CHEMICAL AND PHYSICAL FINDINGS FROM POLLUTION STUDIES ON THE EAST GALLATIN RIVER AND ITS TRIBUTARIES

by

RAYMOND ARTHUR SOLTERO

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Approved:

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Head, Major Department

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Chairman, Examining Committee

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Graduate Dean

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VITA

Raymond Arthur Soltero was born July 20, 1943 at Milwaukee, Wisconsin. He attended Billings Central Catholic and Billings Senior High Schools, Billings, Montana, and graduated from the latter in 1962.

He received a Bachelor of Science Degree from Montana State University, Bozeman, Montana, in December, 1966. He entered the Montana State University graduate school in January, 1967.

In November, 1960, he was married to Patricia A. Mueller, and they have three children: Douglas Raymond (age 7), Kirsten Marie (age 5), and Tamara Jane (age 2).

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ABSTRACT

A section of the East Gallatin River and its tributaries in the vicinity of Bozeman, Montana, were studied in an effort to determine, by chemical-physical means, the water quality at various points and to determine the effects of suspected pollutant sources on this system.

Comparison of the detailed chemical analyses at the upstream and downstream stations demonstrated that the tributaries contributed little if any pollution to the East Gallatin River. The major pollutant of the stream was found to be the Bozeman City Sewage effluent.

INTRODUCTION

Water from streams and lakes in mountainous districts may be relatively free from organic impurities but usually contains varying concentrations of dissolved inorganic salts, while water from lowland rivers and lakes near population centers may be highly polluted. Pollution, in this sense of the word, is anything that renders the water impure or alters the originality of the water in any way.

The growing scarcity of water sources and the ever increasing usage of water for domestic and industrial purposes have been primarily the reasons for the great interest in pollution problems.

The East Gallatin River at Bozeman, Montana provides an excellent opportunity for the study of stream pollution. The major pollutant is the sewage outfall of the Bozeman City Sewage Treatment Plant. This plant is of the primary treatment type, treating an average of 3.5 million gallons per day of raw sewage. Although the sewer system is not of the combined type, during and after heavy storms there is an increase of flow into the plant. During the study period the sewage outfall comprised from 1.4% to 11.8% of the total stream flow.

A slaughter house and stockyards are located upstream from the sewage effluent, both of which are other sources of possible pollution to this river system. The slaughter house discharges unmarketable animal material into the water while the stockyards place the manure pilings from their pens along the stream banks, which when eroded, dump overlying waste material directly into Rocky Creek. Other additional sources of possible pollution are located on the tributaries, Bozeman

Creek and Bridger Creek, which were also sampled in the course of the study.

Since most pollutions that are found in aquatic systems are of a chemical or physical nature, chemical analyses supplemented by physical determinations must in part play a vital role in the detection and estimation of the degree of pollution.

The purpose of the present investigation was to conduct several routine chemical-physical analyses in an attempt to obtain information pertaining to stream quality at the various points sampled. Twenty-four hour sampling periods were also carried out to determine what chemical and physical effects the sewage outfall had on the East Gallatin River.

DESCRIPTION OF THE STUDY AREA

The East Gallatin River is formed by the union of Rocky Creek and Bozeman Creek and flows in a northwesterly direction along the northern margin of Bozeman, a city of some 20,000 people.

The average discharge from this river was 84.7 cfs (2.40 m^3/sec.) for a 22 year period (1939-1961). The discharge normally fluctuates between a fall minimum of approximately 18 cfs (0.51 m^3/sec.) and a spring maximum of 189 cfs (5.35 m^3/sec.). Maximum recorded discharge was 1,230 cfs (35.14 m^3/sec.) on June 4, 1953 and the minimum was 12 cfs (0.34 m^3/sec.) on December 9, 1944 and March 24-26, 1955. The drainage area of this river comprises 148 sq. mi. (384.82 km^2) at an elevation of about 4,701 ft. (1,433.23 m) above mean sea level.

The East Gallatin River is a permanent stream approximately 37 miles (59.58 km) long. It varies from 7 ft. (2.13 m) to 30 ft. (9.15m) in width during low water and varies in depth from a few inches in the riffles to more than 6 ft. in a few pools. The principal natural source of the water is springs and surface runoff from the surrounding mountainous terrain. The flow is augmented, however, by the Bozeman City Sewage Treatment Plant and by Bridger Creek.

The river is of the calcium-magnesium-bicarbonate type, with silica, sodium, and potassium present in small concentrations.

Twelve permanent stations were established during the course of the study (see Figure 1). Station 1 was located on Bozeman Creek 3.7 miles (5.96 km) above its confluence with Rocky Creek.

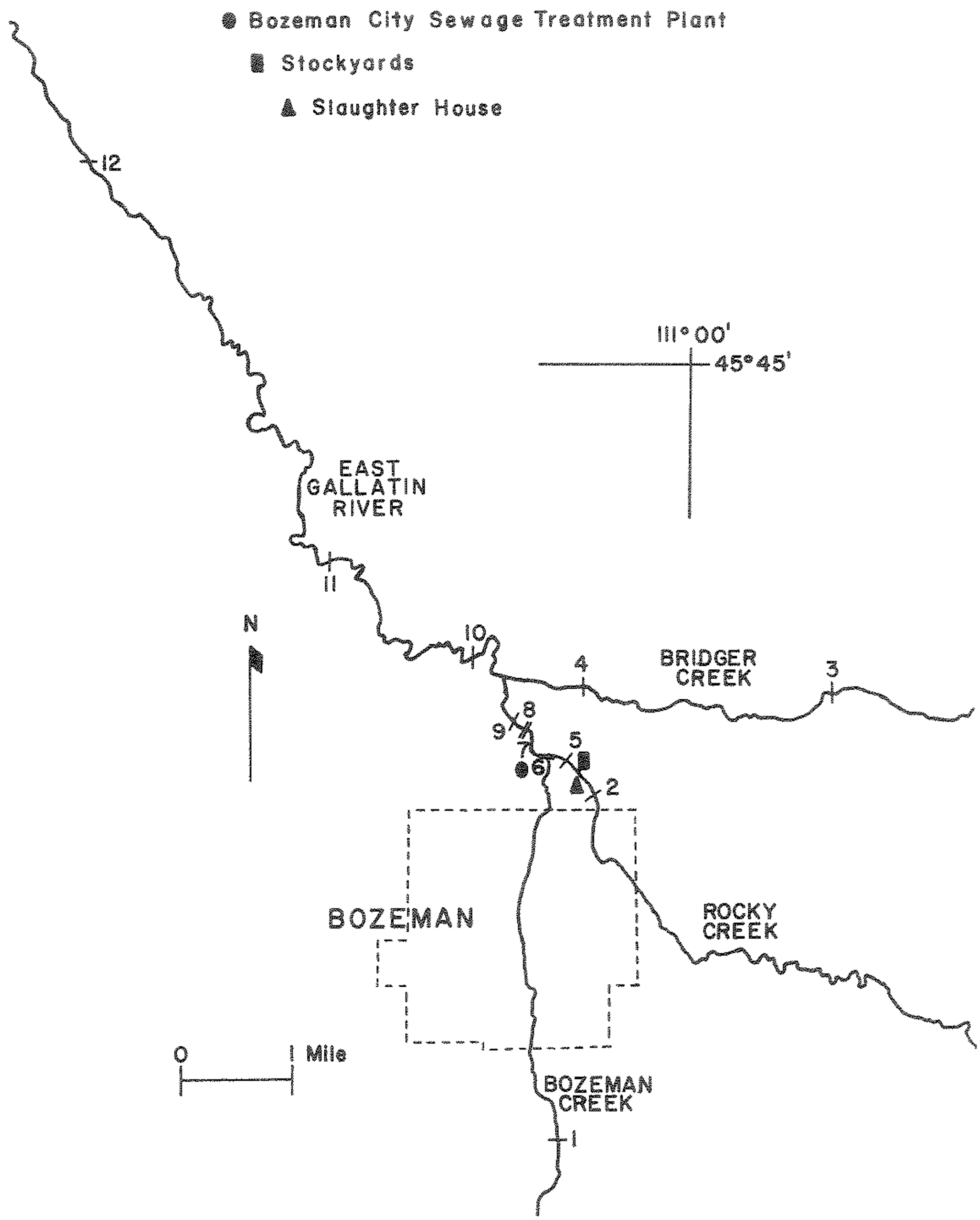

Figure 1. Map of the upper East Gallatin River system showing location of study area and stations

Station 2 was established on Rocky Creek 0.9 miles (1.45 km) upstream from the sewage effluent, 0.4 miles (0.64 km) from the stockyards and 0.2 miles (0.32 km) from the slaughter house.

Station 3 was situated on Bridger Creek 3.4 miles (5.48 km) upstream from its confluence with the East Gallatin River.

Station 4 was also situated on Bridger Creek 0.6 miles (0.97 km) from its confluence with the river. This union with the East Gallatin River is also 0.6 miles (0.97 km) below the sewage outfall.

