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Limnological Survey of the C.J. Strike Hydroelectric Project

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Abstract

Idaho Power Company (IPC) conducted a descriptive limnology survey of C.J. Strike Reservoir from 1993 through 1995. The goal of the study was to characterize the reservoir and evaluate the status of water-quality relative to the State of Idaho water-quality standards. Water-quality issues identified in IPC's study include low dissolved oxygen and high ammonia nitrogen levels during summer stratification, warm summer water temperatures, and phytoplankton blooms. Elevated water temperature is not unique to the reservoir; it is an issue throughout the Snake River system. Problematic dissolved oxygen, ammonia nitrogen, and phytoplankton levels are more site specific and related to the presence of C.J. Strike Reservoir. The causes of the water-quality problems in the reservoir are related to the quality of water being delivered to the project as well as to the processing of pollutants within the reservoir.

1. Introduction

The C.J. Strike Hydroelectric Project was built in 1952 to meet increasing electricity load demands of southern Idaho. Idaho Power Company (IPC) currently operates the project under a license, which expires in 2000, from the Federal Energy Regulatory Commission (FERC). A general limnological study was proposed during the formal consultation process of applying for a new license to continue operations. This study of C.J. Strike Reservoir would describe conditions within the reservoir and provide a basis for management decisions. Identifying limnological characteristics—the physical, biological, and chemical processes—of the reservoir would also enhance management of reservoir fish populations (McConnell 1971). And provide a basic understanding of water-quality problems associated with the reservoir (Milligan et al. 1983).

Therefore, IPC conducted this study of C.J. Strike Reservoir from 1993 through 1995. The goal of the study was to characterize C.J. Strike Reservoir using selected physical, chemical, and biological parameters. The two objectives were to 1) characterize the reservoir based on standard limnological parameters and 2) document water-quality conditions relative to the Idaho State Water Quality Standards.

C.J. Strike Reservoir does not store water on a seasonal basis. Averages of daily flow entering and leaving C.J. Strike Reservoir are highly correlated ($R^2 = 0.94$). This correlation suggests that daily project inflows and outflows are nearly equal.

The reservoir experiences minimal daily water-level fluctuations. The C.J. Strike Project is operated to increase power generation at times of peak demand (block loading). Peak times are typically 7:00 to 10:00 am and 5:00 to 7:00 pm. The block loading results in typical daily reservoir headwater fluctuations of 0.3 feet. Ninety percent of the maximum daily change in headwater elevation is less than 0.4 feet per day.

Water-level fluctuations are more pronounced in the tailwater of the project than in the reservoir. The project tailwater fluctuations are more pronounced than the reservoir. While 90% of the maximum hourly tailwater elevation changes are less than 1 foot, total daily elevation changes of up to 3 feet can be expected during a typical day.

In addition to daily alteration of flow patterns for power production, the hydrology of the Snake River has been significantly affected by large irrigation and flood-control reservoirs upstream of C.J. Strike (i.e., American Falls and Palisades reservoirs). Also, agricultural demands, including the near-total diversion of the Snake River at Milner Dam (RM 639) and several large pumping diversions upstream of C.J. Strike Reservoir, can markedly reduce water supply during the irrigation season.

Prior to this study, descriptive water-quality data for C.J. Strike Reservoir was very limited. Milligan et al. (1983) sampled the reservoir once and classified the reservoir as eutrophic. Specifically, of 85 lakes and reservoirs sampled throughout Idaho, only 12 were classified as more productive than C.J. Strike Reservoir. Dillon (1991 and 1992) collected limited-water-quality characterization data coincidental with fish sampling in the reservoir. General water quality and biological communities within the reservoir and downstream in the early 1950s were described by Irving and Cuplin (1956). Nutrient data collected by IPC in C.J. Strike Reservoir from 1973 to 1975 indicated that nutrient concentrations in the reservoir exceeded the 0.05 mg/l EPA criteria for phosphorus in reservoirs. Data collected by IPC from 1988 to 1993 are summarized by IPC (1993). Myers et al. (1995) and Myers and Pierce (1996) are descriptive studies of other upstream hydroelectric reservoirs which provide a basis for comparisons among reservoirs, and insight into how the Snake River is functioning as a system.

Recent drought conditions in the Snake River drainage have emphasized water-quality problems and concerns. Much of the Snake River from its headwaters in eastern Idaho downstream to Brownlee Dam has been designated as “water quality limited” (IDHW-DEQ 1989; IDHW-DEQ 1992; IDHW-DEQ 1994). The water-quality-limited designation indicates that water quality is not adequate to support all designated beneficial uses. The Environmental Protection Agency (EPA) is under a court-imposed timeline to prepare Total Maximum Daily Load (TMDL) documents for the water-quality-limited segments. The designated uses for waters within the C.J. Strike Project include domestic and agricultural water supply, primary and secondary contact recreation, and coldwater biota. The project area supports self-sustaining populations of warmwater sport fishes and a hatchery-sustained trout fishery. Extensive colonies of an endangered snail (*Pyrgulopsis idahoensis*) inhabit the reservoir and tailwaters (IPC, *unpub. data*).

2. Study Area

The study area is in Elmore and Owyhee counties of southwestern Idaho. Our study area includes approximately 53 miles of the Snake River (from C.J. Strike Dam upstream to King Hill) and 5 miles of the Bruneau River (Figure 1). Approximately 30 of the 53 miles on the Snake River are within the backwaters of the C.J. Strike Project. The remaining 23 miles are upstream of the C.J. Strike backwater. All 5 miles of the Bruneau River are within the backwater of the reservoir.

2.1. Hydrology

The watershed of the study area is approximately 38,500 square miles. The total is the sum of the Snake River Basin (35,800 square miles) and the Bruneau River Basin (2630 square miles). The Snake River Basin includes 450 miles of the Snake River and 24 major subbasins (Low 1991).

Average annual discharge into the study area from the Snake River is 10,730 cfs, resulting in a total annual flow of slightly less than 8 million acre-feet (Brennan et al. 1996*b*). Mean annual discharge in the Bruneau River is 388 cfs, with a corresponding total annual flow of

273,000 acre-feet (Brennan et al. 1996*a*). Mean annual discharge for the Snake River into the study area is 10,730 cfs. Peak runoff, associated with spring snowmelt for both the Snake and Bruneau rivers, occurs from April through June. Summer flows are largely controlled by upstream irrigation reservoirs and diversions.

Upstream construction of water-diversion projects and hydroelectric projects began in the early 1900s with the construction of Milner Dam, which was built to divert irrigation water, and the Shoshone Falls Hydroelectric Project. Snake River hydroelectric projects have a combined capacity of approximately 500 megawatts. Water storage for power production is minimal, with essentially all upstream water storage associated with irrigation or flood control. Approximately 13.2 million acre-feet of water is diverted from the river to irrigate 2.3 million acres in the Snake River Basin (Low 1991).

Four to five million acre-feet of spring water enters the river annually through a series of large springs within 180 miles upstream of the study area. Much of the spring-water is used by aquaculture facilities prior to its discharge into the river. These aquaculture facilities combine to produce most of the commercial trout raised in the United States.

2.2. Land Features and Geology

The study area is located within the Snake River Canyon in the southwestern Snake River Plain of southern Idaho. Much of the canyon resembles a broad, steep-sided trench cut into the plain that extends more than 300 miles across southern Idaho. The Snake River Plain is composed of basaltic lava flows that are about 4000 feet thick. Geologic units within the study area are part of a unique series of basaltic lava flows, pillow lavas (formed by lava extruding under water), river deposits, and deposits from ancestral lakes. Geologic features include deposits associated with the catastrophic Bonneville Flood, which flowed through the canyon about 15,000 years ago. The Bonneville Flood also may have been responsible for the removal of much detritus (rock fragments or loose material caused by disintegration) from the canyon floor, as well as for the erratic deposition of well-rounded basalt boulders (FERC 1990; Malde 1991).

Nearly vertical, black basalt cliffs dominate the canyon and are extensively jointed. This columnar jointing is a result of contraction of the lava during cooling. Unconsolidated deposits occur in the area, usually near the bases of the canyon walls and on talus slopes (FERC 1990; Malde 1991). These unconsolidated materials include windblown dust (loess), river sands and gravels (alluvium), and talus (colluvium). Soils, ranging from silty clay loams to gravelly loams, have formed on the unconsolidated materials. Also, the Snake River and its tributaries, including numerous ephemeral creeks, transport sediments into the study area. Tributaries to the reservoir include the Bruneau River, Jacks Creek, Bennett Creek, Cold Springs, and Little Canyon Creek.

Riparian communities in the C.J. Strike Study Area are limited and lack diversity (Cole 1997). The largest wetland communities are located at the upstream ends of the Snake and

Bruneau river Arms of the reservoir. Elsewhere, *Emergent Wetlands* occur sporadically and are very small. Hardstem bulrush (***Scirpus acutus***) dominates the emergent wetland communities (Cole 1997). *Forested Wetlands* are rare and frequently dominated by species adapted to saline soil conditions, e.g., Russian olive (***Elaeagnus angustifolia***) and coyote willow (***Salix exigua***).

2.3. Climate

The climate of the study area is typical of the Great Basin Desert. The study area is semiarid due to an orographic rainshadow created by the Cascade Mountain Range (Caldwell 1985; Franklin and Dyrness 1988; West 1988). Summers are typically hot and dry. Daytime midsummer temperatures regularly exceed 100 °F (37.8 °C). Total precipitation per year averages less than 10 inches. Most precipitation falls during winter months. Generally, the small amount of precipitation that falls during summer does not percolate in the soil but is lost through evaporation and runoff (Caldwell 1985; West 1988).

The terrain surrounding the reservoir consists of plateaus and low hills, leaving the reservoir unprotected from the prevailing westerly and northwesterly winds. During the summer, winds of 10 to 20 mph occur most afternoons, and higher winds are associated with evening thundershowers or storm fronts that can move through the area any time of year.

2.4. Land Use

Agriculture (rangeland and irrigated cropland) is the dominant land use in the study area. Large expanses of rangelands (publicly and privately owned) occur throughout the study area and adjacent vicinity. Most of the public rangelands are administered by the Bureau of Land Management (BLM). Other public lands in the vicinity are managed by the State of Idaho. Bruneau Dunes State Park, Three Island Crossing State Park, and C.J. Strike Wildlife Management Area are managed primarily for recreational use. The Idaho Department of Fish and Game manages the C.J. Strike Wildlife Management Area primarily to support recreational hunting.

Development of hydroelectric power helped consolidate and extend the development of new farms and towns in the vicinity of the project (Stacy 1991). Electricity enabled additional acreage to be irrigated from the Snake River by electric-powered pumps. These lands include several farms that lie high above C.J. Strike Reservoir. Expanding agriculture resulted in a growing economy, population growth, new towns, and related industrial development. Agriculture dominants the social and economic structure of the region.

3. Methods

3.1. Site Locations

The reservoir was divided into two areas for sampling purposes: the Snake River Arm (from the dam upstream to Loveridge Bridge) and the Bruneau Arm (from the Bruneau Narrows upstream). Sampling sites were systematically located longitudinally through the Snake River Arm of the reservoir (Figure 2). Two sites were located in the Bruneau Arm. One site was in the large pool and the other was in the narrows. We sampled at the deepest point of the channel cross section. In addition, we monitored three sites outside the reservoir areas. One site was at the King Hill Bridge, another was at the Indian Cove Bridge, and the third was at the USGS gauge site (on the bridge) immediately downstream of the dam.

3.2. Sampling Techniques

We sampled sixteen parameters (Table 1) at various locations and times (Tables 2, 3, and 4). Measurements collected using the Hydrolab Surveyor 3® were typically sampled at a maximum depth interval of 5 m and a minimum depth interval of 1 m. Readings were taken at 1 m depth intervals, where changes of temperature or dissolved oxygen exceeded 1° C or 2 mg/l, respectively, within 5 m of depth change. At shallow sites (total depth < 5 m) only surface Hydrolab readings and nutrient samples were taken. Where total depth exceeded 20 m, nutrient samples were collected at the surface, 10 m above the reservoir bottom, and 5 m above the reservoir bottom. Nutrient-sample collection and analyses were consistent with American Public Health Association (1989) and EPA (1983).

Dissolved oxygen and temperature measurements taken at Indian Cove Bridge (RM 525.3) and in the project tailwaters (RM 493.7) were collected at 10-minute intervals. Hydrolab Datasonde 3® datalogger probes submerged in a perforated PVC pipe were used to measure and record data. The oxygen sensors were calibrated at least every two weeks.

Phytoplankton species and chlorophyll *a* surface samples (< 1 m deep) were collected as grab samples directly into a polypropylene bottle. Brown bottles were used for chlorophyll samples to minimize sample contact with light. Samples were stored on ice for a maximum of 48 hours. Samples were filtered using Whatman GFC glass fiber filters, macerated using round-bottom glass grinding tubes and matching pestles, and clarified using a 0.45 µm membrane filter. Chlorophyll *a* values were corrected for pheophytin *a* (APHA 1989:10200.H.2.4.b). Samples collected from depths greater than 1 m were retrieved using a Van Dorn style sampler and transferred to sample containers immediately.

Phytoplankton species samples were scheduled for collection monthly from April through October in 1994 and 1995. Samples were preserved in the field using Lugol's solution. Samples were shipped to AquaID (Carrboro, NC) for species identification and enumeration. Phytoplankton cells were counted using the Utermohol settling chamber technique (Utermohol

1958). Cells were magnified 320 times (320x) for identification and enumeration. The number of “fields” counted varied among samples. Cells were counted until the standard error as a percentage of the mean for dominant species was less than 10% (Lund et al. 1958). Typically, this procedure resulted in counting 400 to 800 cells. In addition, the entire settling chamber was scanned to look for large species such as ***Cratium hirundinella*** or colonies such as ***Microcystis aeruginosa***. Phytoplankton biovolume was estimated by measuring cell dimensions of 10 individuals per species and size class from each sample and averaging those values. If fewer than 10 individuals were found, all individuals collected were measured. Volumetric equations for shapes that most closely resembled the shapes of individual species were used to determine cell volume (Willen 1976). Cell volume was multiplied by cell density to estimate total biovolume.

Zooplankton species samples were scheduled to be collected monthly from April through October in 1994 and 1995. Samples were collected and concentrated using a 20-liter Schindler-Patalis style sampler (80-micron mesh) for all depths. Organisms were preserved in the field with 80% ethanol. Samples were shipped to AquaID for species identification and enumeration. Typically, three subsample aliquots of 0.5–3.0 ml were taken from each zooplankton sample for species identification and enumeration. Organisms were identified to genus at 30x magnification. Microdissection for species identification was done at 100x to 300x magnification. For enumeration, organisms were counted until the standard error as a percentage of the mean for the dominant species was less than 10%. If the criteria could not be met with three subsample aliquots, then more organisms were subsampled.

3.3. Data Analysis

Analyses were descriptive in nature. Statistical analysis of data is limited to calculation of ranges, medians, or means by location, depth, or time. Plots showing changes in water-quality descriptors and indices longitudinally and through time were constructed for descriptive characterization purposes.

Analysis of the 10-minute temperature and dissolved oxygen data included calculation of summary statistics consistent with the Idaho State Water Quality Standards. Instantaneous temperature and dissolved oxygen, 7-day mean dissolved oxygen minima, and 30-day dissolved oxygen means were graphically compared with the state criteria levels. The 30-day and 7-day mean oxygen levels were calculated using the following equations:

$$\text{7-day mean minimum} = (x_{(i)} + x_{(i-1)} + \ldots x_{(i-6)}) / 7$$

where x_i = daily instantaneous minimum dissolved oxygen (x) on a given day (i)

$$\text{30-day mean} = (x_{(i)} + x_{(i-1)} + \ldots x_{(i-29)}) / 30$$

where x_i = daily average dissolved oxygen calculated from 144 10-minute instantaneous readings (x) on a given day (i).

3.4. Quality Control and Assurance

All instruments used to collect field data were calibrated and maintained consistent with the manufacturer's instructions. Nutrient samples were collected in plastic cubitainers. Approximately 20% of the samples were spiked with phosphate, nitrate, and ammonia. Approximately 20% of the samples were collected in duplicate. Locations of sample spiking and duplicate sample collection were randomly chosen prior to each sampling episode. Field blanks were collected for each case of sample containers. Accuracy and precision estimates were calculated based on methodologies described in Bauer (1986). Alchem Laboratories (Boise, ID) conducted all nutrient analyses. Alchem Laboratories have QA/QC guidelines for all nutrient analyses conducted as part of our study (Alchem Laboratory 1991).

4. Results

4.1. Compliance with the Idaho Standard for Waters Discharged from Dams, Reservoirs, and Hydroelectric Facilities

This Idaho standard applies specifically to dissolved oxygen during June 15 through October 15. The standard has three specific levels: an instantaneous minimum level of 3.5 mg/l, a 7-day mean minimum level of 4.7 mg/l, and a 30-day mean level of 6.0 mg/l. Water leaving the project fell below the minimum standard levels for brief periods in 1993 and 1994 (Figure 3).

4.2. Compliance with the Idaho General Surface Water Quality Criteria for all Surface Waters of the State

Parameters relating to the general water quality criteria for all waters of the state include hazardous materials; toxic substances; deleterious materials; radioactive materials; floating, suspended or submerged matter; excessive nutrients; oxygen demanding materials; and sediment. Our study did not include sampling for hazardous, toxic, or radioactive materials. Sampling of deleterious materials; floating, suspended or submerged matter; nutrients; and oxygen demanding material included chlorophyll *a* (as an indicator of suspended algae biomass), total suspended solids, nitrogen, and phosphorus sampling.

Although Idaho has not identified specific chlorophyll *a* levels that limit beneficial uses, the State of Oregon has identified 15 µg/l as the level that should trigger concern. The highest chlorophyll *a* level (165 µg/l) was measured in the Bruneau Arm of the reservoir. The median chlorophyll *a* level in the Bruneau and Snake River Arms of the reservoir exceeded 15 µg/l (Tables 5 and 6). In the tailwater, chlorophyll *a* levels ranged up to 64 µg/l, with a median level of 14 µg/l (Table 7). Approximately 68% of the chlorophyll *a* values measured in the Bruneau Arm exceeded 15 µg/l, while 60% of the values in the Snake River Arm did so (Figure 4). The primary linkage of suspended algae to impaired beneficial uses appears related to the effect of the algae on dissolved oxygen levels in the reservoir. Oxygen demand from senescent and decaying algae cells likely contributes to low dissolved oxygen levels in the reservoir.

Over 90% of the total suspended solids levels measured throughout the study area were less than 30 mg/l (Figure 5). Higher levels were found in the reservoir than in the tailwater, with the highest level in the reservoir being 77 mg/l (Table 6). Generally, the highest levels of suspended solids were in the upstream end of the reservoir. We found evidence that material was settling within the water column and will present more detail on sedimentation processes in the reservoir later in this report.

The State of Idaho has no numeric criteria for “excessive” nutrients but identifies the need for nutrient levels that do not result in visible slime growths or other aquatic growths that impair beneficial uses. The EPA (1986) proposed that a target total phosphorus levels of 0.05 mg/l for water flowing directly into an impoundment should prevent the development of biological nuisances and control eutrophication. The EPA proposed in-reservoir phosphorus level is 0.025 mg/l. All samples collected in the reservoir were above the 0.025 mg/l level, while 98% of the samples we collected in the Snake River Arm of the reservoir also exceeded the less stringent 0.05 mg/l limit for inflowing water (Figure 6). Target levels for ammonia and nitrate nitrogen that would prevent the development of nuisance biological growth are less defined than for phosphorus. The linkage between the nutrient levels in C.J. Strike Reservoir and beneficial uses is likely the support of algal blooms in the reservoir by high nutrient levels that in turn result in some level of oxygen depletion as the algae cells die and decay.

4.3. Compliance with the Idaho Surface Water Quality Criteria for Supporting Designated Uses

Designated beneficial uses for C.J. Strike Reservoir include; domestic and agricultural water supply, primary and secondary recreation, and cold water biota. We did not measure any parameters in this study that should impair domestic or agricultural water supply uses. The primary water quality criterion for determining if primary and secondary recreation are being supported is the lack of fecal coliform in the water. Our study included only two samples for fecal coliform in the reservoir. Samples taken on July 15 and October 20, 1993, had less than 10 counts/100ml. While our data are very limited, they support the conclusion that fecal coliform levels in the reservoir are well within the limits for supporting both primary and secondary recreation.

We found that high water temperatures and low dissolved oxygen levels are probably impairing coldwater biota in the reservoir and tailwaters. Summer water temperatures exceeded the 22°C instantaneous upper limit, and the 18°C daily average upper limit for coldwater biota in both the reservoir and tailwaters (Figure 7, Tables 5 and 6). Likewise, dissolved oxygen levels fell below 6.0 mg/l in the reservoir and tailwater during all three years sampled. The reservoir and tailwaters support two native coldwater fish species: rainbow trout and mountain whitefish.

While rainbow trout are native to the project area, the current population in the reservoir is solely hatchery stock (Brink et al. 1997).

4.4. Descriptive Characterization

4.4.1. Physical Characteristics

C.J. Strike Reservoir is a relatively large reservoir with little active storage (Table 8). The reservoir has two distinct Arms. The Bruneau Arm totals 2164 acres in area, consisting of a large pool that flows into a constricted canyon prior to entering the Snake River. The large pool in the Bruneau Arm is oblong and has a maximum depth of 10 m. In contrast, the Narrows between the Bruneau Pool and the Snake River is relatively narrow and deep. The mean depth for the entire Bruneau Arm is 21 feet. The Snake River Arm consists of a large open pool immediately upstream of the dam. Approximately one mile upstream of the powerhouse, the reservoir narrows as the surrounding topography forms steep canyon walls that extend 15 miles upstream. The surrounding topography then flattens with occasional buttes and rock outcroppings bordering the reservoir. The Snake River Arm has a mean depth of 33 ft.

Water retention times in the reservoir are mainly dependent on flow (Figure 8). The average discharge through the project is approximately 11,000 cfs, which results in a reservoir retention time of approximately eight days.

4.4.2. Water Temperature

The Bruneau Arm, Snake River Arm, and tailwater showed relatively similar ranges of values for most of the standard parameters measured (Tables 5, 6, and 7). The upper limit for temperature was higher in the Bruneau Arm than in the Snake River Arm or tailwater. Also, the median temperature in the tailwater was notably different from those in the reservoir locations. The higher limit in the Bruneau Arm likely accurately reflects slightly warmer water conditions in the Bruneau Arm than in the Snake River Arm. The higher median tailwater temperature, however, is an artifact of sampling methodology. The tailwater monitor took samples throughout the year, while the reservoir monitoring was limited to spring summer and fall. Consequently, the reservoir data does not include cold winter temperatures that were included in the tailwater median.

Thermal gradients begin to appear in the reservoir as inflowing water warms and flows over the cooler water in the deeper parts of the reservoir (Figures 9, 10, 11, and 12). While temperature gradients are present, the reservoir does not exhibit a strong thermocline. Maximum summer temperatures in the deep water generally exceeded 15°C. The maximum water-column profile temperature range we found was 9.4°C at RM 494.5 in 1994 (Table 9).

Comparison of water temperatures flowing into the reservoir at Indian Cove with water temperatures leaving the reservoir and water temperatures 20 miles upstream of the reservoir at

Bliss Dam show that the temperature increase through the unimpounded reach is similar to water temperature increases through the reservoir (Figure 13). The reservoir tailwater data show smaller daily temperature fluctuations than were observed at Indian Cove (Figure 14). This observation would be expected since the larger volume of water contained within the reservoir reach would be less responsive to daily changes in air temperature than would the shallower river at Indian Cove. Springtime warming of water leaving the reservoir generally occurred slightly later than upstream of the reservoir, while water cooling in the fall also lagged slightly behind upstream conditions (Figure 13). Winter temperatures showed a greater decrease from Indian Cove to C.J. Strike Dam than through the upstream reach of similar length from Bliss Dam to Indian Cove.

4.4.3. Dissolved Oxygen

Dissolved oxygen differences were minimal among the three areas. One notable difference, however, was the extremely low oxygen levels in both arms of the reservoir but not in the tailwater(Tables 5, 6, and 7). The reservoir experienced times when some portion of the water column had a very low (< 2 mg/l) dissolved oxygen levels (Figures 15, 16, 17, and 18). These low levels in the reservoir coincided with low dissolved oxygen levels in the tailwater. However, during summer months, shallow water (<1 m deep) typically experienced daily supersaturated oxygen conditions. These conditions resulted from photosynthetic activity of high levels of phytoplankton.

Low dissolved oxygen levels occurred in the reservoir from the dam upstream to RM 502 and were generally confined to depths greater than 10 m. Low dissolved oxygen levels were observed in the reservoir in June of both 1993 and 1995 despite flows exceeding 20,000 cfs (Figure 19).

Comparison of dissolved oxygen levels entering the reservoir at Indian Cove, in the dam tailwater, and 20 miles upstream of the reservoir at Bliss Dam showed more seasonal variation in oxygen levels in the inflow and outflow of C.J. Strike Reservoir than at Bliss Dam (Figure 20). In 1994, low dissolved oxygen levels in the tailwater of C.J. Strike Dam did not correspond with low oxygen levels in inflowing water. In 1995, however, we found low oxygen levels in both the reservoir inflow and outflow.

4.4.4. Water Clarity

We measured water clarity in terms of turbidity and Secchi depth. Turbidity measured at the Indian Cove Bridge, which represents the condition of water flowing into the reservoir, was consistently higher than turbidity of water in the tailwater of the dam as it was leaving the reservoir (Figure 21). Secchi measurements taken in the reservoir corroborate the increase in water clarity downstream through the reservoir (Figure 22). Secchi depth measurements in the Bruneau Arm were similar to measurements taken at locations in the Snake River Arm downstream of RM 500.

The most notable turbidity event occurred in July 1993 (Figure 21) and was associated with a large landslide 40 miles upstream of C.J.Strike Dam near the town of Bliss. The north slope of the canyon moved down into the river channel, altering the flow of the river and releasing large amounts of sediment into the river. While inflowing turbidity to the reservoir exceeded all other turbidity measured throughout the study, this extreme pulse of inflowing turbidity did not elevate outflowing turbidity to extreme levels (Figure 21).

