	950
		1400	3.0	7.9	28.0	1120
		1800	3.4	8.4	24.0	1090
		2200	3.0	8.1	23.5	1095
	3	0200	2.5	7.8	25.0	1050
		0600	3.1	7.9	21.0	1050
		1000	3.8	8.0	24.0	975
		1400	3.1	8.0	25.0	1110
	September 26	1800	6.4	8.2	20.5	875
		2200	6.0	8.8	19.0	990
	27	0200	4.9	8.1	18.5	960
		0600	5.7	9.1	16.0	950
		1000	6.9	9.0	17.0	880
		1400	4.9	8.0	22.0	1020
		1800	5.1	8.5	21.5	975
		2200	5.3	8.2	20.0	1000
	28	0200	4.9	9.0	19.5	990
		0600	5.1	9.0	17.0	1010
		1000	6.2	8.9	18.0	940
		1400	4.9	8.1	24.0	990
QW6	August 1	1800	9.6	8.4	26.0	705
		2200	7.9	8.2	26.0	710
	2	0200	4.6	8.0	25.5	745
		0600	3.9	7.7	26.0	760
		1000	5.5	7.9	27.0	760
		1400	15.8	8.3	30.0	850
		1800	15.6	8.5	22.5	790
		2200	9.7	8.3	26.0	720
	3	0200	6.5	8.2	26.0	760
		0600	4.5	8.1	25.0	770
		1000	6.5	8.2	26.0	800
		1400	8.1	8.2	27.0	780

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milli-grams per liter	pH, in units	Tempera-ture, in degrees Celsius	Specific conductance, in microsiemens per cent-imeter at 25 °Celsius
QW6	September 26	1800	4.5	7.9	18.5	650
		2200	4.2	8.0	18.0	725
	27	0200	3.8	8.0	18.0	740
		0600	4.4	8.3	17.0	780
		1000	4.5	8.3	18.0	780
		1400	6.1	8.6	22.0	915
		1800	4.7	8.0	21.0	740
		2200	3.8	7.9	19.5	750
	28	0200	3.9	8.1	19.0	775
		0600	3.2	8.5	17.0	980
		1000	3.6	8.3	20.0	820
		1400	5.9	8.6	22.0	905
QW7	August 1	1800	7.3	8.3	27.5	750
		2200	5.3	8.1	26.5	650
	2	0200	4.7	8.0	24.5	690
		0600	5.1	7.9	26.0	700
		1000	11.5	8.3	28.0	740
		1400	20.0	8.6	34.0	725
		1800	11.8	8.3	29.0	740
		2200	11.0	8.4	27.0	725
	3	0200	7.9	8.3	27.0	710
		0600	4.5	7.9	25.0	775
		1000	8.8	8.2	27.0	770
		1400	9.0	8.4	27.0	780
	September 26	1800	3.5	7.8	19.5	750
		2200	3.9	7.9	18.0	680
	27	0200	3.9	7.9	17.0	655
		0600	3.3	7.9	17.0	725
		1000	4.3	7.8	18.0	720
		1400	4.8	7.9	22.0	725
		1800	5.5	8.0	22.5	700
		2200	3.8	7.9	20.0	725
	28	0200	3.2	7.9	20.0	720
		0600	2.9	7.9	18.0	770
		1000	3.5	7.8	20.0	760
		1400	6.0	8.0	23.0	760

Table 5.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	Dissolved oxygen, in milligrams per liter	pH, in units	Temperature, in degrees Celsius	Specific conductance, in microsiemens per centimeter at 25 °Celsius
QW8	September 26	1800	5.0	8.0	17.5	690
		2200	4.6	7.9	17.0	700
	27	0200	3.3	7.9	16.0	705
		0600	3.5	7.8	16.0	710
		1000	3.9	7.7	18.0	725
		1400	3.9	7.9	21.0	710
		1800	3.6	7.9	18.5	720
		2200	3.2	7.8	18.0	720
	28	0200	2.6	7.8	17.0	705
		0600	2.3	7.8	17.0	710
		1000	3.7	7.7	18.0	730
		1400	4.6	7.8	19.0	740

