# OBSERVATIONS OF WATER QUALITY IN THE MIXED REACH BELOW THE CONFLUENCE OF THE SACRAMENTO AND FEATHER RIVERS, CALIFORNIA AUGUST AND NOVEMBER 1975

U. S. GEOLOGICAL SURVEY

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## CONVERSION FACTORS

For readers who may prefer to use metric units (International System of Units) rather than English units, the conversion factors for the terms used in this report are listed below.

| *English* | *Multiply by:* | *Metric* |
|---|---|---|
| acre-ft (acre-feet) | $1.234 \times 10^{-3}$ | $hm^3$ (cubic hectometers) |
| ft (feet) | $3.048 \times 10^{-1}$ | m (meters) |
| $ft^3/s$ (cubic feet per second) | $2.832 \times 10^{-2}$ | $m^3/s$ (cubic meters per second) |
| in (inches) | $2.540 \times 10$ | mm (millimeters) |
| mi (miles) | 1.609 | km (kilometers) |

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## ABSTRACT

The area near the confluence of the Sacramento and Feather Rivers was selected for study of water-quality changes that occur when two large rivers mix. Water-quality measurements were made during August 13-14 and November 4-5, 1975. Considering the concentrations of most of the properties and constituents measured, the mixing of the Sacramento and Feather Rivers generally occurs as simple dilution. Specific conductance and silica had consistently larger measured values than theoretical values in the mixed reach. Some deviations from the theoretical value for any one characteristic in the mixed water are probably the result of physical forces such as upwelling near the confluence of the two rivers, or the concentrating effect of evaporation as the mixed water in the Sacramento River flows downstream. Other deviations in values of constituent concentrations or other properties may be the result of plant and animal activities in the water. Benthic invertebrates and phytoplanktonic similarity indexes between selected paired sites correspond to the quantity of water common to each site. Paired sites with the least volume of water in common had the lowest similarity indexes.

# INTRODUCTION

The number of water-quality studies in large rivers has increased because these rivers are now being used more intensively for commerce, recreation, water supply, and waste disposal. The Sacramento River is large, ranking 22d in the United States on the basis of discharge (Iseri and Langbein, 1974). From a water-supply standpoint, it is one of the more important rivers in California. In most years, a large percentage of Sacramento River water is conveyed to southern California where it is used in the Los Angeles basin (California Department of Water Resources, 1974). Because of the river's importance, a study was made in 1960-61 to determine baseline physical, chemical, and biological conditions (California Department of Water Resources, 1962). The Sacramento River was again studied in 1972-73 (Britton and Averett, 1974) to determine what effect more intensive use of the river has had on water quality since the early 1960's. As part of the 1972-73 Sacramento River study, the horizontal and vertical differences in selected water-quality properties and constituents were evaluated to provide additional information for the design of future studies on the Sacramento River. Britton and Averett (1976) found that the water of the Sacramento River at Bend Bridge is generally well mixed, and one sample represents the chemical quality within a stream transect. In larger streams and other reaches of the Sacramento River, complex flow patterns or large natural or manmade inflows could result in incomplete mixing of materials, requiring numerous samples within a transect in order to characterize the water quality. Mackay (1970) has shown that large confluent rivers, such as the Feather and Sacramento, may not completely mix for several miles from their junction. Within the reach where mixing is taking place, physical, chemical, and biological processes may produce water that is different in quality than would be expected from simple dilution.

Knowledge of resultant water-quality values below the confluence of two rivers is important in understanding complex interactions of aquatic ecosystems. An understanding of these interactions is necessary for predicting water-quality changes that might occur when various types of stresses are applied to a river system. In addition, knowledge of the mixing characteristics of two large confluent rivers provides information useful for selecting monitoring sites for water-quality studies of large rivers.

The area near the confluence of the Sacramento and Feather Rivers was selected for study of water-quality changes that occur when two large rivers mix (fig. 1). This study focused on the interaction of several biotic and abiotic components of the aquatic ecosystem. The biotic components included phytoplankton and benthic drift, both of which are important in energy flow and storage in river ecosystems. The abiotic components included those water-quality characteristics that were likely to have a direct influence on the distribution and abundance of the biotic components: Water temperature, specific conductance, dissolved oxygen, pH, silica, phosphorus, and organic carbon. Of ecological interest was whether or not the rivers mixed by simple dilution and whether or not mixing occurred by the same process during different seasons. Water-quality data were collected during two diel periods in August and November 1975.

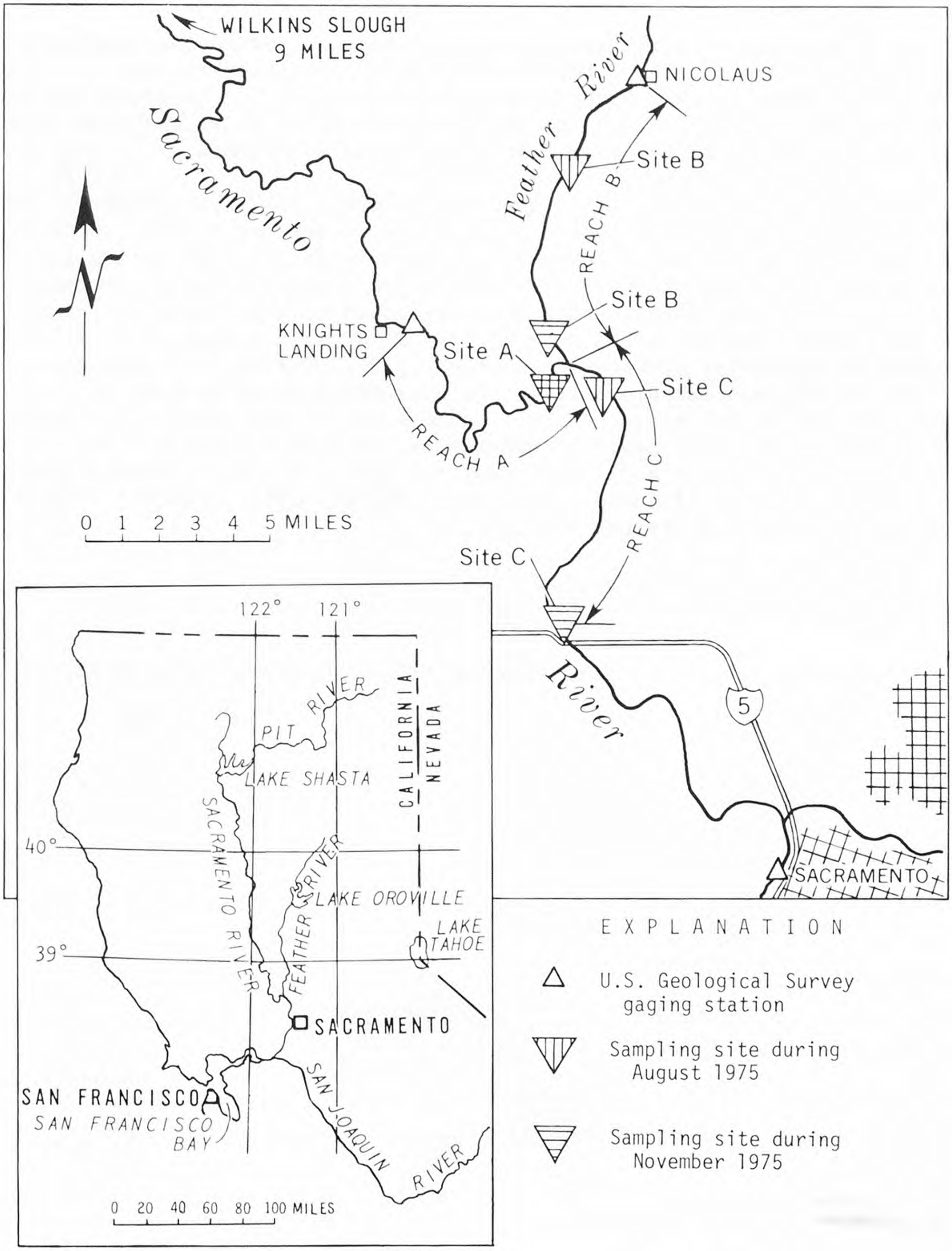



FIGURE 1.--Location of study area.

## STUDY AREA

The study area (fig. 1) included a 19.2-mi reach of the Sacramento River from Knights Landing to the Interstate 5 freeway overcrossing, and a 2.7-mi reach of the lower Feather River downstream from the U.S. Geological Survey gaging station near Nicolaus. The confluence is about 80 mi upstream from San Francisco Bay and 20 mi upstream from the city of Sacramento.

The Sacramento-Feather River area was selected for study primarily because previous water-quality data showed differences in the two rivers. Specific conductance and water temperature, for example, were two contrasting variables on which the selection of this water system for study was based. During March and April 1970, specific-conductance measurements in the Feather River at Nicolaus ranged from 69 to 103 micromhos at 25°C, with a mean of 87 micromhos (California Department of Water Resources, 1971). During this same period, specific-conductance measurements in the Sacramento River near Knights Landing ranged from 116 to 174 micromhos, with a mean of 149 micromhos (U.S. Geological Survey, 1970). The mean maximum temperatures between the Feather and Sacramento Rivers are markedly different throughout the May-September period (fig. 2)(U.S. Geological Survey, 1972-74). Depth, width, velocity, and thus discharge, also were different (table 1).

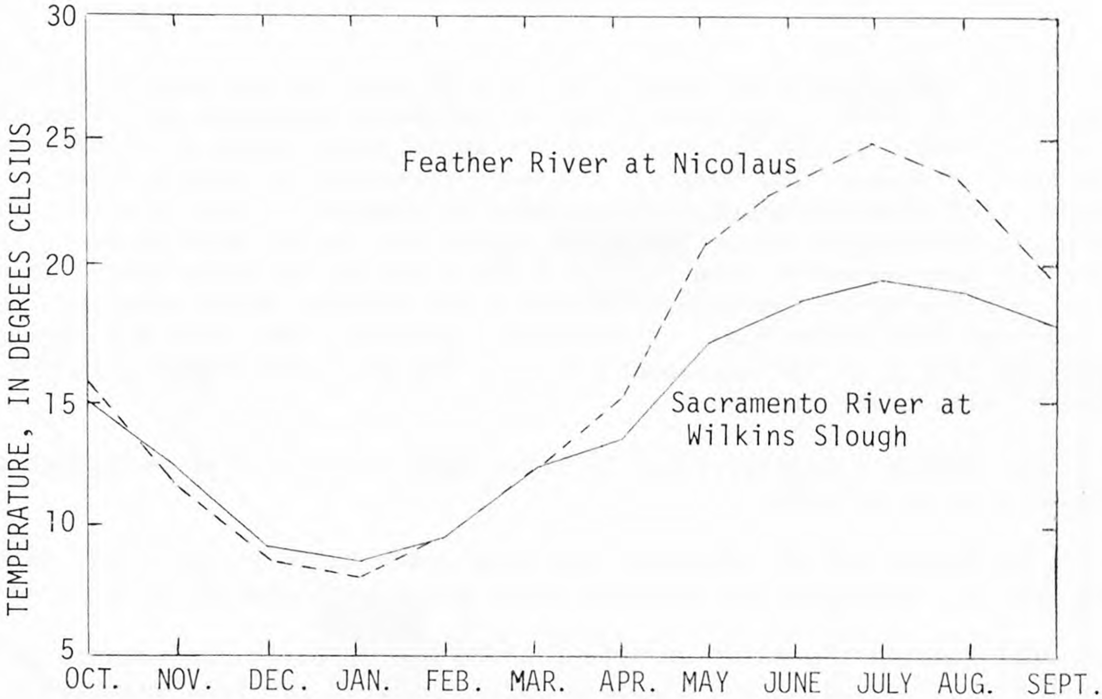



FIGURE 2.--Mean maximum monthly temperatures for 1972-74 water years.

Table 1.--*Daily mean discharge, depth, and approximate width at each sampling site during the August 13-14 and November 4-5 diel measurements*

[Site A = Sacramento River above Feather River; site B = Feather River; and site C = Sacramento River below Feather River]

| Measurements | Sites during August 13-14 | | | Sites during November 4-5 | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| Discharge ($ft^3/s$) | 8,610 | 6,600 | 15,800 | 9,600 | 5,950 | 16,000 |
| Depth (ft) | 20 | 5 | 12 | 26 | 7 | 20 |
| Width (ft) | 200 | 380 | 520 | 210 | 390 | 540 |

## SAMPLING METHODS AND ANALYSES

Diel measurements of water quality were made during August 13-14 and November 4-5, 1975. The August diel measurements provided data from the mixed zone in reach C in the Sacramento River immediately below its confluence with the Feather River. The boating procedure from site to site throughout the August diel study is shown schematically in figure 3. The locations of sampling sites A and B were selected during the August diel study to insure that the sampled water from reaches A and B met at the same time. This was done by allowing for sample-collection time, average river velocity, and downstream boat traveltime. A comparable procedure was used for locating sampling site C in the Sacramento River. The point of sampling in the mixed zone at site C was located by:

(1) Mixing a sample volume of water from each river proportional to the measured river volumes,

(2) Comparing the resultant specific conductance in this test solution to the specific conductances measured along a cross section at site C, and

(3) Finding the point at site C where the specific conductance on the cross section equalled the specific conductance of the test solution.