Turbidity isopleths from profile data collected in the reservoir showed consistently increasing turbidity down through the water column in the reservoir (Figures 23 and 24). Under lower flow conditions in 1994, the turbidity gradient was most apparent upstream of RM 500. Under higher flows in 1995, the gradient extended downstream to the dam.

Our data clearly supports the conclusion that suspended material in the water column is settling out in the reservoir, resulting in a net improvement in water clarity as water passes through the reservoir. Bathymetry data also supports the conclusion that material is settling out in the reservoir. Data collected in 1994 and 1995 indicates that the reservoir currently has a capacity of 226,800 acre-feet (IPC *unpubl. data*). This estimate is 13,200 acre-feet less than the estimated capacity of the reservoir at impoundment (IPC 1993).

4.4.5. Nutrients

C.J. Strike Reservoir is consistently retaining phosphorus and nitrogen (Figures 25 and 26). Specifically, total phosphorus, dissolved orthophosphate, and nitrate nitrogen all show net reductions in loads (concentration times flow) from King Hill to below C.J. Strike Dam. Conversely, with the exception of November 1994 through May 1995, total Kjeldahl nitrogen (TKN) leaving the reservoir exceeded the amount flowing past King Hill. Comparison of total nitrogen (defined as TKN plus nitrate) inflow and outflow show that there is generally a net retention of nitrogen, especially during winter months.

Total phosphorus loads to the reservoir peaked during March and April of 1994, and May and June of 1995 (Figure 25). In 1995, the peak load was the result of high springtime flows. The peak load in 1995 was associated with the large amount of water flowing into the reservoir rather than elevated phosphorus concentrations in the water. Phosphorus concentrations during

May and June, 1995 were only slightly higher than other months of the year. Conversely, in 1994, the high phosphorus load in the spring was not a result of large quantities of water flowing into the reservoir. In 1994, there was no elevated spring runoff (Figure 19). Still, phosphorus loads into the reservoir showed a distinct peak in the spring. The phosphorus load peak in 1994 was related to noticeably higher concentrations of phosphorus in the water rather than elevated water volume.

The dissolved orthophosphate load trends were less identifiable than the total phosphorus load trends. Peaks in orthophosphate loads entering the reservoir occurred in December 1994 and May 1995. Unlike total phosphorus, no consistent seasonal trend between years was apparent. Similar to total phosphorus, high orthophosphate loading in May 1995 coincided with elevated discharge from spring runoff. Unlike total phosphorus, in 1994 when spring flows were no higher than other times of the year, a peak in orthophosphate load to the reservoir did not occur.

Changes in nutrient levels through the water column in the reservoir coincided with thermal and dissolved oxygen gradients. Phosphorus concentrations increased noticeably in the deep anoxic water within the reservoir (Figure 27). The increase is attributable to higher dissolved orthophosphate concentrations in the deeper parts of the reservoir where low dissolved oxygen levels cause anoxic sediments to release phosphorus. Particulate phosphorus (defined as total phosphorus minus dissolved orthophosphate) showed a general decline from the upstream end of the reservoir to the dam, with relatively similar levels throughout the water column. Similar to water clarity data, this pattern indicates the settling of particles from the water column in the reservoir.

Ammonia nitrogen levels were 20 times higher in the deep anoxic water than in the aerobic surface water (Figure 28). Elevated total Kjeldahl nitrogen levels were attributable to the elevated ammonia levels, while nitrate levels in the deep anoxic water were lower than in the overlying aerobic water. As in the phosphorus profiles, it is apparent that low dissolved oxygen conditions in the deep water of the reservoir are resulting in chemical changes in the water column.

4.4.6. Nutrient QA/QC

We collected 33 duplicates and field-spiked 33 samples. Total Kjeldahl nitrogen samples showed the largest absolute and relative range (Table 10). All parameters except total Kjeldahl nitrogen showed a relative range of less than 8%. Field-spiked samples showed the greatest range of recovery for total phosphorus. Nitrate showed the largest deviation from 100% recovery. Field blanks failed to show levels exceeding the minimum detection limits.

4.4.7. Algae

We measured water column algae (phytoplankton) by collecting samples for species identification and enumeration, and also chlorophyll *a* analysis. Samples for species identification were collected on April 7, June 13, July 13, and August 30, 1994. In 1995, species samples were collected on April 17, June 22, August 29, and October 24. We identified 67 phytoplankton species from six Divisions (Table 11). The reservoir was consistently dominated by Chrysophyta and Cyanophyta phytoplankton species (Figure 29). Seasonally, Chrysophyta species were the most prevalent in both numbers and biovolume except for summer months. Chrysophyta species always dominated the April and May samples. Cyanophyta species had high densities during summer months, but did not dominate in biovolume. During summer and fall months, Cyanophyta species replaced Chrysophyta species as the dominants between the dam and RM 500 on approximately half of the sampled dates. In the Bruneau Arm, Cyanophyta species consistently dominated the Bruneau Pool during summer and fall months.

Spatially, Chrysophyta species always dominated upstream of RM 500 on the Snake River Arm of the reservoir. Cyanophyta species showed relatively high densities in the Bruneau River Arm and downstream of RM 500 in the Snake River Arm. While Cyanophyta species accounted for a large proportion of the number of algae cells, biovolume of the Cyanophyta species again remained relatively small because of the relatively small cell size of the Cyanophyta species compared to the Chrysophyta species.

Algae cell density and biovolume showed a marked decline down through the water column downstream of RM 500 (Figure 30). Typically, the Cyanophyta species were more prevalent in water less than 10 m deep, while the Chrysophyta species dominated in deeper water. Upstream of RM 500, we failed to see notable changes in phytoplankton densities through the water column (Figure 31). The lack of change is likely because these sites were shallower and had more riverine hydraulic conditions. We noted reduced algae levels at 10 m of depth in the Bruneau Narrows (RM 2) but found mixed conditions in the Bruneau Pool (Figure 32).

Chlorophyll *a* measurements in the reservoir showed noticably higher upper limits of chlorophyll *a* than the tailrace samples. The maximum chlorophyll *a* level we measured in the tailrace was 64μg/l, while the maximum levels in the two Arms of the reservoir exceeded 130 μg/l (Tables 5, 6, and 7). Summarized surface chlorophyll *a* levels at stations located through the reservoir failed to identify conclusive trends (Figure 33). Chlorophyll a levels in water leaving the reservoir were typically higher than chlorophyll *a* levels entering the reservoir, indicating a net production of algae in the water column as it passes through the reservoir (Figure 34).

4.4.8. Zooplankton

Because of leakage and damage of samples during shipping, zooplankton data are only available for August 30, and October 20 in 1994, and April 17, June 22, August 24, and October 24 in 1995. Zooplankton numbers were very low at all sites except the two Bruneau Arm sites (RM 2 and 4.3), and the two downstream Snake River Arm sites (RM 494.5 and 495.3)(Figure

35). Summer zooplankton numbers were comparable at those four sites. During spring and fall, the Bruneau Arm sites had notably higher zooplankton densities that the Snake River Arm sites. The Bruneau Arm sites appeared to have slightly higher zooplankton densities at shallow depths during summer, although this result is highly speculative given the paucity of data (Figures 36 and 37). In the Snake River Arm, shallow samples generally contained the most organisms in August, while densities were highest in the deep samples in April and October (Figures 38 and 39).

5. Discussion

Our study showed that water quality in C.J. Strike Reservoir is likely not adequate to fully support all designated beneficial uses. Specifically, dissolved oxygen, ammonia nitrogen, water temperature, and nutrient (and resulting algae) levels were at problematic levels during some times of our sampling. The low dissolved oxygen levels and high ammonia nitrogen in the reservoir result from lack of mixing because of reduced water velocity and increased water depth. The elevated ammonia levels are directly attributable to the low dissolved oxygen conditions. Under anoxic conditions, oxidized nitrogen forms are reduced to ammonia. Without low oxygen levels, ammonia levels would not be problematic.

The 1996 Idaho 303(d) list identified C.J.Strike Reservoir as water quality limited because of sediment. EPA (1986) identifies four potential ways that suspended solids may affect fish. Suspended solids may act directly on fish in the water column by killing them; by reducing growth rates or resistance to disease, etc.; by preventing development of fish eggs or larvae; by modifying movement or migrations; or by reducing food abundance. Since sediment levels we measured should be well below toxic thresholds for aquatic biota, we speculate that the primary potential for effects of suspended solids at concentrations found in the study area are related to the settling of material from the water column. Settling of fine sediments could affect benthic macroinvertebrate communities and reduce oxygen levels in the water column.

Water temperatures were problematic upstream of, within, and downstream of the impoundment; and are not directly attributable to project operations. Our study showed that the warming of water as it passes through the reservoir is consistent with upstream warming as water flows through unimpounded reaches of the river. Likewise, Irving and Cuplin (1956) concluded that temperature changes from construction of the hydroelectric project were so small that there was “little effect” on the fishery. Our characterization of the thermal profile within the reservoir is also very similar to what Irving and Cuplin’s (1956) finding that no definite, strong thermocline existed in the reservoir. However, they did note a 7°C change in water temperature from the top to the bottom of the water column.

Algae levels in water entering the reservoir were very similar to levels leaving the reservoir. Surface films caused by blue-green algal blooms were noted during our study, primarily in the Bruneau Pool area of the reservoir. Determining with certainty that algae or nutrient levels are problematic is not possible because problems associated with nutrient levels are typically expressed as excessive or nuisance growths of aquatic plants. “Nuisance” and “excessive growth” are hard to define and vary considerably depending on the resource or user. Our study indicated that phytoplankton levels in the reservoir were within the range to raise concerns about potential negative effects on beneficial uses of the reservoir. Whether the levels of algae are in fact impairing beneficial uses is beyond the scope of our study.

C.J. Strike Reservoir is clearly a settling basin for suspended sediment and organic material transported into the reservoir by the upstream river. Our bathymetry, turbidity, Secchi, total suspended solids, and nutrient data all support this conclusion. Irving and Cuplin (1956) also concluded that the reservoir was acting as a settling basin. They hypothesized benefits to the fishery as a result of lower downstream turbidity and enhanced algae production (as a food source) within the reservoir. Our data indicate that effects such as low dissolved oxygen and high ammonia nitrogen levels are degrading habitat conditions in the reservoir, in part because of the settling of material within the reservoir.

Nutrient levels were typically lowered by water passing through the reservoir, resulting in diminished nutrient loads leaving the project than entering. Our data indicate that the loss of nutrients in the water column is a result of particles settling as water slows within the reservoir. Biological and chemical processes in the reservoir that result in internal recycling or resuspension of nutrients into the water column are not occurring at levels high enough to offset the nutrient loss through settling. This conclusion is supported by our data showing that dissolved orthophosphate and nitrate nitrogen are retained in the reservoir similar to total phosphorus.

Water-quality problems in C.J. Strike Reservoir are related to the quality of inflowing water and the processing of pollutants transported into the reservoir. Activities that decrease the levels of pollutants entering the reservoir should result in improved conditions within the reservoir. Likewise, activities that reduce the amount of pollutant processing occurring in the reservoir should improve water quality in the reservoir, although consideration should be given to downstream effects of flushing pollutants downstream for processing.

Our study provides a good baseline for determining what water-quality problems are occurring in the reservoir and providing insight into causal factors. Potential actions to improve water quality in the reservoir should consider the interrelated nature of water-quality issues in C.J. Strike Reservoir, as well as the project-specific aspects. The relative consistency of our data with data collected since 1956 indicates subtle or no changes in water-quality parameters such as temperature over the past 40 years. The long-term stability of water-quality conditions should be considered in developing future goals and expectations for C.J. Strike Reservoir.

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Table 1. Field collection and laboratory analysis techniques (mdl = minimum detection limit) used to monitor water quality in C.J. Strike Reservoir, Snake River, Idaho, 1993–1995.

Variable	Methodology	
	Field Techniques	Laboratory
Temperature	Thermistor (Hydrolab Surveyor 3, Hydrolab Datasonde 3)	none
Dissolved Oxygen	Polarographic membrane electrode (Hydrolab Surveyor 3, Hydrolab Datasonde 3)	none
Conductivity	6-electrode cell (Hydrolab Surveyor 3)	none
pH	Glass electrode (Hydrolab Surveyor 3)	none
Turbidity	Direct grab	Nephelometric (Hach Model 2100A or 2100P)
Total Phosphate	Direct grab	EPA (1983): 365.2 (Colorimetric, Ascorbic Acid) (mdl 0.01 mg/l)
Orthophosphate	Direct grab	EPA (1983): 365.2 (Colorimetric, Ascorbic Acid) (mdl 0.01 mg/l)
Kjeldahl Nitrogen Probe	Direct grab	EPA (1983): 351.4 (Potentiometric, Ion Selective) (mdl 0.1 mg/l)
Ammonia Nitrogen Probe	Direct grab	EPA (1983): 350.3 (Potentiometric/Ion Selective) (mdl 0.05 mg/l)
Nitrate Nitrogen	Direct grab	EPA (1983): 300.0 (Ion Chromatography) (mdl 0.1 mg/l)
Total Dissolved Solids	Direct grab	EPA (1983): 160.1 (Gravimetric, Dried @ 180 C)
Total Suspended Solids	Direct grab	EPA (1983): 160.2 (Gravimetric, Dried @ 103–105 C)
Fecal coliform	Direct grab	
Chlorophyll a	Direct grab	APHA (1989): 10200.H (Spectrophotometric)
Phytoplankton	Direct grab	Inverted compound microscope
Zooplankton	Schindler-Patalis style trap	Stereoscopic microscope

Table 2. Locations and times of sampling for temperature, dissolved oxygen, conductivity, pH, and turbidity in C.J. Strike Reservoir, 1993–1995.

River Mile	1993	1994	1995
493.7	Jan. 18–Oct. 19 biweekly	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
494.5	NA	April 7–Oct. 20 biweekly	March 23–Oct. 12 biweekly
495.3	May 5–Oct. 20 monthly	March 9–Nov. 2 biweekly	March 23–Oct. 12 biweekly
498	NA	March 9–Nov. 2 biweekly	March 23–Oct. 12 biweekly
500	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
502	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
504	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
506	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
508	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
510	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
513	NA	March 10–Nov. 2 biweekly	March 23–Oct. 12 biweekly
525.3	March 26–Oct. 19 biweekly	March 9–Dec. 20 biweekly	Jan. 5–Dec. 28 biweekly
546.6	March 26–Oct. 19 biweekly	March 8–Dec. 20 biweekly	Jan. 5–Dec. 28 biweekly
2.0	NA	March 9–Nov. 2 biweekly	March 23–Oct. 12 biweekly
4.3	May 5–Oct. 20 monthly	March 9–Nov 2 biweekly	March 23–Oct 12 biweekly

NA indicates no samples were taken

Table 3. Locations and times of sampling for total phosphorus, dissolved orthophosphate, nitrate nitrogen, total Kjeldahl nitrogen, and ammonia nitrogen in C.J. Strike Reservoir, 1993–1995.

River Mile	1993	1994	1995
493.7	Feb. 10, March 26	March 9–Nov. 2 monthly	March 14–Dec. 12 monthly
494.5	NA	April 7–Nov. 2 monthly	March 23–Oct. 24 monthly
495.3	May 5, July 15	March 9–Nov. 2 monthly	March 23–Oct. 24 monthly
500	NA	March 10–Nov. 2 monthly	March 23–Oct. 24 monthly
504	NA	March 10–Nov. 2 monthly	March 23–Oct. 24 monthly
508	NA	March 10–Nov. 2 monthly	March 23–Oct. 24 monthly
513	Feb. 10, March 26	NA	March 23–Oct. 24 monthly
546.6	Feb. 10, March 26	Jan. 12–Dec. 20 monthly	March 14–Dec. 12 monthly
2.0	NA	June 13–Nov. 2 monthly	March 23–Oct. 24 monthly
4.3	May 5, July 15, Oct. 20	April 7–Nov. 2 monthly	March 23–Oct 24 monthly

NA indicates no samples were taken

Table 4. Locations and times of sampling for chlorophyll *a* in C.J. Strike Reservoir, 1993–1995.

River Mile	1993	1994	1995
493.7	Feb. 10–Oct. 7 monthly	Jan. 1–Nov. 2 biweekly	Jan. 18–Sept. 28 biweekly
494.5	NA	March 23–Nov. 2 biweekly	March 23–Sept. 28 biweekly
495.3	May 5–Oct. 7 monthly	March 9–Nov. 2 biweekly	March 3–Sept. 28 biweekly
500	NA	March 10–Nov. 2 biweekly	March 22–Sept. 28 biweekly
504	NA	March 10–Nov. 2 biweekly	March 23–Sept. 12 biweekly
508	NA	March 10–Nov. 2 biweekly	March 23–Sept. 12 biweekly
513	Feb. 10, March 26	NA	April 3–Sept. 28 biweekly
525.3	Feb. 10–Oct. 7 monthly	Jan. 12–April 7 monthly	NA
546.6	Feb. 10–Oct. 6 biweekly	Jan. 12–Nov. 1 monthly	Jan. 18–Sept. 21 monthly
2.0	NA	April 19–Nov. 2 biweekly	March 23–Sept. 12 biweekly
4.3	May 5–Oct. 7 monthly	April 7–Nov. 2 monthly	March 23–Sept. 28 biweekly

Table 5. Ranges and means for 16 water–quality variables monitored in the Bruneau Arm of C.J. Strike Reservoir, May 1993–October 1995.

Variable	Sample Size (n)	Range	Median
Temperature (°C)	379	6.1–26.1	18.5
Dissolved Oxygen (mg/l)	342	0.3–15.0	7.9
Conductivity (msiemens)	379	0.139–0.529	0.421
pH	379	7.2–9.5	8.5
Oxidation/Reduction Potential (mV)	379	82–384	258
Turbidity (ntu)	315	2.3–211	11.6
Secchi Depth (m)	65	0.4–2.6	1.0
Total Phosphorus (mg/l)	23	0.04–0.58	0.08
Orthophosphate (mg/l)	23	<0.01–0.06	0.02
Kjeldahl Nitrogen (mg/l)	23	0.32–6.56	0.56
Ammonia Nitrogen (mg/l)	23	<0.05–1.01	<0.05
Nitrate Nitrogen (mg/l)	23	<0.10–0.79	0.31
Total Dissolved Solids (mg/l)	16	158–350	264
Total Suspended Solids (mg/l)	22	4 –54	10
Chlorphyll *a* (µg/l)	80	1–165	32

Table 6. Ranges and means for 16 water-quality variables monitored in the Snake River Arm of C.J. Strike Reservoir May 1993–October 1995.

Variable	Sample Size (n)	Range	Median
Temperature (°C)	1805	4.0–24.9	16.9
Dissolved Oxygen (mg/l)	1699	0.1–15.8	9.0
Conductivity (msiemens)	1805	0.182–0.542	0.481
pH	1805	7.3–9.0	8.4
Oxidation/Reduction Potential (mV)	1805	–96–455	261
Turbidity (ntu)	1456	2.4–226	16.5
Secchi Depth (m)	261	0.2–2.7	0.8
Total Phosphorus (mg/l)	198	0.03–0.58	0.12
Orthophosphate (mg/l)	198	<0.01–0.43	0.04
Kjeldahl Nitrogen (mg/l)	198	<0.10–2.05	0.0.40
Ammonia Nitrogen (mg/l)	198	<0.05–1.53	<0.05
Nitrate Nitrogen (mg/l)	198	<0.10–1.77	1.02
Total Dissolved Solids (mg/l)	114	250–375	317
Total Suspended Solids (mg/l)	186	<1–77	10
Chlorphyll *a* (µg/l)	521	<1–131	19

Table 7. Ranges and means for 16 water-quality variables monitored in the tailwater of C.J. Strike Reservoir, May 1993–October 1995.

Variable	Sample Size (n)	Range	Median
Temperature (°C)	131608	3.5–24.8	12.7
Dissolved Oxygen (mg/l)	131092	3.5–15.7	9.8
Conductivity (msiemens)	131607	0.220–0.710	0.473
pH	92	7.9–8.9	8.4
Oxidation/Reduction Potential (mV)	92	195–403	296
Turbidity	72	3.0–24.4	7.1
Secchi Depth (m)	0	NA	NA
Total Phosphorus (mg/l)	25	0.05–0.28	0.10
Orthophosphate (mg/l)	25	<0.01–0.3	0.03
Kjeldahl Nitrogen (mg/l)	25	<0.10–0.84	0.50
Ammonia Nitrogen (mg/l)	25	<0.05–0.23	0.06
Nitrate Nitrogen (mg/l)	25	0.44–1.45	1.06
Total Dissolved Solids (mg/l)	12	267–360	306
Total Suspended Solids (mg/l)	21	<1–22	8
Chlorphyll *a* (µg/l)	52	<1–64	14

Table 8. Morphologic data for C.J. Strike Reservoir.

	Snake River Arm		Bruneau Arm		Entire Reservoir	
Pool Elevation (ft msl)	2455	2450	2455	2450	2455	2450
Surface Area (acres)	5480	4416	2164	1828	7650	6240
Total Volume (acre-feet)	180,935	148,525	45,879	36,048	226,800	184,573
Active Storage (acre-feet)	32,410	0	9831	0	44,077	0
Mean Depth (feet)	33	34	21	20	29.6	29.6
Maximum Depth (feet)	139	134	74	69	139	134
Littoral Area (acres)	1533	NA	550	NA	1997	1446
Littoral Volume (acre-feet)	45,030	NA	18,436	NA	60,147	44,077

Table 9. Summary table of maximum changes in water-column temperature (°C) on individual sampling dates at nine sampling locations throughout C.J. Strike Reservoir.

River Mile	1993	1994	1995
4.3	3.6	5.7	5.8
494.5		9.4	7.5
495.3	4.6	8.8	7.1
498		8.5	6.8
500		7.5	6.4
502		7.7	3.4
504		5.4	1.6
506		1.8	1.6
508		2.1	1.2

Table 10. Summary results for field duplicate and spike samples collected as part of the QA/QC program. Summary statistics are based on Bauer (1986).

FIELD DUPLICATES	N	Maximum Range	Mean Range	Relative Range
Total Phosphorus	33	0.06	<0.01	7.3
Dissolved Orthophosphate	26	0.02	0.01	7.3
Nitrate Nitrogen	33	0.09	0.03	3.2
Ammonia Nitrogen	8	0.06	0.01	6.4
Total Kjeldahl Nitrogen	29	0.14	0.05	14.3

FIELD SPIKES	N	Mean	95% C.I.
Total Phosphorus	33	102.9	100.5–105.3
Dissolved Orthophosphate	26	101.0	99.0–103.0
Nitrate Nitrogen	33	93.4	90.5–96.3
Ammonia Nitrogen	11	98.6	97.1–100.1
Total Kjeldahl Nitrogen	31	101.0	98.0–104.0

Table 11. Phytoplankton species list for samples collected in the Snake River Arm and Bruneau Arm of C.J. Strike Reservoir.

DIVISION	SPECIES	BRUNEAU Arm	SNAKE Arm
Chlorophyta	***Actinastrum hantzschii***	*	
Chlorophyta	***Ankistrodesmus falcatus***	*	*
Chlorophyta	***Ankistrodesmus falcatus var. mirabilis***	*	*
Chlorophyta	***Carteria*** sp.	*	*
Chlorophyta	***Chlamydomonas*** sp.	*	*
Chlorophyta	***Chorella*** sp.		*
Chlorophyta	***Closteriopsis longissima***		*
Chlorophyta	***Closterium*** sp.		*
Chlorophyta	***Cosmarium regnesi***	*	*
Chlorophyta	***Cosmarium*** sp.		*
Chlorophyta	***Crucigenia tetrapedia***	*	*
Chlorophyta	***Kirchneriella subsalsa***		*
Chlorophyta	***Lagerheimia subsalsa***		*
Chlorophyta	***Oocystis solitaria***	*	*
Chlorophyta	***Oocystis*** sp.	*	*
Chlorophyta	***Pandorina morum***		*
Chlorophyta	***Pediastrum duplex***	*	*
Chlorophyta	***Scenedismus bijuga***		*
Chlorophyta	***Scenedesmus dimorphus***	*	*
Chlorophyta	***Scenedesmus quadricauda***	*	*
Chlorophyta	***Scenedesmus serratus***		*
Chlorophyta	***Schroederia setigera***	*	*
Chlorophyta	***Sphaerocystis Schroeteri***	*	*
Chlorophyta	***Tetraedron caudatum***		*
Chlorophyta	***Tetraedron minimum***		*
Chrysophyta	***Asterionella foRMosa***	*	*
Chrysophyta	***Cocconeis*** sp.	*	*
Chrysophyta	***Cyclotella*** sp.	*	*
Chrysophyta	***Cymatopleura*** sp.	*	*
Chrysophyta	***Cymbella*** sp.		*
Chrysophyta	***Diatoma*** sp.		*
Chrysophyta	***Dinobryon sertularia***	*	*
Chrysophyta	***Fragilaria construens***		*
Chrysophyta	***Fragilaria crotonensis***	*	*
Chrysophyta	***Fragilaria*** sp.		*
Chrysophyta	***Gomphonema*** sp.	*	*
Chrysophyta	***Gyrosigma*** sp.		*
Chrysophyta	***Mallomonas*** sp.		*
Chrysophyta	***Melosira granulata***	*	*
Chrysophyta	***Melosira granulata var. angustissima***	*	*
Chrysophyta	***Navicula*** sp.		*
Chrysophyta	***Nitzschia*** sp.	*	*
Chrysophyta	***Pennate diatom***	*	*
Chrysophyta	***Pinnularia*** sp.		*
Chrysophyta	***Roicosphenia*** sp.	*	
Chrysophyta	***Stephanodiscus hantzschii***	*	*
Chrysophyta	***Stephanodiscus niagarae***	*	*
Chrysophyta	***Surirella*** sp.		*
Chrysophyta	***Synedra*** sp.	*	*
Chrysophyta	***Synedra ulna***	*	*
Cryptophyta	***Cryptomonas ovata***	*	*
Cryptophyta	***Cryptomonas reflexa***	*	*
Cryptophyta	***Rhodomonas minuta var. nannoplanktica***	*	*
Cyanophyta	***Anabaena flos-aquae***	*	*
Cyanophyta	***Anabaena spiroides***	*	*
Cyanophyta	***Aphanizomenon flos-aquae***	*	*
Cyanophyta	***Chroococcus dispersus var. minor***	*	*
Cyanophyta	***Marssoneilla elegans***		*
Cyanophyta	***Merismopedia tanuissima***	*	*
Cyanophyta	***Microcystis aeruginosa colonies***	*	*
Cyanophyta	***Oscillatoria geminata***	*	*
Cyanophyta	***Oscillatoria limnetica***	*	*
Euglenophyta	***Phacus*** sp.	*	
Euglenophyta	***Trachelomonas*** sp.		*
Pyrrophyta	***Certatium hiundinella***	*	*
Pyrrophyta	***Glenodinium*** sp.	*	*
Pyrrophyta	***Peridinium*** sp.		*

Table 12. Zooplankton species list for samples collected in the Snake River Arm and Bruneau Arm of C.J. Strike Reservoir.