Table 6.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983

[<, less than; --, missing data]

Water-quality sampling site (fig. 1)	Date	Time	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Total ammonia as N, in milligrams per liter	Total nitrate as N, in milligrams per liter	Dissolved orthophosphate as P, in milligrams liter	Suspended solids, in milligrams per liter
QW1	August 1	1800	<2	0 .03	0.60	0.06	--
	2	0600	<4	.16	.68	.07	40
		1800	<4	.01	.59	.05	--
	3	0600	<4	.06	.46	.05	48
	September 26	1800	<4	.11	1.2	.15	40
	27	0600	<4	.13	1.3	.16	31
		1800	<4	.10	1.0	.44	24
	28	0600	<2	.09	.99	.09	29
T1	August 1	1800	27	16	.05	7.3	--
	2	0600	17	11	.05	5.7	25
		1800	18	15	.05	7.9	--
	3	0600	14	12	.05	7.8	10
	Septebmer 26	1800	24	15	.08	8.8	21
	27	0600	16	10	.05	4.9	23
		1800	31	19	.05	14	28
	28	0600	23	14	.05	8.6	24
QW2	August 1	1800	7	5.0	.17	2.6	--
	2	0600	<6	7.2	.12	2.6	32
		1800	7	5.4	.18	2.6	--
	3	0600	8	6.8	.21	2.8	30
	Septebmer 26	1800	5	4.8	.42	3.1	47
	27	0600	6	8.4	.38	3.2	36
		1800	7	5.9	.39	2.5	34
	28	0600	<6	9.2	1.1	3.4	24
QW3	August 1	1800	4	4.7	.90	1.5	--
	2	0600	5	5.0	.65	1.9	105
		1800	4	3.9	.87	1.1	--
	3	0600	7	4.9	.86	1.4	122

Table 6.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Total ammonia as N, in milligrams per liter	Total nitrate as N, in milligrams per liter	Dissolved orthophosphate as P, in milligrams liter	Suspended solids, in milligrams per liter
QW3	September 26	1800	4	2.2	0.61	3.0	74
	27	0600	<4	5.8	.61	2.9	86
		1800	4	5.8	.72	2.4	68
	28	0600	4	7.2	.70	2.7	96
QW4	August 1	1800	6	3.3	6.8	.84	--
	2	0600	7	4.1	2.0	1.4	94
		1800	3	2.0	3.1	.72	--
	3	0600	4	4.1	1.7	.99	94
	September 26	1800	<4	5.5	1.5	1.9	124
	27	0600	<4	6.3	1.2	2.3	716
		1800	<6	6.6	1.1	2.2	254
	28	0600	3	7.0	1.3	2.4	100
QW5	August 1	1800	10	1.1	3.4	.48	--
	2	0600	6	1.1	3.0	.39	84
		1800	11	1.6	4.8	.50	--
	3	0600	<4	1.6	3.8	.48	92
	September 26	1800	<4	2.9	2.8	1.0	59
	27	0600	<6	4.0	2.0	1.1	58
		1800	4	4.2	2.1	.63	46
	28	0600	5	4.7	2.3	1.3	71
T2	August 1	1800	<2	.02	.62	.06	--
	2	0600	<2	.12	.67	.05	18
		1800	<2	.02	.63	<.05	--
	3	0600	<4	.05	.65	.08	23
	September 26	1800	<4	0.01	.82	.13	45
	27	0600	<4	0.12	.77	.12	89
		1800	<4	0.05	.82	.11	53
	28	0600	<2	0.02	.82	.09	61

