WATER-QUALITY APPRAISAL

MAMMOTH CREEK AND HOT CREEK,

MONO COUNTY, CALIFORNIA

By James G. Setmire

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For those readers who may prefer metric (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
feet	0.3048	meters
ft/s (feet per second)	3.048	m/s (meters per second)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
inches	25.4	millimeters
lb (pounds)	0.4536	kg (kilograms)
miles	1.609	kilometer
mi^2 (square miles)	2.590	km^2 (square kilometers)
tons	0.9072	Mg (megagrams)
ton/d (tons per day)	0.9072	Mg/d (megagrams per day)
µmho/cm at 25°C (micromhos per centimeter at 25° Celsius)	1.000	µS/cm at 25°C (microsiemens per centimeter at 25° Celsius)

Additional abbreviations used:

col/100 mL - colonies per 100 milliliters
mg/L - milligrams per liter
mL - milliliter
AGP - algal growth potential
BOD - biochemical oxygen demand
COD - chemical oxygen demand
DO - dissolved oxygen
DOC - dissolved organic carbon
ROE - residue on evaporation
rm - river mile

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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ABSTRACT

A late summer reconnaissance in 1981 and a spring high-flow sampling in 1982 of Mammoth Creek and Hot Creek, located in the Mammoth crest area of the Sierra Nevada, indicated that three water-quality processes were occurring: (1) Mineralization, (2) eutrophication, and (3) sedimentation. Limited areas of fecal contamination were also observed. Mineralization due primarily to geothermal springs increased dissolved-solids concentration downstream, which changed the chemical composition of the water. The percentage of calcium decreased gradually, the percentage of magnesium and sodium increased, and the percentage of fluoride, sulfate, and chloride fluctuated, but increased overall. These changes produced water quality in Mammoth Creek similar to that of the springs forming Hot Creek.

Twin Lakes and the reach of Hot Creek below the fish hatchery showed evidence of eutrophication. Twin Lakes had floating mats of algae and a high dissolved-oxygen saturation of 147 percent at a pH of 9.2. Hot Creek had abundant growth of aquatic vascular plants and algae, dissolved-oxygen saturations ranging from 65 to 200 percent, algal growth potential of 30 milligrams per liter, nitrate concentration of 0.44 milligram per liter, and phosphate concentration of 0.157 milligram per liter. Eutrophication reduces the value of Mammoth Creek and Hot Creek as a cold-water habitat by depressing dissolved-oxygen saturation below 80 percent. The extensive aquatic plant growth can affect stream velocity, thereby causing deposition of fine materials that can interfer with fish feeding and spawning in the stream.

Sediment deposition was determined from detailed observations of bed-material composition, which showed that fine material was deposited at Sherwin Creek Road and downstream. Fecal contamination was indicated by fecal-coliform bacteria counts of 250 colonies per 100 milliliters and fecal-streptococcal bacteria counts greater than 1,000 colonies per 100 milliliters. Although bacterial sampling was sporadic and incomplete, it did indicate adverse effects on water quality for the following beneficial uses that have been identified for Mammoth Creek and Hot Creek: (1) Municipal supply, (2) cold-water habitat, and (3) contact and noncontact water recreation.

INTRODUCTION

Mammoth Creek originates from a series of small lakes near the Mammoth crest area of Inyo National Forest (fig. 1 [in pocket] and fig. 2). From the small mountain lakes, Mammoth Creek flows through one of California's major mountain recreation centers and continues through a highland meadow to a junction below the Hot Creek Fish Hatchery, where it becomes Hot Creek. Hot Creek courses through an area of visible thermal activity, including numerous thermal springs, fumaroles, and zones of thermally altered rock (fig. 3). From the thermal area, Hot Creek flows into Long Valley, where it joins the Owens River immediately upstream of Lake Crowley. Water from Lake Crowley represents more than 50 percent of the water entering the Los Angeles-Owens River aqueduct.

In the winter season, Mammoth Mountain is one of the most popular and heavily used ski areas in California. As many as 20,000 visitors crowd into "Mammoth" for a weekend of downhill skiing. Also, as many as 1.5 million cross-country skiers utilize the area in the winter season. During the spring and summer, the Mammoth area plays host to a large number of fishermen. Lake Crowley is particularly noted for fishing, as are Twin Lakes, Lake Mary, and Lake George. Day hiking and backpacking are also major recreational uses of the Mammoth area.

FIGURE 2. — Mammoth Mountain. Ridge in background is Mammoth Crest.

FIGURE 3. – Hot Creek gorge.

Problem

Although the Mammoth area provides a great source of recreation and enjoyment for the population of southern California (about 3 million visitor-days in the summer), such use is not without its deleterious effects. The trash and refuse deposited by summer and winter recreationists pose a considerable threat to the stability of the natural Sierra stream ecology.

Mammoth Creek has been classified by the California State Water Resources Control Board as an effluent-limited segment (El-1-A). An effluent-limited segment of this type is a stream reach that is suspected of violating the water-quality objectives requisite to maintain the stated beneficial uses. The quality of the water in Mammoth Creek is suspected of violating the numerical objectives for coliform bacteria, nutrients, and possibly sediment. The affected beneficial uses of Mammoth Creek are: (1) Municipal supply, (2) cold-water habitat, and (3) contact and noncontact water recreation. Other beneficial uses are: Ground-water recharge (Mammoth Creek and Hot Creek); agricultural use (Mammoth Creek, Lake Mary, and Hot Creek); and wildlife habitat (Mammoth Creek and its lakes and Hot Creek).

Purpose and Scope

The purpose of this report is to describe water-quality conditions in Mammoth Creek and Hot Creek. The sources and effects of these water-quality conditions are also described. The report is based on streamflow and water-quality data collected during a late-summer 1981 reconnaissance and a spring 1982 sampling of 13 sites in the Mammoth Creek-Hot Creek basin. Field observations and water-quality samples were collected to (1) define the mineral content and spacial variations in mineral quality throughout the watershed, (2) establish the extent of eutrophication, (3) determine if fecal contamination is occurring, and (4) evaluate the extent of streambed aggradation.

Approach

The reconnaissance of the Mammoth Creek area was performed September 23-29, 1981, to find any major water-quality problems that merited further investigation. The reconnaissance involved:

1. Familiarization with the area, including the geology, geography, land development, and culture.

2. Field measurements of selected physical, chemical, and biological properties, and (or) constituents during different times of the daily cycle of the aquatic system.

3. Detailed observations of the composition of streambed material and of the eutrophication of the creek.

4. Conversing with the residents of the area.

Because of the extensive aquatic vascular plant and algal growth, the large morning-afternoon dissolved-oxygen saturation variations, the apparent mineralization, and the presence of fine materials in the streambed, it was decided to proceed with a second sampling to obtain a better understanding of these conditions. This sampling was performed May 23-26, 1982, during the high-runoff period of spring snowmelt. The spring sampling also attempted to determine the seasonal variations in water quality and the loads of selected nutrients at sites along Mammoth Creek and Hot Creek.

DESCRIPTION OF STUDY AREA

The Mammoth Creek study area in Mono County is about 360 miles northeast of Los Angeles (fig. 1). The study area is bounded on the north by Lookout Mountain, Deer Mountain, Dry Creek drainage, and Owens River; on the west by Minaret Summit, Mammoth Mountain, and Mammoth crest; on the south by Mammoth crest, and Duck Lake; on the southeast by Bloody Mountain, Laurel Mountain, Convict Lake, and Convict Creek drainage; and on the east by Long Valley. The study area comprises 85.5 mi^2 of prime mountain recreational land. From its headwaters to the junction with Hot Creek, Mammoth Creek is approximately 15 miles long, and from there Hot Creek runs 7 miles to the Owens River. The altitude of the creek ranges from 10,960 feet in the headwaters at the drainage divide to 6,840 feet at the junction with Owens River (fig. 4).

Mammoth Creek joins Hot Creek below the Hot Creek Fish Hatchery. Hot Creek, which is fed by waters from four major springs, serves as the major water supply for the fish hatchery. After circulation through the hatchery, the water is discharged to Mammoth Creek, which then becomes Hot Creek.

The average annual air temperature in the study area for the last 10 years has been about 5.6°C with high temperatures of about 32.2°C and low temperatures of about -29.4°C. Total precipitation averages about 10 inches per year, although with a study-area altitude greater than 7,000 feet, most of the precipitation occurs as snowfall. Because the lakes in the area usually freeze over each year and snowfall is the dominant form of precipitation, most of the runoff occurs during the spring as a result of snowmelt. The Mammoth area is also often subject to high winds, especially in the afternoons.

DATA COLLECTION

Sample Collection

Water samples for field measurements and laboratory analyses were collected at the sites shown in figure 1 according to U.S. Geological Survey standard methods. With the exception of below Lake Mamie and between Twin Lakes, all sites were wadable for both sample collection and streamflow measurement. A handheld depth-integrating sampler (DH-48) and the equal-width-increment (EWI) method were used for sample collection. Water from the sampler was composited into a churn splitter prior to processing. Samples for bacteria were collected in sterilized glass bottles. Samples for DOC (dissolved organic carbon) were collected in glass bottles that were baked at 350°C to remove organics.

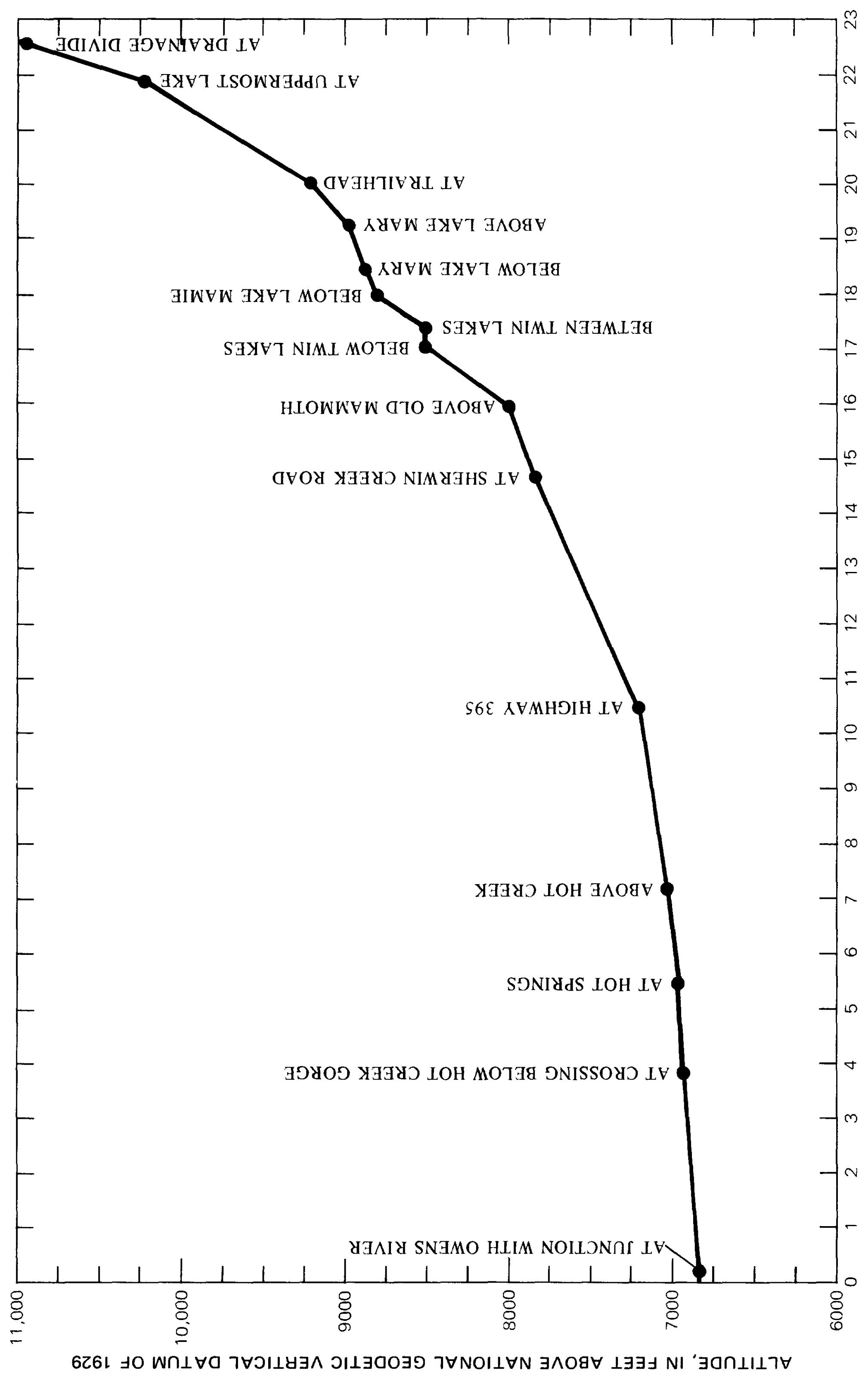

FIGURE 4. — Altitude at selected sites along Mammoth Creek and Hot Creek.

Field and Laboratory Methods

Field determinations of specific conductance, water temperature, DO (dissolved oxygen) concentration, and pH were made according to standard U.S. Geological Survey procedures. Alkalinity was determined in the field using the method of electrometric titration to a pH of 4.5. Tests for fecal-coliform and fecal-streptococcal bacteria were performed according to methods specified in Greeson and others (1977). Samples for laboratory analysis were sent to the U.S. Geological Survey's Central Laboratory at Arvada, Colo. Methods for analysis of most constituents are as specified in Skougstad and others (1979).

Site Selection

Prior to the reconnaissance, tentative sampling sites were selected from U.S. Geological Survey topographic maps. This initial site selection was made on the basis of features such as lakes, major gradient changes, land use, and tributary inflow. At the start of the reconnaissance, a survey of the area was used to confirm, add to, or subtract from the tentative list of sites. The chosen sites are given in table 1.