ORDER	SPECIES	BRUNEAU Arm	SNAKE Arm
Cladocera	***Alona guttata***		*
	Alona sp.		*
	Bosmina longirostris	*	*
	Chydorus sphaericus	*	*
	Camptocercus rectirostris		*
	Ceriodaphnia quadrangula	*	*
	Daphnia pulex	*	*
	Daphnia retrocurva	*	*
	Daphnia rosea		*
	Daphnia thorata	*	*
	Daphnia sp.		*
	Diaphanosoma brachyurum	*	*
	Eurycercus lamellatus		*
	Leptodora kindtii	*	*
	Macrothricid sp.		*
	Macrothrix laticornis		*
	Polyphemus pediculus		*
	Sida sp.		*
	Simocephalus laticornis		*
Copepoda	***Cyclops bicuspidatus thomasi***	*	*
	Cyclops vernalis	*	*
	Cyclops sp.	*	*
	Diaptomus sp.	*	*
	Harpacticoid sp.	*	*
	Mesocyclops edax	*	*
Rotidera	***Asplancha*** sp.	*	*
	Brachionus sp.		*
	Filinia sp.	*	*
	Kellicottia sp.	*	
	Keratella coclearis	*	*
	Keratella sp.	*	*
	Polyarthra sp.	*	*
	Unknown	*	*
Volvocida	***Volvox*** sp.	*	
Hydracarina			*

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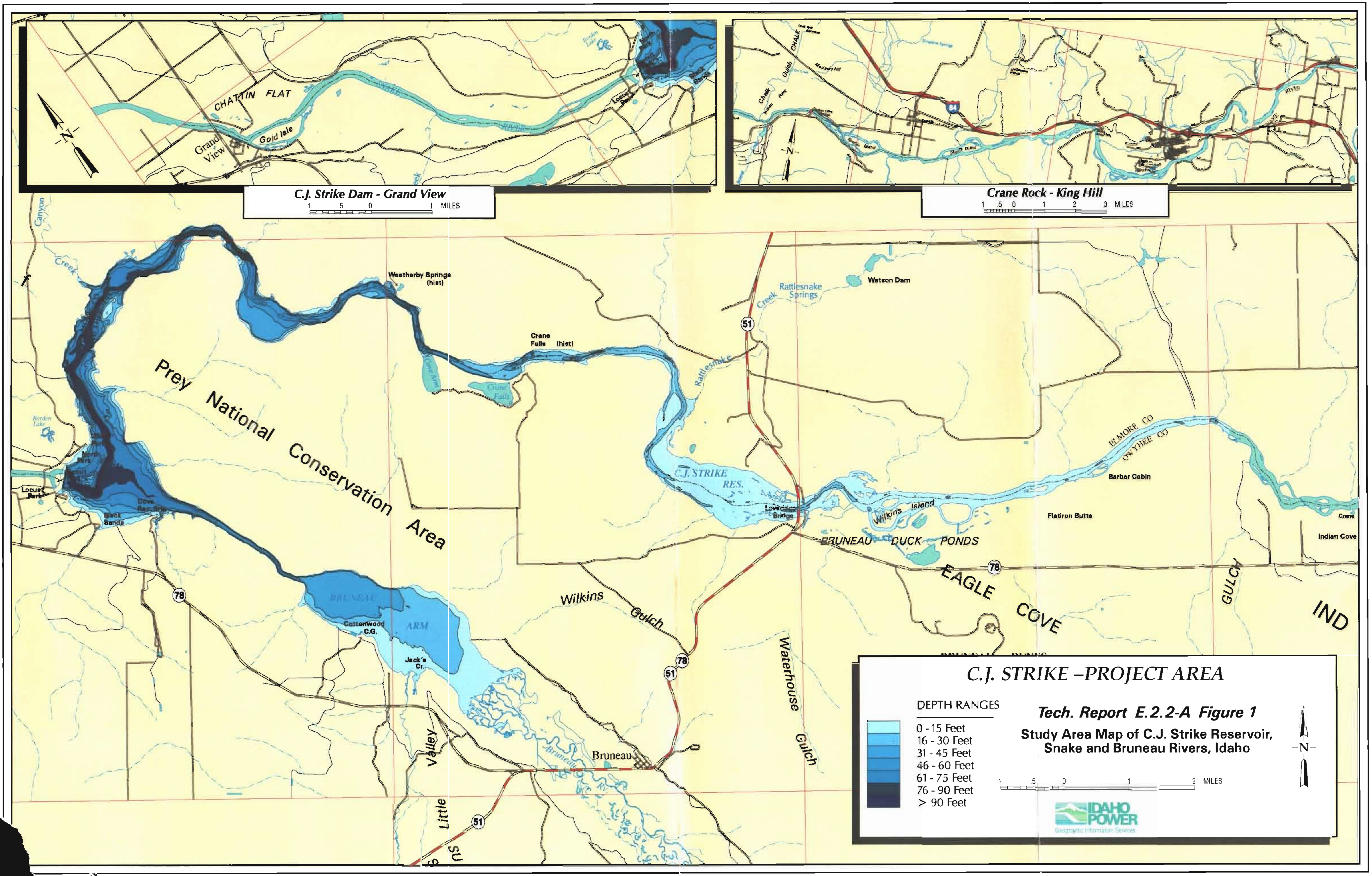


C.J. STRIKE –PROJECT AREA

Tech. Report E.2.2-A Figure 1

Study Area Map of C.J. Strike Reservoir, Snake and Bruneau Rivers, Idaho

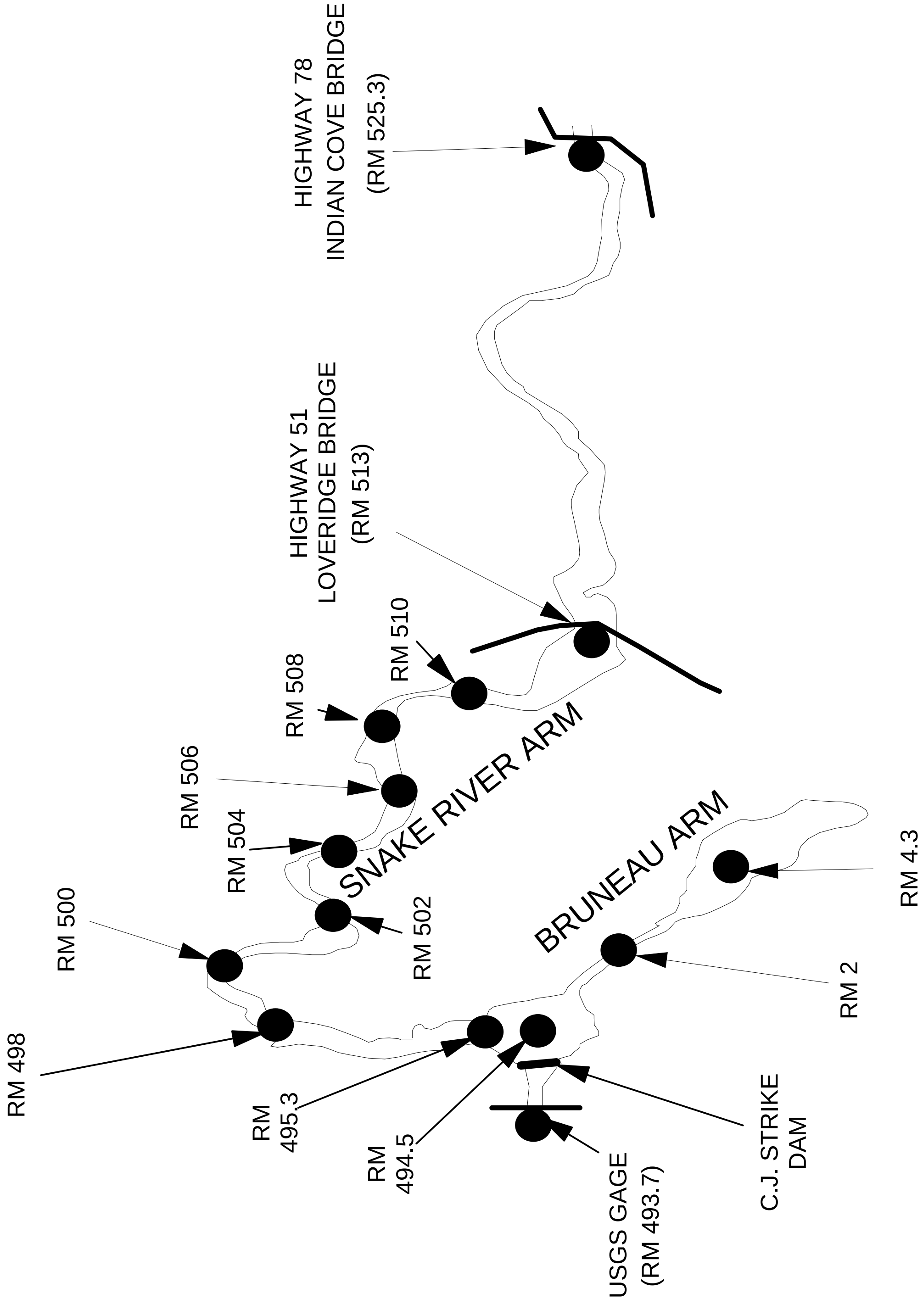


Figure 2. Schematic depiction of the locations of sampling sites monitored in C.J. Strike Reservoir.

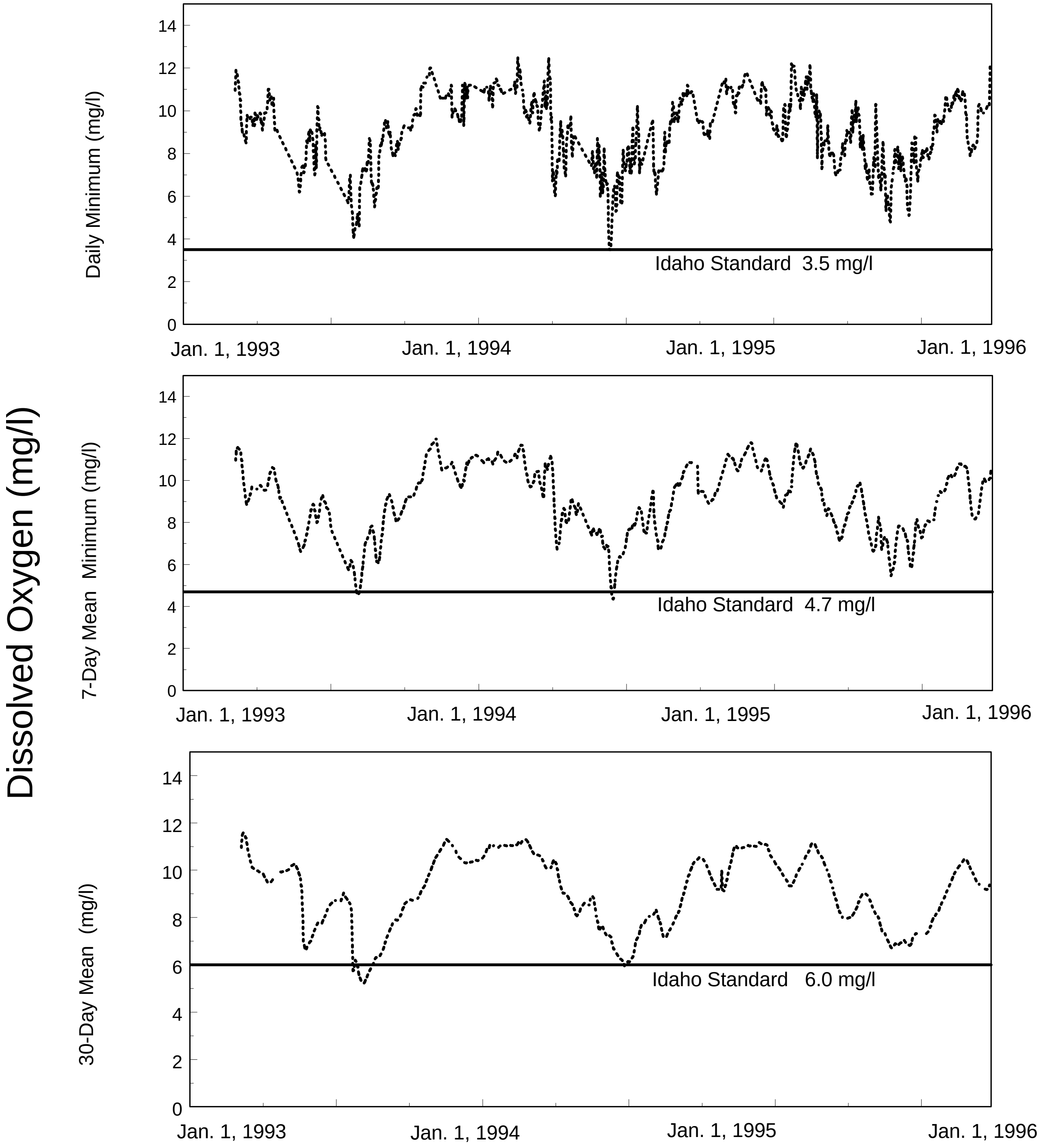


Figure 3. Dissolved oxygen levels in water discharged from the C.J. Strike Project relative to the Idaho State Standard.

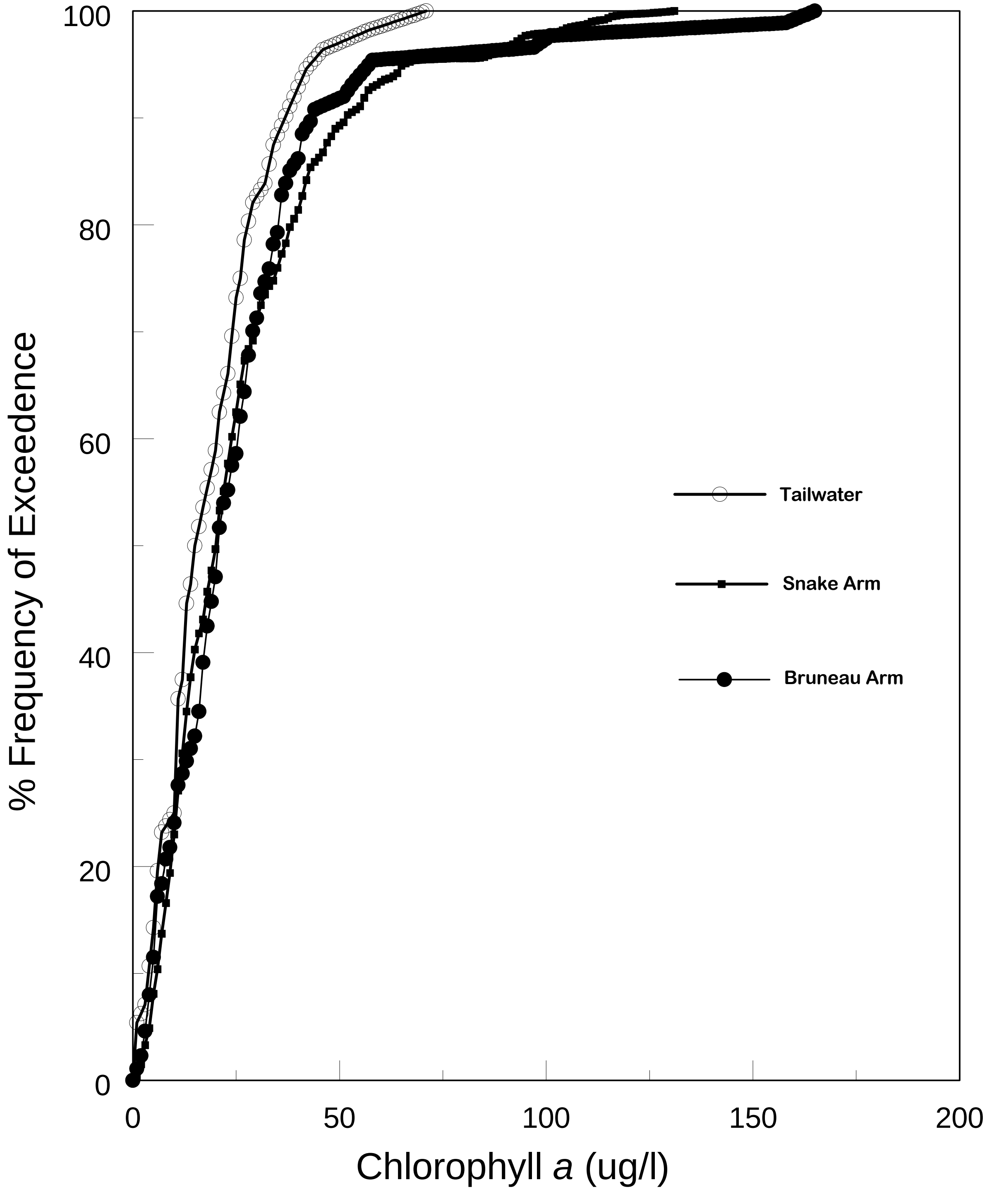


Figure 4. Percent exceedence curves for chlorophyll *a* levels in the Bruneau Arm, the Snake River Arm, and the tailwaters of the C.J. Strike Project.

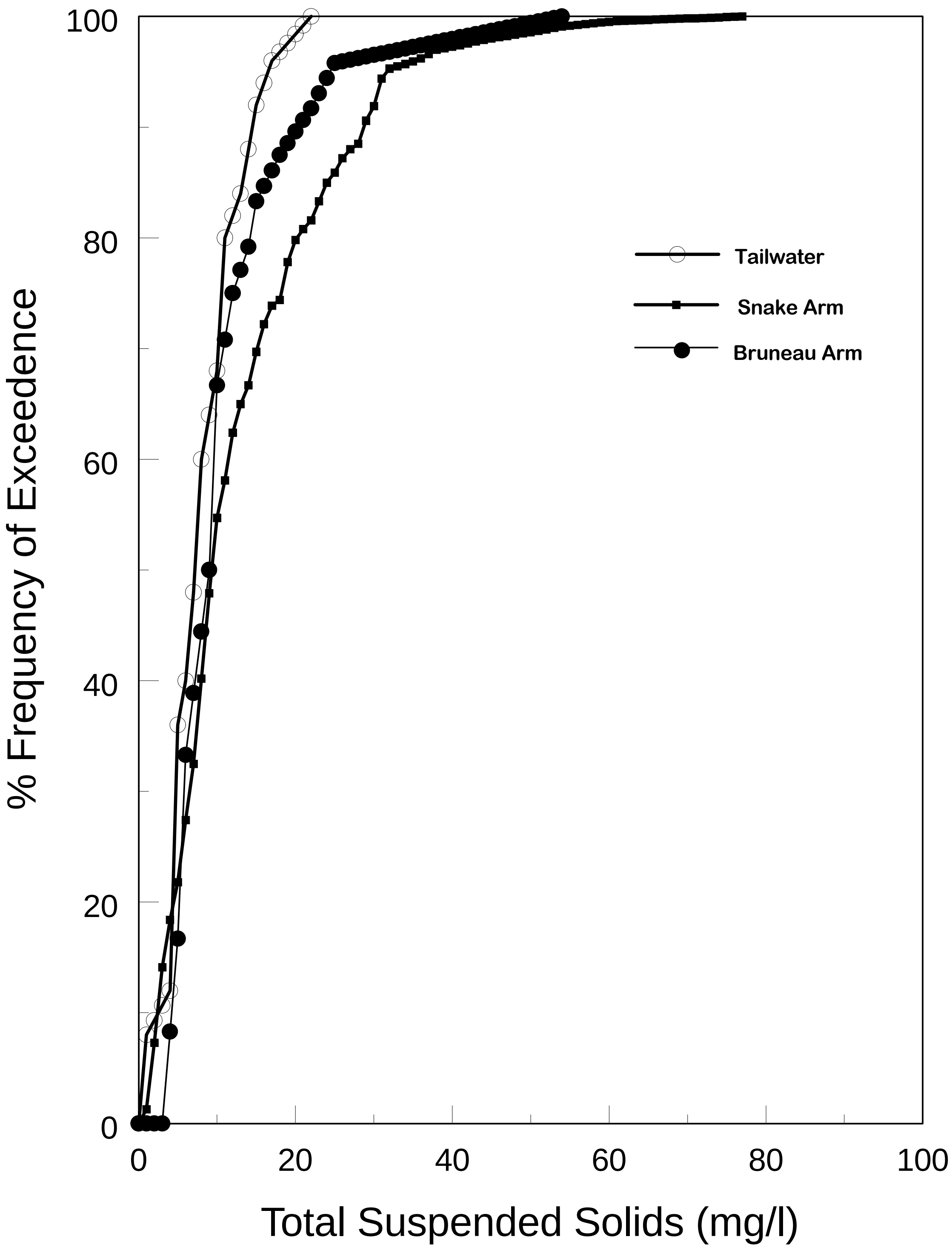
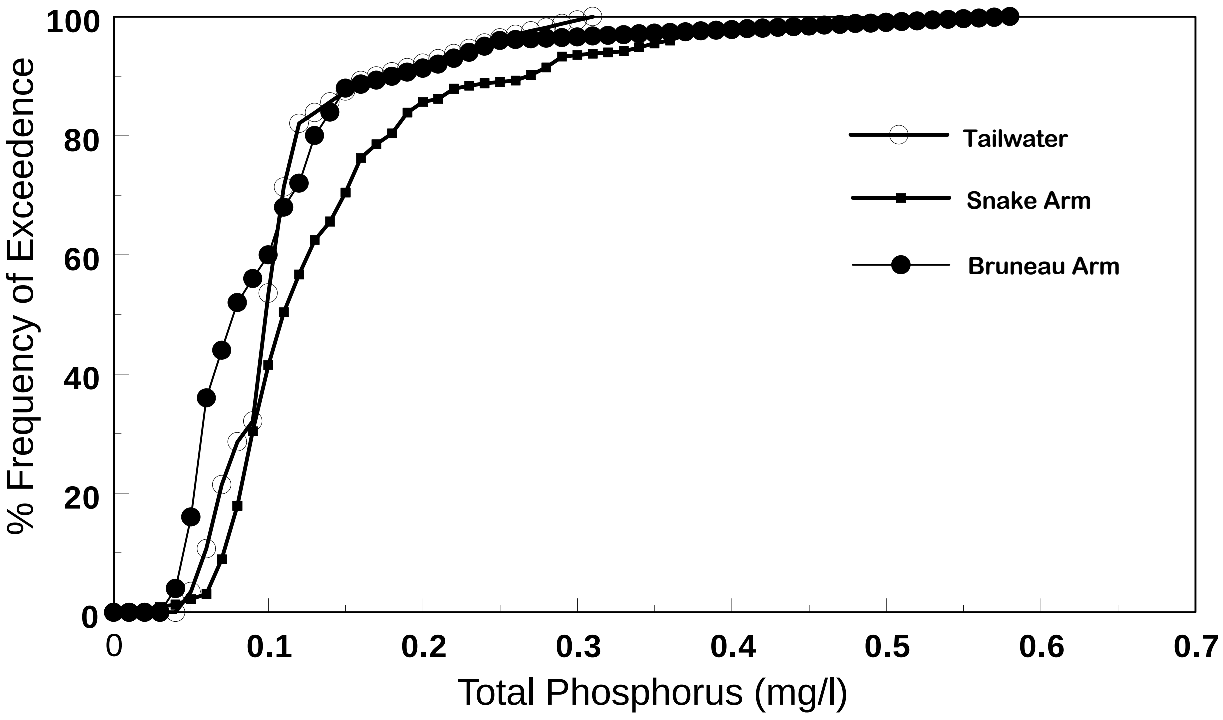


Figure 5. Percent exceedence curves for total suspended solids levels in the Bruneau Arm, the Snake River Arm, and the tailwaters of the C.J. Strike Project.



