Potential effects of coal mining and road construction on the water quality of Scofield Reservoir and its drainage area, central Utah, October 1982 to October 1984

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96–4020

Prepared in cooperation with the
[U.S.] BUREAU OF LAND MANAGEMENT

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MARCH 3, 1849

Cover photograph showing Eccles Canyon, Utah. View is to the west and shows coal-loading facility at the canyon mouth. Photograph taken by David Allen, U.S. Geological Survey, May 14, 1984.

POTENTIAL EFFECTS OF COAL MINING AND ROAD CONSTRUCTION ON THE WATER QUALITY OF SCOFIELD RESERVOIR AND ITS DRAINAGE AREA, CENTRAL UTAH, OCTOBER 1982 TO OCTOBER 1984

By Doyle W. Stephens, Kendall R. Thompson, and
James B. Wangsgard

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
centimeter	0.3937	inch
cubic hectometer	810	acre-foot
cubic meter	0.00081	acre-foot
	35.31	cubic foot
cubic meter per square kilometer	91.45	cubic foot per square mile
hectometer	2.471	acre
gram	0.03527	ounce
gram per kilogram	0.0160	ounce per pound
kilogram	2.205	pound
kilogram per square kilometer	0.0089	pound per acre
kilometer	0.6214	mile
liter	0.2642	gallon
meter	1.094	yard
metric ton	0.9072	short ton
metric ton per square kilometer	1.46	short ton per square mile
micrometer	0.00003937	inch
milliliter	0.0338	fluid ounce
millimeter	0.0394	inch
square kilometer	0.3861	square mile

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{o}F = 1.8\ (^{o}C) + 32.$$

In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United Sates and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration and water temperature are reported only in metric units. Chemical concentration in water is reported in milligrams per liter (mg/L) or micrograms per liter (µg/ L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water, and is about the same as parts per million unless concentrations are more than 7,000 milligrams per liter. One thousand micrograms per liter is equivalent to one milligram per liter. Radioactivity is expressed in picocuries per liter, which is the amount of radioactive decay producing 2.2 disintegrations per minute in a unit volume (liter) of water. Chemical concentration in sediment is reported in milligrams per kilogram or micrograms per gram, which are both equal to parts per million. Specific conductance is reported in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

POTENTIAL EFFECTS OF COAL MINING AND ROAD CONSTRUCTION ON THE WATER QUALITY OF SCOFIELD RESERVOIR AND ITS DRAINAGE AREA, CENTRAL UTAH, OCTOBER 1982 TO OCTOBER 1984

By Doyle W. Stephens, Kendall R. Thompson, and James B. Wangsgard

ABSTRACT

Studies were done during 1983-84 to determine the effect of coal mining in Pleasant Valley and construction of State Road 264 in Eccles Canyon on the water quality of local streams and on Scofield Reservoir. Streamflow during 1983-84 set high-flow records in all gaged streams and transported considerable sediment and associated trace metals and nutrients to Scofield Reservoir. Concentrations of most toxic substances were not sufficient to constitute a hazard in the streams or reservoir; however, concentrations of total phosphorus in the streams commonly exceeded water-quality criterion for phosphate as phosphorus of 0.05 milligram per liter, established by the State as an indicator of pollution.

Data from Eccles Canyon creek, which is in an actively mined area, were compared to data from Boardinghouse Canyon creek, which is in a nearby canyon with no active mining or construction activities. Concentrations of iron, manganese, and zinc were substantially larger in Eccles Canyon creek than in Boardinghouse Canyon creek. Loads of suspended sediment during storms and base-flow conditions also were larger in Eccles Canyon creek.

Concentrations of ammonia nitrogen, total phosphorus, mercury, and zinc in water from Scofield Reservoir occasionally exceeded Utah State water-quality standards and criteria for protection of aquatic wildlife that were in effect during 1983-84. In combination with the generally cooler spring temperatures, shortened growing season, and greater flushing rate for the reservoir, the large inflow of water into the reservoir prevented the occurrence of blue-green blooms common in earlier years. Large concentrations of orthophosphorus and manganese were released from sediment cores, and concentrations of manganese in the hypolimnion frequently exceeded the Federal drinking-water standard.

INTRODUCTION

The Pleasant Valley area in central Utah, as defined in this report, is the area that drains into Scofield Reservoir (fig. 1). Increased coal mining and related activities in Pleasant Valley (principally Eccles Canyon) south of Scofield Reservoir might affect the water quality of streams that flow into the reservoir and might affect future use of the reservoir. Eccles Canyon creek flows into Mud Creek, which flows into Scofield Reservoir. Much of the load of suspended trace metals and nutrients from Eccles Canyon creek is deposited as sediment in Mud Creek and can be transported by large flows and deposited in Scofield Reservoir. Large concentrations of nitrogen and phosphorus from septic-tank systems that enter the reservoir have caused algal blooms and accelerated the aging process of the reservoir. The reservoir is reported to be mesotrophic, with eutrophic trends (Denton and others, 1983, p. 30).

Because state mining regulations require extensive open areas for fire protection near mines and coal-processing sites, 11 hectares of forest in Eccles Canyon were clearcut in 1979. Large concentrations of total nitrogen and phosphorus were measured in Eccles Canyon creek and Mud Creek in 1980, probably as a result of the flushing of debris after the clear cutting (Waddell and others, 1985, p. 9).

Between 1981 and 1983, State Road 264 that begins in Eccles Canyon and connects Pleasant Valley with the town of Fairview (20 miles west of Pleasant Valley) was enlarged and paved. The road construction

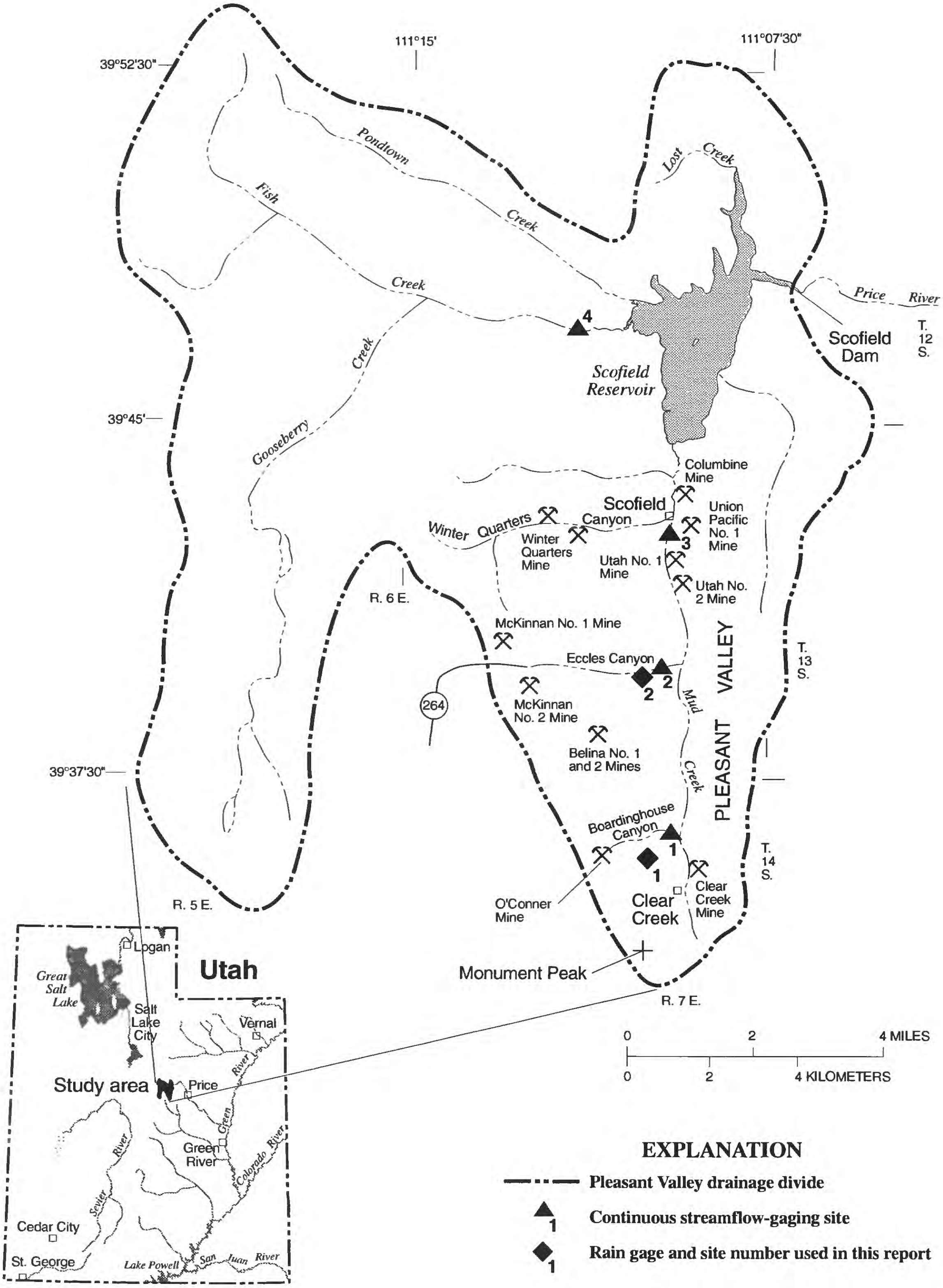

Figure 1. Continuous streamflow- and rain-gaging sites in the Pleasant Valley area, central Utah.

released additional loads of sediment, nutrients, and trace elements into Eccles Canyon creek.

This study, done by the U.S. Geological Survey in cooperation with the [U.S.] Bureau of Land Management, was needed to augment and update a study of water quality and sediment in Scofield Reservoir by Waddell and others (1985) and to describe the quality of water in streams that drain coal-mined areas in Pleasant Valley. A principal objective of this study was to evaluate the effects of coal-mine development and road construction on the water quality of Eccles Canyon creek, which drains an actively mined area. The method used in this evaluation was the paired-basin technique described by Ponce and others (1982). Because mine operation and road construction were underway in Eccles Canyon before this study started, it was not possible to use before and after stream sampling in Eccles Canyon. Instead, Boardinghouse Canyon, a nearby and similar drainage with no active coal mining, was selected as a control. Because natural water-quality characteristics in both drainage basins are expected to be similar, differences in water quality of the streams that drain these basins could indicate the effects of current coal development and road construction in Eccles Canyon.

A second objective of this study was to improve knowledge of the potential for trace-metal remobilization from sediment in Scofield Reservoir. The water in Scofield Reservoir commonly stratifies during the summer, and dissolved-oxygen concentrations decrease to near zero in the lower 3 meters of the reservoir. Reducing conditions in this zone of the reservoir could release many of the trace metals sorbed on the sediment, which could adversely affect the fishery at the reservoir and the use of the Price River.

Purpose and Scope

This report describes the results of a study to:

1. Determine if coal mining and road construction in Eccles Canyon have increased concentrations and loads of sediment, trace metals, and nutrients in Eccles Canyon creek in excess of those contributed by Boardinghouse Canyon creek, a nearby canyon with no active mining or development.
2. Determine loads of suspended sediment, trace metals, and nutrients that enter Scofield Reservoir from the major drainages of Mud Creek (Pleasant Valley) and Fish Creek.
3. Determine if concentrations of metals in sediment cores from shallow-water sites in Scofield Reservoir near inflows from Fish and Mud Creeks differ from those in sediment of deeper parts of the reservoir, and determine if the sediment contains sufficient metals to adversely affect use of the reservoir and the Price River.
4. Determine if nitrogen and phosphorus concentrations are increasing in Scofield Reservoir.
5. Identify possible limiting nutrients for algal growth in Scofield Reservoir.
6. Provide a base of sediment inflow and water-quality data that could be used to evaluate future changes in sediment deposition and quality of inflow to Scofield Reservoir.

This report is limited to Scofield Reservoir and to major streams that discharge to Scofield Reservoir. Because the study was oriented toward determination of changes in water quality, the emphasis of the report is on suspended sediment, trace elements, and nutrients.

Methods of Investigation

Data Collection

Weighing-bucket rain gages were installed near the streamflow-gaging stations in both Boardinghouse and Eccles Canyons during June 1983 (fig. 1). The rain gages were operated from about July to November 1983 and from June to October 1984, respectively. Additional precipitation and temperature data were available from National Oceanic and Atmospheric Administration sites in the town of Scofield and at Scofield Dam.

Continuous streamflow-gaging stations have been operated on Eccles Canyon creek since October 1979 and on Mud Creek since August 1978 as part of the U.S. Geological Survey program of hydrologic monitoring in coal areas. Considerable water-quality data were collected from Eccles Canyon creek during the 1980-81 water years and from Mud Creek during the 1979-81 water years. Fish Creek, the principal inflow to Scofield Reservoir, had been continuously gaged since 1938, but substantial water-quality data have been available only since the 1980 water year. The only outflow from Scofield Reservoir is the Price River, which had a continuous gage operating near Scofield, Utah, from 1926-31, 1938-68, and 1979-80. In September 1980, the U.S. Geological Survey discontinued gaging on the Price River near Scofield; subsequent gaging has been done by the Price River Distribution System. Flow and water-quality data for Fish Creek and other streams in the Pleasant Valley area are published in ReMillard and others (1983) and earlier volumes in the annual series titled, "Water Resources Data for Utah."

The gaging stations on Boardinghouse Canyon and Eccles Canyon creeks and on Mud and Fish Creeks are identified by site numbers 1 through 4 on figure 1. The U.S. Geological Survey station numbers for the sites are:

Stream	Site number used in this report (fig. 1)	U.S. Geological Survey station number
Boardinghouse Canyon creek	1	09310575
Eccles Canyon creek	2	09310600
Mud Creek	3	09310700
Fish Creek	4	09310500

A continuous-record streamflow-gaging station was established on Boardinghouse Canyon creek in November 1982 to provide flow data for comparison with Eccles Canyon creek. Water-quality samples were collected at Boardinghouse Canyon creek, Eccles Canyon creek, and Mud Creek at least monthly from April to October and usually twice during the remainder of the year. Fish Creek was sampled generally bimonthly during the same periods. Flow and water quality were not measured on Pondtown Creek because its annual flow accounted for only 6 percent of the inflow and 7 percent of the dissolved solids entering Scofield Reservoir during the 1980 water year (Waddell and others, 1985, table 1).

Sampling and Laboratory Procedures

Water samples were filtered, acidified when necessary, and measured in the field for pH, specific conductance, temperature, and dissolved oxygen. Water-quality samples were collected from Scofield Reservoir at four data sites; the sampling was done at 2- to 3-week intervals during June to September, and about once a month during May and October. The four chosen sites were near the inflows of Mud Creek (M65) and Fish Creek (M90B), a deep-water site near midlake (M30), and a site near the dam (M5) (fig. 2). Water quality was analyzed at an additional site (M110) in the north arm only when sediment cores were collected. A plastic 3-liter water bottle was used to prevent contamination by trace metals. Water samples were collected at a single depth when the reservoir was well mixed, and at near-surface and near-bottom depths when the reservoir was stratified.

Laboratory analyses were done by the U.S. Geological Survey in Denver using procedures given by Skougstad and others (1979). Analytical reporting levels for most trace metals generally were less than 1 microgram per liter, but there were variations depending on the specific methods (table 1). Forms of elements reported as "suspended" were calculated as the difference between "total" and "dissolved." Reporting levels for these elements are the larger of the reported limits for the other two forms. Where pH is presented as a mean value, it was calculated as a true mean using the negative logarithm of the mean of the hydrogen ion concentration.

Sediment samples were collected weekly from Eccles Canyon creek by a local observer, and samples were collected periodically on all the streams by project personnel. Samples were collected using standard equal-width-increment and depth-integration procedures and a DH-48 suspended-sediment sampler (U.S. Geological Survey, 1977, section 3, p. 20-26). Sediment samples also were collected from Boardinghouse Canyon creek, Eccles Canyon creek, and Mud Creek during storms using an automatic sampler. When possible, the samplers were used to collect samples of suspended sediment at 15- to 60-minute intervals during the rise and fall of the storm-flow hydrograph. The sampler intake was near midstream, and several tests were made to compare its performance with equal-width-increment and depth-integrated manual sampling. Comparison of samples collected concurrently using manual sediment sampling and the automatic equipment on May 29, 1983, during large, springtime flows showed that the automatic equipment underestimated the suspended-sediment concentration by 15 to 53 percent when concentrations exceeded about 200 milligrams per liter. Comparison on August 2, 1983, indicated that under low to moderate flow, the point sampler functioned equally as well as integrated manual sampling (paired t test, 95- percent confidence limit). Use of the automatic samplers therefore was limited to storms that produce only limited runoff that typically occurred between July and October.

Bottom-material cores were collected on August 31, 1983, from sites in Scofield Reservoir that were representative of the main reservoir (M5, M30) and also from the deltaic deposits of Mud Creek (M65),

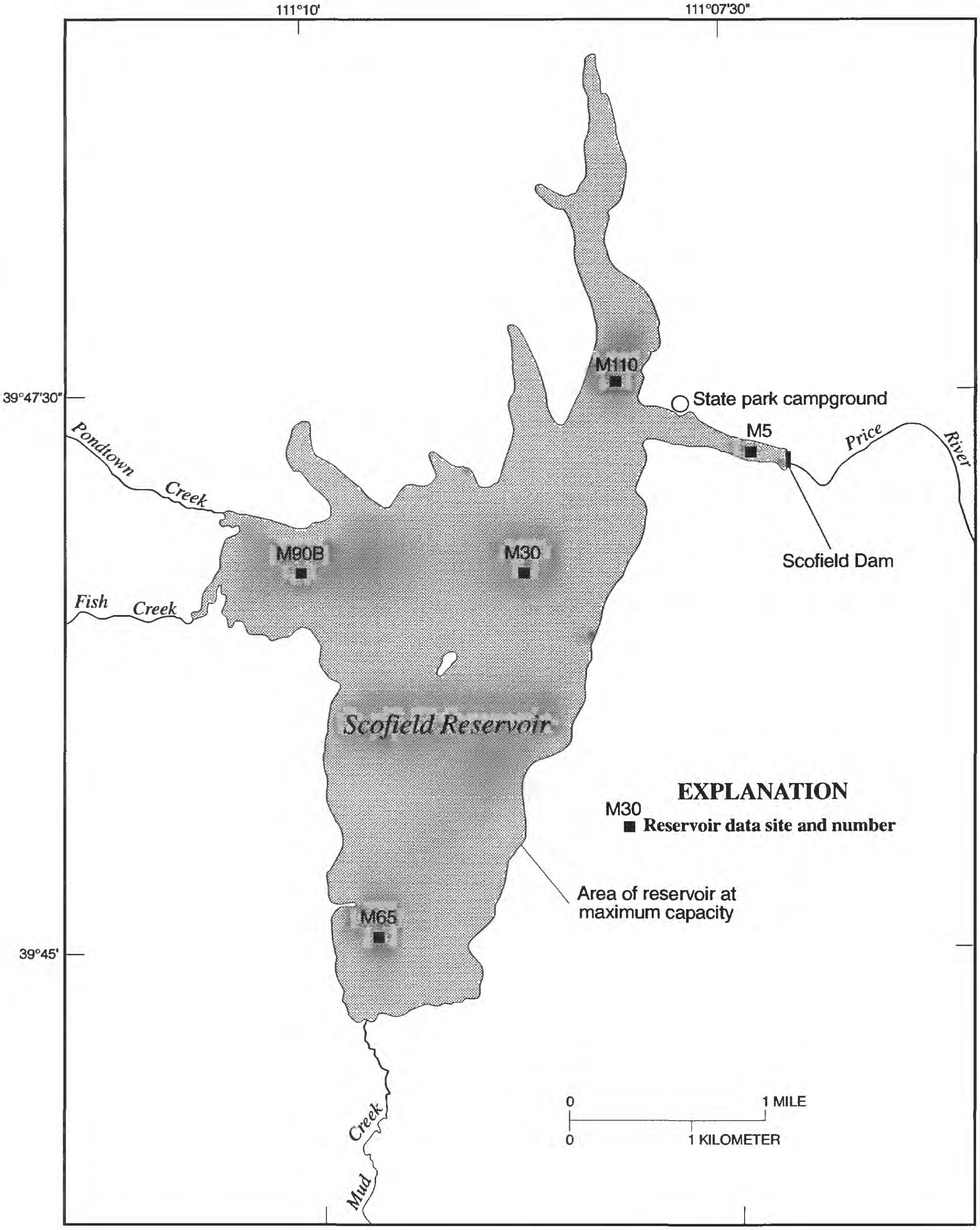

Figure 2. Data sites in Scofield Reservoir, Pleasant Valley, central Utah.

Table 1. Reporting level of constituents selected for analysis

[µg/L, micrograms per liter; mg/L, milligrams per liter; µg/g, micrograms per gram; g/kg, grams per kilogram]

Constituent	Reporting level	
Arsenic, dissolved	1	µg/L
Arsenic, total	1	µg/L
Barium, dissolved	100	µg/L
Barium, total	100	µg/L
Beryllium, dissolved	0.5	µg/L
Beryllium, total	10	µg/L
Boron, dissolved	10	µg/L
Cadmium, dissolved	1	µg/L
Cadmium, total	1	µg/L
Chromium, dissolved	1	µg/L
Chromium, total	1	µg/L
Copper, dissolved	1	µg/L
Copper, total	1	µg/L
Iron, dissolved	3	µg/L
Iron, total	10	µg/L
Lead, dissolved	1	µg/L
Lead, total	1	µg/L
Manganese, dissolved	1	µg/L
Manganese, total	10	µg/L
Mercury, dissolved	.1	µg/L
Mercury, total	.1	µg/L
Nickel, dissolved	1	µg/L
Nickel, total	1	µg/L
Selenium, dissolved	1	µg/L
Selenium, total	1	µg/L
Zinc, dissolved	3	µg/L
Zinc, total	10	µg/L
Phenols, total	1	µg/L
Carbon, organic, dissolved	.1	mg/L
Carbon, organic, suspended	.1	mg/L
Nitrogen, ammonia, dissolved as N	.01	mg/L
Nitrogen, ammonia, total as N	.01	mg/L
Nitrogen, ammonia + organic dissolved as N	.1	mg/L
Nitrogen, NH_4 + organic suspended as N	.1	mg/L
Nitrogen, NO_2 + NO_3, dissolved as N	.1	mg/L
Nitrogen, NO_2 + NO_3, total as N	.1	mg/L
Phosphorus, dissolved as P	.01	mg/L
Phosphorus, total as P	.01	mg/L
Phosphorus, ortho, dissolved as P	.01	mg/L
Arsenic, total in bottom material	15	µg/g
Chromium, recoverable from bottom material	15	µg/g
Cobalt, recoverable from bottom material	55	µg/g
Copper, recoverable from bottom material	15	µg/g
Iron, recoverable from bottom material	15	µg/g
Lead, recoverable from bottom material	105	µg/g
Manganese, recoverable from bottom material	105	µg/g
Mercury, recoverable from bottom material	.015	µg/g
Selenium, total in bottom material	15	µg/g
Zinc, recoverable from bottom material	15	µg/g
Coal, recoverable from bottom material	1	g/kg

Fish Creek (M90B), and at the mouth of the north arm (M110) (fig. 2). A gravity-drop corer with a lead collar and 6.4-centimeter diameter polycarbonate-plastic core liner was used to obtain multiple cores at each site. Prior to coring, all core liners and core sample containers were immersed overnight in a 10-percent hydrochloric acid solution, rinsed in deionized water, and stored in plastic wrap until used. Most cores were collected at a sediment depth of 25 to 45 centimeters and contained 20 to 40 centimeters of overlying water. Dissolved oxygen was measured near the mud-water interface in the core tube using an oxygen probe immediately after the core was raised to the surface. Cores were prepared for chemical analyses by carefully removing the overlying water (containing fine sediment) and extruding the core onto a polyethylene surface. The upper 20 or 40 centimeters of the core was then sectioned into 4- or 8-centimeter slices using a plastic knife, and each slice was weighed so that density could be calculated. Samples were packaged in polyethylene containers and shipped to the U.S. Geological Survey laboratory for analysis.

In the laboratory, each core section was digested using three different chemical procedures, and the extractant was used to determine the concentration of metals in the silicate, nonsilicate, and nondetrital phases by the methodology of Skei and Paus (1979). These methods were used because they indicate the relative ease with which various metals could become available to the overlying water. These same methods were used by Waddell and others (1985) for cores collected from Scofield Reservoir. Additional analyses were done to determine total phosphorus, and radiochemical dating of the sediment was done to obtain information on deposition.

Intact sediment cores were incubated anaerobically at 15 °C and aerobically at 20 °C, and samples of overlying water were withdrawn at intervals for chemical analysis to quantify the release of elements from the sediment to the water column. Prior to the start of the experiments, the overlying water in each core tube was replaced with 700 milliliters of filtered (0.45 micrometer) water of known chemical composition collected near the lake surface at each core site. Water used in the deep-water cores was purged of oxygen using ultra-pure nitrogen. The core tubes were capped with rubber stoppers having three ports. Two ports contained glass tubing that extended into the 30 centimeters of water overlying the sediment. The third port consisted of a short glass tube that functioned as a gas vent and extended into the small airspace above the water. Prior to sampling the cores, nitrogen (for anaerobic cores) or air (for aerobic cores) was bubbled through one of the long tubes to mix the water without suspending the loose sediment. The short tube was then closed, and water flowed out of the second long tube. Cores were sampled at 4- to 7-day intervals with 50 milliliters of water removed for each sample. Samples were filtered (0.45 micrometer) and stabilized by the addition of nitric acid (for metals analyses) or mercuric chloride (phosphorus analyses) and shipped to the analytical laboratory of the U.S. Geological Survey in Denver. All analyses for metals were done using inductively coupled plasma methods. Orthophosphorus was determined using the phosphomolybdate method without digestion.

Analytical procedures for total phosphorus included digestion using an acid-persulfate solution that releases all forms of phosphorus for analysis (Skougstad and others, 1979, p. 487). Radiochemical analyses for lead-210 and radium-226 were done on dried samples using a lithium-drifted germanium detector and radium de-emanation method. Values for unsupported lead-210 were obtained by subtraction of the radium-226 activity from the lead-210 activity. Cesium-137 was determined from the same gamma spectrum as lead-210 and radium-226. Counting time for all isotopes was 4 days. The density of core segments within any one core varied by a maximum of 11 to 34 percent. Owing to the subjective nature of the methods used to normalize data for varying water content and the small range of density differences, the results of radioisotope dating of the cores were not normalized prior to calculation of sedimentation rates.

Phytoplankton present in Scofield Reservoir during 1975 and 1981-84 were identified by Dr. Samuel Rushforth of Brigham Young University, Provo, Utah. Preparation and examination methods consisted of suspension of phytoplankton on a 1.2 micrometer filter, resuspension in distilled water, and identification and enumeration using a Palmer counting cell. Diatoms were analyzed as permanent mounts prepared by acid cleaning and suspension in high-resolution mounting media. Percent relative density for each diatom species in these slides was calculated by dividing the number of valves of each individual taxon observed by the total number of valves counted in the entire sample. This method allowed a comparison of density of taxa within and across samples. The method did not provide an absolute density value for the number of diatoms present in the water column. Data from 1975 and 1981-

82 are published by the Utah Department of Health (1984, appendix Q).

Data Evaluation

Commonly, analytical results for trace metals and nutrients in water are characterized by values that are less than the reporting limit for the analytical procedure. These values, termed "censored data," represent real numbers ranging from 0 to the reporting limit and are meaningful in evaluating summary statistics of concentrations.

In this report, summary statistics for observed stream data that include censored data were estimated by combining observed data above the reporting limit with below-limit values. The below-limit values were extrapolated assuming a distributional shape used only to calculate summary statistics (Helsel and Hirsch, 1992). The statistics program mdl95 was used to calculate summary statistics for censored data using the Weibull plotting positions (Helsel and Cohn, 1988). Where summary statistics were calculated, the variability in the data is shown by the coefficient of variation that is the standard deviation expressed as a percentage of the mean.

When there were paired data observations between the streams, all censored data were represented by ranks tied at values lower than the lowest number above the reporting limit (Helsel and Hirsch, 1992). The paired data were evaluated at the 95-percent confidence level by performing the rank-sum test using the statistics software STATIT version 3.0o. STATIT was used to calculate the rank-sum test by computing a normal approximation with a continuity correction, when both of the sample sizes were greater than 10. The exact P-value was calculated if both of the sample sizes were less than or equal to 10.

General water quality was evaluated by comparing results of the analyses with water-quality standards applicable to the area (table 2).The State of Utah has developed standards to preserve the waters of the State and to protect, maintain, and improve the quality of water for public supply, wildlife (including fish and aquatic life), domestic, agricultural, industrial, recreation, and other beneficial uses (Utah Department of Social Services, 1978, revised November 1984). The upper Price River and its headwater tributaries (including the Pleasant Valley streams) are protected under use classes 1C, 3A, and 4, and Scofield Reservoir is protected under classes 1C, 2B, 3A, and 4. The following is a description of these classes:

Class 1C—Protected for domestic purposes with prior treatment by standard complete treatment processes as required by the Utah State Division of Health.

Class 2B—Protected for boating, water skiing, and similar uses, excluding recreational bathing (swimming).

Class 3A—Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.

Class 4—Protected for agricultural uses including irrigation of crops and stock watering.

Interpretation of the biological availability of phosphorus as determined from a variety of chemical analyses is difficult. Concentrations of phosphate (PO_4) as phosphorus (P) have State-specified values (as indicators of pollution) of 0.025 milligram per liter for lakes and 0.05 milligram per liter for streams, but the analytical procedure to be used is not defined. Commonly, analytical procedures are used that determine total phosphorus by rigorous chemical digestion and orthophosphorus by ammonium molybdate-ascorbic acid reduction. It has been recognized that 60 percent or less of total phosphorus is biologically available (Sonzogni and others, 1982, p. 555) and that analyses of orthophosphorus (also called dissolved reactive phosphorus) underestimate the biologically available phosphorus by exclusion of the condensed and organic forms of phosphorus. Recognizing these deficiencies, the authors have followed the practice used by the State of Utah (Gunnell and others, 1982, p. 26; Gunnell, 1984, p. 48; Utah Department of Health, 1982, p. 787) and evaluated the water quality in the streams and Scofield Reservoir using determinations of total phosphorus. This method is useful because it identifies potential problems with phosphorus, but it does overstate their severity.

The un-ionized form of ammonia (NH_3) is toxic to fish in very small concentrations, whereas the ionized form ($NH_4{}^+$) exhibits little or no toxicity. As pH and temperature increase, the fraction of un-ionized ammonia in solution also increases. Concentrations of dissolved ammonia nitrogen were evaluated using temperature, pH, and tables (Willingham, 1976) giving concentrations of un-ionized ammonia that exceed the State standard of 0.02 milligram per liter.

Previous Investigations

Prior to 1981, no published reports of detailed water-quality studies in the Pleasant Valley-Scofield

Table 2. State of Utah water-use classes, water-quality standards, and pollution indicators applicable to streams in the Pleasant Valley area and to Scofield Reservoir, Utah
(Utah Department of Social Services, 1978, revised November 1984)

[—, insufficient evidence to warrant the establishment of numerical standard; limits are assigned on case-by-case basis; <, less than]

Constituent	Water-use class			
	Domestic source (1C)	Recreation (2B)	Aquatic wildlife[1] (3A)	Agriculture (4)
Bacteria (number of colonies per 100 milliliters)				
(30-day geometric mean)				
Maximum total coliforms	5,000	5,000	—	—
Maximum fecal coliforms	2,000	2,000	—	—
Physical				
Total dissolved gases (percent saturation)	—		<110	—
Minimum DO (milligrams per liter)	5.5	5.5	6.0	—
Maximum temperature (degrees Celsius)	—		20.0	—
Maximum temperature change (degrees Celsius)	—		2.0	—
pH	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0
Turbidity increase (NTU)[2]	—	10	10	—
Chemical (maximum, milligrams per liter)				
Arsenic, dissolved	.05		.14	.1
Barium, dissolved	1		—	—
Cadmium, dissolved	.010		.008	.01
Chromium, dissolved, trivalent	.05		2.4	.10
Copper, dissolved	—		.025	.2
Cyanide	—		.02	—
Iron, dissolved	—		1.0	—
Lead, dissolved	.05		.13	.1
Mercury, total	.002		.001	—
Phenol	—		.01	—
Selenium, dissolved	.01		.05	.05
Silver, dissolved	.05		.01	—
Zinc, dissolved	—		.05	—
Ammonia, as nitrogen (un-ionized)	—		.02	—
Chlorine	—		.002	—
Fluoride, dissolved[3]	1.4-2.4		—	—
Nitrate, as nitrogen	10			
Boron, dissolved	—		—	.75
Hydrogen sulfide	—		.002	—
Dissolved solids[4]	—		—	1,200
Radiological (maximum, picocuries per liter)[5]				
Gross alpha	15		15	15
Radium 226, 228 combined	5		—	—
Strontium 90	8		—	—
Tritium	20,000		—	—
Pesticides (maximum, micrograms per liter)				
Endrin	.2		.004	—
Lindane	4		.01	—
Methoxchlor	100		.03	—
Toxaphene	5		.005	—
2, 4-D herbicide	100		—	—
2, 4, 5-TP herbicide	10		—	—

Table 2. State of Utah water-use classes, water-quality standards, and pollution indicators applicable to streams in the Pleasant Valley area and to Scofield Reservoir, Utah—Continued

Constituent	Water-use class			
	Domestic source (1C)	Recreation (2B)	Aquatic wildlife[1] (3A)	Agriculture (4)
Pollution indicators				
Gross beta (picocuries per liter)[5]	50	—	50	50
Biochemical-oxygen demand (BOD, 5 day) (milligrams per liter)	5	5	5	5
Nitrate as nitrogen (milligrams per liter)	—	4	4	—
Phosphate as phosphorus (milligrams per liter)	—	.05	.05	—

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[1] Maximum concentration based on a water hardness ranging from 150 to 200 milligrams per liter.