Station 5 was located on Rocky Creek just downstream from the stockyards, 0.2 miles (0.32 km) from the slaughter house and 0.2 miles (0.32 km) from its confluence with Bozeman Creek.

Station 6 was established on Bozeman Creek about 50 ft. (15.24 m) above its confluence with Rocky Creek. The confluence is 0.4 miles (0.64 km) above the sewage outfall.

Station 7 was situated on the East Gallatin River approximately 100 ft. (30.49 m) upstream from the sewage effluent.

Station 8 was the sewage effluent itself, 0.4 miles (0.64 km) by underground cement pipe from the treatment plant area.

Station 9 was located in the area where the sewage outfall became completely mixed with the rest of the river, 0.3 miles (0.48 km) downstream from the sewage outfall.

Station 10 was established 1.4 miles (2.25 km) downstream from station 9.

Station 11 was situated 2.5 miles (4.02 km) below station 10.

Station 12 was established 6.3 miles (10.15 km) downstream from station 11 and 10.5 miles (16.89 km) from the sewage outfall.

The stream bottom types at these various stations consisted mainly of large to small cobbles and coarse to fine gravel.

METHODS

Water samples and field measurements were taken at the various stations at weekly intervals, when possible, throughout the duration of the study.

Table I shows the date and the station at which 24-hour and single samples were taken. Diurnal sampling at stations 7, 8, 9, 10, and 11 commenced at 0600 hours and proceeded through 0600 hours the following day. Sample collections were made every three hours except between 2400 hours and 0600 hours when samples were not taken. The single samples were generally collected at all stations. Sampling began at 0600 hours and was complete by 0800 hours that same day.

All samples were obtained by lowering an 8 liter polyethylene bucket over the side of a bridge into the middle of the stream. This container was rinsed well with the surface water before a sample was taken. Upon collection, one 300 ml and one-1 liter aliquots were collected in Pyrex glass-stoppered bottles. These storage bottles were rinsed twice before being filled with the water sample.

Water Chemistry

After returning to the laboratory, the one-liter sample was filtered through "Millipore" filters with a pore size of 0.8 microns. After filtering, the samples were placed back in the Pyrex glass-stoppered bottles, which had been rinsed with a small quanity of the filtrate.

Table I. The date and the station at which 24-hour and single samples were taken during the summer (1967).

DATE	24-HOUR SAMPLES	SINGLE SAMPLES
	Stations	Stations
6/13/67	——	1-2, 5-8, 10-11
6/20/67	——	1-12
6/27/67	——	1-8, 10-12
7/11/67	——	1-12
7/18-19/67	7-11	——
7/25/67	——	1-2, 5-12
8/1-2/67	7-11	——
8/8/67	——	1-12
8/15-16/67	7-11	——
8/22/67	——	1-2, 5-12
8/29-30/67	7-11	——
9/12/67	——	1-12

—— Samples were not collected.

The electrical resistance of each sample was measured with a YSI Conductivity Bridge (Model 31). An Industrial Instruments (Model CEL 4) dipping cell was used with the YSI Conductivity Bridge. The cell constant of the dipping cell was approximately 2.1 throughout the study.

The specific conductance of the water at 25°C was computed from the observed resistance which was corrected for temperature and cell resistance.

Measurements of the hydrogen ion concentrations were made with a Beckman Expanded Sclae pH meter (Model 76).

Total alkalinity, Biochemical Oxygen Demand (B.O.D.), chloride, fluoride, nitrite, total and soluble nitrogen, total, soluble and inorganic phosphate, silica, sulfate, and turbidity determinations were made as described by the American Public Health Association (1965). Ammonia was determined by the phenoxide and hypochlorite method as described by Charlot (1964). The colorimetric equipment used in the various analyses was either a Bausch and Lomb "Spectronic 20" or a Klett-Summerson colorimeter.

Nitrate determinations were made according to the method of West and Lyles as described in Analytica Chimica Acta (1960).

Total carbon, total organic carbon and soluble organic carbon were determined by a Beckman Laboratory Carbonaceous Analyzer, following the procedure given in the Beckman Bulletin #1307-6A (February, 1965). Total inorganic carbon was also computed from pH, temperature, and total alkalinity, using the formulae derived by

Saunders et al. (1962).

Calcium, potassium, and sodium were determined by flame emission with a Beckman DU Flame Spectrophotometer, following the procedures given in the Beckman Instruction Manual #334-A (March, 1957), and magnesium was determined by atomic absorption spectroscopy using the Beckman Spectrophotometer.

Bicarbonate ion was determined as described by Hutchinson (1957).

The Precision Galvanic Cell Oxygen Analyser was used for the determination of dissolved oxygen as described in Precision Scientific Company Bulletin #TS-68850. The Oxygen Analyser was calibrated by allowing the electrode system equilibrate in a sample of known oxygen content. The Alsterberg modification of the Winkler technique (APHA, 1965) was the chemical test used to determine the dissolved oxygen of the standardizing sample.

Upon attaining a water sample from the stream the probe was immersed in the sample and gently swirled for several minutes. The meter current and temperature were recorded and the dissolved oxygen of the sample was obtained from a nomograph supplied with the instrument. A nomograph was also used for calculating the percentage saturation of oxygen in the water sample as described by Mortimer (1956).

All of the above mentioned analyses were run on the single samples within 30 hours after field collection. Free ammonia, total alkalinity, total carbon, total and soluble organic carbon, total and soluble nitrogen, nitrate, nitrite, total, soluble, and inorganic phosphate, and pH determinations were made within 5 hours after collection.

In the sampling periods of 24-hour duration determinations of temperature, dissolved oxygen, conductivity, pH, total alkalinity, total carbon, total organic carbon, total nitrogen, and total phosphate were made at 3 hour intervals.

The net changes in total carbon, total nitrogen, total phosphate, and dissolved oxygen were computed by the upstream-downstream method (Odum, 1956; Wright et al, 1967).

For each 24-hour sampling period a series of graphs were produced by first plotting the total carbon, total nitrogen, total phosphate, or dissolved oxygen concentrations at station 7 as the ordinate against the time of collection as the abscissa. At each successive station, carbon, nitrogen, phosphate, or dissolved oxygen concentrations were displaced to the left by a time interval equivalent to the flow time from station 7 to the station whose data was being plotted.

The vertical distance between the two curves will give the net change in concentration of the substance (total carbon, total nitrogen, total phosphate, or dissolved oxygen) during the time required for it to flow through the reach.

The net changes in concentration per unit area per minute of total carbon and etc. were computed according to equation 1:

$$C = \frac{h\ (c_1 - Rc_2)}{t} \qquad (1)$$

Where:

C = net change in concentration per unit area per minute, $g/m^2/min$.

h = average depth of the reach, m.

c_1 = upstream concentration, g/m^3.

c_2 = downstream concentration, g/m^3.

R = ratio obtained from dividing the discharge (cfs) at the upper station of the reach by the discharge (cfs) at the lower one.

t = flow time, min.

Temperature

The temperature of the sample upon collection was measured with the Precision Galvanic Cell Oxygen Analyser which had a thermistor attachment. The themistor used with the Oxygen Analyser had an accuracy within 0.1°C.

Hydrology

Discharge measurements on the East Gallatin River were obtained from the rating table for the gauging station maintained by the U. S. Geological Survey 500 ft. below the confluence of Rocky Creek and Bozeman Creek.

Vertical staff gauges were installed at station 4 on Bridger Creek and station 6 on Bozeman Creek. The average stream velocity was computed by obtaining sufficient point velocities. The average velocity multiplied by the cross-sectional area was used for computing the total discharge. Velocity measurements were determined by using a Gurley Current Meter (No. 622).

The above procedure was repeated numerous times for various stream stages. The stage record was then transformed to a discharge record by calibration.

The sewage discharge measurements were made by means of a free flow discharge Parshall 12" flume and a float level recorder located at the Bozeman City Sewage Treatment Plant.

Rate of flow between consecutive stations on the East Gallatin River was determined by introducing an appropriate quantity of fluorescent dye (rhodamine-B) in the main current of the stream at an upstream station. At the downstream station the water was pumped through a Turner Fluorimeter (Model 110) which was equipped with a Rustrak recorder and continuous flow cell to determine the passage of the peak dye concentration. The elapsed time for the dye to flow from the upstream station to the downstream station was considered to be the flow time.

This procedure was repeated for several different river stages. Flow times were plotted against the river stage during that period and flow times for water levels between those measured were obtained from the graphs.

Morphometry

Aerial photographs were measured for the lengths and widths used in calculating the area of the different river reaches. Average depths were computed according to equation 2:

$$h = \frac{d\ (t)}{A} \qquad (2)$$

Where:

h = average depth of the reach, m.

d = discharge, m^3/min.

t = flow time, min.

A = area of the reach, m^2.

The average current velocity was determined by dividing the flow time between two stations into the length of the reach.