Sampling Program

Samples were collected at the reconnaissance sites to determine the following constituents:

Chemical oxygen demand

Nitrogen, dissolved NO_2 + NO_3 as nitrogen

Nitrogen, dissolved ammonium as nitrogen

Nitrogen, total ammonium + organic nitrogen as nitrogen

Phosphate, dissolved ortho as phorphorus

Phosphorus, dissolved

Phosphorus, total

Residue on evaporation at 180°C

TABLE 1. - *Mammoth Creek and Hot Creek site location and altitude information*

Site	Distance from downstream site, in miles	River mile, cumulative distance from confluence with Owens River	Altitude, in feet
Mammoth Creek			
at trailhead	0.8	19.9	9,200
above Lake Mary	.8	19.1	8,960
below Lake Mary	.3	18.3	8,880
below Lake Mamie*	.7	18.0	8,880
between Twin Lakes*	.3	17.3	8,570
below Twin Lakes	1.1	17.0	8,560
above Old Mammoth	1.4	15.9	8,000
at Sherwin Creek Road	3.9	14.5	7,840
at Highway 395	3.5	10.6	7,200
above Hot Creek	0	7.1	7,040
Hot Creek			
below hatchery	1.8	7.1	7,040
at hot springs	1.5	5.3	6,960
below hot springs at crossing	3.8	3.8	6,925

*Spring sampling only.

An additional set of samples for nutrient analysis was collected over the weekend at each of the sites. The purpose of this set of samples was to determine any immediate effect of weekend recreational use on water quality in the Mammoth Creek-Hot Creek system. Unfortunately, by the date that the reconnaissance was performed, recreational use in the Mammoth Lakes area had dramatically tapered off so that the weekend sampling did not meet its objectives.

Field measurements for the determination of DO concentration, specific conductance, pH, and temperature were made at each site. An attempt was also made to determine, at least to a limited degree, the biological productivity of the aquatic system. DO concentration was measured at selected sites in the early morning, when percent saturations are probably low after a night of respiration and again in the afternoon when photosynthetic activity is at or near its peak. The DO percent-saturation levels can help to pinpoint areas of significant biological activity.

The spring 1982 sampling was performed in May, when runoff from snowmelt was close to its peak. Sites for the spring sampling were similar to those of the reconnaissance except for the addition of two sites: Mammoth Creek below Lake Mamie and Mammoth Creek between Twin Lakes. Analysis for dissolved-organic carbon was substituted for COD (chemical oxygen demand). Mineral analysis for major cation and anions was added at selected sites where changes in the chemical composition of the water were suspected. Nutrients analysis and field measurements were the same as for the reconnaissance.

Samples were also collected at selected sites to determine algal growth potential (AGP), which is reported as maximum standing crop in milligrams dry weight algae per liter. The technique is described by Greeson and others (1977): "A 100 mL aliquot of a water sample is field filtered and placed in a covered Erlenmeyer flask. This sample is innoculated with an appropriate number of algal cells of a known species and incubated under constant temperature and light intensity until the rate of growth is less than 5 percent per day." A particle counter is then used to determine the maximum standing crop.

RESULTS AND DISCUSSION

The reconnaissance was performed in late summer, September 23-29, 1981, a time when many streams exhibit their poorest water quality. Streamflow is usually at its lowest point of the water year, and the lakes that compose the upper Mammoth Creek system (the area upstream of and including the site below Twin Lakes) have received a summer of heavy recreational use. With water temperatures at their maximum, DO saturation levels are lower and BOD (biochemical oxygen-demand) rates higher than at any other time during the year. If sufficient nutrients are available, algae blooms occur and incorporate much of those available nutrients into their cellular mass. High daytime photosynthetic activity and high nighttime respiration can cause large fluctuations in DO concentrations, which can cause stress to aquatic organisms such as fish.

The spring sampling was performed May 23-26, 1982, and presented a different set of hydrologic conditions. The upper lakes were still frozen, so that biological activity was minimal. DO saturation levels were higher as a result of lower water temperatures. Little diel variation in DO concentration was observed. Discharge resulting from snowmelt was at or near its maximum, 24 ft^3/s at the trailhead site compared to <5 ft^3/s during the reconnaissance, indicating that nutrient loads might be at their maximum.

Mineralization

Considerable mineralization occurs in Mammoth Creek from the headwaters to the junction with Owens River. No cation or anion determinations were made for the reconnaissance, only specific conductance and dissolved solids (residue on evaporation). Without the cation and anion concentrations, no statement can be made about the composition of the inflow to Mammoth Creek and Hot Creek, only that the effect is to increase the mineral content. Mineral content apparently increases in three reaches, as is shown in figure 5 and table 2. In September 1981, specific conductance of the water released from Twin Lakes increased 204 percent over that from Lake Mary. Water entering Lake Mary via Mammoth Creek at the trailhead (rm 19.9) had a specific conductance of 65 μmho/cm at 25°C and a ROE (residue on evaporation) of 38 mg/L; the water released from Lake Mary (rm 18.3) had a specific conductance of 46 μmho. The discharge from Lake Mary enters Lake Mamie, a shallow lake approximately 0.3 mile long, which in turn empties into Twin Lakes. The specific conductance for the discharge from Twin Lakes was 140 μmho and the ROE was 78 mg/L.

The next major increase in mineral concentration occurs in the reach between Highway 395 (rm 10.6) and the site upstream of Hot Creek (rm 7.1). The specific conductance increased almost 87 percent, from 135 μmho/cm at 25°C at Highway 395 to 252 μmho above Hot Creek. The ROE increased 130 percent from 87 to 200 mg/L. Specific conductance increased 118 percent in the reach between the fish hatchery (rm 7.1) and the hot springs (rm 5.3). Specific conductance increased from 252 μmho and a ROE of 200 mg/L at the Mammoth Creek site upstream of the junction with Hot Creek (rm 7.1) and 218 μmho and a ROE of 164 mg/L at the Hot Creek below the hatchery site (rm 7.1) to 475 μmho and a ROE of 325 mg/L at the hot springs (rm 5.3).

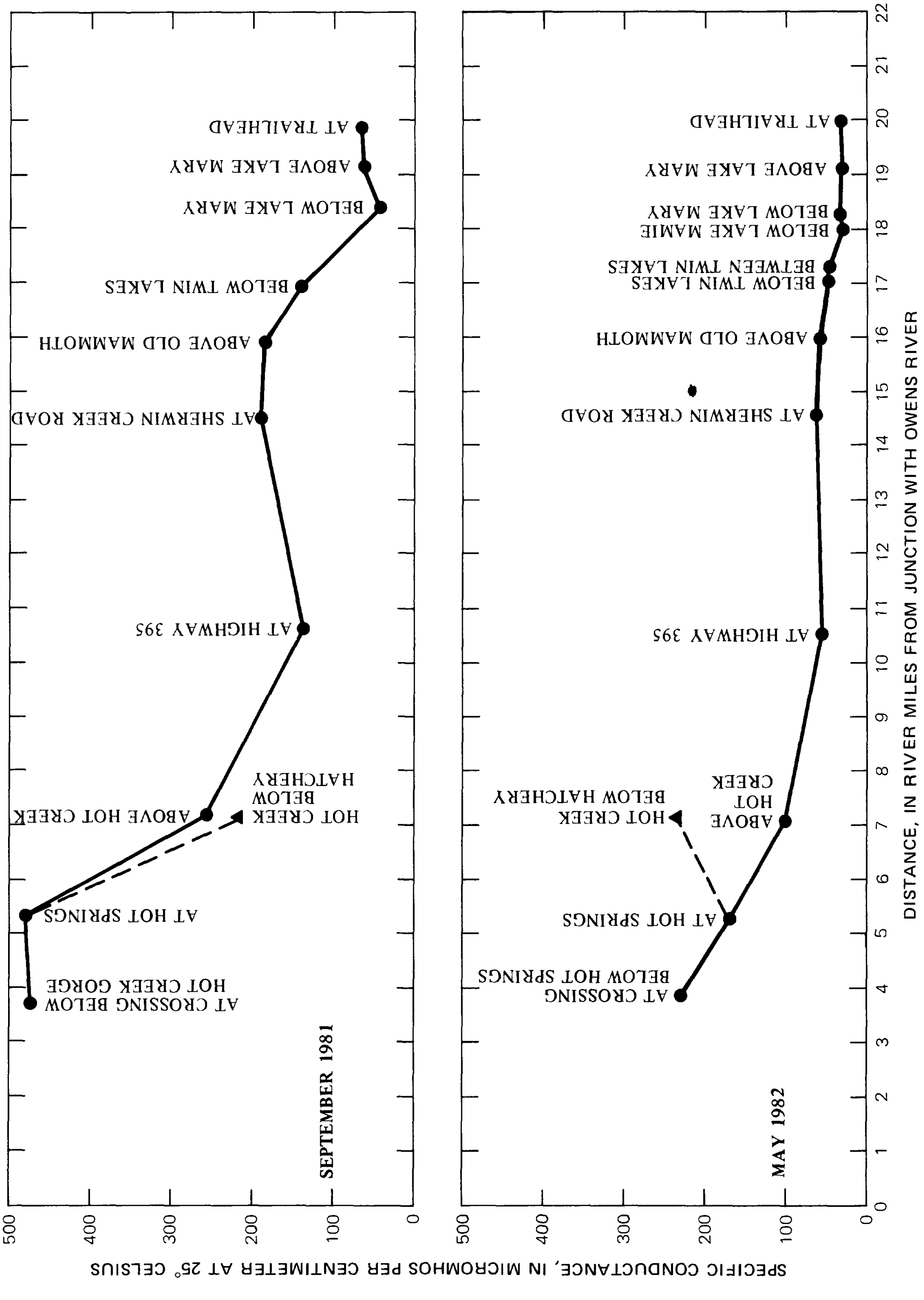

FIGURE 5. – Specific conductance at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance, and May 1982 spring high-flow sampling.

TABLE 2. - *Selected physical properties and chemical concentrations at sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance*

River mile	Site	Date	Time	Specific conductance (µmho/cm at 25°C)	pH	Water temperature (°C)	Dissolved oxygen (mg/L)	Chemical oxygen demand (mg/L)	Residue on evaporation at 180°C (mg/L)	Dissolved nitrite plus nitrate as N (mg/L)	Total nitrogen as N (mg/L)	Dissolved ammonium as N (mg/L)	Total phosphorus as P (mg/L)
	Mammoth Creek												
19.9	at trailhead	9-24	1145	65	7.7	9.8	11.1	54	38	0.14	0.72	0.17	0.01
18.3	below Lake Mary	9-24	0910	46	7.1	12.7	10.1	--	--	--	--	--	.01
17.0	below Twin Lakes	9-24	1300	204	9.2	10.2	15.4	52	78	.12	.69	.13	.01
15.9	above Old Mammoth	9-25	1600	185	7.6	9.8	9.7	55	112	.18	.60	.24	.05
14.5	at Sherwin Creek Road	9-25	1710	185	7.8	12.5	--	--	--	--	--	--	--
10.6	at Highway 395	9-25	1800	135	8.0	10.4	10.4	65	87	.21	.63	.29	.01
7.1	above Hot Creek	9-28	1140	252	8.1	15.4	11.4	63	200	.15	.65	.14	.08
	Hot Creek												
7.1	below hatchery	9-28	1115	218	7.4	14.7	9.0	65	164	.33	1.43	.31	.23
5.3	at hot springs	9-29	0830	475	7.0	26.2	7.0	73	325	0.28	1.05	0.19	.14
3.8	below hot springs at crossing	9-28	1350	470	--	30.8	14.2	--	--	--	--	--	0.15

During the May 1982 spring high-flow sampling, there was little variation in the specific conductance at the upper Mammoth Creek sites, from the trailhead (rm 19.9) to below Lake Mamie (rm 18.0), (fig. 5 and table 3). The specific conductance was about 30 μmho. Results of mineral analyses from samples collected at these sites showed little variation in cation and anion concentrations (fig. 6 and table 4). Water composition was predominatly calcium carbonate (table 4). The first significant increase in mineral concentration, accompanied by a 52 percent increase of specific conductance, occurred in the reach from below Lake Mamie (rm 18.0) to below Twin Lakes (rm 17.0). The largest increase, about 510 percent, was in magnesium, which rose from 0.18 mg/L to 1.1 mg/L. Other anions and cations increased between 26 and 125 percent, although sulfate and fluoride apparently did not increase.

The second major increase in mineral concentrations during the May 1982 sampling occurred between Highway 395 (rm 10.6) and the site above Hot Creek (rm 7.1) (figs. 5 and 6 and table 4). Specific conductance increased 86 percent, from 57 to 106 μmho. One of the major compositional changes was in the chloride ion concentration, which increased about 530 percent, from 0.38 mg/L to 2.4 mg/L (table 4).

The chemical composition of the springs forming Hot Creek differed from the composition of the water in the upper reach of Mammoth Creek (upstream from the site below Twin Lakes). Hot Creek had 21 percent sodium, compared to 7-8 percent for upper Mammoth Creek (table 5). Calcium, potassium, and magnesium also differed greatly in percent-ion composition between upper Mammoth Creek and Hot Creek below the hatchery. Specific conductance increased 60 percent from 106 μmho at Mammoth Creek above Hot Creek to 170 μmho at Hot Creek at the hot springs (table 3). At Hot Creek below hatchery, immediately upstream from the junction of Hot Creek and Mammoth Creek, specific conductance was 234 μmho, which was 221 percent of the specific conductance at Mammoth Creek above Hot Creek and 138 percent of the specific conductance of Hot Creek at the hot springs. Water from springs near the hatchery makes up the flow at Hot Creek below the hatchery. From Hot Creek at hot springs (rm 5.3) to Hot Creek below the hot springs at the crossing (rm 3.8), specific conductance increased by about 39 percent (170 to 236 μmho) (table 3). No samples for mineral analyses were collected below hot springs at the crossing site.

Inspection of the data from the reconnaissance and the spring high-flow sampling indicates that mineralization is occurring in the Mammoth Creek-Hot Creek system. Evidence of mineralization included an increase in specific conductance from the headwaters to the junction with Owens River. Increases in the dissolved-solids concentration of Mammoth Creek and Hot Creek from the sources of these creeks to their mouths resulted from the inflow of water from geothermal areas. A downstream increase in dissolved-solids concentration is a familiar pattern for many streams that have their headwaters in mountain areas and that flow through an urban area. Generally, the dissolved-solids increase in many of these streams is from weathering or water use, not from geothermal springs.