[2] Nephelometer turbidity unit (NTU)—A measurement of suspended particles in a liquid measured with an instrument that measures light scatter at a 90° angle to the source. When formazine is used as a standard, values are expressed as formazine turbidity units (FTU). For classes 2A, 2B, 3A, and 3B at background levels of 100 NTUs or greater, a 10- percent increase limit will be used instead of the numeric values listed. For Class 3D at background levels of 150 NTUs or greater, a 10-percent increase limit will be used instead of the numeric value listed. Short-term variances may be considered on a case-by-case basis.

[3] Maximum concentration varies according to the daily maximum mean air temperature.

Temperature (degrees Celsius)	Concentration (milligrams per liter)
12.0 and below	2.4
12.1 to 14.6	2.2
14.7 to 17.6	2.0
17.7 to 21.4	1.8
21.5 to 26.2	1.6
26.3 to 32.5	1.4

[4] Dissolved-solids limit may be adjusted on a case-by-case basis.

[5] A picocurie per liter is one trillionth (1x10^{-12}) the amount of radioactivity represented by a curie. A curie is the amount of radioactivity that yields 3.7 x 10^{10} radioactive disintegrations per second. A picocurie yields 2.22 disintegrations per minute.

Reservoir area were available; however, a reconnaissance study of surface water and sediment in the Price River drainage was done by Mundorff (1972, p. 9). Mundorff (1972) reported that concentrations of dissolved-solids in tributaries upstream of the reservoir generally were less than 200 milligrams per liter, water in Mud and Fish Creeks was a calcium bicarbonate type, and streamflow is derived from ground water during low-flow periods. Coal mining in the area was not active during the Mundorff study (1969-70).

Surface-water quality in the Pleasant Valley area was reported by Clyde and others (1981) as part of an investigation of the contamination of shallow ground water. Sampling at 5 surface-water sites and 23 shallow wells indicated that domestic waste-disposal practices in the area may be degrading the quality of the shallow ground water. In addition to possible septic tank contamination, the study found an average total phosphorus concentration of 1.18 milligrams per liter in surface-water samples collected during high flows in May. The large concentration of phosphorus was believed to be from natural sources. Surface- and ground-water samples collected during high flow also contained total mercury concentrations that exceeded 3 micrograms per liter (Clyde and others, 1981, p. 50, 51). Water-quality samples collected during 1978-79 from Mud Creek had phenol concentrations that ranged from 2 to 7 micrograms per liter and sediment concentrations as large as 1,300 milligrams per liter (Lines and Plantz, 1981, p. 8-9). The 1982 biennial water-quality report for Utah indicated that large concentrations of manganese, total phosphorus, and phenols were present in surface-water samples from Mud Creek (Gunnell and others, 1982, p. 26).

Summary statistics related to water quality and water-quality problems in Scofield Reservoir were reported under the Clean Lakes Inventory program by the Utah Department of Health; problems consisted of large concentrations of total phosphorus, ammonia nitrogen, and mercury. Small concentrations of dissolved oxygen were common at depth, and undesirable growths of aquatic macrophytes and algae were present in the reservoir during the summer. The reservoir was assigned a high priority rank because of nonpoint-source pollution problems caused by soil erosion (Utah Department of Health, 1982, p. 787, 791).

After the Clean Lakes Inventory, an intensive study of basin geology, land use, pollutant identification, and control and restoration procedures was completed by the Utah Department of Health (Denton and others, 1983). This study indicated that annual precipitation and stream loads to the reservoir added about 6,600 kilograms of total phosphorus, 24,600 kilograms of inorganic nitrogen, and 4,900 kilograms of total suspended solids (Denton and others, 1983, p. 54). Calculated loads in the outflow from Scofield Reservoir to the Price River reduced the annual load retained by the reservoir to about 27 percent of total phosphorus and 40 percent of inorganic nitrogen. Virtually all suspended solids were retained by the reservoir. Mud Creek (also called Pleasant Valley creek) contributed 18 to 28 percent of the total loads for each of these constituents, and Fish Creek contributed 51 to 66 percent.

Ratios of total nitrogen to total phosphorus indicated that phosphorus was the limiting nutrient during 1981, and nitrogen was limiting during the summer of 1982. Because of the nitrogen-fixing abilities of some microorganisms (blue-greens), phosphorus was identified as the principal nutrient that required control. The combination of cold water temperatures, lower nutrient availability, and short growing season led Denton and others (1983, p. 61) to conclude that although Scofield Reservoir was mesotrophic to eutrophic, algal productivity in the reservoir was less than that in other waters with equivalent nutrient loading.

Relations between sediment and phosphorus in Scofield Reservoir were studied by Messer and Ihnat (1983), who reported that apatite-phosphorus concentrations in the reservoir were larger than in any other Utah reservoir they had studied. In the apatite form, however, the phosphorus was not available for biological reaction, and the organic-phosphorus concentrations that were biologically available were quite small. The ratio of extractable iron to phosphorus in the sediment was large and indicated that phosphorus in the anaerobic sediment would tend to bind with the iron, and thereby reduce the rate of phosphorus release to the overlying water.

The U.S. Geological Survey in cooperation with the [U.S.] Bureau of Land Management did a study of the physical and chemical characteristics of Scofield Reservoir during September 1979 to August 1980 (Waddell and others, 1982, 1985). The study of water quality and sediment in Scofield Reservoir by Waddell and others (1985) included an analysis of sediment cores taken near the inflow of Mud Creek and in the center of the reservoir. The analysis indicated insignificant differences in concentrations of common trace metals in sediment deposited by Mud Creek and those in the main body of the reservoir. The analysis also indicated that either (1) sediment that enters the reservoir through Mud Creek was not enriched with trace metals typically associated with mining, or (2) the metals in sediment were associated with fine sediment naturally eroded from soil throughout the basin. Available data show that concentrations of cobalt and lead in the reservoir sediment (both 40 milligrams per liter) are three to five times larger than in soil in the drainage basin, but the concentrations of other metals in the reservoir sediment are equal to or smaller than those of drainage-basin soil.

Waddell and others (1985, p. 23) reported that sedimentation since 1943 had decreased the original storage capacity of the reservoir by 4 percent. Some coal was present in the reservoir sediment and was deposited prior to 1950. During the study period, Mud Creek contributed 16 percent of the total inflow to the reservoir, and 24 percent of the total phosphorus load. Fish Creek contributed 72 percent of the inflow and 60 percent of the phosphorus load, and Pondtown Creek contributed 6 percent of the inflow and 16 percent of the phosphorus load. Concentrations of trace metals in the reservoir sediments near the mouth of Mud Creek were not substantially different from concentrations in the middle of the reservoir, indicating that sediments from Pleasant Valley had not been enriched with trace metals or that the fine-grained sediments (and associated trace metals) had been uniformly distributed throughout the reservoir. Concentrations of total mercury in the sediments ranged from 0.08 to 0.46 parts per million and were primarily in the least-soluble silicate form.

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DESCRIPTION OF THE STUDY AREA

Physiography and Drainage

Scofield Reservoir is in the mountainous terrain of central Utah. Altitudes in the study area range from 2,322 meters at Scofield Reservoir to 3,186 meters at Monument Peak in the southern end of the drainage basin. The southern end of Pleasant Valley is a flat alluvial plain consisting of unconsolidated deposits eroded from the neighboring ridges. The central part of the valley is occupied by Scofield Reservoir, and north of the reservoir the valley is hilly and rocky. Steep, narrow canyons are cut into the ridges that form rugged terrain surrounding Pleasant Valley. Slopes of 25 to 33 percent are common (U.S. Department of the Interior, 1979b, p. BO-II-1), and approach 72 percent in the upper reaches of Pleasant Valley creek (Denton and others, 1983, p. 96). Average stream gradients in the basin range from 3 to 5 percent.

Pleasant Valley is a sub-basin of about 75 square kilometers in the Price River drainage system. The Price River flows southeast from Scofield Reservoir 188 kilometers to join the Green River. Major stream courses in Pleasant Valley follow fault traces in the graben valley, and smaller tributary streams have cut into the ridges and canyon walls to form a dendritic drainage pattern. Mud Creek drains this Pleasant Valley subbasin and flows north into Scofield Reservoir. Several smaller, intermittent streams also flow into Mud Creek. The principal drainages that flow into Scofield Reservoir from the west are Pondtown Creek, with a basin size of 20 square kilometers, and Fish Creek, with a basin size of 156 square kilometers. Boardinghouse Canyon and Eccles Canyon drain to Mud Creek; their drainage area constitutes about 5 percent of the Scofield Reservoir drainage area of 400 square kilometers. The Price River is the only flow from the reservoir. The river provides culinary water for about 20,000 people in the Price area and is used for irrigation of about 5,700 hectares (Denton and others, 1983, p. 13).

Boardinghouse Canyon creek drains a basin of 5.3 square kilometers, flows eastward, and joins Mud Creek about 11 kilometers upstream of Scofield Reservoir (fig. 1). There are more than 450 meters of relief in the narrow, steep-walled canyon. The average basin slope in the canyon is about 38 percent, and average stream gradient is almost 10 percent. Eccles Canyon creek drains a basin of 14.3 square kilometers, flows eastward and joins Mud Creek about 7.5 kilometers upstream of Scofield Reservoir (fig. 1). The average basin slope in Eccles Canyon is about 34 percent, and the average stream gradient is 6 percent.

Scofield Reservoir was created by damming the Price River in 1926. The reservoir inundated the lower reaches of Mud, Fish, and Pondtown Creeks. The original dam was replaced in 1945-46 by an earth-fill structure with rock facing built 244 meters downstream of the old dam. The altitude of the water surface at maximum storage is 2,321.8 meters and the useable capacity between altitudes of 2,321.8 and 2,312.2 meters is 81 cubic hectometers. There are 10 cubic hectometers of dead storage below an altitude of 2,312.2 meters. The deepest part of the reservoir at maximum altitude of the water surface is 14.3 meters.

Climate

The climate of the study area is varied and strongly influenced by local factors such as altitude, topography, and geographic location relative to the predominant west-to-east storm track (Mundorff, 1972, p. 6). Average annual precipitation in the town of Scofield ranges from 51 to 76 centimeters (Mundorff, 1972, pl. 2), and precipitation generally increases with altitude. Total annual precipitation recorded during the 1983 and 1984 water years was 40 centimeters and 38.9 centimeters, respectively. Locally, more than 100 centimeters per year of precipitation has been recorded along the high ridges of the area. Precipitation during October through April at altitudes above 1,800 meters mainly is snow with accumulation averages of about 1.4 meters, but maximum snow depth may reach 2.5 meters (U.S. Department of the Interior, 1979b, p. BO-II-1).

During the 1983 and 1984 study, single-storm rainfall and monthly rainfall were larger in Boardinghouse Canyon than in Eccles Canyon. Although the canyons are only 3 kilometers apart, comparison of monthly totals between the two canyons showed that Boardinghouse Canyon often received more rainfall than Eccles Canyon. Paired t tests of 111 paired dates of rainfall accumulation in 1983 (August 3 to November 21) and 69 paired measurements in 1984 (June 18 to September 24) indicated that on any given day, total rainfall accumulation in Boardinghouse Canyon was substantially greater than in Eccles Canyon (95-percent confidence level). Mean rainfall (per storm) for 1983 was 0.57 centimeters in Boardinghouse Canyon and 0.44 centimeters in Eccles Canyon. Corresponding means for 1984 were 0.62 and 0.48 centimeters per storm. Differences in rainfall accumulation likely were caused by topographic control, because both gages were at an altitude of about 2,536 meters.

Rainstorms did not always occur simultaneously in both canyons. According to 24-hour total accumulation data, there were 29 paired storms in 1983 and 17 paired storms in 1984. The ratio of the number of paired storms to the total number of storms occurring in both canyons can be expressed as a percentage of coincident storms. In 1983, coincident storms with measurable precipitation occurred 63 percent of the time in both canyons, and in 1984 coincident storms occurred 65 percent of the time.

Average monthly temperatures in the study area ranged from -9 °C in January to 16 °C in July. Extreme temperatures are about -40 °C and 27 °C (U.S. Department of the Interior, 1979b, p. BO-II-1). Temperatures recorded by the National Weather Service observer at the dam ranged from -36 °C to 31 °C during October 1982 to October 1984.

Geology

Pleasant Valley is characterized by gently warped, dipping strata broken by normal faults that elevate the local geologic formations as much as 1,830 meters above their counterparts in the Sanpete-Sevier Valley to the west of the study area (Walton, 1954, p. 79). The Pleasant Valley area contains the most complex and intricate faults in the area. The fault zone is 5 to 8 kilometers wide and extends about 56 kilometers through the northern end of the plateau (Spieker, 1931, p. 54-56, 91). The central, down-dropped block of the Pleasant Valley fault zone constitutes the floor of the graben valley in the Scofield area (Spieker, 1949, p. 90). Scofield Reservoir is situated in this graben, which is transected by a smaller, nearly perpendicular fault zone.

The Wasatch Plateau is underlain by a succession of Cretaceous rocks that contain valuable deposits of coal. Upper Cretaceous sedimentary rocks of the Mesaverde Group dominate the near-surface strata that crop out in the Scofield area, and remnants of younger formations are found capping ridges surrounding Pleasant Valley.

In ascending order, the Mesaverde Group in the study area consists of the Star Point Sandstone, Blackhawk Formation, Castlegate Sandstone, and Price River Formation. The strata generally consist of a series of fine- to medium-grained clastic rocks and coal-bearing units that were deposited in continental and littoral marine environments. Overlying the Mesaverde Group are fluvial, flood-plain, and freshwater lacustrine deposits of the North Horn Formation and the Flagstaff Limestone (Katich, 1954, p. 42; Hintze, 1973, p. 67-72). Unconsolidated Quaternary alluvium is confined to the valley floors of the major drainages.

The basal unit of the Mesaverde Group is the Star Point Sandstone, which is nearly 300 meters thick in the Scofield area (Doelling, 1972, p. 69). This sandstone is normally overlain, either directly or within a few meters, by the lowest coal bed of the Blackhawk Formation.

The Blackhawk Formation consists of sandstone, shale, carbonaceous shale, and coal and is the source of the coal mined in the Pleasant Valley area. Most of the producing coal beds are found in the lower 90 meters of the formation, which ranges from 210 to 300 meters in thickness (Doelling and Smith, 1982, p. 11).

Numerous coal beds in the Blackhawk Formation are of minable thickness only in certain areas. The important coal seams in the study area and the rock intervals that separate them are highly variable in thickness. Coal beds in the area range from 0.3 to 9 meters in thickness and are separated by rock intervals of less than 0.3 meter up to 120 meters thick (Doelling and Smith, 1982, p. 12).

Soils

Soils in Eccles Canyon have developed from the sandstone and shale of the underlying bedrock. Surface soils typically have a silty loam to loam texture, and subsoils have a sandy loam to clayey loam texture. They range from 61 to 102 centimeters deep and contain 20 to 60 percent coarse fragments. The soils are deeper along the narrow floor of Eccles Canyon and are formed from alluvial and old landslide deposits (U.S. Department of the Interior, 1979b, p. MC-II-4).

Boardinghouse Canyon, like Eccles Canyon, is underlain by the Star Point Sandstone and Blackhawk and Price River Formations. The dominant soils are very similar to those in Eccles Canyon and have developed on colluvial materials derived principally from sandstone. They have dark-colored surface horizons with a silty loam to loam texture over sandy loam to clayey loam textured subsoils, with 20- to 60-percent coarse-fragment content. The soils are 50 to 100 centimeters deep. Natural erosion by runoff where vegetation is present is estimated at about 0.4 cubic meter per hectare per year, but the erosion potential could approach 40 cubic meters per hectare per year where the soils are exposed (U.S. Department of the Interior, 1979b, p. BO-II-3).

History of Coal Mining in Pleasant Valley

The first large coal mine in the Pleasant Valley coal field was the Utah No. 1 mine operated by the Utah Fuel Company (fig. 1). The mine opened in 1878 in Pleasant Valley, and was 4.8 kilometers south of Scofield (Hayes and others, 1977, p. 31). In 1882, the Denver and Rio Grande Western Railroad built a line into Pleasant Valley, and the Utah Fuel Company, a subsidiary of the railroad, began to obtain coal property in the area. By 1900, Utah Fuel mined 90 percent of the coal produced in Utah (Alexander, 1963, p. 237). In 1884, the Winter Quarters Mine was opened in Winter Quarters Canyon, and near the town of Scofield, the mine that later became the Union Pacific No. 1 Mine was opened by the Pleasant Valley Coal and Coke Company (Spieker, 1931, p. 2). In 1899, at the head of Pleasant Valley, the Clear Creek Mine was opened by the Utah Fuel Company and was active until 1967 (Doelling, 1972, p. 63, 90). Between 1878 and 1909, all of the coal shipped from the Wasatch Plateau coal field was mined in Pleasant Valley (Hayes and others, 1977, p. 31).

More than 20 major mines and several smaller mines have produced coal in Pleasant Valley with as many as 7 mines operating at the same time (Doelling, 1972, p. 90). Both Boardinghouse and Eccles Canyons contained active coal mines in the past, but mining in Boardinghouse Canyon was discontinued in 1967. By 1969-70, only one mine was operating in the Scofield area. The Colombine Mine, just north of Scofield, produced 27,800 metric tons of coal in 1969, and 10,385 metric tons in 1970 (Doelling, 1972, p. 87). In 1971, no coal mines were operating in the area (Mundorff, 1972, p. 11).

In 1976, Valley Camp of Utah submitted plans for approval to mine 2.2 million metric tons of coal per year from two proposed underground mines, the Belina No. 2 and O'Conner mines (fig. 1). Routt County Development, Limited, a subsidiary of Energy Fuels Corporation, also submitted plans in 1976 to mine 3.2 million metric tons of coal annually from two other underground mines (McKinnan Nos. 1 and 2). The four above-mentioned mines, however, were not producing coal during data collection (1983-84) for this report.

By about 1980, there was renewed mining activity south of Scofield in response to the construction of several coal-fired power plants within shipping distance in the intermountain west. In 1983 and 1984, there were two mines open in Pleasant Valley (Lamar Bishop, Mine Safety and Health Administration, oral commun., 1985), both supplying coal to electric generating plants. Valley Camp of Utah, Inc. was operating the Utah No. 1 mine in Pleasant Valley about 3 kilometers south of Scofield (fig. 1) and the Belina No. 1 mine in a side canyon halfway up Eccles Canyon. Four other underground mines also were being developed or refurbished during those years.

GEOCHEMISTRY OF COAL, STREAMBED SEDIMENT, AND CANYON SOILS

The organic composition of coal is very complex, consisting mainly of aromatic rings in a large polymeric configuration with a large number of easily hydrolyzable chemical bonds (Seierstad and others, 1983, p. 5). Coal contains small quantities of virtually all metallic and non-metallic elements embedded within the mineralogical matrix that are introduced into the coal bed in one or more of four different ways: (1) as inert material washed into the coal swamp at the time of plant accumulation, (2) as a biochemical precipitate from the swamp water, (3) as a minor constituent of the original plant cells, and (4) as a later addition, introduced after coal formation, primarily by ground water moving downward or laterally (Averett, 1975, p. 79).

Most of the minor elements occur in coal in about the same concentration as their estimated average concentration in the Earth's crust, but 25-30 elements occur locally in greater concentrations. A few elements such as uranium, germanium, arsenic, boron, and beryllium may occur in much larger concentrations in coal than occur on average in the crust. Barium, bismuth, cobalt, copper, gallium, lanthanum, lead, lithium, mercury, molybdenum, nickel, scandium, selenium, silver, strontium, tin, vanadium, yttrium, zinc, and zirconium may occur in coal in slightly larger concentrations than their estimated average crustal concentrations. Chromium, manganese, phosphorus, tellurium, thallium, titanium, and tungsten generally occur in smaller concentrations than the average for crustal composition (Averett, 1975, p. 80).

The chemical mobility of constituents commonly found in coal constitutes the largest potential for deterioration of water quality. Acid-mine drainage is not a problem in the Wasatch Plateau coal field because the coal typically has a low sulfur content. Some mine drainage in this region, however, contains larger concentrations of trace elements, particularly arsenic, iron, manganese, and selenium, than those normally found in local streams. This has been reported for several coal mines in central Utah (U.S. Department of the Interior, 1979a, p. IV-6).

Hayes and others (1977, p. 53) report that 900 analyses of coal samples from the Wasatch Plateau coal field show little difference in quality among the coal beds. Selected results of the analyses are presented in table 3 and are discussed in detail by Doelling (1972). In general, coal from the Pleasant Valley coal field has the following average composition: volatile matter, 41.4 percent; fixed carbon, 45.2 percent; and sulfur, 0.65 percent (Doelling, 1972, p. 556-557). The coal generally is bituminous, high-volatile B rank, and noncoking (Hayes and others, 1977, p. 53).

Samples of streambed sediment were collected annually during 1983-84 from the major streams in the Scofield area as part of the Coal Area Hydrologic Monitoring program of the U.S. Geological Survey. All bed-material samples were sieved to retain only sand-sized particles (0.062-2.0 millimeters) for analysis. Although this procedure quantified the potential transport of trace metals in the sand fraction, it excluded the

Table 3. Concentration of trace elements in coal ash in 48 samples from the Wasatch Plateau, central Utah (Adapted from Hayes and others, 1977)

[Concentration reported in parts per million; <, less than]

Element	Average	Minimum	Maximum
Barium	700	70	3,000
Beryllium	15	<3	50
Boron	1,000	200	3,000
Cadmium	.9	<1	2
Chromium	100	30	200
Cobalt	15	<10	50
Copper	95	32	266
Gallium	30	10	70
Lead	55	<25	195
Lithium	111	15	288
Molybdenum	10	<7	20
Nickel	50	10	200
Niobium	20	<20	50
Scandium	20	<10	50
Strontium	1,000	100	5,000
Vanadium	100	70	300
Ytterbium	7	3	15
Yttrium	70	30	300
Zinc	84	19	237
Zirconium	200	100	500

clay and silt that are geochemically the most effective media for metal transport. Data from Boardinghouse Canyon creek, Mud Creek, and Fish Creek indicated that 60 percent of the suspended sediment was in the size range of clay and silt (less than 0.062 millimeters). Nearly 70 percent of the suspended sediment in Eccles Canyon creek was silt-sized.

The composition of sand-sized material in the streambed samples and of unsieved soils in Boardinghouse and Eccles Canyons is shown in table 4. Because the composition for the streambed samples did not include clay and silt, reported concentrations of elements in the streambeds are smaller than the actual values. Small amounts of coal were present in both streambeds, but the maximum of 14 grams per kilogram occurred in Eccles Canyon. The trace metals arsenic, cadmium, chromium, cobalt, and lead were present in very small concentrations in all samples. With the exception of a streambed sample from Boardinghouse Canyon creek containing a copper concentration of 30 micrograms per gram, copper was present in small concentrations.

The composition of sand-sized material in streambed samples from Mud and Fish Creeks is shown in table 5. Both streambeds contained some coal particles; however, the Fish Creek samples contained less coal owing to the absence of mining activities and exposed coal seams in the drainage basin. The mean concentration of mercury in the streambed samples was 0.12 microgram per gram and corresponds closely to the mean mercury content of 0.14 microgram per gram for coals reported by Smith (1981, p. 15). Iron and manganese, which occur as the principal trace metals in soils, had large concentrations in the streambed samples. In general, concentrations of iron and manganese were smaller in samples from Mud and Fish Creeks than in those from Boardinghouse and Eccles Canyon creeks, possibly because of steeper stream gradients in Boardinghouse and Eccles Canyons.

The analysis of soil cores from Boardinghouse and Eccles Canyons (table 4) indicated that concentra-

Table 4. Composition of unsieved soil and sand-sized streambed sediment in Boardinghouse Canyon and Eccles Canyon, Utah

[Streambed sediment includes only the 0.062-2 millimeter sand fractions; µg/g, micrograms per gram; mg/kg, milligrams per kilogram; —, no data; <, actual value is smaller than value shown]

		Boardinghouse Canyon				Eccles Canyon			
		Soil sampled		Streambed sediment sampled		Soil sampled		Streambed sediment sampled	
		July 19, 1984		February 15, 1983	August 28, 1984	July 19, 1984		February 15, 1983	August 28, 1984
Depth of sample (centimeters)		0-5	25-30	0-10	0-10	0-5	15-20	0-10	0-10
Coal (grams per kilogram)		—	—	8.9	8	—	—	5.7	14
Moisture (percent)		5.5	5.3	—	—	19.7	10.8	—	—
Arsenic	(µg/g)	3	3	4	1	2	1	3	2
Cadmium	(µg/g)	<1	<1	1	<1	<1	<1	1	<1
Chromium	(µg/g)	3	3	6	10	4	3	4	7
Cobalt	(µg/g)	<10	<10	<10	<10	<10	<10	<10	<10
Copper	(µg/g)	6	3	30	4	5	3	3	3
Iron	(µg/g)	4,500	3,000	3,600	4,900	5,200	3,000	3,400	6,400
Lead	(µg/g)	<10	<10	10	10	<10	<10	10	20
Manganese	(µg/g)	250	160	330	120	350	160	240	250
Mercury	(µg/g)	.08	.03	.02	.24	.05	.04	.03	.19
Zinc	(µg/g)	35	15	30	20	56	17	27	30
Ammonia nitrogen	(mg/kg)	20	4.9	—	—	11	7	—	—
Nitrite plus nitrate nitrogen	(mg/kg)	<2	<2	—	—	5	<2	—	—
Phosphorus	(mg/kg)	400	340	—	—	730	530	—	—

Table 5. Composition of sand-size particles (0.062-2 millimeters) in streambed sediment of Mud Creek and Fish Creek, Utah

[g/kg, grams per kilogram; μg/g, micrograms per gram; <, actual value is smaller than value shown; —, no data]

		Mud Creek (site 3)		Fish Creek (site 4)
		Feb. 15, 1983	Aug. 28, 1984	Sept. 11, 1984
Coal	(g/kg)	8.9	6.7	1.3
Arsenic	(μg/g)	2	<1	—
Cadmium	(μg/g)	1	<1	<1
Chromium	(μg/g)	3	3	3
Cobalt	(μg/g)	<10	<10	<10
Copper	(μg/g)	4	4	3
Iron	(μg/g)	4,500	3,200	2,000
Lead	(μg/g)	10	20	10
Manganese	(μg/g)	230	70	67
Mercury	(μg/g)	.03	.14	.2
Zinc	(μg/g)	25	18	9

tions of trace metals and forms of nitrogen and phosphorus in soils were generally similar. However, soils from Eccles Canyon had slightly larger concentrations of phosphorus and zinc than soils from Boardinghouse Canyon. Concentrations of most elements in the soils were within the same range measured for the streambed sediments. Analyses of phosphorus and nitrogen in the soil indicated that ratios of phosphorus to nitrogen were large in both canyons. Suspended sediments collected from Fish Creek, 3 kilometers upstream of the gaging station (fig. 1, site 4), were reported by Denton and others (1983, p. 122) to contain concentrations of phosphorus of 440 milligrams per kilogram with biologically available phosphorus constituting 60 percent of the total concentration.

SURFACE-WATER HYDROLOGY

Boardinghouse Canyon creek and Eccles Canyon creek are tributaries to Mud Creek that, with Fish Creek, contribute the largest volume of inflow to Scofield Reservoir. During 1938-70, Fish Creek averaged about 75 percent of the inflow to Scofield Reservoir, and during the 1980 water year, the combined inflow of Mud and Fish Creeks was about 88 percent of the total inflow to the reservoir (Waddell and others, 1985, table 1). During the 1983 and 1984 water years, Fish Creek contributed about 80 percent of the total inflow. Flow in both Mud and Fish Creeks during the 1983 and 1984 water years was much larger than average. Summary statistics for each of the gaged streams in the study area during the 1983 and 1984 water years and their relation to the long-term mean discharge are shown in table 6. The Boardinghouse Canyon station was installed specifically for this study and had no previous record. Flows at all other sites were typically 140 to 200 percent greater in 1983 and 1984 than the historical average. Historical record flows occurred on May 30, 1983, in the four gaged streams within the study area. Boardinghouse Canyon creek had a maximum flow of 6.6 cubic meters per second as determined from a slope-area measurement of peak flow resulting from the breach of a beaver dam upstream. Eccles Canyon creek had a maximum flow of 1.8 cubic meters per second, and Fish Creek had a maximum flow of 37 cubic meters per second. Even larger flows of 2 cubic meters per second occurred in May 1984 in Eccles Canyon creek, 11 cubic meters per second in Mud Creek, and 41 cubic meters per second in Fish Creek.

Monthly average flow for each of the gaged streams in Pleasant Valley is shown in figure 3. All streams were perennial during 1983 and 1984, but only Mud and Fish Creeks are perennial in most years. Typically, 60 to 70 percent of the total annual flow in each creek is derived from snowmelt in April, May, and June.

Runoff in the Boardinghouse Canyon basin differed considerably from that in the Eccles Canyon basin during 1983-84. The limited data for Boardinghouse Canyon indicated runoff of about 0.6 million cubic meters per square kilometer, twice that of the Eccles Canyon basin. Runoff in the Eccles Canyon

Table 6. Summary of the flow of monitored streams in the Pleasant Valley area, Utah, water years 1983-84

	Total flow, in million cubic meters			
	Boardinghouse Canyon creek (site 1)	Eccles Canyon creek (site 2)	Mud Creek (site 3)	Fish Creek (site 4)
1983	[1]2.9	5.8	23.9	100.9
1984	3.2	6.1	27.5	96.6
1982-84 mean	3.05	5.95	25.7	98.75
Long-term mean	[2]3.1	[3]4.2	[4]16.3	[5]44.6

[1] Incomplete record—missing values were estimated.

[2] 1983-84 mean flow.

[3] 1979-84 mean flow.

[4] 1978-84 mean flow.

[5] 1938-84 mean flow.

basin was about 0.3 million cubic meters per square kilometer. Although the data used to calculate runoff from the Boardinghouse Canyon basin were collected during two wetter-than-average water years, total flow in Eccles Canyon creek during the same two water years was about 1.4 times the 5-year average flow of this creek. The drainage basin of Boardinghouse Canyon therefore was concluded to have considerably more runoff per square kilometer than the larger Eccles Canyon basin.

The large inflow of water from Mud and Fish Creeks during 1983 caused the altitude of Scofield Reservoir to reach a historical peak of 2,323.14 meters during June 1983. The peak for 1984 was 2,322.48 meters, also in June. The average flow from Scofield Reservoir to the Price River for each month of the 1983 and 1984 water years is shown in figure 4. For many months, the average flow was considerably greater in 1983-84 than the average of 1,719 liters per second for the 30-year period following completion of the dam (1939-68).

POTENTIAL EFFECTS OF COAL MINING AND ROAD CONSTRUCTION ON WATER QUALITY OF BOARDINGHOUSE CANYON CREEK AND ECCLES CANYON CREEK

Coal mining in Pleasant Valley could potentially affect the quantity and quality of surface water. If not properly mitigated, the construction of surface facilities and roads can release oil and grease into streams, increase erosion and sediment loads, and increase concentrations of trace metals and nutrients in streams and Scofield Reservoir. In some instances, mine dewatering could change the direction of ground-water movement and thereby affect the low-flow regime of streams. Although water entering a mine probably would be about the same quality as water in nearby streams, water generally becomes mineralized as water moves through mine workings; therefore, mine effluent entering streams could affect the quality of surface water (Danielson and Sylla, 1983, p. 34).

The pH of water in mining areas of the Pleasant Valley coal field is not substantially lowered by mine drainage because the sulfur content of the coal is small. Also, most of the water in the study area is alkaline and immediately buffers mine drainage, resulting in some precipitation of metal oxides. Sulfur in coal occurs in sulfate and pyrite, and in organic forms. In the Pleasant Valley coal field, sulfur content of the coal ranges from 0.31 to 1.60 percent (Heiner, 1972, p. 562).

Mining activities can release trace metals associated with coal into local water sources and can contaminate the water. Seierstad and others (1983) studied metals and other substances released into coal mine accrual waters in central Utah. They determined that few problems were associated with the mining, with the exception of large concentrations of boron and mercury that, on several occasions, exceeded concentration levels established by the Utah Department of Social Services (1978) for drinking, irrigation, and freshwater aquatic life. They also reported that concentrations of dissolved manganese occasionally exceeded the 50 micrograms per liter maximum contaminant level established for drinking water by the Environmental Protection Agency (Seierstad and others, 1983, p. 64).