RESULTS

Water Chemistry of Bozeman Creek and Bridger Creek

The average results of the water chemistry of Bozeman Creek and Bridger Creek for single sampling periods are recorded in Table II. This table includes both the inorganic and organic fractions that were analyzed.

Upon examination of the various cations found in both drainage systems, calcium was found to be dominant with magnesium, sodium, and potassium following in that order. Potassium is usually the least dominant cation in natural waters because of several processes which remove it from solution.

Bicarbonate and sulfate were less concentrated in Bozeman Creek than in Bridger Creek, but in both creeks the dominance order of the anions was the same, bicarbonate being most dominant, then sulfate, chloride, and fluoride.

The carbon determinations showed inorganic carbon to be higher in Bridger Creek. Soluble organic carbon was approximately the same for both streams (4-5 mg/1 C). A decline in particulate carbon was noted at both stations 4 and 6.

Soluble organic nitrogen was higher than any of the other nitrogen fractions analyzed in Bozeman and Bridger Creeks. The mean particulate nitrogen differed from 0.24 mg/1 at station 4 to 0.65 mg/1 at station 1. Nitrates were consistently higher than free ammonias and nitrites which were essentially void in each creek.

Table II. Average water chemistry for Bozeman Creek and Bridger Creek during the summer for the single sampling periods.

STATION	1	3	4	6
Ca^{++} (meq/l)	1.48	1.83	1.85	1.67
Mg^{++} (meq/l)	1.15	1.17	1.39	1.32
Na^{+} (meq/l)	0.16	0.68	0.51	0.25
K^{+} (meq/l)	0.07	0.04	0.04	0.08
HCO_3^- (meq/l)	2.38	3.32	3.32	2.71
SO_4^{-2} (meq/l)	0.19	0.32	0.34	0.20
Cl^- (meq/l)	0.03	0.04	0.04	0.04
F^- (meq/l)	less than 0.01 for all stations			
Inorganic Carbon (C) (mg/l)	24.70	37.00	39.70	33.30
Soluble Organic C (mg/l)	4.80	5.00	4.80	4.30
Particulate C (mg/l)	2.80	2.30	0.90	1.90
$N-NO_3^-$ (mg/l)	0.20	0.41	0.33	0.31
$N-NO_2^-$ (mg/l)	less than 0.01 for all stations			
$N-NH_3$ (mg/l)	0.11	0.02	0.04	0.07
Soluble Organic $N-NH_3$ (mg/l)	0.95	1.40	1.49	1.20
Particulate $N-NH_3$ (mg/l)	0.65	0.46	0.24	0.51
Inorganic $P-PO_4^{-3}$ (mg/l)	0.36	0.12	0.11	0.39
Soluble Organic $P-PO_4^{-3}$ (mg/l)	0.01	0.08	0.03	0.15
Particulate $P-PO_4^{-3}$ (mg/l)	0.23	0.21	0.17	0.32
Silica (mg/l)	20.60	10.50	9.50	22.00
Dissolved Oxygen (mg/l)	9.26	9.53	9.41	9.48
% O_2 Saturation	70.50	73.80	73.60	73.10
Conductance (micromhos)	247.40	340.70	343.50	284.70
pH Ranges	8.14	8.25	8.29	8.18

The average of the phosphate analyses showed inorganic phosphate and particulate phosphate to be lower in Bridger Creek. Mean soluble organic phosphate values for Bozeman Creek varied from 0.01 mg/1 at station 1 to 0.15 mg/1 at station 6, with Bridger Creek values falling within these limits.

Silica concentrations were higher in Bozeman Creek. This apparently was due to the flowing of these waters over a basic igneous area. The lower silica content of Bridger Creek was attributed to its drainage basin being primarily sedimentary.

The dissolved oxygen content of both systems was usually greater than 9.0 mg/1 with an oxygen saturation of about 73%.

The mean specific conductance and pH range was usually greater in Bridger Creek than in Bozeman Creek.

An examination of the concentrations of the various chemical fractions at both the upstream and downstream stations indicates that there was no gross addition of pollution to either of the systems at the time of the study.

Water Chemistry of Rocky Creek and the East Gallatin River

In the following section, many of the graphs may have both solid and broken line curves. The solid lines represent the concentration of chemical factors in the length of Rocky Creek and the East Gallatin River that was sampled. Broken lines indicate the contributions from the major tributaries of the East Gallatin River system at appropriate points. Station 2 was selected as the starting point (0 miles) in making graphs. The downstream distances of the remaining Rocky Creek and East Gallatin River stations from station 2 are recorded in Table III.

The average specific conductance and total alkalinity for Rocky Creek and the East Gallatin River during the study period are shown in Figure 2. An increase in the conductance and total alkalinity was noted within 0 to 0.4 miles, then a definite decrease between 0.4 and 0.9 miles. The decline was primarily due to the dilution effect of Bozeman Creek (station 6). Another increase in conductance and alkalinity was observed from 0.9 to 1.2 miles because of the added enrichment of the sewage outfall. Alkalinity and conductance both decreased within 1.2 to 2.6 miles downstream from station 2 which was attributed to the dilution effect from Bridger Creek (station 4). Between 2.6 miles and 11.4 miles there was a slight rise in both conductance and alkalinity.

Figure 3 shows the mean % O_2 saturation and dissolved oxygen for the single sampling periods during the summer. Fluctuations are noticed from 0 to 0.9 miles, the highest O_2 saturation being at 0.4 miles and a dissolved oxygen high near 9.1 mg/l between 0.4 and 0.9 miles. A decline in O_2 saturation and dissolved oxygen was noted from 0.9 to 2.6 miles and then a gradual increase of the two between 5.1 and 11.4 miles.

As can be seen from Figure 3, the greatest oxygen depletion was in the vicinity of the sewage effluent. This demand for oxygen was of such magnitude that the stream at 11.4 miles had still not regained its original O_2 concentration. If it were not for the highly oxygenated

Table III. The downstream distances from station 2 for the Rocky Creek and East Gallatin River sampling stations.

STATION	DISTANCE (miles)
2	0
5	0.4
7	0.9
9	1.2
10	2.6
11	5.1
12	11.4

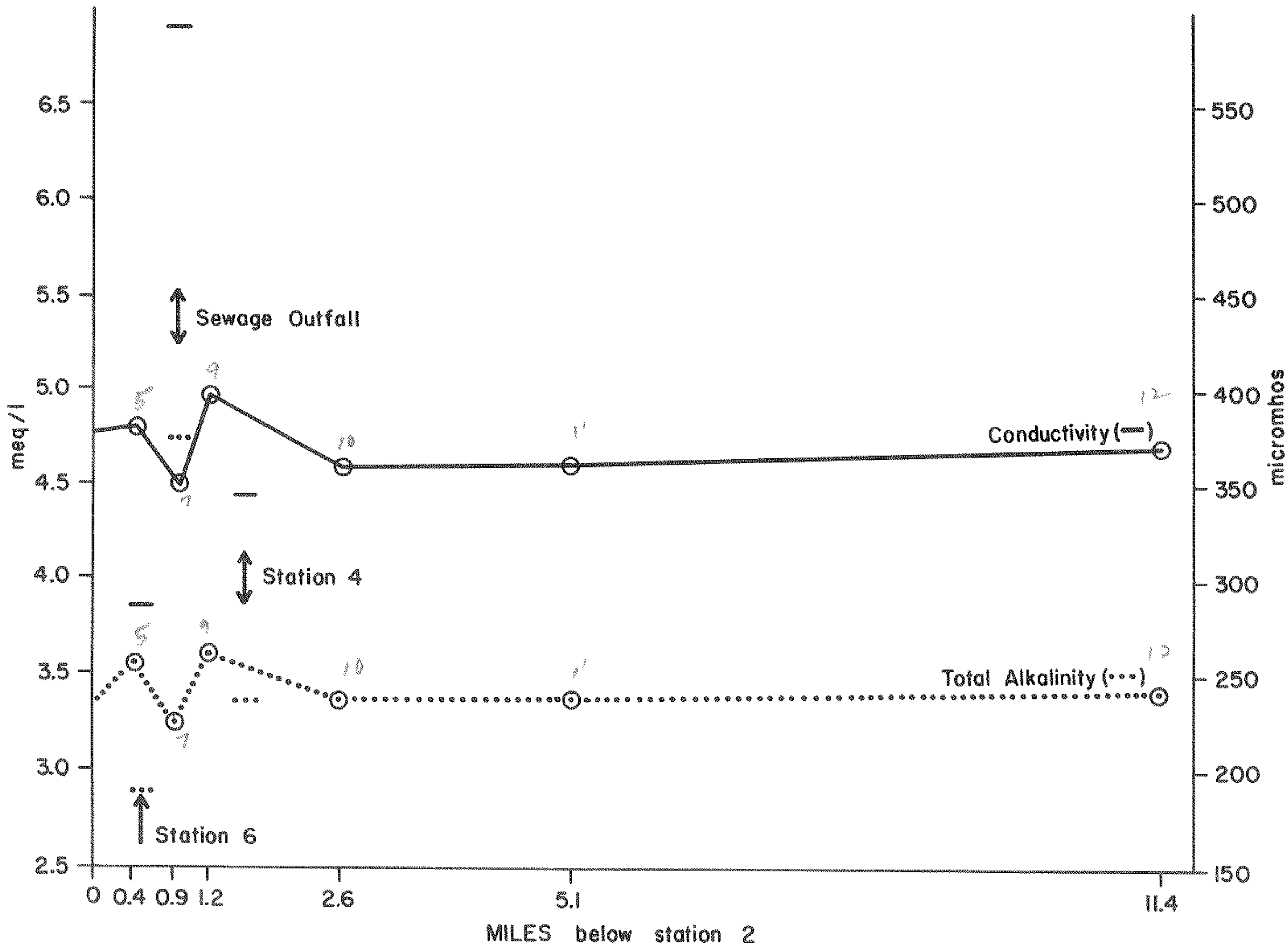

Figure 2. Average conductance at 25°C and total alkalinity at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