Table 6.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Total ammonia as N, in milligrams per liter	Total nitrate as N, in milligrams per liter	Dissolved orthophosphate as P, in milligrams liter	Suspended solids, in milligrams per liter
T3	August 1	1800	15	15	0.22	4.0	--
	2	0600	<6	13	.69	3.5	194
		1800	11	19	.13	2.8	--
	3	0600	13	13	1.0	3.4	196
	September 26	1800	8	.16	5.4	4.7	160
	27	0600	--	.34	2.6	2.7	495
		1800	<19	.41	7.4	2.8	465
	28	0600	8	.43	4.1	2.3	1,090
T4	August 1	1800	12	16	.25	3.9	--
	2	0600	8	16	.54	3.6	276
		1800	9	17	.07	5.8	--
	3	0600	15	15	.53	4.2	900
	September 26	1800	8	.31	5.5	4.2	298
	27	0600	--	.41	4.4	3.7	700
		1800	20	.48	7.2	5.3	356
	28	0600	11	.51	5.5	3.2	44
QW6	August 1	1800	10	5.3	2.2	1.3	--
	2	0600	10	7.5	1.8	1.8	72
		1800	15	5.6	2.5	.32	--
	3	0600	10	8.1	2.5	1.4	82
	September 26	1800	<4	2.9	2.9	1.5	98
	27	0600	9	2.1	3.8	2.8	94
		1800	11	1.9	4.4	2.0	69
	28	0600	10	1.1	6.3	4.6	99
QW7	August 1	1800	12	7.0	1.6	1.4	--
	2	0600	12	5.5	1.9	1.2	120
		1800	11	6.9	2.2	.95	--
	3	0600	11	6.5	2.2	1.4	135

Table 6.--Water-quality data collected on Dardenne Creek from August 1 to 3 and September 26 to 28, 1983--Continued

Water-quality sampling site (fig. 1)	Date	Time	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Total ammonia as N, in milligrams per liter	Total nitrate as N, in milligrams per liter	Dissolved orthophosphate as P, in milligrams liter	Suspended solids, in milligrams per liter
QW7	September 26	1800	6	2.5	3.8	2.8	122
	27	0600	11	1.9	4.0	2.0	100
		1800	6	2.1	4.1	1.9	58
	28	0600	7	2.2	3.9	1.6	96
QW8	September 26	1800	<4	1.7	--	1.3	--
	27	0600	10	2.0	--	1.3	--
		1800	7	1.9	--	1.2	--
	28	0600	6	2.1	--	1.2	--

Table 7.--Water-quality data collected on August 2, 3, September 27, and 28, 1983, on Dardenne Creek

[<, less than; --, missing data; ND, none detected; >, greater than]

Water-quality sampling site (fig. 1)	Date	Time	Chlorophyll "a", in micrograms per liter	Fecal coliform, in colonies per 100 milliliters	Fecal streptococci, in colonies per 100 milliliters	Chloride, in milligrams per liter	Total-recoverable mercury, in micrograms per liter	Selected pesticides[1], in micrograms per liter	Total-recoverable iron, in micrograms per liter	Chemical-oxygen demand, in milligrams per liter
QW1	August 2	0600	--	910	490	17	<0.5	ND	2,000	<5
	3	0600	8	660	670	14	--	--	--	23
	September 27	0600	--	170	380	14	<0.2	ND	1,600	--
	28	0600	--	400	770	77	--	--	--	--
T1	August 2	0600	1	>60,000	59,000	42	--	--	--	70
	3	0600	1	430,000	37,000	42	--	--	--	74
	September 27	0600	--	1,130,000	101,000	41	--	--	--	--
	28	0600	--	4,300,000	260,000	47	--	--	--	--
QW2	August 2	0600	6	>6,000	8,300	31	--	--	--	33
	3	0600	11	76,000	16,000	31	--	--	--	54
	September 27	0600	--	240,000	16,000	30	--	--	--	--
	28	0600	--	150,000	10,000	37	--	--	--	--
QW3	August 2	0600	--	5,900	360	29	<0.5	ND	2,500	27
	3	0600	12	19,000	1,000	27	--	--	--	40
	September 27	0600	--	20,000	2,400	29	<0.2	ND	3,800	--
	28	0600	2	21,000	1,900	33	--	--	--	--

[1]Selected pesticides are dieldrin, chlordane, lindane, and toxaphene.