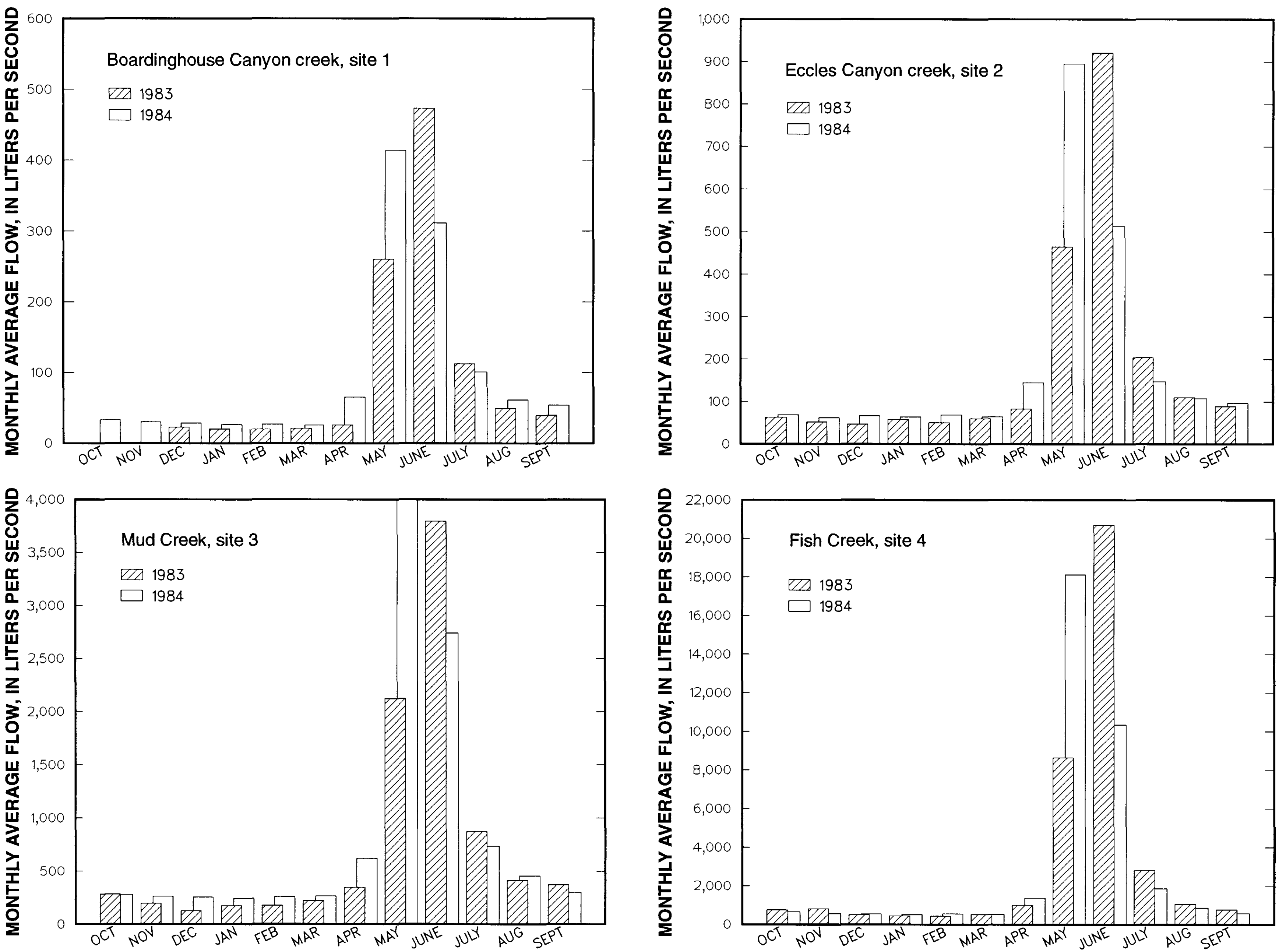

Figure 3. Monthly average flow for gaged streams in the Pleasant Valley area, Utah, water years 1983–84.

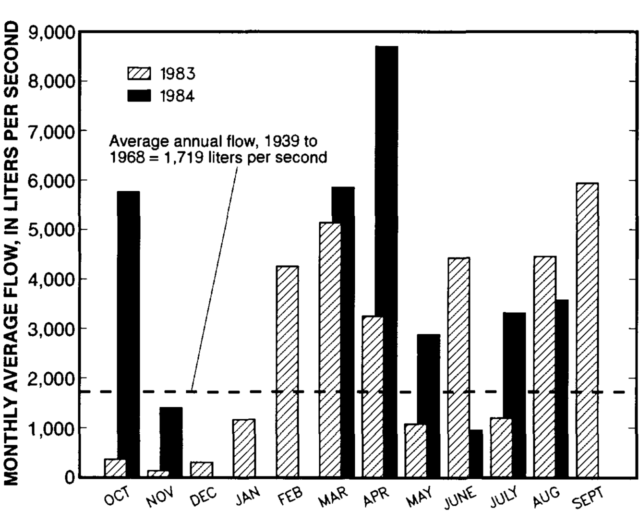

Figure 4. Monthly average flow for gaged streams in the Pleasant Valley area, Utah, water years 1983-84.

Chemical Quality

Summary statistics of water-quality characteristics for Boardinghouse Canyon creek and Eccles Canyon creek are shown in table 7. The coefficient of variation is used to express the variability of the data and is the ratio of the standard deviation to the mean expressed as a percent. None of the water samples from Boardinghouse Canyon creek or Eccles Canyon creek that were analyzed for the trace metals listed in table 1 contained concentrations that exceeded the State water-quality standards applicable for the headwater streams of the Price River.

Concentrations of nitrate and phosphorus, the nutrients responsible for cultural eutrophication of lakes, occasionally exceeded values established by the State as indicators of pollution. The concentration of nitrate in 1 of 18 samples from Eccles Canyon creek exceeded the criterion of 4 milligrams per liter for dissolved nitrate. This sample was collected on December 9, 1982, and had a concentration of nitrite plus nitrate of 77 milligrams per liter. Concentrations of total phosphorus exceeded the State criterion of 0.05 milligram per liter in 5 of 17 samples from Boardinghouse Canyon creek with a maximum phosphorus concentration of 0.7 milligram per liter, and in 10 of 18 samples from Eccles Canyon creek with a maximum of 0.6 milligram per liter. Concentrations of all other measured constituents were within State standards.

Analyses of water samples collected from Boardinghouse Canyon creek and Eccles Canyon creek were compared to determine if there were any statistically significant differences in the water quality of the creeks. By means of a rank sum test, concentrations of some trace metals normally associated with sediments (total and suspended iron, total and dissolved manganese, and total and suspended zinc) were determined to be larger in Eccles Canyon creek than in Boardinghouse Canyon creek.

Compared to Boardinghouse Canyon creek, mean concentrations in Eccles Canyon creek were about twice as large for total and suspended iron and total manganese, and larger than three times for total and suspended zinc. Concentrations of iron, manganese, and zinc in bottom sediment from Eccles Canyon creek also were 10 to 20 percent larger.

Concentrations of dissolved solids were statistically determined to be larger in Eccles Canyon creek than in Boardinghouse Canyon creek. In addition, the specific conductance of stream water, a measurement closely associated with dissolved solids, was statistically larger in Eccles Canyon creek than in Boardinghouse Canyon creek. Concentrations of nitrite plus nitrate were statistically larger in Eccles Canyon creek, but this was because of a single value of 77 milligrams per liter. There was no statistically significant difference in the concentration of any other constituent listed in table 7 for water from the two creeks.

In most flowing water, the concentration of suspended sediment and associated suspended trace metals increases in proportion to increases in flow. This increase results from increased carrying capacity of water at faster flow velocities generally associated with larger flows. The concentration of dissolved substances, however, decreases with increasing flows, mostly because of dilution (Leopold and others, 1964, p. 71). In streams with regulated flows, these relations can be obscured. Analysis of data for suspended sediment, iron, manganese, and dissolved solids in Boardinghouse Canyon creek and Eccles Canyon creek during the 1983-84 water years indicated several differences between the water years as well as between the creeks. Regressions of the logarithms of the concentration of dissolved solids and the logarithms of the flow produced coefficients of determination of 0.78 or larger for both 1983 and 1984 data from Boardinghouse Canyon creek. Analysis of covariance testing of the data indicated there was a significant difference (95-percent confidence level) between the two years, with larger concentrations of the suspended constituents and smaller concentrations of dissolved solids for any given flow in 1983 than in 1984. Total annual flow in 1983 was about 10 percent less than in 1984.

Table 7. Summary statistics for water-quality constituents and water properties in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, October 1982 through October 1984

[µS/cm, microsiemens per centimeter; <, actual value is smaller than value shown; —, no data]

Constituent or property	Number of analyses	Minimum value	Maximum value	Mean	Standard deviation	Coefficient of variation, in percent
Boardinghouse Canyon creek at site 1						
pH (standard units)	14	7.1	8.6	8.1	0.4	4.9
Specific conductance (µS/cm)	21	235	560	449	98	22
Temperature (degrees Celsius)	21	0	13	6.9	4.1	59
Concentration, in micrograms per liter						
Arsenic, total	4	<1.0	2.0	1.1	.6	58
Arsenic, dissolved	5	<1	1.0	<1	—	—
Barium, total recoverable	2	<100	100	<100	—	—
Barium, dissolved	2	47	51	49	2.8	5.8
Beryllium, total	4	<10	<10	—	—	—
Beryllium, dissolved	4	<.5	<1	—	—	—
Boron, dissolved	5	10	30	22	8.4	38
Cadmium, total recoverable	8	<1	<1	—	—	—
Cadmium, dissolved	9	<1	<1	—	—	—
Chromium, total recoverable	8	<1	20	7.0	8.4	12
Chromium, dissolved	8	<10	<10	—	—	—
Copper, total recoverable	8	3.0	60	17	18	103
Copper, dissolved	8	1.0	10	5.9	4.4	76
Copper, suspended recoverable	3	10	17	13	3.6	27
Iron, total recoverable	17	130	13,000	2,407	4,447	185
Iron, dissolved	17	<3.0	52	18	15	84
Iron, suspended recoverable	16	150	13,000	2,540	4,558	179
Lead, total recoverable	8	<1.0	16	4.6	5.2	112
Lead, dissolved	8	<1	<1	—	—	—
Manganese, total recoverable	17	20	500	98	157	160
Manganese, dissolved	11	6.0	21	13	5.4	41
Manganese, suspended recoverable	11	7.0	490	86	157	182
Mercury, total	10	<.1	.3	.1	.1	72
Mercury, dissolved	4	<.1	<.1	—	—	—
Nickel, total recoverable	4	4.0	21	12	9	73
Nickel, dissolved	4	1.0	3.0	1.5	1.0	67
Nickel, suspended recoverable	2	2.0	20	11	13	116
Selenium, total	4	<1	1	<1	—	—
Selenium, dissolved	4	<1	<1	—	—	—
Zinc, total recoverable	8	<10	70	29	28	95
Zinc, dissolved	8	5.0	18	11	4.6	42
Zinc, suspended recoverable	6	<1	70	26	31	116
Phenols, total	5	1.0	10	5.4	3.3	61
Concentration, in milligrams per liter						
Carbon, organic total as C	5	1.8	5.3	3.2	1.9	58
Carbon, organic suspended as C	5	.2	3.8	1.4	1.6	116
Nitrogen, dissolved as N	5	.5	1.8	1.1	.6	52
Nitrogen, ammonia total as N	5	.01	.08	.034	.028	82
Nitrogen, ammonia dissolved as N	9	<.01	.07	.04	.02	34
Nitrogen, ammonia+organic total as N	17	.2	2.1	.58	.5	86
Nitrogen, ammonia+organic dissolved as N	8	.2	.8	.48	.2	42
Nitrogen, NH_4 + organic suspended total as N	6	<.10	1.3	.44	.6	130
Nitrogen, $NO_2 + NO_3$ total as N	4	.1	.3	.2	.1	55
Nitrogen, $NO_2 + NO_3$ dissolved as N	17	<.1	1.2	.3	.3	95
Oxygen, dissolved	11	8.1	9.9	8.9	.7	7.6
Phosphorus, total as P	17	<.01	.7	.1	.2	169
Phosphorus, dissolved as P	17	<.01	.05	.019	.016	85
Phosphorus, ortho, dissolved as P	10	<.01	.04	.016	.013	80
Solids, residue at 180 degrees Celsius, dissolved	17	155	312	250	50	20

Table 7. Summary statistics for water-quality constituents and water properties in Boardinghouse Canyon creek and Eccles Canyon creek, October 1982 through October 1984—Continued

Constituent or property	Number of analyses	Minimum value	Maximum value	Mean	Standard deviation	Coefficient of variation, in percent
Eccles Canyon creek at site 2						
pH (standard units)	15	7.4	8.6	8.0	.3	4
Specific conductance (μS/cm)	19	290	640	519	106	20
Temperature (degrees Celsius)	21	0	14	6.7	4.7	71
Concentration, in micrograms per liter						
Arsenic, total	5	<1.0	1.0	<1.0	—	—
Arsenic, dissolved	6	<1.0	1.0	<1.0	—	—
Arsenic, suspended total	2	<1	<1	—	—	—
Barium, total recoverable	3	<100	100	<100	—	—
Barium, dissolved	3	55	58	56	1.7	3.1
Beryllium, total	5	<10	<10	—	—	—
Beryllium, dissolved	5	<1	<1	—	—	—
Boron, dissolved	6	<10	40	22	15	66
Cadmium, total recoverable	9	<1	<1	—	—	—
Cadmium, dissolved	10	<1	<1	—	—	—
Chromium, total recoverable	9	≤3.0	20	10	7.7	76
Chromium, dissolved	9	<10	<10	—	—	—
Copper, total recoverable	9	1.0	70	24	23	98
Copper, dissolved	9	1.0	10	5.2	4.5	87
Copper, suspended recoverable	4	7	75	26	33	124
Iron, total recoverable	18	350	28,000	4,443	7,065	159
Iron, dissolved	18	<3	60	20	17.6	88
Iron, suspended recoverable	12	390	28,000	6,254	8,144	130
Lead, total recoverable	9	<1	30	8.3	10	125
Lead, dissolved	9	<1	2.0	1.2	.6	53
Manganese, total recoverable	18	60	860	204	193	95
Manganese, dissolved	12	16	110	66	30	45
Manganese, suspended recoverable	12	10	400	90	136	151
Mercury, total	11	<.1	.3	.1	.08	84
Mercury, dissolved	5	<.1	<.1	—	—	—
Nickel, total recoverable	5	<1	40	13	18	139
Nickel, dissolved	5	1.0	3.0	1.6	.9	56
Nickel, suspended recoverable	3	<1.0	39	—	—	—
Selenium, total	5	<1	1	<1	—	—
Selenium, dissolved	5	<1	2.0	—	—	—
Zinc, total recoverable	9	20	330	92	99	107
Zinc, dissolved	9	5	28	14	8.8	61
Zinc, suspended recoverable	9	15	320	76	98	129
Phenols, total	5	3.0	8.0	4.8	2.2	45
Concentration, in milligrams per liter						
Carbon organic total as C	6	1.2	5.4	2.9	1.7	62
Carbon organic suspended as C	6	.2	3.5	1.2	1.5	122
Hardness (as $CaCO_3$)	1	320	320	320	—	—
Nitrogen, dissolved as N	7	.6	2.3	1.0	.6	57
Nitrogen, ammonia total as N	6	<.01	.06	.03	.02	67
Nitrogen, ammonia dissolved as N	9	<.01	.1	.05	.02	46
Nitrogen, ammonia+organic total as N	18	.2	6.1	1.1	1.5	134
Nitrogen, ammonia+organic dissolved as N	9	.2	1.1	.6	.2	44
Nitrogen, NH_4 + organic suspended total as N	6	<.1	5.0	.97	2.0	204
Nitrogen, NO_2 + NO_3 total as N	4	.2	.5	.3	.1	44
Nitrogen, NO_2 + NO_3 dissolved as N	18	.15	77	4.6	18	390
Oxygen, dissolved	11	7.8	10	8.6	.9	10
Phosphorus, total as P	18	<.01	.6	.14	.18	123
Phosphorus, dissolved as P	18	<.01	.06	.02	.02	96
Phosphorus, ortho, dissolved as P	10	<.01	.06	.02	.02	132
Solids, residue at 180 degrees Celsius, dissolved	18	182	533	304	83	27

Coefficients of determination for the relation of the suspended constituents (sediment, iron, manganese) and flow did not exceed 0.5 during 1983 and 0.8 in 1984. Coefficients of determination were larger than 0.65 for relations between dissolved solids and flow during both years. Total annual flow during both years was similar. Analysis of covariance was used to determine if there were significant differences in the relations of flow to suspended and dissolved constituents between Boardinghouse Canyon creek and Eccles Canyon creek for the 1983 and 1984 water years. Regressions of dissolved solids against flow were found to be significantly different at the 95-percent confidence level. These differences were significant for both 1983 and 1984 and indicate that for any given flow, Boardinghouse Canyon creek had a smaller concentration of dissolved solids than Eccles Canyon creek (figs. 5 and 6). The data indicate that for total dissolved-solids concentration and for several elements, coal mining and road construction in Eccles Canyon have increased concentrations in water over concentrations found in water from Boardinghouse Canyon creek.

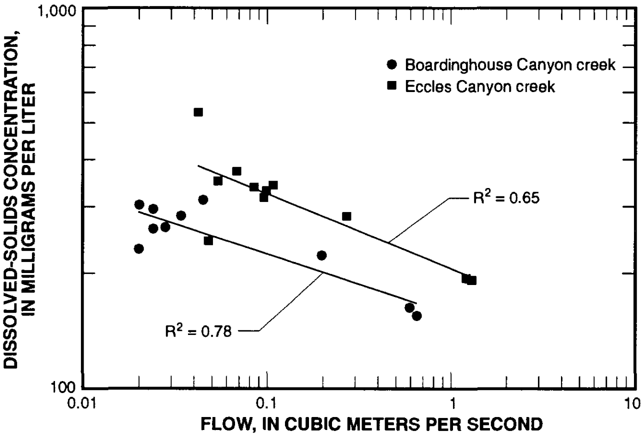

Figure 5. Relation between dissolved-solids concentration and instantaneous flow in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, water year 1983.

Trace-Metal and Nutrient Loads

Loads of selected constituents from Boardinghouse Canyon creek and Eccles Canyon creek are listed in table 8. Loads of about half of the constituents were larger in Eccles Canyon creek than in Boardinghouse Canyon creek. Typically, loads of soil-associated constituents such as total phosphorus and organic carbon were larger in Boardinghouse Canyon creek and may represent overland flow of water and transport of soils into the stream. Loads of mineral-associated constituents such as suspended copper, zinc, and total phenol were larger in Eccles Canyon creek, probably as a result of deep mining and road construction. Mean loads of all forms of zinc were larger in Eccles Canyon creek than in Boardinghouse Canyon creek, as were mean concentrations (table 7). Mean loads of all forms of iron and total and suspended manganese were larger in Boardinghouse Canyon creek than in Eccles Canyon creek; however, the coefficients of variation for total recoverable and suspended forms of iron and manganese in Boardinghouse Canyon creek and Eccles Canyon creek were between 100 and 200 percent.

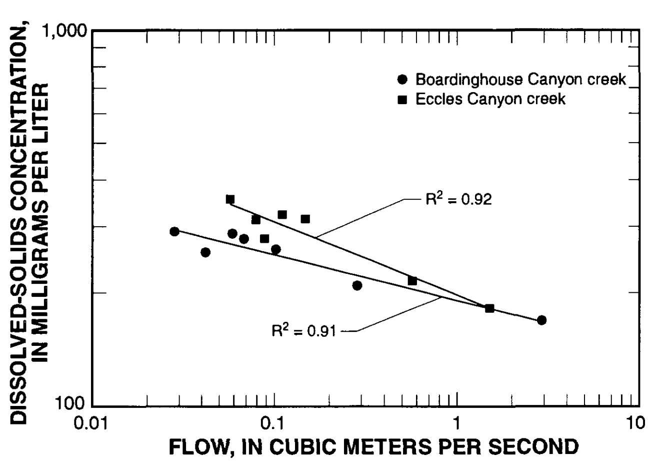

Figure 6. Relation between dissolved-solids concentration and instantaneous flow in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, water year 1984.

Basin yield in kilograms per square kilometer per day also is presented in table 8. When expressed in terms of basin yield per square kilometer per day, the yields of most constituents were larger in Boardinghouse Canyon primarily because the flow per square kilometer was twice as large in Boardinghouse Canyon.

Suspended Sediment

Storm Data

Summary statistics for concentrations of suspended sediment measured during storms are shown in table 9. The concentrations were tested to determine if there was a significant difference in the sediment yields of Boardinghouse Canyon and Eccles Canyon basins. A t test on grouped means (all suspended-sediment

Table 8. Mean load and yield of constituents in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, water years 1983-84

[—, no data]

Constituent	Load, in kilograms per day		Yield, in kilograms per square kilometer per day	
	Boardinghouse Canyon creek (site 1)	Eccles Canyon creek (site 2)	Boardinghouse Canyon creek (site 1)	Eccles Canyon creek (site 2)
Arsenic, total	0.10	0.05	0.02	0.004
Arsenic, dissolved	.08	.04	.02	.003
Arsenic, suspended total	.002	—	.0004	—
Barium, total recoverable	.17	.54	.03	.04
Barium, dissolved	.08	.30	.02	.02
Barium, suspended recoverable	.09	.19	.02	.01
Beryllium, total	1.0	.54	.19	.04
Beryllium, dissolved	.09	.05	.02	.003
Cadmium, total recoverable	.06	.04	.01	.003
Cadmium, dissolved	.05	.03	.01	.002
Chromium, total recoverable	1.2	.68	.23	.05
Chromium, dissolved	.64	.36	.12	.02
Copper, total recoverable	.91	1.4	.17	.10
Copper, dissolved	.13	.09	.02	.006
Copper, suspended recoverable	1.3	3.2	.24	.22
Iron, total recoverable	341	229	65	16
Iron, dissolved	1.4	.86	.26	.06
Iron, suspended recoverable	372	346	70	24
Lead, dissolved	.06	.07	.01	.005
Lead, suspended recoverable	—	4.5	—	.32
Lead, total recoverable	.54	.59	.10	.04
Manganese, suspended recoverable	16	8.6	3.0	.60
Manganese, total recoverable	11	8.2	2.1	.58
Manganese, dissolved	.54	1.1	.10	.08
Mercury, total	.004	.004	.0008	.0003
Mercury, dissolved	.009	.004	.002	.0003
Nickel, dissolved	.10	.08	.02	.006
Nickel, suspended recoverable	.50	1.9	.09	.13
Nickel, total recoverable	1.9	1.4	.36	.10
Selenium, total	.10	.05	.02	.003
Selenium, dissolved	.10	.07	.02	.005
Zinc, total recoverable	4.3	6.4	.81	.45
Zinc, dissolved	.43	.50	.08	.04
Zinc, suspended recoverable	3.8	5.4	.72	.38
Phenols, total	.02	.04	.004	.003
Nitrogen, dissolved as N	108	59	20	4.2
Nitrogen, ammonia, total as N	—	.04	—	.003
Nitrogen, ammonia, dissolved as N	.06	.15	.01	.01
Nitrogen, ammonia, dissolved as NH_4	.15	.40	.03	.03
Nitrogen, ammonia+organic, total as N	42	61	8.0	4.3
Nitrogen, ammonia+organic, dissolved as N	30	27	5.7	1.9
Nitrogen, NH_4+organic, suspended total as N	53	87	10	6.1
Nitrogen, $NO_2 + NO_3$ total as N	1.5	4.1	.28	.29
Nitrogen, $NO_2 + NO_3$ dissolved as N	30	32	5.7	2.2
Phosphorus, total as P	10	7.7	1.9	.52
Phosphorus, dissolved as P	.009	.02	.002	.001
Phosphorus, ortho, dissolved as P	.009	.02	.002	.001
Carbon organic, dissolved as C	536	211	102	15
Carbon organic, suspended as C	267	127	50	8.9

Table 9. Summary of suspended-sediment concentrations in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, during storms, water years 1983-84

Site	Number of samples	Concentration, in milligrams per liter Mean	Minimum	Maximum	Standard deviation	Coefficient of variation, in percent
Boardinghouse Canyon creek at site 1	53	2,210	29	12,300	3,440	156
Eccles Canyon creek at site 2	68	2,380	23	11,468	3,150	132

concentrations for all storms) showed no significant difference (95-percent confidence limit) between the suspended-sediment concentrations of Boardinghouse Canyon creek and Eccles Canyon creek during storms.

Suspended-sediment loads for individual storms are shown in table 10 for each sampling site.The sampling was designed so that the sites would be sampled by the automatic equipment through the duration of each storm. Twelve storms were sampled during this study; however, numerous equipment failures and the poor distribution of storms made simultaneous data collection at both sites possible only during the storm of September 30, 1983. This storm, with a rainfall of about 1 centimeter, produced a suspended-sediment load of 1,700 kilograms in Boardinghouse Canyon creek and 6,800 kilograms in Eccles Canyon creek, equivalent to a sediment yield of 320 kilograms (0.32 metric ton) per square kilometer in Boardinghouse Canyon creek and 480 kilograms (0.48 metric ton) per square kilometer in Eccles Canyon creek. For this storm, Eccles Canyon creek contributed more sediment per unit area of drainage than did Boardinghouse Canyon creek.

The mean suspended-sediment load in Boardinghouse Canyon creek during all storms was about 4.3 metric tons and for Eccles Canyon creek was 10.5 metric tons. Direct comparison of the mean suspended-sediment loads was complicated because data were generally not available for the same storm at both sites. Boardinghouse Canyon had a mean sediment yield of 0.81 metric ton per square kilometer; Eccles Canyon had a mean sediment yield of 0.74 metric ton per square kilometer. The mean sediment yield for Boardinghouse Canyon was greater because a single, large storm (August 19, 1984) was sampled at the site on Boardinghouse Canyon creek but not at the site on Eccles Canyon creek. The load from this storm greatly influenced the mean load for Boardinghouse Canyon creek. If the load from this storm is excluded, the mean storm load for Boardinghouse Canyon is only 0.16 metric ton per square kilometer, with a coefficient of variation of 86 percent. In addition, the steeper stream gradient (10 percent in Boardinghouse Canyon compared to 6 percent in Eccles Canyon) and the larger total rainfall per storm (about 20 percent) in Boardinghouse Canyon may have contributed to the larger apparent loads.

It was not possible to identify a significant relation between rainfall quantity and suspended-sediment load resulting from individual storms by means of regression analysis. Other factors not determined in this study such as rainfall duration, time between storms, and rainfall intensity contribute to the dynamic system that affects suspended-sediment loads.

Base-Flow Data

Many samples of suspended sediment were collected from Eccles Canyon creek by a local observer during the 1983-84 water years in addition to those samples collected as part of this study. Unfortunately, only two samples were available from Boardinghouse Canyon creek for the 1984 water year. Summary statistics for suspended-sediment concentrations collected during conditions of base flow during 1983-84 appear in table 11. Seven values for concentrations from Boardinghouse Canyon creek and 40 values for Eccles Canyon creek, representing data for only the 1983 water year, were tested by means of a grouped-means t test to determine if there was a significant difference in suspended-sediment concentrations between sites. The test (using log-transformed data) indicated that at the 95-percent confidence limit, the mean of 325 milli-

Table 10. Rainfall and suspended-sediment load in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, during selected storms, water years 1983-84

[—, no data]

Date	Boardinghouse Canyon creek (site 1)		Eccles Canyon creek (site 2)	
	Rainfall (centimeters)	Load (metric tons)	Rainfall (centimeters)	Load (metric tons)
July 6-7, 1983	—	—	—	—
August 16-17, 1983	—	—	.64	14.7
August 18-19, 1983	—	—	.38	10.1
September 1, 1983	.76	1.07	—	—
September 30, 1983	1.02	1.70	1.14	6.8
August 19-20, 1984	1.27	18.20	—	—
September 11-12, 1984	.76	.20	—	—
September 20-21, 1984	.51	.3	—	—
Mean	.86	4.29	.72	10.5
Coefficient of variation, in percent	34	182	60	38

grams per liter for samples from Boardinghouse Canyon creek was not significantly different from the mean of 2,870 milligrams per liter for samples from Eccles Canyon creek. The lack of a statistically significant difference in the means was a result of the small sample size and the large variation in data for the 1983 water year for both creeks. The coefficient of variation for the Boardinghouse Canyon creek data was 169 percent and for Eccles Canyon creek was 282 percent.

Suspended-sediment loads were calculated from samples collected during conditions of base flow using data for the 1983-84 water years (table 12). Boardinghouse Canyon creek contributed a smaller load than Eccles Canyon creek, as was noted for storm samples. The median load (median rather than mean loads were used owing to the large coefficient of variation) for Boardinghouse Canyon creek was 0.75 metric ton per day and for Eccles Canyon creek was 1.08 metric tons per day. Expressed as sediment yield, Boardinghouse Canyon had a yield of 0.14 metric ton per square kilometer per day, and Eccles Canyon 0.08 metric ton per square kilometer per day. The sediment yield was larger in Boardinghouse Canyon primarily because the runoff per square kilometer in Boardinghouse Canyon was twice as large as in Eccles Canyon.

WATER QUALITY IN MUD CREEK AND FISH CREEK BASINS

Chemical Quality

Summary statistics of water-quality characteristics for Mud and Fish Creeks are shown in table 13. Phenols were reported by Gunnell and others (1982, p. 26) to exceed the State water-quality standard of 10 milligrams per liter in Pleasant Valley streams. During the current study, concentrations of total phenols exceeded the standard of 10 micrograms per liter in one of five samples from Mud Creek. This sample was collected on July 19, 1983, and had a concentration of 12 micrograms per liter. Water samples from Fish Creek were not analyzed for phenols.

Several forms of the plant nutrients nitrogen and phosphorus were quantified in water samples from Mud Creek and Fish Creek as a result of concerns about eutrophication of Scofield Reservoir. For nitrogen, concentrations of nitrite plus nitrate in samples from Mud Creek and Fish Creek were smaller than the State criterion of 4 milligrams per liter as a pollution indicator. None of the samples collected from either stream contained concentrations of un-ionized ammonia that exceeded the State standard of 0.02 milligram per liter;

Table 11. Summary of suspended-sediment concentrations during conditions of base flow in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, water years 1983-84

Site	Number of samples	Concentration, in milligrams per liter			Standard deviation	Coefficient of variation, in percent
		Mean	Minimum	Maximum		
Boardinghouse Canyon creek at site 1	9	447	28	1,750	649	145
Eccles Canyon creek at site 2	94	1,462	10	45,100	5,421	371

Table 12. Summary of suspended-sediment loads during conditions of base flow in Boardinghouse Canyon creek and Eccles Canyon creek, Utah, water years 1983-84

Site	Number of samples	Load, in metric tons per day			Standard deviation	Coefficient of variation, in percent
		Median	Minimum	Maximum		
Boardinghouse Canyon creek at site 1	9	0.75	0.07	349	106	208
Eccles Canyon creek at site 2	94	1.08	.05	675	107	283

however, the total loads of nitrite plus nitrate, and ammonia plus organic nitrogen, for both streams were 38 and 142 metric tons annually, respectively. About 80 percent of these loads originated in Fish Creek.

Concentrations of total phosphorus in both streams occasionally exceeded the State criterion of 0.05 milligram per liter. In Mud Creek, the concentration exceeded the criterion in 11 of 16 samples, with a maximum of 0.9 milligram per liter. In Fish Creek, the concentration exceeded the criterion in 4 of 11 samples, with a maximum of 0.6 milligram per liter. Concentrations of all other measured constituents were either within the State standards or applicable State standards had not yet been established.

Trace-Metal and Nutrient Loads to Scofield Reservoir

Streamflow during 1983 and 1984 for both Mud and Fish Creeks was considerably larger than average flows for the period of record (table 6). Flow in Mud Creek was 147 percent of average in 1983 and 169 percent in 1984, and flow in Fish Creek was more than 200 percent of average in both years. This larger flow resulted in loads of constituents that were larger than normally would be expected.

Mean loads for selected constituents in each of the basins are shown in table 14. Because sampling for most trace elements in Fish Creek was infrequent, comparison of loads for only a small number of constituents was possible. Also, concentrations of many trace elements were near the lower detection limit, voiding any valid calculation of loads. Because Fish Creek typically contributes about 75 percent of the inflow to Scofield Reservoir, it also is expected to contribute a larger proportion of the constituent loads to the reservoir than Mud Creek. This relation was verified for all constituents for which loads were calculated. For total manganese and mercury, and for ammonia plus organic nitrogen, Fish Creek contributed 84 to 97 percent of the total load discharged to Scofield Reservoir. When expressed as basin yield (table 15), only loads of total manganese and mercury, and ammonia plus organic nitrogen, were larger than 70 percent for Fish Creek basin. Fish Creek contributed only 53 to 64 percent of the total loads for the other constituents.