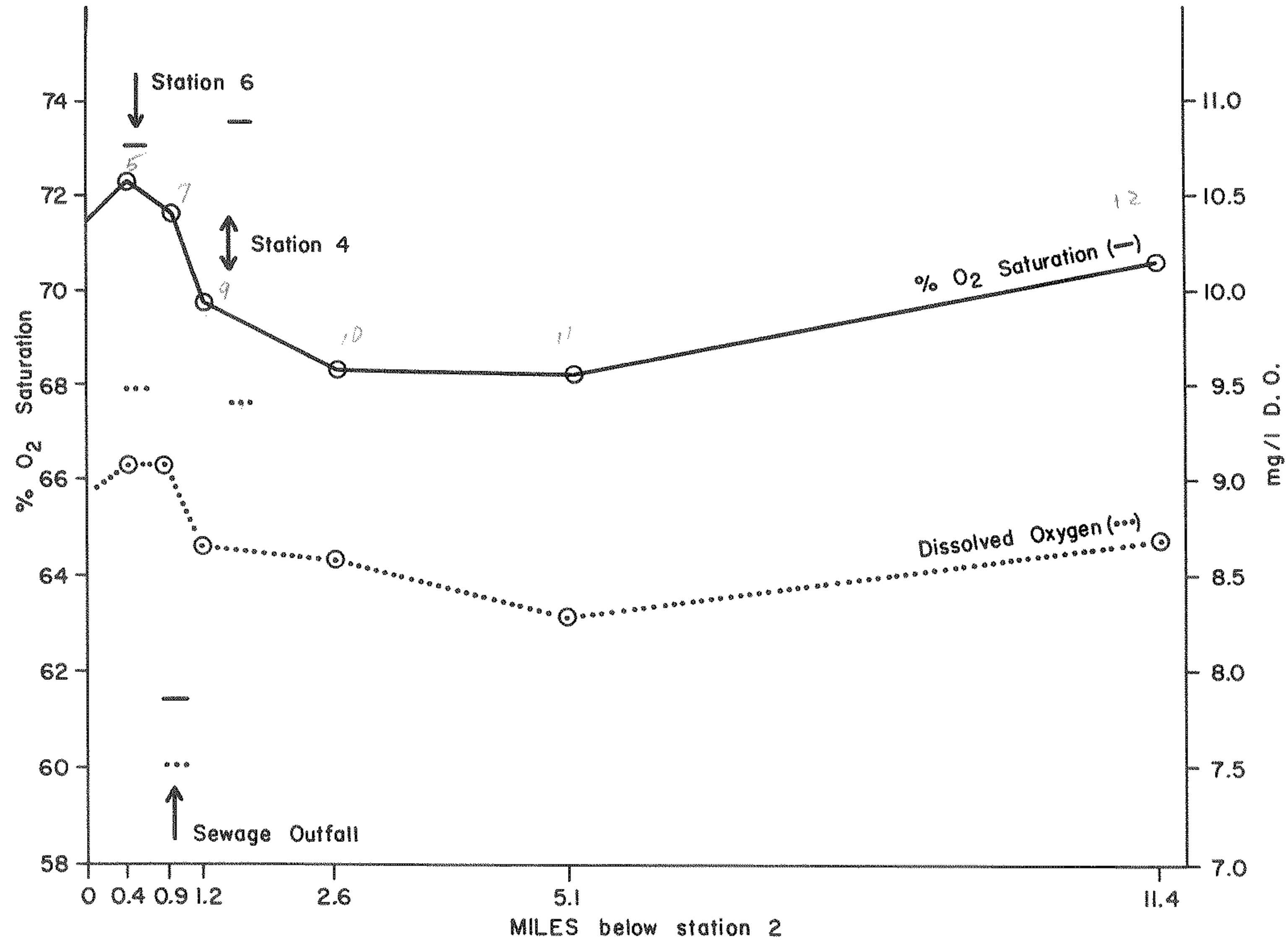

Figure 3. Average % O_2 saturation and dissolved oxygen concentration at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

waters of Bozeman Creek and Bridger Creek conditions would have been considerably worse.

The results of a 5-day B.O.D. for the Rocky Creek and East Gallatin River sampling stations is shown in Figure 4. Low B.O.D.'s are observed for 0.9 miles below station 2. A three fold rise is noted between 0.9 and 1.2 miles. This increase is probably due to the sewage outfall (Figure 4). The suspected low B.O.D. of Bridger Creek would explain the decrease between 1.2 and 2.6 miles. Another boost in the B.O.D. is noticed within 2.6 and 5.1 miles and a reduction from 5.1 to 11.4 miles.

Only forty per-cent of the B.O.D. was satisfied in the ten miles of stream sampled below the sewage outfall. Other sampling runs revealed some variation in the B.O.D. values obtained. The amount of sewage dilution, water temperature, and time of flow greatly influence B.O.D. satisfaction and the rate of stream purification (Weston, 1947).

Mean concentrations of the major metallic cations found in Rocky Creek and the East Gallatin River for the summer single sampling periods are given in Figure 5. Overall there was a reduction of calcium and magnesium downstream except for the rise in magnesium at 0.4 miles below station 2. The general reduction of these ions was attributed to the dilution effects of Bozeman Creek, Bridger Creek, and the sewage outfall in the case of magnesium. The average concentration of calcium ion at the sewage outfall was approximately 0.3 meq/1 higher than that found in the river, but since the volume of flow from the river was much greater than that of the outfall, one would expect a limited masking of the