TABLE 3. - *Field measurements at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Date	Time (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C)	pH	Water temperature (°C)	Dissolved oxygen (mg/L)	Dissolved oxygen saturation (percent)
Mammoth Creek								
at trailhead	5-23	1030	24.2	31	7.2	2.0	11.5	101
above Lake Mary	5-23	1200	24.2	30	7.2	2.0	13.0	114
below Lake Mary	5-23	1500	52.5	33	6.9	1.0	11.0	95
below Lake Mamie	5-24	0815	32	31	7.2	1.5	12.1	104
between Twin Lakes	5-24	0955	--	47	7.2	3.0	10.3	104
below Twin Lakes	5-24	1135	78.3	49	7.3	5.0	10.8	115
above Old Mammoth	5-24	1340	86.7	58	7.0	6.5	11.8	128
at Sherwin Creek Road	5-24	1500	104	62	7.4	9.0	9.9	112
at Highway 395	5-25	0805	102	57	8.0	5.5	10.2	105
above Hot Creek	5-25	1350	96.1	106	7.9	18.0	8.6	116
Hot Creek								
below hatchery	5-25	1310	40.8	234	7.6	17.0	9.4	120
at hot springs	5-25	1545	174	170	7.9	21.0	9.5	136
below hot springs at crossing	5-26	0900	206	236	7.6	17.0	8.4	112

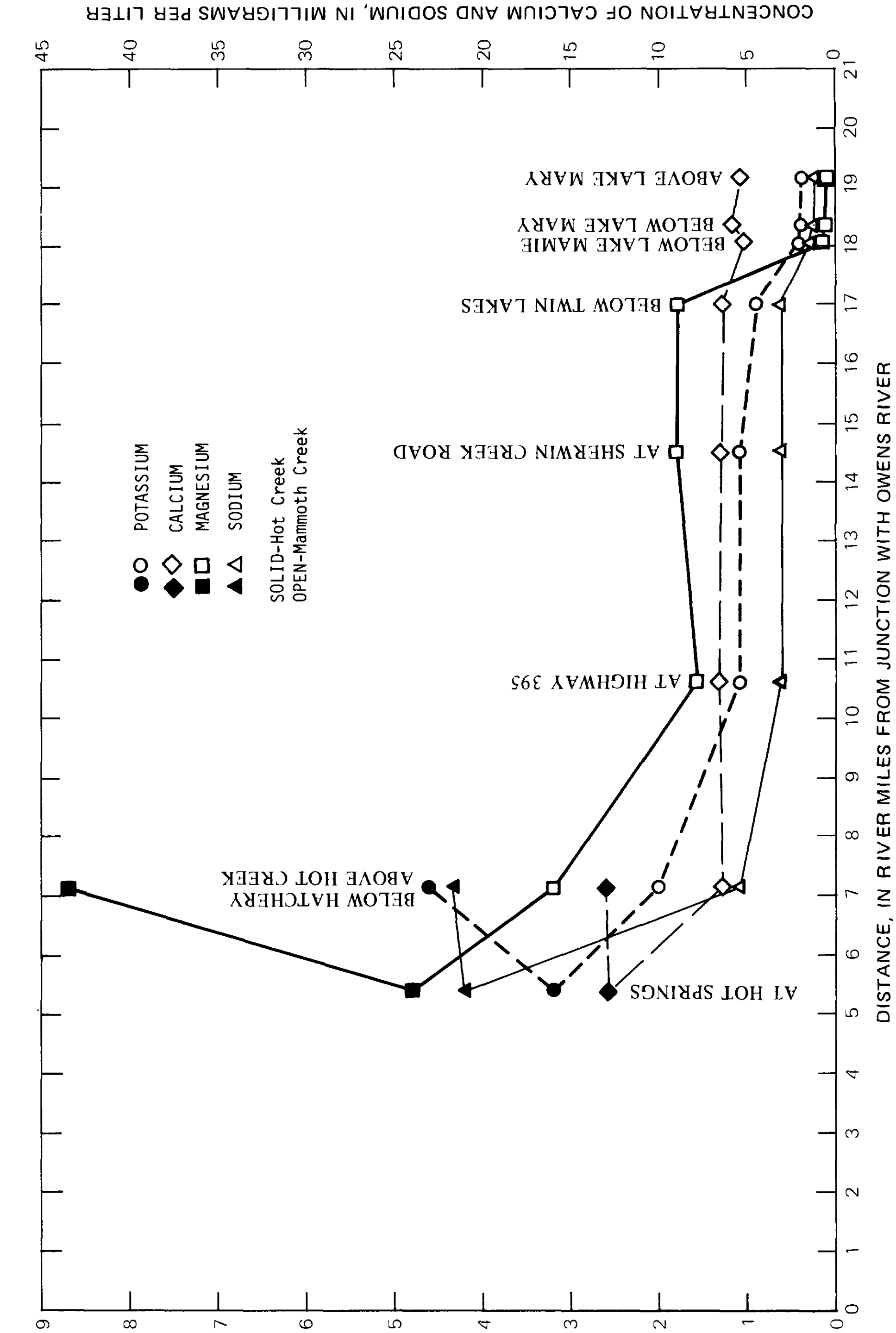

FIGURE 6. — Concentration of cations at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling.

TABLE 4. - *Cation and anion concentrations at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

[Constituents in milligrams per liter except specific conductance in micromhos per centimeter at 25°C]

Site	Specific conductance	Calcium	Magnesium	Sodium	Potassium	Alkalinity	Chloride	Fluoride	Sulfate
Mammoth Creek									
above Lake Mary	30	5.4	0.14	1.1	0.4	14	0.37	<0.1	<5
below Lake Mary	33	5.9	.16	1.2	.4	16	.24	<.1	<5
below Lake Mamie	31	5.3	.18	1.2	.4	15	.31	<.1	<5
below Twin Lakes	49	7.2	1.1	2.3	.9	28	.39	.1	<5
at Sherwin Creek Road	62	6.4	1.8	3.3	1.1	30	.38	<.1	<5
at Highway 395	57	6.5	1.6	3.2	1.1	32	.38	<.1	<5
above Hot Creek	106	8.6	3.2	7.3	2.0	--	2.4	.2	5
Hot Creek									
below hatchery	234	13.0	8.7	24.0	4.6	101	6.1	.3	8
at hot springs	170	11.0	4.8	21.0	3.2	--	--	--	--

TABLE 5. - *Percentage composition[1,2] of cations and anions at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Potassium	Calcium	Magnesium	Sodium	Fluoride	Sulfate	Nitrate	Chloride	Bicarbonate
Mammoth Creek									
above Lake Mary	1.6	42.8	1.9	7.6	0	0	0	1.6	44.5
below Lake Mary	1.4	42	1.9	7.5	0	0	0	1.0	46
below Lake Mamie	1.5	40.6	2.3	8.0	0	0	0	1.4	46
below Twin Lakes	2.0	31.2	7.8	8.7	.4	0	0	.9	48.7
at Sherwin Creek Road	2.2	25.5	11.8	11.5	0	0	0	.9	48
at Highway 395	2.2	25.4	10.4	10.9	0	0	0	.9	50.2
above Hot Creek	2.4	20.2	12.4	15.0	.5	4.9	0	3.2	41.4
Hot Creek									
below hatchery	2.4	13	14.5	21.2	.3	3.4	.5	3.5	41

[1]Calculated by total ion milliequivalents.
[2]When chemical constituents were found to be less than their lower limit of detection, their milliequivalents per liter concentrations were set to equal zero for these computations.

Geothermal activity is visible in the Hot Creek gorge, where there are numerous fumaroles; it is also seen to a lesser degree in the reach between Highway 395 and the fish hatchery (fig. 3). Geothermal springs increase the dissolved-solids concentration in the stream water. This increase was more evident in the reconnaissance than in the spring high-flow sampling, because baseflow conditions provided less of a buffer to the dissolved-solids increase than the high-flow (maximum discharge observed was 200 ft^3/s) conditions observed during the spring sampling, which occurred at or near peak snowmelt runoff.

Water from snowmelt runoff in the upper reaches of the Mammoth Creek drainage was primarily calcium carbonate. Water composition was 42.8 percent calcium and 44.5 percent bicarbonate at the site above Lake Mary (table 5). The contribution by other ions is minimal. As has been mentioned earlier, the first ionic concentration and compositional changes in the water occur in Twin Lakes. The calcium decreases from 42.8 percent at the site above Lake Mary to 31.2 at the site below Twin Lakes. Despite this percent decrease in one of the major ions, the dissolved solids increased, as the increase in specific conductance, 30 µmho to 49 µmho, indicates (table 4). Percent magnesium also increased from 1.9 (above Lake Mary) to 7.8 (below Twin Lakes).

The changes in ionic composition between the two sites appears to represent a trend that culminates at the junction of Mammoth Creek and Hot Creek: (1) A gradual decrease in the percent of calcium, (2) an increase in the percent of magnesium and sodium, and (3) fluctuation but overall increase in percent of fluoride, sulfate, and chloride. These changes seem to produce a water quality in Mammoth Creek similar to that of the springs that form Hot Creek, as indicated by the ionic composition of water from Hot Creek below the hatchery site (tables 4 and 5). The water quality of Mammoth Creek is apparently influenced by numerous thermal springs, possibly as far upstream as Twin Lakes. The increase in mineral content observed in Mammoth Creek is, therefore, the result of the inflow of water from geothermal areas. The concentrations of measured constituents are well below recommended limits for the beneficial uses stated for those streams and therefore have no negative impact.

Eutrophication

Dissolved Oxygen

DO concentration and percent saturation can be an excellent indicator of the eutrophic state of a stream or lake. Figure 7 shows the DO concentration and percent saturation during September 1981 at selected sites on Mammoth Creek and Hot Creek. DO measurements shown in this figure were made concurrent with sampling for chemical analysis, and therefore the measurement time was different at each site, ranging from 0830 hours to 1800 hours. DO concentration and saturation varies throughout the day and from day to day depending upon a number of factors including biological activity, temperature, cloud cover, and barometric pressure. Ideally, measurements are made simultaneously at all sites--a synoptic survey--eliminating some of these variables and providing a true comparison from site to site. Funding and manpower constraints often prohibit the synoptic approach, so that comparisons are made between sites for measurements made at different time and even on different days. This type of data can nevertheless provide insight into the level of biological activity and other processes occurring at each site. Although DO concentration is the measured constituent, percent saturation is a better indicator of productivity in the aquatic system. DO percent saturation is the ratio expressed in percent between the measured DO concentration and the theoretical DO concentration of the water at 100 percent saturation. The DO concentration at 100 percent saturation is regulated by the temperature of the water, the barometric pressure, and the salinity.

During the reconnaissance, the three upper Mammoth Creek sites, at the trailhead (rm 19.9), above Lake Mary (rm 19.1), and below Lake Mary (rm 18.3), showed equivalent percent saturations, ranging from 105 to 101, whereas the DO concentration ranged from 10.1 mg/L below Lake Mary to 11.4 mg/L above Lake Mary (fig. 7). The first noticeable change occurred below Twin Lakes (rm 17.0), where the DO concentration was 15.4 mg/L and the saturation was correspondingly high at 147 percent. The next major change was the decrease in DO concentration for the morning measurement of 7.0 mg/L at Hot Creek at the hot springs (rm 5.3). The water, nevertheless, was close to saturation at 92 percent. Hot Creek below the hot springs at the crossing (rm 3.8) showed the highest saturation level at 200 percent for a DO concentration of 14.2 mg/L.

Comparison of measurements of DO concentration and percent saturation in the morning and afternoon can indicate the productivity of the aquatic community. Figure 8 shows the DO concentration and percent saturation for morning and afternoon measurements made at selected sites on Mammoth Creek and Hot Creek. The morning samples were collected before to just after sunrise and probably represent the effects of nighttime respiration (uptake of oxygen by aquatic plants and animals) and the afternoon sample the effects of photosynthesis (production of oxygen by aquatic plants).

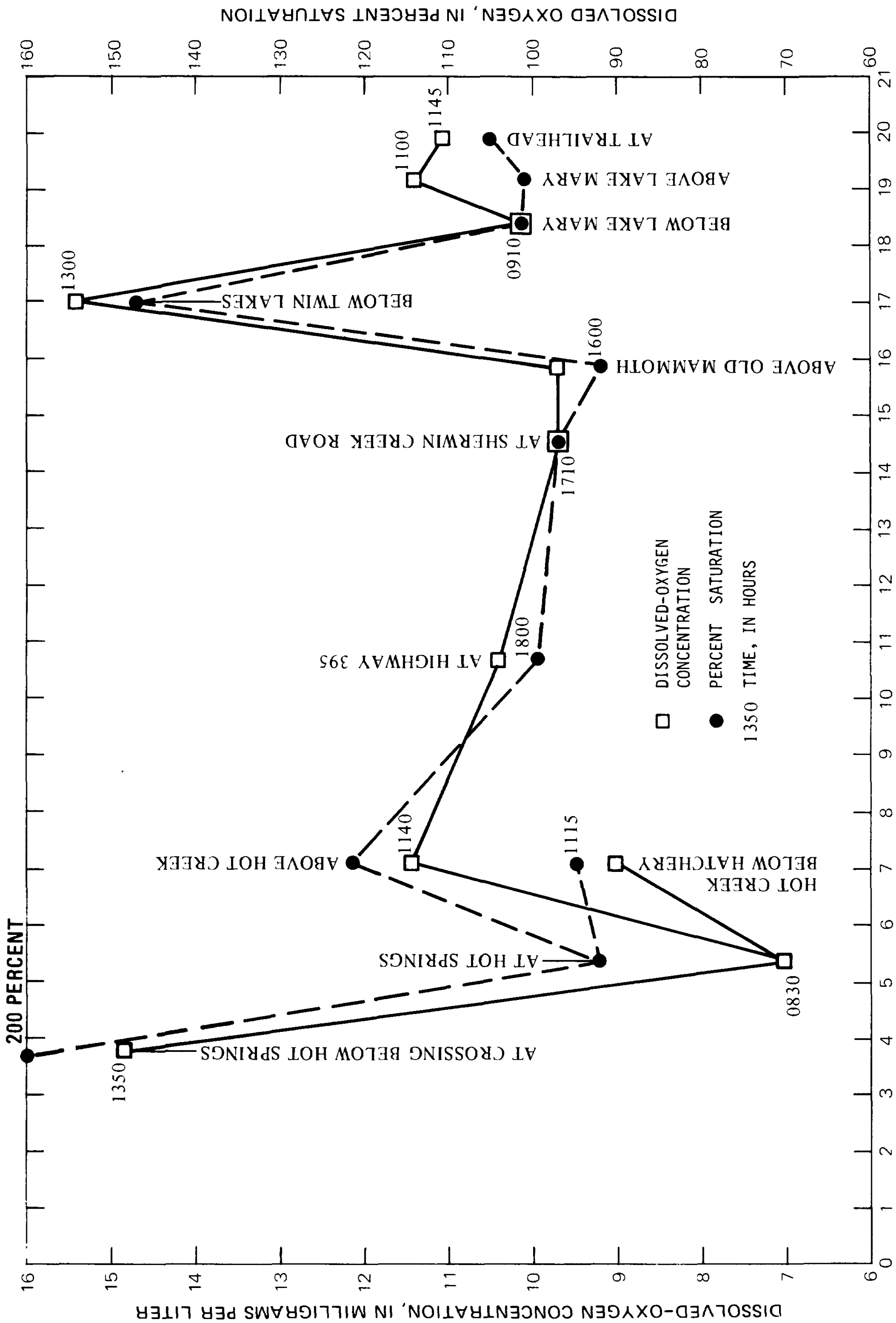

FIGURE 7. — Dissolved-oxygen concentration and percent saturation at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance.