Annual loads of several forms of nitrogen and of total phosphorus for water years 1981 and 1982 were presented by Denton and others (1983, p. 40) and for October 1979 through September 1980 by Waddell and others (1985, table 2). Because of differences in the forms of nitrogen that were analyzed, comparison of loads for the different time periods is limited to total phosphorus. (Flows and loads given by Waddell and

Table 13. Summary statistics for water-quality constituents and water properties in Mud Creek and Fish Creek, Utah, October 1982 through October 1984

[µS/cm, microsiemens per centimeter; <, actual value is smaller than value shown; —, no data]

Constituent or property	Number of analyses	Minimum value	Maximum value	Mean	Standard deviation	Coefficient of variation, in percent
		Mud Creek at site 3				
pH (standard units)	14	7.6	8.6	8.3	0.3	4
Specific conductance (µS/cm)	18	255	620	498	100	20
Temperature (degrees Celsius)	18	0	18	8.4	7.2	86
		Concentration, in micrograms per liter				
Arsenic, total	4	<1	1	<1	—	—
Arsenic, dissolved	5	<1	1	<1	—	—
Arsenic, suspended total	1	0	0	—	—	—
Barium, total recoverable	3	<100	200	—	—	—
Barium, dissolved	3	46	61	52	7.8	15
Beryllium, total	4	<10	<10	—	—	—
Beryllium, dissolved	4	<.5	<1.0	—	—	—
Boron, dissolved	6	20	50	35	10	30
Cadmium, total recoverable	6	<1.0	1.0	<1	—	—
Cadmium, dissolved	7	<1.0	<1.0	—	—	—
Chromium, total recoverable	6	<1	30	8.1	11.2	138
Chromium, dissolved	6	<10	<10	—	—	—
Copper, total recoverable	6	1.0	40	15	15	99
Copper, dissolved	6	1.0	10	4.3	4.4	103
Copper, suspended recoverable	3	2.0	24	12	11	93
Iron, total recoverable	15	260	20,000	2,751	5,020	182
Iron, dissolved	14	<3.0	100	23	26	111
Iron, suspended recoverable	14	250	20,000	2,883	5,182	180
Lead, total recoverable	6	<1.0	24	6.8	9.2	135
Lead, dissolved	6	<1.0	4.0	—	—	—
Manganese, total recoverable	15	40	490	121	112	92
Manganese, dissolved	12	10	78	37	20	54
Manganese, suspended recoverable	12	6.0	470	78	131	169
Mercury, total	8	<.1	.5	.1	.17	181
Mercury, dissolved	4	<.1	<.1	—	—	—
Nickel, total recoverable	4	1.0	26	12	10	90
Nickel, dissolved	4	1.0	2.0	1.5	.6	38
Nickel, suspended recoverable	2	<1	11	—	—	—
Selenium, total	4	<1	1	<1	—	—
Selenium, dissolved	4	<1	<1	—	—	—
Zinc, total recoverable	6	10	120	50	38	77
Zinc, dissolved	6	<3.0	35	13	13	102
Zinc, suspended recoverable	3	0	100	53	50	94
Phenols, total	5	3.0	12	6.4	4.3	67
		Concentration, in milligrams per liter				
Carbon, organic dissolved	6	2.0	6.5	3.8	2.0	52
Carbon, organic suspended	4	.3	3.8	1.2	1.7	144
Nitrogen, dissolved as N	4	.6	2.2	1.2	.7	58
Nitrogen, ammonia total as N	6	<.01	.06	.026	.018	67
Nitrogen, ammonia dissolved as N	8	.01	.06	.049	.018	37
Nitrogen, ammonia+organic total as N	16	.2	4.0	.9	.9	105
Nitrogen, ammonia+organic dissolved as N	8	.2	.8	.5	.2	46
Nitrogen, NH_4+ organic suspended total as N	5	.1	3.2	.92	1.3	142
Nitrogen, NO_2+ NO_3 total as N	3	<.1	.14	—	—	—
Nitrogen, NO_2+ NO_3 dissolved as N	14	<.1	1.5	.3	.4	130
Hardness (as $CaCO_3$)	1	320	320	320	—	—
Oxygen, dissolved	11	7.1	12	8.8	1.5	18
Phosphorus, total as P	15	<.01	.9	.16	.23	144
Phosphorus, dissolved as P	15	<.01	.03	.01	.008	54
Phosphorus, ortho, dissolved as P	9	<.01	.05	.02	.01	77
Solids, residue at 180 degrees Celsius, dissolved	16	162	361	294	61	21

Table 13. Summary statistics for water-quality constituents and water properties in Mud Creek and Fish Creek, Utah, October 1982 through October 1984—Continued

Constituent or property	Number of analyses	Minimum value	Maximum value	Mean	Standard deviation	Coefficient of variation, in percent
Fish Creek at site 4						
pH (standard units)	6	7.7	8.6	7.9	0.3	4.1
Specific conductance (µS/cm)	11	25	640	369	140	38
Temperature (degrees Celsius)	10	0	16	5.6	5.7	103
Concentration, in micrograms per liter						
Boron, dissolved	1	20	20	—	—	—
Cadmium, total recoverable	2	<1	<1	—	—	—
Cadmium, dissolved	2	<1	1	<1	—	—
Chromium, total recoverable	2	9	15	—	—	—
Chromium, dissolved	2	<10	<10	—	—	—
Copper, total recoverable	2	20	80	—	—	—
Copper, dissolved	2	10	10	—	—	—
Iron, total recoverable	11	190	11,000	2,360	3,703	157
Iron, dissolved	11	8	120	36	38	105
Iron, suspended recoverable	11	170	110,000	11,330	32,807	290
Lead, total recoverable	2	1.0	6.0	—	—	—
Lead, dissolved	2	<1.0	2.0	—	—	—
Lead, suspended recoverable	1	4.0	4.0	—	—	—
Manganese, total recoverable	11	20	400	104	126	121
Manganese, dissolved	8	11	30	20	6.8	34
Manganese, suspended recoverable	8	5.0	390	101	147	145
Mercury, total	5	<.1	.8	—	—	—
Zinc, total recoverable	2	10	50	—	—	—
Zinc, dissolved	2	<3.0	23	—	—	—
Zinc, suspended recoverable	1	30	30	—	—	—
Concentration, in milligrams per liter						
Nitrogen, dissolved as N	1	.9	.9	—	—	—
Nitrogen, ammonia total as N	1	<.06	<.06	—	—	—
Nitrogen, ammonia dissolved as N	8	<.01	.6	.1	.20	185
Nitrogen, ammonia+organic total as N	11	.2	6.0	1.2	1.6	134
Nitrogen, ammonia+organic dissolved as N	3	.3	.6	.47	.15	33
Nitrogen, NH_4 + organic suspended total as N	3	.1	1.1	.5	.5	96
Nitrogen, NO_2 + NO_3 total as N	2	<.1	<.1	—	—	—
Nitrogen, NO_2 + NO_3 dissolved as N	11	<.1	1.2	.3	.3	116
Oxygen, dissolved	4	7.9	11	9.6	1.3	13
Phosphorus, total as P	11	.01	.7	.1	.2	161
Phosphorus, dissolved as P	11	<.01	.05	.02	.01	90
Phosphorus, ortho, dissolved as P	8	<.01	.03	.02	.01	62
Solids, residue at 180 degrees Celsius, dissolved	11	187	226	202	14	7.0

others, 1985, were adjusted to represent a full water year.) During 1980-82, the load of total phosphorus in Mud Creek ranged from 1 to 1.7 metric tons per year for a flow of 5 to 17 cubic hectometers per year. Corresponding loads in Fish Creek ranged from 3.5 to 4.1 metric tons per year for flows ranging from 28 cubic hectometers per year in 1981 to 76 cubic hectometers per year in 1980. The mean load in Mud Creek during the 1983-84 water years was 8.2 metric tons per year at a flow of about 25 cubic hectometers per year, and the Fish Creek load was 10 metric tons per year at a flow of about 100 cubic hectometers per year. The increased flows of 1983-84 discharged considerably larger loads of total phosphorus than the average for previous years.

Suspended-Sediment Loads to Scofield Reservoir

Storm Data

Mud Creek is the receiving stream for both Boardinghouse Canyon creek and Eccles Canyon creek and is a significant source of sediment deposited in Scofield Reservoir. Sampling site 3 on Mud Creek is downstream from the confluences of both Boardinghouse Canyon creek and Eccles Canyon creek, and there are several small intermittent tributaries that discharge to Mud Creek upstream of the sampling site. Owing to the remoteness and lack of observers in the

Table 14. Mean load and concentration of selected constituents that entered Scofield Reservoir from Mud Creek and Fish Creek, Utah, water years 1983-84

[Number of samples is in parentheses]

Constituent	Mean load, in metric tons			Mean concentration, in milligrams per liter			
	Mud Creek	Fish Creek	Total	Mud Creek		Fish Creek	
Iron, total	71	233	304	2.75	(15)	2.36	(11)
Manganese, total	3	103	106	.12	(15)	1.04	(11)
Mercury, total	.003	.02	.023	.0001	(8)	.0002	(5)
Zinc, total	1.3	3	4.3	.05	(6)	.03	(2)
Ammonia plus organic nitrogen, total	23	119	142	.9	(16)	1.2	(11)
Nitrogen, nitrite plus nitrate, dissolved	8	30	38	.3	(16)	.3	(11)
Phosphorus, total	4	10	14	.15	(16)	.10	(11)
Solids, dissolved	7,560	19,960	27,520	294	(16)	202	(11)

Table 15. Mean annual basin yield for load of selected constituents discharged from Mud Creek and Fish Creek basins, Utah, water years 1983-84

[kg/km^2, kilograms per square kilometer]

Constituent	Mud Creek basin		Fish Creek basin	
	Yield (kg/km^2)	Percent of total	Yield (kg/km^2)	Percent of total
Iron, total	1,494	61	947	39
Manganese, total	660	94	40	6
Mercury, total	.13	76	.04	24
Zinc, total	19	53	17	47
Ammonia plus organic nitrogen, total	763	71	307	29
Nitrogen, nitrate plus nitrite, dissolved	192	64	107	36
Phosphorus, total	64	55	53	45
Solids, dissolved	127,949	56	100,800	54

Fish Creek basin, suspended-sediment data were not collected during storms in Fish Creek.

A summary of storm loads of suspended sediment for Mud Creek is presented in table 16. Because storms were not coincident in the basins of Boardinghouse and Eccles Canyons and the Mud Creek drainage, it is not possible to compare loading on a storm-by-storm basis. Comparison of the mean suspended-sediment loads of 4.3 metric tons per storm for Boardinghouse Canyon creek and 10.5 metric tons per storm for Eccles Canyon creek (table 10), shows that nearly 75 percent of the mean storm load of 20 metric tons of suspended sediment transported in Mud Creek was contributed by Boardinghouse and Eccles Canyons, which comprise only 25 percent of the Mud Creek drainage area. As the sediment enters Mud Creek from the tributaries during summer storms, suspended sediment can be deposited as bed material as a result of the small channel slope and several beaver dams along the creek. Flows from subsequent storms can then transport some of this material to Scofield Reservoir.

Base-Flow Data

A summary of suspended-sediment loads during conditions of base flow in Mud and Fish Creeks is presented in table 17. On the basis of a small number of

Table 16. Rainfall and suspended-sediment load in Mud Creek, Utah, for selected storms, water years 1983-84

Date	Rainfall (centimeters)	Load (metric tons)
July 6-7, 1983	0.28	17.6
August 18-19, 1983	.51	7.5
September 1, 1983	.18	8.7
September 30, 1983	1.07	15.4
August 19-20, 1984	1.47	65.1
September 11-12, 1984	.64	12.7
September 20-21, 1984	.51	13.3
Mean	.67	20.0
Coefficient of variation, in percent	46	101

samples from each site, Mud Creek had a median suspended-sediment load of 2.63 metric tons per day during base flow conditions, or a suspended-sediment yield of 0.04 metric ton per square kilometer per day. Fish Creek basin had a median suspended-sediment yield of about 1.1 metric tons per square kilometer per day. The larger flow and channel slope of Fish Creek results in much larger loads of suspended sediment than are found in Mud Creek.

WATER QUALITY IN SCOFIELD RESERVOIR

Scofield Reservoir becomes thermally stratified during the summer. The thermocline (metalimnion) that forms during this season varies in depth and intensity and separates the upper water (epilimnion) from the more dense lower water (hypolimnion). The anaerobic condition of the hypolimnion is the result of large quantities of biological production in the reservoir followed by deposition of biomass and subsequent oxygen depletion caused by decay. The biological degradation of the organic matter under anaerobic conditions results in a decline of redox potentials and solubilization of trace metals and nutrients from the sediments. During winter, the reservoir also stratifies with temperature near 0 °C at the surface and slightly warmer (2 to 4 °C) water near the bottom (Utah Department of Health, 1984). Scofield Reservoir is dimictic, mixing twice a year, typically in May and September.

Sampling during periods of thermal stratification was done in both the epilimnion (above the thermocline) and the hypolimnion (below the thermocline). When the reservoir was mixed, one representative sample was collected. Because sites M65 and M90B were too shallow to become thermally stratified, a single, representative sample from the water column was collected at these two sites during each visit. A summary of mean concentration of each constituent in the epilimnion and hypolimnion at five reservoir sites is presented in table 18.

Table 17. Summary of suspended-sediment load during conditions of base flow in Mud Creek and Fish Creek, Utah, water years 1983-84

Site	Number of samples	Load, in metric tons per day			Standard deviation	Coefficient of variation, in percent
		Median	Minimum	Maximum		
Mud Creek (site 3)	5	2.63	0.64	1,291	576	221
Fish Creek (site 4)	3	165	65	1,700	916	142

The following constituents were compared with the applicable State water-quality standards and criteria to evaluate general water quality:

total dissolved solids
dissolved iron
dissolved cadmium
total mercury
dissolved zinc
dissolved copper
dissolved arsenic
pH
dissolved lead
dissolved chromium
total phosphorus
dissolved ammonia nitrogen

Mercury, zinc, phosphorus, and ammonia were the only constituents that were found to exceed the State standards or criteria. Mercury concentrations exceeded a previous State standard of 0.05 microgram per liter in all samples from site M65, and site M90B, in 12 of 15 samples from site M30, in 13 of 19 samples from site M5, and in both samples from site M110; however, mercury did not exceed the State standard of 1 microgram per liter (as dissolved mercury) adopted by the State of Utah in 1984 in any of the samples. Only one sample, a near-surface sample from site M110 had a zinc concentration of 70 micrograms per liter and exceeded the State standard of 50 micrograms per liter. None of the other samples had zinc concentrations that exceeded the State standard. Total phosphorus exceeded the State criterion of 0.025 microgram per liter (phosphate as phosphorus) for lakes in nearly 50 percent of all samples collected from the reservoir: in 6 of 11 samples from site M65, in 4 of 10 samples from site M90B, in 8 of 16 samples from site M30, in 9 of 22 samples from site M5, and in 1 of 2 samples from site M110. Un-ionized ammonia exceeded the standard of 0.02 milligram per liter on August 31, 1983, at sites M30 and M110. Considerable algal material was present, and the pH at both sites had increased as a result of algal removal of carbon dioxide from the water. The water temperature was above 18 °C.

Dissolved sulfate concentrations from the near-surface water were similar at all five sites; however, dissolved sulfate concentrations in samples collected from the hypolimnion at the deep-water sites (M5, M30, M110) were smaller than the concentrations in the epilimnion. The smaller sulfate concentrations in the hypolimnion of the reservoir probably were caused by the reduction of sulfate to sulfide by sulfate-reducing bacteria in the oxygen-depleted water characteristic of the hypolimnion.

Concentrations of dissolved silica were similar in the near-surface water at all five sites; however, the concentrations in the hypolimnion were larger than the concentrations in the epilimnion at the deep-water sites. Because of the release of silica from the anaerobic sediments to the hypolimnion, variations in concentrations of silica were similar to those of phosphorus. Large concentrations of total phosphorus at sites M30 and M5 correspond to periods of thermal stratification. Mean phosphorus concentrations at these two sites were consistently larger in the hypolimnion than in the epilimnion.

Total aluminum, total and suspended iron, and total and suspended manganese, elements commonly associated with soils, were present in larger concentrations in the near-surface waters of the two sites near the major inflows to the reservoir (sites M65 and M90B) than in the near-surface waters of the other three sampling sites. This relation was caused by incomplete settling of the suspended material in the tributary inflows from these sites. The other sampling sites were far enough away from the inflow so that only a small quantity of suspended material was present.

Aluminum, iron, manganese, and phosphorus generally were found in considerably larger concentrations in the hypolimnion than in the epilimnion at the three deep-water sites or in the epilimnion at the two shallow-water sites. In many lakes, dissolved aluminum, iron, manganese, and phosphorus are released from the sediments into the oxygen-depleted waters of the hypolimnion. Not much mixing occurs between the hypolimnion and the epilimnion during stratification, which results in increased concentrations of these elements in the hypolimnion. During lake turnover, however, the elements are mixed throughout the water column, and concentrations of manganese in the epilimnion occasionally exceeded the public-water-supply criteria (50 micrograms per liter) of the U.S. Environmental Protection Agency (1976, p. 178). Dissolved aluminum, iron, manganese, and phosphorus also adsorb to fine materials suspended near the bottom of the water body, as evidenced by the large concentrations of suspended and total forms of these elements in the hypolimnion of Scofield Reservoir.

Large differences between concentrations of certain constituents and characteristics of water in the epilimnion and the hypolimnion at sites M30 and M5 were determined using a paired t test. At site M30, the paired t test, using 95-percent confidence levels, showed that pH, temperature, and concentrations of dissolved oxygen and dissolved sulfate were larger in the epilimnion, while concentrations of dissolved silica, dissolved manganese, and total alkalinity were determined to be larger in the hypolimnion. At a 90-percent confidence level, concentrations of total manganese, total alumi-

Table 18. Mean concentration of selected water-quality constituents and water properties in water samples from five sites in Scofield Reservoir, Utah, water years 1983-84

[μS/cm, microsiemens per centimeter; —, no data; <, value is less than reporting limit of analysis]

Constituent	M65	M90B	M30		M5		[1] M110	
	Epilimnion	Epilimnion	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion	Epilimnion	Hypolimnion
Specific conductance (μS/cm)	343	343	346	357	336	356	315	370
pH, standard units	7.9	7.8	8.2	7.5	8.1	7.5	8.3	7.1
Hardness (as $CaCO_3$)	166	162	166	174	167	177	160	190
Hardness, noncarbonate (as $CaCO_3$)	13	8	10	3.3	8.8	6.5	3.0	—
Concentration, in milligrams per liter								
Calcium, dissolved (as Ca)	48	48	48	52	48	52	45	58
Magnesium, dissolved (as Mg)	11	11	11	11	11	11	11	11
Sodium, dissolved (as Na)	3.3	3.2	3.2	3.1	3.4	3.1	3.1	3.0
Potassium, dissolved (as K)	1.1	1.2	1.2	1.3	1.2	1.3	1.4	1.4
Chloride, dissolved (as Cl)	4.5	4.4	4.5	4.1	4.6	4.4	4.3	4.0
Sulfate, dissolved (as SO_4)	14	13	13	10	13	11	13	5.8
Fluoride, dissolved (as F)	.13	.10	.12	.12	.11	.10	.10	.10
Silica, dissolved (as SiO_2)	2.0	1.6	1.6	4.3	1.5	3.9	1.5	6.6
Solids, residue at 180 degrees Celsius, dissolved	182	179	180	191	177	199	167	196
Nitrogen, dissolved (as N)	.86	.67	.75	—	.45	.68	—	—
Nitrogen, total (as N)	.6	.7	.6	.6	.5	.9	1.7	.5
Nitrogen, nitrite dissolved (as N)	.02	.02	.02	.02	.02	.02	.02	.02
Nitrogen, NO_2 + NO_3 dissolved (as N)	.15	.18	.14	<.1	<.1	.14	<.10	<.10
Nitrogen, ammonia dissolved (as N)	.06	.06	.12	.22	.05	.31	1.0	.07
Nitrogen, organic dissolved (as N)	.38	.38	.34	.32	.39	.31	.60	.33
Nitrogen, organic total (as N)	.56	.67	.56	.58	.51	.87	1.7	.50
Nitrogen, ammonia + organic dissolved (as N)	.44	.42	.46	.53	.43	.62	1.6	.40
Nitrogen, ammonia + organic total (as N)	.56	.65	.56	.72	.48	.87	1.7	.50
Nitrogen, NH_4 + organic suspended total (as N)	.11	.28	.16	.20	.10	.18	.10	.10
Phosphorus, total (as P)	.03	.04	.04	.06	.02	.08	.24	<.01
Phosphorus, dissolved (as P)	.01	.01	.01	.02	.01	.04	.03	<.01
Phosphorus, ortho, dissolved (as P)	<.01	<.01	.05	<.01	<.01	.16	.13	.002
Phosphorus, ortho, total (as P)	.02	.02	.02	.04	.01	.05	.11	.02
Concentration, in micrograms per liter								
Aluminum, total recoverable (as Al)	187	157	94	626	100	191	80	500
Arsenic, total recoverable (as As)	1.0	1.0	<1.0	1.8	1.0	1.1	1.0	2.0
Cadmium, total recoverable (as Cd)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium, dissolved (as Cr)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cobalt, total recoverable (as Co)	<50	<50	<50	<50	<50	<50	<50	<50
Copper, dissolved (as Cu)	1.7	1.3	1.0	1.8	1.3	1.3	1.0	<1.0
Iron, dissolved (as Fe)	9.9	10	6	64	5.8	120	<3.0	400
Iron, total recoverable (as Fe)	423	596	139	1,090	161	539	150	1,800
Iron, suspended recoverable (as Fe)	505	814	170	1,293	210	443	140	1,400
Lead, dissolved (as Pb)	1.9	1.6	1.2	1.8	1.1	1.7	2.0	1.0
Lead, total recoverable (as Pb)	.5	1.7	1.8	1.4	1.0	1.7	<1.0	<1.0
Lead, suspended recoverable (as Pb)	<1.0	<1.0	5.0	1.0	<1.0	<1.0	<1.0	<1.0
Manganese, dissolved (as Mn)	42	59	36	406	28	282	2.0	530
Manganese, total recoverable (as Mn)	64	101	55	380	53	307	20	600
Manganese, suspended recoverable (as Mn)	32	62	29	60	32	30	20	70
Mercury, total recoverable (as Hg)	.23	.26	.19	.12	.11	.10	.10	.10
Nickel, total recoverable (as Ni)	4.2	5.3	7.5	9.8	5.4	3.3	<1.0	<1.0
Zinc, dissolved (as Zn)	6.9	13	13	7.8	14	7.3	70	50
Zinc, total recoverable (as Zn)	20	50	—	—	30	30	—	—
Zinc, suspended recoverable (as Zn)	10	20	—	—	20	20	—	—

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[1] At site M110, values other than specific conductance are for single samples.

num, and specific conductance also were determined to be larger in the hypolimnion at site M30.

At site M5, temperature, pH, and concentrations of dissolved oxygen were larger in the epilimnion while specific conductance, dissolved ammonia nitrogen, total ammonia plus organic nitrogen, dissolved silica, total and dissolved manganese, dissolved-solids concentration, and total alkalinity were determined to be larger in the hypolimnion. At a 90-percent confidence level, concentrations of dissolved calcium and suspended iron also were determined to be larger in the hypolimnion.

Phytoplankton and Nutrients in Scofield Reservoir

Denton and others (1983) reported that during 1975, populations of phytoplankton were quite diverse and, although some objectionable blue-greens (Cyanophyta) were present, their numbers did not reach bloom proportions. The presence of certain species was indicative of generally acceptable water quality that year. Diatom floras observed during 1981 consisted primarily of *Asterionella formosa* during the spring, and *Melosira granulosa* and *Stephanodiscus minutula* later in the summer. The diatom *Stephanodiscus minutula* has been observed to be a reliable indicator of eutrophic conditions in other Utah reservoirs.

During the summer of 1981, large numbers of the blue-greens *Anabaena flos-aquae* and *Aphanizomenon flos-aquae* developed, reaching concentrations of several million filaments per liter. These concentrations, although indicative of eutrophication, are considerably smaller than those observed in eutrophic reservoirs of this region (Denton and others, 1983, p. 129). The bloom of blue-greens in 1981 resulted in considerable damage to the fish population, most likely caused by release of extra-cellular products and oxygen depletion through respiration and decay. The minimum useable water storage in the reservoir during 1981 declined to 31 percent of the 25-year annual average. This decline concentrated the fish into a much smaller area characterized by large algal densities and small concentrations of dissolved oxygen. As a result, a fishkill of about 200,000 fish occurred (Walter Donaldson, Utah Division of Wildlife Resources, oral commun., 1984).

Phytoplankton conditions during 1983 were similar to those during 1981, with diverse populations of diatoms and green algae present in the spring followed by the appearance of blue-greens in small to moderate numbers in the fall. Although densities of blue-greens also were large in 1982, there was not much damage to the fishery because large inflows to the reservoir resulted in a minimum useable water storage that was larger than 130 percent of the 25-year annual average.

Phytoplankton populations observed during 1983 were diverse; the appearance of several species indicated the water was relatively free of pollutants. Populations of the blue-greens did not develop significantly during the late summer, but the diatom *Stephanodiscus minutula*, an indicator of eutrophication, was the principal diatom present during late August. Results of the sample analyses for 1983 appear in tables 19 and 20.

A species-rich flora was observed during the summer of 1984 (table 21). The diatom flora was diverse and similar to that observed in August of 1983, except that *Stephanodiscus minutula* was less dominant in 1984 (table 22). Densities of the blue-greens and the diatom indicative of eutrophication, *Stephanodiscus minutula*, are shown in figure 7 for August 1981 through September 1984. In general, the phytoplankton observed in 1981-82 indicated eutrophic conditions, whereas populations in 1983-84 indicated improved water-quality conditions. Although the density of *Stephanodiscus minutula* was large in 1983, the density of the blue-greens during 1983-84 decreased considerably as compared to 1981-82 (fig. 7). Record inflow of water during 1983-84 produced a minimum useable water storage that was more than 140 percent of the 25-year annual average. Cooler-than-average spring temperatures shortened the growing season by preventing densities of blue-greens from reaching bloom proportions. Because of increased dilution and a more rapid flushing rate, available supplies of phosphorus from hypolimnetic release did not enrich the epilimnion as in September of 1980 and 1981.

Limiting Nutrients

With favorable temperatures and sufficient sunlight, algal growth will proceed until the supply of a single nutrient is exhausted. At this point, the growth becomes nutrient-limited, and the nutrient in short supply is referred to as the limiting nutrient. Although any one of many trace nutrients such as iron or manganese may become limiting, growth typically is limited by one of the major nutrients, nitrogen or phosphorus. Because phosphorus compounds are only partly soluble in water, the weathering of rock produces a small phosphorus supply, and algal growth is thereby limited by phosphorus.

Table 19. Phytoplankton in near-surface water from Scofield Reservoir, Utah, at site M5 during two dates in 1983

[—, not determined]

Organism	Cell volume, in millions of cubic micrometers per liter	Number of cells per liter
	August 3	
Sphaerocystis schroeteri	5,282	11,120
Ceratium hirundinella	1,852.61	11,120
Dinobryon divergens	229.59	122,320
Stephanodiscus niagarae	175.97	5,560
Asterionella formosa	170.14	100,080
Oocystis borgei	155.89	38,920
Ankistrodesmus falcatus	48.01	61,160
Oocystis species	25.02	16,690
Ankyra judayi	6.65	22,240
Mallomonas species	6.56	5,560
Mougeotia species	—	11,120
Pteromonas species	—	16,680
Spherical green alga	—	5,560
Centric diatoms	—	11,120
Pennate diatoms	—	11,120
	August 17	
Sphaerocystis schroeteri	63,384	133,440
Ceratium hirundinella	9,263	55,600
Pediastrum duplex	721.8	5,560
Dinobryon divergens	688.78	361,400
Oocystis borgei	177.48	44,480
Stephanodiscus niagarae	175.97	5,560
Fragilaria crotonensis	137.44	66,720
Mallomonas species	6.56	5,560
Pteromonas species	—	16,680
Spherical green alga	—	55,600
Centric diatoms	—	66,720
Pennate diatoms	—	38,920

The atomic ratio of nitrogen to phosphorus in aquatic organic matter and algal cells is about 15 to 1 (Stumm and Morgan, 1970, p. 432, 433). This ratio also is inferred to be required for balanced algal nutrition. As a working guideline, when the ratio of total nitrogen to total phosphorus is less than 15, the water is said to be nitrogen limited. Ratios greater than 15 indicate a phosphorus limitation. Analysis of nutrient concentrations reported by Waddell and others (1985, table 6) indicated that the ratios of the average concentrations for total nitrogen and total phosphorus in Scofield Reservoir during September through October 1979 and August 1980 were larger than 15, indicating a phosphorus limitation. Denton and others (1983, p. 137) reported that the nitrogen to phosphorus ratios at 5 sites in the reservoir during the summer of 1981 generally were larger than 15, also indicating that phosphorus was limiting. Ratios after June 1982 generally were less than 15, indicating that nitrogen was the limiting nutrient during the summer of 1982.

An estimate of the readily available nitrogen was calculated as the sum of dissolved nitrite, nitrate, and ammonia, and this value was compared with the concentrations of total phosphorus for each sampling date

Table 20. Density of diatoms in near-surface water from Scofield Reservoir, Utah, at site M5 during two dates in 1983

Organism	Percent relative density
August 3	
Asterionella formosa	51.1
Fragilaria crotonensis	14.3
Stephanodiscus minutula	11.3
Nitzschia frustulum var. *perpusilla*	3.0
Achnanthes minutissima	2.3
Diatoma tenue var. *elongatum*	2.3
Nitzschia recta	2.3
Nitzschia dissipata	1.5
Stephanodiscus niagarae	1.5
Synedra cyclopum	1.5
Navicula cryptocephala var. *veneta*	1.5
Cocconeis placentula var. *lineata*	.8
Melosira granulata var. *angustissima*	.8
Navicula pupula	.8
Navicula salinarum var. *intermedia*	.8
Nitzschia acicularis	.8
Nitzschia palea	.8
Rhoicosphenia curvata	.8
August 17	
Stephanodiscus minutula	58.7
Fragilaria crotonensis	10.7
Achnanthes minutissima	6.6
Asterionella formosa	3.3
Synedra cyclopum	3.3
Cymbella microcephala	2.4
Navicula salinarum var. *intermedia*	2.4
Diatoma tenue var. *elongatum*	1.7
Nitzschia frustulum var. *perminuta*	1.7
Gomphonema parvulum	.8
Gomphonema truncatum	.8
Melosira granulata	.8
Navicula cryptocephala var. *veneta*	.8
Navicula mutica	.8
Navicula species	.8
Nitzschia frustulum var. *perpusilla*	.8
Nitzschia palea	.8
Nitzschia recta	.8
Stephanodiscus niagarae	.8
Synedra famelica	.8

Table 21. Phytoplankton in Scofield Reservoir, Utah, at site M30 during four dates in 1984

Organism	Number of cells per liter
June 27, near-surface water	
Fragilaria crotonensis	300,240
Asterionella formosa	216,840
Melosira granulata var. *angustissima*	77,840
Dinobryon divergens	33,360
Pandorina morum	22,240
Ankistrodesmus falcatus	11,120
Stephanodiscus niagarae	11,120
Melosira granulata	5,560
Pediastrum duplex	5,560
Pennate diatoms	639,400
Centric diatoms	50,040
August 1, 5-meter depth	
Unknown colonial bacterium	344,720
Spherical green alga	227,960
Fragilaria crotonensis	222,400
Oocystis borgei	55,600
Ankistrodesmus falcatus	55,600
Aphanizomenon flos-aquae	50,040
Synedra cyclopum	33,360
Planktosphaeria gelatinosa	16,680
Ceratium hirundinella	5,560
Pennate diatoms	100,080
Centric diatoms	11,120
August 14, 1-meter depth	
Dinobryon divergens	389,200
Sphaerocystis schroeteri	61,160
Oocystis borgei	22,240
Pteromonas species	11,120
Penate diatoms	11,120
Centric diatoms	33,360
September 18, 1-meter depth	
Cyclotella comta	311,360
Aphanizomenon flos-aquae	205,720
Dinobryon divergens	189,040
Fragilaria crotonensis	83,400
Oocystis borgei	50,040
Melosira granulata var. *angustissima*	38,920
Melosira granulata	33,360
Ankistrodesmus falcatus	11,120
Sphaerocystis schroeteri	5,560
Ceratium hirundinella	5,560
Centric diatoms	61,160

Table 22. Density of diatoms in Scofield Reservoir, Utah, at site M30 during four dates in 1984

Organism	Percent relative density
June 27, near-surface water	
Asterionella formosa	38.8
Diatoma tenue var. *elongatum*	33.8
Fragilaria crotonensis	13.2
Melosira granulata	6
Stephanodiscus minutula	6
Cyclotella comta	.4
Cyclotella meneghiniana	.4
Stephanodiscus niagarae	.4
Stephanodiscus cf. *invisitatus*	.4
Synedra cf. *famelica*	.4
Fragilaria crotonensis var. *oregonica*	present [1]
Fragilaria vaucheriae	present [1]
Synedra ulna	present [1]
August 1, 5-meter depth	
Synedra cyclopum	77.6
Stephanodiscus minutula	8.2
Fragilaria crotonensis	4.3
Cyclotella comta	2.7
Achnanthes minutissima	1.6
Diatoma tenue var. *elongatum*	.9
Melosira granulata	.9
Navicula cryptocephala var. *veneta*	.9
Asterionella formosa	.5
Gyrosigma species	.5
Nitzschia microcephala	.5
Stephanodiscus niagarae	.5
Stephanodiscus cf. *invisitatus*	.4
August 14, 1-meter depth	
Cyclotella comta	50.3
Asterionella formosa	14.3
Fragilaria crotonensis	10.2
Synedra cyclopum	9.5
Stephanodiscus minutula	5.4
Melosira granulata	1.4
Stephanodiscus invisitatus	1.2
Stephanodiscus niagarae	1.2
Achnanthes minutissima	.7
Diatoma tenue var. *elongatum*	.7
Cyclotella meneghiniana	.6
Melosira granulata var. *angustissima*	.6
Navicula salinarum var. *intermedia*	.6
Navicula cf. *anglica*	.6
Nitzschia frustulum var. *perminuta*	.6
Navicula bacillum	present [1]
Nitzschia linearis	present [1]
September 18, 1-meter depth	
Cyclotella comta	62.7
Fragilaria crotonensis	25.3
Melosira granulata	5.6
Stephanodiscus niagarae	2.8
Asterionella formosa	2.2
Stephanodiscus minutula	1.1
Synedra cyclopum	.5

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[1] "Present" indicates organism was observed but in small numbers.