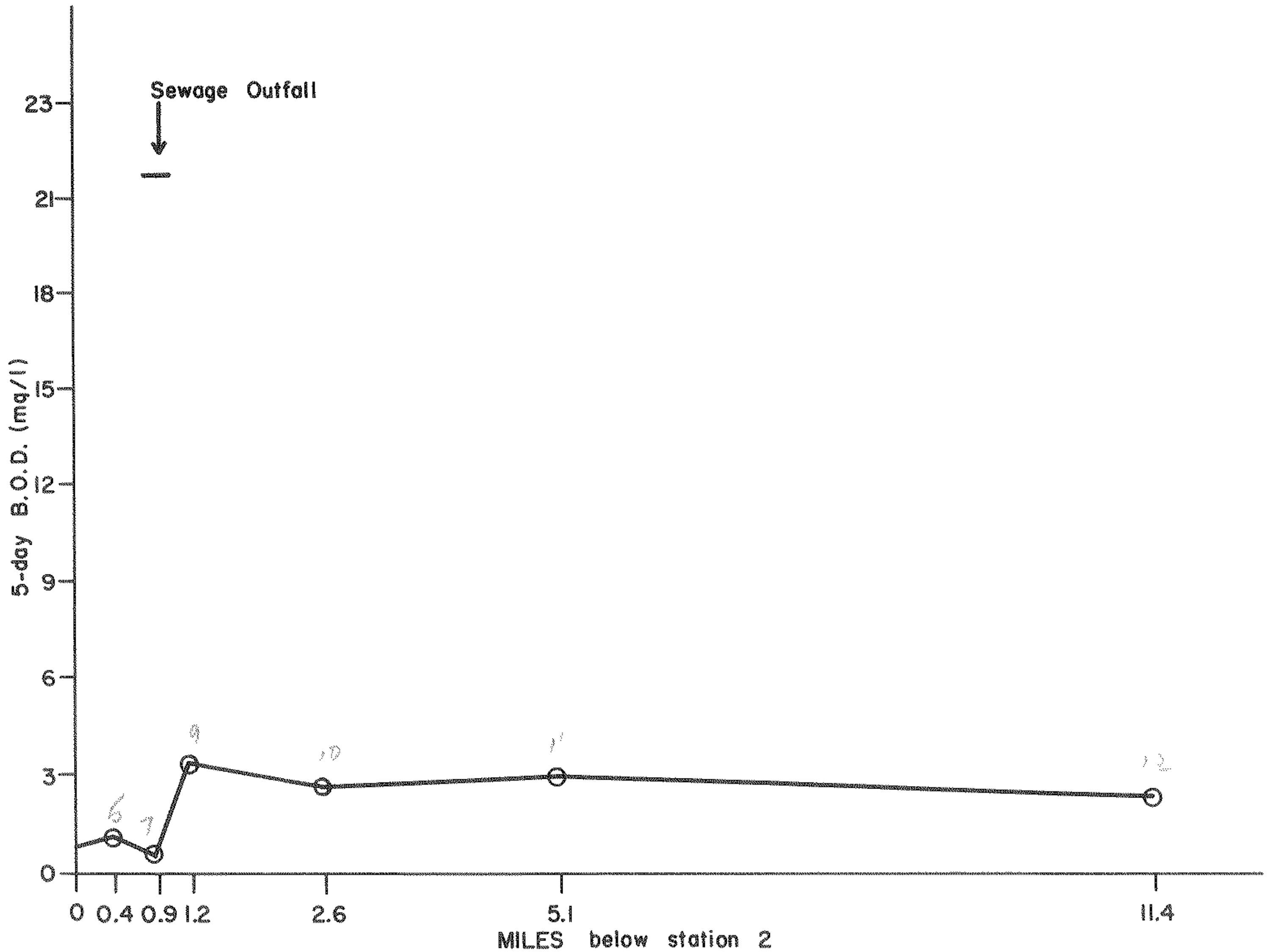

Figure 4. An example of a 5-day B.O.D. at the Rocky Creek and East Gallatin River stations during a single sampling period (8/22/67).

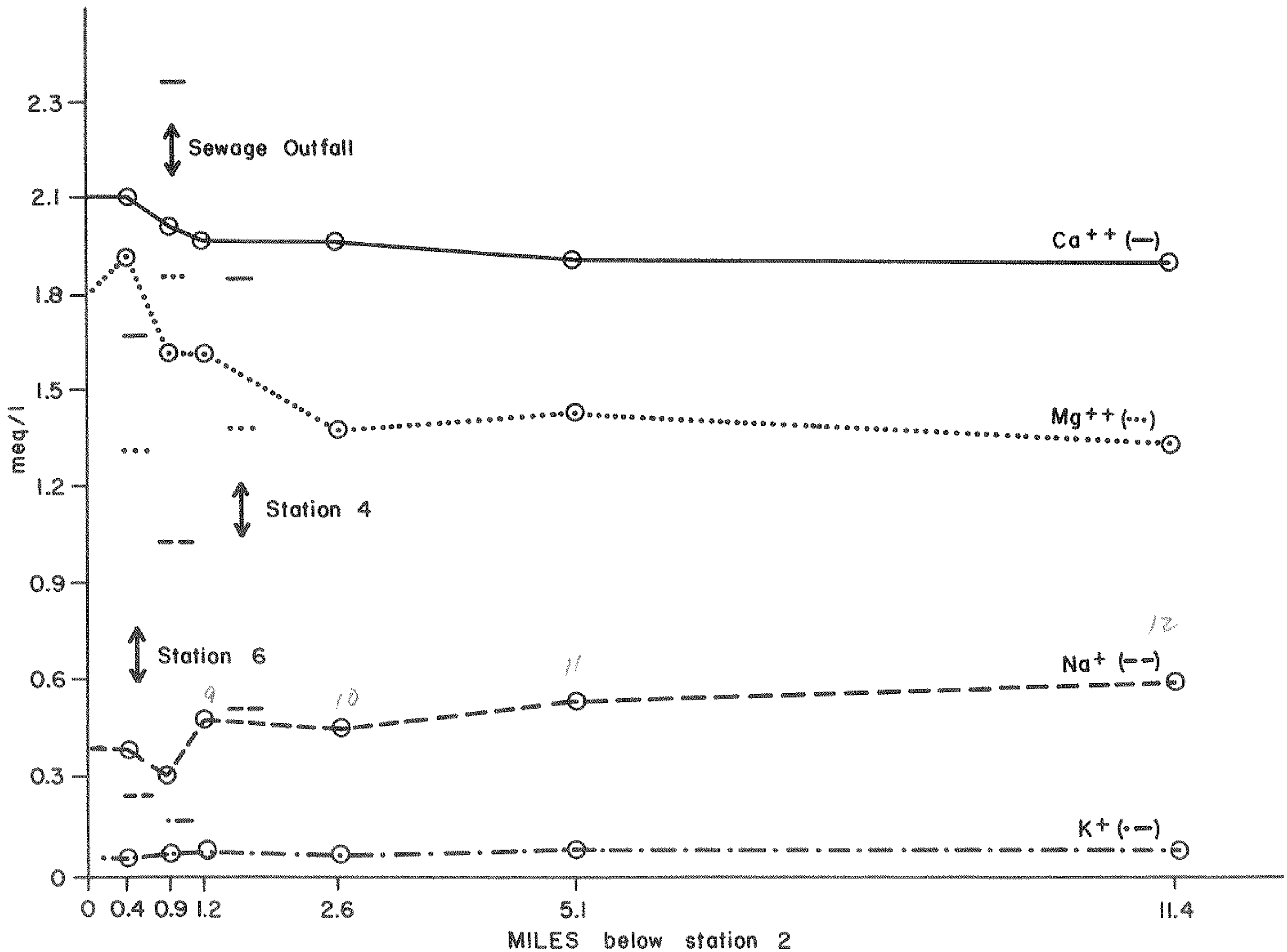

Figure 5. Average concentrations of the major metallic cations at the Rocky Creek and East Gallatin River stations during 8/8/67 - 9/12/67 for single sampling periods.

higher Ca++ concentrations found in the sewage effluent flow. Sodium was relatively constant for 0.4 miles below station 2 and declined within 0.4 and 0.9 miles due to the lesser concentrations in Bozeman Creek. Between 0.9 and 1.2 miles the stream was fortified with more sodium by the sewage outfall. This fortification was strong enough to increase the sodium ion concentrations for the ten miles sampled below the sewage outfall. Potassium ion concentrations remained essentially the same for Rocky Creek and the East Gallatin River.

Bicarbonate was the major anion for the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods as indicated in Figure 6. The effect of the Bozeman Creek outflow was noted by the decline of bicarbonate ion concentration in the reach of 0.4 to 0.9 miles. The increase of bicarbonate within 0.9 to 1.2 miles was attributed to the sewage discharge. Another decrease in concentration was shown between 1.2 and 2.6 miles, this being due again to the dilution effect of Bridger Creek. Bicarbonate remained at approximately 3.35 meq/1 at 2.6 miles through 11.4 miles.

Sulfate became less abundant downstream and it attained a new lower level of 0.42 meq/1 as compared to the higher concentration of 0.59 meq/1 found for the first 0.4 miles (Figure 6). Bozeman Creek had an average sulfate concentration of about 0.20 meq/1 while Bridger Creek had an average of approximately 0.33 meq/1. The average sulfate content of the sewage outfall for the summer was 0.59 meq/1.