The November diel measurements provided data on water-quality changes after the two rivers had completely mixed. Sampling during this diel study was done by a boat crew anchored at each site (fig. 4). Sampling intervals were scheduled to allow water passing sites A and B to meet at about the same time in reach C, similar to that in the August diel study. Sampling site B was relocated farther downstream from the August sampling site to compensate for flow traveltime. The beginning of the completely mixed zone, 9.5 mi downstream from the confluence, was located by cross-sectional measurements of specific conductance and water temperature. The distance of the mixed zone from the confluence required that sampling site C be relocated farther downstream from the August sampling site.

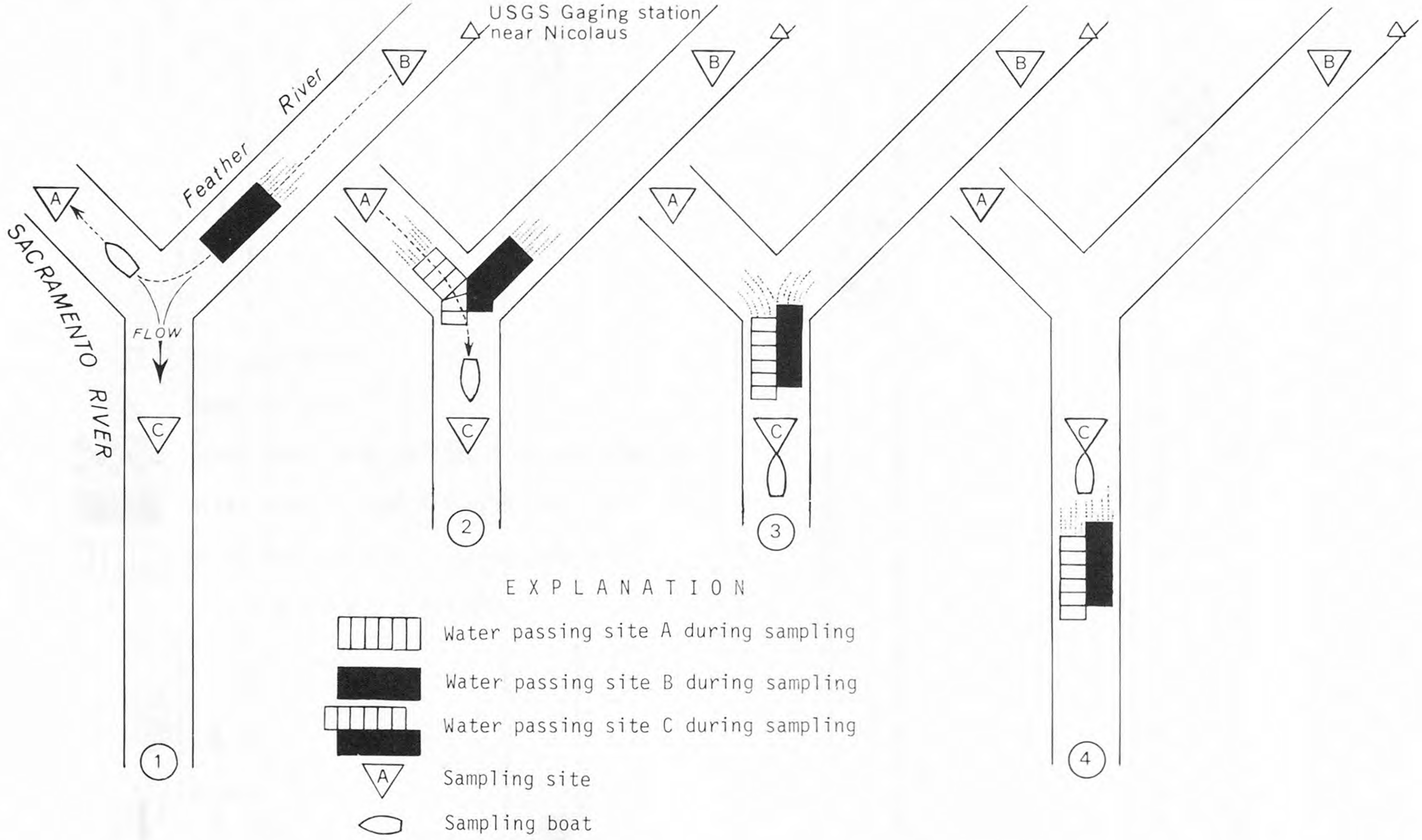



FIGURE 3.--Schematic of boating procedure used to obtain samples from the Feather and Sacramento Rivers during the August 13-14 diel measurements.

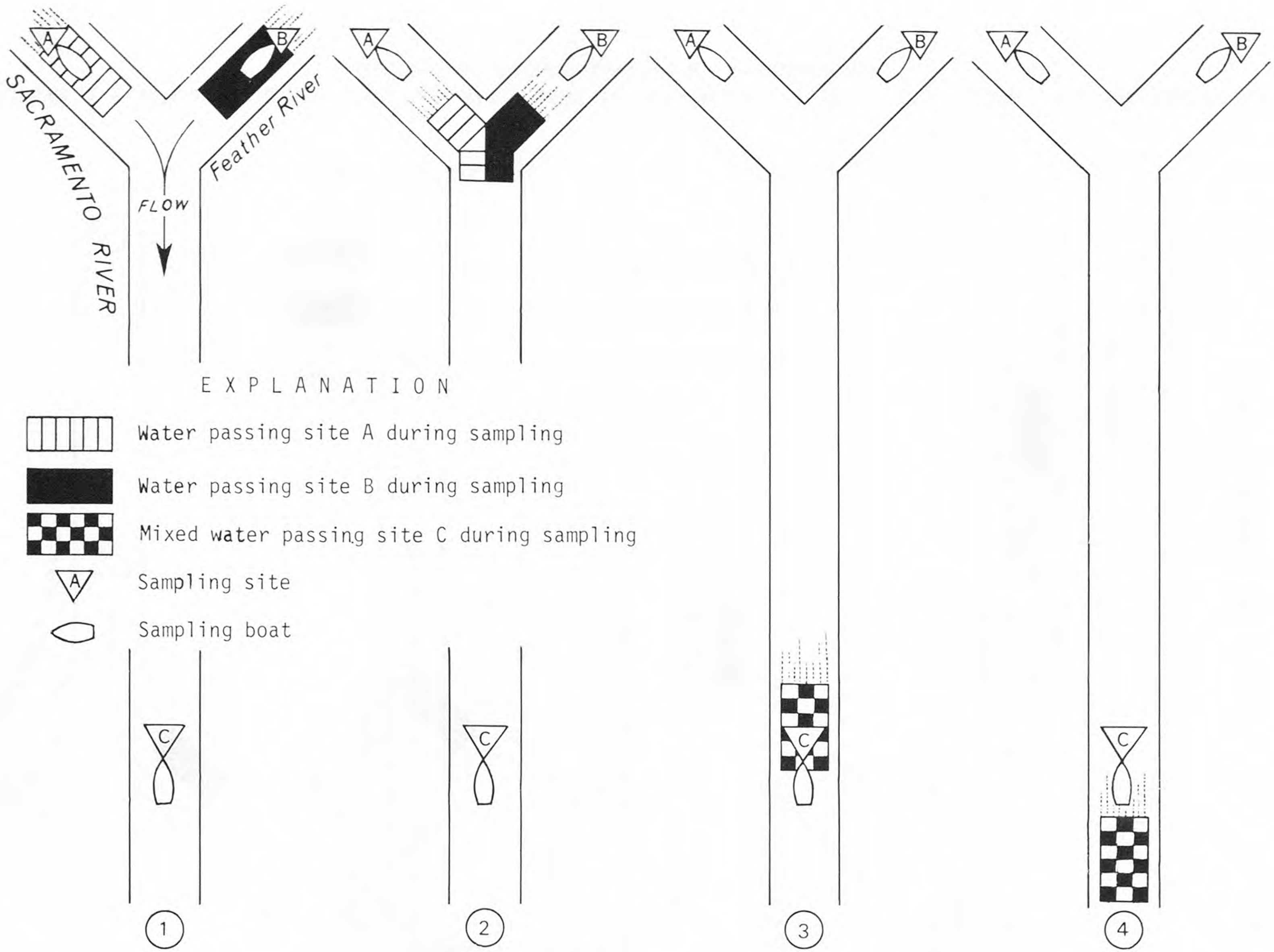



FIGURE 4.--Schematic of boating procedure used to obtain samples from the Feather and Sacramento Rivers during the November 4-5 diel measurements.

Samples of water were collected using a D-49 sampler (Guy and Norman, 1970) at the centroid of flow. But, water samples collected at site C in August may not have been from the centroid of flow, because they were collected in the zone of mixing in the Sacramento River below its confluence with the Feather River.

Specific conductance, water temperature, dissolved oxygen, and pH were measured with a multipurpose instrument. Most measurements were made about 1 m below the water surface; however, additional measurements were occasionally made at middepth and near the river bottom. River velocity, depth, and width were used to determine discharge measurements, using methods described by Buchanan and Somers (1969).

Water samples collected for the determination of total-phosphorus concentrations were kept chilled until analysis. Water samples collected for the determination of dissolved phosphorus and silica were filtered through a prerinsed 0.45-micrometer membrane filter and chilled to 4°C or lower. Water samples for seston analysis were preserved with mercuric chloride and chilled to 4°C or lower. Water samples for dissolved-organic-carbon analyses were filtered through prerinsed 0.45-micrometer silver filters into glass bottles and chilled to 4°C or lower. The silver filters, which retained the suspended organic carbon, were placed in glass vials and chilled to 4°C or lower. All water samples for the previously mentioned chemical constituents, except for seston, were analyzed at the Geological Survey Central Laboratory in Salt Lake City, Utah, using methods described by Brown and others (1970) and Goerlitz and Brown (1972). Seston analysis was done at the Geological Survey Central Laboratory in Doraville, Ga., using methods described by Slack and others (1973).

Water samples for phytoplankton analysis were preserved with Lugol's solution (Slack and others, 1973). The algae were identified and counted by a commercial laboratory. Faunal drift (collected during the August diel measurements only) was sampled using drift nets with a frame size of 150 by 300 mm and and netting with a 210-micrometer mesh opening. Three nets were connected to a boat boom with one net just below water surface, a second net 1 m, and a third net 3 m below water surface (fig. 5). Because of shallow depths in the Feather River, only one net positioned at middepth was used. Each net was suspended in the river for a 30-minute collection period. After each collection period the net contents were removed and preserved with 40 percent isopropyl alcohol. The fauna in the drift samples were later identified and counted by a commercial laboratory.

Theoretical chemical-quality values were calculated for water flowing past site C, assuming that proportionate amounts of water from reaches A and B had completely mixed and that no chemical reactions had occurred.

To compare the composition of phytoplankton communities between sampling sites, the index of similarity, $S=2z/(y+x)$ (Odum, 1971), was used, where $y$ = number of taxa in sample $y$, $x$ = number of taxa in sample $x$, and $z$ = number of taxa common to both $x$ and $y$.