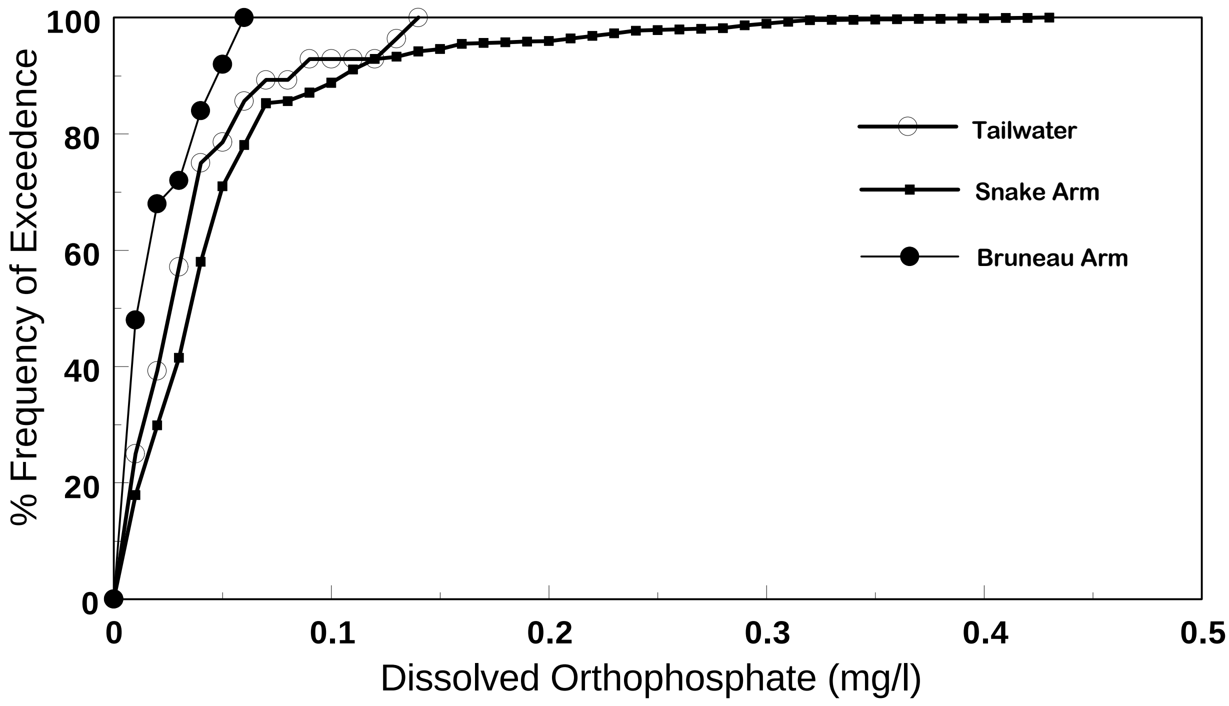


Figure 6. Percent exceedence curves for total phosphorus and dissolved orthophosphate in the Bruneau Arm, the Snake River Arm, and the tailwaters of the C.J. Strike Project.

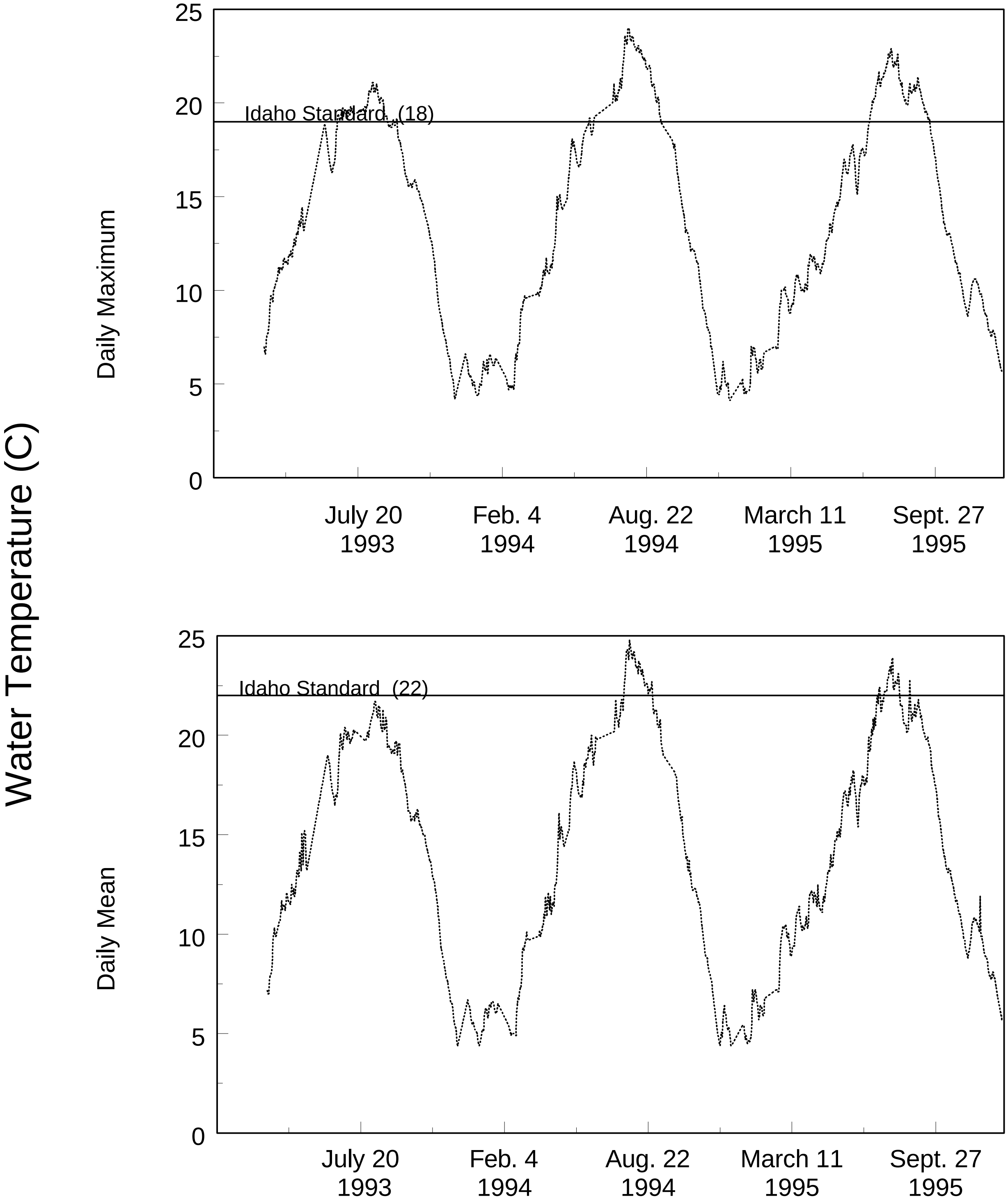


Figure 7. Daily maximum and daily mean water temperatures for water discharged from the C.J. Strike Project during 1993–1995.

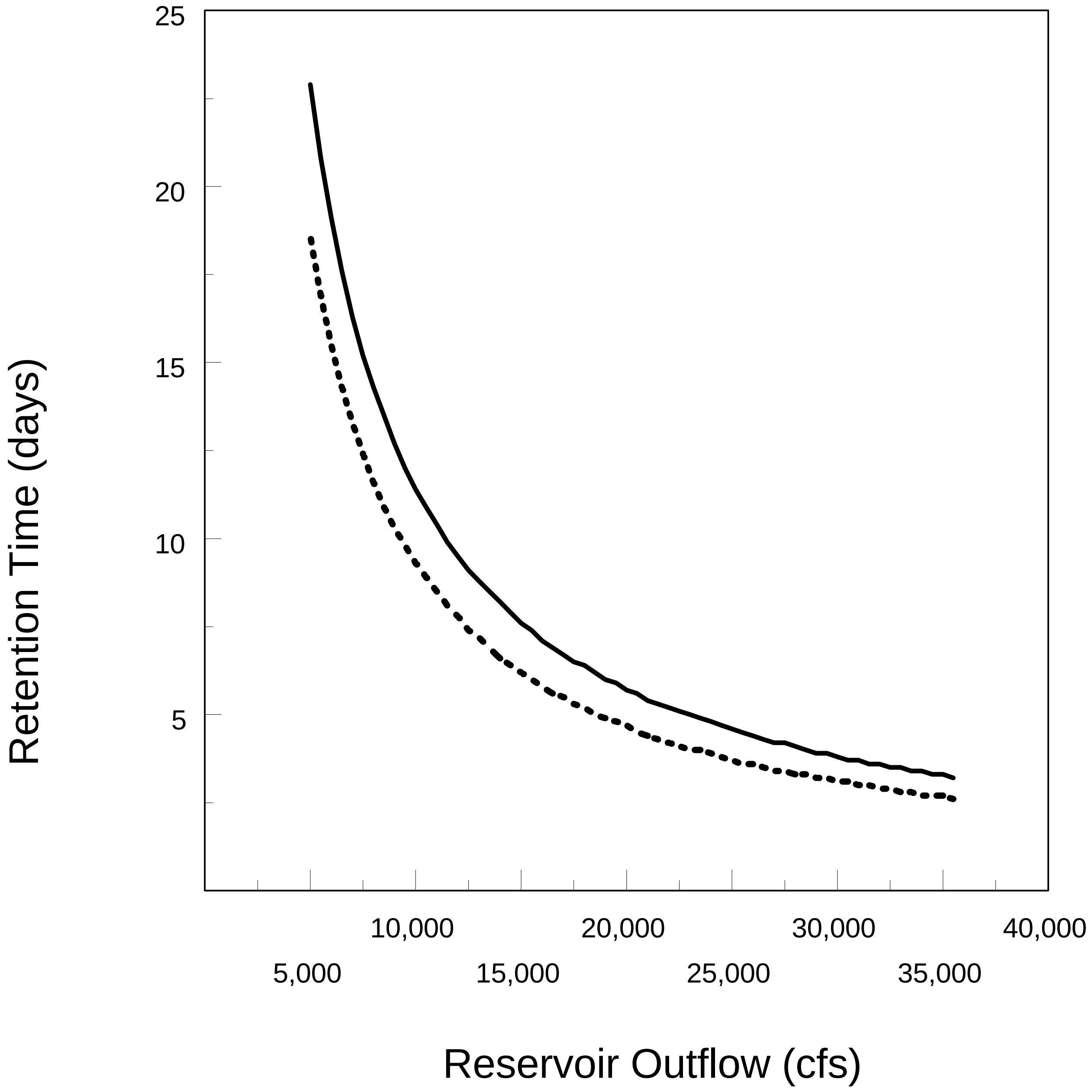


Figure 8. Retention time estimates for C.J. Strike Reservoir at full pool (solid line) and minimum pool (dashed line) over a range of flows.

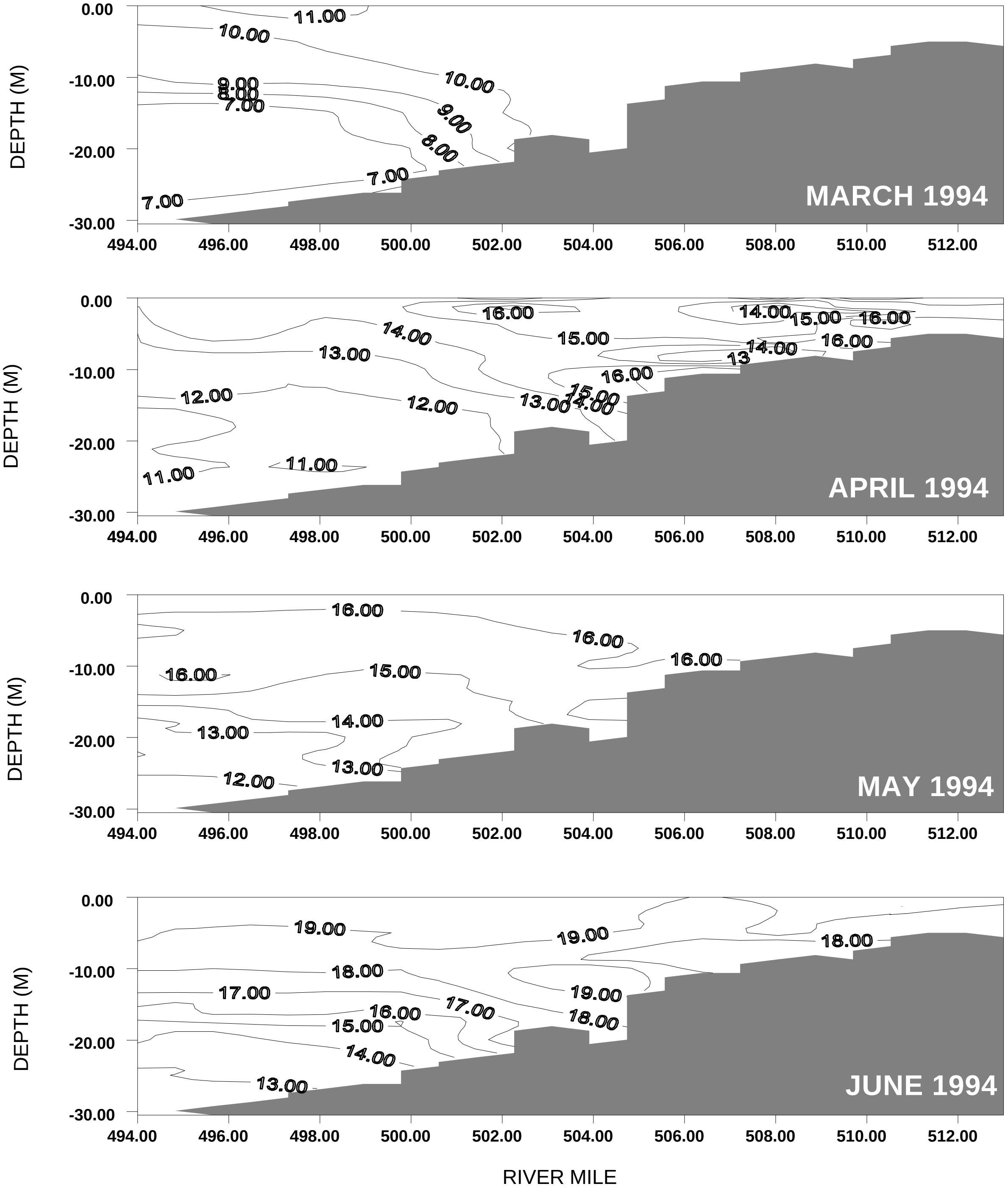


Figure 9. Water temperature isopleths for C.J. Strike Reservoir, March–June 1994.

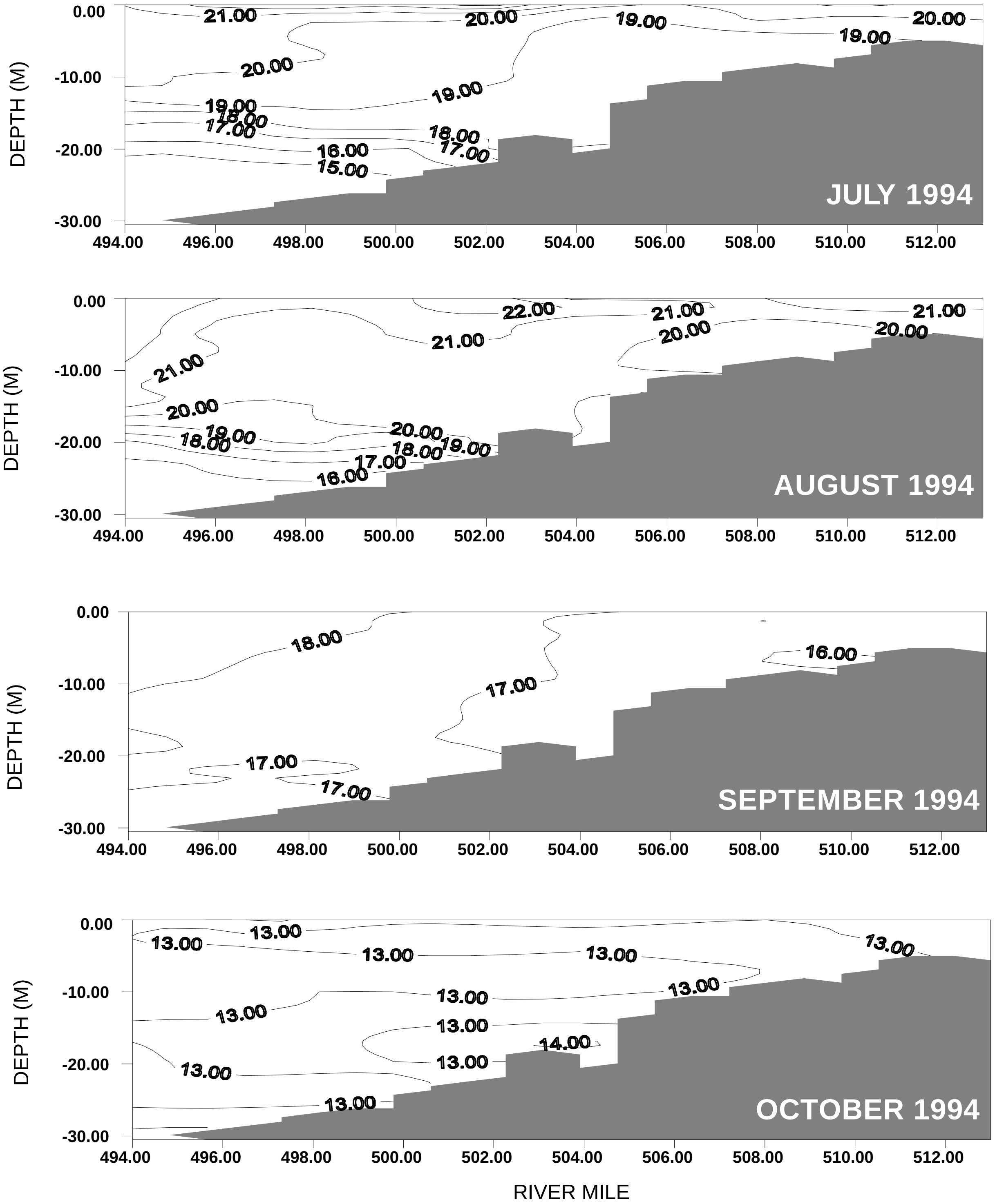


Figure 10. Water temperature isopleths for C.J. Strike Reservoir, July–October 1994.

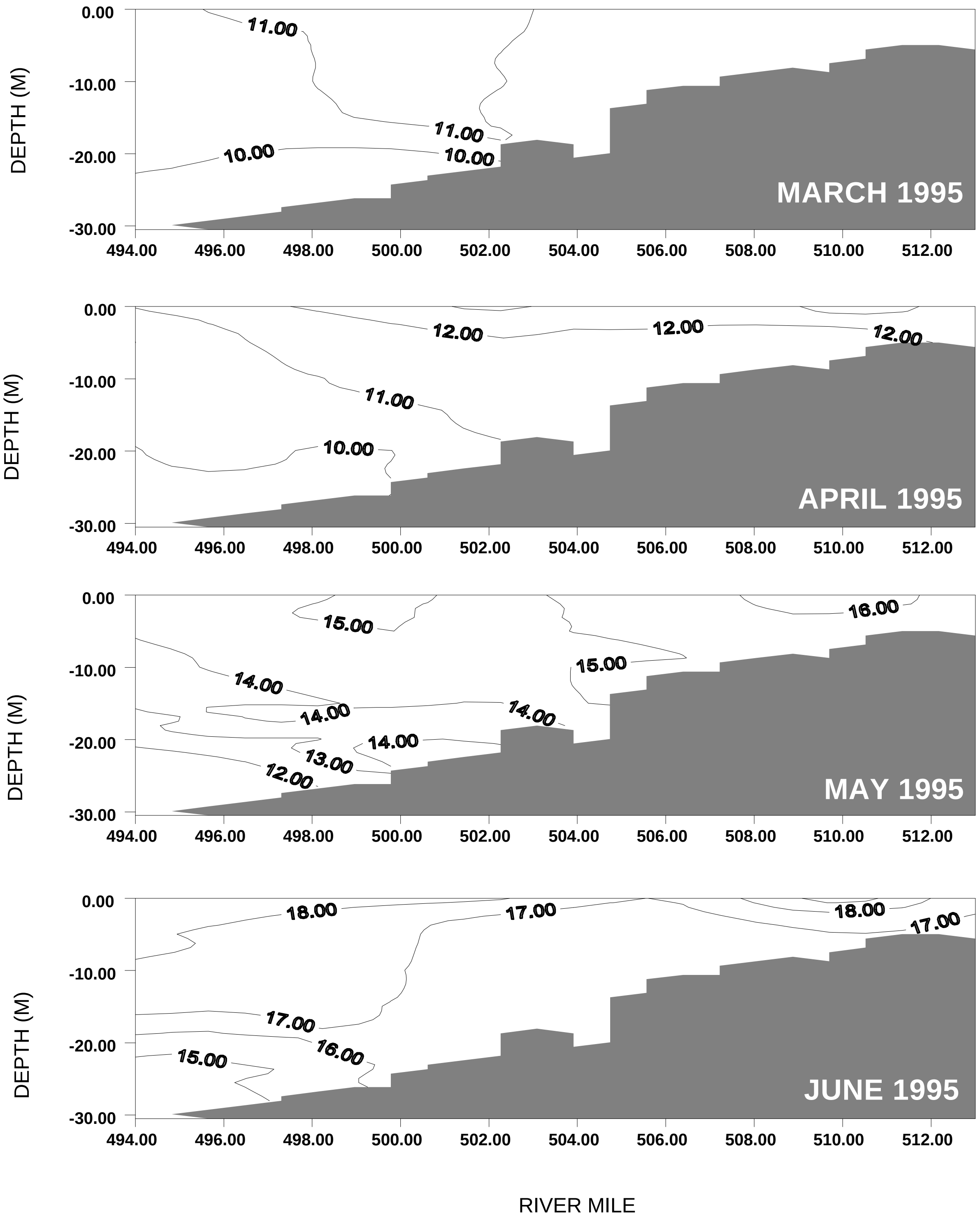


Figure 11. Water temperature isopleths for C.J. Strike Reservoir, March–June 1995.

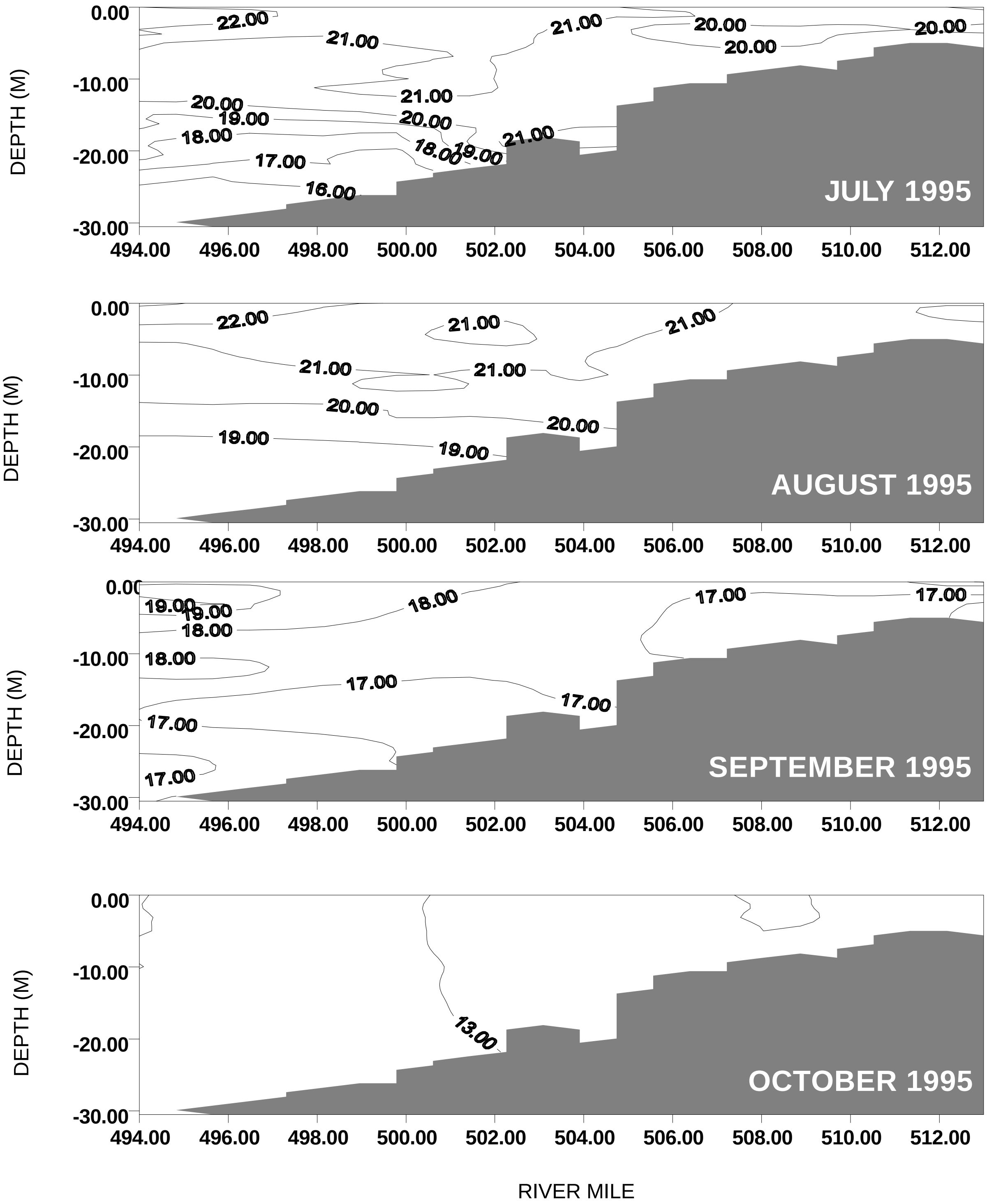


Figure 12. Water temperature isopleths for C.J. Strike Reservoir, July–October 1995.