Table 7.--Water-quality data collected on August 2, 3, September 27, and 28, 1983, on Dardenne Creek--Continued

Water-quality sampling site (fig. 1)	Date	Time	Chlorophyll "a", in micrograms per liter	Fecal coliform, in colonies per 100 milliliters	Fecal streptococci, in colonies per 100 milliliters	Chloride, in milligrams per liter	Total-recoverable mercury, in micrograms per liter	Selected pesticides[1], in micrograms per liter	Total-recoverable iron, in micrograms per liter	Chemical-oxygen demand, in milligrams per liter
QW4	August 2	0600	20	3,300	360	31	--	--	--	31
	3	0600	20	1,380	520	30	--	--	--	43
	September 27	0600	3	1,900	350	37	--	--	--	--
	28	0600	--	--	--	40	--	--	--	--
QW5	August 2	0600	--	1,200	120	25	<0.5	ND	4,100	32
	3	0600	48	820	60	28	--	--	--	32
	September 27	0600	--	340	40	34	<0.2	ND	3,000	--
	28	0600	--	300	200	35	--	--	--	--
T2	August 2	0600	4	1,010	650	50	--	--	--	9
	3	0600	--	2,000	600	47	--	--	--	9
	September 27	0600	--	2,000	940	39	--	--	--	--
	28	0600	3	2,200	1,000	46	--	--	--	--
T3	August 2	0600	1	670	1,700	160	--	--	--	49
	3	0600	2	13,000	920	170	--	--	--	68
	September 27	0600	--	500	<100	150	--	--	--	--
	28	0600	--	--	--	48	--	--	--	--
T4	August 2	0600	1	6,800	1,900	170	--	--	--	60
	3	0600	--	9,800	2,900	179	--	--	--	76
	September 27	0600	--	9,000	300	170	--	--	--	--
	28	0600	--	900	800	175	--	--	--	--

[1]Selected pesticides are dieldrin, chlordane, lindane, and toxaphene.

Table 7.--Water-quality data collected on August 2, 3, September 27, and 28, 1983, on Dardenne Creek--Continued

Water-quality sampling site (fig. 1)	Date	Time	Chlorophyll "a", in micrograms per liter	Fecal coliform, in colonies per 100 milliliters	Fecal strep-tococci, in colon-ies per 100 milliliters	Chloride, in milli-grams per liter	Total-recov-erable mercury, in micro-grams per liter	Selected pesti-cides[1], in micro-grams per liter	Total-recov-erable iron, in micro-grams per liter	Chemical-oxygen demand, in milli-grams per liter
QW6	August 2	0600	64	5,900	500	71	--	--	--	57
	3	0600	96	2,100	300	80	--	--	--	23
	September 27	0600	--	9,000	1,200	92	--	--	--	--
	28	0600	4	21,000	1,200	150	--	--	--	--
QW7	August 2	0600	--	5,300	530	63	<0.5	ND	6,100	56
	3	0600	90	2,500	400	70	--	--	--	58
	September 27	0600	--	3,000	430	80	--	--	--	--
	28	0600	--	--	--	88	--	--	--	--
QW8	September 27	0600	--	1,300	400	71	<0.2	ND	2,300	--
	28	0600	25	400	<1,000	74	--	--	--	--

[1]Selected pesticides are dieldrin, chlordane, lindane, and toxaphene.

Table 8.--Type of macroinvertebrate identified in Dardenne Creek and Spencer Creek on August 1, 1983

[--, organism not detected; X, organism detected]

Organism scientific name Phylum .Class ..Order ...Family ....*Genus Species*	Water-quality sampling site (fig. 1)			
	QW1	QW3	T2	T4
Annelida				
.Hirudinea				
..Rhyachobdellida				
...Glossiphoniidae				
....*Helobdella elongata*	--	X	--	--
Mollusca				
.Gastropoda				
..Basommotophora				
...Ancylidae				
....*Ferrissia* sp.	--	--	X	--
.Pelecypoda				
..Heterodonta				
...Sphaeriidae	X	--	--	--
Arthopoda				
.Encrustacea				
..Amphipoda				
...Gammaridae				
....*Gammarus pseudolimnaeus*	X	X	--	--
..Isopoda				
...Asellidae				
....*Asellus intermedius*	X	X	X	--
.Decapoda				
..Astacidae	X	X	--	--
.Insecta				
..Emphemeroptera				
...Heptageniidae				
....*Stenonema interpunctatum*	X	X	X	--
....*Stenonema bipunctatum*	--	X	--	--