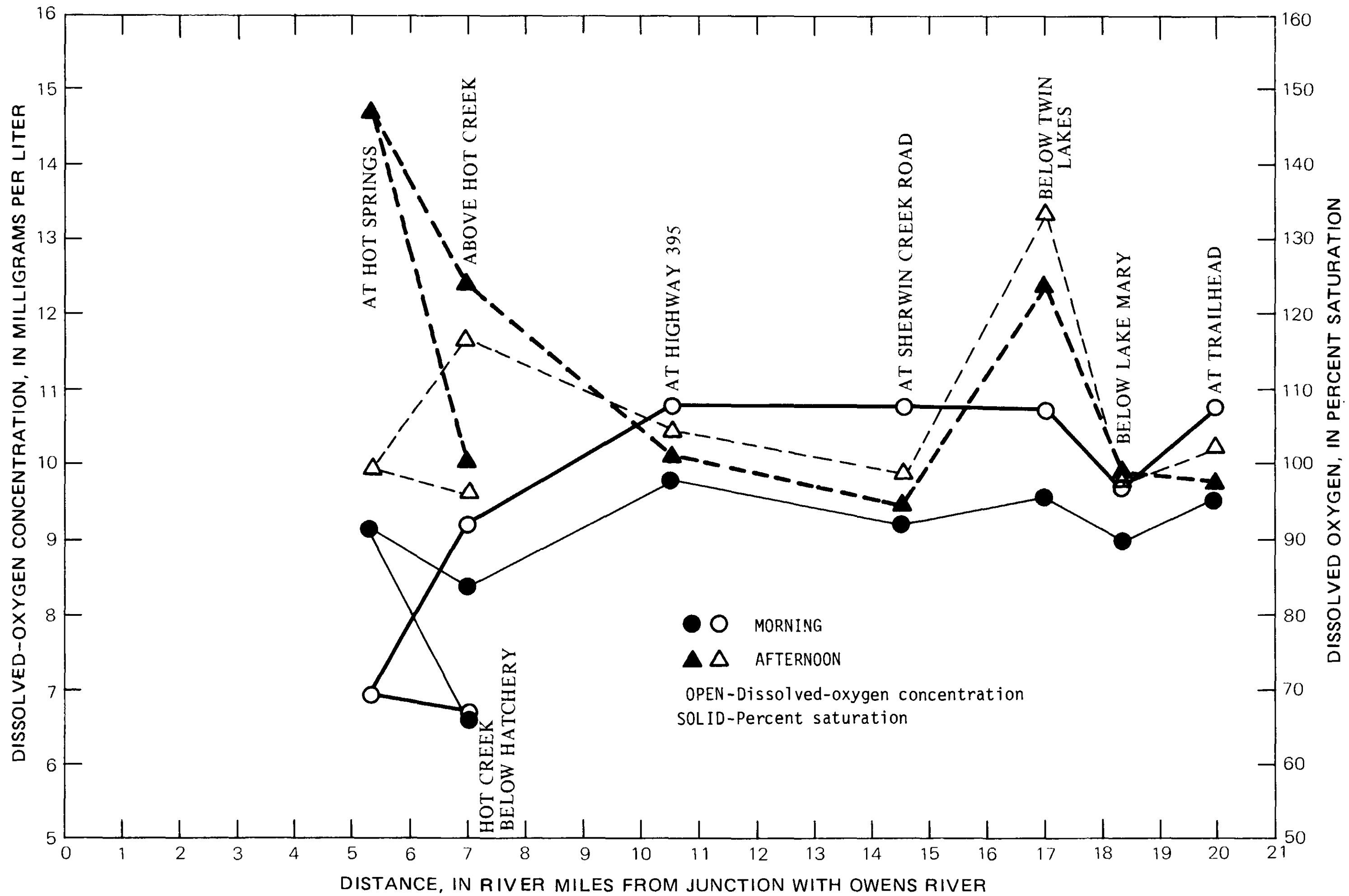

FIGURE 8. – Morning and afternoon dissolved–oxygen concentration and percent saturation at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance.

The most upstream site, Mammoth Creek at trailhead (rm 19.9), showed little variation in DO saturation, only increasing from 95 to 97 percent. The first major change was at the site below Twin Lakes (rm 17.0) where DO concentration increased from a morning low of 10.6 mg/L at a saturation of 95 percent to 13.3 mg/L at a saturation of 123 percent. The next two sites, Sherwin Creek Road (rm 14.5) and Highway 395 (rm 10.6), showed little variation in percent saturation. Mammoth Creek above Hot Creek (rm 7.1) had a large morning-to-afternoon variation in DO saturation, increasing from 83 to 129 percent as the DO concentration changed from 9.2 mg/L to 11.6 mg/L. At Hot Creek below the hatchery, DO saturation increased from 65 to 100 percent while the DO concentration increased from 6.6 to 9.5 mg/L. Hot Creek at the hot springs (rm 5.3) showed the largest variation in DO saturation, increasing from 92 percent to 146 percent. DO concentration increased from 7.0 mg/L to 9.9 mg/L.

For the spring high-flow sampling, DO saturation levels in the upper reaches of Mammoth Creek ranged from a low of 95 percent below Lake Mary, DO concentration 11.0 mg/L, to a high of 114 percent above Lake Mary, DO concentration 13.0 mg/L (table 3). From between Twin Lakes to below Twin Lakes the DO saturation increased from 104 percent to 115 percent while the DO concentration increased from 10.3 to 10.8 mg/L. For Mammoth Creek, the site above Old Mammoth (rm 15.9) exhibited the highest DO saturation level for the spring sampling, 128 percent at a DO concentration of 11.8 mg/L.

DO saturation levels were lower at the next two downstream sites (fig. 9), although at Highway 395 the measurement was made at 0805 hours. The Mammoth Creek above Hot Creek site (rm 7.1) and the Hot Creek sites reflect the effect of increased temperature (table 3) from thermal activity on DO concentration. Although DO saturation levels were all above 100 percent for these sites, DO concentrations were below 10 mg/L (fig. 7). Hot Creek at hot springs (rm 5.3) had the highest DO saturation of all sites for the spring sampling, 136 percent at a DO concentration of 9.5 mg/L. DO saturation for Hot Creek below hot springs at the crossing (rm 3.8) might have exceeded this if an afternoon measurement had been made. A morning measurement showed 112 percent saturation at 8.4 mg/L of DO.

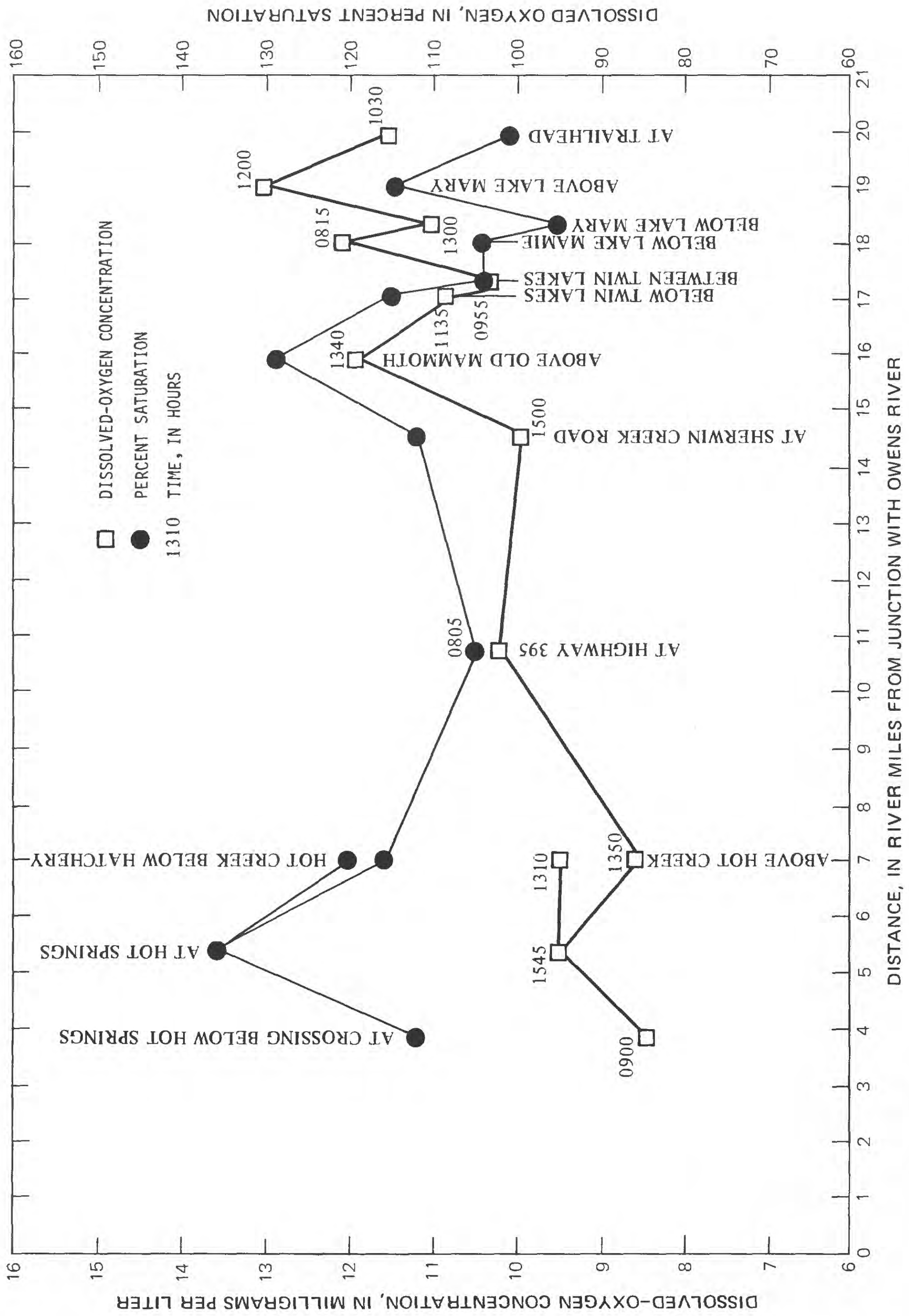

FIGURE 9. — Dissolved–oxygen concentration and percent saturation at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high–flow sampling.

Eutrophication is also apparently active in the Mammoth and Hot Creek system. During the reconnaissance, a visual inspection of the study area prior to sampling showed two areas of apparent eutrophication. More than 20 percent of the surface area of Twin Lakes was covered with floating mats of algae (fig. 10 and table 6). Field measurements of DO concentration and calculations of percent saturation also indicated that Twin Lakes was possibly showing signs of eutrophication. During the initial sampling of the site below Twin Lakes, the DO concentration at 1300 hours was 15.4 mg/L at a saturation of 147 percent. Measurements made later in the reconnaissance (see early morning-afternoon measurements under DO section) also confirm the photosynthetic activity that would be expected from the visual observations of algal growth and the DO saturation levels. These saturation levels show that sufficient photosynthetic activity is occurring to cause the water of Twin Lakes to become supersaturated with respect to oxygen. Along with the 147-percent saturation level was a correspondingly high pH measurement of 9.2, illustrating the effect of the CO_2 uptake and oxygen production on the chemistry of Twin Lakes. Sites upstream of and downstream of Twin Lakes had pH readings of 7.1 and 7.6, respectively (both taken in the afternoon) (table 2). In contrast to Twin Lakes, Lake Mary showed 101-percent saturation for an afternoon measurement of 10.1 mg/L of DO. No algal growth was observed in Lake Mary.

FIGURE 10. – Algae on surface of Twin Lakes.

TABLE 6. - *Field observations of lakes during September 1981 reconnaissance and during May 1982 spring high-flow sampling*

Lakes	Observations
	September 1981
Lake Mary -	Water in lake is clear, no aquatic vascular plants or algae visible. Tributary from Lake George had white-brown algae on rocks. Sewage spills occurred in spring and in August 1981.
Lake Mamie -	Free of aquatic vascular plants and algae. Release is regulated with discharge to Twin Lakes down a 320-foot drop.
Twin Lakes -	At least 20 percent of surface area covered with floating mats of algae. Extensive aquatic vascular plant growths. Have had aquatic vascular plant growth for over 30 years. Algal growth has been in last 20 years, increasing in severity last 5 to 10 years. Area of lake called Chinaman's Hole is supposed to have warm springs (located across from Tamarack Lodge).
	May 1982
Lake Mary -	Surface completely frozen over, discharge from lake 52 ft^3/s.
Lake Mamie -	Surface 90-percent frozen over, beginning to thaw downstream at release point, discharge from lake 32 ft^3/s.
Twin Lakes -	Surface only 10-percent frozen over, algae beginning to grow, water has greenish tint, discharge from lake 78 ft^3/s.