(see tables 35 and 36 in the Supplemental Data section of this report). During June, July, and early August of 1983, ratios of nitrogen to phosphorus were between 3 and 6, indicating that nitrogen likely was the nutrient limiting algal growth. By late August, phosphorus was depleted in the near-surface water and ratios were larger than 15, but the ratio in the hypolimnion was only 7, indicating that phosphorus was being released from anaerobic sediments. By mid-September, the ratio in the hypolimnion had increased to 20 as phosphorus was depleted by circulation to the epilimnion during lake turnover and through bacterial growth. During late September and into November, ratios were less than 15, again indicating a nitrogen limitation.

Ratios of nitrogen to phosphorus during 1984 indicated a different pattern of nutrient limitation than was determined for previous years. In May, ratios were near 10 in near-surface and deep water, indicating nitrogen limitation. During June, phosphorus became depleted throughout the reservoir and ratios ranged from 20-30, indicating phosphorus limitation. This change was probably a result of uptake of phosphorus during a spring bloom of diatoms, because the total of pennate and centric diatoms on June 27 was nearly 700,000 per liter. The phosphorus deficiency continued into July, but by August, nitrogen to phosphorus ratios indicated nitrogen limitation. The relatively large ratios of phosphorus to nitrogen during August and the lack of large numbers of blue-greens contrasted markedly with conditions during August of previous years.

Trends in concentrations of total phosphorus from June 1979 through September 1984 are shown in figure 8. Trends for nitrogen in the biologically available forms of nitrate and ammonium are shown in figure 9. In addition to data collected during this study, historical data were available in Waddell and others (1985) and Utah Department of Health (1984). Nutrient cycling occurs in the deep waters of the hypolim-

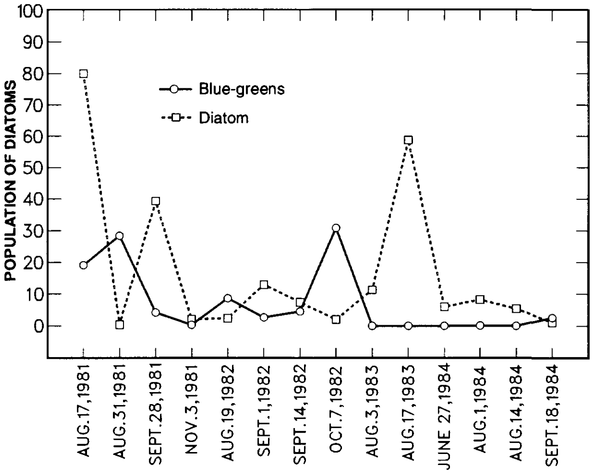

Figure 7. Population fluctuation of the blue-greens *Anabaena flos-aquae* and *Aphanizomenon flos-aquae* and the diatom *Stephanodiscus minutula* in Scofield Reservoir, Pleasant Valley, Utah, at or near site M30.

nion, where concentrations increase during summer stratification and then decrease as the lake mixes in September. Because of large variations in concentrations of nitrogen and total phosphorus in the hypolimnion, it was not possible to determine any trends for these nutrients in the deep water. Concentrations of nitrate and ammonia, and total phosphorus to a lesser degree in the near-surface water, seem to have decreased slightly since 1979. Because of the large variability, however, statistical verification was not possible. The decrease in concentrations of these nutrients may have been caused by the large inflows during 1983-84. The large bloom of algae in August 1981 occurred when concentrations of available nitrogen in the near-surface water were very large and concentrations of total phosphorus were large.

Algal Growth Potential

Data on concentrations of plant nutrients in water provide information on the total quantity of those nutrients but do not indicate the actual fertility of the water. "Algal growth potential" is a bioassay test in which a sample is filtered to remove all indigenous algae and then inoculated with the alga *Selanastrum capricornutum*. Cell growth is monitored in a control series with no additional nutrients and then in the presence of additional nutrients. Growth of the test algae is monitored for several days to several weeks, and the average growth rate or maximum standing crop is calculated as an indicator of the fertility of the water. Water samples were collected during the summer of 1984 at a depth of 5 to 7 meters at site M30, and bioassays were done using methods described by Greeson (1979, p. 80-85). The control series consisted of filtered (0.45 micrometer) but untreated reservoir water. The experimental series was treated with 2 milligrams of nitrogen per liter, 0.4 milligram of phosphorus per liter, and a combination of both nitrogen and phosphorus.

Untreated water collected from Scofield Reservoir on three dates during 1984 and used as a control did not provide a fertile medium for the growth of the test algae (fig. 10). Also, the declining values for the standing crop, with time, in both the control and experimental series indicated a reduction in concentrations of plant nutrients other than nitrogen and phosphorus during the summer. For all dates, the addition of nitrogen alone did not stimulate growth substantially in excess of that observed for the controls. The addition of phosphorus alone resulted in standing crops that were 10 to 20 times as large as the untreated control. Large increases in standing crops occurred when both nitrogen and phosphorus were added, with a 300-fold increase over the control growth for water collected July 31. These results indicate that on these three dates, nitrogen was not limiting algal growth, but the addition of small quantities of phosphorus stimulated growth to the extent that nitrogen did become limiting. The relatively poor growth observed for the combined nitrogen and phosphorus treated sample of September 19 may have resulted from the release of toxic materials during reservoir turnover that occurred at that time, or the depletion of a necessary micro-nutrient. For example, concentrations of plant-required trace elements such as copper and silica, while not excessively large on July 31, were three to nine times larger than on September 19.

CHARACTERISTICS OF SCOFIELD RESERVOIR SEDIMENTS

Core Dating and Sediment Deposition Rates

Radioisotope methods for dating sediments are based on the deposition of radioactive isotopes in the sediment column and the continual decay of the isotopes with time as sediment is buried by subsequent deposits. Lead-210 and cesium-137 isotopes are com-

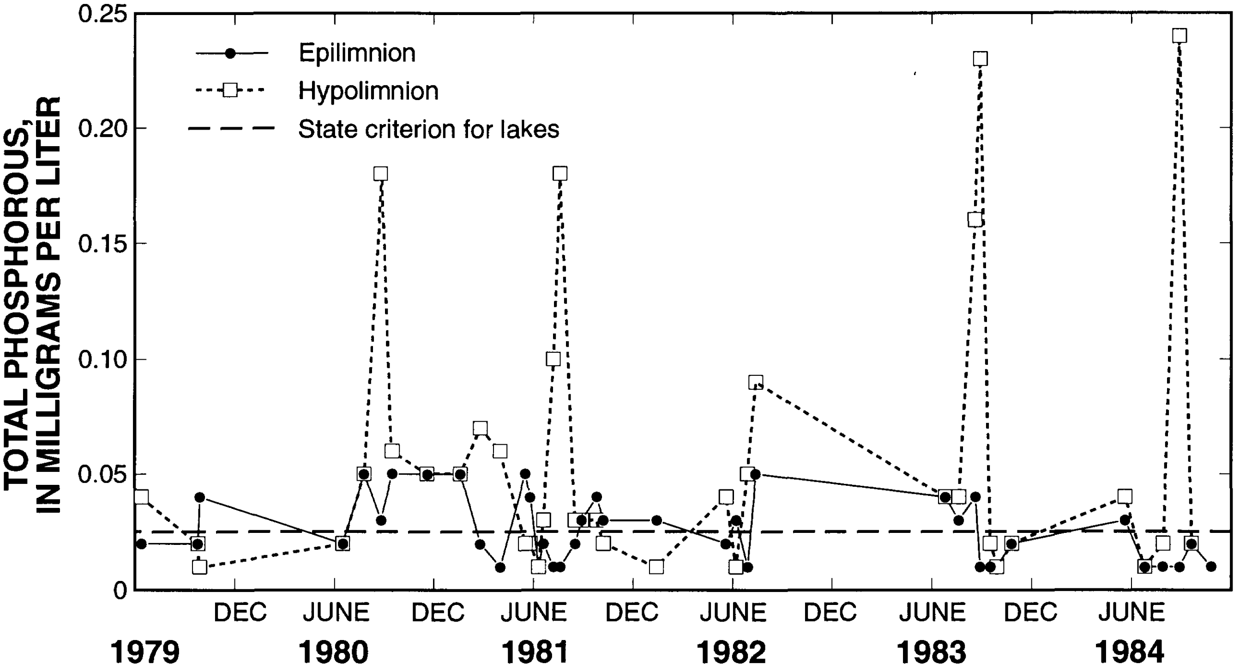

Figure 8. Concentration of total phosphorus in water from Scofield Reservoir, Pleasant Valley, Utah, site M5.

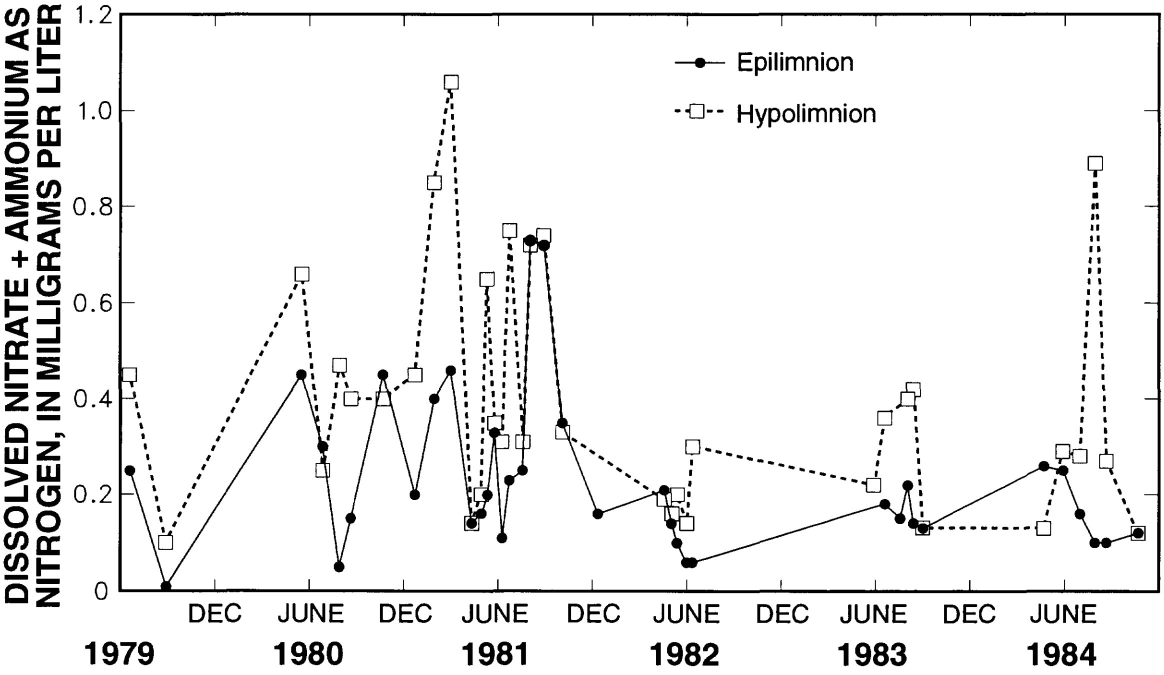

Figure 9. Concentration of dissolved nitrate plus ammonium as nitrogen in water from Scofield Reservoir, Pleasant Valley, Utah, site M5.

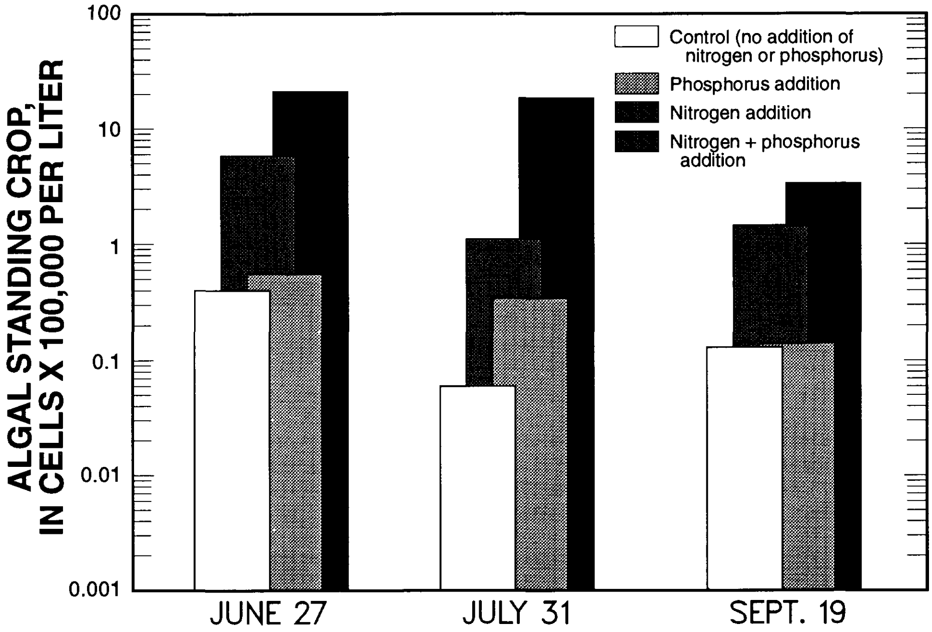

Figure 10. Effect of the addition of nitrogen and phosphorus to water from Scofield Reservoir, Pleasant Valley, Utah, on the standing crop of test algae, June 27 to September 19, 1984.

monly used for sediment that was recently deposited. Lead-210 is a member of the uranium-238 decay series; radon-222 gas, normally present in rocks and soils, diffuses from the soil into the atmosphere and decays rapidly through several short-lived isotopes to lead-210. The lead is removed from the atmosphere by rain and snow and falls at an annual rate of about 0.2 to 0.5 picocurie per minute per square centimeter. Runoff carries the isotope into lakes and reservoirs where the lead-210 is rapidly adsorbed by clays and organic particles and settles to the bottom. The lead-210 (half-life of 22.3 years) then decays through several unstable forms to the stable form of lead-206.

The decay of another isotope, radium-226, also produces lead-210; therefore, the presence of lead-210 emanating from decay of radium-226 must be considered. Typically, the activity of radium-226 is determined for each core segment and is subtracted from the lead-210 activity to give the "unsupported lead-210" activity, which is then used to calculate sedimentation rates. In most aquatic systems, the maximum dating range for lead-210 is 100-150 years. Discussion of the decay process and analytical procedures for lead-210 dating appear in Martin and Rice (1981).

Cesium-137, a man-made isotope released to the atmosphere when nuclear-weapons testing began in 1954, provides a dating tool for recently deposited sediments (Ritchie and others, 1973). Prior to the onset of atmospheric testing in 1954, a very small quantity of cesium-137 was in the atmosphere. Atmospheric testing peaked in 1963 and then declined until it was discontinued in the 1970s. This pattern provides two markers for dating sediments: the onset in 1954, and the peak in 1963. Sedimentation rates for each of the five core sites were calculated from the lead-210 data presented in figures 11 to 15. Isotope activities in Scofield Reservoir are reported for the midpoint of each core segment. Rates also were determined using the onset (1954) and peak (1963) cesium-137 activity.

Sedimentation rates for the alluvial areas of Mud and Fish Creeks are presented in figures 11 and 12. Lead-210 methods resulted in estimated sedimentation rates of 0.18 centimeter per year for the Mud Creek area (site M65) and 0.12 centimeter per year for the Fish Creek area (site M90B). The relatively uniform distribution of lead-210 in the upper 6 centimeters, accompanied by a sharp reduction in activity at 10 centimeters, indicates that active mixing as a result of bioturbation was common in these shallow areas. An estimated rate of 0.3 centimeter per year was calculated using cesium-137 (peak method) for M65 and 0.5 centimeter per year (onset method) for site M90B.

The sedimentation rate in the midlake area (site M30) is presented in figure 13. There was fair agree-

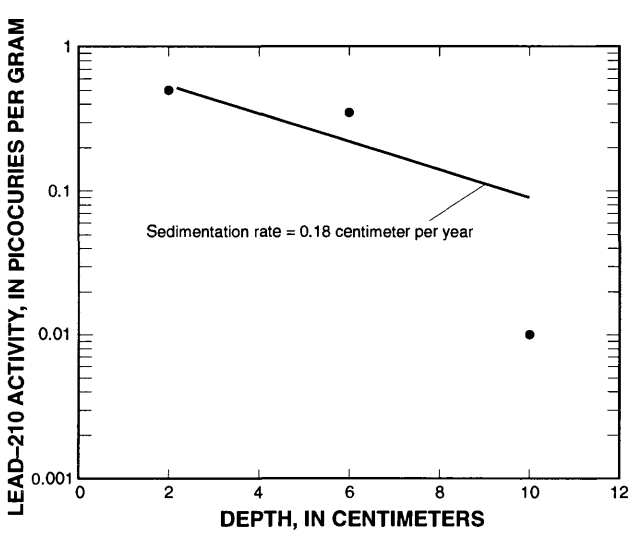

Figure 11. Relation of lead-210 activity with depth in a sediment core from Scofield Reservoir, Pleasant Valley, Utah, site M65.

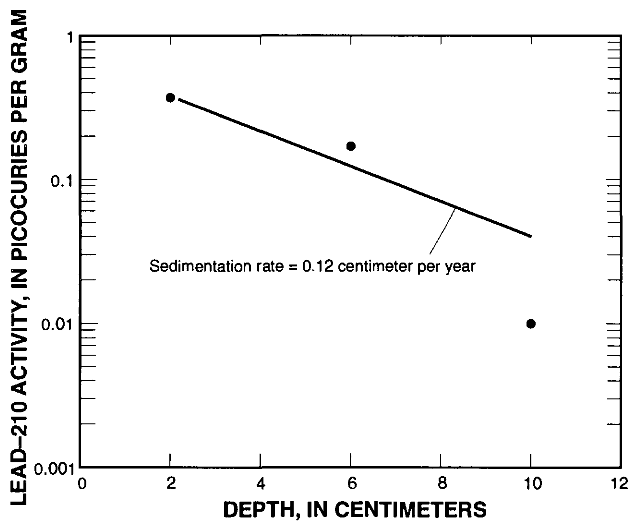

Figure 12. Relation of lead-210 activity with depth in a sediment core from Scofield Reservoir, Pleasant Valley, Utah, site M90B.

ment between the rate of 0.7 centimeter per year calculated using lead-210 and rates of 1.0 and 1.2 calculated using cesium-137. Waddell and others (1985, fig. 17) reported a rate of 0.6 centimeter per year for this site using lead-210 data determined by gamma scan. The sedimentation rate of 0.4 centimeter per year (fig. 14) near the dam (site M5) was considerably less than the rate calculated for midlake. The rate calculated using the cesium-137 peak was 0.3 centimeter per year. The cesium-137 onset was not discernible in the core. The rate of 0.4 centimeter per year (fig. 15) also was calculated for the north arm (site M110) using lead-210.

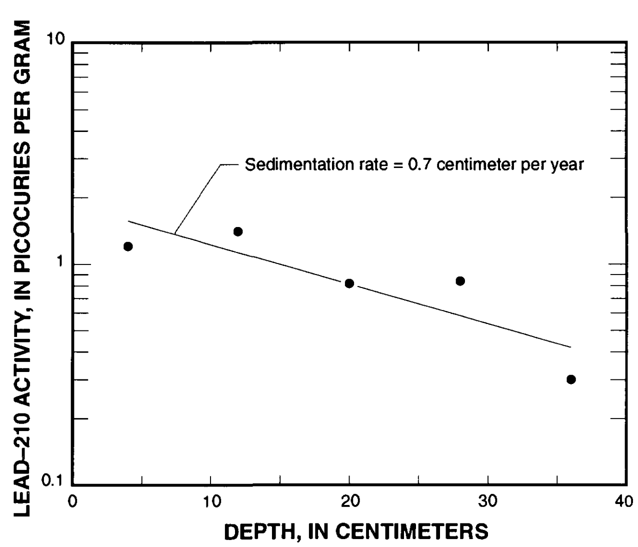

Figure 13. Relation of lead-210 activity with depth in a sediment core from Scofield Reservoir, Pleasant Valley, Utah, site M30.

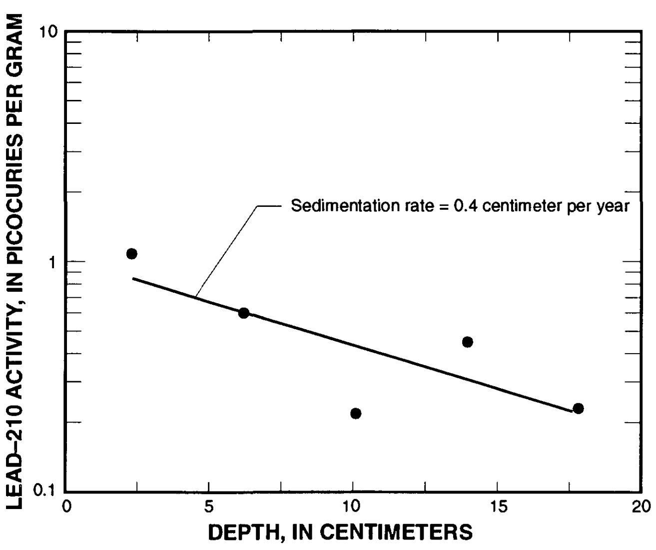

Figure 14. Relation of lead-210 activity with depth in a sediment core from Scofield Reservoir, Pleasant Valley, Utah, site M5.

Rates calculated using cesium-137 varied from 0.6 to 0.9 centimeter per year for the peak and onset data for the north arm.

Sedimentation rates in the alluvial areas (M65 and M90B) may be underestimated. Both sites are characterized by considerable sediment deposition and varying flow velocities. Sediments deposited in these areas are unstable and are periodically moved toward the center of the reservoir by larger snowmelt and storm inflows. In addition, biological activities such as worm

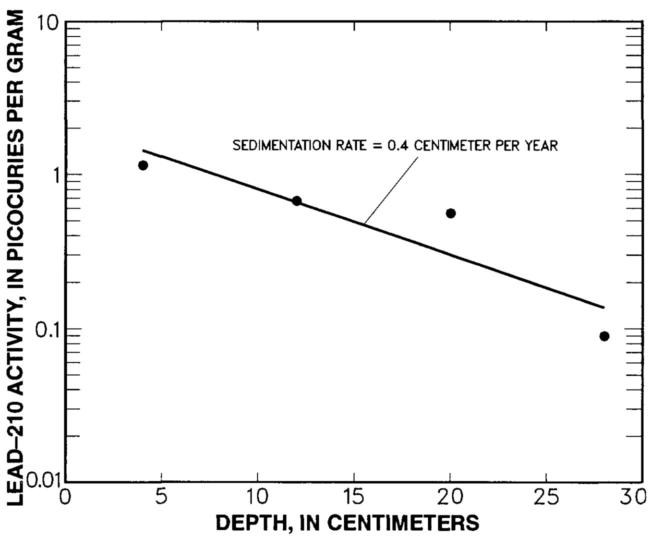

Figure 15. Relation of lead-210 activity with depth in a sediment core from Scofield Reservoir, Pleasant Valley, Utah, site M110.

burrowing and rooted plant growth in these shallow areas continually disturb the sediment profile, making it difficult to date accurately. Waddell and others (1985, fig. 17) also reported a slow sedimentation rate of 0.27 centimeter per year for the alluvial deposits of Mud Creek.

In summary, isotope dating methods indicate that sedimentation rates within the reservoir were not uniform. Sedimentation rates near the major inflow sources could not be determined accurately but were believed to be faster than rates for the main reservoir area. Sediments accumulating in these shallow areas periodically are moved toward the center of the lake, where the sedimentation rate is 0.7 centimeter per year.

Sediment Chemistry

The partial-chemical extraction procedures of Skei and Paus (1979) that were used in the U.S. Geological Survey laboratory on the cored segments provide an estimate of the availability of trace metals in the sediment. These estimates are operationally defined only by the extraction procedure; the opinions of geochemists differ on methods of determining bioavailability.

The procedure for total-extractable metal should release nearly all forms of metals from the sediment. Extractions using the nonsilica extractable method should represent all metals except those held in the lattice of silicate and crystalline-oxide minerals. The numerical difference between the total extractable and nonsilica extractable metals is, therefore, an estimate of the metals present as silicates and oxides. The extraction for nondetrital metals should release forms such as carbonates that are held loosely by ion-exchange forces, and iron and manganese oxy-hydroxides and metals attached to organic matter. Although there is much controversy in determining bioavailability, metals in the nondetrital form are believed to be most readily available to the biota (Skei and Paus, 1979, p. 241). The difference between nonsilica and nondetrital forms represents metals bound tightly to organics, in sulfides, or adsorbed strongly to clays.

Because of some overlap in the extraction procedures, the sum of concentrations for the nonsilica and nondetrital phases almost always is larger than the concentration obtained for total extractable metal. Also, the cored segments were homogenized prior to being split for the three extraction procedures, but the inclusion of small rocks or gravel in any one split has the potential of disproportionately weighting the concentration.

The Skei and Paus extraction procedures were used on a National Bureau of Standards (NBS) reference standard for river sediment (NBS reference standard 1645) to establish a comparative reference for extraction efficiencies. The reference sediment was dredged from the Indiana Harbor Canal near Gary, Indiana, and is representative of sediment very contaminated by heavy metals. Data on the concentrations of total metals in this standard (Raspberry, 1982, p. 140-141) are presented for comparison with the results obtained using the methods of Skei and Paus in figure 16. Because the NBS values were obtained using a method for the extraction of total metals, they should be comparable with the total-extractable method of Skei and Paus.

For cadmium, copper, iron, manganese, and zinc, the total-extractable method of Skei and Paus results in concentrations that are comparable with NBS analyses (fig. 16). The NBS values for arsenic and cobalt are not certified NBS values but are likely estimates provided by NBS. The concentrations of cobalt and nickel for this study, as reported by the U.S. Geological Survey laboratory, were identified as "probable" because of analytical problems. These factors could explain the lack of agreement between the NBS "probable" value for cobalt and the actual value reported by the laboratory.

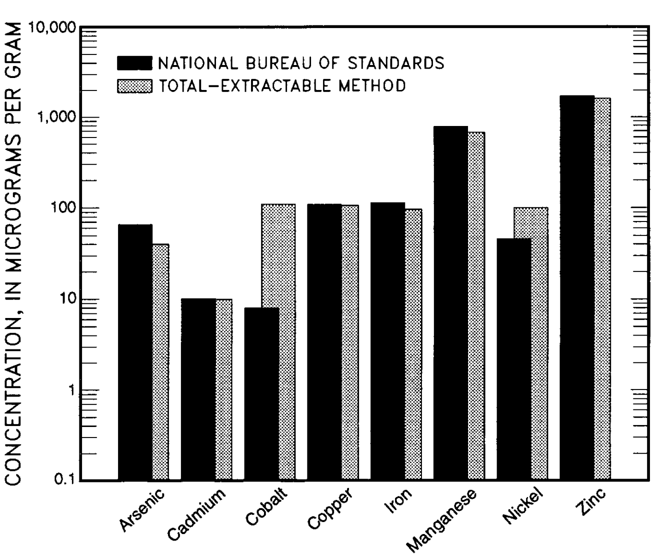

Figure 16. Concentration of selected trace metals in reference standard 1645 extracted by means of the total-extractable method of Skei and Paus (1979) and values reported by the National Bureau of Standards.

Concentrations of mercury were very small, with an NBS value of 1.1 micrograms per gram and a U.S. Geological Survey value of 0.36 microgram per gram using the total-extractable metal method. The trace-metal contamination of the Indiana Harbor Canal reference sediment is most evident in NBS reported concentration of total copper, which was 5 times larger than the concentrations found in an estuary sample (NBS reference standard 1646), and in zinc, which was 13 times as large (Raspberry, 1982, p. 140-141).

Changes in metal concentration with depth in sediment cores could result from three situations: (1) Physical disruption of the sediment caused by dredging, currents, or biological activities such as worm burrowing; (2) variable deposition rates for specific elements as a result of man-induced changes in the drainage basin; and (3) increased mobility of soluble forms of elements following a decrease in the redox potential within the sediment profile. The inability to date accurately the sediments from sites M65 and M90B using two different radio-chemical methods indicates there was physical disruption of these sediments. Because of this disruption, most of the discussion of sediment chemistry is limited to cores from sites M5, M110, and M30 that were collected from deeper areas of the reservoir and represent more stable sedimentary environments.

The results of the partial-chemical extractions of Scofield Reservoir cores are presented in tables 23 to 27. The content of arsenic, cadmium, and mercury in the sediment was small and indicated no trends. Cobalt was present primarily in a tightly bound form, possibly adsorbed onto colloidal particles of iron or manganese (Hem, 1970, p. 201). In general, the content of most other elements was similar from site to site, but there were differences in the availability of elements within each site. If total extractable iron is regarded as somewhat conservative or representative of the surface chemistry, then the ratios of the other total-extractable forms of metals to iron may be used to determine relative changes in metal distributions with depth in the sediment cores. When expressed relative to total iron, the total forms of manganese, nickel, and zinc at site M5 showed an increase with time since the completion of the dam in 1926. By use of a sedimentation rate of 0.4 centimeter per year, the upper 23 centimeters of sediment were deposited subsequent to completion of the dam; thus, all data reported for the 20-centimeter core from site M5 represent sediment accumulation subsequent to 1926. With the exception of manganese, increases in content of other trace metals following completion of the dam were not observed at core sites M30 or M110, which were also in stable, deep-water areas.

The copper content of the sediments ranged from 1 to 24 micrograms per gram in all cores but M30, in which the maximum was 150 micrograms per gram (fig. 17). The reason for the large value for the 12- to 16-centimeter section from site M30 is not known, but this core segment also had large quantities of iron and manganese. Most of the copper was present in the non-silica fraction. Skei and Paus (1979) suggest that metals released by this treatment could be bound to clay, sulfide, or carbonate minerals. The occurrence of the largest quantities of copper and zinc in the non-silica fraction indicates that both of these metals could be removed from the water and deposited in the sediment by carbonate precipitation, an important mechanism for the removal of heavy metals in other hard-water lakes (Forstner, 1982, p. 281). Generally, the quantity of easily extracted copper (nondetrital-extractable form) was less than 10 micrograms per gram; however, at site M110 in the northern arm, virtually all copper present in the top 4 centimeters of sediment was in an easily extracted form (fig. 17). The physical characteristics of the core indicated an organically rich, sulfurous sediment was present at this site.