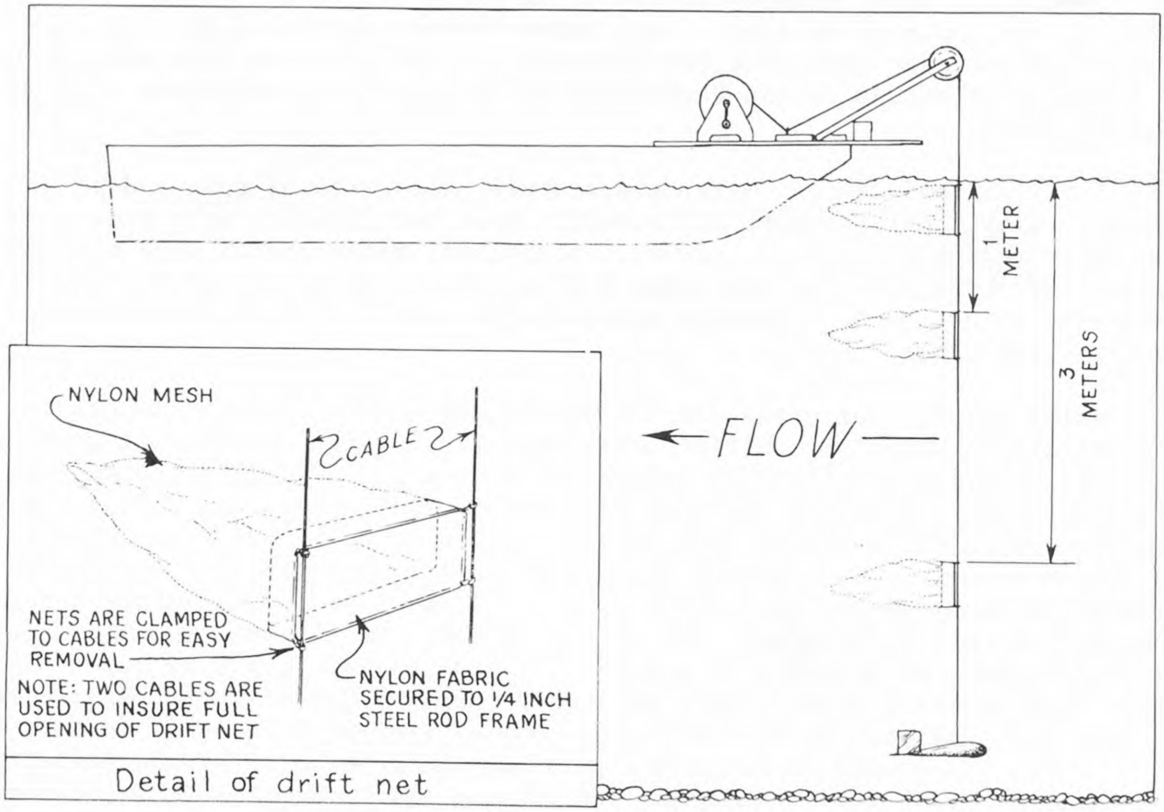



FIGURE 5.--Diagram of drift net apparatus.

# RESULTS

## Physical and Chemical

Water-quality data from each reach in the Sacramento and Feather Rivers are grouped into sampling intervals according to the time of day the water passed all three sites (figs. 6-16). Theoretical (calculated) water-quality values for each sampled water mass flowing past site C also are shown.

During both diel periods, most of the measured water-quality values were significantly larger in the Sacramento River at site A than in the Feather River at site B (table 2). Temperatures during August and dissolved oxygen during November were the only water-quality values significantly larger at site B than at site A.

Most of the water-quality characteristics showed no significant difference between theoretical and measured values in reach C (table 3). Specific conductance and silica in reach C were the only water-quality variables that had consistently larger measured than theoretical values.

Three chemical and physical characteristics showed cyclic trends during the diel periods. During the August diel measurements, dissolved oxygen and temperature showed diel cycling, with high oxygen values at each sampling site occurring in sampling intervals I and II and high temperature values at each sampling site occurring in sampling intervals I, II, and III (figs. 6 and 7). During the November diel measurements, dissolved oxygen did not display a cyclic pattern at site B in the Feather River nor at site C in the Sacramento River; however, there was a slight peak at site A in sampling intervals I and VI in the Sacramento River. Temperature values in the Feather River peaked in sampling interval III during the November diel measurements. During the August diel period, specific conductance at site C showed a slight cyclic pattern with low conductance occurring during sampling intervals II and III (fig. 8). During the November diel period, specific conductance at sites A and C showed a slight cyclic pattern with low conductance occurring during sampling intervals IV and V (fig. 8).

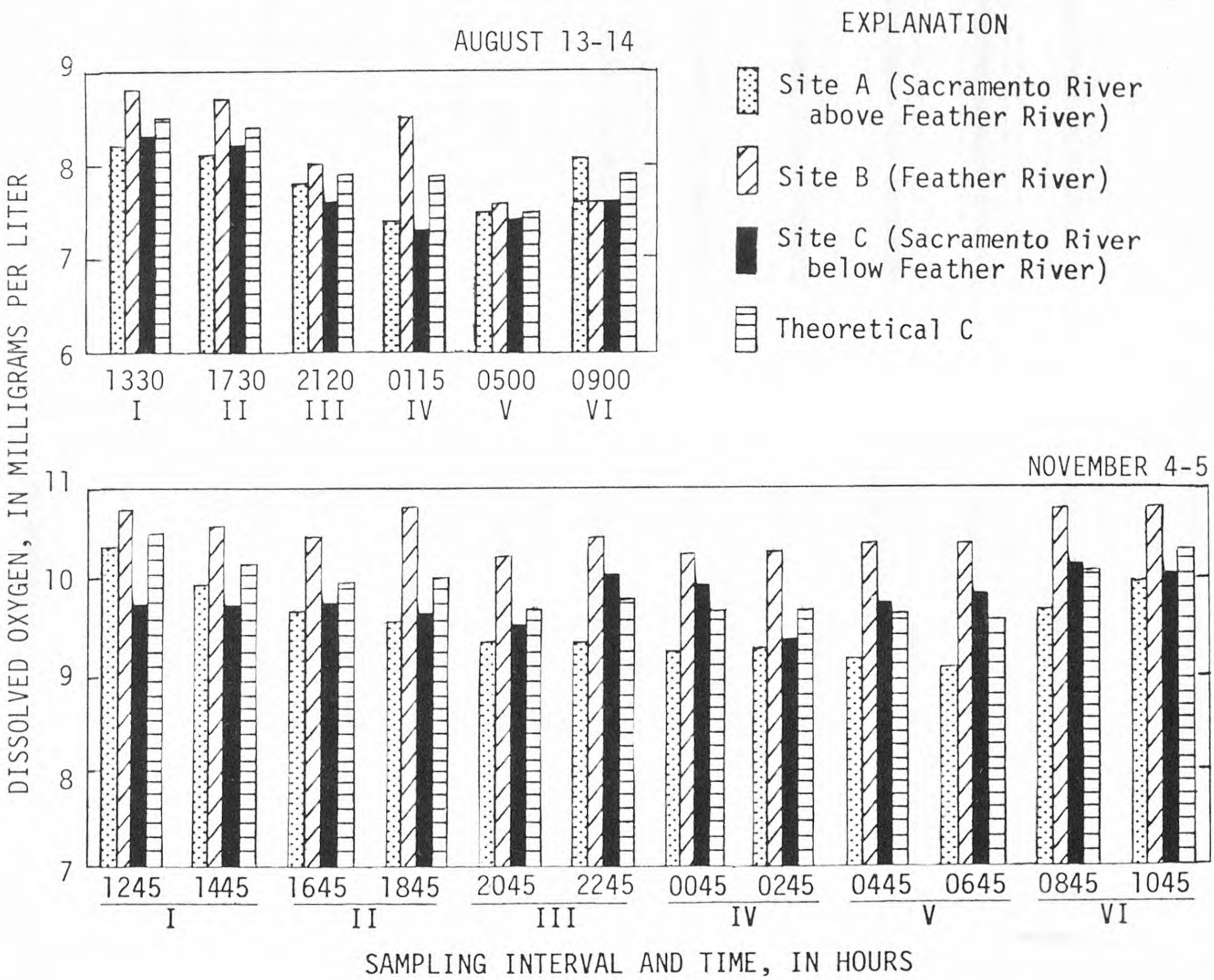



FIGURE 6.--Dissolved-oxygen concentration during August and November diel measurements.

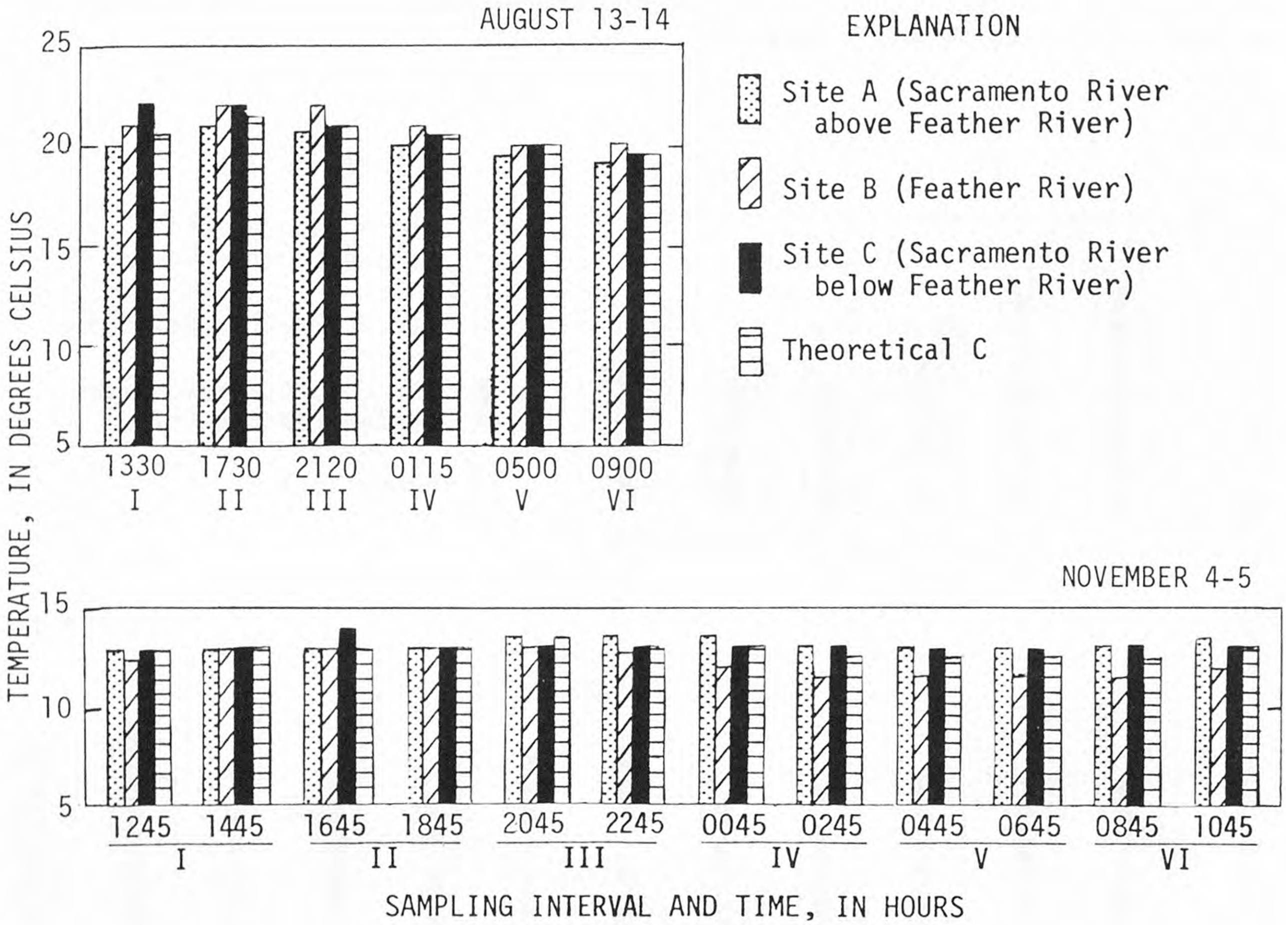



FIGURE 7.--Temperature during August and November diel measurements.