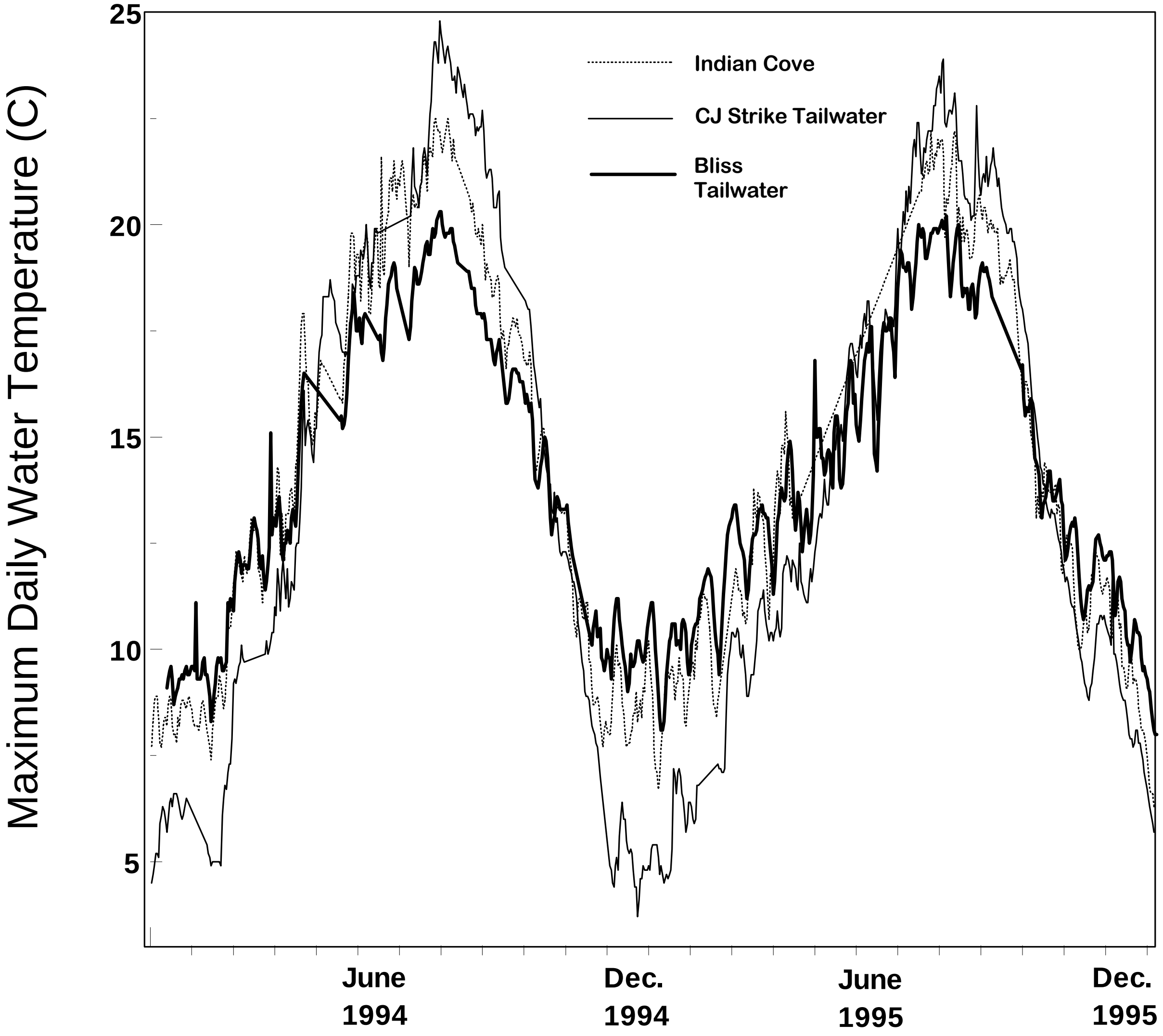


Figure 13. Maximum daily water temperature at three locations in the Snake River from Bliss Dam downstream to C.J. Strike Dam, 1994 and 1995.

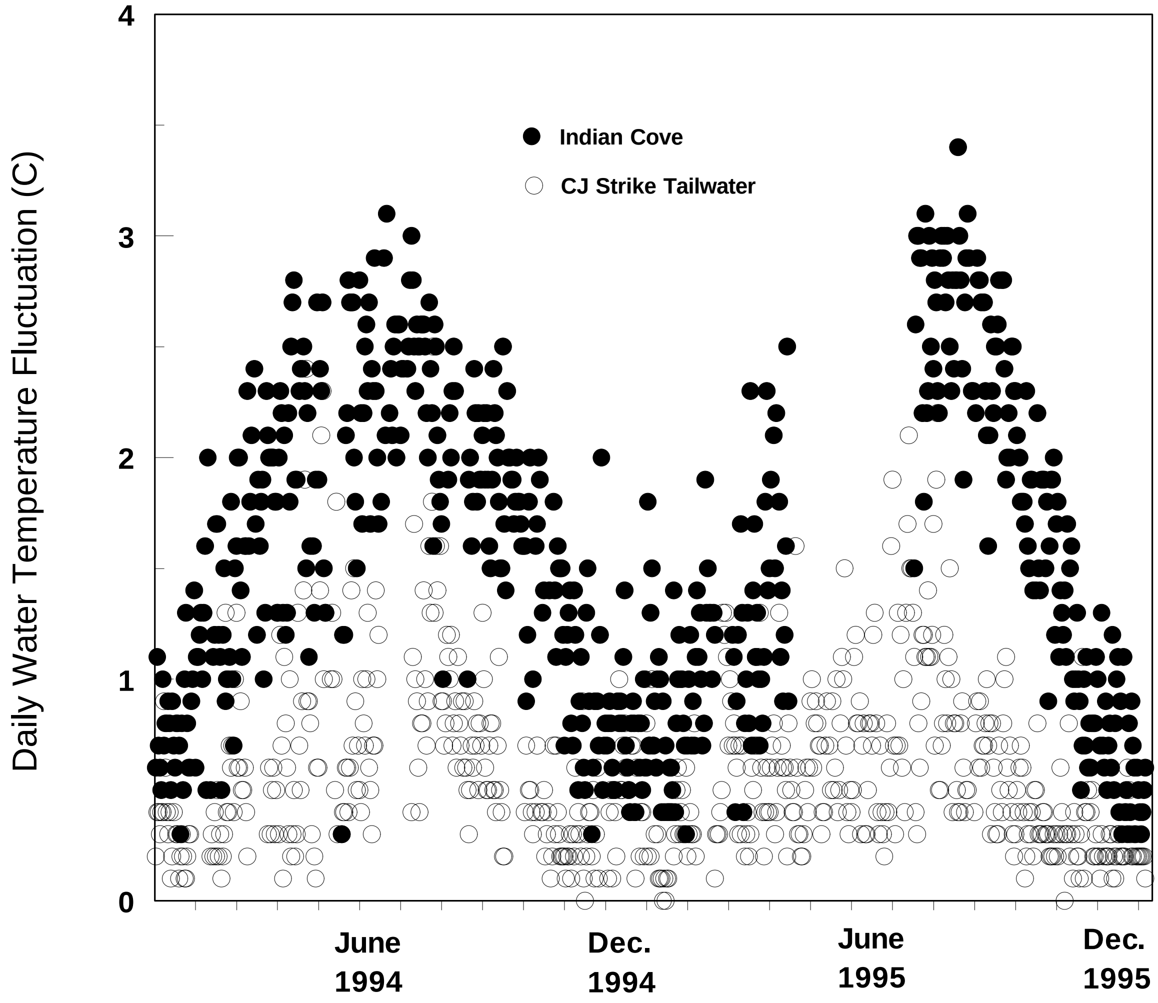


Figure 14. Diel water-temperature fluctuations of water entering C.J. Strike Reservoir at Indian Cove (RM 525.3) and water leaving the reservoir (RM 493.7), 1994 and 1995.

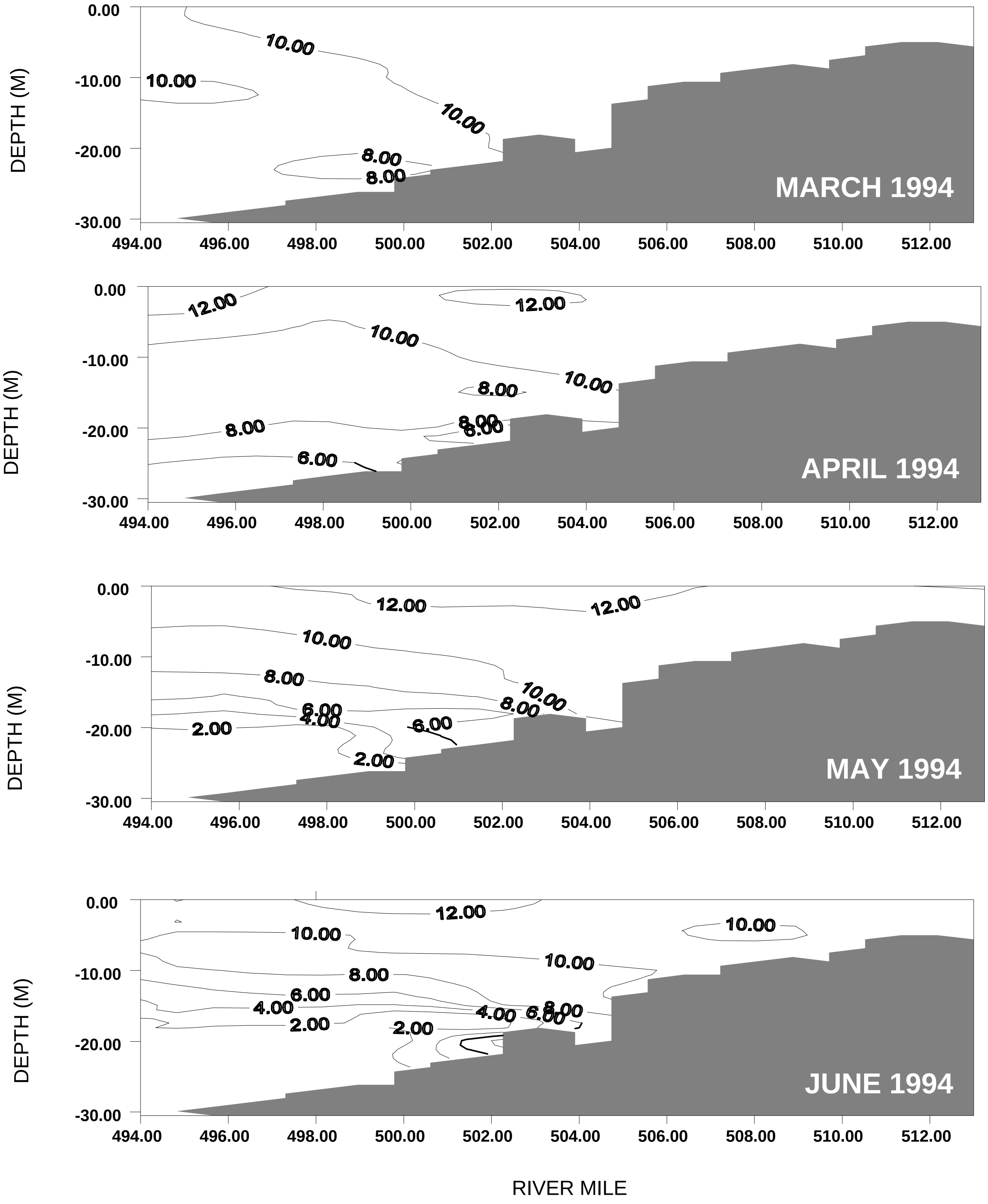


Figure 15. Dissolved oxygen isopleths for C.J. Strike Reservoir, March–June 1994.

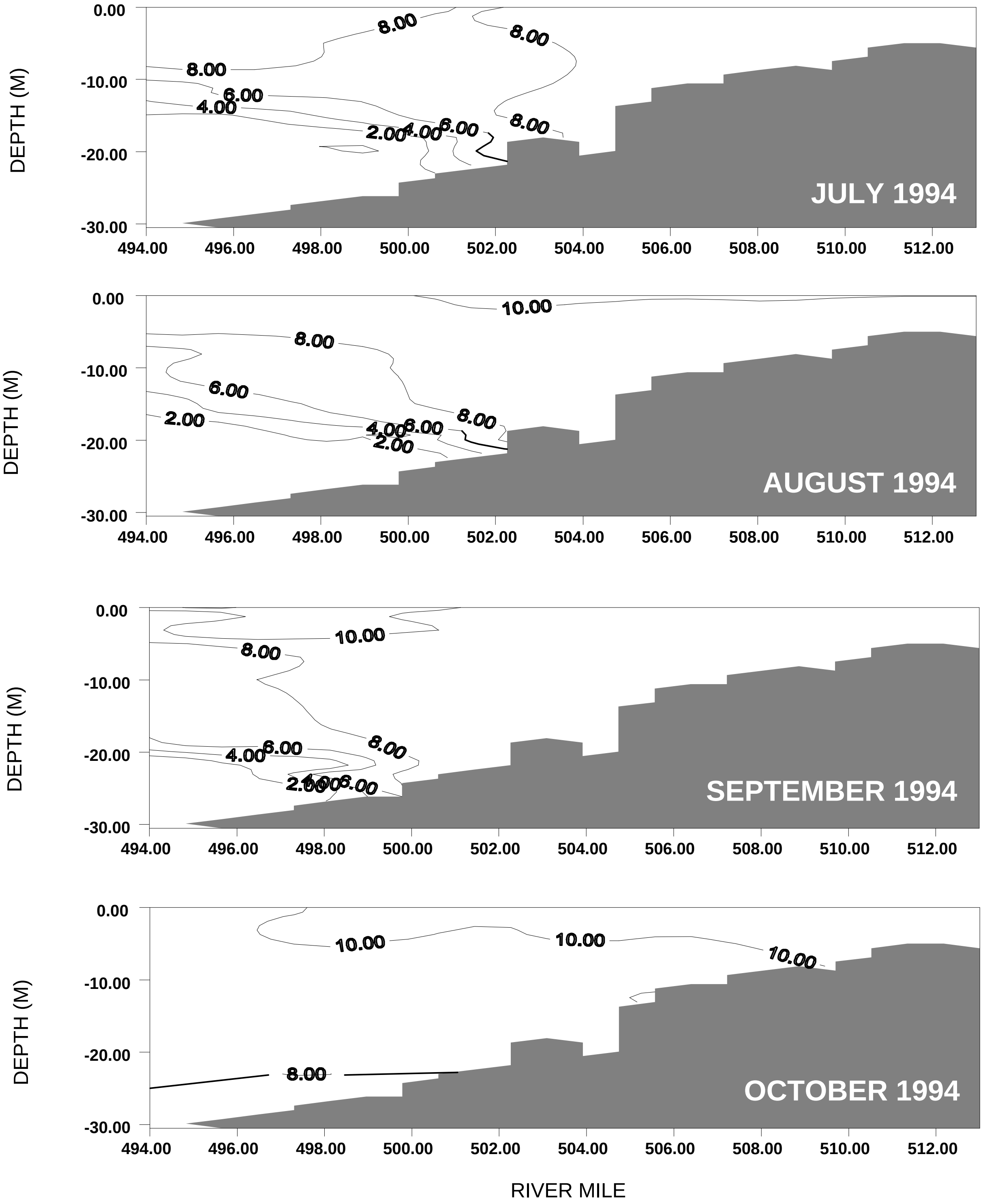


Figure 16. Dissolved oxygen isopleths for C.J. Strike Reservoir, July–October 1994.

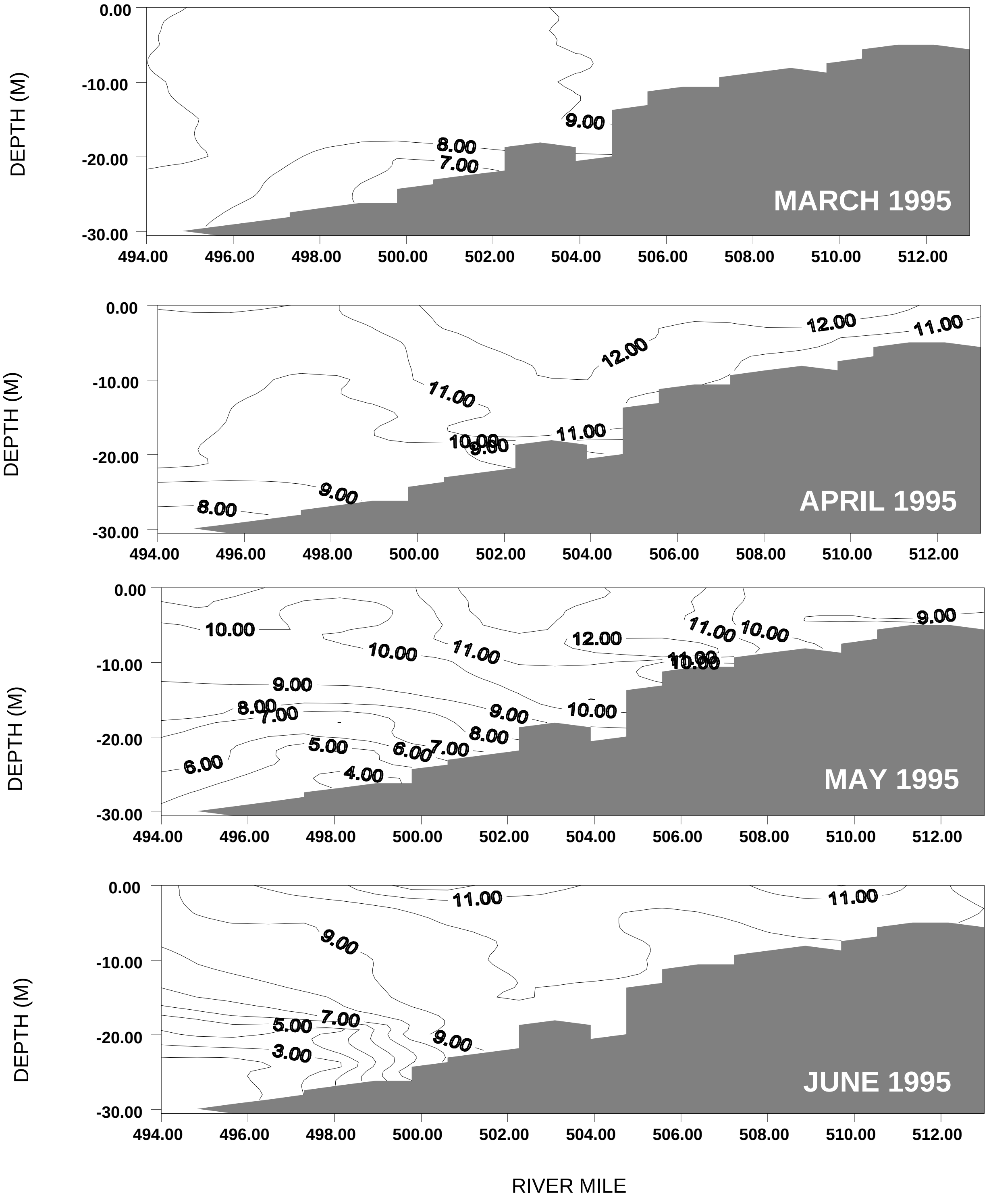


Figure 17. Dissolved oxygen isopleths for C.J. Strike Reservoir, March–June 1995.

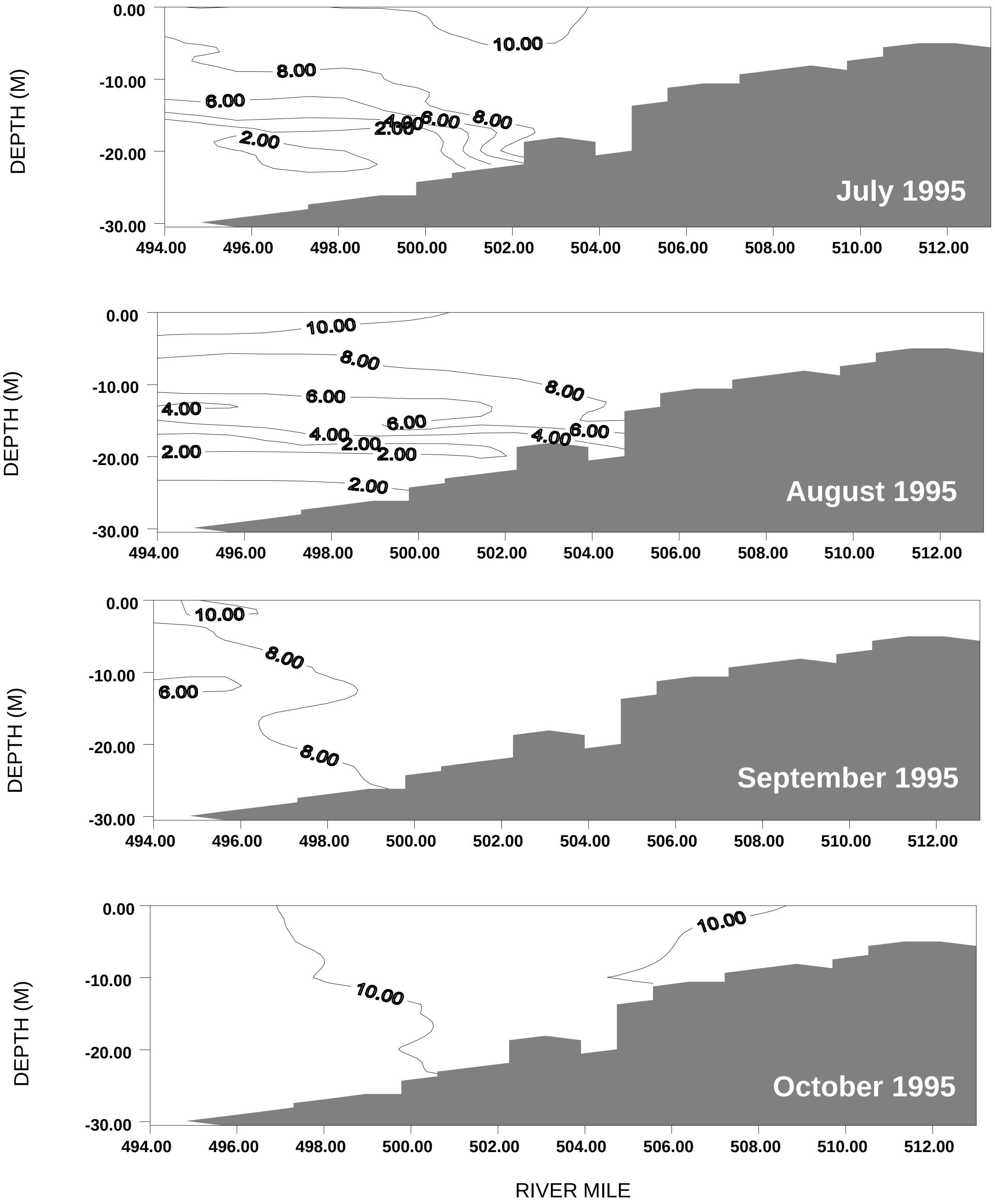


Figure 18. Dissolved oxygen isopleths for C.J. Strike Reservoir, July–October 1995.

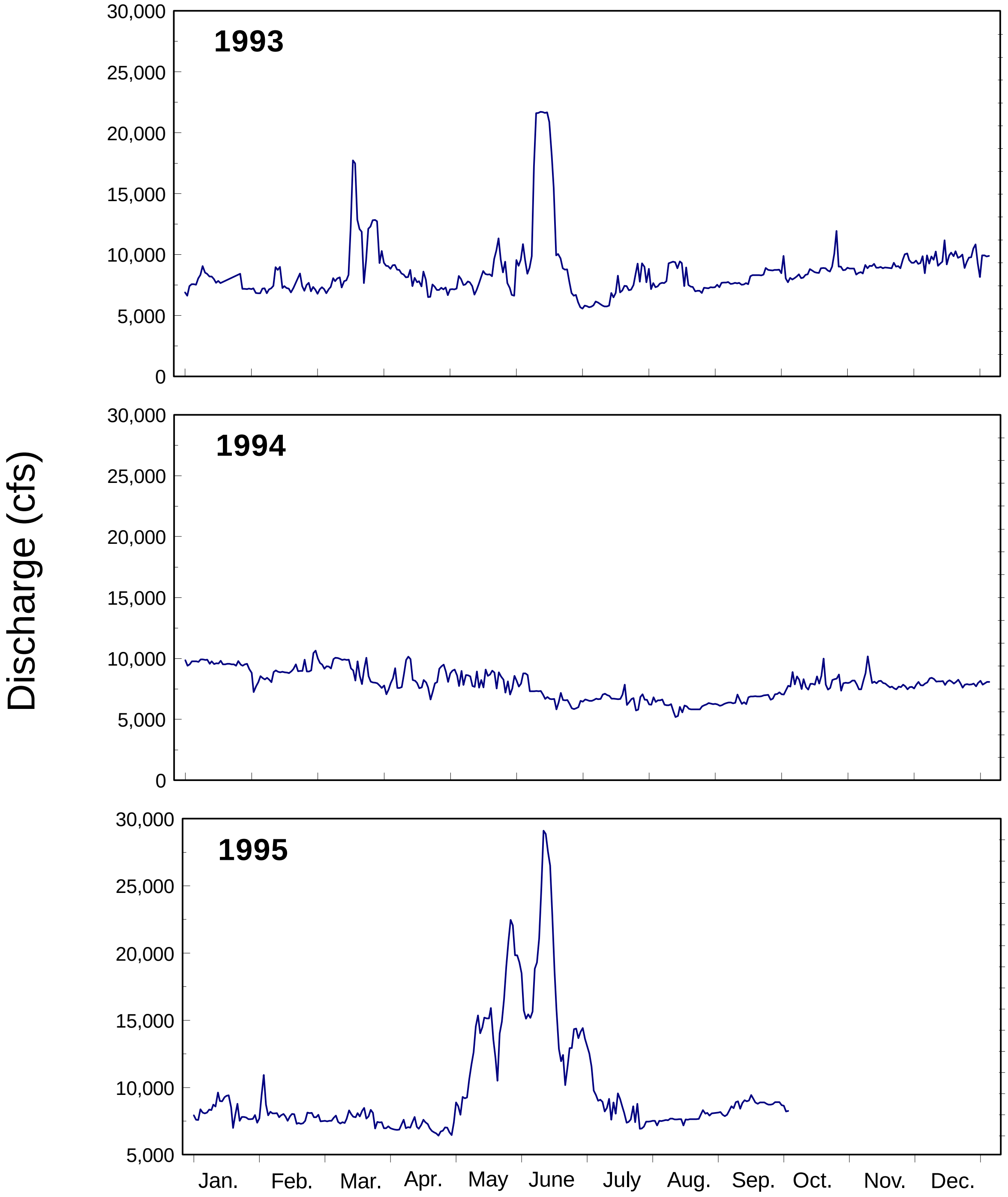


Figure 19. Hydrograph of Snake River flows leaving the C.J. Strike Project during 1993–1995.