There were few trends in the quantity of iron in the sediment cores (fig. 18). The relative distribution of several forms of iron, as indicated by the partial-chem-

Table 23. Chemical analyses of a sediment core collected from Scofield Reservoir, Utah, at site M65 on August 31, 1983

[See figure 2 for location of site; <, value is less than reporting limit]

Depth of sediment (centimeters)	Method	Concentration, in micrograms per gram									
		Arsenic	Cadmium	Cobalt	Copper	Iron	Manganese	Mercury	Nickel	Zinc	Phosphorus
0-4	total extractable	<2.0	2	40	14	13,600	360	0.02	40	58	820
	nonsilica extractable	1.6	<1	6	16	12,600	400	.04	20	72	
	nondetrital extractable	1.2	<1	5	2	2,500	275	<.01	5	20	
4-8	total extractable	<2.0	<2	30	16	11,600	320	.02	40	54	700
	nonsilica extractable	1.4	1	6	17	11,000	340	.04	14	60	
	nondetrital extractable	1.5	1	<5	4	2,375	250	.02	2	18	
8-12	total extractable	<2.0	<2	30	10	8,200	150	<.02	20	28	550
	nonsilica extractable	.2	1	4	13	6,200	144	<.02	9	38	
	nondetrital extractable	1.0	1	<5	1	1,200	115	.02	1	12	
12-16	total extractable	<2.0	<2	30	14	7,400	144	.02	20	28	480
	nonsilica extractable	.4	1	3	12	5,800	136	<.02	9	38	
	nondetrital extractable	1.2	1	<5	1	1,250	115	.02	2	15	
16-20	total extractable	<2.0	<2	30	10	8,200	174	<.02	20	28	570
	nonsilica extractable	.4	<1	20	13	6,600	184	<.01	14	40	
	nondetrital extractable	.8	1	<5	2	1,350	140	<.01	<1	12	

Table 24. Chemical analyses of a sediment core collected from Scofield Reservoir, Utah, at site M90B on August 31, 1983

[See figure 2 for location of site; <, value is less than reporting limit]

Depth of sediment (centimeters)	Method	Concentration, in micrograms per gram									
		Arsenic	Cadmium	Cobalt	Copper	Iron	Manganese	Mercury	Nickel	Zinc	Phosphorus
0-4	total extractable	<2.0	2	110	14	14,600	380	<0.02	80	46	<2
	nonsilica extractable	1.6	1	5	16	12,400	380	<.02	13	58	
	nondetrital extractable	1.5	2	5	5	2,425	325	<.01	5	12	
4-8	total extractable	<2.0	2	130	14	11,600	340	<.02	80	42	590
	nonsilica extractable	1.0	<1	4	14	9,600	340	<.02	11	50	
	nondetrital extractable	1.5	1	<5	15	1,925	275	.02	9	12	
8-12	total extractable	<2.0	<2	40	12	10,400	280	<.02	40	42	750
	nonsilica extractable	.8	<1	5	15	11,000	300	<.01	11	58	
	nondetrital extractable	1.2	1	5	5	1,300	235	.02	5	12	
12-16	total extractable	<2.0	2	40	18	10,400	280	<.02	40	98	560
	nonsilica extractable	.2	<1	5	15	9,400	260	.02	13	56	
	nondetrital extractable	1.2	2	<5	4	1,275	200	.02	1	10	
16-20	total extractable	<2.0	2	110	14	9,800	220	<.02	80	54	<2
	nonsilica extractable	.4	1	4	14	9,600	220	<.01	9	60	
	nondetrital extractable	1.2	2	5	6	1,100	155	<.01	10	10	

Table 25. Chemical analyses of a sediment core collected from Scofield Reservoir, Utah, at site M30 on August 31, 1983

[See figure 2 for location of site; <, value is less than reporting limit; —, no data]

Depth of sediment (centimeters)	Method	Concentration, in micrograms per gram									
		Arsenic	Cadmium	Cobalt	Copper	Iron	Manganese	Mercury	Nickel	Zinc	Phosphorus
0-8	total extractable	<2.0	2	30	22	22,000	680	0.46	60	84	1,500
	nonsilica extractable	1.8	<1	6	24	19,600	680	.12	18	90	
	nondetrital extractable	1.2	<1	<5	6	5,250	550	<.01	5	20	
8-16	total extractable	<2.0	2	30	26	18,800	600	.24	40	88	1,200
	nonsilica extractable	2.0	<1	7	34	17,600	600	.52	20	96	
	nondetrital extractable	1.5	1	<5	5	5,500	500	.02	3	20	
16-24	total extractable	<2.0	2	30	22	22,000	620	.06	60	84	1,100
	nonsilica extractable	1.8	<1	7	22	19,000	620	.28	22	92	
	nondetrital extractable	.8	1	5	6	6,000	525	<.1	5	22	
24-32	total extractable	<2.0	2	60	150	32,000	820	.06	—	—	1,300
	nonsilica extractable	2.0	<1	7	22	18,600	600	.06	20	88	
	nondetrital extractable	1.5	2	5	9	7,250	500	<.01	11	28	
32-40	total extractable	<2.0	2	30	26	24,000	580	.04	60	96	1,200
	nonsilica extractable	2.2	1	8	22	20,000	580	6.00	20	92	
	nondetrital extractable	2.0	2	5	8	8,250	475	.02	5	32	

Table 26. Chemical analyses of a sediment core collected from Scofield Reservoir, Utah, at site M5 on August 31, 1983

[See figure 2 for location of site; <, value is less than reporting limit]

Depth of sediment (centimeters)	Method	Concentration, in micrograms per gram									
		Arsenic	Cadmium	Cobalt	Copper	Iron	Manganese	Mercury	Nickel	Zinc	Phosphorus
0-4	total extractable	<2.0	2	40	20	18,800	480	0.14	60	76	990
	nonsilica extractable	1.2	<1	6	20	14,200	460	.04	18	72	
	nondetrital extractable	1.2	1	<5	5	5,250	400	<.01	4	20	
4-8	total extractable	<2.0	2	30	18	16,400	420	.04	40	64	950
	nonsilica extractable	.8	<1	7	24	14,600	400	.02	18	72	
	nondetrital extractable	1.2	<1	5	5	5,250	325	<.01	4	22	
8-12	total extractable	<2.0	<2	30	18	16,600	400	.02	40	56	870
	nonsilica extractable	.6	<1	4	18	12,400	380	.16	13	66	
	nondetrital extractable	1.2	<1	5	6	5,250	325	<.01	9	20	
12-16	total extractable	<2.0	2	30	14	15,800	340	.02	40	56	820
	nonsilica extractable	.8	<1	5	18	12,400	360	.12	12	56	
	nondetrital extractable	1.2	1	<5	6	4,750	275	.02	4	18	
16-20	total extractable	<2.0	<2	30	12	11,200	260	.02	20	34	590
	nonsilica extractable	.4	1	4	14	9,200	240	.04	9	46	
	nondetrital extractable	1.2	<1	5	5	3,250	200	<.01	10	15	

Table 27. Chemical analyses of a sediment core collected from Scofield Reservoir, Utah, at site M110 on August 31, 1983

[See figure 2 for location of site; <, value is less than reporting limit]

Depth of sediment (centimeters)	Method	Concentration, in micrograms per gram									
		Arsenic	Cadmium	Cobalt	Copper	Iron	Manganese	Mercury	Nickel	Zinc	Phosphorus
0-8	total extractable	<2.0	2	40	22	22,000	620	0.02	40	80	1,200
	nonsilica extractable	2.2	<1	5	22	19,600	660	<.02	18	88	
	nondetrital extractable	1.5	1	5	23	7,250	525	<.01	6	25	
8-16	total extractable	<2.0	2	40	22	19,600	560	.02	60	80	1,100
	nonsilica extractable	1.8	<1	7	22	18,000	600	.04	20	82	
	nondetrital extractable	1.5	1	5	5	6,500	450	<.01	2	20	
16-24	total extractable	<2.0	2	40	22	19,600	400	.04	60	88	980
	nonsilica extractable	1.8	<1	6	24	17,400	420	.06	15	84	
	nondetrital extractable	1.5	1	<5	6	7,500	300	<.01	4	30	
24-32	total extractable	<2.0	2	40	22	24,000	400	.02	80	96	1,200
	nonsilica extractable	3.0	<1	8	24	22,000	460	.02	28	102	
	nondetrital extractable	2.2	<1	5	9	6,750	325	<.01	6	22	
32-40	total extractable	<2.0	2	60	22	22,000	440	.02	80	98	1,000
	nonsilica extractable	2.2	<1	8	22	17,800	480	.02	32	94	
	nondetrital extractable	2.0	<1	5	8	5,000	350	.02	5	20	

ical extraction methods, remained similar at different depths within a single core and generally among cores from different sites, except site M30. Both total iron and total manganese (fig. 19) increased toward the surface in cores M65, M90B, and M5, as did nondetrital forms of both metals.

Manganese at most sites showed a general increase from the bottom of the cored interval to the sediment surface (fig. 19). The quantities of total manganese varied between 174 and 580 micrograms per gram in the bottom sediments and increased as much as 50 percent to the sediment surface. A large part of the total manganese was present in the "easily extracted fraction" and could be readily available for cycling to the overlying water. This pattern is typical for manganese in lake sediments. The oxidized forms of manganese are deposited in the sediments and gradually buried. As oxygen is excluded from the sediments and reducing conditions become established, the oxides are reduced and solubilized, releasing manganese in a +2 valence that migrates upward in the interstitial water (Skei and Paus, 1979, p. 244). Nondetrital-extractable manganese comprised 76 to 86 percent of the total manganese in the near-surface sediment at all sites in Scofield Reservoir.

The content of mercury in the sediments generally was less than 0.02 microgram per gram, particularly in the surface layers at sites M90B and M65 (tables 23-27). Sediments from two of the deeper water sites, M30 and M5, had considerably larger quantities of mercury, with a maximum content of 6 micrograms per gram in a cored segment from a depth of 32 to 40 centimeters at site M30. Quantities in the more easily extracted (nondetrital) form never exceeded 0.02 microgram per gram. At sites M5 and M110, where the sediments were sufficiently stable to date accurately, mercury tended to increase following completion of the dam, indicating the mercury was derived from sediment entering the reservoir and not from underlying soils.

Quantities of mercury in the non-silica extractable form occasionally exceeded quantities in the total-extractable form for the core from site M5. This anomaly was believed to be a result of the digestion methods used on the sediment. In the total-extractable method, hydrofluoric, hydrochloric, and nitric acids were used at 120 °C in a sealed container to completely digest the sediment. This procedure could have resulted in a loss of mercury through volatilization when the container was opened. Volatilization could also result in a loss of mercury in the nonsilica-extractable method, but

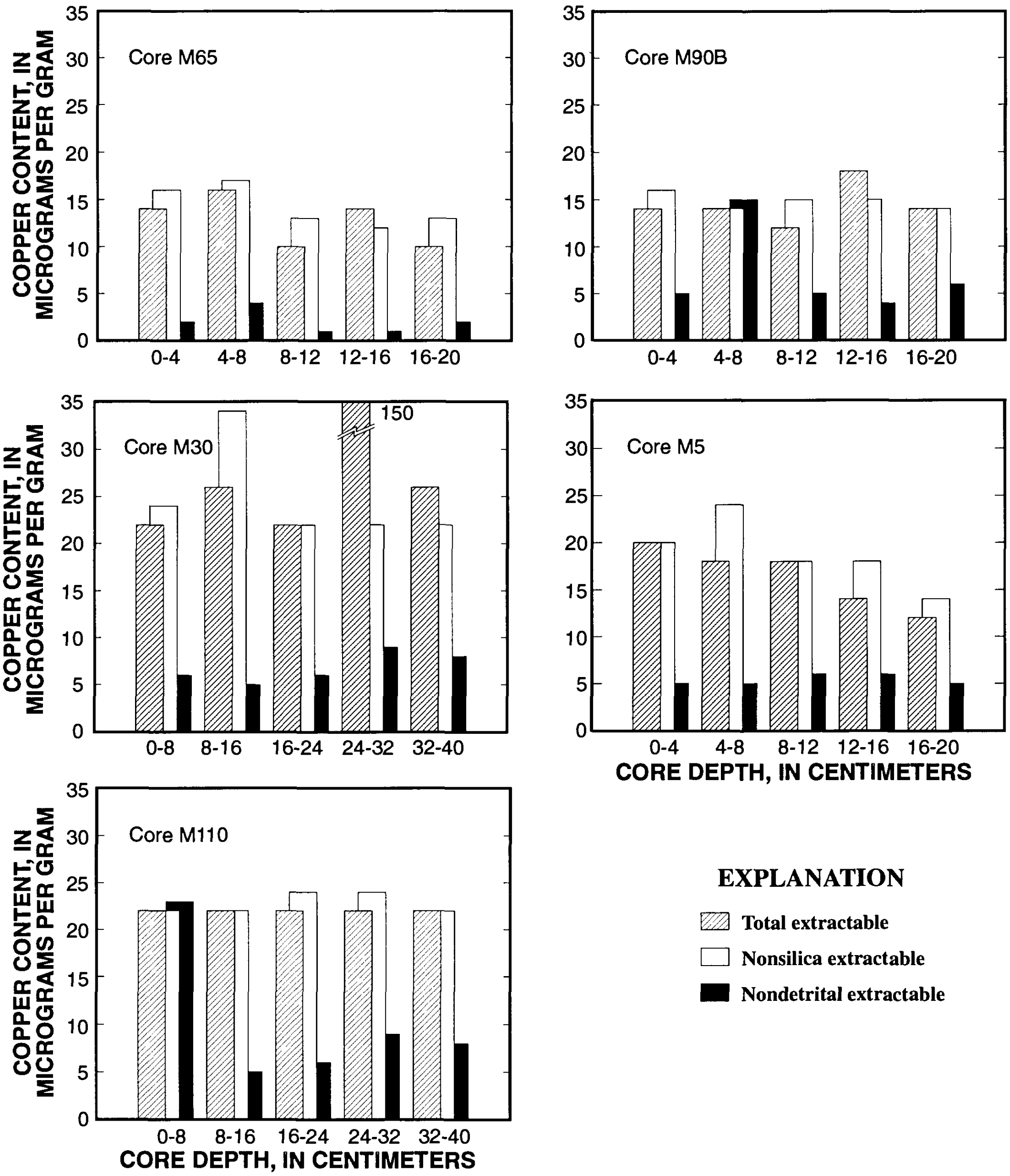

Figure 17. Copper content in sediment cores from five sites in Scofield Reservoir, Pleasant Valley, Utah.

because of the cooler (100 °C) extraction temperature, the losses would not be as large. This mechanism also might have been responsible for apparent losses in total-extractable copper and zinc. Skei and Paus (1979, p. 244) reported that the total-digestion method resulted in some losses of copper in their studies.

Total-extractable nickel content ranged from 20 to 80 micrograms per gram in all cores (fig. 20). Quantities of total nickel and total cobalt at most sediment depths in the core from site M90B (table 23) were slightly larger than for cores from the other sites. The geochemical reactions of nickel are similar to cobalt, and both can concentrate on particles of manganese oxide and iron oxy-hydroxides in soils (Hem, 1970, p. 201).

The content of zinc in the sediment generally was less than 100 micrograms per gram and was primarily in the form believed by Skei and Paus (1979) to represent metals associated with organics or sulfides, or tightly adsorbed to clays (nonsilica extractable) (fig.

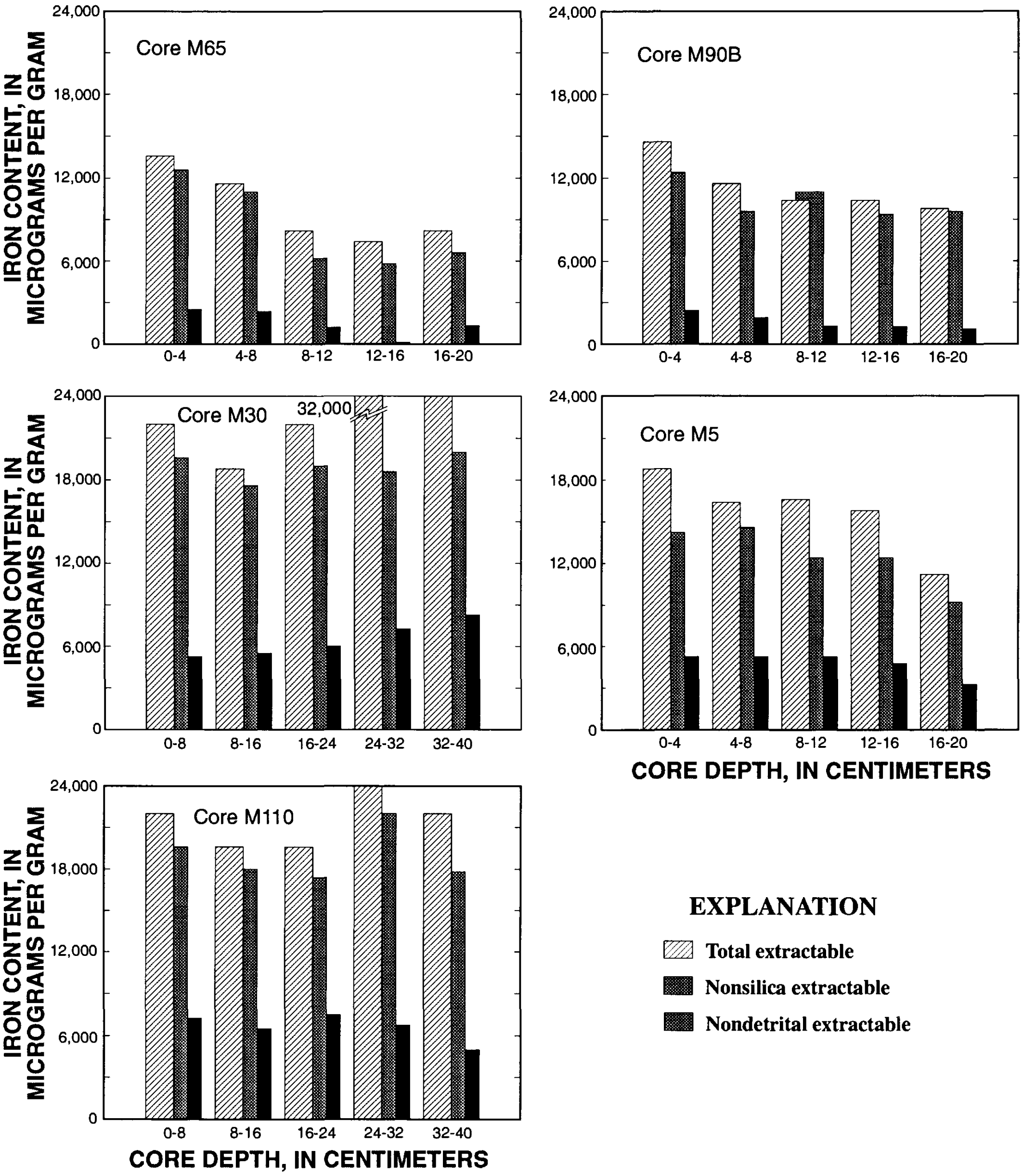

Figure 18. Iron content in sediment cores from five sites in Scofield Reservoir, Pleasant Valley, Utah.

21). Generally, less than one-third of the zinc was present in the readily available nondetrital form. The core from site M5 showed a distinct pattern of increasing quantities of zinc from the core bottom to the top (table 26), and a similar pattern was observed in the less-stable sediment at site M65. Data from the M5 core indicate an increase in the quantity of zinc since completion of the dam. Studies in New England have shown increased quantities of zinc in lake sediments were attributed to increased human activity (Norton and others, 1979, p. 543), and increased quantities of zinc, copper, lead, and mercury in sediment cores collected in Norway have been associated with increased mining of metals (Skei and Paus, 1979, p. 245).

All cores except the site M90B core showed gradual reductions of about 20 to 30 percent in the content of total phosphorus from the surface to a depth of 16 centimeters. Cores from sites M30 and M110 had increases in the 24- to 32-centimeter-deep section followed by subsequent decreases at depths of 32 to 40

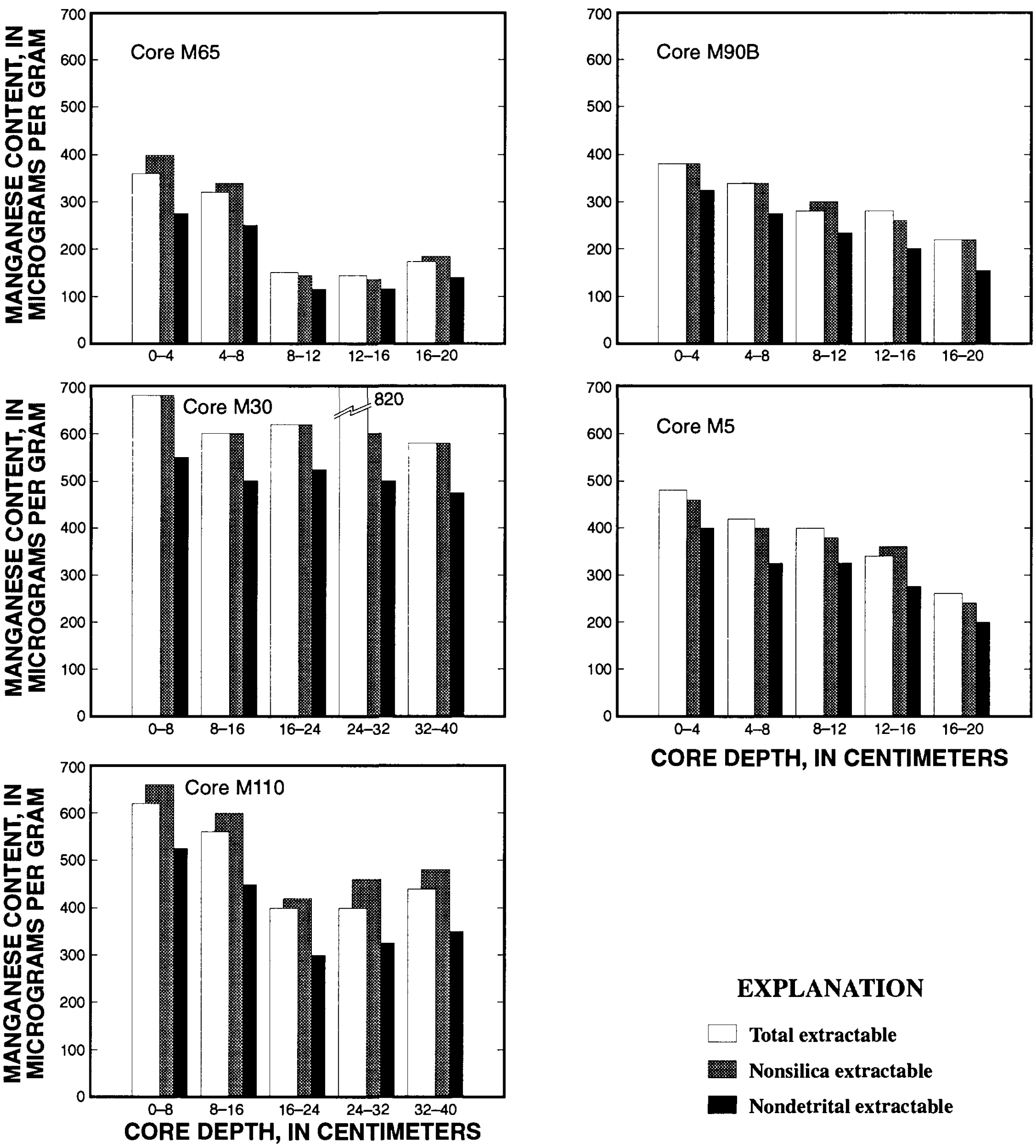

Figure 19. Manganese content in sediment cores from five sites in Scofield Reservoir, Pleasant Valley, Utah.

centimeters. Overall, total phosphorus generally decreased 17 to 35 percent with sediment depth (except at site M90B), and the quantity in any one core generally followed the quantity of total iron. Ratios of total iron to total phosphorus were typically 15 to 20:1, indicating that at the sites where anaerobic conditions prevail during the summer, the low equilibrium solubility of the iron-phosphorus association would result in minimal phosphorus release to the overlying water. Low rates of internal phosphorus release in Scofield Reservoir also were suggested by Messer and Ihnat (1983, p. 9) based on the large ratio of 17:1 for iron:phosphorus in a single core collected near site M110.

Mobility of Elements to Overlying Water

Trace metals deposited in the sediment of Scofield Reservoir could be released to the water as the sediment becomes anaerobic and could contaminate the

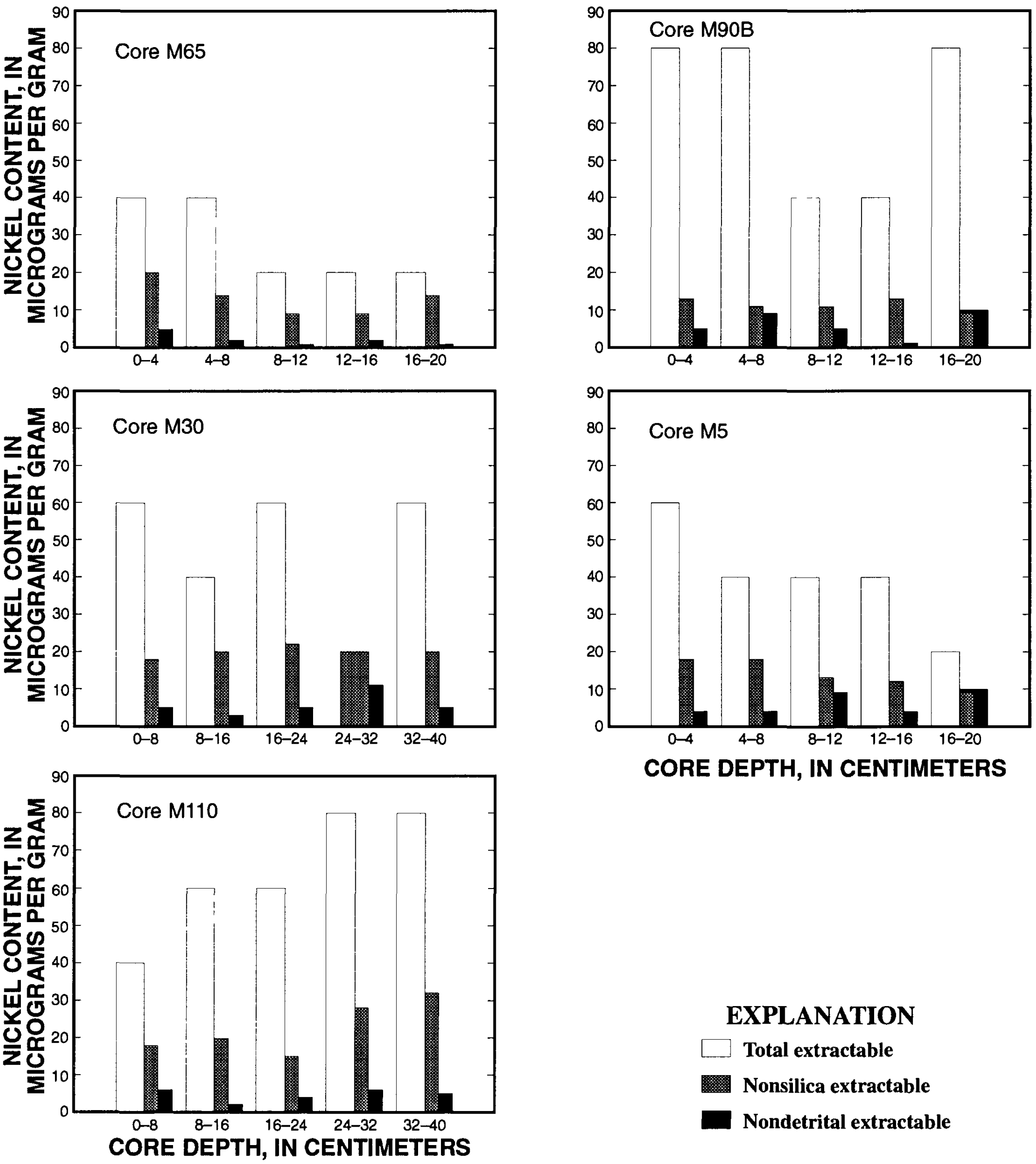

Figure 20. Nickel content in sediment cores from five sites in Scofield Reservoir, Pleasant Valley, Utah.

drinking-water supply for cities downstream. Similarly, phosphorus could be released that could then stimulate algal growth, contributing to eutrophication of the reservoir. The movement of selected elements from and within the sediment was investigated in laboratory studies of sediment-core leaching and in a field study of the movement of elements into interstitial water within the sediment.

Core-Leaching Experiments

Trace metals and orthophosphorus are leached from sediment cores to the dissolved phase in the overlying water at a rate determined from several laboratory experiments. Cores were collected during the September 1983 sampling at shallow-water sites M65 and M90B and from deep-water sites M30, M5, and M110. Cores from both shallow and deep-water sites were incubated at 15 °C and maintained anaerobically by purging the water column with ultra-pure nitrogen before and after sampling. In addition, duplicate cores from M65 and M90B were incubated at 20 °C but were maintained aerobically using an aquarium air pump and ambient air.

Release rates were calculated as the total change in concentration in the overlying water during the incu-

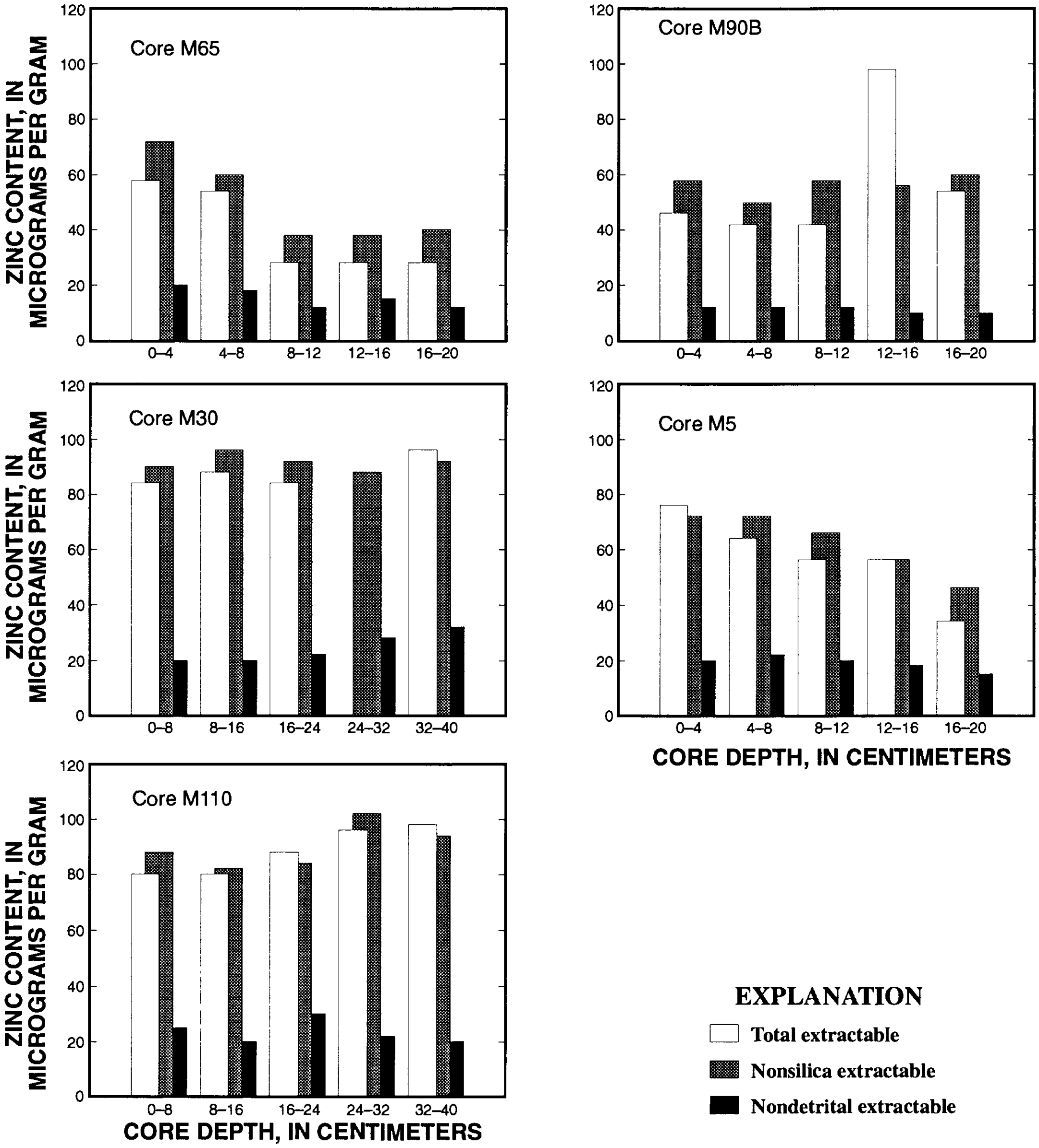

Figure 21. Zinc content in sediment cores from five sites in Scofield Reservoir, Pleasant Valley, Utah.

bation time and were expressed on a surface area of exposed sediment basis. For most elements there was a continual increase in concentration with time, but for orthophosphorus in several of the cores, the release rate was largest within 14 days and declined slightly thereafter. In these instances, the release rate was calculated to the time of the maximal rate.

Under both aerobic and anaerobic conditions, dissolved concentrations of beryllium, cadmium, cobalt, copper, lead, mercury, molybdenum, and vanadium were near the detection limit and did not exhibit any fluctuation during the experiments. Calcium, magnesium, strontium, and sodium were present in larger concentrations, but the concentrations did not vary more than 30 percent during the experiments. Dissolved constituents showing significant changes with time were orthophosphorus, silica, iron, manganese, and zinc.

The pattern for release of orthophosphorus was variable. Under anaerobic conditions, release from four cores ranged from less than 0.1 to almost 2 milligrams per square meter per day (table 28). The core from site M110 (north arm) actively removed orthophosphorus from the water column at the rate of nearly 1 milligram per square meter per day. Release rates from this site were anticipated to be larger because of the dark, organic character of the sediment. This type of sediment was reported by Mawson and others (1983, p. 1,109) to release considerable quantities of soluble reactive (ortho) phosphorus. The uptake of phosphorus by the core could have been a result of suspension of the very fine sediment particles in the water followed by sorption of the phosphorus onto the particles, a mechanism observed in similar studies by Holdren and Armstrong (1980, p. 82).

Release rates for cores from shallow-water sites (M65, M90B) under aerobic conditions were equal to or greater than the rates under anaerobic conditions. Under anaerobic conditions, release rates of orthophosphorus from deep-water sites M5 and M30 were two to three times the mean rate for all sites. The release rates were comparable to rates of 1.2 to 3.7 milligrams per square meter per day (at 25 °C) reported by Messer and Ihnat (1983, p. 8) for Deer Creek Reservoir, 75 kilometers northwest of Scofield Reservoir.

There is a potential for release of 372 kilograms of orthophosphorus to the hypolimnion of Scofield Reservoir during summer stratification, based on the mean release rate of about 1.5 milligrams per square meter per day from core sites M5 and M30, a 70-day period of lake stratification, and an area of 3.8 square kilometers of anaerobic sediment. The release and cycling of phosphorus is evident in fluctuations of total phosphorus in the surface (epilimnion) and deep (hypolimnion) water shown in figure 8. Phosphorus released from the anaerobic sediments accumulates in the hypolimnion water during the summer; when the lake becomes homothermal in the fall, the hypolimnion water mixes with the epilimnetic water and increases the phosphorus concentration of the near-surface water. The same pattern was observed on a smaller scale during winter stratification and spring turnover.

Silica showed a large release under both anaerobic and aerobic conditions; anaerobic rates were about three times as great as aerobic rates. The large release rates for silica probably are a result of the dissolution of siliceous diatom cells rather than equilibrium reactions within the clays. Fanning and Schink (1969, p. 67) reported that sediment in biologically productive areas in the ocean may have three to six times the concentration of silica expected when in equilibrium with clays; this relation is caused by dissolution of phytoplankton cells.