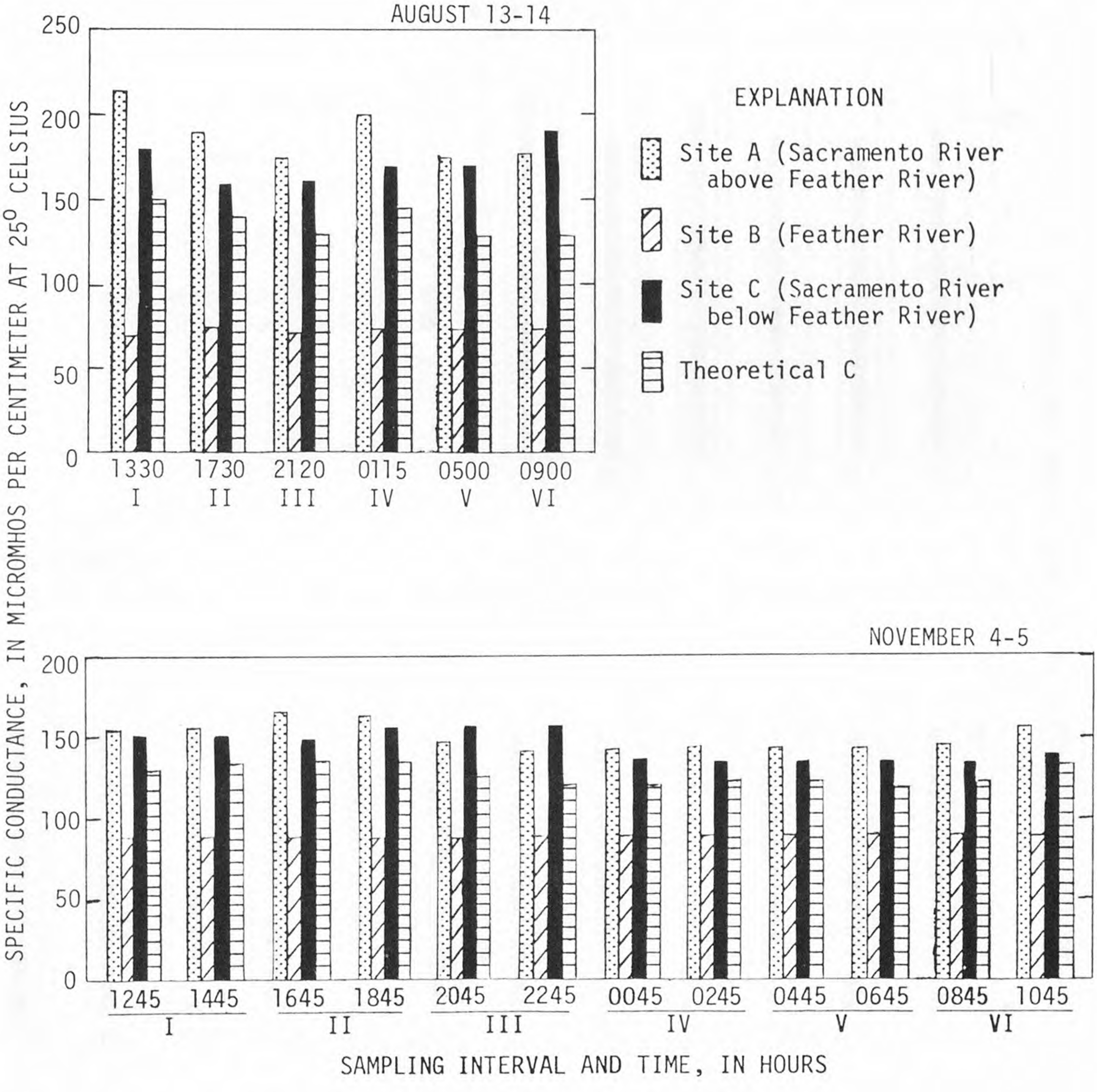



FIGURE 8.--Specific conductance during August and November diel measurements.

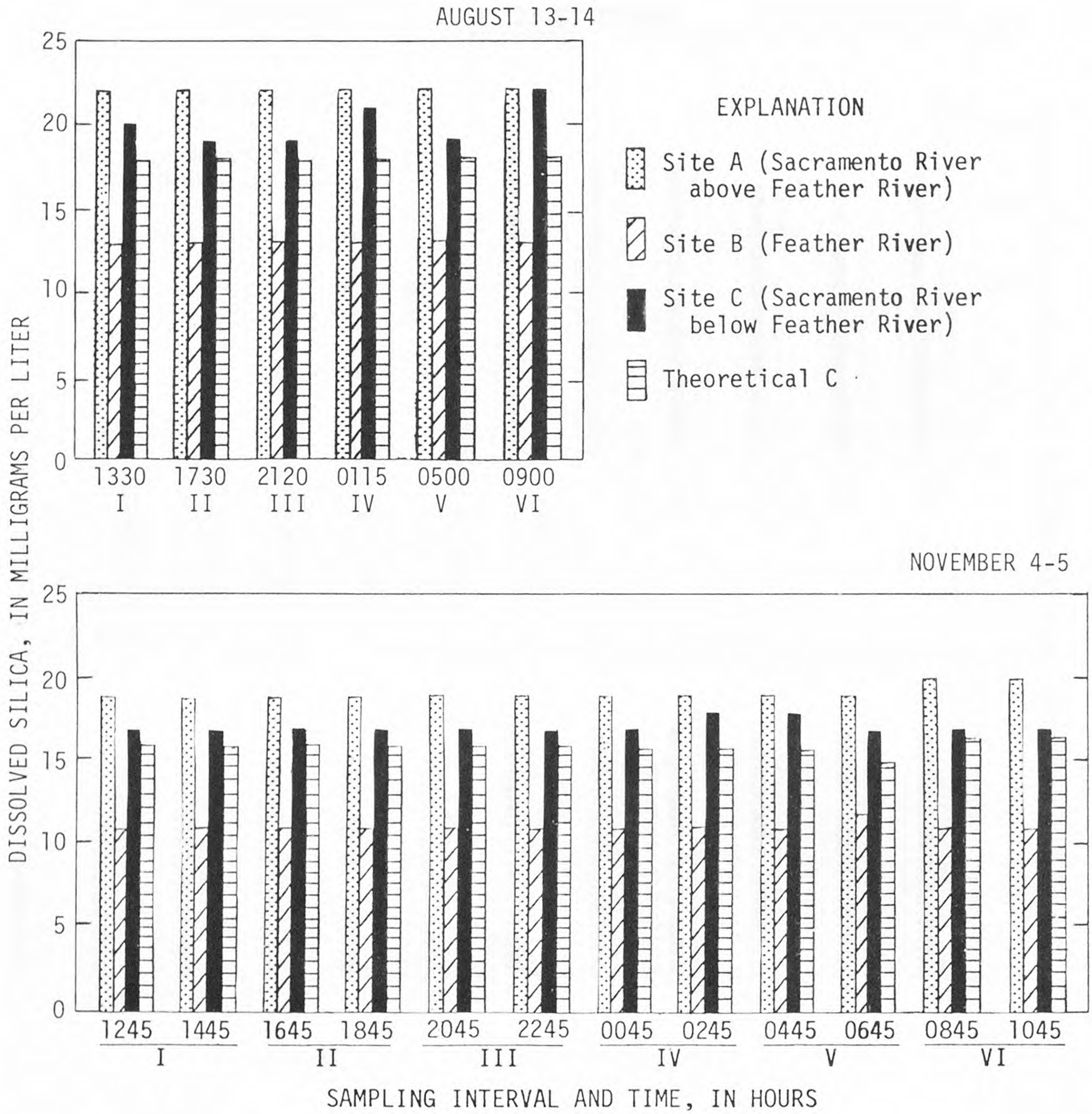



FIGURE 9.--Silica concentration during August and November diel measurements.

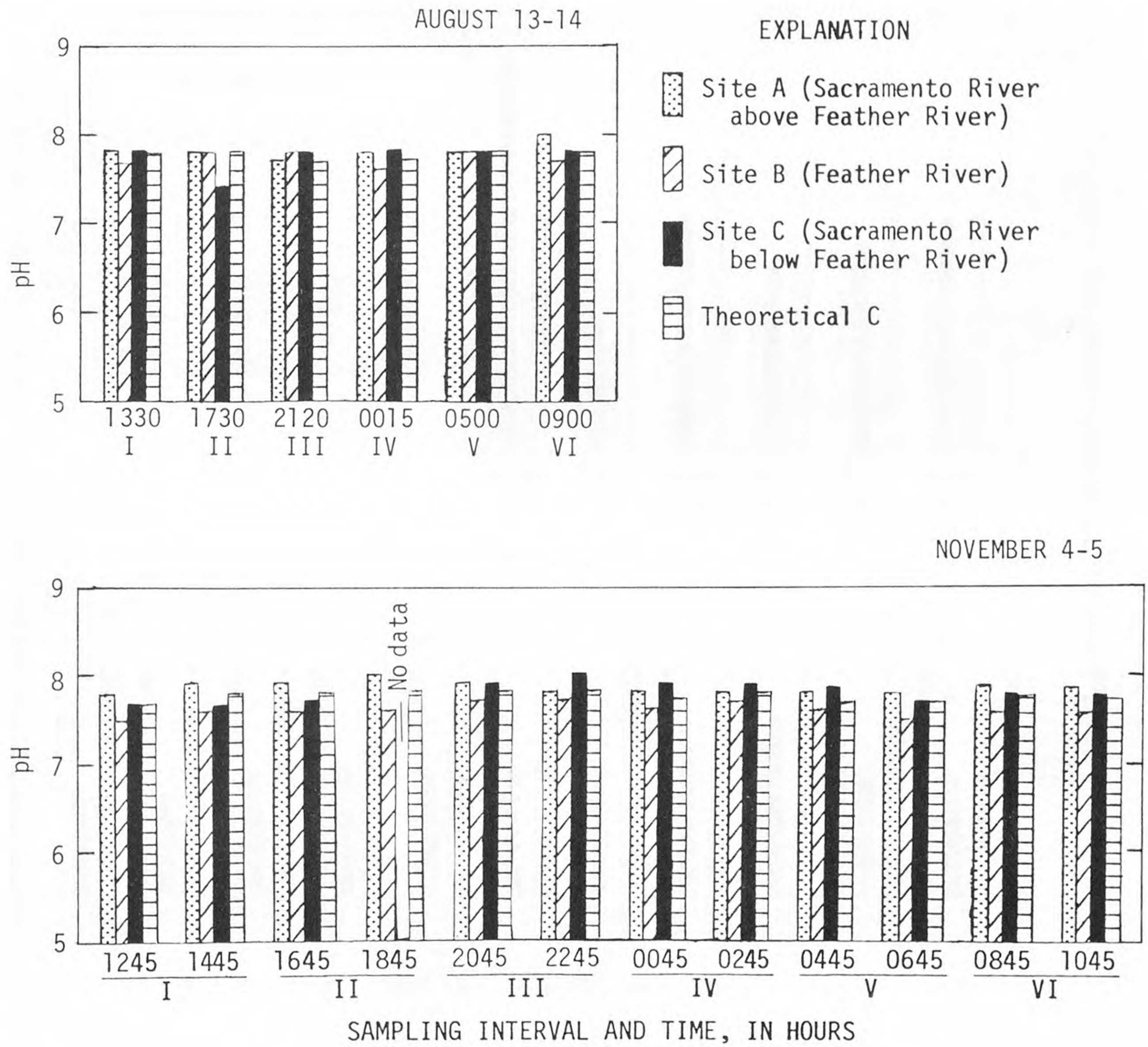



FIGURE 10.--pH during August and November diel measurements.