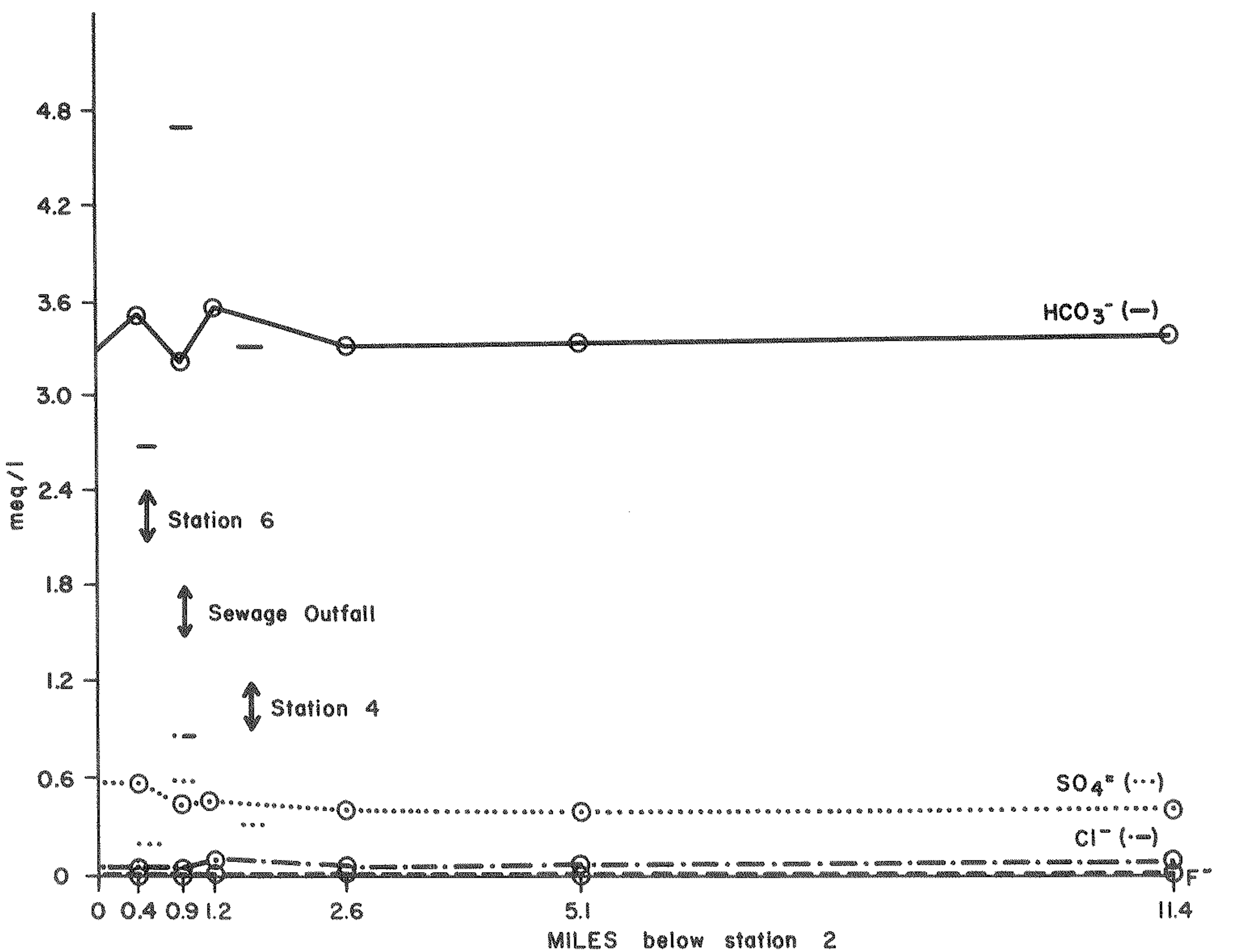

Figure 6. Average concentrations of the major anions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

The average chloride content in the upper reaches stayed relatively constant as shown in Figure 6. It increased between 0.9 and 1.2 miles and decreased between 1.2 to 2.6 miles, then remained at a level higher than that found at any of the other stations above the sewage effluent.

During the study fluoride remained essentially the same throughout the stream (Figure 6.)

Figure 7 shows the average concentration of the various carbon fractions analyzed during the summer for the single sampling periods. No major changes in the carbon content of the stream took place until the area of the sewage outfall was encountered. Due to the latter there was an increase in inorganic and soluble organic carbon and a decrease in particulate carbon. A decline in both inorganic and soluble organic carbon was noted from 1.2 through 2.6 miles, presumably because of the dilution by Bridger Creek. A small rise in particulate carbon was noted between 1.2 and 2.6 miles. Inorganic carbon increased within 2.6 to 5.1 miles and slightly from 5.1 miles to 11.4 miles. The soluble organic and particulate carbon concentrations from 2.6 miles through 11.4 miles remained about the same.

The mean inorganic carbon content at 11.4 miles was 40.8 mg/l while that at 0 miles was 38.1 mg/l (Figure 7). Soluble organic and particulate carbon had nearly the same concentration at 0 and 11.4 miles. It was found that the sewage outfall had an average of 63.9 mg/l inorganic carbon, 62.4 mg/l soluble organic carbon, and 16.3 mg/l particulate carbon for the summer.

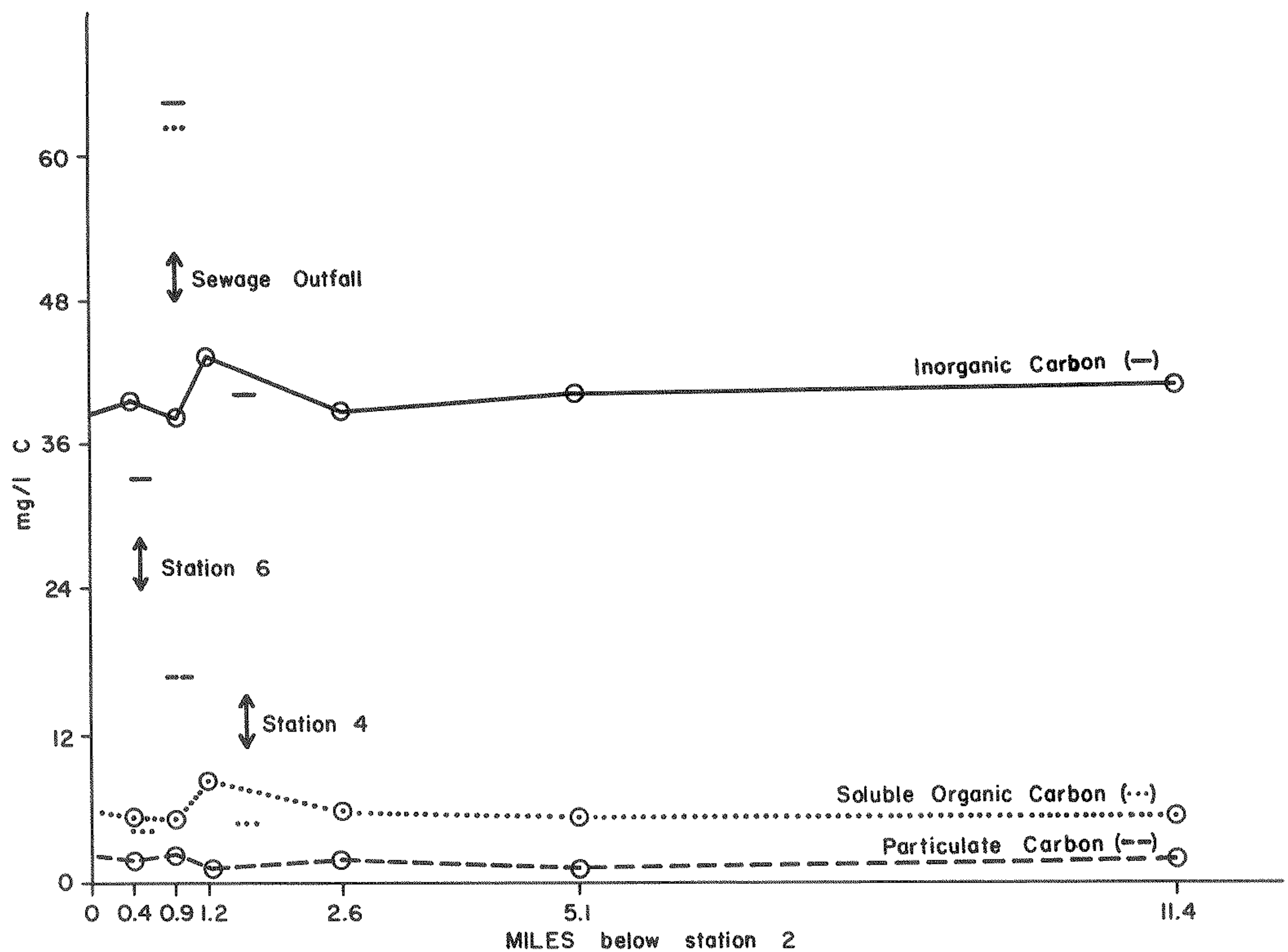

Figure 7. Average concentrations of the various carbon fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

The average of the different inorganic nitrogen fractions analyzed at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods are given in Figure 8. The mean ammonia and nitrate nitrogen concentrations fluctuated for the first 0.9 miles. There is an increase of both because of the predominant influence of the sewage outfall within the reach of 0.9 miles to 1.2 miles. The dilution effect of Bridger Creek is noted between 1.2 and 2.6 miles with the nitrate and ammonia concentrations becoming less in this section of the stream. From 2.6 miles to 5.1 miles ammonia remains approximately 0.22 mg/l while nitrate still decreases within this reach. There is a definite loss of ammonia with a corresponding increase of nitrate from 5.1 to 11.4 miles. The concentration of both substances at station 12 exceeds that found at station 2.

For the single sampling periods during the summer the sewage outfall had an average concentration of 3.13 mg/l nitrate and 2.39 mg/l ammonia.

Nitrite was almost absent in the stream until the sewage entered (Figure 8). The sewage outfall had a mean content of 0.02 mg/l of nitrite for the summer. A rise in nitrite was observed from the sewage outfall area through the remaining stations that were sampled.