Under anaerobic conditions, iron release followed a pattern similar to that of phosphorus in all cores except the core from site M110. Rates of iron release were variable and ranged from 0.25 milligram per square meter per day at site M65 to 8.22 milligrams

Table 28. Daily release rate of elements from sediment cores from Scofield Reservoir, Utah, incubated under anaerobic and aerobic (in parentheses) conditions in the laboratory

[Daily release rate in milligrams per square meter]

Reservoir site (see fig. 2)	Orthophosphorus		Silica		Iron		Manganese		Zinc	
M65	0.09	(0.29)	107	(38)	0.25	(0.01)	0.09	(0.11)	0.20	(-0.01)
M90B	.44	(.45)	89	(30)	2.63	(1.59)	9.07	(.08)	.24	(.65)
M30	1.01		118		.84		5.59		.25	
M5	1.87		114		8.22		3.39		.40	
M110	-.89		139		1.29		3.27		-.38	
Mean	**.50**	**(.37)**	**113**	**(34)**	**2.65**	**(.80)**	**4.28**	**(.10)**	**.14**	**(.32)**
Coefficient of variation, in percent	206		16		122		78		215	

per square meter per day at site M5. Sites M5 and M90B had relatively large release rates for both iron and phosphorus, whereas site M65 had small release rates for both elements.

Manganese was released from most anaerobic sediments in large quantities. For most sites, there was a short period of rapid release followed by a more gradual, linear release. The core from site M110, in the north arm of the reservoir, was characterized by black, sulfurous, unconsolidated sediment and showed an exponential release rate. The large release of manganese from anaerobic sediments during summer stratification of the reservoir resulted in a mean concentration of about 300 micrograms per liter of dissolved manganese in the hypolimnion, compared with a summer mean concentration of about 40 micrograms per liter in the epilimnion. A total of 1,140 kilograms of dissolved manganese could be released into the hypolimnion during summer stratification, on the basis of a mean release rate of about 4.3 milligrams per square meter per day (table 28) and a calculated area of 3.8 square kilometers of anaerobic sediments. When the reservoir becomes homothermal in September, the manganese-enriched water mixes with the epilimnetic water and increases the concentration of manganese throughout the water column as shown by the pattern in figure 22. This mixing occasionally resulted in concentrations of manganese that exceeded the public water-supply criterion of 50 micrograms per liter (U.S. Environmental Protection Agency, 1976, p. 178) in the near-surface water.

Aerobic sediment also released small quantities of manganese, with a mean of 0.1 milligram per square meter per day (table 28), or about 2 percent of the mean for anaerobic release. The pattern of the release showed an initial loss of dissolved manganese at the start of the incubation period, probably as a result of the suspension of sediments that adsorbed some of the manganese in the water. A continual but gradual rate of release persisted from day 6 through day 28.

Release of dissolved zinc from the cores was difficult to interpret. Under anaerobic conditions, all cores but the site M110 core released a small quantity of zinc. Under aerobic conditions, the site M65 core showed virtually no change, but the site M90B core released 0.65 milligram per square meter per day, a rate larger than any rate under anaerobic conditions. The selective extraction of metals from the sediment cores indicated that most of the zinc was tightly bound to the sediment and would not be released easily to the overlying water. This bonding partly explains the small and variable release rates observed (table 28).

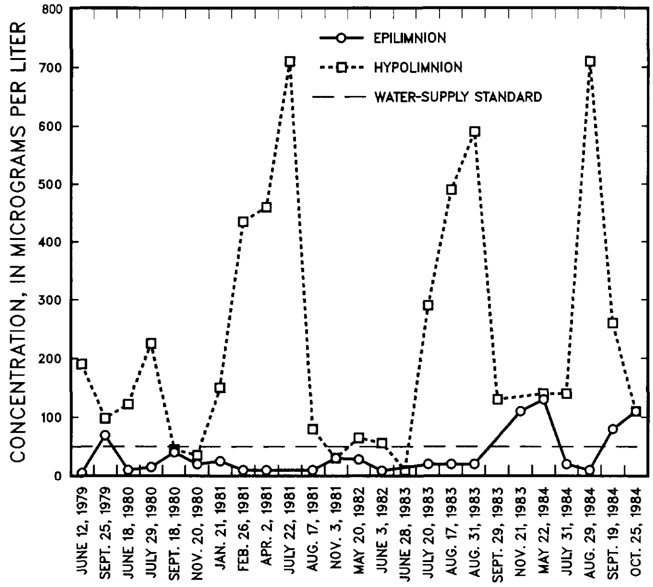

Figure 22. Concentration of total manganese in water from Scofield Reservoir, Pleasant Valley, Utah, site M5.

Diffusion of Elements into Interstitial Water

The diffusion of elements from the sediment into the interstitial water within the sediment was investigated by means of a diffusion chamber. This information is useful because elements already solubilized in the interstitial water may be rapidly released to the water column following any disturbance of the surficial sediments, and chemical interaction between the water body and the sediments is the result of solute transfer associated with the interstitial fluid. The chamber was based on the design of Hesslein (1976) and was constructed of polyvinyl chloride plastic and operated using the principal of diffusion through a semipermeable membrane. The sampler was 36 centimeters long, 11.5 centimeters wide, and 2.4 centimeters thick and contained eight chambers, each with an individual capacity of 50 milliliters. Each chamber was separated from the sediment by a layer of polycarbonate membrane with a porosity of 0.2 micrometer. One day prior to use, each chamber was filled with high-purity deionized water, sealed with a layer of the membrane, and placed in a deionized-water bath containing nitrogen gas that displaced all dissolved oxygen within the chamber water.

On August 8, 1984, a diver gently inserted the sampler into reservoir sediment at a water depth of 10.5

meters at the mouth of the east arm of Scofield Reservoir near the dam (fig. 2). The water temperature in the hypolimnion was 15 °C, the dissolved-oxygen concentration was less than 0.5 milligram per liter, and the pH was 7.6. A well-developed hypolimnion was present that contained dark brown, sulfide-enriched water. The upper two chambers of the sampler were positioned in the water above the sediment, and the third chamber was positioned at the sediment-water interface. All other chambers were positioned progressively deeper within the sediment at 3.2-centimeter intervals, the deepest chamber being about 16 centimeters into the sediment. The sampler was retrieved on September 12, 1984, and placed in a nitrogen-filled glove bag where the contents of each chamber were removed with a plastic syringe. Samples for metal analyses were stabilized by the addition of 0.1 milliliter of nitric acid, and samples for phosphorus analysis were preserved by the addition of 20 milligrams of mercuric chloride to a 25-milliliter sample. All analyses were done at the U.S. Geological Survey laboratory in Denver by means of inductively coupled plasma methods. Concentrations of most elements were very low within the chamber positioned at a sediment depth of 9.7 centimeters and indicated either sampling or analytical errors. These values were not used in the analysis. Data from a core collected at site M5 indicate that about 23 centimeters of sediment have been deposited in this area since the reservoir was completed in 1926.

Concentrations of beryllium, cadmium, cobalt, copper, lead, mercury, molybdenum, and vanadium in the interstitial water remained near the detection limit from the sediment surface to a depth of 16 centimeters. There were small variations in concentrations of barium, calcium, and magnesium. Changes in those elements showing variation and trends with depth in the sediment are shown in figure 23. With the exception of zinc, all elements increased in concentration between the overlying water and the first few centimeters of sediment. Changes in concentrations of orthophosphorus, iron, and manganese showed large increases at the sediment-water interface followed by decreases in concentrations within interstitial water with depth in the sediment. Sodium, and to a lesser degree, strontium, increased considerably with depth in the sediment. Zinc concentrations decreased nearly tenfold at the sediment-water interface from the concentration 6.5 centimeters above the sediment. This decrease may have been caused by the co-precipitation of zinc with or upon iron or manganese sulfides (Nembrini and others, 1982, p. 372).

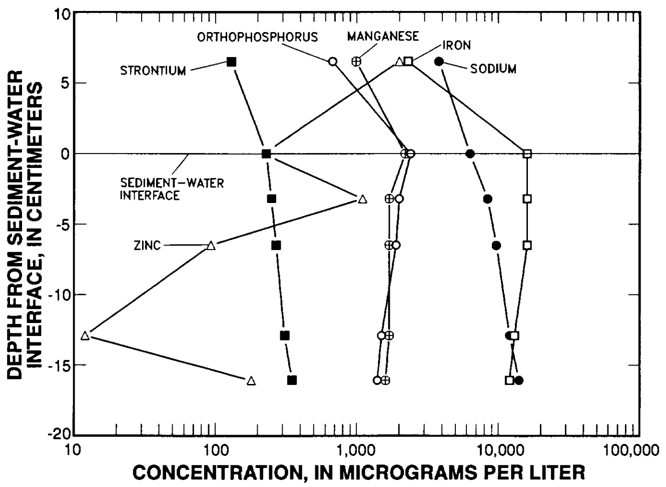

Figure 23. Concentrations of selected dissolved constituents in the overlying water column and interstitial water at several sediment depths adjacent to the dam in Scofield Reservoir, Pleasant Valley, Utah.

These results indicate that for the common trace metals such as iron and manganese, and the common cations sodium and strontium, any disruption of the reservoir sediments could release considerable quantities of those elements dissolved in the interstitial water to the overlying waters. It is unlikely that a substantial quantity of the more toxic trace metals such as cadmium and zinc would be released from the interstitial water of the surficial sediments. Resuspension of sediments, however, would increase the concentrations of total forms of trace metals to the overlying water.

SUMMARY

Record flows ranging from 140 to 200 percent of average were recorded in all gaged streams in the Pleasant Valley area during 1983-84. The large inflows caused Scofield Reservoir to reach a peak altitude of 2,323.14 meters in June 1983. These large flows transported large loads of sediment and associated trace metals and nutrients to Scofield Reservoir, but water quality in the streams was suitable for most designated uses. With the exception of one water sample from Mud Creek with a total phenol concentration of 12 micrograms per liter, streams were free of potentially toxic constituents. Concentrations of total phosphorus, an algal nutrient associated with lake eutrophication, exceeded the State criterion of 0.05 milligram per liter for streams in 11 of 16 samples from Mud Creek and in 4 of 11 samples in Fish Creek.

The potential effects of underground coal mining and road construction of the water resources of Eccles Canyon were evaluated using paired data from Boardinghouse Canyon, a nearby canyon with no contemporary mining or road construction. At any given flow, the concentration of dissolved solids in Boardinghouse Canyon creek was significantly smaller than the concentration in Eccles Canyon creek. By means of a rank sum test, concentrations of some trace metals normally associated with sediment (total and suspended iron, total and dissolved manganese, and total and suspended zinc) were determined to be larger in Eccles Canyon creek than in Boardinghouse Canyon creek. Mean concentrations in water from Eccles Canyon creek were about twice as large as in water from Boardinghouse Canyon creek for total and suspended iron and total manganese, and larger than three times for total and suspended zinc. Concentrations of iron, manganese, and zinc in bottom sediment from Eccles Canyon creek also were 10 to 20 percent larger. These data indicate that mining and construction activities in Eccles Canyon increase concentrations of dissolved solids and some elements above concentrations found in water in Boardinghouse Canyon, where there is no active mining or road construction.

The mean concentration of suspended sediment collected during conditions of base flow was 325 milligrams per liter for Boardinghouse Canyon creek and 2,870 milligrams per liter for Eccles Canyon creek, but these differences were not significantly different because the variation of the data was large. The median loads of suspended sediment during conditions of base flow were 0.75 metric ton per day for Boardinghouse Canyon creek and 1.08 metric tons per day for Eccles Canyon creek. Concentrations of suspended sediment in both creeks increased considerably during storms; means were 2,210 milligrams per liter for Boardinghouse Canyon creek and 2,380 milligrams per liter for Eccles Canyon creek. For a single coincident storm with about 1 centimeter of rainfall in each canyon, the sediment yield for Boardinghouse Canyon was 0.32 metric ton per square kilometer and for Eccles Canyon was 0.48 metric ton per square kilometer.

Median loads of suspended sediment entering Scofield Reservoir under base-flow conditions were 2.63 metric tons per day for Mud Creek and 165 metric tons per day for Fish Creek. The median sediment yield for the Fish Creek basin (1.1 metric tons per square kilometer per day) was nearly 30 times greater than the yield for the Mud Creek basin (0.04 metric tons per square kilometer per day).

Fish Creek contributed about 75 percent of the total flow into Scofield Reservoir and 84 to 97 percent of the loads for most trace metals or nutrients. The increased flows during 1983-84 resulted in loads of total phosphorus that were two to three times larger for Fish Creek and four to eight times larger for Mud Creek, compared with loads during 1980-82. Under base-flow conditions, Mud Creek discharges a median suspended-sediment load of 2.63 metric tons per day to Scofield Reservoir and Fish Creek discharges 165 metric tons. During a storm, Mud Creek may discharge as much as 65 metric tons. Storm loads from Fish Creek are expected to be large but were not measured.

Total phosphorus and manganese were the principal elements that did not meet water-quality standards in Scofield Reservoir during 1983-84. Total phosphorus exceeded the State criterion of 0.025 milligram per liter for lakes in nearly 50 percent of all samples collected from the reservoir. Concentrations of manganese in most samples collected from the hypolimnion and several samples collected from the epilimnion exceeded the criterion of 50 µg/L for public water supply established by the Environmental Protection Agency. This excess was caused by the release of manganese from anaerobic sediment in the hypolimnion and subsequent mixing throughout the lake during fall turnover.

In spite of the large inflow of nutrients, blooms of blue-greens *(Anabaena flos-aquae and Aphanizomenon flos-aquae)*, common in 1981-82, did not develop in 1983. The diatom *Stephanodiscus minutula*, which is indicative of eutrophic conditions, was quite abundant in 1983 but less abundant in 1984. The large inflows of water to the reservoir in 1983-84 resulted in a minimum useable water storage that was more than 140 percent of the average for the preceding 25 years. Generally cooler spring temperatures, a shortened growing season, and a faster flushing rate in the reservoir during 1983 also helped prevent the blooms of blue-greens that occurred in 1981-82.

Ratios of total nitrogen to total phosphorus in the reservoir generally indicated that phosphorus was limiting algal growth in 1979-81. During fall of 1982 and spring of 1983 and 1984, nitrogen was the principal limiting nutrient. By August, phosphorus was often limiting in the epilimnion, but when phosphorus was released from the hypolimnion following turnover, nitrogen again became limiting. Concentrations of nitrate and ammonia, and total phosphorus to a lesser degree, seem to have decreased slightly in the near-surface water since 1979, but the large variability precluded statistical verification.

Radioisotope dating of sediments in Scofield Reservoir indicated that sediment-deposition rates were not uniform and ranged from 0.4 centimeter per year near the dam to 0.7 centimeter per year midlake. Sedimentation rates near major inflow sources could not be determined accurately but were believed to be greater than rates for the main body of the reservoir. Partial-chemical extractions of trace metals from the sediment indicated that arsenic, cadmium, and mercury were present in small concentrations and most were in stable silicate forms not readily available for biological uptake. Concentrations of copper and zinc were slightly larger and were predominantly in the more readily released forms of sulfides, organic compounds, and oxides. Large ratios of total iron to total phosphorus in the sediments indicated that the low equilibrium solubility of the iron-phosphorus association would likely result in small rates of internal phosphorus loading during stratification. This relation was corroborated by nutrient data that showed phosphorus was the limiting nutrient in late summer, prior to turnover.

Experiments that measured the release rates of selected trace metals and orthophosphorus from bottom-sediment cores indicated that beryllium, cadmium, cobalt, copper, lead, mercury, molybdenum, and vanadium were not released in any appreciable quantity under aerobic or anaerobic conditions. Calcium, magnesium, strontium, and sodium had minimal release, but orthophosphorus, silica, iron, manganese, and zinc were released in large quantities from the cores. Manganese released at a mean rate of 4.3 milligrams per square meter per day under anaerobic conditions resulted in mean summer concentrations greater than 300 micrograms per liter in the hypolimnion. When turnover of the water in the reservoir occurred in the fall, mixing of the manganese-rich water resulted in concentrations that exceeded the maximum-contaminant level of 50 micrograms per liter established for drinking water by the Environmental Protection Agency.

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SUPPLEMENTAL DATA

Table 29. Twenty-four-hour precipitation at rain gage R1 in Boardinghouse Canyon, Utah, 1983

[ND, no data; —, no measurable precipitation]

Day	Precipitation, in centimeters				
	July	August	September	October	November
1	ND	—	0.76	1.65	0.13
2	ND	—	—	.13	—
3	ND	—	1.65	1.02	—
4	ND	—	—	—	—
5	ND	1.14	—	—	—
6	ND	—	—	—	—
7	ND	—	—	—	.64
8	ND	—	—	—	1.27
9	ND	—	—	—	—
10	ND	.38	—	.25	—
11	ND	.25	—	—	.38
12	ND	—	—	—	.51
13	ND	—	—	.25	.38
14	ND	—	—	.51	1.14
15	ND	.25	—	—	—
16	ND	—	—	—	—
17	ND	—	—	.13	.89
18	ND	.51	—	—	.64
19	ND	.13	—	—	.25
20	ND	—	—	—	.89
21	.13	—	—	—	—
22	.51	—	—	—	ND
23	.33	—	1.52	—	ND
24	—	.64	—	—	ND
25	.38	—	—	—	ND
26	.13	—	.25	—	ND
27	.25	.25	.76	—	ND
28	—	.38	.25	—	ND
29	.25	.13	.13	—	ND
30	1.52	—	1.02	—	ND
31	—	—		.25	

Table 30. Twenty-four-hour precipitation at rain gage R1 in Boardinghouse Canyon, Utah, 1984

[ND, no data; —, no measurable precipitation]

Day	Precipitation, in centimeters				
	June	July	August	September	October
1	ND	—	0.25	—	—
2	ND	—	—	—	—
3	ND	—	.89	—	—
4	ND	—	—	—	—
5	ND	—	.13	—	—
6	ND	—	—	—	—
7	ND	—	—	—	.38
8	ND	—	—	—	—
9	ND	—	—	—	—
10	ND	—	—	—	ND
11	ND	—	.51	.76	ND
12	ND	—	—	—	ND
13	ND	—	.13	—	ND
14	ND	.13	.25	—	ND
15	—	—	1.14	—	ND
16	—	—	—	.25	ND
17	—	—	—	—	ND
18	—	—	—	—	ND
19	—	—	1.27	—	ND
20	—	—	—	.51	ND
21	—	—	—	.89	ND
22	—	.38	—	—	ND
23	—	.38	.13	—	ND
24	—	.25	—	.25	ND
25	—	.13	.76	—	ND
26	—	1.40	—	—	ND
27	—	.13	—	—	ND
28	—	—	—	.89	ND
29	—	.76	—	1.78	ND
30	.13	2.79	—	1.14	ND
31		—	—		ND

Table 31. Twenty-four-hour precipitation at rain gage R2 in Eccles Canyon, Utah, 1983

[ND, no data; —, no measurable precipitation]

Day	Precipitation, in centimeters				
	July	August	September	October	November
1	ND	ND	—	1.40	0.13
2	ND	ND	—	.38	—
3	ND	0.25	—	.89	—
4	ND	—	—	—	—
5	ND	.13	—	—	—
6	ND	—	—	—	—
7	ND	—	—	—	.51
8	ND	.25	—	.25	.76
9	ND	.38	—	—	—
10	ND	—	—	.13	—
11	ND	—	—	—	.51
12	ND	—	—	—	.25
13	ND	—	—	.13	.64
14	ND	—	—	.51	1.02
15	ND	—	—	—	—
16	ND	.64	—	—	—
17	ND	—	—	—	.89
18	ND	.38	—	—	.38
19	ND	—	—	—	.25
20	ND	—	—	—	.13
21	ND	.13	—	—	—
22	ND	.13	.13	—	—
23	ND	—	1.27	—	ND
24	ND	.38	—	.13	ND
25	ND	.13	—	—	ND
26	ND	—	.25	—	ND
27	ND	—	.89	—	ND
28	ND	.25	.13	—	ND
29	ND	.38	.13	—	ND
30	ND	—	1.14	—	ND
31	ND	—		.51	

Table 32. Twenty-four-hour precipitation at rain gage R2 in Eccles Canyon, Utah, 1984

[ND, no data; —, no measurable precipitation]

Day	Precipitation, in centimeters		
	July	August	September
1	ND	0.38	—
2	ND	—	—
3	ND	—	—
4	ND	—	—
5	ND	—	—
6	ND	—	—
7	ND	—	—
8	ND	—	—
9	ND	—	—
10	ND	—	—
11	ND	.51	.38
12	ND	—	.13
13	ND	.13	—
14	ND	.25	—
15	ND	.38	—
16	ND	—	.38
17	ND	—	—
18	—	—	—
19	—	1.65	—
20	—	—	.51
21	.13	—	—
22	.51	—	—
23	.13	.13	—
24	—	.13	—
25	.51	.76	ND
26	1.52	—	ND
27	—	—	ND
28	—	—	ND
29	.38	—	ND
30	.76	—	ND
31	—	—	

Table 33. Field water-quality data collected from Scofield Reservoir, Utah, during 1983

[m, meters; µS/cm, microsiemens per centimeter; °C, degrees Celsius; mg/L, milligrams per liter; —, no data available;<, less than]

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M65	06-28-83	1430	3.7	340	—	14.0	—	11.0
	07-20-83	0900	1.0	300	—	16.5	—	7.2
	07-20-83	0905	2.0	295	—	16.0	—	7.2
	07-20-83	0910	3.0	295	7.1	16.0	1.5	7.1
	07-20-83	0915	4.0	290	—	16.0	—	7.0
	07-20-83	0920	5.0	295	—	16.0	—	7.1
	07-20-83	0925	6.0	325	—	14.5	—	6.2
	08-17-83	1245	0	—	—	20.0	—	—
	08-17-83	1300	0	315	8.3	21.0	—	6.5
	08-17-83	1302	1.0	315	8.3	21.0	1.7	6.5
	08-17-83	1310	3.0	310	8.2	20.5	—	7.2
	08-17-83	1305	5.0	345	7.8	20.0	—	7.0
	08-31-83	0905	0	325	8.1	17.0	—	5.2
	08-31-83	0915	1.0	325	8.1	17.0	1.0	5.2
	08-31-83	0920	3.0	330	8.1	17.0	—	5.0
	08-31-83	0925	4.0	330	7.8	17.0	—	3.8
	09-14-83	1125	0	370	8.2	17.5	—	6.4
	09-14-83	1135	1.0	365	8.2	17.0	2.3	6.4
	09-14-83	1140	3.0	370	8.0	16.5	—	6.1
	09-14-83	1145	3.5	370	8.0	16.5	—	6.0
	09-29-83	1130	1.0	310	8.2	12.0	—	6.7
	09-29-83	1135	3.0	330	8.2	12.0	1.0	6.5
M90B	06-28-83	1515	5.5	410	8.2	12.5	—	8.8
	07-20-83	1030	1.0	300	7.5	18.0	1.8	6.3
	07-20-83	1035	2.0	300	—	18.0	—	6.2
	08-17-83	1330	0	280	8.7	21.0	—	9.0
	08-17-83	1335	1.0	280	8.7	21.0	1.8	9.0
	08-17-83	1340	2.5	265	8.4	19.0	—	10.0
	08-31-83	1010	0	300	8.2	18.0	—	6.0
	08-31-83	1000	1.0	310	8.2	18.0	1.0	6.0
	08-31-83	1020	3.0	300	7.7	16.5	—	3.6
	09-14-83	1155	0	370	8.3	17.0	—	6.5
	09-14-83	1200	1.0	370	8.2	17.0	2.0	6.0
	09-14-83	1205	3.0	375	7.7	15.0	—	5.2
	09-29-83	1110	1.0	340	8.3	13.0	—	6.8
	09-29-83	1115	3.0	340	8.3	13.0	1.0	6.8
M30	07-20-83	1100	1.0	290	7.7	18.0	2.5	7.4
	07-20-83	1105	2.0	310	—	18.0	—	7.1
	07-20-83	1110	4.0	315	—	18.0	—	7.6
	07-20-83	1115	6.0	305	—	18.0	—	7.2
	07-20-83	1120	7.0	325	—	13.0	—	2.9
	07-20-83	1125	8.0	325	—	13.0	—	2.2
	07-20-83	1130	10.0	340	—	11.0	—	1.2
	07-20-83	1135	12.0	335	—	9.5	—	.8
	08-17-83	1400	0	295	8.6	21.5	—	6.5
	08-17-83	1402	1.0	315	8.6	21.5	3.3	6.5
	08-17-83	1405	3.0	305	8.6	21.5	—	6.4

Table 33. Field water-quality data collected from Scofield Reservoir, Utah, during 1983—Continued

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M30	08-17-83	1410	5.0	310	8.6	20.5	—	6.1
	08-17-83	1415	7.0	305	7.3	17.0	—	<.1
	08-17-83	1425	9.0	355	7.4	12.0	—	.1
	08-17-83	1430	11.0	370	7.4	10.0	—	<.1
	08-17-83	1435	12.0	365	7.6	10.0	—	<.1
	08-31-83	1100	1.0	290	8.3	18.5	2.5	5.8
	08-31-83	1105	3.0	315	8.3	18.5	—	5.4
	08-31-83	1110	5.0	315	8.2	18.0	—	5.5
	08-31-83	1115	7.0	325	8.1	18.0	—	5.4
	08-31-83	1135	8.0	335	8.2	16.0	—	3.8
	08-31-83	1120	9.0	365	7.2	13.0	—	.2
	08-31-83	1125	10.0	365	7.1	11.0	—	.1
	08-31-83	1130	11.0	370	7.0	11.0	—	<.1
	09-14-83	1235	0	355	8.4	17.5	—	6.8
	09-14-83	1240	1.0	355	8.3	17.5	3.0	6.6
	09-14-83	1245	3.0	355	8.2	17.0	—	6.0
	09-14-83	1250	5.0	360	8.2	16.5	—	6.0
	09-14-83	1255	7.0	360	8.1	16.0	—	5.4
	09-14-83	1305	8.0	380	7.7	15.5	—	4.4
	09-14-83	1257	9.0	390	7.5	14.5	—	.4
	09-14-83	1302	10.0	415	7.1	12.0	—	<.1
	09-14-83	1300	11.0	430	7.1	11.5	—	<.1
	09-29-83	1030	1.0	310	8.3	14.0	—	6.7
	09-29-83	1040	3.0	320	8.4	13.5	—	6.7
	09-29-83	1045	5.0	310	8.3	13.5	1.2	6.6
	09-29-83	1050	7.0	320	8.3	13.5	—	6.6
	09-29-83	1055	9.0	310	8.3	13.5	—	6.4
	09-29-83	1100	10.0	—	8.2	13.5	—	6.3
M5	06-28-83	1545	8.0	330	8.4	16.0	—	12.0
	07-20-83	1135	2.0	290	—	18.0	—	7.3
	07-20-83	1140	4.0	300	—	17.5	—	7.3
	07-20-83	1145	6.0	295	7.4	17.0	1.8	6.8
	07-20-83	1147	6.5	—	—	15.0	—	3.5
	07-20-83	1150	7.0	—	—	13.0	—	2.2
	07-20-83	1155	8.0	335	—	11.5	—	1.3
	07-20-83	1200	10.0	325	—	10.5	—	.5
	07-20-83	1205	12.0	340	7.3	10.5	—	.5
	08-03-83	1245	2.0	320	7.9	20.5	—	—
	08-17-83	1500	0	310	8.5	22.0	—	6.2
	08-17-83	1503	1.0	315	8.4	21.0	—	5.6
	08-17-83	1505	3.0	315	8.4	21.0	—	5.6
	08-17-83	1510	5.0	335	7.7	19.0	—	1.0
	08-17-83	1515	7.0	360	7.8	15.0	—	<.1
	08-17-83	1520	9.0	380	7.6	12.0	—	<.1
	08-17-83	1525	11.0	365	7.3	10.5	—	<.1
	08-17-83	1527	12.0	365	7.2	10.5	1.0	.1
	08-17-83	1530	13.0	370	7.2	10.0	—	<.1
	08-31-83	1450	0	320	8.4	20.0	—	5.5
	08-31-83	1455	1.0	320	8.4	20.0	2.5	5.5
	08-31-83	1500	3.0	320	8.3	19.0	—	5.0
	08-31-83	1505	5.0	310	8.2	18.5	—	4.4

Table 33. Field water-quality data collected from Scofield Reservoir, Utah, during 1983—Continued

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M5	08-31-83	1535	6.0	305	7.7	17.0	—	2.0
	08-31-83	1510	7.0	330	7.7	17.0	—	.2
	08-31-83	1530	8.0	345	7.4	14.0	—	<.1
	08-31-83	1515	9.0	360	7.5	13.0	—	<.1
	08-31-83	1520	11.0	370	7.1	11.0	—	.1
	08-31-83	1525	12.5	395	7.1	10.5	—	<.1
	09-14-83	1320	0	340	8.4	18.5	—	7.0
	09-14-83	1325	1.0	345	8.4	18.5	3.3	7.0
	09-14-83	1327	3.0	345	8.4	18.0	—	7.0
	09-14-83	1345	4.0	340	8.2	17.0	—	7.0
	09-14-83	1330	5.0	340	8.0	17.0	—	4.4
	09-14-83	1343	6.0	350	7.9	16.0	—	4.3
	09-14-83	1332	7.0	350	7.9	16.0	—	3.8
	09-14-83	1340	8.0	355	7.6	16.0	—	2.7
	09-14-83	1335	9.0	365	7.6	15.0	—	<.1
	09-14-83	1337	10.0	390	7.4	13.0	—	<.1
	09-29-83	1200	1.0	340	8.2	14.0	—	6.4
	09-29-83	1205	3.0	340	8.2	14.0	—	6.4
	09-29-83	1210	5.0	350	8.2	14.0	—	6.4
	09-29-83	1215	7.0	350	8.2	14.0	—	6.4
	09-29-83	1220	9.0	350	8.2	14.0	1.0	6.4
	09-29-83	1225	11.0	340	8.2	14.0	—	6.2
	11-21-83	1350	1.0	—	7.6	2.0	—	7.8
	11-21-83	1355	3.0	—	7.8	2.5	—	7.7
	11-21-83	1400	5.0	—	7.9	3.0	—	7.6
	11-21-83	1405	7.0	—	8.0	3.0	—	7.4
	11-21-83	1410	9.0	—	8.1	3.0	—	7.5
	11-21-83	1415	11.0	—	8.1	2.5	—	7.2
M110	08-31-83	1355	0	315	8.3	19.0	—	6.4
	08-31-83	1320	1.0	305	8.3	19.0	2.0	5.4
	08-31-83	1325	3.0	320	8.3	19.0	—	5.4
	08-31-83	1330	5.0	320	8.2	19.0	—	5.6
	08-31-83	1335	7.0	335	7.4	16.5	—	.4
	08-31-83	1340	9.0	375	7.1	13.0	—	.1
	08-31-83	1345	11.0	380	7.1	11.0	—	<.1
	08-31-83	1350	12.0	390	7.0	10.0	—	.1

Table 34. Field water-quality data collected from Scofield Reservoir, Utah, during 1984

[m, meters; µS/cm, microsiemens per centimeter; °C, degrees Celsius; mg/L, milligrams per liter; —, no data available]

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M65	05-22-84	1150	1.0	375	7.4	7.5	0.40	8.4
	05-22-84	1145	4.0	375	7.5	7.5	—	8.0
	06-27-84	1200	0	410	—	16.0	—	13.5
	06-27-84	1205	1.0	410	8.1	15.0	2.3	14.0
	06-27-84	1210	2.0	417	8.1	14.5	—	14.0
	06-27-84	1215	3.0	416	8.1	14.0	—	13.5
	06-27-84	1220	4.7	449	7.9	12.0	—	10.5
	07-31-84	1443	1.0	—	—	19.0	1.8	—
	07-31-84	1440	3.0	—	8.4	18.5	—	—
	07-31-84	1438	5.0	—	8.4	18.5	—	—
	08-29-84	0945	1.0	310	7.9	18.0	1.5	7.4
	08-29-84	0948	2.0	315	7.9	18.0	—	7.3
	08-29-84	0949	3.0	320	7.9	17.5	—	7.5
	09-19-84	0947	1.0	335	8.0	15.0	—	7.4
	09-19-84	0945	2.0	335	8.0	15.5	1.6	7.3
	09-19-84	0940	4.0	345	7.7	15.0	—	6.0
M90B	05-22-84	1225	1.0	400	7.8	6.0	.40	8.9
	05-22-84	1215	3.5	345	7.8	3.5	—	9.2
	06-27-84	1125	0	391	—	14.0	—	11.9
	06-27-84	1130	1.0	395	7.9	13.0	1.6	11.9
	06-27-84	1135	2.0	409	—	12.0	—	10.5
	06-27-84	1140	3.0	409	—	12.0	—	11.0
	06-27-84	1145	4.0	433	—	11.0	—	9.0
	07-31-84	1430	1.0	—	8.5	19.0	2.5	—
	07-31-84	1428	3.0	—	8.5	19.0	—	—
	07-31-84	1425	4.0	—	8.5	18.5	—	—
	08-29-84	0930	1.0	315	7.9	18.0	1.5	7.0
	08-29-84	0935	3.0	315	7.8	17.5	—	6.8
	08-29-84	0938	4.0	315	7.8	17.0	—	6.8
	09-19-84	0930	1.0	335	8.0	15.5	—	6.7
	09-19-84	0925	2.0	335	8.0	15.5	1.0	6.5
	09-19-84	0920	3.0	340	7.7	15.5	—	4.6
M30	05-22-84	1315	1.0	405	8.2	8.5	.80	9.5
	05-22-84	1310	2.0	400	8.3	8.0	—	9.6
	05-22-84	1305	4.0	400	7.9	6.5	—	8.3
	05-22-84	1300	6.0	400	7.9	6.0	—	8.3
	05-22-84	1255	8.0	375	7.8	5.5	.80	8.3
	05-22-84	1250	10.0	360	7.8	4.5	—	8.3
	06-27-84	1225	0	410	8.4	16.0	—	14.5
	06-27-84	1230	1.0	410	8.3	16.0	3.0	14.0
	06-27-84	1235	2.0	418	8.3	15.0	—	14.0
	06-27-84	1240	3.0	422	8.3	14.0	—	13.0
	06-27-84	1245	4.0	436	8.2	12.0	—	12.0
	06-27-84	1250	5.0	439	8.2	11.0	—	11.5
	06-27-84	1255	7.0	430	8.2	11.0	—	9.5
	06-27-84	1300	9.0	440	8.1	9.0	—	7.0
	06-27-84	1305	11.0	437	8.1	8.0	—	3.5