The second area of visible eutrophication is located in the reach below the Hot Creek hatchery. Before it joins Hot Creek, Mammoth Creek is virtually free of the aquatic vascular plants and floating mats of algae found choking the channel in the reach below the Hot Creek hatchery. This plant growth is first seen at the springs forming Hot Creek. The entire surface area of one of these springs was covered with algae. This type of extensive growth is also observed downstream through the Hot Creek gorge and past the site below the hot springs at the crossing (rm 3.8). The eutrophic state of this reach manifests itself in several ways. One indicator is the diel variation in DO saturation. At Hot Creek sites below the hatchery, DO saturation varies greatly between early morning and afternoon; levels range from 65 percent in the early morning to 146 percent in the afternoon. This range in saturation reflects a sizable photosynthetic aquatic community.

During the reconnaissance, water at Hot Creek below the hot springs at the crossing was super-saturated at 200 percent for a concentration of 14.2 mg/L of DO. This measurement made at 1350 hours indicates significant photosynthetic activity. The water temperature was 30°C, indicating a high metabolic rate, which when coupled with the available nutrients probably contributes to the extensive aquatic plant growth. While DO saturations as high as 200 percent were not observed at other Hot Creek sites, the range in DO saturation nevertheless indicated a sizeable photosynthesizing and respiring aquatic community. Although no comparison was made between early-morning and afternoon DO concentrations during the spring high-flow sampling, DO saturations as high as 136 percent were observed in the reach below the hatchery. Despite the large diel fluctuations, all the sites during both the reconnaissance and the spring sampling had DO concentrations greater than the 5.0 mg/L minimum criterion established by the U.S. Environmental Protection Agency (1976) for the protection of freshwater aquatic life.

Nutrients

The concentration of nutrients is a key factor in determining the eutrophic state of an aquatic system. For biological growth to occur, a balance of various nutritive elements must be present. Concentrations of nutrients such as nitrogen and phosphorus indicate the potential for algal and aquatic vascular plant growth. Figures 11 and 12 show the concentrations of total nitrogen as N (total nitrogen = dissolved NO_2 + NO_3 as N + total organic N + NH_4 as N) and total phosphorus at selected sites on Mammoth Creek and Hot Creek. During the reconnaissance, concentrations of nitrogen were low, approximately 0.7 mg/L or less in the headwaters of Mammoth Creek, not increasing until the site below the junction with Hot Creek. Hot Creek below the fish hatchery (rm 7.1) had the highest observed total nitrogen concentration of 1.4 mg/L and at the hot springs (rm 5.3) the concentration was 1.05 mg/L.

Total phosphorus concentrations were also low ($\leq$0.05 mg/L) in the upper reaches of Mammoth Creek during the reconnaissance (fig. 12). Concentrations increased downstream of Highway 395 (rm 10.6) to a maximum of 0.23 mg/L below the Hot Creek hatchery (rm 7.1).

With the exception of the Mammoth Creek sites at the trailhead (rm 19.9) and below Twin Lakes (rm 17.0), the spring high-flow samples from Mammoth Creek had total nitrogen concentrations greater than those during the reconnaissance (figs. 11 and 12). The highest total nitrogen concentration, 1.6 mg/L, was at Hot Creek below the hatchery (rm 7.1). In the upper reaches of Mammoth Creek, concentrations of nitrite plus nitrate as nitrogen were less than 0.10 mg/L (table 7). Hot Creek below the hatchery (rm 7.1) had the highest detected nitrate concentration, 0.33 mg/L.

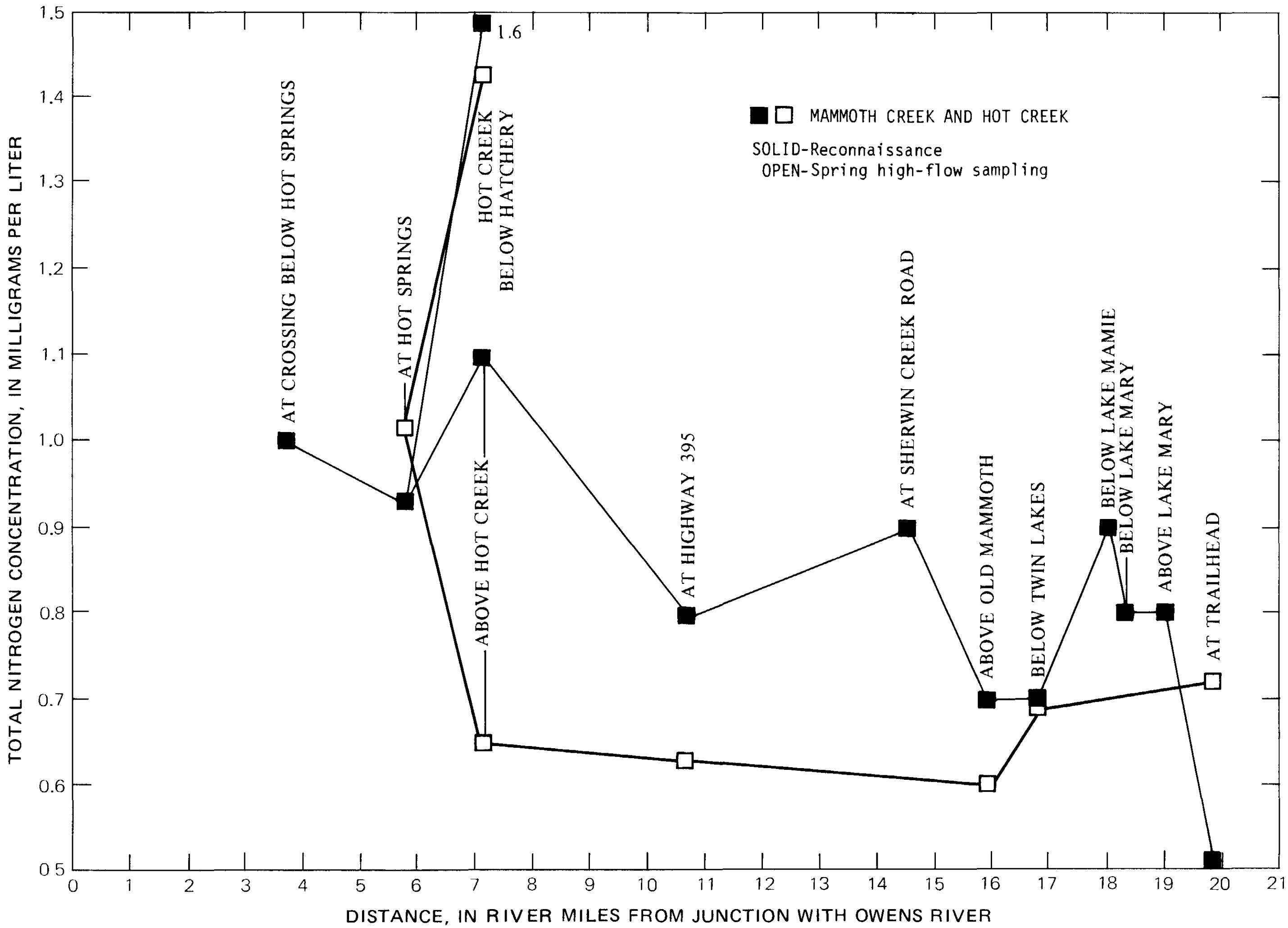

FIGURE 11. – Total nitrogen concentration at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance, and May 1982 spring high-flow sampling.

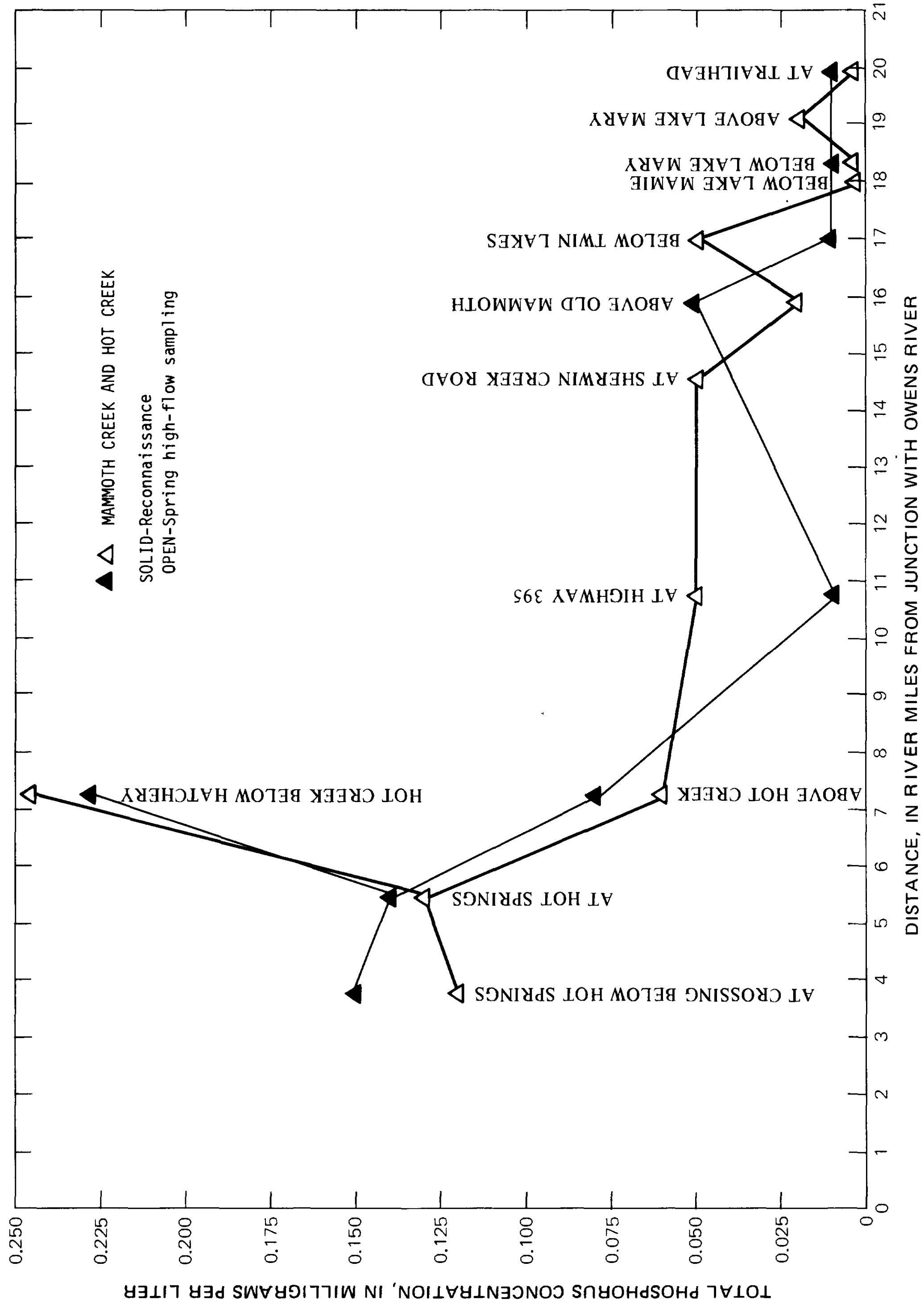

FIGURE 12.— Total phosphorus concentration at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance, and May 1982 spring high-flow sampling.

TABLE 7. - *Concentration of nitrogen species at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Dissolved $NO_2 + NO_3$ as N (mg/L)	Total NH_4 + Org N as N (mg/L)
Mammoth Creek		
at trailhead	<0.10	0.4
above Lake Mary	<.10	.7
below Lake Mary	<.10	.7
below Lake Mamie	<.10	.8
below Twin Lakes	<.10	.6
above Old Mammoth	<.10	.6
at Sherwin Creek Road	<.10	.8
at Highway 395	<.10	.7
above Hot Creek	<.10	1.0
Hot Creek		
below hatchery	.33	1.3
at hot springs	.13	.8
below hot springs at crossing	.12	.9

Total phosphorus concentrations ranged from less than 0.01 mg/L at the upper Mammoth Creek sites to 0.33 mg/L for Hot Creek below the hatchery (fig. 12). As with total nitrogen, the two most downstream sites were also high in total phosphorus, 0.13 mg/L at the hot springs and 0.12 mg/L below hot springs at the crossing (table 8).

In order to obtain some estimate of the amount of various nutrient species available to the aquatic system, loads were calculated at sites on Mammoth Creek and Hot Creek. These loads (reported as rates in pounds per day) are only rough estimates based on a single instantaneous measurement with assumed steady flow and constant nutrient concentrations. Despite the crudeness of the estimates, the results provide some idea of the nutrient loads transported by Mammoth Creek and Hot Creek.

TABLE 8. - *Concentration of phosphorus species at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Orthophosphate as phosphorus (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
Mammoth Creek			
at trailhead	0.006	<0.01	<0.01
above Lake Mary	.012	.02	.04
below Lake Mary	.005	<.01	<.01
below Lake Mamie	.005	<.01	<.01
below Twin Lakes	.013	.05	.05
above Old Mammoth	.015	.02	.03
at Sherwin Creek Road	.021	.05	.03
at Highway 395	.022	.05	.03
above Hot Creek	.029	.06	.05
Hot Creek			
below hatchery	.256	.33	.33
at hot springs	.091	.13	.12
below hot springs at crossing	.065	.12	.09

Runoff during the spring high-flow sampling was primarily snowmelt, so that day-to-day variations in the quality and quantity of the flow were not as significant as for other flow conditions. Although samples collected from the springs forming Hot Creek confirm the magnitude of the nutrient concentrations observed at Hot Creek below the hatchery, the fish food and excrement from the hatchery probably contribute to the nutrient load in the reach below the hatchery. Instantaneous loads were calculated for selected nutrients at sites on Mammoth Creek and Hot Creek. This load is the product of streamflow measurements made during sample collection and the concentrations of the selected constituents. The load in pounds per day = (concentration in milligrams per liter x (discharge in cubic feet per second) x (5.39 conversion factor for pounds per day). At the hot springs the total nitrogen load of 874 lb/d was lower than the combined total of 930 lb/d for the upstream sites of Mammoth Creek above Hot Creek and Hot Creek below hatchery. See table 9 and figures 13 and 14 for loads of nitrogen and phosphorus compounds at selected sites on Mammoth Creek and Hot Creek.