The organic nitrogen analyses for the summer single sampling periods are shown in Figure 9. Soluble organic nitrogen sharply increased and particulate nitrogen abruptly decreased within the first 0.4 miles below station 2. Just the opposite of the above was observed from 0.4 miles through 2.6 miles with more gradual changes in the reach of 2.6 to 5.1

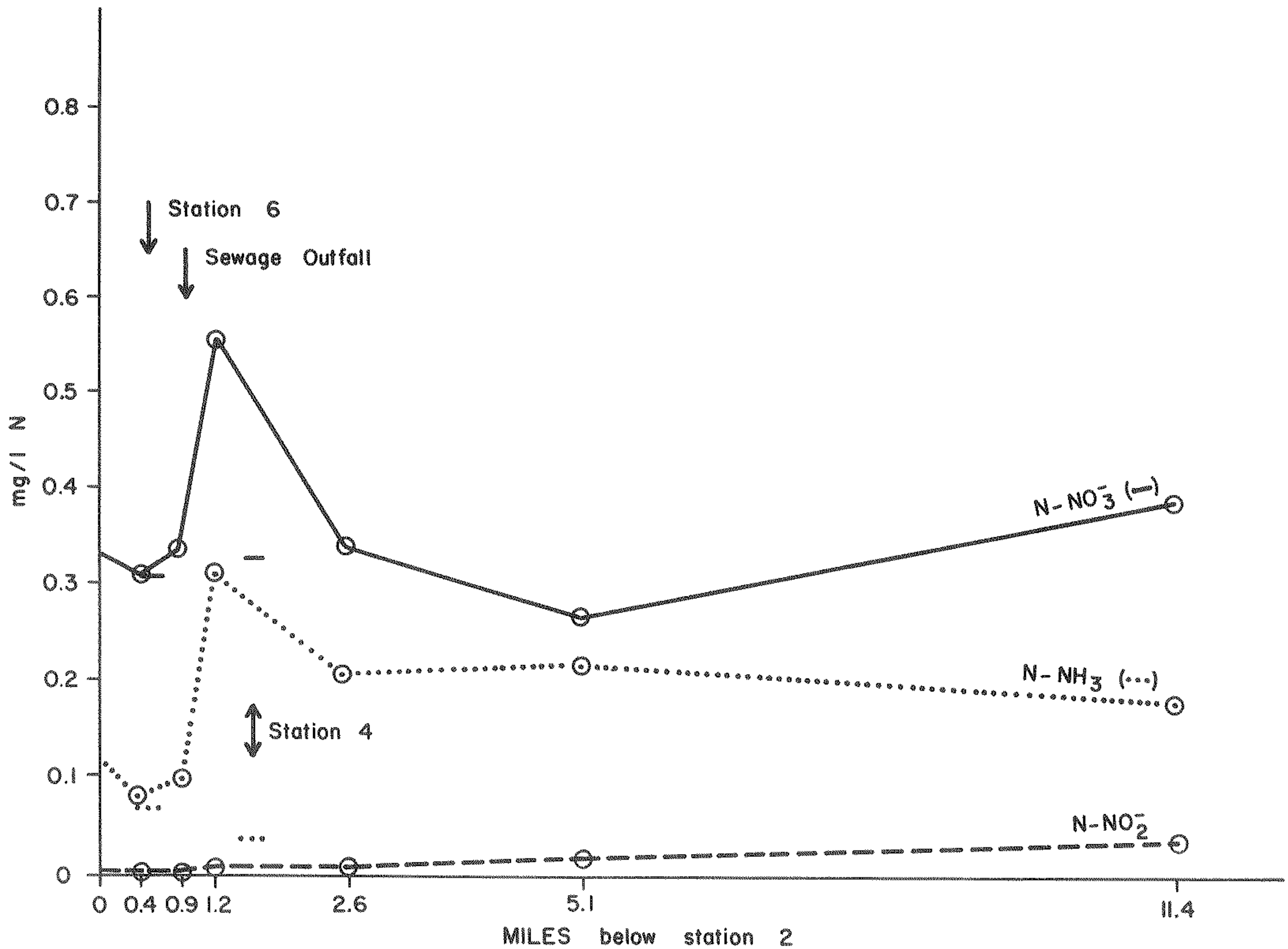

Figure 8. Average of the inorganic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

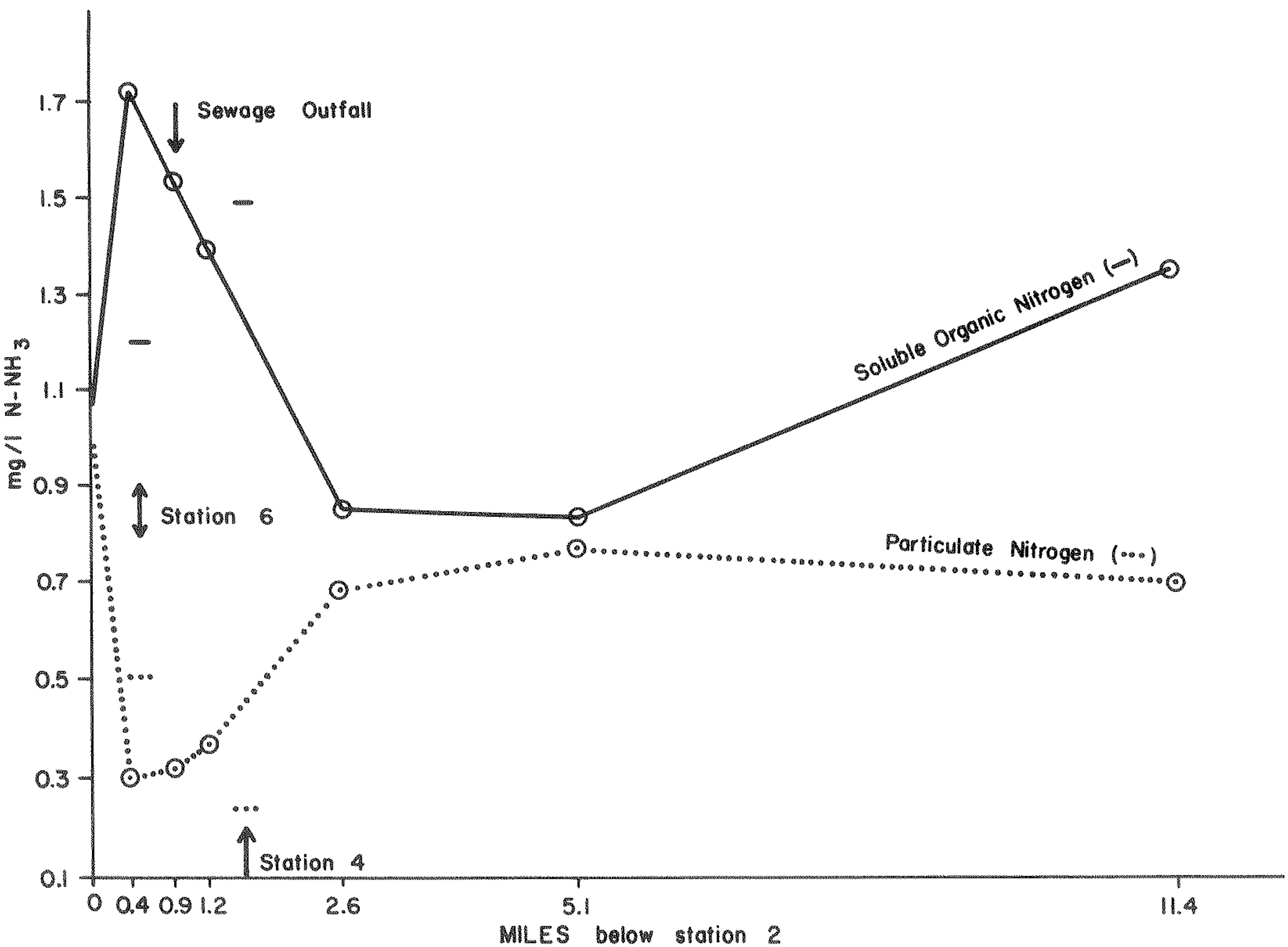

Figure 9. Average of the organic nitrogen fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

miles. Between 5.1 and 11.4 miles there was another increase of soluble organic nitrogen and a comparable decrease of particulate nitrogen.

The sewage outfall had an average concentration of 11.61 mg/l soluble organic nitrogen and 6.90 mg/l particulate nitrogen during the single sampling periods for the summer.

The mean concentrations of the various phosphate fractions are given in Figure 10 for the summer single sampling periods. Some fluctuation was observed for the first 0.4 miles downstream for all of the phosphate substances analyzed. An increase in particulate and inorganic phosphate was noted between 0.4 and 0.9 miles which was attributed to the higher concentrations found in Bozeman Creek, but a decrease in soluble organic phosphate was observed even though the average Bozeman Creek concentrations of the above was higher.

During the summer, the sewage outfall had an average of 1.28 mg/l soluble organic phosphate, 2.02 mg/l particulate phosphate, and 7.17 mg/l inorganic phosphate.

The sewage effluent discharge between 0.9 and 1.2 miles caused a rise in both inorganic and soluble organic phosphate, but a decline in the mean particulate phosphate content was found in this reach even when the sewage outfall concentrations of this fraction were greater. Apparently a sedimentation of the particulate phosphate had occurred in this stretch of stream.