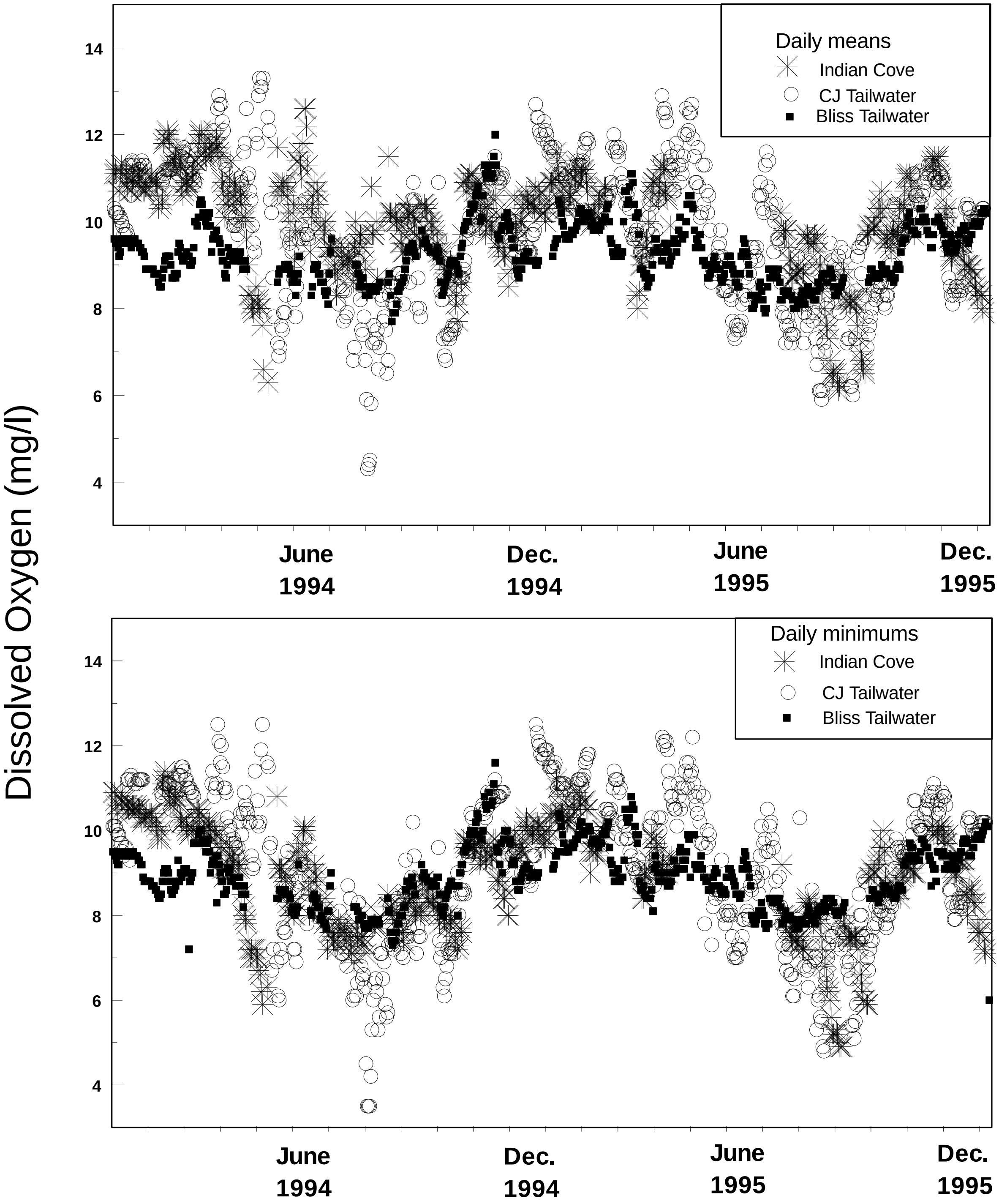


Figure 20. Daily minimum and mean dissolved oxygen levels at three locations in the Snake River from Bliss Dam downstream to C.J. Strike Dam, 1994 and 1995.

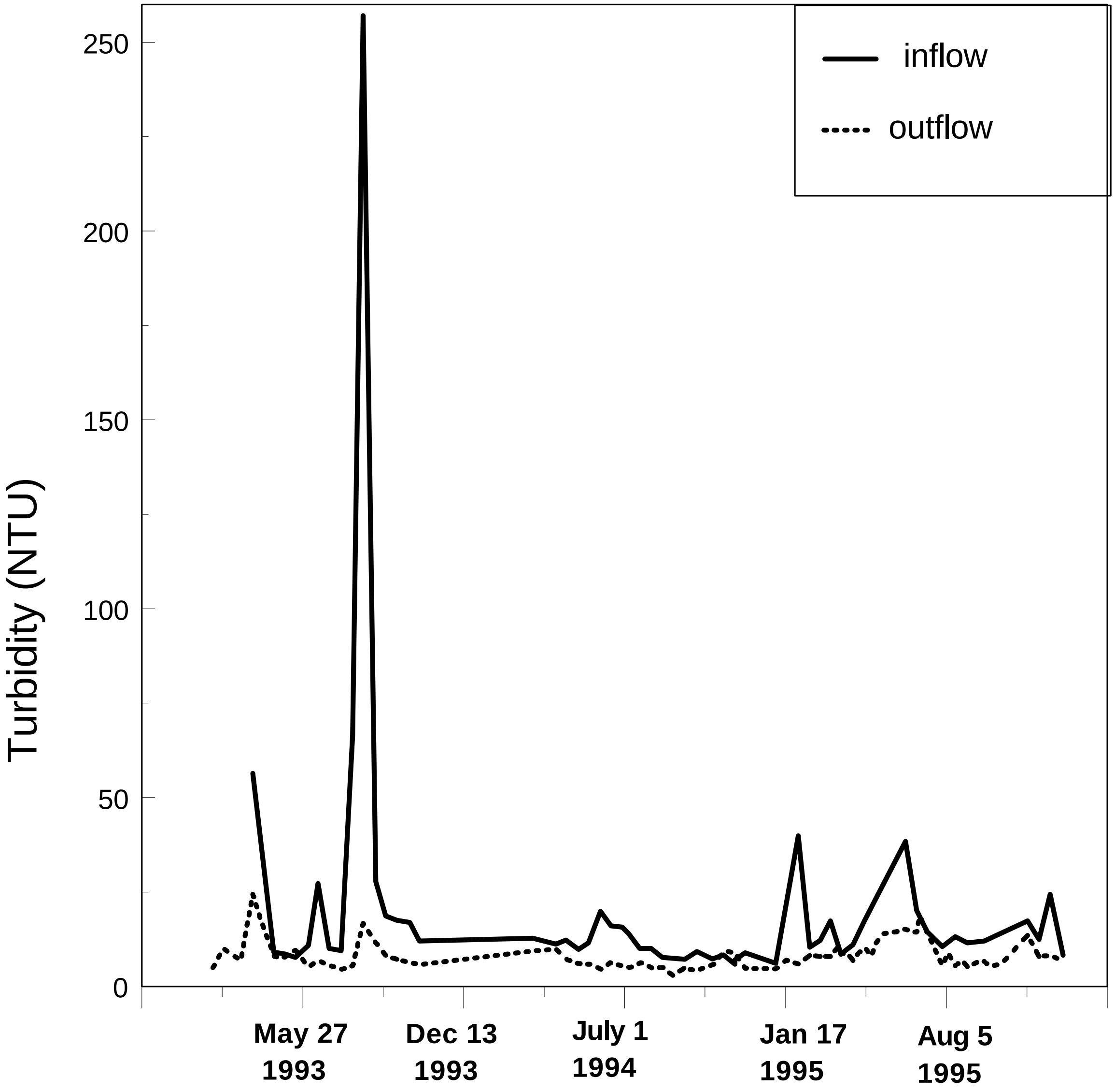


Figure 21. Turbidity of water flowing into C.J. Strike Reservoir at Indian Cove Bridge (RM 525.3) and leaving the reservoir (RM 493.7).

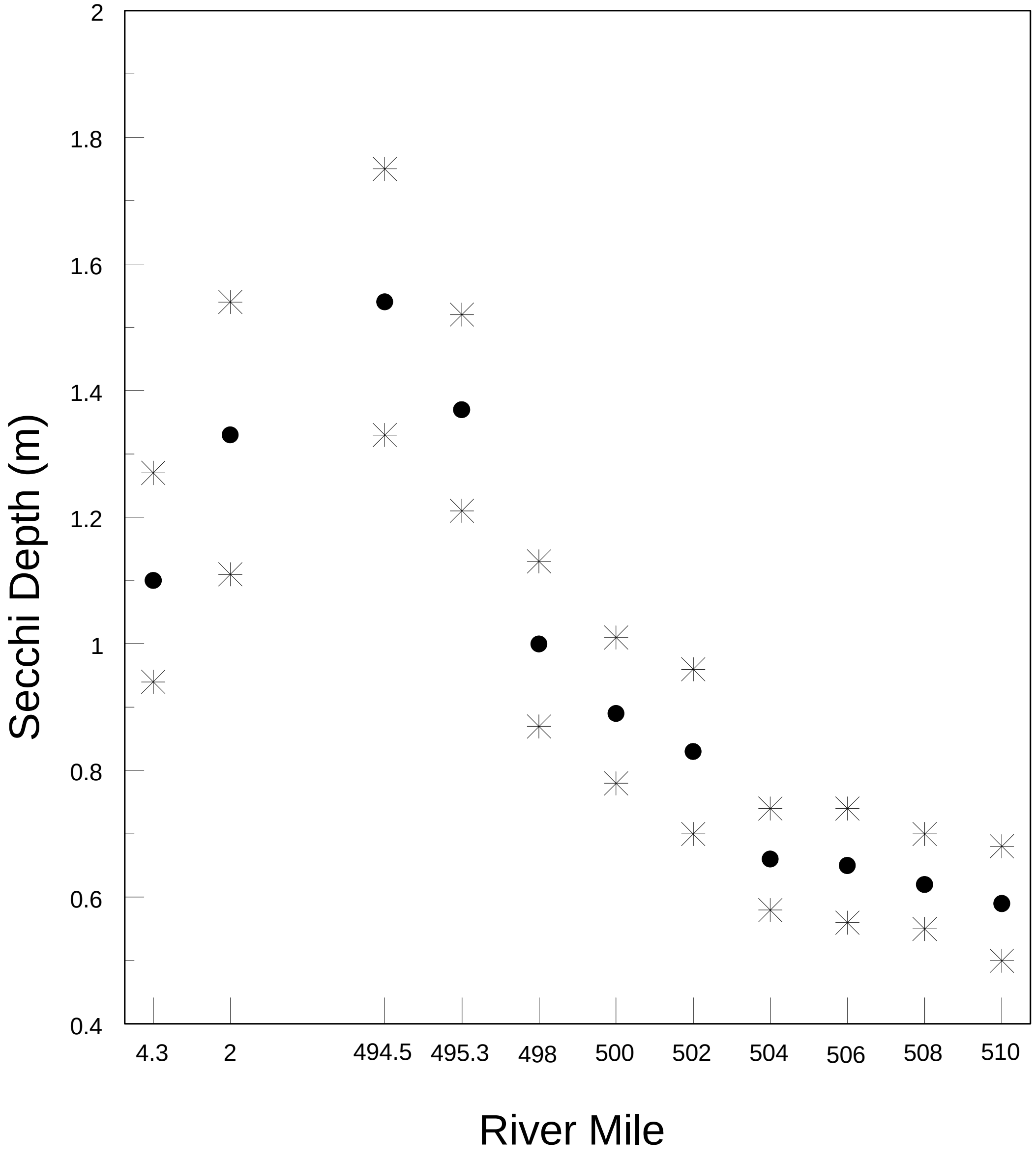


Figure 22. Mean Secchi depth (solid dot) with 95% confidence limits (asterisk) measured at 11 sites throughout the study area.

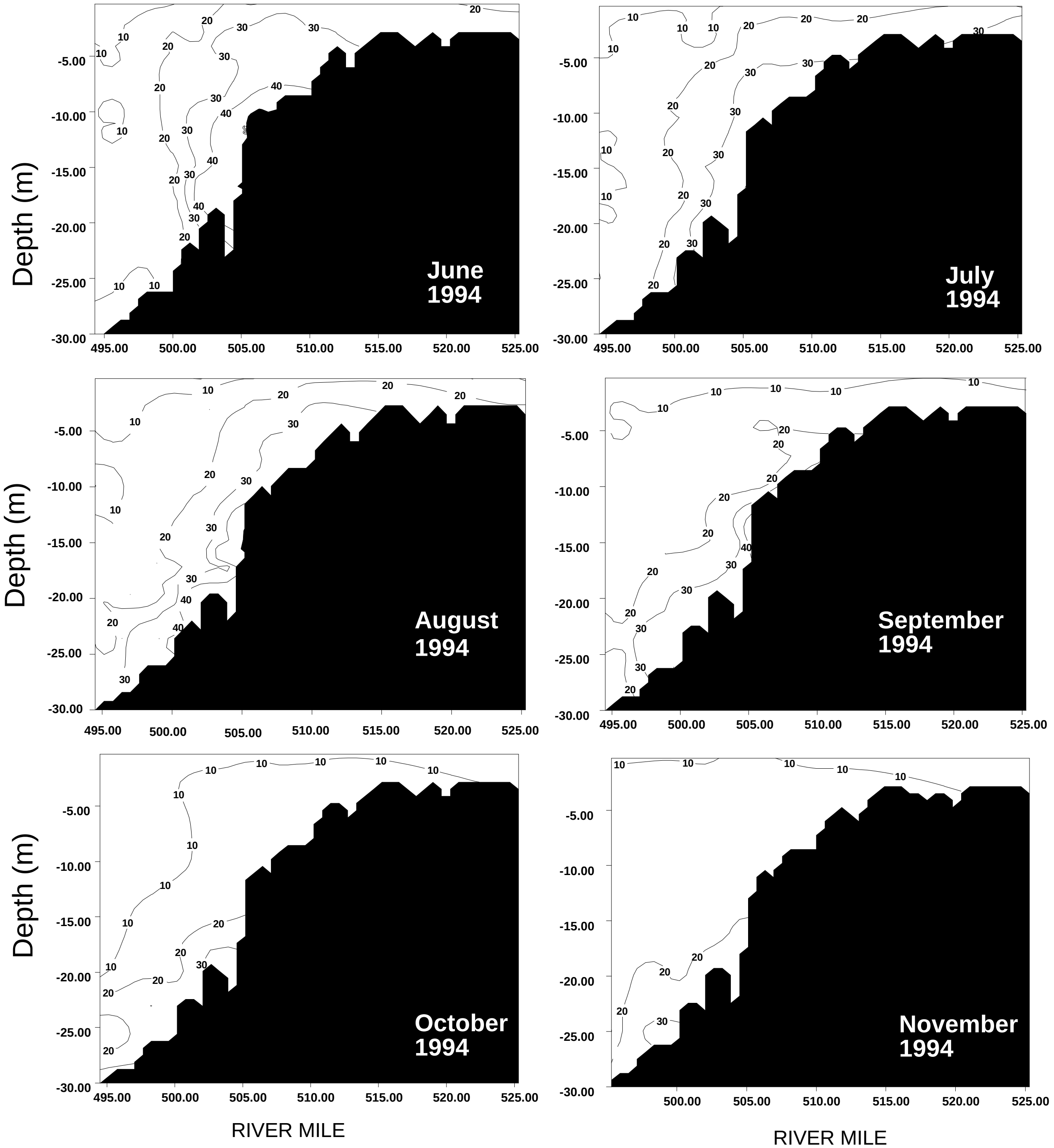


Figure 23. Turbidity isopleths for C.J. Strike Reservoir for June–November, 1994.

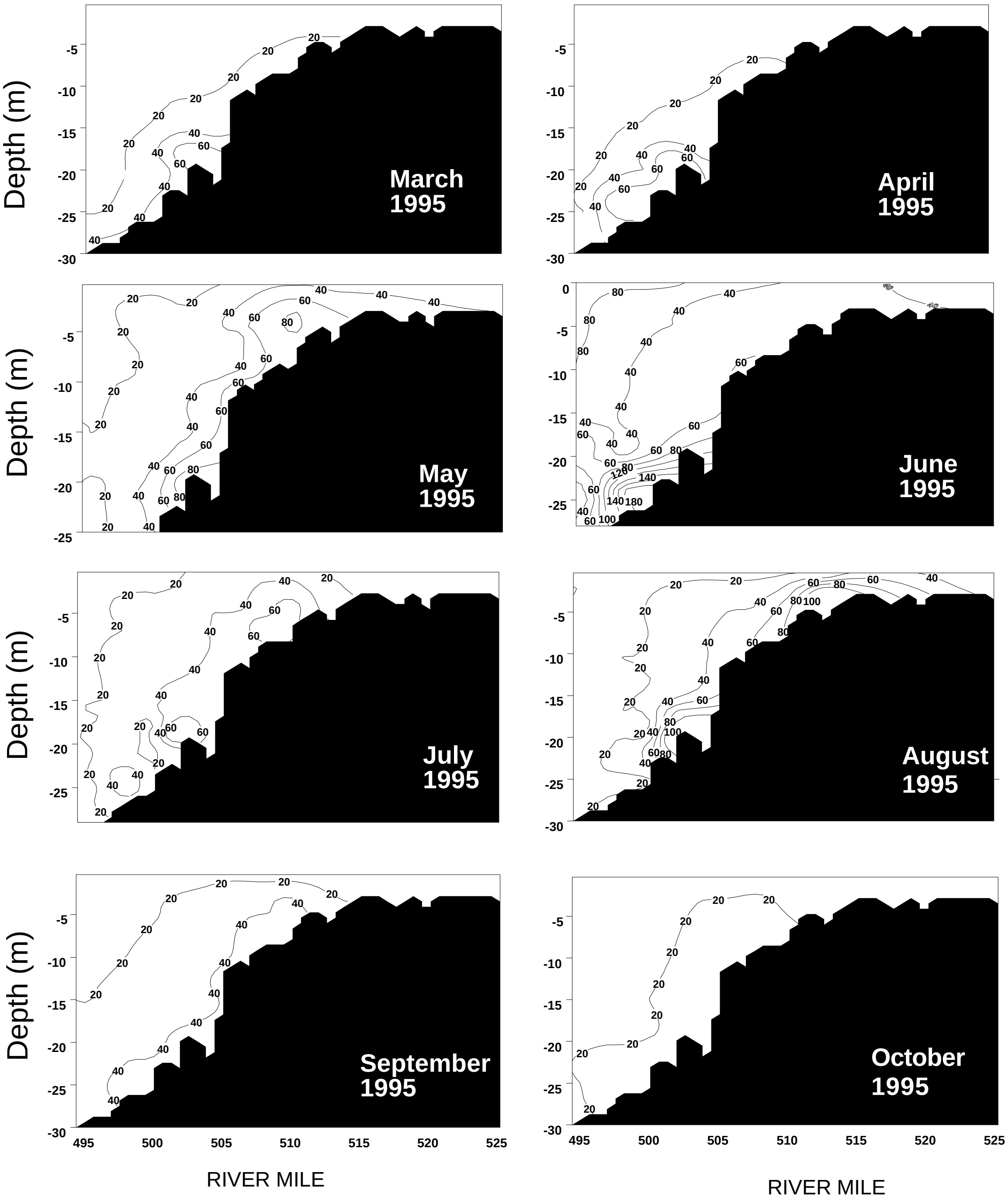


Figure 24. Turbidity isopleths for C.J. Strike Reservoir for March–October, 1995.

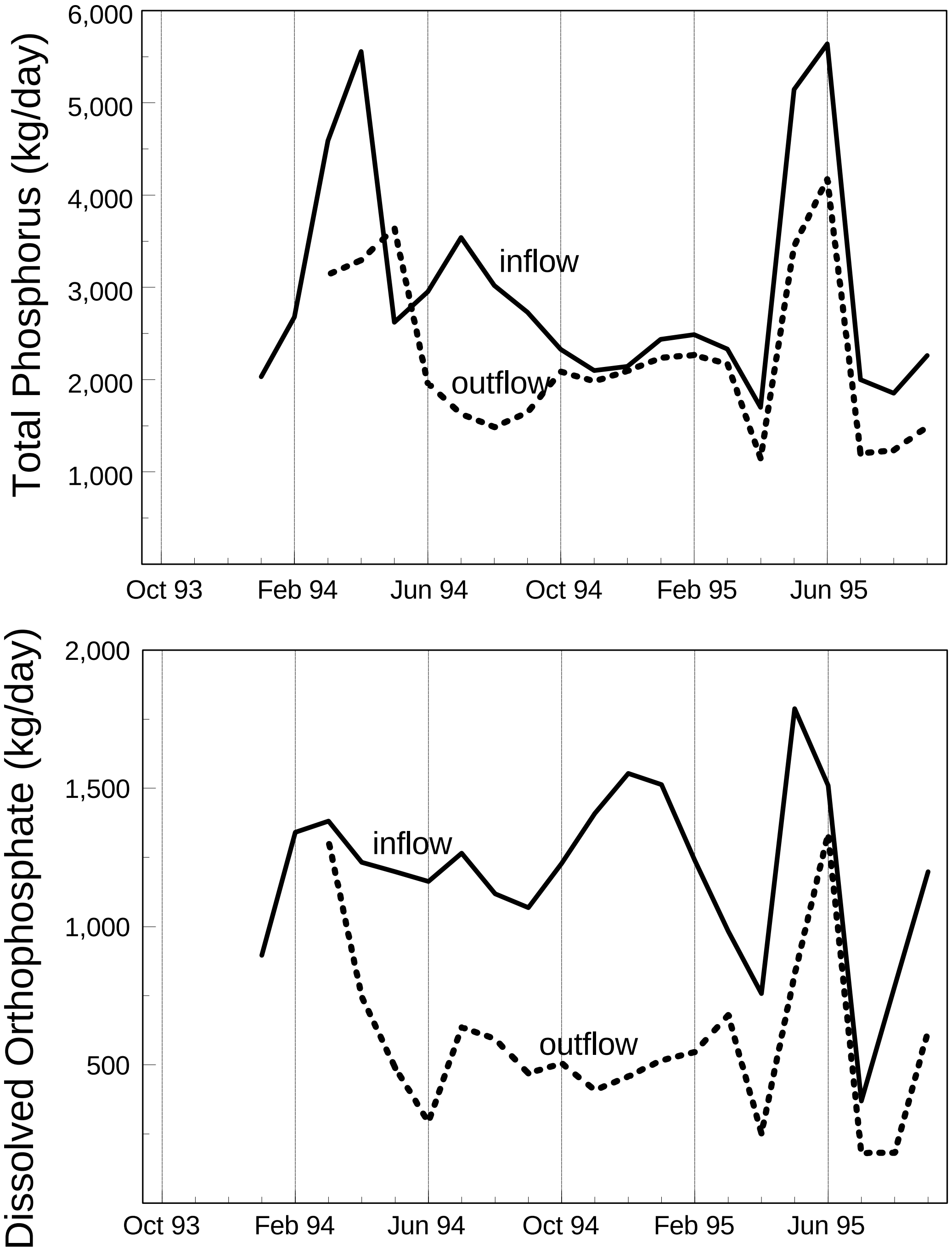


Figure 25. Total phosphorus and dissolved orthophosphate loads at King Hill (inflow) and in the C.J. Strike Project tailrace (outflow), 1994 and 1995.

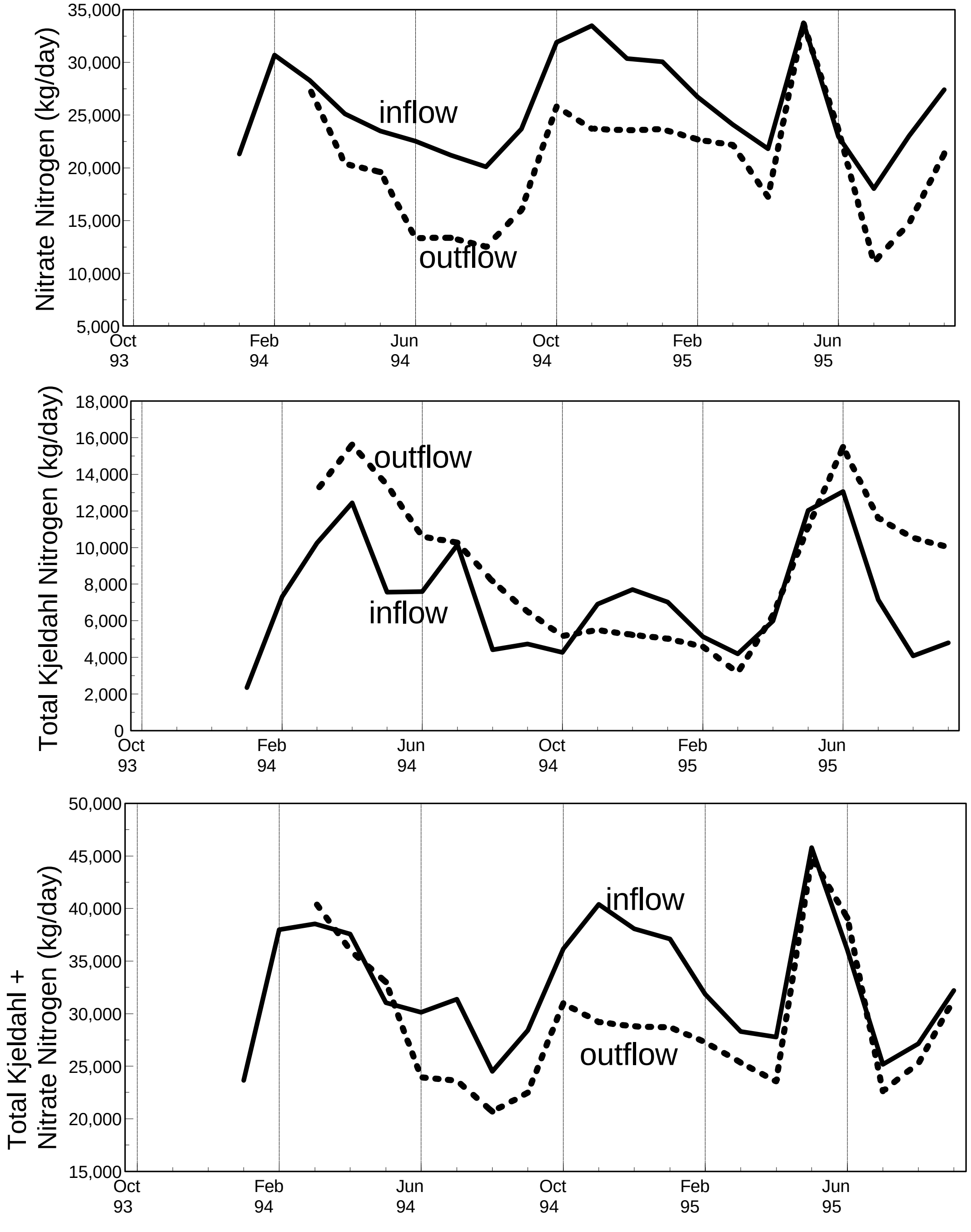


Figure 26. Nitrate nitrogen, total Kjeldahl nitrogen, and total nitrogen (defined as total Kjeldahl and nitrate) loads at King Hill (inflow) and in the C.J. Strike Project tailrace (outflow), 1994 and1995.