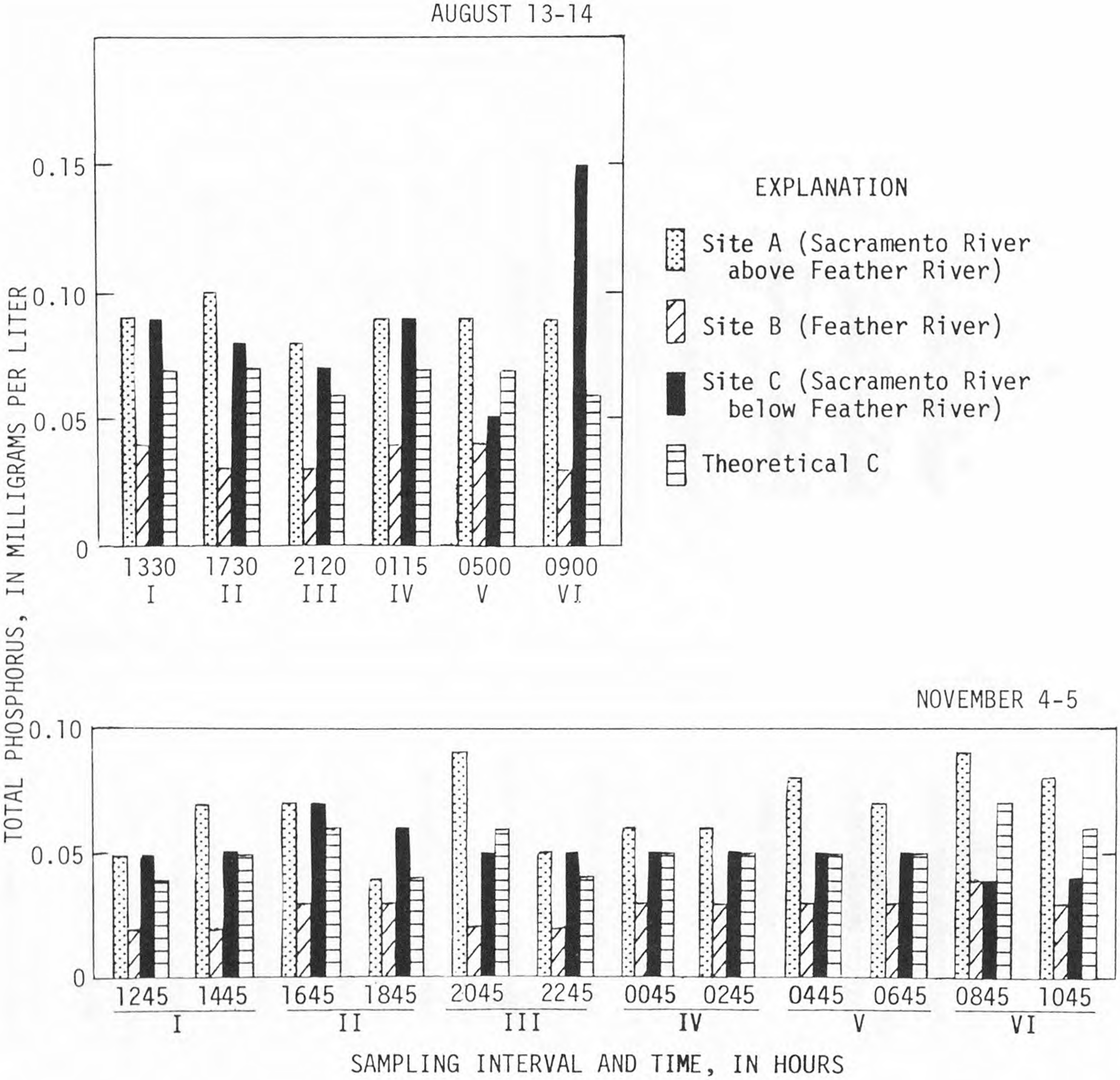



FIGURE 11.--Total-phosphorus concentration during August and November diel measurements.

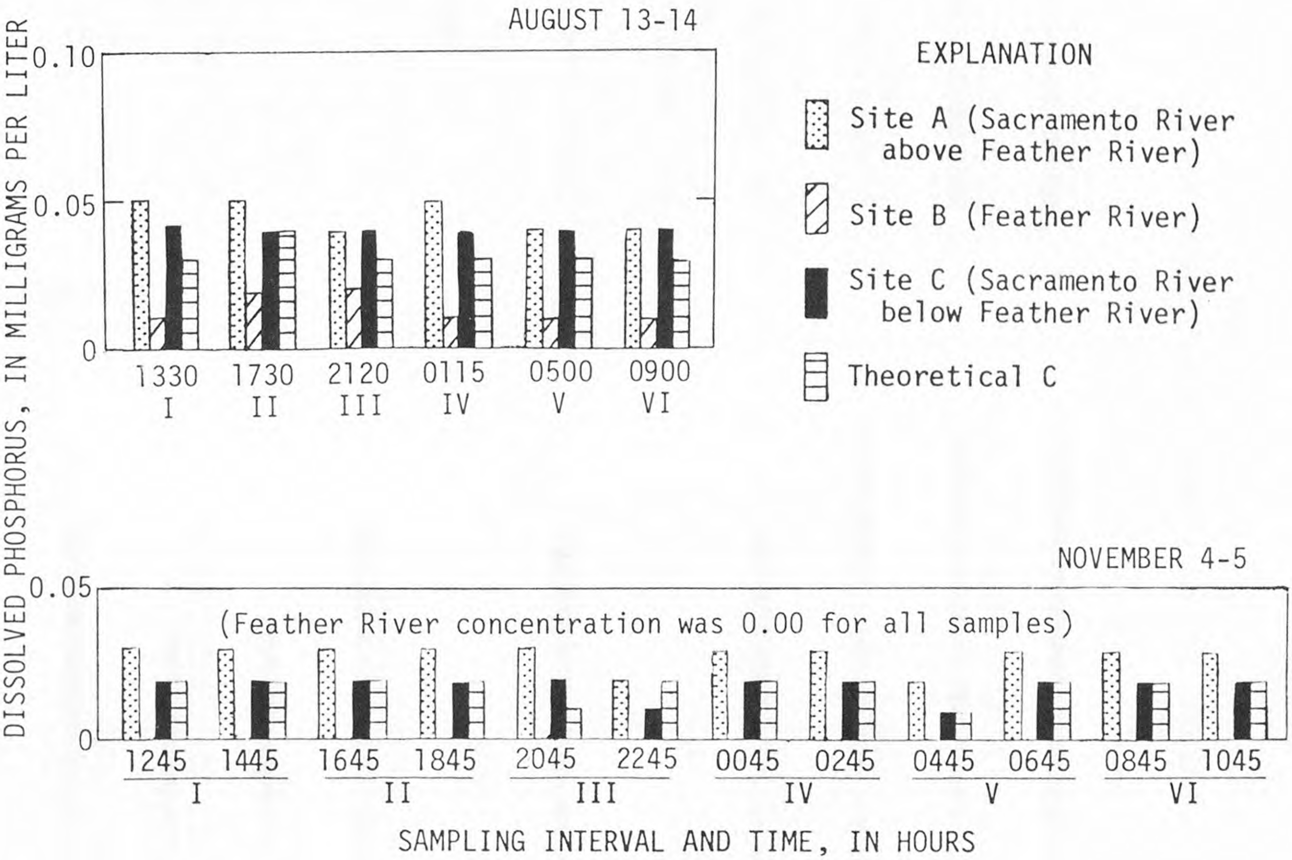



FIGURE 12.--Dissolved-phosphorus concentration during August and November diel measurements.

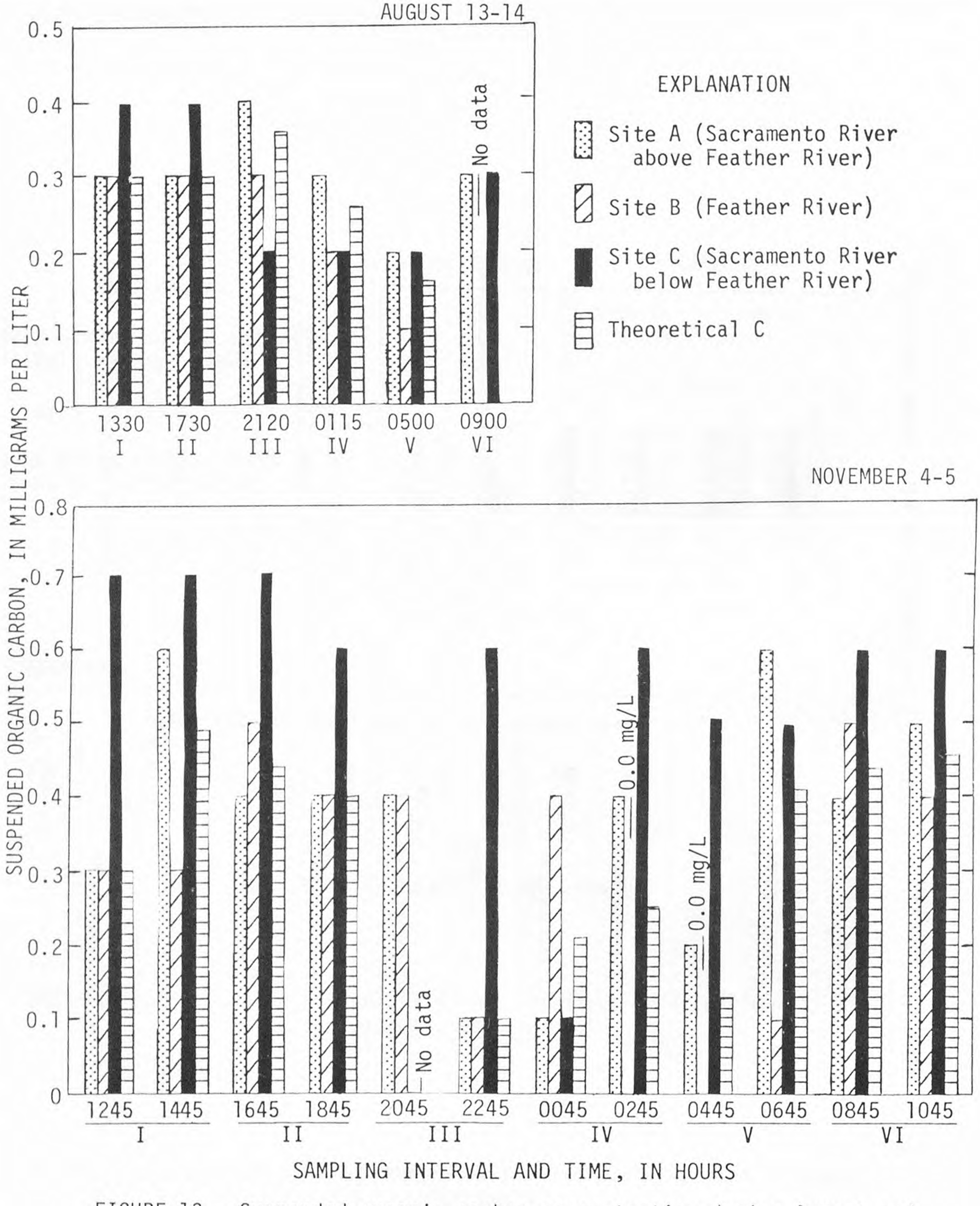



FIGURE 13.--Suspended-organic-carbon concentration during August and November diel measurements.

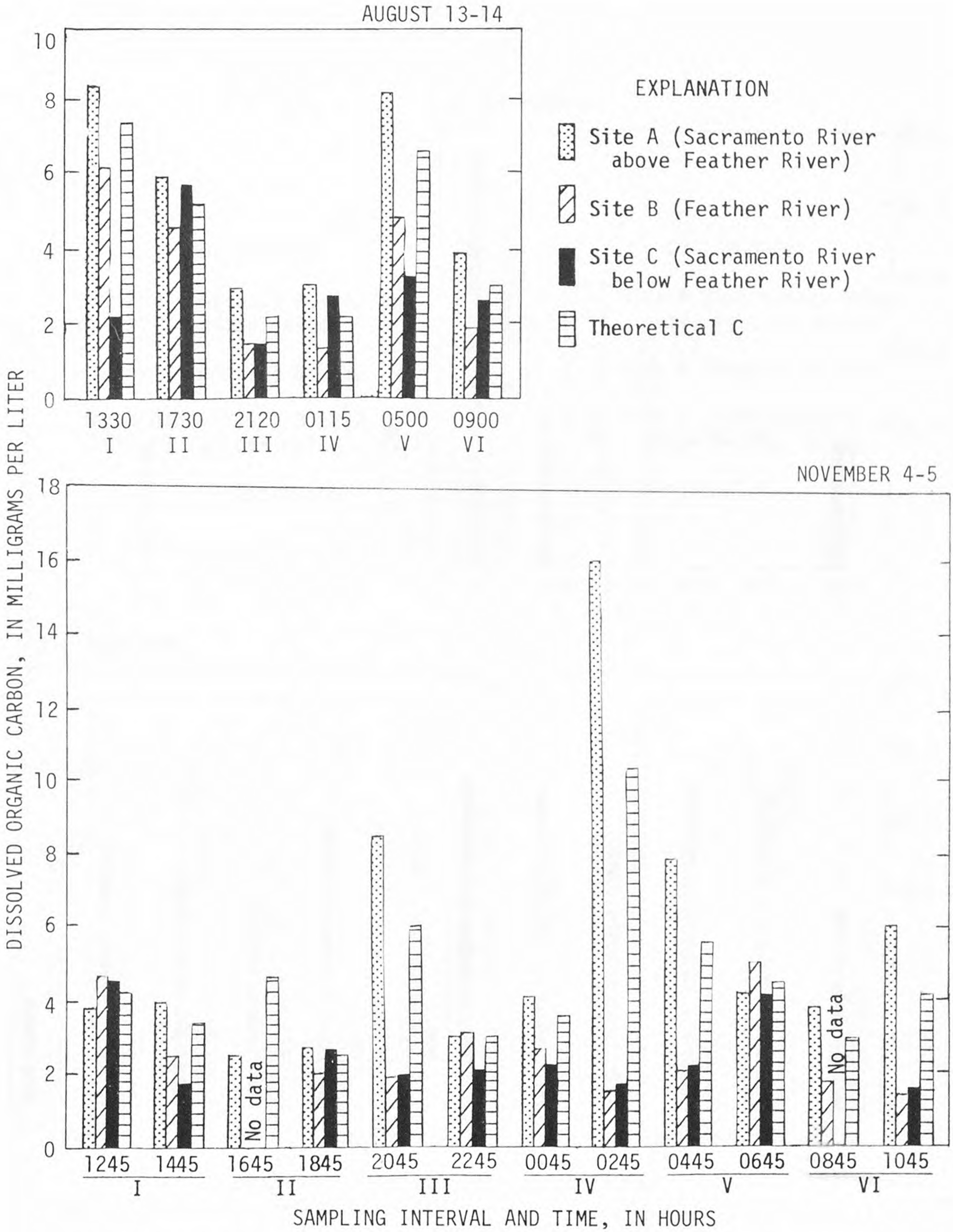



FIGURE 14.--Dissolved-organic-carbon concentration during August and November diel measurements.