Table 8.--Type of macroinvertebrate identified in Dardenne Creek and Spencer Creek on August 1, 1983--Continued

Organism scientific name Phylum .Class ..Order ...Family ....*Genus Species*	Water-quality sampling site (fig. 1)			
	QW1	QW3	T2	T4
Arthopoda				
.Encrustacea				
..Amphipoda				
...Baetidae				
....*Baetis* sp.	X	X	--	--
..Hemiptera				
...Corixidae	--	--	X	X
..Megaloptera				
...Corydalidae				
....*Corydalus cornutus*	X	--	--	--
..Tricpotera				
...Hydropsychidae				
....*Cheumatopsyche* sp.	X	X	X	--
....*Hydropsyche simulans*	X	--	--	--
...Hydroptilidae				
....*Agraylea multipunctata*	X	X	--	--
...Philopotamidea	--	--	--	--
....*Chimarra obscura*	X	--	--	--
..Coleoptera				
...Elmidae				
....*Stenelmis* sp.	X	X	--	--
....*Dubiraphia* sp.	X	--	--	--
..Diptera				
...Simuliidae				
....*Simulium* sp.	--	X	--	--
...Empididae	--	X	--	--

Table 8.--Type of macroinvertebrate identified in Dardenne Creek and Spencer Creek on August 1, 1983--Continued

Organism scientific name Phylum .Class ..Order ...Family ....Genus Species	Water-quality sampling site (fig. 1)			
	QW1	QW3	T2	T4
Arthopoda				
.Encrustacea				
..Amphipoda				
...Chionomidae				
....*Polypedilum convictum*	X	--	--	--
....*Polypedilum illinonense*	--	X	X	--
....*Dicrotendipes neomodestus*	--	--	X	--
....*Dicrotendipes nervosus*	--	X	--	--
....*Cryptochironomum fulvus*	--	--	X	--
....*Zavrelia* sp.	--	X	--	--
....*Tanytarsus glabrescens*	X	--	--	--
...Orthocladiinae				
....*Orthocladius* sp.	--	X	--	--
....*Cricotopus bicinctus*	--	X	X	--
....*Cricotopus tridfascia*	--	--	X	--
....*Thienemanniella* sp.	--	X	--	--
....*Heterotrissocladius* sp.	--	X	--	--
...Tanypodinae				
....*Theinemannimyia* sp.	X	X	X	--
Total number of taxa:	16	20	11	1

Table 9.-- Composite water-quality samples collected at the wastewater-treatment plants on August 2, 3, September 27 and 28, 1983

[--, missing data; <, less than]

Date	pH, in units	Suspended solids, in milligrams per liter	5-day carbonaceous biochemical-oxygen demand, in milligrams per liter	Total ammonia as N, in milligrams per liter	Total nitrate as N, in milligrams per liter	Dissolved orthophosphate as P, in milligrams per liter
		Harvester-Dardenne Wastewater-Treatment Plant				
August 2	--	--	42	16	0.06	9.4
August 3	--	--	34	14	<.05	5.4
September 27	--	26	29	18	.87	.92
September 28	--	31	42	21	<.05	9.8
		St. Peters Wastewater-Treatment Plant				
August 2	7.5	24	19	24	<0.05	7.6
August 3	7.3	25	18	23	<.05	6.6
September 27	7.4	11	12	.56	7.3	2.6
September 28	7.4	21	11	.67	7.8	9.3

Table 10.--Additional data collected during August 1983 on Dardenne Creek

[--, missing data]

Water-quality sampling site (fig. 1)	Discharge, in cubic feet per second	Average velocity, in feet per second	Reaeration coefficient, in base e, per day at 20° Celsius	Streambed-oxygen demand, in grams per square foot per day
QW1	3.14	0.15	--	0.078
QW2	6.38	.15	--	.111
QW3	6.68	.11	--	.130
QW4	6.42	.13	2.76	.069
QW5	--	.17	--	--
QW6	10.6	.17	2.06	.093
QW7	--	.13	2.06	--
T4	4.45	.77	6.95	.111