The dilution effect of Bridger Creek on the river was noted with inorganic and soluble organic phosphate concentrations decreasing

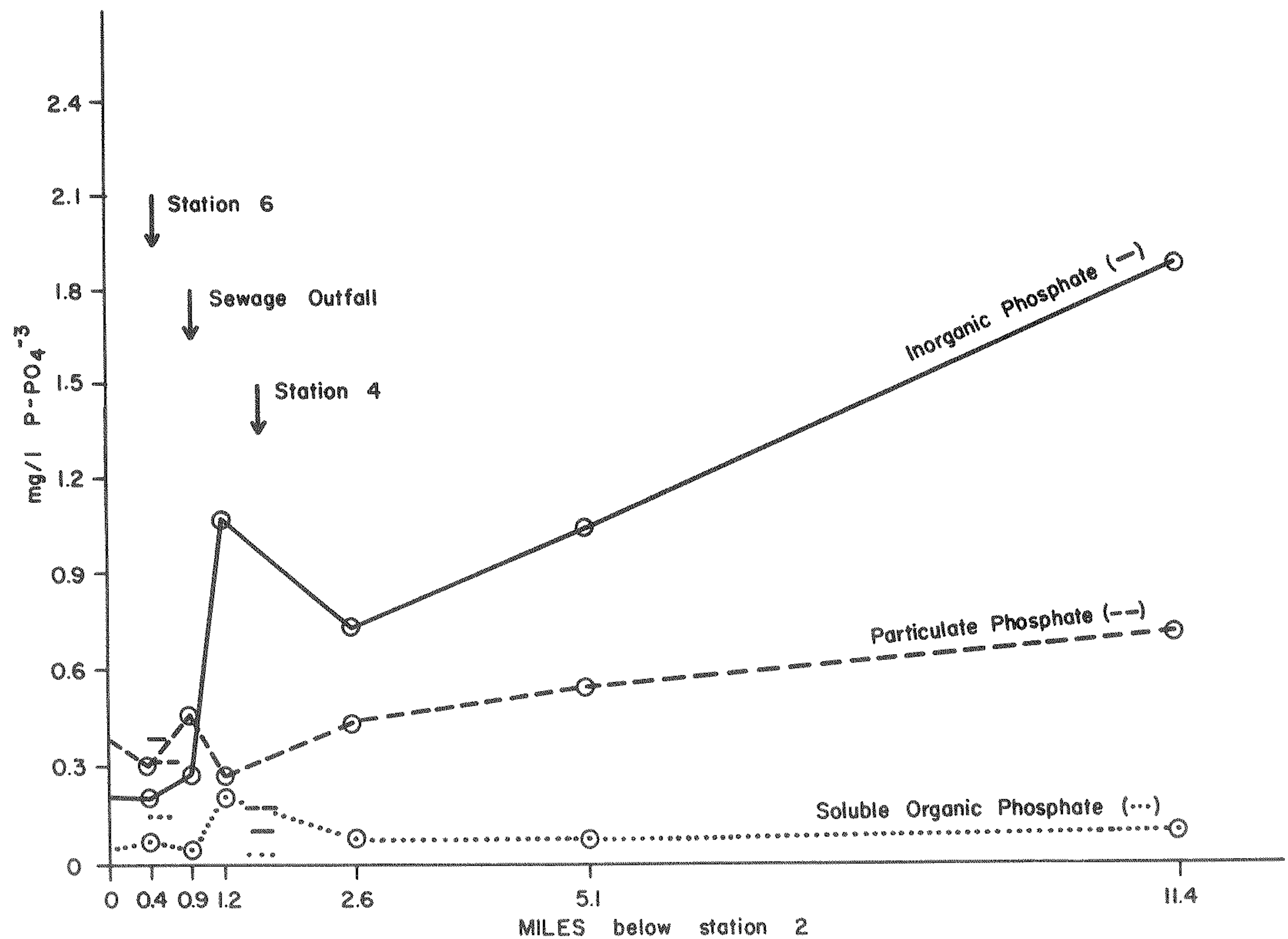

Figure 10. Average of the various phosphate fractions at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.

between 1.2 and 2.6 miles. Figure 10 shows that the average concentration of particulate phosphate in Bridger Creek was considerably lower than that found in the East Gallatin River between 1.2 and 2.6 miles and highly suggests that the former had no dilution effect on the latter. All of the phosphate fractions progressively increased from 2.6 miles through 11.4 miles with the inorganic phosphate enrichment being almost 9.5 times greater at station 12 than at station 2.

Synthetic detergents (syndets) are common constituents in solution that enter sewage and water treatment plants. A typical syndet formulation is illustrated below.

30% alky benzene sulfonate
28% polyphosphate
6% sodium silicate
35% sodium sulfate
1% carboxymethyl cellulose

The polyphosphates are used as binders and will vary with the different products (McKinny, 1957). The majority of the polyphosphates used in syndets are not detectable with the specific phosphate test (orthophosphate - stannous chloride method) employed during the course of the study.

The rapid increase downstream from the sewage outfall of inorganic phosphate (Figure 10) could be due to the hydrolysis of these polyphosphates by microbial activity to orthophosphate.

The average silica concentrations for the Rocky Creek and East Gallatin River stations during the summer single sampling periods are indicated in Figure 11. A decline is noted from 0 to 0.4 miles. The

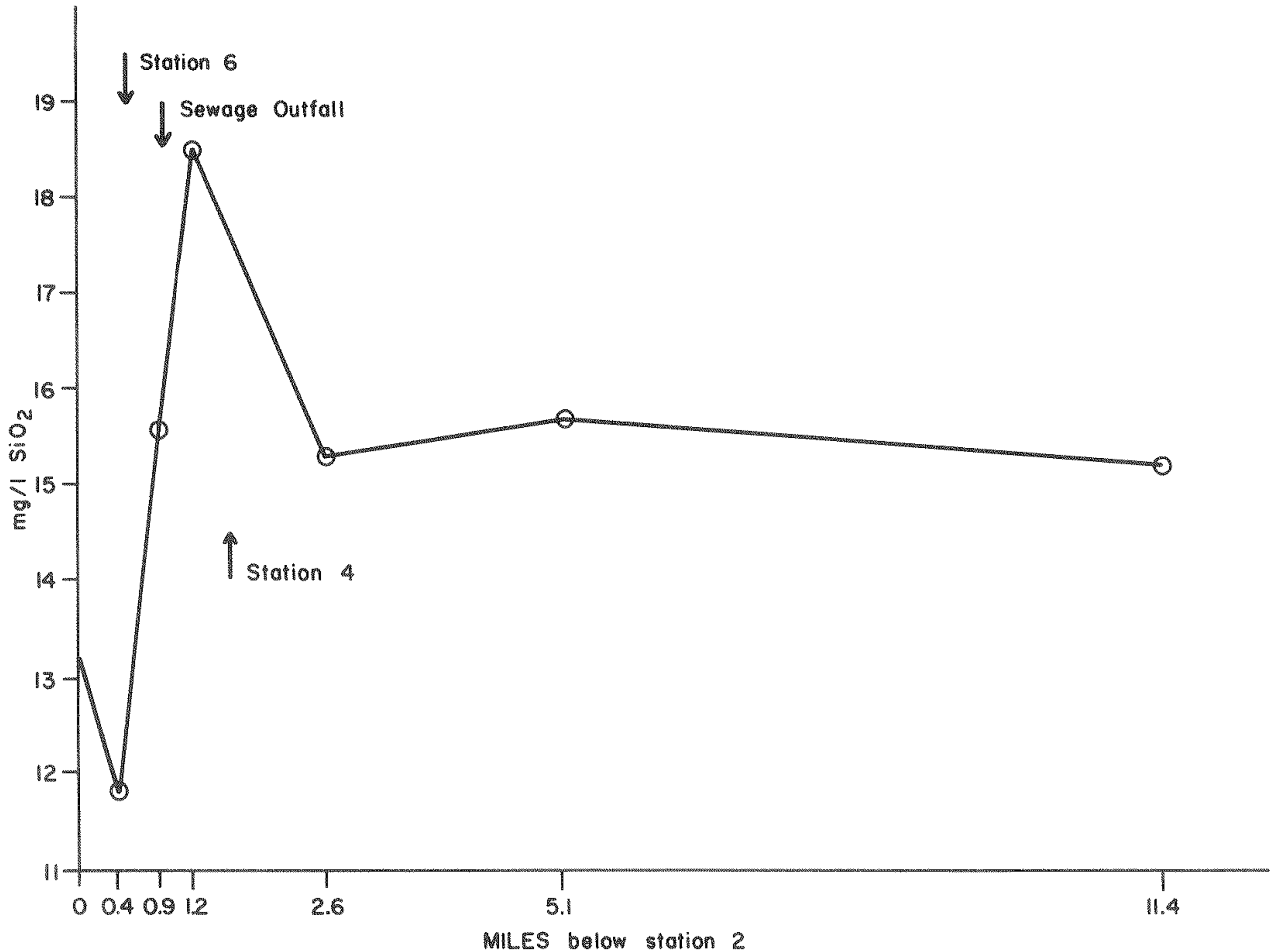

Figure 11. Average silica concentrations at the Rocky Creek and East Gallatin River stations during the summer for the single sampling periods.