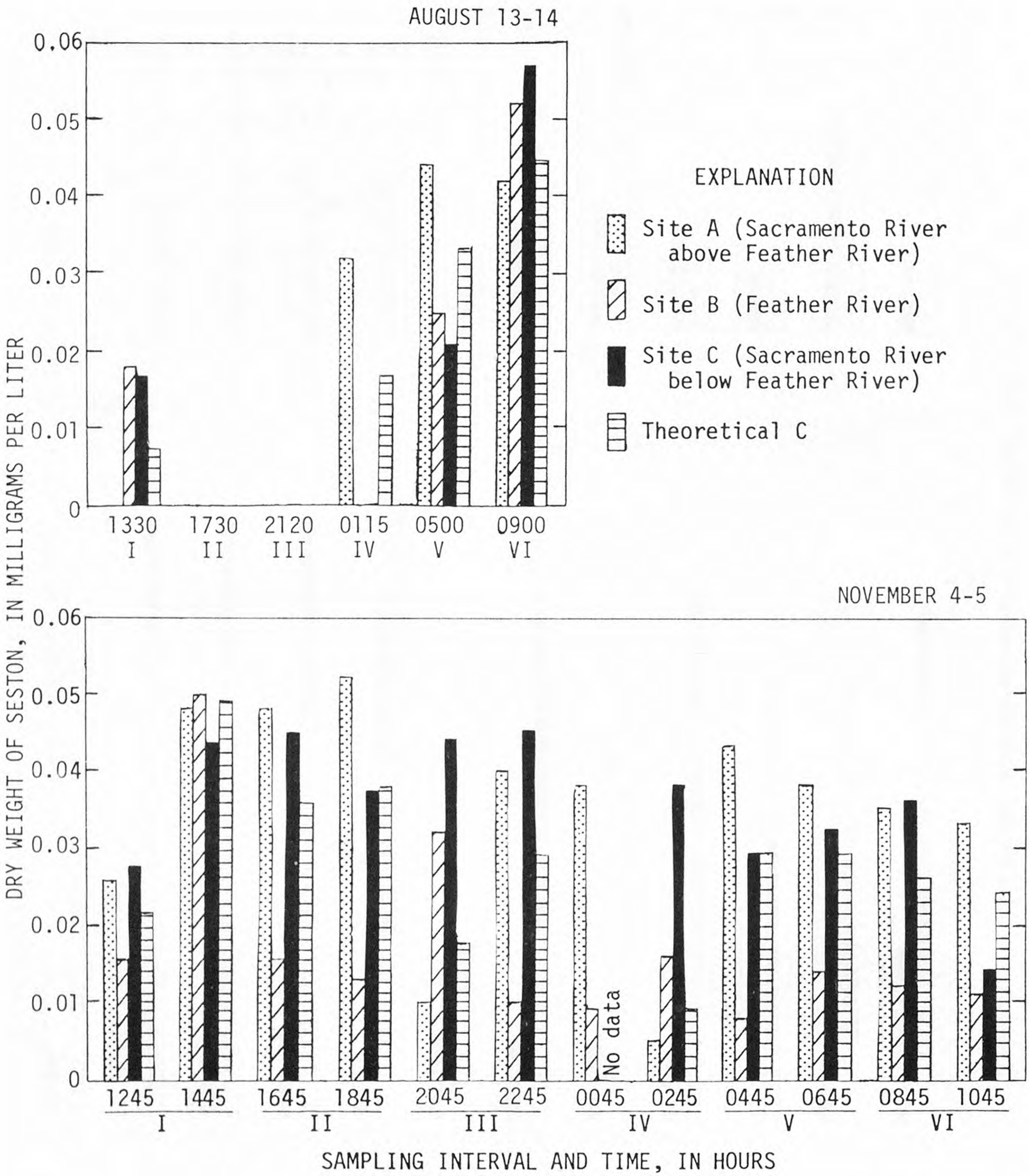



FIGURE 15.--Dry weight of seston during August and November diel measurements.

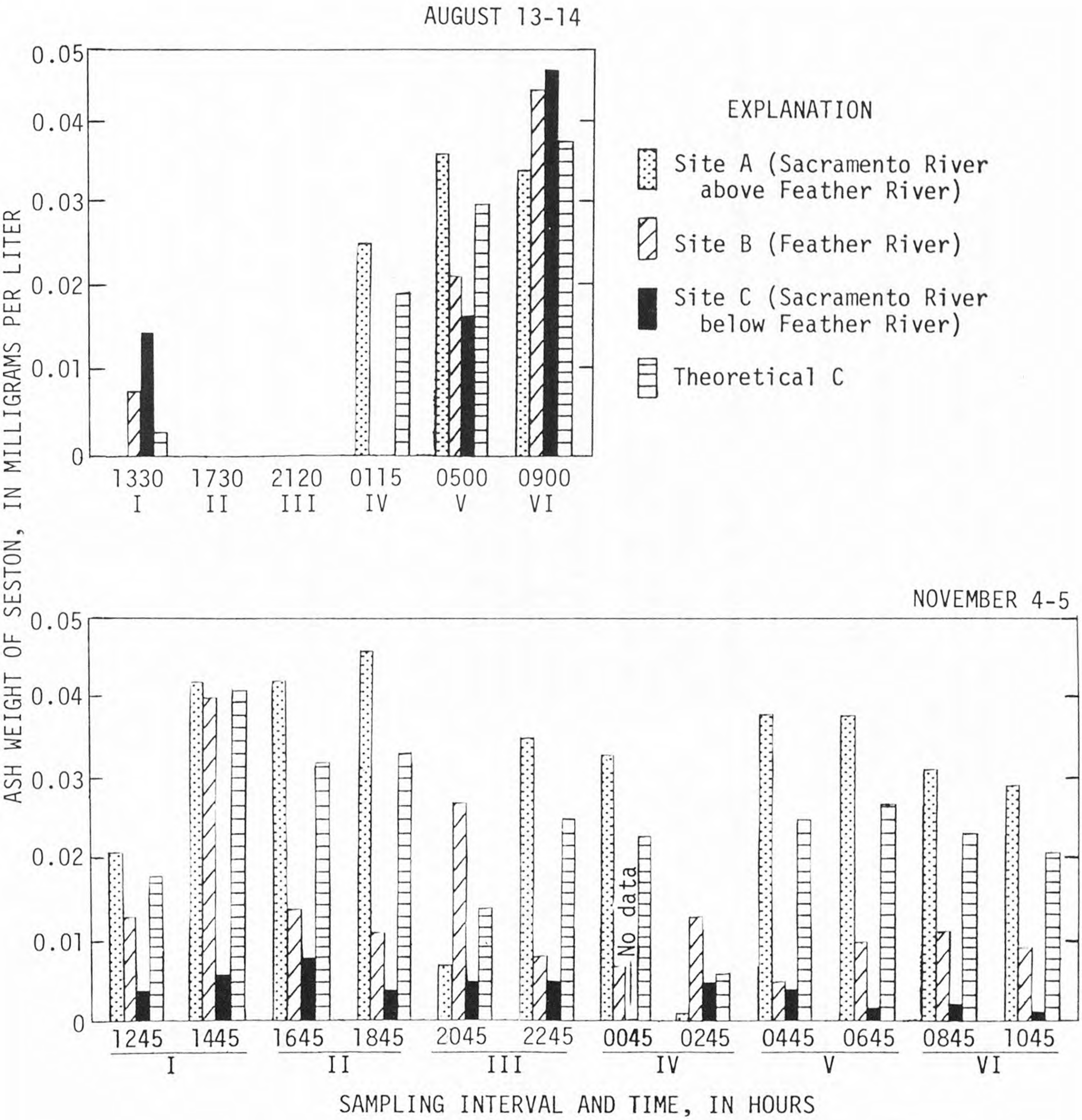



FIGURE 16.--Ash weight of seston during August and November diel measurements.

Table 2.--*Statistical comparison between water-quality values in the Sacramento River above the Feather River (site A) and the Feather River (site B), using the paired* t *statistic at the 5-percent level of significance*

[August 13-14 diel measurements, 5 degrees of freedom; November 4-5 diel measurements, 11 degrees of freedom]

| | August 13-14 | November 4-5 |
|---|---|---|
| No significant difference between Sacramento River value (site A) and Feather River value (site B) | Suspended organic carbon<br>pH<br>Dissolved oxygen<br>Dry weight of seston<br>Ash weight of seston | Suspended organic carbon |
| Sacramento River value (site A) significantly larger than Feather River value (site B) | Specific conductance<br>Silica<br>Total phosphorus<br>Dissolved phosphorus<br>Dissolved organic carbon | Specific conductance<br>Silica<br>Total phosphorus<br>Dissolved phosphorus<br>Dissolved organic carbon<br>Dry weight of seston<br>Ash weight of seston<br>Temperature<br>pH |
| Feather River value (site B) significantly larger than Sacramento River value (site A) | Temperature | Dissolved oxgyen |

Table 3.--*Statistical comparison between water-quality values in the Sacramento River below the Feather River (site C) and theoretical values calculated for the same site, using the paired* t *statistic at the 5-percent level of significance*

[August 13-14 diel measurements, 5 degrees of freedom; November 4-5 diel measurements, 11 degrees of freedom]

| | August 13-14 | November 4-5 |
|---|---|---|
| No significant difference between Sacramento River value (site C) and theoretical value | Temperature<br>pH<br>Total phosphorus<br>Dry weight of seston<br>Ash weight of seston<br>Suspended organic carbon<br>Dissolved organic carbon | Temperature<br>pH<br>Total phosphorus<br>Dry weight of seston<br>Dissolved phosphorus<br>Dissolved oxygen |
| Sacramento River value (site C) is significantly larger than theoretical value | Specific conductance<br>Silica<br>Dissolved phosphorus | Specific conductance<br>Silica<br>Dissolved organic carbon |
| Theoretical value is significantly larger than Sacramento River value (site C) | Dissolved oxygen | Ash weight of seston<br>Dissolved organic carbon |

## Biological

The total number of phytoplankton cells and taxa per milliliter during the August 13-14 and November 4-5, 1975, diel measurements are shown in figures 17 and 18. Figure 17 shows that there are generally fewer cells per milliliter at all sites during the November diel measurements than during the August diel measurements. The number of cells per milliliter and the number of taxa per milliliter at each site varied with time during both diel measurements; however, there is a general decrease with time in number of taxa during the August diel measurements at all sites, in contrast to a general increase with time in number of taxa during the November diel measurements (figs. 17 and 18).

Among the three major algal phyla collected at each site from the Sacramento and Feather Rivers (tables 4 and 5), Chrysophyta (yellow-green algae), particularly the class Bacillariophyceae (diatoms), composed the largest percentage of cells present during both diel measurements. Bacillariophyceae were dominated by three genera: *Fragilaria*, *Cyclotella*, and *Nitzschia*. Cyanophyta (blue-green algae) were the least abundant of the three major algal phyla, in both number of cells per milliliter and number of taxa per milliliter.