Table 34. Field water-quality data collected from Scofield Reservoir, Utah, during 1984—Continued

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M30	07-31-84	1410	1.0	—	8.5	20.0	3.5	—
	07-31-84	1408	3.0	—	8.5	19.0	—	—
	07-31-84	1405	5.0	—	8.4	18.5	—	—
	07-31-84	1403	7.0	—	7.5	14.5	—	—
	07-31-84	1400	8.0	—	7.4	12.0	—	—
	07-31-84	1355	9.0	—	7.3	11.0	—	—
	07-31-84	1350	10.0	—	7.4	10.0	—	—
	08-29-84	1012	1.0	310	7.9	18.0	2.0	7.0
	08-29-84	1010	2.0	310	7.9	18.0	—	6.9
	08-29-84	1008	4.0	315	7.9	18.0	—	6.8
	08-29-84	1006	6.0	315	7.9	17.5	—	6.2
	08-29-84	1004	7.0	320	7.6	17.0	—	4.1
	08-29-84	1002	8.0	330	7.3	16.0	—	.6
	08-29-84	1001	9.0	345	7.4	14.5	—	.3
	08-29-84	1000	10.0	355	7.4	12.0	—	.2
	09-19-84	1014	1.0	330	8.1	16.0	2.0	8.1
	09-19-84	1012	3.0	335	8.1	16.0	—	8.0
	09-19-84	1010	5.0	335	8.2	16.0	—	7.8
	09-19-84	1008	7.0	335	8.1	15.5	—	6.9
	09-19-84	1005	8.0	—	—	—	—	—
	09-19-84	1006	9.0	340	7.8	15.0	—	4.3
	09-19-84	1004	10.0	345	7.7	15.0	—	2.3
M5	05-22-84	1400	1.0	310	8.3	9.0	.60	9.3
	05-22-84	1355	3.0	310	8.0	9.0	—	9.2
	05-22-84	1350	5.0	310	7.8	8.5	—	9.0
	05-22-84	1345	7.0	310	7.6	6.5	—	6.9
	05-22-84	1340	9.0	310	7.2	6.0	—	6.4
	05-22-84	1335	11.0	310	7.3	6.0	.60	5.8
	06-27-84	1310	0	410	8.6	16.0	—	16.0
	06-27-84	1315	1.0	410	8.6	16.0	2.7	14.5
	06-27-84	1320	2.0	418	8.6	15.0	—	14.0
	06-27-84	1325	3.0	418	8.5	15.0	—	14.0
	06-27-84	1330	5.0	422	8.5	14.0	—	14.5
	06-27-84	1335	7.0	440	8.4	11.0	—	10.5
	06-27-84	1340	9.0	447	8.3	9.0	—	7.5
	06-27-84	1342	11.0	451	7.9	8.0	—	5.0
	07-31-84	1335	1.0	—	8.4	20.0	3.0	—
	07-31-84	1330	2.0	—	8.4	20.0	—	—
	07-31-84	1325	4.0	—	8.4	19.5	—	—
	07-31-84	1323	6.0	—	7.9	18.0	—	—
	07-31-84	1318	7.0	—	7.7	12.5	—	—
	07-31-84	1312	8.0	—	7.6	11.5	—	—
	07-31-84	1305	9.0	—	7.4	10.0	—	—
	07-31-84	1300	10.0	—	6.8	10.0	—	—
	08-29-84	1051	1.0	310	8.0	18.5	2.2	7.5
	08-29-84	1049	2.0	310	8.0	18.5	—	7.6
	08-29-84	1047	4.0	310	8.0	18.0	—	7.1
	08-29-84	1045	6.0	315	7.8	17.5	—	5.8
	08-29-84	1043	7.0	320	7.6	17.0	—	4.0
	08-29-84	1041	8.0	330	7.3	16.0	—	0
	08-29-84	1039	9.0	340	7.3	15.0	—	0

Table 34. Field water-quality data collected from Scofield Reservoir, Utah, during 1984—Continued

Station	Date	Time	Sampling depth (m)	Specific conductance (µS/cm at 25°C)	pH (standard units)	Temperature (°C)	Transparency, secchi disk (m)	Oxygen, dissolved (mg/L)
M5	08-29-84	1037	10.0	350	7.3	12.5	—	0.1
	08-29-84	1036	11.0	355	7.3	11.5	—	.2
	08-29-84	1035	12.0	360	7.3	11.0	—	.2
	09-19-84	1100	1.0	325	8.2	17.0	1.8	8.9
	09-19-84	1058	2.0	330	8.1	16.5	—	8.4
	09-19-84	1056	4.0	335	7.9	15.5	—	5.6
	09-19-84	1054	6.0	335	7.8	15.5	—	4.5
	09-19-84	1052	8.0	340	7.7	15.0	—	2.6
	09-19-84	1050	9.0	345	7.7	15.0	—	1.5
	09-19-84	1045	10.0	345	7.7	15.0	—	.5
	10-25-84	1338	2.0	360	8.3	5.0	4.0	8.9
	10-25-84	1335	4.0	358	8.3	5.5	—	8.9
	10-25-84	1328	6.0	356	8.9	5.5	—	8.9
	10-25-84	1325	8.0	356	8.9	5.5	—	8.9

Table 35. Water-quality data collected from Scofield Reservoir, Utah, during 1983

[m, meters; µS/cm, microsiemens per centimeter; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data available;

Station	Date	Time	Sampling depth (m)	pH (standard units)	Specific conductance, lab (µS/cm at 25°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
M-65	06-28-83	1430	3.7	—	—	—	—	—	—	—	—	—	—	—	—
	07-20-83	0910	3.0	7.1	341	170	—	50	11	3.3	.1	1.3	26	13	.1
	08-17-83	1302	1.0	8.3	311	160	22	44	11	2.9	.1	1.2	1.3	13	.1
	08-31-83	0915	1.0	8.1	325	150	—	43	11	3.1	.1	1.4	2.4	14	.1
	09-14-83	1135	1.0	8.2	324	170	7	48	11	3.2	.1	1.2	1.9	12	.2
	09-29-83	1135	3.0	8.2	—	—	—	—	—	—	—	—	—	—	—
M-90B	06-28-83	1515	5.5	8.2	—	—	—	—	—	—	—	—	—	—	—
	07-20-83	1030	1.0	7.5	—	—	—	—	—	—	—	—	—	—	—
	08-17-83	1335	1.0	8.7	272	140	9	39	11	3.1	.1	.6	.5	14	.1
	08-31-83	1000	1.0	8.2	322	160	.68	45	11	3.1	.1	1.3	1.9	13	.1
	09-14-83	1200	1.0	8.2	321	170	13	49	11	3.1	.1	1.3	1.9	11	.1
	09-29-83	1115	3.0	8.3	—	—	—	—	—	—	—	—	—	—	—
M-30	07-20-83	1100	1.0	7.7	—	—	—	—	—	—	—	—	—	—	—
	08-17-83	1402	1.0	8.6	309	160	4	44	11	2.7	.1	1.3	.7	12	.1
	08-17-83	1425	9.0	7.4	356	180	2	55	11	2.7	.1	1.0	14	10	.1
	08-31-83	1100	1.0	8.3	320	160	—	44	11	3.1	.1	1.3	1.5	13	.1
	08-31-83	1125	10.0	7.1	372	180	—	54	11	3.0	.1	1.3	29	6.9	.1
	09-14-83	1240	1.0	8.3	321	170	12	49	11	3.1	.1	1.3	1.5	12	.2
	09-14-83	1302	10.0	7.1	354	170	—	50	11	3.0	.1	1.2	27	8.4	.2
	09-29-83	1045	5.0	8.3	323	160	—	45	11	3.2	.1	1.2	1.5	10	<.1
M-5	06-28-83	1545	8.0	8.4	—	—	—	—	—	—	—	—	—	—	—
	07-20-83	1145	6.0	7.4	327	170	6	50	11	4.2	.1	1.3	13	12	.1
	07-20-83	1205	12.0	7.3	354	180	—	53	11	2.8	.1	1.3	18	11	.1
	08-17-83	1503	1.0	8.4	310	160	2	44	11	2.9	.1	1.3	1.2	15	.1
	08-17-83	1527	12.0	7.2	364	190	—	56	11	2.8	.1	1.2	23	9.7	.1
	08-31-83	1455	1.0	8.4	319	160	2	45	11	3.0	.1	1.3	1.2	13	.1
	08-31-83	1520	11.0	7.1	371	190	—	56	11	3.0	.1	1.6	29	6.4	.1
	09-14-83	1325	1.0	8.4	319	170	11	49	11	3.1	.1	1.4	1.2	12	.2
	09-14-83	1335	9.0	7.6	334	170	4	50	11	3.1	.1	1.3	8.1	11	.1
	09-29-83	1220	9.0	8.2	321	160	7	44	11	3.1	.1	1.1	1.8	11	.1
	11-21-83	1400	5.0	7.9	328	170	3	47	12	3.5	.1	1.3	4.0	15	.1
M-110	08-31-83	1320	—	8.3	320	160	3	45	11	3.1	.1	1.4	1.5	13	.1
	08-31-83	1350	—	7.0	374	190	.14	58	11	3.0	.1	1.4	37	5.8	.1

Table 35. Water-quality data collected from Scofield Reservoir, Utah, during 1983—Continued

<, less than]

Silica, dis-solved (mg/L as SiO_2)	Solids, residue at 180 °C, dis-solved (mg/L)	Solids, sum of consti-tuents, dis-solved (mg/L)	Nitro-gen, dis-solved (mg/L as N)	Nitro-gen, Nitrite, dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3, dis-solved (mg/L as N)	Nitro-gen, ammonia, dis-solved (mg/L as N)	Nitro-gen, ammonia, dis-solved (mg/L as NH_4)	Nitro-gen, organic, total (mg/L as N)	Nitro-gen, organic, dis-solved (mg/L as N)	Nitro-gen, ammonia + organic, total (mg/L as N)	Nitro-gen, total (mg/L as N)	Phos-phorus, total (mg/L as P)
—	—	—	0.62	<0.02	0.22	0.06	0.08	0.7	0.34	0.7	0.7	0.04
1.2	190	187	—	<.02	<.1	.07	.09	.8	.53	.8	.8	.04
1.1	168	157	—	<.02	<.1	.11	.14	.6	.39	.6	.6	.04
2.5	169	173	—	<.02	<.1	.06	.08	.6	.54	.6	.6	.01
2.2	174	177	—	<.02	<.1	<.10	.13	.7	.4	.7	.7	.04
—	—	—	—	<.02	<.1	.13	.17	.6	.47	.6	.6	.04
—	—	—	.67	<.02	.27	.06	.08	1.2	.34	1.20	1.2	.20
—	—	—	—	<.02	<.1	.07	.09	1.0	.73	1.00	1.0	.04
.9	145	153	—	<.02	<.1	.09	.12	—	.41	—	—	—
1.8	172	174	—	<.02	<.1	.04	.05	.5	.36	.5	.5	<.01
2.1	173	175	—	<.02	<.1	.08	.1	.9	.52	.9	.9	.01
—	—	—	—	<.02	<.1	.11	.14	.6	.49	.6	.6	.04
—	—	—	—	<.02	<.1	.07	.09	.6	.53	.6	.6	.03
	1	166	167	—	<.02	<.1	.09	.12	—	.51	—	——
4.4	195	198	—	<.02	<.1	.30	.39	1.0	.5	1.00	1.0	.12
1.7	170	174	—	<.02	<.1	.83	1.1	1.5	.17	1.50	1.5	.07
6.7	176	200	—	<.02	<.1	.07	.09	.5	.23	.5	.5	.02
2.0	172	177	.76	<.02	.16	.08	.1	.9	.52	.9	.9	.00
5.7	189	191	—	<.02	<.1	.63	.81	—	.47	—	—	—
4	170	171	—	<.02	<.1	.11	.14	.7	.59	.7	.7	.02
—	—	—	.46	<.02	.16	<.06	.08	.5	.24	.5	.5	.04
1.3	175	182	—	<.02	<.1	.08	.1	.8	.62	.8	.8	.03
4.5	193	197	.9	<.02	.1	.34	.44	1.0	.46	1.00	1.0	.04
1.0	179	173	—	<.02	<.1	.11	.14	.6	.49	.6	.6	.04
5.7	202	204	—	—	—	—	—	1.3	—	1.30	1.3	.16
1.6	169	173	—	<.02	<.1	.12	.15	.4	.18	.4	.4	<.01
6.3	193	206	—	<.02	<.1	.95	1.2	1.5	.25	1.50	1.5	.23
1.8	173	177	—	<.02	<.1	.04	.05	.7	.46	.7	.7	.01
3.4	183	184	—	<.02	<.1	.32	.41	.9	.38	.9	.9	.02
.8	185	164	—	<.02	<.1	.11	.14	.7	.49	.7	.7	.01
2.0	185	184	—	<.01	<.1	.08	.1	.7	.62	.7	.7	.02
1.5	167	174	—	<.02	<.1	1.00	1.3	1.7	.6	1.70	1.7	.24
6.6	196	205	—	<.02	<.1	.07	.09	.5	.33	.5	.5	<.01

Table 35. Water-quality data collected from Scofield Reservoir, Utah, during 1983—Continued

Station	Date	Phos phorus, dis- solved (mg/L as P)	Phos phorus, ortho, total (mg/L as P)	Phos phorus, ortho, dis- solved (mg/L as P)	Phos phorus, organic, total (mg/L as P)	Phos phorus, organic, dis- solved (mg/L as P)	Alumi- num, total recov- erable (µg/L as Al)	Arsenic, total (µg/L as As)	Cadmium, total recov- erable (µg/L as Cd)	Chro- mium, dis- solved (µg/L as Cr)	Cobalt, total recov- erable (µg/L as Co)	Copper, dis- solved (µg/L as Cu)	Iron, total recov- erable (µg/L as Fe)	Iron, sus- pended recov- erable (µg/L as Fe)
M-65	06-28-83	0.01	<0.01	—	0.03	0.01	—	—	—	—	—	—	250	240
	07-20-83	.02	<.01	—	.03	.02	80	1	1	—	—	3	800	800
	08-17-83	.04	.03	—	.01	.04	100	1	<1	—	—	2	200	160
	08-31-83	.01	<.01	0	—	.01	100	1	<1	<1	<50	<1	320	310
	09-14-83	.01	.03	—	.01	.01	—	1	—	—	—	2	—	—
	09-29-83	<.01	.03	—	.01	.01	—	—	—	—	—	—	440	420
M-90B	06-28-83	.01	.02	—	.18	.01	—	—	—	—	—	—	2,500	2,500
	07-20-83	.04	<.01	—	.03	.04	—	—	—	—	—	—	—	—
	08-17-83	—	—	—	—	—	50	<1	<1	—	—	1	100	90
	08-31-83	<.01	.02	0	—	.01	100	1	<1	<1	<50	2	320	310
	09-14-83	<.01	.02	—	—	.01	—	1	—	—	—	1	—	—
	09-29-83	<.01	.02	—	.02	.01	—	—	—	—	—	—	480	450
M-30	07-20-83	.02	0	—	.03	.02	—	—	—	—	—	—	—	—
	08-17-83	—	—	—	—	—	80	<1	<1	—	—	<1	100	90
	08-17-83	.10	.08	—	.04	.1	60	1	<1	—	—	6	270	160
	08-31-83	.06	.06	.05	.01	.01	80	1	<1	<1	<50	1	140	130
	08-31-83	0	.02	0	—	—	1,400	3	<1	<1	<50	<1	2,900	2,900
	09-14-83	0	.02	—	—	—	—	<1	—	—	—	1	—	—
	09-14-83	—	—	—	—	—	—	2	—	—	—	<1	—	—
	09-29-83	0	.03	—	—	—	100	1	1	—	—	2	190	190
M-5	06-28-83	.01	<.01	—	.03	.01	—	—	—	—	—	—	110	100
	07-20-83	.03	<.01	—	.02	.03	100	1	<1	—	—	2	140	130
	07-20-83	.03	<.01	—	.03	.03	100	1	<1	—	—	1	420	400
	08-17-83	.04	.03	—	.01	.04	100	1	<1	—	—	3	360	350
	08-17-83	.09	.10	—	.06	.09	100	1	<1	—	—	3	760	440
	08-31-83	<.01	<.01	0	—	.01	100	1	<1	<1	<50	1	150	140
	08-31-83	.14	.14	.16	.09	—	300	2	<1	<1	<50	<1	1,400	860
	09-14-83	<.01	.02	—	—	.01	—	1	—	—	—	<1	—	—
	09-14-83	.01	.02	—	—	.01	—	1	—	—	—	1	—	—
	09-29-83	.01	.02	—	—	.01	200	<1	1	—	—	1	260	260
	11-21-83	<.01	.01	—	.01	.01	50	1	<1	—	—	1	100	90
M-110	08-31-83	.03	.11	.13	.13	—	80	1	<1	<1	<50	1	150	140
	08-31-83	<.01	.02	0	—	.01	500	2	<1	<1	<50	<1	1,800	1,400

Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lead, suspended recoverable (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, total recoverable (µg/L as Hg)	Nickel, total recoverable (µg/L as Ni)	Zinc, total recoverable (µg/L as Zn)	Zinc, suspended recoverable (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)	Carbon, organic, suspended total (mg/L as C)
0	—	—	—	20	20	3	—	—	20	10	0	—
0	0	—	<1	20	20	5	.1	0	—	—	10	—
30	0	—	1	20	20	5	.2	0	—	—	10	—
10	0	0	1	70	40	26	.2	0	—	—	10	—
0	—	—	<1	—	—	48	.4	—	—	—	0	—
20	—	—	—	130	20	110	—	—	—	—	—	—
20	—	—	—	240	140	98	—	—	50	20	30	—
—	—	—	—	—	—	—	—	—	—	—	—	—
0	0	—	<1	20	20	4	.5	0	—	—	0	—
10	0	0	1	50	40	12	.1	0	—	—	10	—
5.00	—	—	2	—	—	53	.1	—	—	—	4.00	—
30	—	—	—	130	40	90	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
9.00	<1.00	—	<1	20	20	2	.3	5.00	—	—	7.00	—
110	1.00	—	<1	400	40	360	<.1	4.00	—	—	10	—
7.00	2.00	—	<1	10	6	4	.1	4.00	—	—	10	—
50	2.00	1.00	1	710	100	610	<.1	20	—	—	7.00	—
7.00	—	—	1	—	—	40	.1	—	—	—	10	—
200	—	—	<1	—	—	740	.1	—	—	—	4.00	—
5.00	6.00	5.00	1	120	10	110	.1	6.00	—	—	8.00	.5
0	—	—	—	10	7	3	—	—	30	20	10	—
10	0	—	<1	20	9	11	.1	10	—	—	50	—
20	0	—	<1	290	10	280	.1	0	—	—	10	—
0	0	—	1	20	20	3	.2	0	—	—	10	—
320	0	—	<1	490	40	450	<.1	0	—	—	10	—
0	0	0	2	20	20	3	.1	0	—	—	0	—
540	0	0	1	590	20	570	<.1	0	—	—	0	—
10	—	—	<1	—	—	19	.1	—	—	—	3.00	—
9.00	—	—	2	—	—	300	<.1	—	—	—	5.00	—
0	0	0	2	130	30	100	.1	0	—	—	10	—
10	4.00	—	<1	110	0	110	.2	7.00	—	—	40	—
0	0	0	2	20	20	2	.1	0	—	—	70	—
400	0	0	1	600	70	530	.1	0	—	—	50	—

Table 36. Water-quality data collected from Scofield Reservoir, Utah, during 1984

[m, meters; µS/cm, microsiemens per centimeter; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data available;

Station	Date	Time	Sampling depth (m)	pH (standard units)	Specific conductance, lab (µS/cm at 25°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
M-65	05-22-84	1150	1.0	7.4	356	170	11	51	11	3.6	0.1	0.6	12	15	0.1
	06-27-84	1305	1.0	8.1	—	—	—	—	—	—	—	—	—	—	—
	07-31-84	1443	1.0	—	326	170	13	50	11	3.2	.1	1.0	—	14	.2
	08-29-84	0945	1.0	7.9	—	—	—	—	—	—	—	—	—	—	—
	09-19-84	0945	2.0	8.0	341	170	11	50	12	3.5	.1	1.0	3.1	15	.1
M-90B	05-22-84	1225	1.0	7.8	355	170	7	52	10	3.4	.1	1.5	5.0	13	.1
	06-27-84	1130	1.0	7.9	—	—	—	—	—	—	—	—	—	—	—
	07-31-84	1430	1.0	8.5	325	160	8	49	10	3.1	.1	1.0	.9	13	.1
	08-29-84	0930	1.0	7.9	—	—	—	—	—	—	—	—	—	—	—
	09-19-84	0925	2.0	8.0	339	170	13	50	12	3.4	.1	1.3	3.1	14	.1
M-30	05-22-84	1315	1.0	8.2	357	180	13	52	11	4.0	.1	1.6	2.0	16	.1
	05-22-84	1255	8.0	7.8	351	170	14	53	10	3.2	.1	1.3	4.9	11	.1
	06-27-84	1230	1.0	8.3	—	—	—	—	—	—	—	—	—	—	—
	06-27-84	1255	7.0	8.2	—	—	—	—	—	—	—	—	—	—	—
	07-31-84	1410	1.0	8.5	321	160	9	49	10	3.0	.1	.9	.9	14	.1
	07-31-84	1405	5.0	8.4	328	160	8	49	10	3.1	.1	1.0	1.2	13	.2
	08-29-84	1012	1.0	7.9	334	170	13	50	11	3.3	.1	1.1	3.8	12	.1
	08-29-84	1001	9.0	7.4	356	170	—	51	11	3.2	.1	1.2	14	12	.1
	09-19-84	1014	1.0	8.1	340	170	11	50	11	3.4	.1	1.3	2.4	14	.1
	09-19-84	1005	8.0	—	340	170	13	50	12	3.4	.1	1.7	—	14	.1
M5	05-22-84	1400	1.0	8.3	353	170	12	50	11	3.9	.1	1.6	1.5	15	.1
	05-22-84	1335	11.0	7.3	355	170	10	50	11	4.0	.1	1.1	16	15	<.1
	06-27-84	1315	1.0	8.6	—	—	—	—	—	—	—	—	—	—	—
	06-27-84	1335	7.0	8.4	—	—	—	—	—	—	—	—	—	—	—
	07-31-84	1335	1.0	8.4	329	160	9	49	10	3.2	.1	1.1	1.2	13	.1
	07-31-84	1318	7.0	7.7	354	170	.54	51	10	3.0	.1	1.1	6.5	12	.1
	08-29-84	1051	1.0	8.0	330	170	12	50	11	3.2	.1	1.1	3.0	12	.1
	08-29-84	1036	11.0	7.3	378	190	—	57	11	3.1	.1	1.3	19	9.0	.1
	09-19-84	1100	1.0	8.2	331	170	17	50	12	3.4	.1	1.2	1.9	13	.1
	09-19-84	1050	9.0	7.7	344	170	11	50	12	3.4	.1	1.3	6.3	16	.1
	10-25-84	1338	2.0	8.3	335	170	14	50	12	3.6	.1	1.0	1.5	15	.1

<, less than]

Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 °C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	NItrogen, dissolved (mg/L as N)	Nitrogen, Nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as NH_4)	Nitrogen, organic, total (mg/L as N)	Nitrogen, organic, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)
4.6	205	189	1.1	<0.01	0.56	0.03	0.04	0.5	0.47	0.5	0.5	0.05
—	—	—	—	<.01	.27	<.01	.01	.4	.39	.4	.4	.01
1.9	178	180	—	<.01	<.1	.07	.09	.3	.23	.3	.3	.01
—	—	—	—	<.01	<.1	<.01	.01	.4	.19	.4	.4	.01
.2	193	184	—	<.01	<.1	.02	.03	.6	.18	.6	.6	.02
4.2	207	188	—	<.01	.44	.02	.03	.8	.18	.8	.8	.04
—	—	—	—	<.01	.27	.02	.03	.6	.58	.6	.6	.02
1.9	183	177	—	<.01	<.1	.06	.08	.3	.24	.3	.3	.01
—	—	—	—	<.01	<.1	.04	.05	.4	.16	.4	.4	.01
.3	188	183	—	<.01	<.1	.04	.05	.4	.16	.4	.4	.02
3.5	213	191	.73	<.01	.33	.01	.01	.4	.39	.4	.4	.03
4.4	203	183	—	<.01	.49	.04	.05	.2	.16	<.2	.2	.04
—	—	—	—	<.01	.23	<.01	.01	.2	.19	.2	.2	.01
—	—	—	—	<.01	.33	<.01	.01	.4	.29	.4	.4	.01
1.8	179	177	—	<.01	<.1	.05	.06	.3	.25	.3	.3	.01
1.9	185	177	—	<.01	<.1	.05	.06	.3	.25	.3	.3	.01
1.7	178	177	—	<.01	<.1	.04	.05	.3	.16	.3	.3	.16
4.3	195	193	—	<.01	<.1	.41	.53	.8	.29	.8	.8	.08
.2	187	180	—	<.01	<.1	.02	.03	.4	.18	.4	.4	.01
.4	189	183	—	<.01	<.1	.08	.1	1.4	.22	1.40	1.4	.06
3.2	199	186	.45	<.01	.25	.01	.01	.4	.19	.4	.4	.03
4.0	214	187	.68	<.01	.28	.12	.15	.5	.28	.5	.5	.04
—	—	—	—	<.01	.25	.01	.01	.5	.49	.5	.5	.01
—	—	—	—	<.01	.28	.02	.03	.6	.28	.6	.6	.01
1.7	185	176	—	<.01	<.1	.07	.09	.3	.23	.3	.3	.01
2.9	229	186	—	<.01	.1	.19	.24	.7	.31	.7	.7	.02
1.6	174	178	—	<.01	<.1	<.01	.01	.3	.29	.3	.3	.01
6.4	205	208	—	<.01	<.1	.80	1.0	1.2	.3	1.20	1.2	.24
.1	170	179	—	<.01	<.1	<.01	.01	.4	.29	.4	.4	.02
1.1	186	187	—	<.01	<.1	.18	.23	.7	.12	.7	.7	.02
.1	166	183	—	<.01	<.1	.03	.04	.4	.37	.4	.4	.01

Table 36. Water-quality data collected from Scofield Reservoir, Utah, during 1984—Continued

Station	Date	Phos phorus, dis- solved (mg/L as P)	Phos phorus, ortho, total (mg/L as P)	Phos phorus, ortho, dis- solved (mg/L as P)	Phos phorus, organic, total (mg/L as P)	Phos phorus, organic, dis- solved (mg/L as P)	Alumi- num, total recov- erable (µg/L as Al)	Arsenic, total (µg/L as As)	Cadmium, total recov- erable (µg/L as Cd)	Chro- mium, dis- solved (µg/L as Cr)	Cobalt, total recov- erable (µg/L as Co)	Copper, dis- solved (µg/L as Cu)	Iron, total recov- erable (µg/L as Fe)	Iron, sus- pended recov- erable (µg/L as Fe)
M-65	05-22-84	0.01	0.02	—	0.03	0.01	700	<1	<1	—	—	2	1,100	1,100
	06-27-84	.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	07-31-84	<.01	<.01	—	—	.01	70	<1	<1	—	—	1	70	—
	08-29-84	<.01	<.01	—	—	.01	—	—	—	—	—	—	—	—
	09-19-84	<.01	.02	—	—	.01	70	<1	1	—	—	<1	200	—
M-90B	05-22-84	.01	.02	—	.02	.01	500	<1	<1	—	—	2	730	720
	06-27-84	.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	07-31-84	<.01	<.01	—	—	.01	40	<1	<1	—	—	1	60	—
	08-29-84	<.01	<.01	—	—	.01	—	—	—	—	—	—	—	—
	09-19-84	<.01	.02	—	—	.01	100	<1	1	—	—	<1	290	—
M-30	05-22-84	.01	.02	—	.01	.01	300	<1	<1	—	—	2	270	270
	05-22-84	<.01	.02	—	.02	.01	700	<1	<1	—	—	<1	830	820
	06-27-84	<.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	06-27-84	<.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	07-31-84	<.01	<.01	—	—	.01	50	<1	<1	—	—	<1	30	—
	07-31-84	<.01	.01	—	—	.01	60	<1	<1	—	—	3	50	—
	08-29-84	.01	<.01	—	.15	.01	70	<1	<1	—	—	<1	120	—
	08-29-84	.03	.05	—	.03	.03	200	2	<1	—	—	<1	350	—
	09-19-84	.01	.02	—	—	.01	40	<1	1	—	—	1	210	—
	09-19-84	<.01	.02	—	.04	.01	800	<1	1	—	—	<1	1,100	—
M-5	05-22-84	.01	.02	—	.01	.01	300	<1	<1	—	—	<1	350	340
	05-22-84	.01	.02	—	.02	.01	500	<1	<1	—	—	<1	610	600
	06-27-84	<.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	06-27-84	<.01	.03	—	—	.01	—	—	—	—	—	—	—	—
	07-31-84	<.01	<.01	—	—	.01	60	<1	<1	—	—	3	90	—
	07-31-84	<.01	.01	—	.01	.01	50	<1	<1	—	—	1	50	—
	08-29-84	<.01	.01	—	—	.01	70	<1	<1	—	—	<1	110	—
	08-29-84	.09	.17	—	.07	.09	200	2	<1	—	—	<1	1,000	—
	09-19-84	<.01	.01	—	.01	.01	80	<1	<1	—	—	2	90	—
	09-19-84	.01	.02	—	—	.01	90	<1	1	—	—	1	240	—
	10-25-84	<.01	<.01	—	—	.01	70	<1	<1	—	—	<1	110	—

Iron, dis-solved (µg/L as Fe)	Lead, total recov-erable (µg/L as Pb)	Lead, sus-pended recov-erable (µg/L as Pb)	Lead, dis-solved (µg/L as Pb)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, sus-pended recoverable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, total recov-erable (µg/L as Hg)	Nickel, total recov-erable (µg/L as Ni)	Zinc, total recov-erable (µg/L as Zn)	Zinc, sus-pended recov-erable (µg/L as Zn)	Zinc, dis-solved (µg/L as Zn)	Carbon, organic, sus-pended total (mg/L as C)
20	<1.00	—	<1	130	70	64	0.2	10	—	—	9.00	—
—	—	—	—	—	—	—	—	—	—	—	—	—
10	<1.00	—	4	20	—	30	.2	10	—	—	10	—
—	—	—	—	—	—	—	—	—	—	—	—	—
<3.00	<1.00	—	4	100	—	85	.3	2.00	—	—	6.00	—
9.00	<1.00	—	2	120	70	52	.2	10	—	—	9.00	—
—	—	—	—	—	—	—	—	—	—	—	—	—
9.00	<1.00	—	3	30	—	22	.3	20	—	—	9.00	—
—	—	—	—	—	—	—	—	—	—	—	—	—
5.00	4.00	—	<1	110	—	99	.3	2.00	—	—	20	—
4.00	<1.00	—	2	130	80	46	.1	10	—	—	40	—
10	<1.00	—	4	90	40	46	.1	10	—	—	5.00	—
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
5.00	<1.00	—	<1	20	—	11	.4	10	—	—	7.00	—
8.00	<1.00	—	<1	30	—	25	.2	10	—	—	20	—
4.00	<1.00	—	<1	30	—	11	.2	9.00	—	—	<3.00	—
7.00	1.00	—	<1	530	—	550	<.1	10	—	—	<3.00	—
5.00	1.00	—	2	80	—	71	.2	1.00	—	—	6.00	—
5.00	2.00	—	3	170	—	130	.2	1.00	—	—	20	—
8.00	1.00	0	1	130	110	24	<.1	10	—	—	20	—
10	5.00	1.00	4	140	70	70	.1	7.00	—	—	6.00	—
—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
5.00	<1.00	—	<1	20	—	6	.2	10	—	—	10	—
4.00	<1.00	—	<1	140	—	140	.2	20	—	—	7.00	—
<3.00	<1.00	—	<1	10	—	4	<.1	6.00	—	—	<3.00	—
290	<1.00	—	<1	710	—	690	<.1	2.00	—	—	<3.00	—
7.00	<1.00	—	<1	80	—	31	.1	2.00	—	—	10	—
<3.00	2.00	—	2	260	—	220	.1	2.00	—	—	10	—
<3.00	2.00	—	<1	110	—	93	.2	<1.00	—	—	10	—