Nutrient concentrations measured at the site below Twin Lakes would not be expected to produce the amount of algal growth that was observed. Analysis of dissolved nitrite plus nitrate as nitrogen concentrations showed 0.12 mg/L for the reconnaissance and less than 0.10 mg/L for the spring sample (tables 2 and 7). Coupled with the low dissolved orthophosphate concentrations, less than 0.01 mg/L for the reconnaissance and 0.013 mg/L as phosphorus for the spring sample, it would seem that nutrients were at sufficiently low levels that algal growth would not occur. During the reconnaissance sampling, it is likely that the nutrients were tied up in the cellular mass of the algae so that virtually none were detected in the water. During the spring sampling, the nutrients might have been contained in the upper boundary layer of the bottom sediments, not in the sampled surface water. Some algal growth had already begun at the thawed edges of the lake (table 6), even though 10 percent of the lake was still frozen at the time of the spring sampling.

Twin Lakes is a popular fishing and recreational area with a lodge that has been in operation since the 1920's and a campground that borders the lake. The combination of these potential nutrient sources, the morphology and alinement of the lake (longer than wide, shallow, lengthwise axis alined in the direction of prevailing winds), and spring and autumn overturn to recycle the nutrients might perpetuate the algal problem. A number of years ago the aquatic vascular plants were destroyed (conversations with residents). These plants have not grown in the lake since then. Algae, which produce at a much higher rate, might have metabolized the nutrients released by destruction of aquatic vascular plants, preventing the aquatic vascular plants from growing.

TABLE 9. - *Loads of selected nutrients and discharge at sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

[Loads are expressed as a rate in pounds per day unless otherwise noted. This is calculated from the expression load in pounds per day = (concentration in milligrams per liter) x (discharge in cubic feet per second) x (5.4) correction factor for pounds per day]

Site	Dissolved nitrite + nitrate as nitrogen	Total ammonia + organic nitrogen as nitrogen	Dissolved ortho-phosphate as phosphorus	Dissolved phospho-rus	Total phos-phorus	Dissolved organic carbon	Discharge (ft^3/s)
Mammoth Creek							
at trailhead	13	52	0.8	<1.3	<1.3	300	24.2
above Lake Mary	13	91	1.6	2.6	5.2	--	24.2
below Lake Mary	28	198	1.4	2.8	2.8	538	52.5
below Lake Mamie	17	138	.9	1.7	1.7	--	32
below Twin Lakes	42	254	5.5	21	21	2,030	78.3
above Old Mammoth	47	281	7.0	14	9	--	86.7
at Sherwin Creek Road	56	450	12	17	28	1,680	104
at Highway 395	55	384	12	16	27	1,370	102
above Hot Creek	52	519	15	26	31	2,230	96.1
Hot Creek							
below hatchery	73	286	56	73	73	620	40.8
at hot springs	122	752	86	113	122	4,040	174
below hot springs at crossing	133	1,000	72	100	133	4,340	206

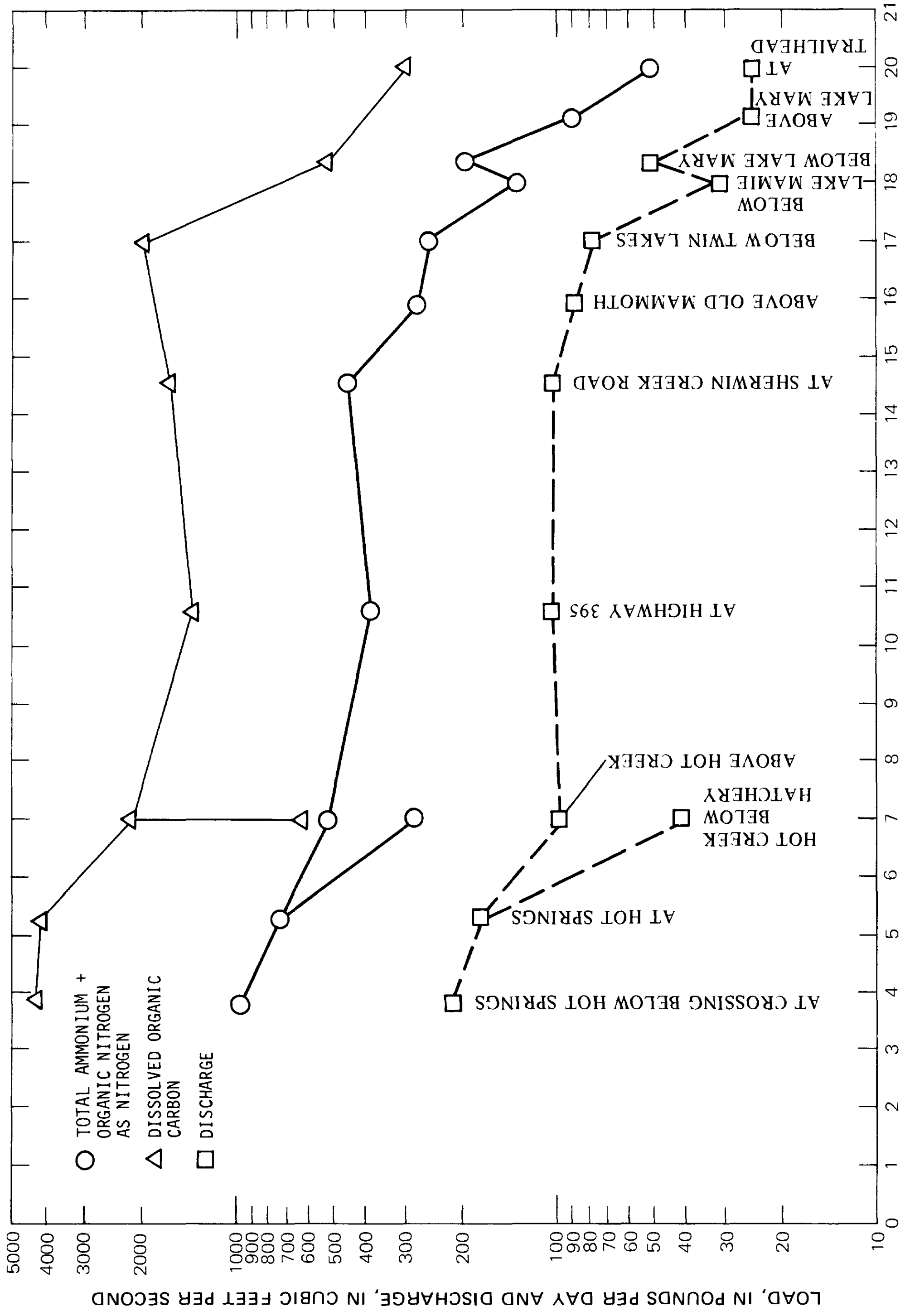

FIGURE 13. – Water discharge and loads of total ammonium plus organic nitrogen as nitrogen, and dissolved organic carbon at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling.

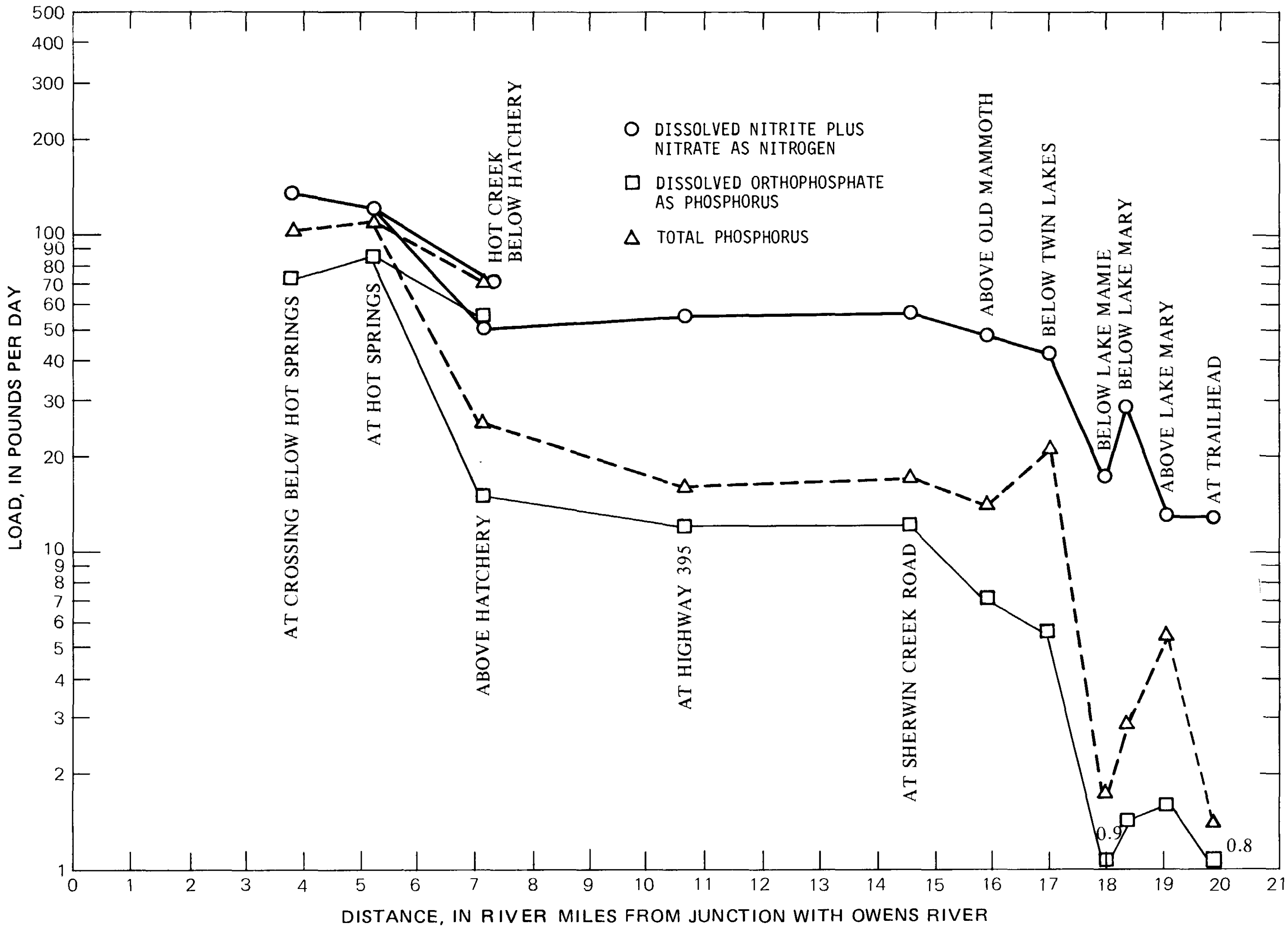

FIGURE 14. – Loads of dissolved nitrite plus nitrate as nitrogen, dissolved orthophosphate as phosphorus, and total phosphorus at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high–flow sampling.

The hot springs forming Hot Creek contain nitrite plus nitrate as nitrogen concentrations as high as 0.44 mg/L and of orthophosphate as phosphorus concentrations as high as 0.157 mg/L. Nitrates and phosphates at these concentrations, plus the potential sources from the hatchery, provide sufficient nutrients to support the growth of the aquatic vascular plants and algae observed within and below the fish hatchery. The plant growth in this reach is so extensive as to provide a food source for cattle that graze in the area around the hatchery. During the reconnaissance, cattle were observed in Hot Creek grazing on the aquatic plants (fig. 15). The cattle droppings in turn can provide an additional sporadic source of nitrogen and phosphorus as well as bacterial contamination.

Another method for determining the eutrophic state of an aquatic system is to measure algal growth potential (AGP). The Hot Creek site below the hatchery is about an order of magnitude greater in its AGP than the Mammoth Creek sites (table 10). The difference in AGP between the 4 mg/L at the Mammoth Creek above Hot Creek site (rm 7.1) and the 30 mg/L at the Hot Creek below hatchery site (rm 7.1) offers further explanation for the observations of no growth at the Mammoth Creek site and abundant growth at the Hot Creek site.

The extensive aquatic plant and algal growth in Hot Creek is partially caused by naturally occurring spring water from geothermal areas containing high concentrations of nitrates and phosphates. This nutrient enrichment is probably compounded by use of the Hot Creek water by the fish hatchery. The eutrophic problem is, however, largely of natural origin. The aquatic growth might be accelerated by warm waters from the local geothermal areas, which increase the metabolic rate and nutrient uptake and therefore the productivity and growth of the aquatic community.

FIGURE 15. – Cattle in Hot Creek.

TABLE 10. - *Algal growth potential at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Algal growth potential (mg/L)
Mammoth Creek	
above Lake Mary	3
below Lake Mary	<1
below Lake Mamie	<1
between Twin Lakes	2
below Twin Lakes	3
above Hot Creek	4
Hot Creek	
below hatchery	30

Bacteria

Recreational use of the streams and lakes of the Mammoth area depends upon the aesthetic beauty and pristine nature of the water. Water that is unsafe to drink because of fecal contamination poses a threat to the hikers and campers, who expect to drink clean, healthful water from the mountain streams. In order to determine the healthfulness of mountain streams in the Mammoth area, samples to determine the number of fecal-coliform and fecal-streptococcal bacteria were collected at selected sites on Mammoth Creek. These are indicator bacteria, because their presence in a water sample indicates fecal contamination. Where water has been contaminated with fecal matter, water-borne pathogens may be present. Correlations between the density of indicator organisms and the occurrence of specific pathogens are not available except for the *Salmonella* group. Geldreich's study (1970) of the occurrence of *Salmonella* in freshwater indicated almost 32 percent positive detection of *Salmonella* when fecal-coliform levels were between 1 and 200 colonies per 100 mL (milliliter). Detection of *Salmonella* increased to 83 percent for samples having fecal-coliform levels of 201 to 1,000 colonies per 100 mL. For fecal-coliform levels of 1,000 to 2,000 colonies per 100 mL, more than 88 percent positive detection was found, and positive detection increased to nearly 98 percent for levels over 2,000. *Salmonella* causes diseases such as typhoid and paratyphoid fever and a variety of types of food poisoning. Other diseases possibly resulting from fecal contamination of water are dysentery, cholera, hepatitis, and a wide range of parasitic infections such as giardiasis.