Table 4.--*Percentage composition of phytoplankton phyla at each sampling site during the August 13-14 diel measurements*

| Phyla | Percentage composition (six samples collected at each site) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sacramento River above Feather River (site A) | | | Feather River (site B) | | | Sacramento River below Feather River (site C) | | |
| | Minimum | Mean | Maximum | Minimum | Mean | Maximum | Minimum | Mean | Maximum |
| Chlorophyta | 30 | 35 | 38 | 7 | 13 | 24 | 16 | 29 | 56 |
| Chrysophyta | 54 | 60 | 66 | 76 | 87 | 93 | 30 | 50 | 77 |
| Cyanophyta | 0 | 6 | 16 | 0 | 0 | 0 | 0 | 21 | 54 |

Table 5.--*Percentage composition of phytoplankton phyla at each sampling site during the November 4-5 diel measurements*

| Phyla | Percentage composition (12 samples collected at each site) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sacramento River above Feather River (site A) | | | Feather River (site B) | | | Sacramento River below Feather River (site C) | | |
| | Minimum | Mean | Maximum | Minimum | Mean | Maximum | Minimum | Mean | Maximum |
| Chlorophyta | 14 | 22 | 32 | 5 | 14 | 25 | 11 | 21 | 38 |
| Chrysophyta | 58 | 73 | 86 | 61 | 79 | 95 | 36 | 69 | 89 |
| Cyanophyta | 0 | 5 | 22 | 0 | 8 | 18 | 0 | 10 | 48 |

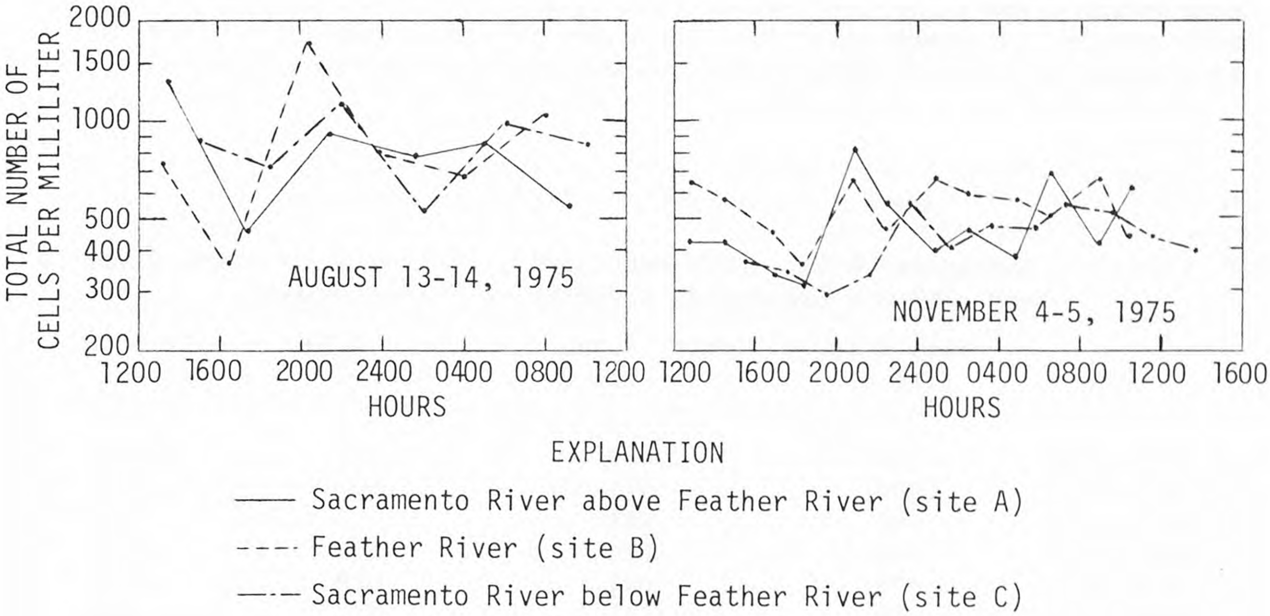



FIGURE 17.--Total number of phytoplankton cells per milliliter in the Sacramento and Feather Rivers, August 13-14 and November 4-5.

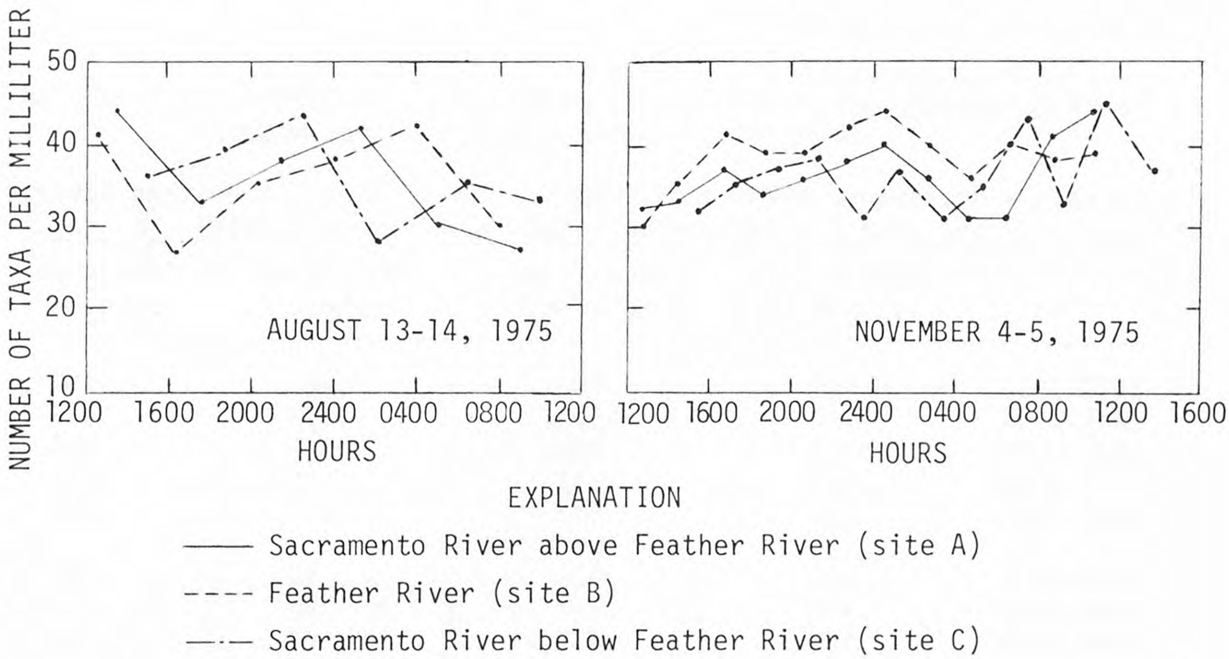



FIGURE 18.--Number of phytoplankton taxa per milliliter in the Sacramento and Feather Rivers, August 13-14 and November 4-5.

The similarity index between sites for phytoplankton taxa (tables 6 and 7) is consistent between the two diel periods. Of the pairs tested, the Sacramento River above the Feather River (site A) had the least similarity with the Feather River (site B). These two rivers combined had the most similarity with the Sacramento River below the Feather River (site C).

Table 6.--*Phytoplankton similarity index between selected sites sampled during the August 13-14 diel measurements*

[Site A = Sacramento River above Feather River; site B = Feather River; and site C = Sacramento River below Feather River]

| Time | Site A to site B | Sites A and B to site C | Site B to site C | Site A to site C |
|---|---|---|---|---|
| 1230-1500 | 0.518 | 0.619 | 0.597 | 0.575 |
| 1615-1830 | .500 | .527 | .606 | .528 |
| 2015-2215 | .548 | .681 | .615 | .716 |
| 2460-0200 | .600 | .610 | .576 | .571 |
| 0400-0615 | .472 | .641 | .519 | .554 |
| 0800-1000 | .456 | .533 | .444 | .600 |
| Mean | 0.516 | 0.602 | 0.560 | 0.591 |

Table 7.--*Phytoplankton similarity index between selected sites sampled during the November 4-5 diel measurements*

[Site A = Sacramento River above Feather River; site B = Feather River; and site C = Sacramento River below Feather River]

| Time | Site A to site B | Sites A and B to site C | Site B to site C | Site A to site C |
|---|---|---|---|---|
| 1245-1530 | 0.554 | 0.506 | 0.400 | 0.531 |
| 1445-1730 | .500 | .535 | .429 | .559 |
| 1645-1930 | .487 | .625 | .590 | .568 |
| 1845-2130 | .548 | .571 | .545 | .556 |
| 2045-2330 | .480 | .591 | .514 | .571 |
| 2245-0130 | .525 | .625 | .582 | .587 |
| 0045-0330 | .476 | .547 | .560 | .592 |
| 0245-0530 | .526 | .637 | .560 | .563 |
| 0445-0730 | .478 | .681 | .472 | .568 |
| 0645-0930 | .479 | .644 | .630 | .500 |
| 0845-1130 | .405 | .704 | .554 | .674 |
| 1045-1330 | .434 | .588 | .526 | .519 |
| Mean | 0.491 | 0.604 | 0.530 | 0.566 |

Faunal drift identified at each site included terrestrial insects and benthic invertebrates. All depths sampled at each site showed a maximum number of taxa in the early morning (fig. 19). There also was a slight peak in the evening surface sample in the Sacramento River below the Feather River (site C). Although the exact patterns of fluctuation are not the same among all the depths sampled at each station, the trend at each depth is out of phase but similar for sites A and C.

The number of drift organisms per second at sites A and C also peaks in the early morning at each depth (fig. 20). The number of organisms per second at the surface shows a peak in the evening hours with the peaks at site C more distinct. Site C generally had more organisms per second than site A.

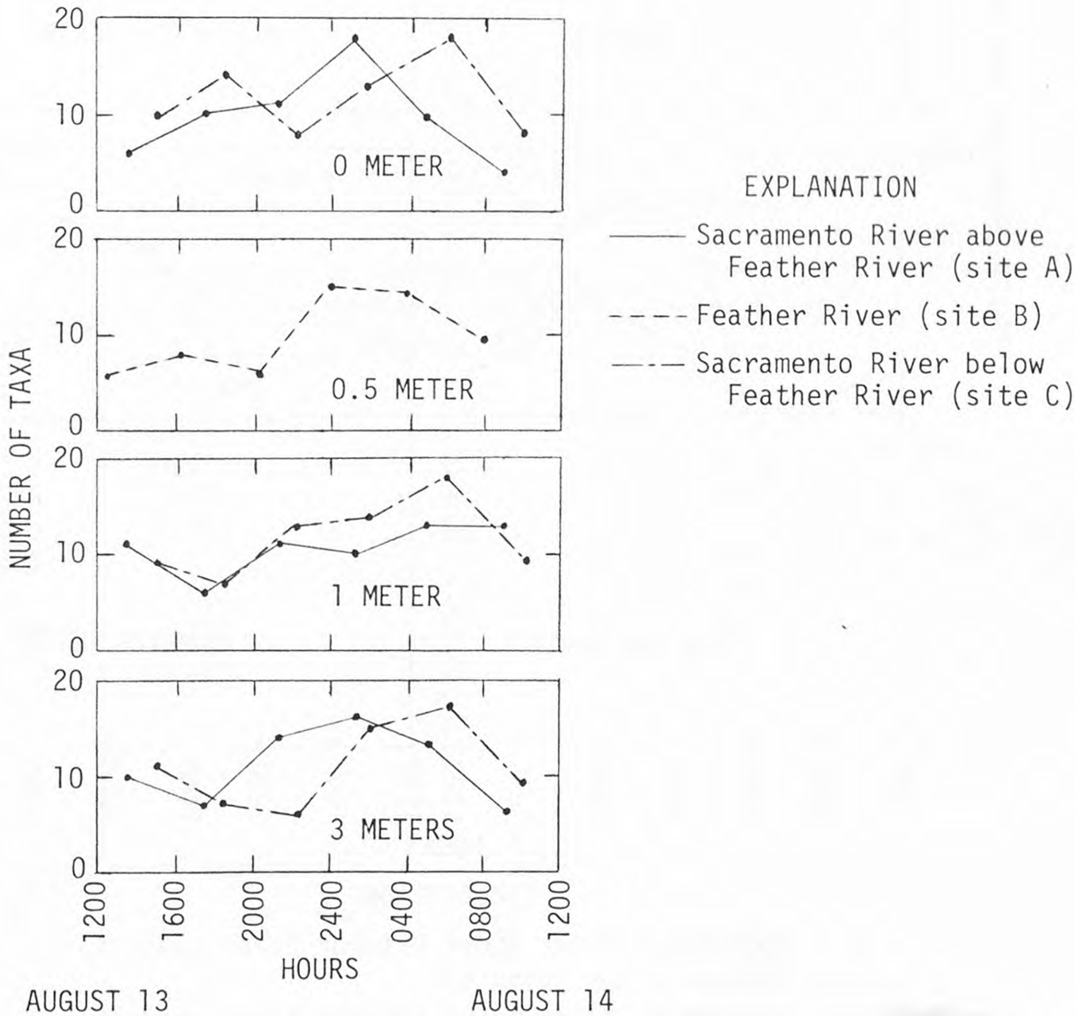
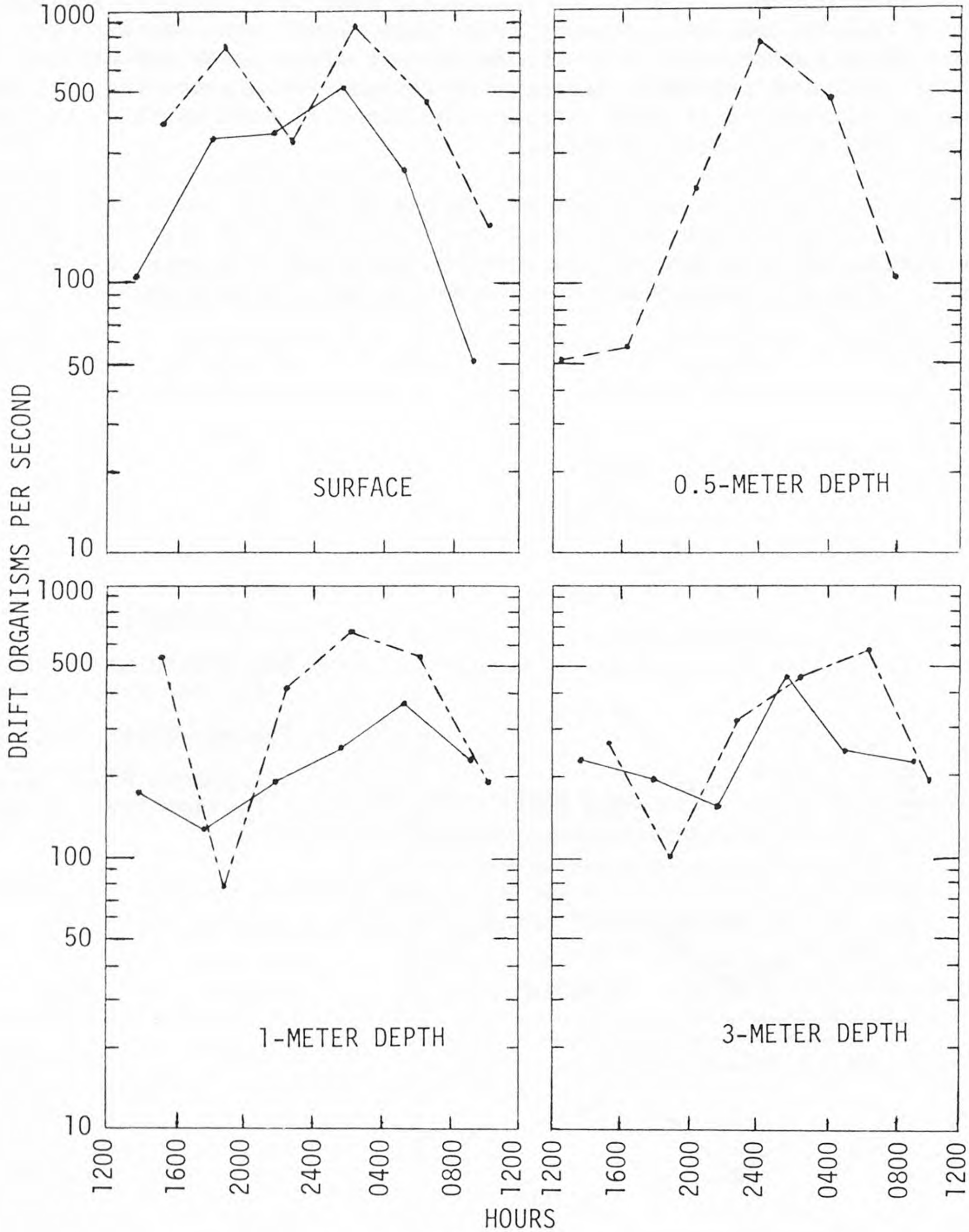