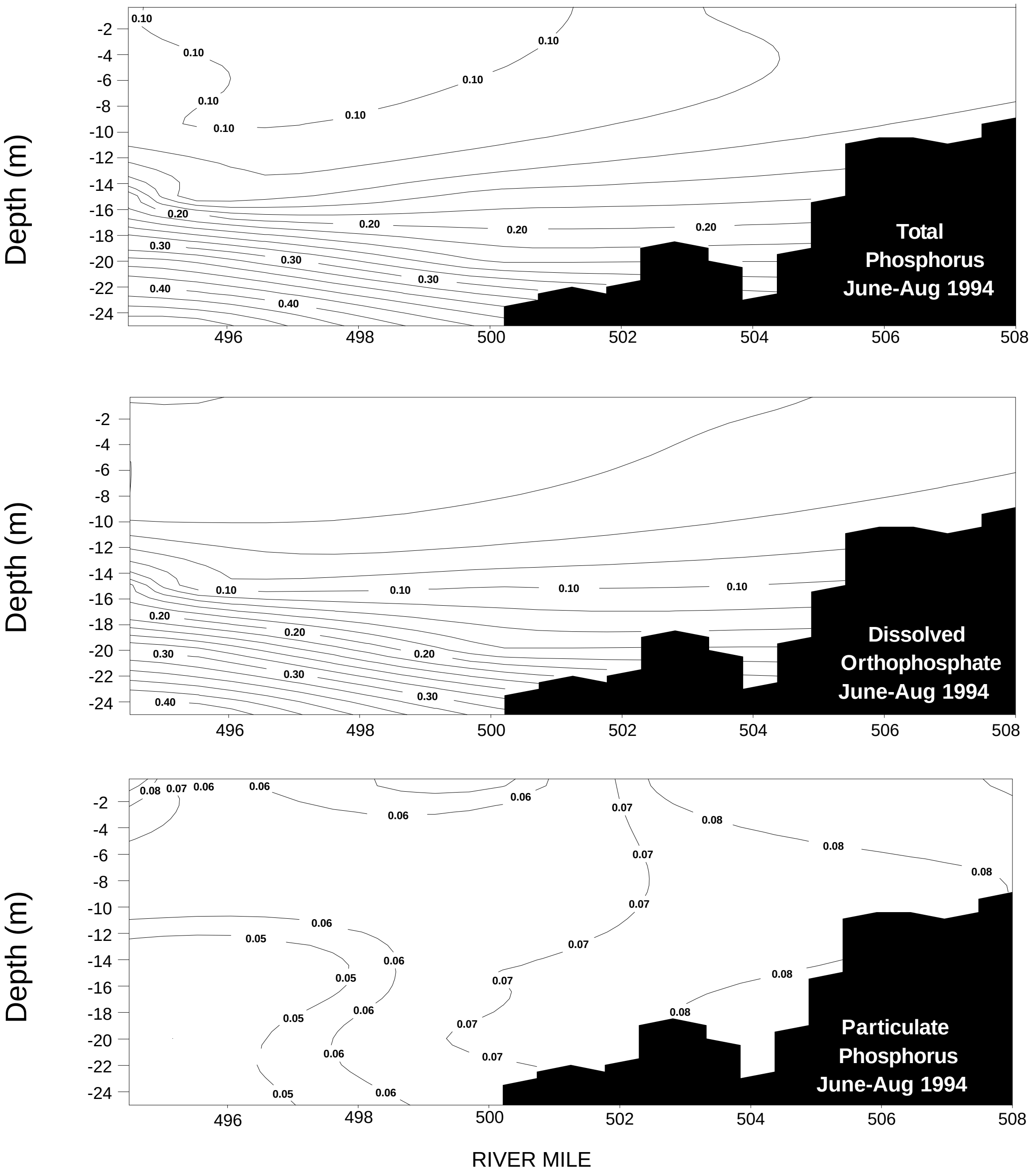


Figure 27. Isopleths for total phosphorus, dissolved orthophosphate, and particulate phosphorus (defined as the difference between total phosphorus and dissolved orthophosphate) for C.J. Strike Reservoir, based on time-averaged profile data for June–August, 1994.

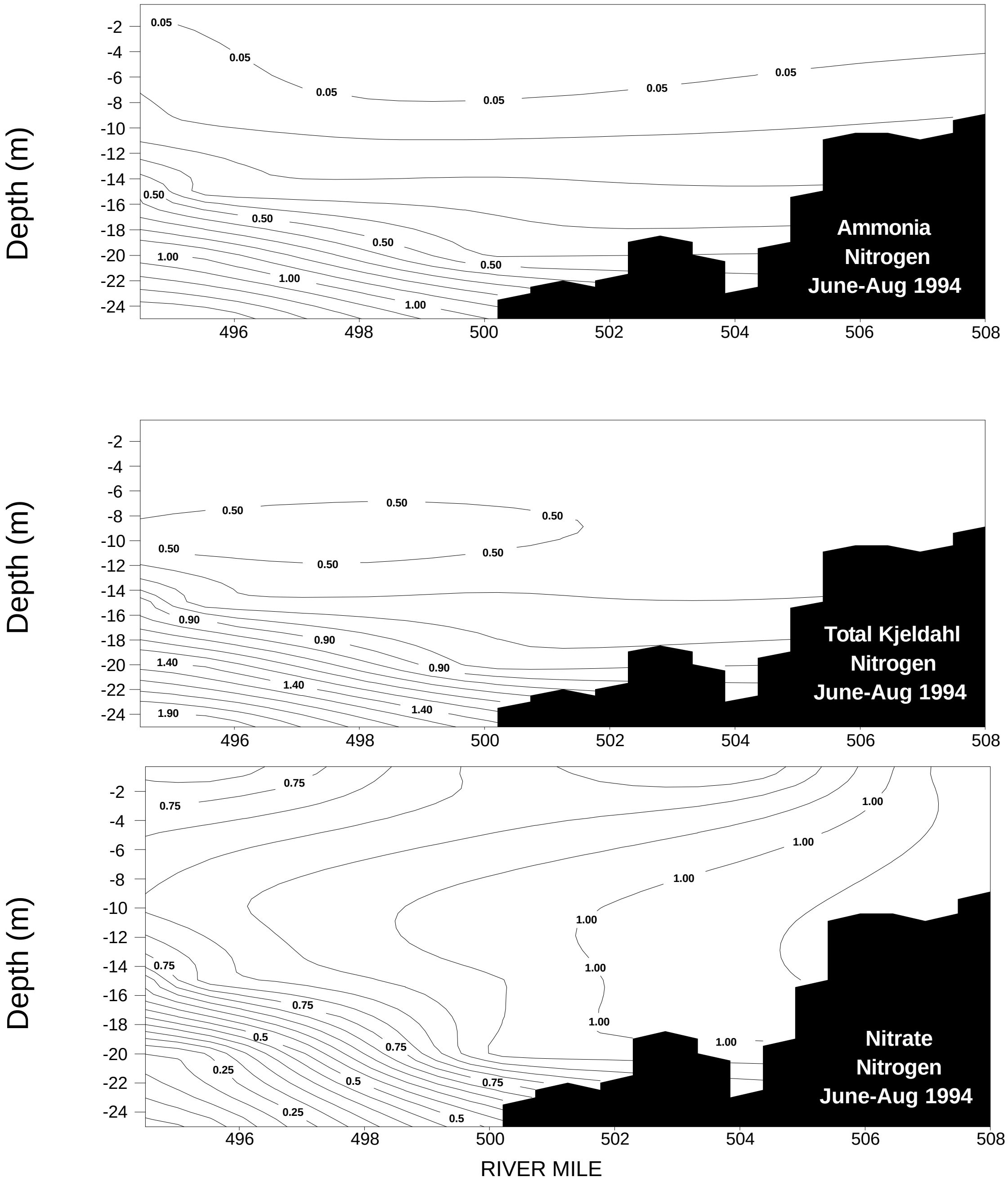


Figure 28. Isopleths for ammonia, total Kjeldahl, and nitrate nitrogen for C.J. Strike Reservoir, based on time-averaged profile data for June–August 1994.

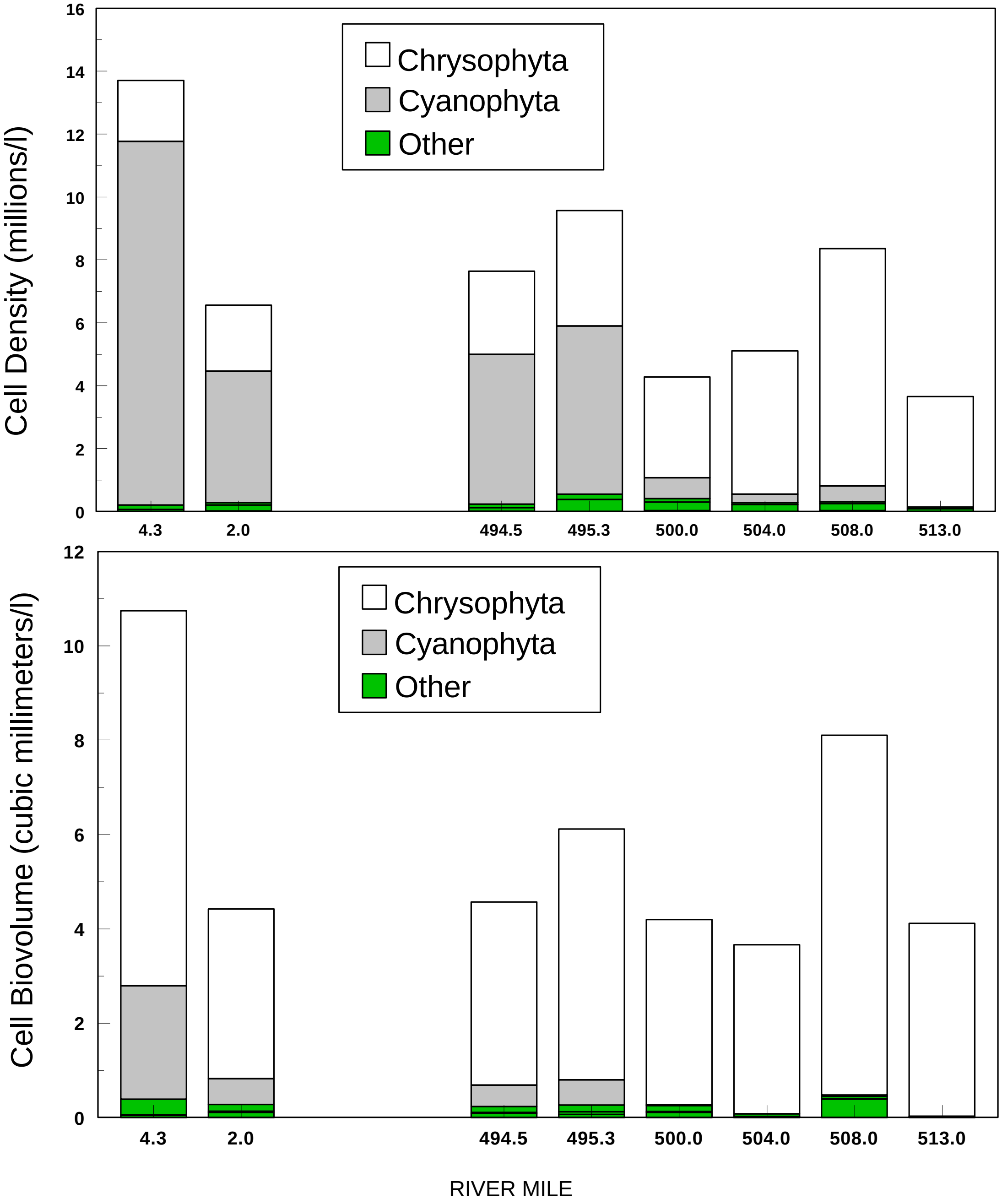


Figure 29. Average cell densities and biovolume for major phytoplankton divisions at eight sampling locations sampled in 1994 and 1995 throughout the study area.

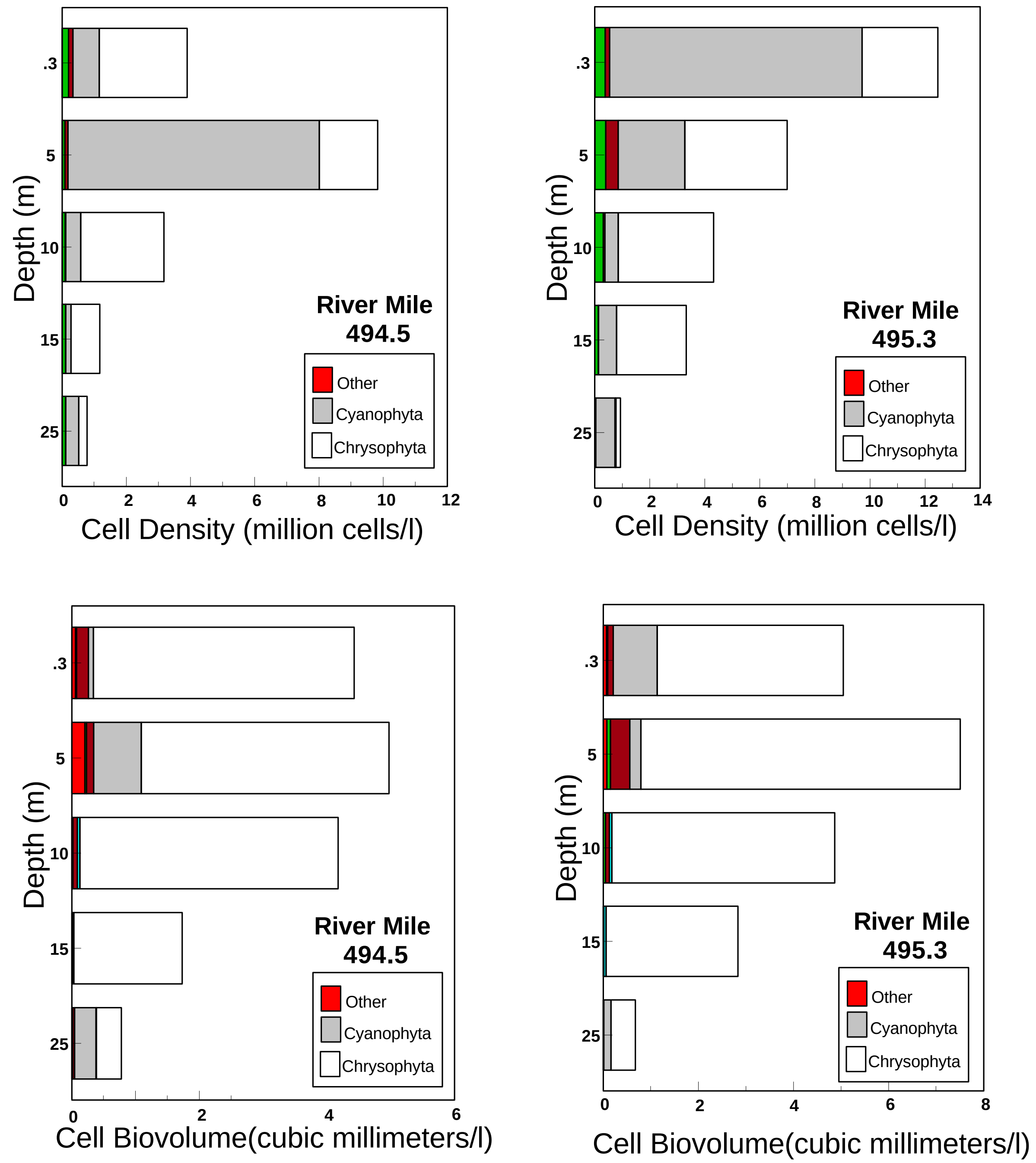


Figure 30. Average cell densities and biovolume for major phytoplankton divisions summarized by depth at RM 494.5 and RM 495.3 based on samples collected in 1994 and 1995.

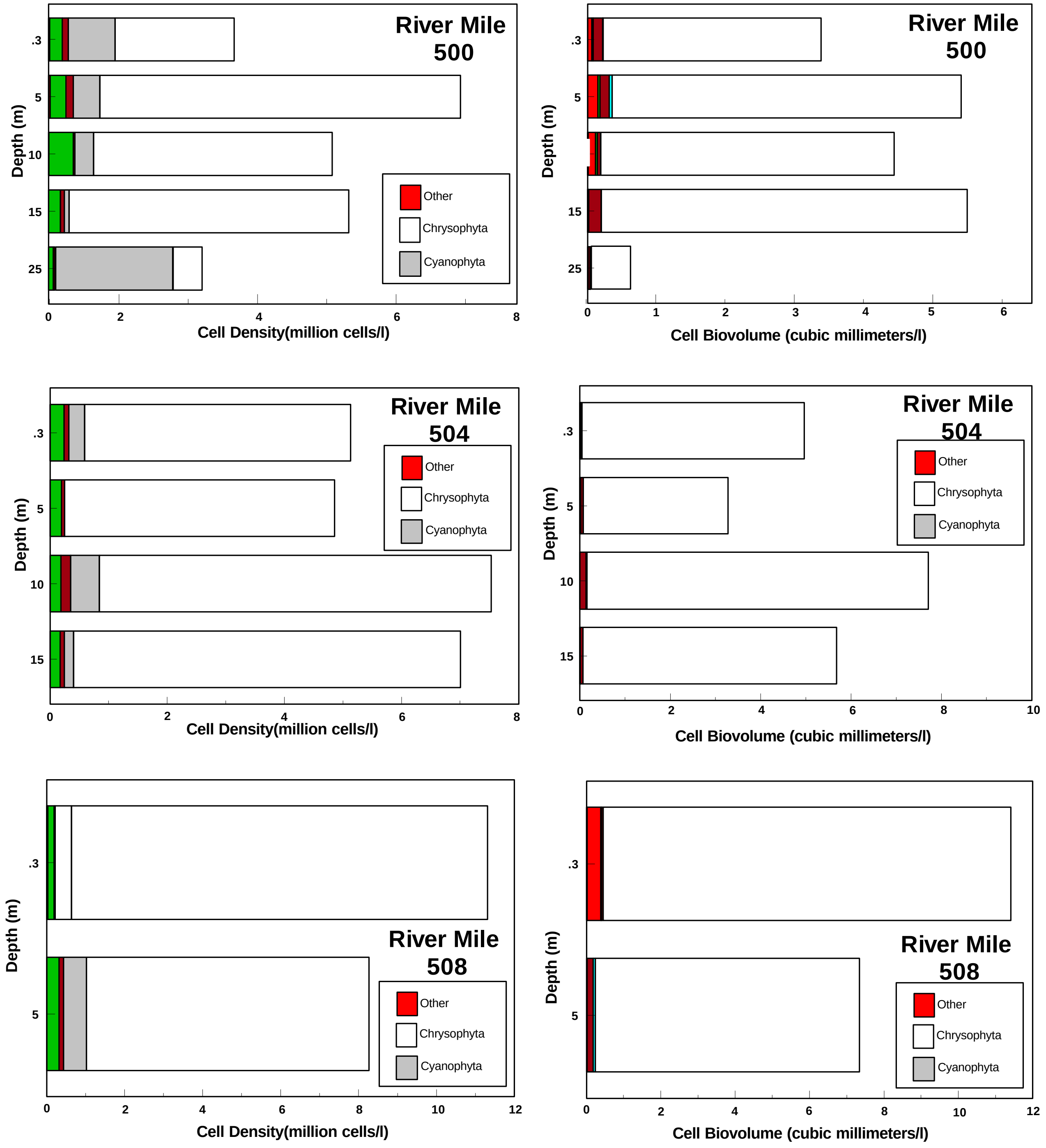


Figure 31. Average cell densities and biovolume for major phytoplankton divisions summarized by depth at RM 500, 504, and 508 based on samples collected in 1994 and 1995.

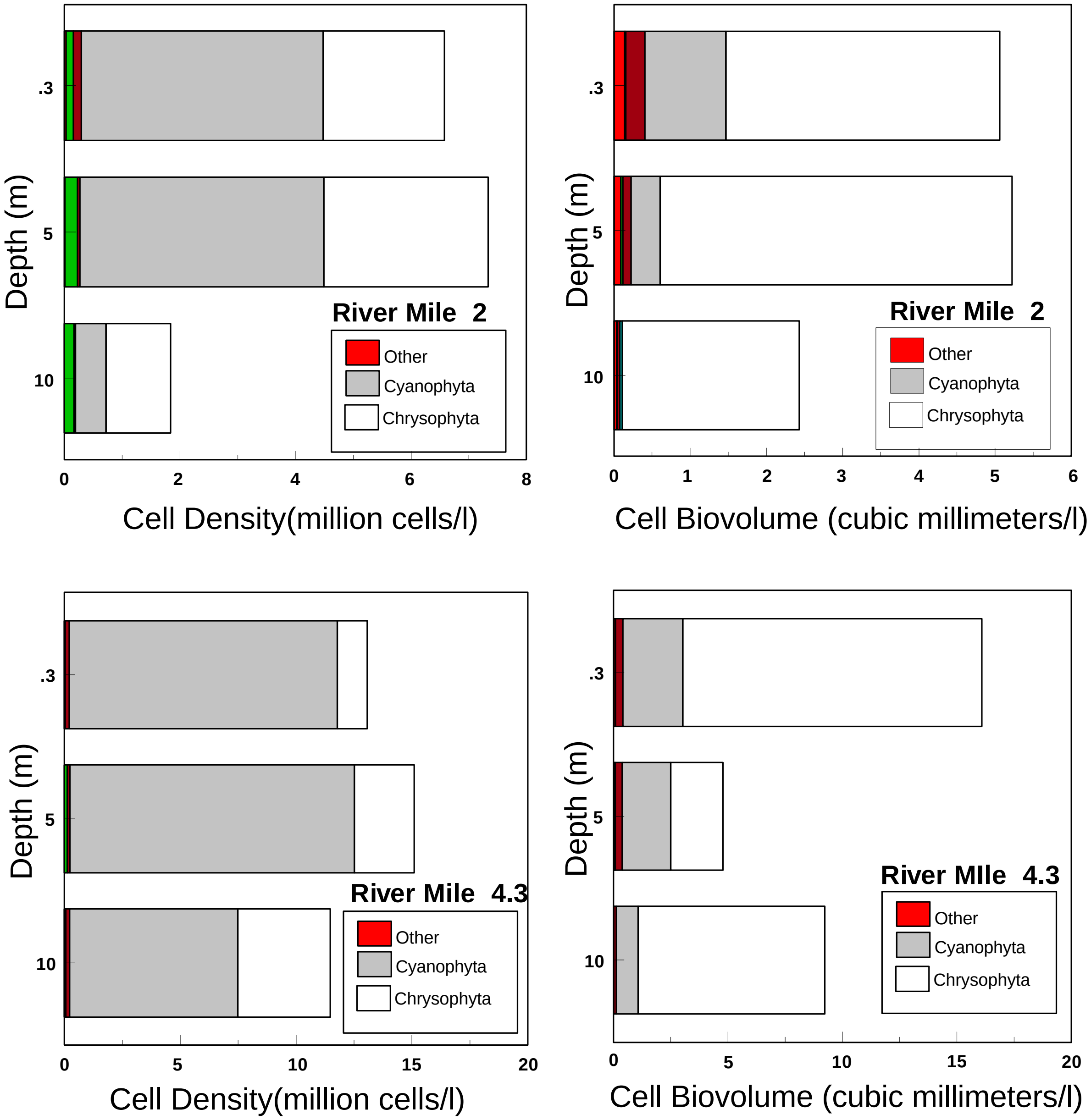


Figure 32. Average cell densities and biovolume for major phytoplankton divisions summarized by depth at RM 2 and 4.3 in the Bruneau Arm of C.J. Strike Reservoir based on samples collected in 1994 and 1995.