Samples to determine the number of fecal-coliform and fecal-streptococcal bacteria were collected during the reconnaissance at selected sites on Mammoth Creek and Hot Creek (table 11). Mammoth Creek at the trailhead (rm 19.1) had a fecal-coliform count of 12 colonies per 100 mL and a fecal-streptococcal count of 160 colonies per 100 mL, while Mammoth Creek below Lake Mary (rm 18.3) had a count of less than 1 fecal-coliform colony per 100 mL and 4 fecal streptococcal colonies per 100 mL. The highest counts during the reconnaissance, 250 colonies per 100 mL for fecal-coliform bacteria and 170 colonies per 100 mL for fecal-streptococcal bacteria, were observed at Mammoth Creek at Highway 395 (rm 10.6).

For the spring high-flow period, samples were also collected to determine the density of fecal-coliform and fecal-streptococcal bacteria at selected sites on Mammoth Creek and Hot Creek (table 11). Only 3 of the determinations for fecal-coliform bacteria were within the ideal range (20-60 colonies per plate). For fecal-coliform bacteria, counts were reported as less than 1 per 100 mL when no colonies grew on the plate for which 100 mL of sample was filtered. For fecal-streptococal bacteria, counts of greater than 1,000 per 100 mL and greater than 3,000 per 100 mL are estimated densities calculated by assuming a count of 100 colonies on the petri plate that received the smallest filtered volume but still had colonies too numerous to count.

A number of factors point to the possibility of fecal contamination in Mammoth Creek. In the reach below Sherwin Creek Road the reduced slopes and abundant grass provide an ideal area for the grazing of cattle. Hot Creek below the fish hatchery has extensive algae and aquatic vascular plant growth, which provide an additional food source for cattle. Field observations document grazing in and around Mammoth Creek and Hot Creek and the presence of cattle droppings on the banks and in the water. Hot Creek below the hatchery had 130 colonies per 100 mL of fecal-streptococcal bacteria during the reconnaissance and greater than 1,000 colonies per 100 mL during the spring sampling.

Counts of fecal-coliform and fecal-streptococcal bacteria in the upper reaches of Mammoth Creek suggest contamination from other sources, such as wildlife and packhorses. Such contamination probably occurs in the reach of Mammoth Creek above the trailhead. Human feces from campers and hikers may be another source, as well as from cross-country skiers in the winter, which probably affects the streams only during spring snowmelt and runoff.

A third possible source of fecal contamination is wastewater treatment plant effluent and sewage spills. Two spills may have occurred in the Lake Mary area, one in spring 1981 and the other in August 1981 (based on conversations with local residents). Samples to determine the number of fecal-coliform bacteria were collected below Lake Mary. The results showed less than 1 fecal-coliform colony per 100 mL and 4 fecal-streptococcal colonies per 100 mL for the late summer sample and less than 1 fecal-coliform colony per 100 mL and 19 fecal-streptococcal colonies per 100 mL for the spring sample. Thus, fecal contamination from wastewater-treatment plant effluent and sewage spills was not evident.

TABLE 11. - *Bacterial count at selected sites on Mammoth Creek and Hot Creek*

Site	Fecal-coliform bacteria (col/100 mL)		Fecal-streptococcal bacteria (col/100 mL)	
	September 1981	May 1982	September 1981	May 1982
Mammoth Creek				
at trailhead	12	<1 nonideal	160	88
above Lake Mary	--	<1 nonideal	--	9
below Lake Mary	<1 nonideal	<1 nonideal	4 nonideal	19
below Lake Mamie	--	<1 nonideal	--	42
between Twin Lakes	--	3 nonideal	--	126
below Twin Lakes	<1 nonideal	<1 nonideal	14	<1 nonideal
above Old Mammoth	--	--	32	--
at Old Mammoth	--	2 nonideal	--	48
at Sherwin Creek Road	--	<1 nonideal	--	45
at Highway 395	250	21	170	53
above Hot Creek	--	<1 nonideal	8 nonideal	<1 nonideal
Hot Creek				
below hatchery	--	4	130	>1,000 nonideal
at hot springs	<1 nonideal	<1 nonideal	31	<1 nonideal
below hot springs at crossing	--	50	--	>3,000 nonideal

Generally, fecal-coliform and fecal-streptococcal bacteria counts in samples collected from Mammoth Creek were low (fecal-coliform bacteria usually less than 10 per 100 mL and fecal streptococcal bacteria usually less than 50 per 100 mL), which indicates that fecal contamination was not severe except at Highway 395. During the spring high-flow sampling, counts exceeding 1,000 colonies per 100 mL indicated severe contamination at the Hot Creek sites below the hatchery and below the hot springs at the crossing.

Sediment

Observations of bed material were made at selected sites on both creeks during the reconnaissance to locate sediment deposition and to determine the general character of the deposited material. Table 12 contains a record of those observations, which indicates that the siltation problem begins between the site above Old Mammoth (rm 15.9) and at Sherwin Creek Road (rm 14.5). At Mammoth Creek above Hot Creek the bed material was 80 percent silt in the top 1/8 to 1/4 inch. Poorly sorted sand lay below the silt. At Highway 395, 3-1/2 miles upstream, the bed material was 60 percent poorly sorted sand and silt and at Sherwin Creek Road, four miles upstream at the lower end of the developing area, the bed was 20 percent gravel and 30 percent silt (table 12). Above Old Mammoth (rm 15.9), 1-1/2 miles upstream, there is no visible silt, and the interstices of the gravel are filled with poorly sorted sand.

Bed-material observations for the spring high-flow sampling were substantially obscured by the quantity of the flows in Mammoth Creek and Hot Creek. Because of this limited visibility, bed-material descriptions (table 13) are only of a general character, not in the detail of the reconnaissance. The results of samples collected for the determination of sediment concentration are shown in table 14. As with the reconnaissance, the results of the spring high-flow sampling indicated that there was little to no suspended sediment or silt deposition in the upper reaches of Mammoth Creek. The first signs of deposition were at the Sherwin Creek Road site (rm 14.5) (table 13). Mammoth Creek above Old Mammoth (rm 15.9) had well sorted sand but no silt. Silt deposits were also observed at Mammoth Creek at Highway 395 (rm 10.6), 3.9 miles downstream of Sherwin Creek Road, and at Mammoth Creek above Hot Creek (rm 7.1).

Sedimentation in Mammoth Creek is a problem that has apparently been around for at least 6 years. On May 20, 1978, a meeting was held by the California Department of Fish and Game at the Hot Creek Fish Hatchery for an evaluation of an apparent vegetation-sediment problem in the area downstream of the hatchery. The consensus of those present was that a sediment problem does exist in Mammoth Creek beginning at the point where it becomes Hot Creek and extending downstream.

TABLE 12. - *Field observations of bed material at selected sites on Mammoth Creek and Hot Creek, September 1981 reconnaissance*

Site	Remarks
Mammoth Creek	
at trailhead	Bed 20 percent small cobbles, 80 percent coarse gravel. Some finer material near bank. Pool and riffle system.
above Lake Mary	Riffle and pool system. 10-feet reach: 4 boulders, bed 40 percent large cobbles, 60 percent small cobbles with interstices filled with 20 percent coarse gravel, 30 percent fine gravel, 50 percent detritus.
below Lake Mary	Large boulders. Bed 5 percent coarse gravel, 10 percent fine gravel, 70 percent medium sand, 15 percent fine sand. White-brown algae covering rocks below outlet. Sewage manhole and pump 20 feet from creek.
below Twin Lakes	30 percent boulders, 15 percent large cobbles, 15 percent small cobbles, 20 percent coarse to fine gravel, 10 percent coarse sand, 10 percent finer material. Extensive algae growth on rocks below outlet. Extensive weed and algae growth in Twin Lakes.
above Old Mammoth	Riffle and pool system. Riffles: 80 percent small cobbles, 20 percent very coarse sand. Pool: Coarse to very fine gravel with interstices filled with poorly-sorted sand.
at Sherwin Creek Road	In 10-feet reach (approximately 15-feet wide): 7 boulders, 20 percent small cobbles, 20 percent well-sorted gravel, 30 percent silt.
at Highway 395	In 10-feet reach (approximately 10-feet wide): 2 boulders, 40 percent large and small cobbles, 60 percent poorly-sorted sands and silt, little visible gravel. Fecal matter from cows all about on banks.
Mammoth Creek	
above Hot Creek (in riffle area)	Few boulders, large and small cobbles, banks have poorly-sorted gravel and silt. Bed is 80 percent silt (top 1/8 to 1/4 inch). Below that is well-sorted sand. Completely different algae growth than Hot Creek, not extensive, decreases with travel upstream.
Hot Creek	
below hatchery	Very extensive weed growth and floating clumps of algae. Bed material has small cobbles with interstices filled with silt. In areas not choked with weeds, bed has well-sorted gravel with sand and silt in interstices. Cattle grazing in water.
at hot springs	Extensive weed and algae growth (algae mostly within last week). Streambed partly obscured by weeds. Small cobbles observed in deeper, fast-moving sections with sand and silt in between. Some areas of silt and sludge-type deposits.
below hot springs at crossing	Extensive weed growth, some over 10 feet long. Periphyton on rocks near bank.

TABLE 13. - *Bed-material observations and remarks on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	Remarks
Mammoth Creek	
at trailhead	In 10-feet reach; small cobbles, gravel, 10-percent sand in pooled areas, no silt. Hiked in from main road, packed snow entire way.
above Lake Mary	Large cobbles and medium gravels, no silt or sand. Had to cut through snowpack on banks to make measurements.
below Lake Mary	Poorly sorted boulders, cobbles, and gravel. Some sand in interstices, but no silt.
below Lake Mamie	Cobbles, gravels, and sand present, but no silt.
below Twin Lakes	Boulders, cobbles, and gravel, some sand, no silt. Strong sewage smell present. Bed material covered with brown algae.
above Old Mammoth	Riffle in 10-feet reach: 2 boulders, 5 large cobbles, poorly-sorted gravel with interstices filled with poorly-sorted sand. Pool; 25-percent large cobbles, 25-percent coarse gravel, 50-percent well-sorted sand. In 10-feet reach; 5 small clumps of algae. Tributary on right bank, has visibly higher turbidity.
Sherwin Creek Road	Small cobbles, gravel, sand, some silt. Some light debris in flow.
at Highway 395	Some boulders, cobbles, firm gravel, sand, and silt. Water brown with silt. Scats on banks and in stream.
above Hot Creek	Medium to fine gravel with deposits of sand and silt along the fill bank.
Hot Creek	
below hatchery	Stream choked with macrophytes, cobbles covered with silt. Water slightly turbid with fine debris. Brown algae on stream banks and bottoms.
at hot springs	Channel choked with macrophytes; a few boulders, medium gravel, and some sand deposits.
below hot springs at crossing	Channel choked with macrophytes; cobbles, gravel, and silt.

TABLE 14. - *Sediment concentrations and loads at selected sites on Mammoth Creek and Hot Creek, May 1982 spring high-flow sampling*

Site	River mile	Water discharge (ft^3/s)	Sediment concentration (mg/L)	Instantaneous load[1] (ton/d)	Segment stream velocity (ft/s)
Mammoth Creek					
at trailhead	19.9	24.2	6	0.39	2.02
above Lake Mary	19.1	24.2	1	.06	1.63
above Old Mammoth	15.9	86.7	8	1.8	2.99
at Sherwin Creek Road	14.5	104	83	23	2.43
at Highway 395	10.6	102	42	12	2.95
above Hot Creek	7.1	96.1	36	9.3	1.92
Hot Creek					
below hatchery	7.1	40.8	7	.77	.749
at hot springs	5.3	174	16	7.6	2.15
below hot springs at crossing	3.8	206	41	23	2.92

[1]Load = (sediment concentration) (discharge) (0.0027).

For the spring sampling, sediment concentrations in the upper reaches of Mammoth Creek through the site above Old Mammoth (rm 15.9) were all less than 10 mg/L (table 14), indicating a pristine water (in terms of sediment). From the site above Old Mammoth to the site at Sherwin Creek Road, sediment concentration increased by an order of magnitude, and the instantaneous load increased from 1.8 to 23 tons per day. This change indicates an increased availability of sediment for transport, which implies either a change in stream morphology or a change in land use that made more material available. Although an increase from 8 to 83 mg/L is significant, a sediment concentration of 83 mg/L does not represent a heavily silt-laden water. The load information given here is a rough estimate based upon the instantaneous water discharge and sediment concentration. Runoff from snowmelt late in May probably represents a fairly constant source. Downstream, the site at Highway 395 showed a decrease in both sediment concentration and suspended-sediment load to 42 mg/L and 12 ton/d, respectively. Coincident with the decrease in suspended-sediment concentration and load are the observed increases in silt deposition at the sites from Sherwin Creek Road to Hot Creek.

The presence of these fine materials suggests that the areas downstream from Highway 395 may be aggrading, with some aggradation possibly beginning near Sherwin Creek Road. A number of factors probably contribute to this silt deposition. One factor is the slope of the creek. Figure 4 shows the altitude at selected sites along Mammoth Creek and Hot Creek, from which can be seen that slopes from above Old Mammoth (rm 15.9) to the drainage divides are, with the exception of Lake Mary, much greater than those downstream of Highway 395. The reach beginning near Sherwin Creek Road is probably subject to deposition because of the reduced slope and the corresponding reduction in the competency of the creek to move sediment. Coupled with this reduced competency are the likelihood of additional sources of sediment from the ongoing construction in the town of Mammoth Lakes and the reduced stream velocities produced by the extensive aquatic vascular plant and algal growth below the Hot Creek Fish Hatchery. This sediment problem chiefly affects the spawning of fish and the survival and emergence of the fish embryo. A range of 10- to 20-percent fine material is considered to be optimum for the spawning of fish. As the percentage of material less than about 1/8-inch increases, the fish embryo's survival to emergence decreases. No suspended-sediment samples were collected during the reconnaissance because low-flow conditions did not support any noticeable sediment discharge.