FIGURE 19.--Number of faunal drift taxa in the Sacramento and Feather Rivers, August 13-14.




EXPLANATION

——— Sacramento River above Feather River (site A)

– – – Feather River (site B)

—·— Sacramento River below Feather River (site C)

FIGURE 20.--Number of faunal drift organisms per second occurring in the Sacramento and Feather Rivers, August 13-14.

The similarity indexes for faunal drift between selected sites sampled during the August diel measurements (table 8) show the greatest similarity of taxa occurring between site C and the composite of sites A and B. Sites A and B had the greatest dissimilarity of taxa.

Drift organisms consisted of autochthonous and allochthonous organisms. Of the allochthonous organisms, aphids of the genus *Rhopalosiphum* were the most numerous. Aphids were a dominant drift taxa at all sites. Of autochthonous organisms, the order Diptera (flies) were found at all the sites, with taxa of the families Simuliidae and Chironomidae most common. The amphipod *Corophium spinicorne* occurred only in the Sacramento River sites (A and C), with a large number per second occurring during the midnight hours. Freshwater clams *Corbicula fluminea*, a dominant taxa, occurred in drift at all sites, with extremely large numbers in the Feather River drift (site B) during the night.

Table 8.--*Similarity index for faunal drift between sites sampled during the August 13-14 diel measurements*

[Site A = Sacramento River above Feather River; site B = Feather River; and site C = Sacramento River below Feather River]

| Time | Site A to site B | Sites A and B to site C | Site B to site C | Site A to site C |
|---|---|---|---|---|
| 1230-1500 | 0.476 | 0.727 | 0.522 | 0.688 |
| 1615-1830 | .583 | .606 | .480 | .581 |
| 2015-2215 | .250 | .737 | .435 | .686 |
| 2400-0200 | .488 | .642 | .486 | .625 |
| 0400-0615 | .667 | .826 | .684 | .791 |
| 0800-1000 | .364 | .606 | .417 | .571 |
| Mean | 0.471 | 0.691 | 0.504 | 0.657 |

# DISCUSSION

Considering the properties and constituents studied, the mixing of the Sacramento and Feather Rivers generally occurs as simple dilution. Deviations from the theoretical value for any one variable in the mixed water are perhaps the result of physical forces, such as upwelling at the confluence of the two rivers, or the concentrating effect of evaporation as the mixed water in the Sacramento River flows downstream. Other deviations may result from plant and animal activities in the water.

Heat and dissolved gases can move in and out of water easily and usually show diel fluctuations. Water temperature varies by heat exchange with the atmosphere and bottom sediments. The concentration of dissolved gases in water can be influenced by biological processes, as well as by ambient temperature and pressure.

Dissolved solids and plant nutrients do not move in and out of the water easily. Biological processes, sorption by suspended material, or pH changes can reduce the concentrations of dissolved solids and dissolved plant nutrients in water; however, diel fluctuations of these characteristics are generally imperceptible, because either the amounts of these materials taken from the water are unmeasurable or the rate of uptake is constant.

Temperature and dissolved oxygen showed diel trends during this study. Because of the ability of heat and dissolved oxygen to move in and out of water easily, their cyclic patterns were similar at each site.

Normally, tributary streams are cooler than the stream into which they flow; however, the Feather River was warmer than the Sacramento River during the spring and summer irrigation season when water was released from the epilimnion (warm top layer) of Oroville Lake. In late autumn, irrigation return water, warmed by solar radiation while flowing through agricultural lands, resulted in Sacramento River water being slightly warmer than Feather River water. This temperature difference is maintained until late winter when both rivers are at approximately the same temperature. Annually, 900,000 acre-ft of irrigation return flow is discharged to the 20-mile reach of the Sacramento River above the Feather River (California Department of Water Resources, 1962).

Because of the diel cycling of temperature at each site and the time lapse between sampling upstream sites A and B and downstream site C, a significant difference was expected between the theoretical temperature and measured temperature at site C. The amount of heat exchange with the atmosphere and sediments in reach C of the Sacramento River was not enough to cause a significant difference between theoretical temperature and measured temperature at site C during both diel measurements.

Dissolved-oxygen concentrations were similar at sites A and B during the August diel study, but the mixed water at site C had consistently lower dissolved-oxygen concentrations than those calculated. During the November diel study, the dissolved-oxygen concentrations at site A were significantly lower than at site B, yet the mixed water at site C had dissolved-oxygen concentrations similar to the theoretical calculations. The difference in the comparisons of theoretical and actual dissolved-oxygen concentrations between the August and November diel studies may be the result of temperature differences between the Sacramento and Feather Rivers in conjunction with a probable higher biochemical oxygen demand in the Sacramento River. In August a higher biochemical oxygen demand at site A compared to site B, as indicated by the lower water temperature and therefore lower percentage saturation of dissolved oxygen at site A, along with the warm water from site B, could have consumed dissolved oxygen and decreased the ability of mixed water at site C to hold oxygen. In November, the larger dissolved-oxygen concentration and cooler water temperature from site B might have compensated for a high biochemical oxygen demand at site A, resulting in similar theoretical and measured dissolved-oxygen concentrations of the mixed water in reach C.

Differences between concentrations of dissolved solids and plant nutrients in reach A and reach B could be the result of geological and land-use differences in the respective drainage basins. Theoretical values for mixed water at site C were calculated with the assumption that simple mixing would occur. When the concentrations of dissolved solids and plant nutrients in reach A were equal to those in reach B, the same concentration was expected in the mixed water in reach C. During the August diel measurements, pH, dry weight of seston, ash weight of seston, and suspended organic carbon followed this conceptual model.

Dissolved-solids and nutrient concentrations that were different in reach A compared to reach B were expected to have mixed concentrations with values between the concentrations of the incoming water. Total phosphorus in both diel periods, dissolved organic carbon in the August diel measurements, and dry weight of seston and dissolved phosphorus in the November diel measurements followed this conceptual model.

Dissolved-solids and nutrient concentrations that showed a significant difference between the theoretical and measured values indicate that processes other than simple mixing had occurred. Specific conductance and silica were the only two characteristics that consistently showed significantly larger measured than theoretical values at site C.

The larger measured than theoretical specific-conductance and silica values in the August diel could be the result of sampling to the right (facing downstream) of the mixed zone, as the Sacramento River, with a significantly higher specific conductance, joins the Feather River on the right.

During the November diel measurements, site C was 9.5 mi downstream from the confluence of the Sacramento and Feather Rivers and was therefore free of possible effects of upwelling and incomplete mixing. Evaporation and the accumulation of dissolved solids along this distance may have increased the concentration of dissolved solids (Hynes, 1972), resulting in measured specific-conductance and silica values significantly larger than the theoretical values.

Other water-quality characteristics in this study that showed a significant difference between theoretical and measured values did not show this difference during both diel periods. Suspended organic carbon was the only constituent, other than dissolved oxygen, that had similar concentrations at sites A and B and showed a significant difference between the theoretical and the measured values at site C. This occurred in the November diel period, with the Sacramento River measured value significantly larger than the theoretical value. The large concentration of suspended organic carbon at site C, compared to the theoretical values in the November diel measurements, could be caused by input from external sources such as leaf fall.

Dissolved phosphorus in August and ash weight of seston and dissolved organic carbon in November each had significantly larger concentrations at site A than at site B. The measured values of each of these also were significantly different from the theoretical concentrations at site C. The measured dissolved-phosphorus concentration was larger than the theoretical concentration at site C and could be the result of nonideal sampling on either side of the mixing zone or upwelling at the Sacramento and Feather Rivers' confluence. The measured dissolved-organic-carbon concentrations in November were smaller than the theoretical concentrations. This could be the result of biological uptake.

There is no valid explanation for the significantly larger theoretical than measured ash weight of seston in the November diel measurements. This characteristic and others not consistent between theoretical and measured values for both diel periods could have been affected by sampling and analytical procedure bias.

The number of phytoplankton taxa and cells per milliliter at each site showed the same time trend. Generally, the dominant taxa collected from sites A and B were also collected from site C. The similarity index between selected pairs of sites corresponded to the quantity of water common to each site. The water that passed through sites A and B also passed through site C, resulting in the higher similarity index between site C and the composite of sites A and B. A larger percentage of the water passing through site C came from site A; therefore, the similarity index between sites A and C was larger than the similarity index between sites B and C. Because sites A and B have no water in common, they have the lowest similarity index.

The number of organisms in faunal drift can be increased by allochthonous species. Large numbers of allochthonous organisms (aphids) were present in the faunal drift samples at each site during the August diel measurements. But, because the same taxa of allochthonous organisms occurred at each site, the similarity index between sites was not greatly affected. Similarity indexes calculated with the taxa of faunal drift followed the same model as phytoplankton similarity indexes. Paired sites with the most water in common had the highest faunal similarity, and sites with the least water in common had the lowest faunal similarity.

Taxa that showed strong diel periodicity at one of the upstream sites (A or B) affected faunal periodicity at site C. For example, *Corbicula fluminea* drifted in large numbers at site B during the night. Although *C. fluminea* drift occurred at sites A and C, large numbers of these organisms occurred at night only at site C, which is downstream from site B.

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