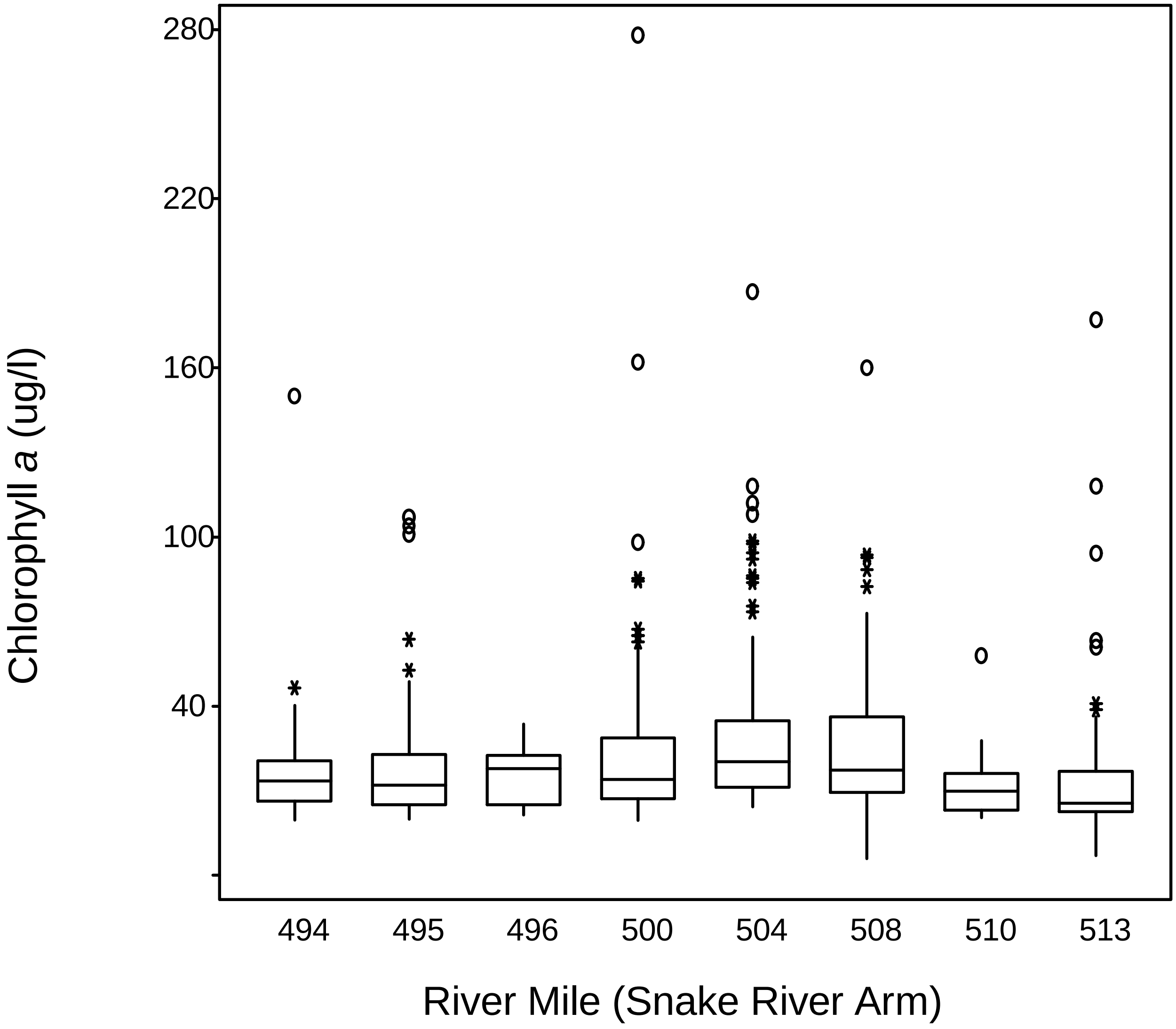


Figure 33. Box and whisker plot of chlorophyll *a* levels measured at eight sites along the length of C.J. Strike Reservoir during 1994 and 1995.

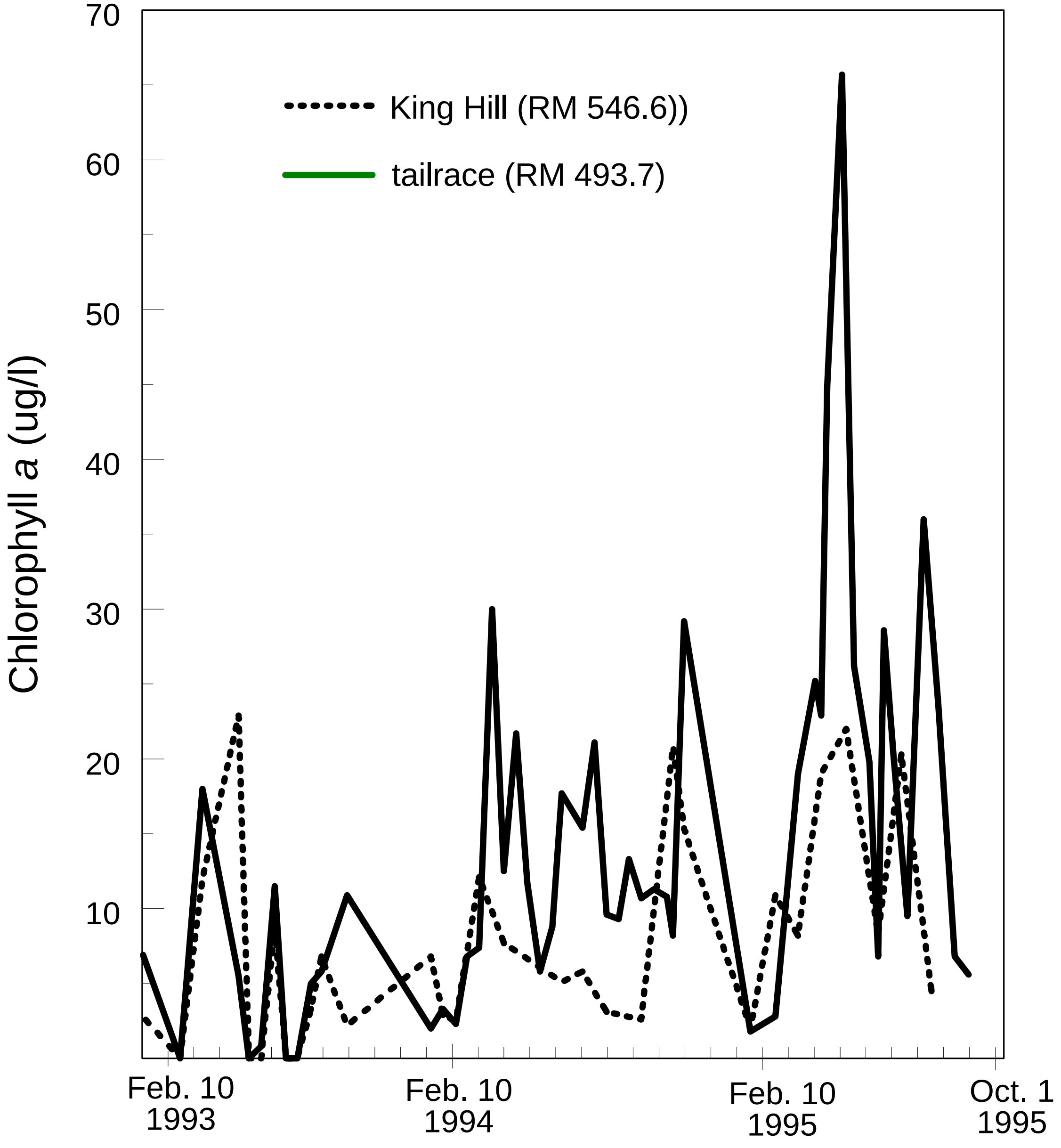


Figure 34. Summary plot of chlorophyll *a* levels measured in water at King Hill (RM 546.6) and in the tailrace of C.J. Strike Dam (RM 493.7), October 1993–September 1995.

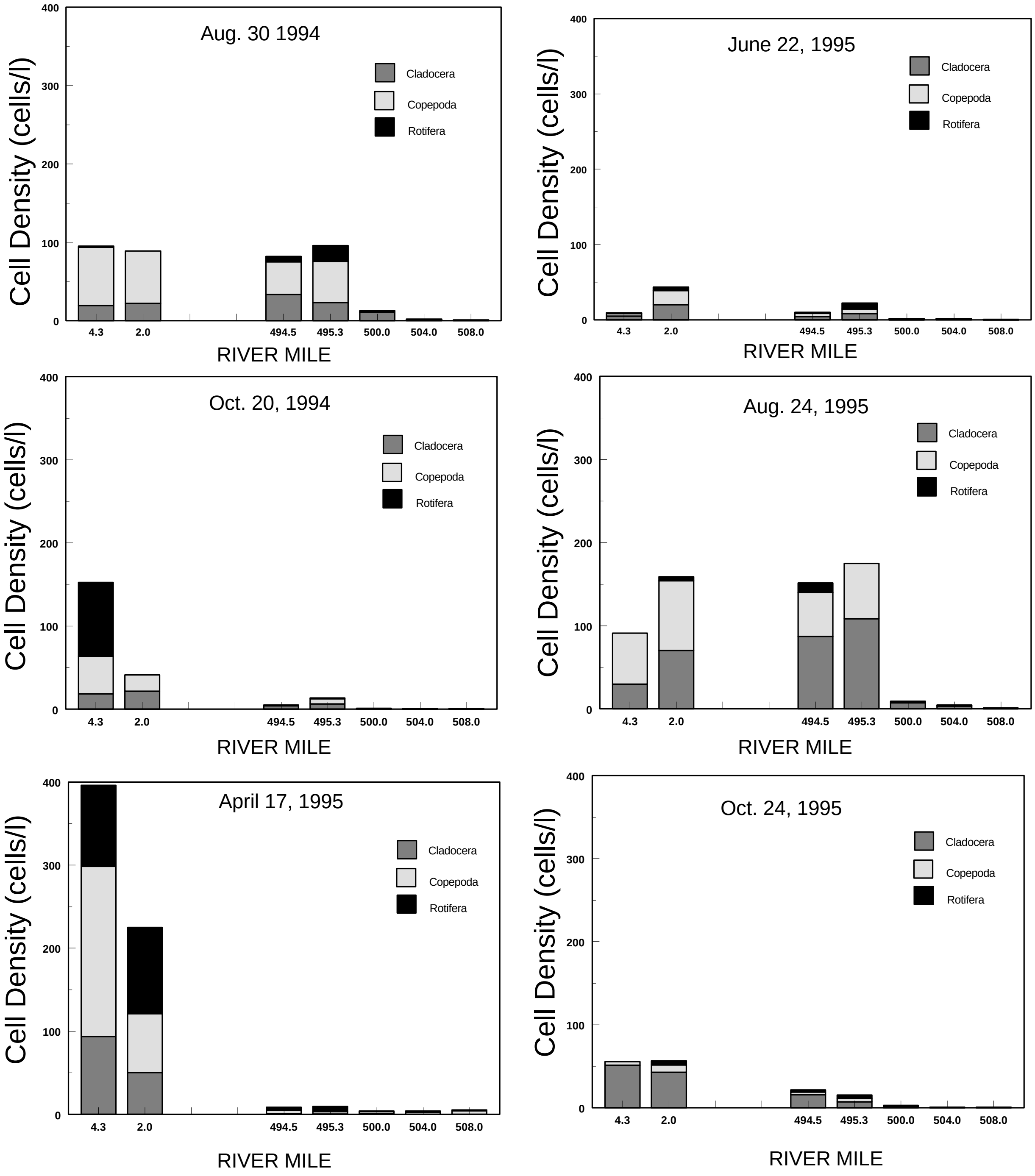


Figure 35. Cell densities for zooplankton divisions on six dates in 1994 and 1995 from samples collected at depths of 5 meters or less at seven sites throughout C.J. Strike Reservoir.

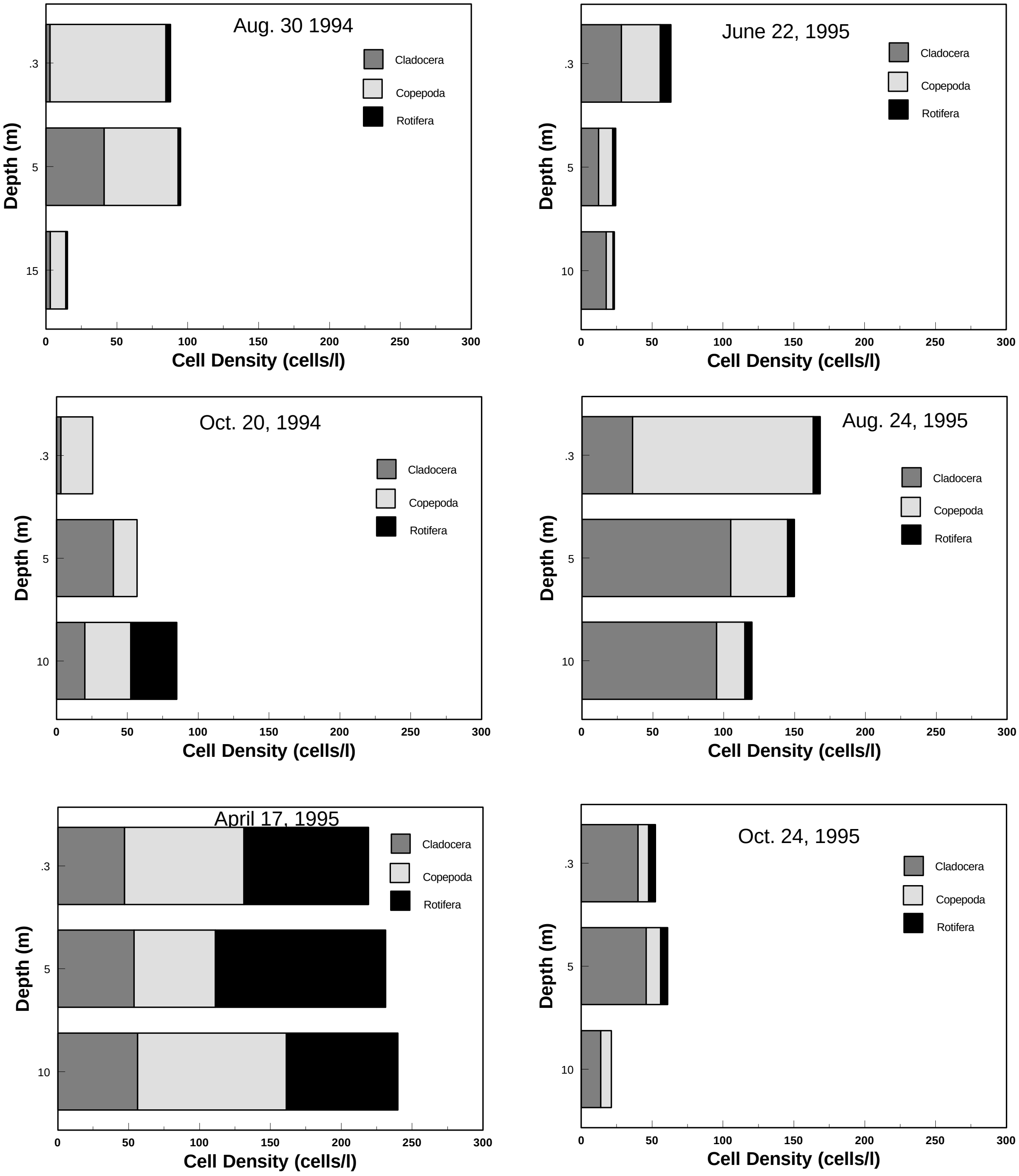


Figure 36. Zooplankton densities summarized by depth at RM 2 (Bruneau Arm) of C.J. Strike Reservoir on six sampling dates in 1994 and 1995.

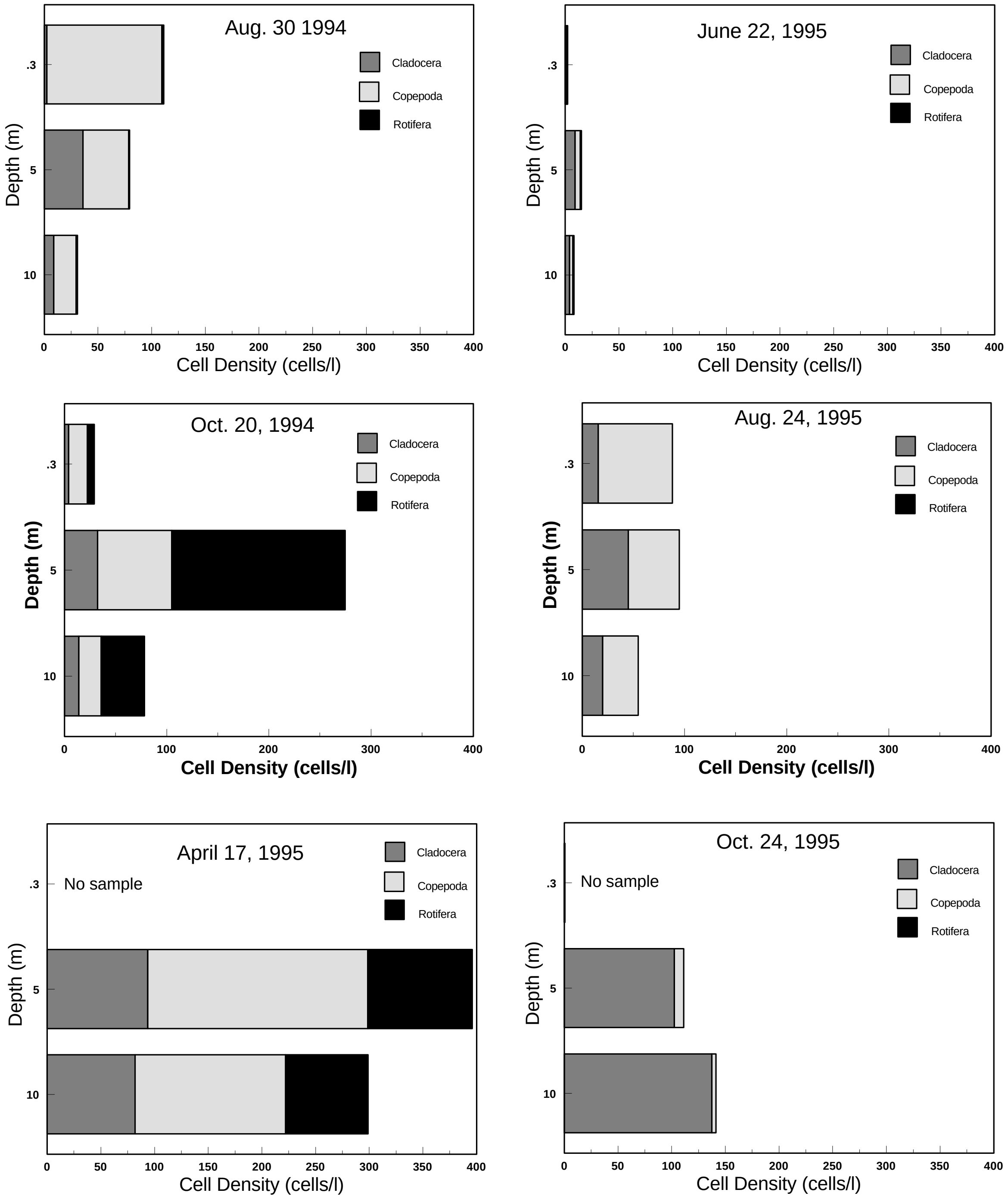


Figure 37. Zooplankton densities summarized by depth at RM 4.3 (Bruneau Arm) of C.J. Strike Reservoir on six sampling dates in 1994 and 1995.

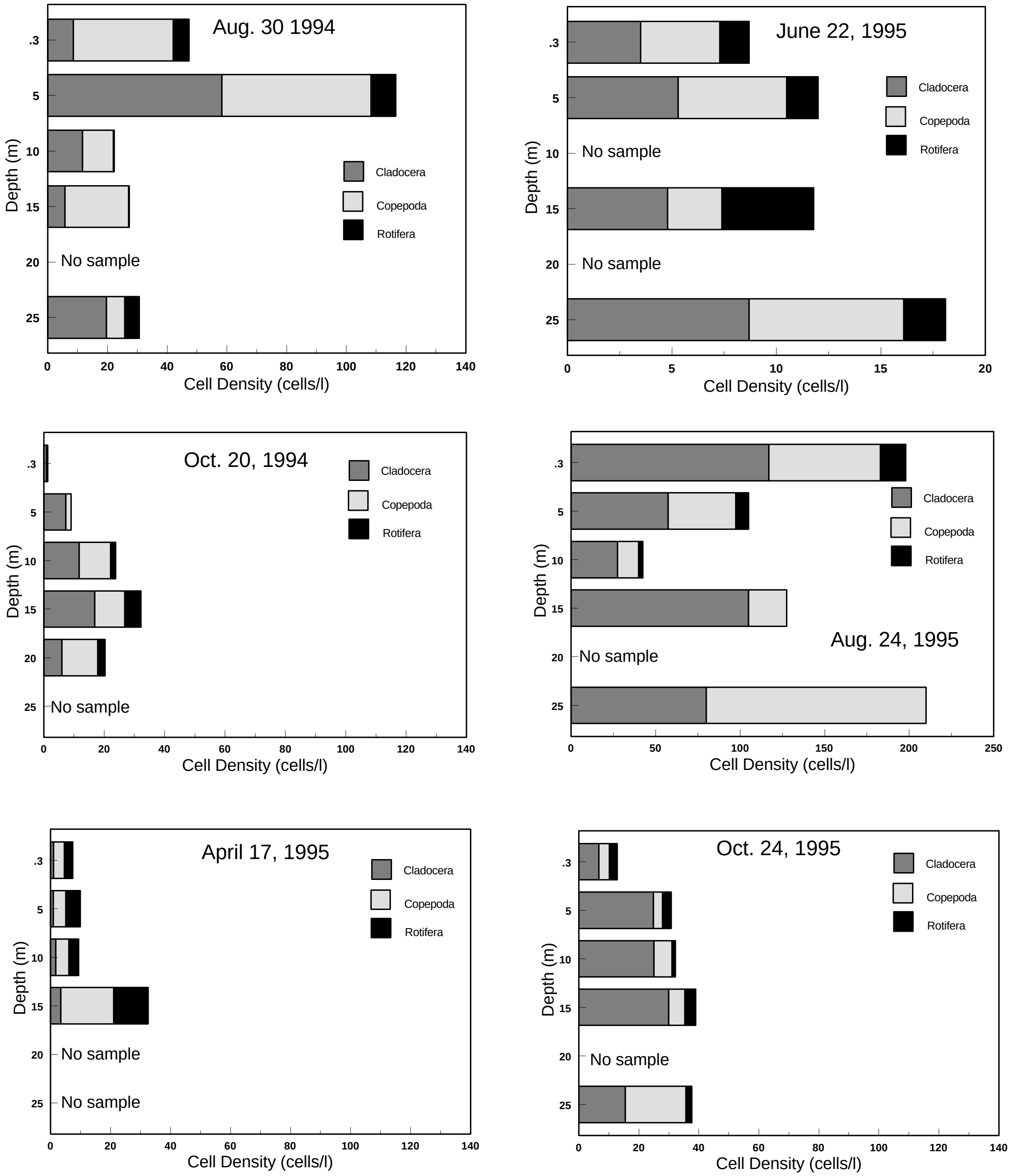


Figure 38. Zooplankton densities summarized by depth at RM 494.5 (Snake River Arm) of C.J. Strike Reservoir on six sampling dates in 1994 and 1995.

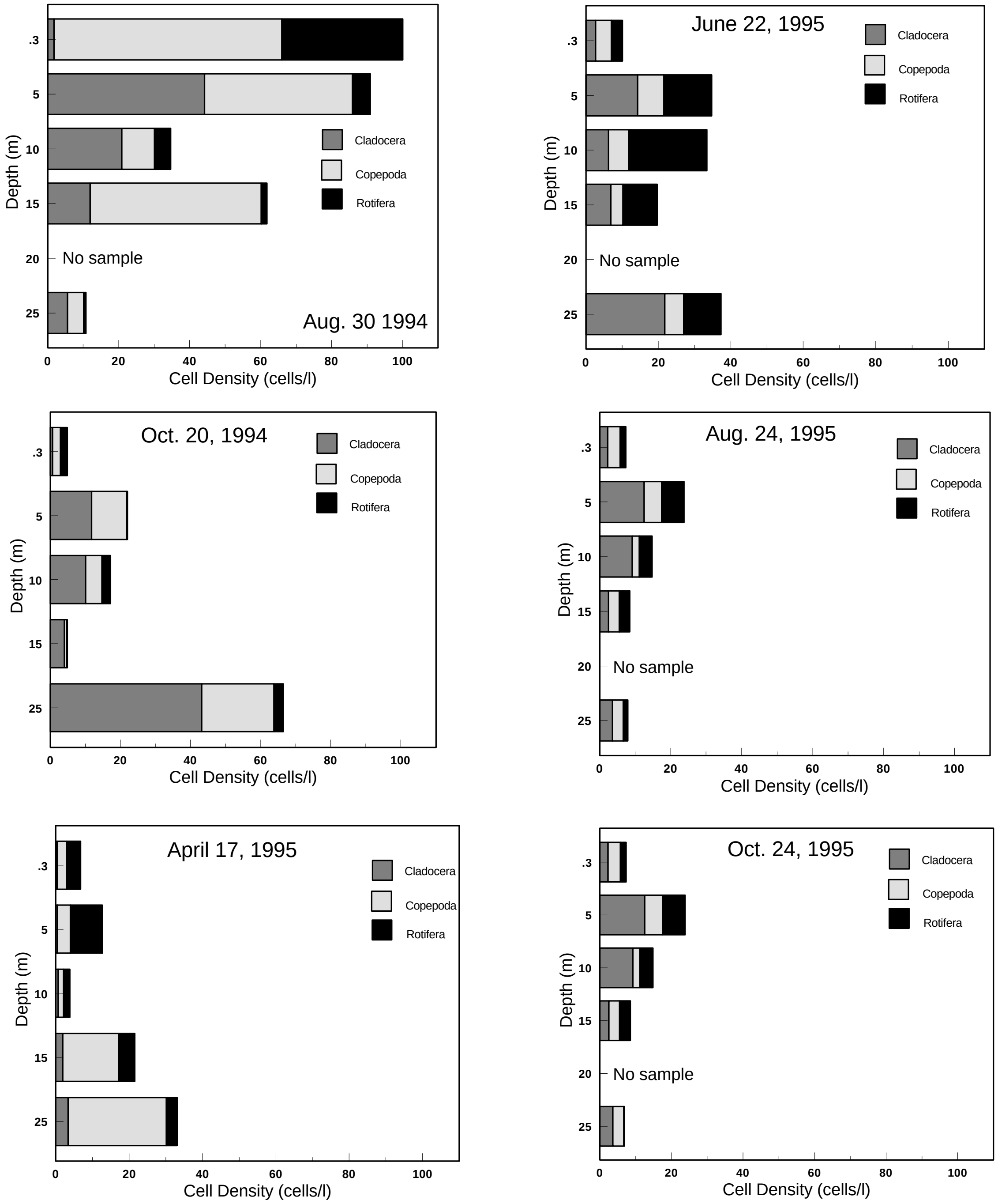


Figure 39. Zooplankton densities summarized by depth at RM 495.3 (Snake River Arm) of C.J. Strike Reservoir on six sampling dates in 1994 and 1995.

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