Water-Quality Objectives at Selected Sites

The California Regional Water Quality Control Board, Lahontan Region (Lahontan Board), has established numerical objectives for selected water-quality constituents at 3 sites on Mammoth Creek: (1) Below Twin Lakes, (2) at Old Mammoth Road, and (3) at Highway 395. These objectives were established to prevent degradation of the water quality in Mammoth Creek and to protect the designated beneficial uses. These objectives are based upon average values from available data with a 90-percentile limit. Additionally, general objectives for DO, pH, and bacteria have been established (table 15). Because the numerical objectives were determined from average values, it is likely that concentrations of those constituents from the reconnaissance and spring sampling, for which objectives exist, would fall within the 90-percentile range, as indeed was observed except for phosphate concentrations (tables 2 and 8), which during the spring high-flow sampling exceeded the limits at the below Twin Lakes site (table 15). Also, during the reconnaissance, the pH at the outflow from Twin Lakes exceeded the numerical objective of 8.5 with an afternoon value of 9.2, as was discussed in the section on "Dissolved oxygen."

During the reconnaissance, DO saturation at Hot Creek below the hatchery was not in compliance with the 80-percent objective (fig. 8). An early-morning value of 65 percent was observed at a DO concentration of 6.6 mg/L. This stream reach has dense aquatic vegetation and high nutrient concentrations, which, when coupled with elevated stream temperatures from the thermal springs, are likely to produce large diel variations in DO concentration and saturation during the low-flow summer period. Mammoth Creek above Hot Creek had an early morning DO saturation of 83 percent, which, although depressed by more than 10 percent from saturation, is not below the 80 percent minimum stated in the general objective.

Only one set of samples was collected at each site for determination of indicator bacteria. Noncompliance with fecal-coliform objectives was indicated in this study only at Mammoth Creek at Highway 395. The Mammoth Creek site at Highway 395 had 250 fecal-coliform colonies per 100 mL during the reconnaissance. Considering the extensive cattle grazing and the observed abundance of cattle droppings in and around the creek, this density is probably exceeded frequently during certain times of the year. Fecal-coliform bacterial densities at other Mammoth Creek sites are, perhaps, also related to season and event. Rainstorms, which can flush nearby human and animal wastes into the stream, may produce conditions noncompliant with the objectives.

TABLE 15. - *Specific and general numerical objectives for Mammoth Creek*

[From California Regional Water Quality Control Board (1975). Number before the slash is the average value of all data. Number after the slash is the maximum value based on 90-percentile value; only 10 percent of data exceeds this value]

Constituents (mg/L)	Mammoth Creek Stations: Twin Lakes	Old Mammoth Road	Highway 395
	Specific objectives		
Dissolved solids	60/90	85/115	75/100
Chloride	0.6/1.0	0.8/1.4	1.0/1.4
Sulfate	--	--	6/11
Fluoride	--	--	0.3/1.0
Boron	--	--	0.03/0.05
Nitrate as nitrogen	0.4/0.8	0.4/0.8	0.4/0.8
Total nitrogen	0.5/1.0	0.6/1.0	0.6/1.0
Phosphate	0.03/0.05 (0.010/0.016 as P)	0.27/0.5 (0.090/0.165 as P)	0.11/0.22 (0.036/0.073 as P)

General objectives

Bacteria (fecal coliform) - For no less than 5 samples in a 30-day period, the logarithmic mean should not be greater than 200 colonies per 100 mL nor should 10 percent of the samples exceed 400 colonies per 100 mL.

pH - Range should be between 6.5 and 8.5.

Dissolved oxygen - Shall not be depressed by more than 10 percent nor shall the minimum be less than 80-percent saturation or 5.0 mg/L for warm-water habitat and 7.0 mg/L for cold-water habitat, whichever of the above is more restrictive.

POSSIBLE FUTURE SAMPLING PROGRAMS

Future sampling programs in the Mammoth Creek-Hot Creek system can focus on sediment and fecal-contamination problems along with additional investigation into the eutrophication of Twin Lakes. Mineralization in Mammoth Creek and the eutrophication of Hot Creek appear to be largely of natural origin and therefore difficult to control. The sediment problem can be more clearly defined by:

1. Beginning at the site above Old Mammoth and working downstream, identify the particle-size distribution in the upper inch of bed material. This identification can show the particle size being deposited and the extent of the aggradation.

2. Collect event-related (rainstorm, earthquake, high wind, and snowmelt) suspended-sediment samples with size breakdown at sites on Mammoth Creek from above Old Mammoth to the junction with Hot Creek, including major and minor tributaries. This data can show the areas contributing sediment to the system and the size of the contributed material.

3. Evaluate the sediment system of a similar drainage in an undisturbed area for comparison with the Mammoth Creek-Hot Creek drainage.

4. Identify the land use in the area capable of contributing to sediment loading.

To help determine sources of fecal contamination, event-related samples can be collected on Mammoth Creek and Hot Creek. Initially, the sampling can focus on determining when and where the highest densities of fecal-coliform and fecal-streptococcal bacteria occur and documenting the survival pattern at the sites having the highest densities. Unconfined grazing cattle and the sewer lines near Lake Mary and Twin Lakes warrant special emphasis to identify the activities producing the contamination.

A limnological study of Twin Lakes can be done to determine its productivity and the AGP of its waters. This study can include seasonal water-quality sampling and collection of bottom-material samples, which can help determine the nutrient cycle of Twin Lakes. The identification and enumeration of phytoplankton, zooplankton, and aquatic vascular plants can also help to elucidate nutrient-cycling processes and the trophic character of Twin Lakes. Other sources of nutrients, such as sewage overflow and spills, can also be investigated.

SUMMARY AND CONCLUSIONS

Mammoth Creek originates in the Mammoth crest area of the Sierra Nevada and flows through a major mountain recreational area onto a highland meadow to join Hot Creek, which is formed from water from springs in an active geothermal area near the fish hatchery. Hot Creek then courses through an active geothermal area and into Long Valley, where it joins the Owens River immediately upstream of Lake Crowley.

The California State Water Resources Control Board classified Mammoth Creek as an effluent-limited segment because it was suspected of violating the water-quality objectives requisite for such beneficial uses as municipal supply, cold-water habitat, and contact and noncontact water recreation, ground-water recharge, agricultural, and wildlife habitat. In order to find major water-quality problems that might interfere with these beneficial uses, a reconnaissance sampling was performed September 23-29, 1981. Results from the reconnaissance indicated that at least one additional sampling, preferably in the spring, would be helpful in understanding the aquatic system of Mammoth Creek and Hot Creek. A spring sampling was performed May 23-26, 1982, during the snowmelt high-runoff period.

Results from the reconnaissance and the spring sampling pointed to three processes and one potential problem occurring in Mammoth Creek and Hot Creek--mineralization, eutrophication, sedimentation, and some limited areas of fecal contamination. Mineralization is evident upon analysis of the field measurements from the reconnaissance. There is a general downstream increase in dissolved-solids concentration from the headwaters to the junction with Owens River. During the reconnaissance, the increase was shown by measurements of specific conductance, and during the spring sampling by determination of individual cation and anion concentrations. This increase appears to occur in the three reaches, below Lake Mamie to below Twin Lakes, from Highway 395 to Hot Creek, and from Hot Creek to the crossing below the Hot Springs. Changes in ionic composition from the upper reaches of Mammoth Creek to the junction with Hot Creek indicate a trend that shows:

1. A gradual decrease in the percentage of calcium.

2. An increase in the percentage of magnesium and sodium.

3. Fluctuations, but an overall increase in fluoride, sulfate, and chloride.

These changes seem to produce water quality in Mammoth Creek similar to that of the springs forming Hot Creek. Mineralization probably results from the natural inflow of water from geothermal areas.

Eutrophication was visually evident at Twin Lakes and in Hot Creek from the source springs to the crossing below the hot springs. Twin Lakes had afternoon DO saturations as high as 147 percent with an accompanying pH of 9.2. This high DO saturation and pH probably resulted from photosynthesis by algae and aquatic vascular plants. During the reconnaissance, more than 20 percent of the surface of the lake was covered with floating mats of algae. Although low levels of nutrients were detected in the water from Twin Lakes, nitrates and phosphates were probably tied up in the vegetative growth during the reconnaissance and in the top layer of the bottom sediments during the spring sampling.

Below the junction with Mammoth Creek, Hot Creek is choked with aquatic vascular plants and floating mats of algae. This growth, first evident at the springs forming Hot Creek, is also present below the hot springs at the crossing. In this reach of Hot Creek, DO saturation levels ranged from a high of 200 percent to a low of 65 percent, indicating the effects of photosynthesis by the extensive vegetative growth. Water temperatures as high as 30°C were measured in this reach.

Nutrient levels, AGP, DO saturation, and field observations of aquatic vascular plants and algal growth indicate that eutrophication occurs in the Mammoth Creek-Hot Creek system. The evidence for eutrophication lies in a comparison of water quality between the upper sites of Mammoth Creek (at the trailhead, Lake Mary, and Lake Mamie), and the Hot Creek sites below the hatchery. It is in this comparison that the term eutrophication is applied, not in comparison with other systems external to Mammoth Creek and Hot Creek. At the upper sites of Mammoth Creek concentrations of total nitrogen and total phosphorus were less than 0.9 and 0.03, respectively. At Hot Creek sites below the hatchery, concentrations of total nitrogen ranged from about 0.9 to 1.6 mg/L and concentrations of total phosphorus ranged from 0.12 to 0.33 mg/L. The springs forming Hot Creek had nitrate as nitrogen concentrations as high as 0.44 mg/L and orthophosphate as phosphorus concentrations as high as 0.157 mg/L. Nutrients at these concentrations are sufficient to support the large growth of aquatic vascular plants and algae in Hot Creek. Algal growth potential indicates the potential of a sampled water to produce algal growth. Mammoth Creek above Hot Creek had an AGP of 4 mg/L and Hot Creek below the hatchery had an AGP of 30 mg/L. This disparity further explains the visual observations of little growth at the upper Mammoth Creek sites and abundant growth at the Hot Creek sites.

Sedimentation in Mammoth Creek was observed by examining bed-material composition. Fine material, beginning at Sherwin Creek Road and continuing downstream, signified that silt deposition and aggradation are probably occurring in Mammoth Creek. An order-of-magnitude increase in sediment concentration occurs from the site above Old Mammoth to the site at Sherwin Creek Road, along with a increase in the instantaneous load from 1.8 to 23 ton/d. From the site at Sherwin Creek Road to the site at Highway 395, the sediment concentration and load decreased to 42 mg/L and 12 ton/d respectively, and silt deposition apparently increased. This aggradation may adversely affect spawning of fish and the survival and emergence of the fish embryo.

Local areas of fecal contamination may be a problem. The possible sources of this limited contamination are wildlife and packhorses; numerous cattle grazing in and around Mammoth and Hot Creeks; the recreational users of the Mammoth area--campers, hikers, and cross-country skiers; and possibly infrequent sewage spills. During the reconnaissance, Mammoth Creek at Highway 395 had a fecal-coliform bacteria count of 250 colonies per 100 mL and a fecal-streptococcal bacteria count of 170 colonies per 100 mL, and for the spring sampling Hot Creek below the hatchery and Hot Creek below hot springs at the crossing had more than 1,000 fecal-streptococcal colonies per 100 mL. Bacterial counts at other sites were generally less than 10 fecal-coliform colonies per 100 mL and 50 fecal-streptococcal colonies per 100 mL. Because fecal contamination is intermittent, individual samples do not accurately reflect the true impact of the possible sources of contamination on the health safety of the stream. The samples for the reconnaissance and spring sampling do, however, indicate that fecal contamination does occur in Mammoth Creek and Hot Creek and that recreational users should be aware of the potential hazard.

The reconnaissance and spring sampling showed that the Mammoth Creek-Hot Creek system suffers water-quality problems. The mineralization and eutrophication observed in Mammoth Creek and Hot Creek seems to be largely of natural origin, produced by geothermal springs that are sufficiently high in nitrates and phosphates to promote extensive algal and aquatic vascular plant growth in Twin Lakes and the reach of Hot Creek below the fish hatchery. The California Regional Water Quality Control Board, Lahontan Region, has developed numerical objectives for Mammoth Creek that are based upon the ambient conditions, which means that the mineralization and eutrophication are recognized as inherent water-quality problems representative of ambient conditions. The other two possible water-quality problems, sedimentation and fecal contamination, are, perhaps, more influenced by man's activities. Development in an undisturbed area generally increases overland runoff of sediment because of disruption of the top layer of the soil, decrease in the vegetative cover, and an increase in erosion. However, drawing direct correlations between land development and the presence of fine material in the streambed material is difficult. Fine material is deposited in the reach of Mammoth Creek downstream of Sherwin Creek Road. Sediment contribution from the reach Mammoth Creek at trailhead to above Old Mammoth is minimal, which implies that the source of material lies between the site above Old Mammoth and Sherwin Creek Road. The actual sources of this material and its effect upon the fishery are questions for which the answers must await further investigation.

The problem of local areas of fecal contamination is more firmly established in that the presence of the indicator organisms points to fecal contamination of the water. In the lower reaches of Mammoth Creek, the source is predominantly cattle grazing in and around Mammoth Creek and Hot Creek. In the upper reaches of Mammoth Creek, there was some fecal contamination probably from packhorses, animals, and recreational users. In this reach, however, fecal bacteria counts were low. Although an insufficient number of samples were collected for results to be compared to the numerical objectives, fecal contamination was still indicated in Mammoth Creek and Hot Creek. Since the contamination is probably intermittent, a more frequent and event-related sampling program can better determine the sources and extent of contamination.

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