A WATER-QUALITY STUDY OF THE RUSSIAN RIVER BASIN DURING THE LOW-FLOW SEASONS, 1973-78, SONOMA AND MENDOCINO COUNTIES, CALIFORNIA

By Marc A. Sylvester and Ronald L. Church

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For readers who prefer to use International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	0.4047	ha (hectares)
ft (feet)	0.3048	m (meters)
ft/s (feet per second)	0.3048	m/s (meters per second)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
gal/min (gallons per minute)	0.003785	m^3/min (cubic meters per minute)
in (inches)	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
μmho/cm at 25°C (micromhos per centimeter at 25° Celsius)	1	μS/cm at 25°C (microsiemens per centimeter at 25° Celsius)

Degrees Celsius are used in this report. To convert degrees Celsius (°C) to degrees Fahrenheit (°F) use the formula:

Temp. °F = 1.8 (temp °C) + 32

Explanation of abbreviations

mg/L	milligrams per liter
μg/L	micrograms per liter
μm	micrometer
mg/m^2	milligrams per square meter
mL	milliliters
MF	membrane filter
MPN	most probable number
NTU	nephlometric turbidity unit
AI	autotrophic index
AGP	algal growth potential
COD	chemical oxygen demand
$g\ O_2/(m^2/d)$	grams of oxygen per square meter per day
$(mg/m^2)/d$	milligrams per square meter per day
P/R	production/respiration ratio

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

Water Year: The water year starts October 1 and ends September 30; it is designated by the calendar year in which it ends.

The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Station Number and Name	
11461000	Russian River near Ukiah
11462000	East Fork Russian River near Ukiah
11462050	Russian River at Ukiah
11462690	Russian River at Hopland
11463000	Russian River near Cloverdale
11463150	Russian River at Preston
11463210	Big Sulphur Creek at mouth, near Cloverdale
11463400	Russian River at Asti
11463500	Russian River at Geyserville
11463680	Russian River at Alexander Valley Road Bridge
11464010	Russian River at Healdsburg
11465400	Russian River at Wohler Bridge
11466800	Mark West Creek near Mirabel Heights
11466850	Russian River at Mirabel Heights
11467000	Russian River near Guerneville
11467002	Russian River at Johnson's Beach
11467006	Russian River at Vacation Beach
11467210	Russian River at Duncan Mills

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By Marc A. Sylvester[1] and Ronald L. Church[2]

ABSTRACT

Water quality and streamflow in the Russian River basin during the low-flow season (May to October) were studied during water years 1973 through 1978 to document water-quality and streamflow conditions in the basin, and to determine the extent and cause(s) of any water-quality impairment during the low-flow season. Prior to May 1977, sampling was done by the California Regional Water Quality Control Board, North Coast Region. During 1977 and 1978 low-flow seasons, the California Regional Water Quality Control Board and the U.S. Geological Survey jointly participated in water-quality sampling. Properties and constituents measured included streamflow, water temperature, pH, specific conductance, dissolved oxygen, turbidity, fecal-coliform and fecal-streptococcal bacteria, *Pseudomonas aeruginosa* bacteria, nutrients (nitrogen and phosphorus) chemical oxygen demand, phytoplankton counts and cellular contents, periphyton cellular contents, and algal growth potential.

The most important factors affecting surface-water quality and streamflow in the Russian River basin during the period of study were wastewater discharges during the low-flow season, their abatement beginning in 1975, and the drought during 1976 and 1977. During the 1974 low-flow season, concentrations of fecal-coliform bacteria at most sampling stations were not in accordance with water-quality objectives. Fecal-coliform bacteria and nutrient concentrations decreased markedly after 1974, coinciding with the implementation of regulations specifying no discharge of wastewater during the low-flow season. After 1974, water-quality objectives for fecal-coliform bacteria were met at all stations except Mark West Creek near Mirabel Heights (11466800). Until 1978, the Mark West Creek drainage continued to receive wastewater during the low-flow season from the basin's principal urban area, Santa Rosa and nearby communities.

Rainfall and streamflows in the Russian River basin were much below normal during the drought (water years 1976 and 1977). Abnormally low rainfall and streamflows in the basin during the drought resulted in some improvement in water quality. Generally, turbidity and organic and inorganic nitrogen were least during the 1977 low-flow season.

[1]Hydrologist, U.S. Geological Survey, Menlo Park, Calif.
[2]Environmental Specialist, California Regional Water Quality Control Board, North Coast Region, Santa Rosa, Calif.

Deleterious effects of the drought on the quality of surface waters in the basin were increases in specific conductance and pH and decreases in dissolved oxygen. As a result, at most stations during the 1977 low-flow season, these water-quality properties were not in accordance with the water-quality objectives.

Algal growth in the Russian River depends on the amount of nitrogen in the water and is not limited by the amount of phosphorus in the water.

Basin geomorphology, diversion of water and diversion impoundments, recreational impoundments and associated human activities, land use (other than wastewater discharges), and tidewater did not have much effect on water quality of the Russian River during the period of this study.

Big Sulphur and Mark West Creeks did affect the water quality of the Russian River during the low-flow season. Specific conductance and pH values were greater downstream of Big Sulphur Creek. The dissolved-solids, and specific-conductance values of this creek are determined by geology and geothermal activity. Specific-conductance values and concentrations of orthophosphorus and phytoplankton in the Russian River were greater downstream of Mark West Creek. Due mostly to the influence of wastewater discharges, Mark West Creek had much greater values of these properties and constituents than did other stations.

During the low-flow season, local climatic conditions have an important impact on water temperature of the Russian River. Water released from Lake Mendocino composes most of the flow of the Russian River during the low-flow season. As cold water released from Lake Mendocino proceeds downstream, it is markedly warmed in climatic areas receiving little ocean influence. Releases of cold bottom water from Lake Mendocino probably maintain downstream water temperatures within the range of tolerance of certain aquatic organisms (for example, salmon and trout), inhibit aquatic community respiration, and minimize nuisance growths of phytoplankton and periphyton.

Results of a diel study in the Russian River indicate photosynthetic production of oxygen during the low-flow season is not sufficient to offset respiration. Thus, depletion of dissolved oxygen to levels harmful to some aquatic plants and animals appears probable. The section of the river most likely to be affected is the reach downstream of Mirabel Park with the least gradient, slowest water velocities, most pooled sections, and least potential for reaeration by physical mechanisms such as diffusion. The probability of nuisance algal growths occurring appears to be low, if the heterotroph-dominated aquatic community that was present during the diel study persists. This conclusion is supported by periphyton data, that indicate periphyton at most stations during the 1977 and 1978 low-flow seasons was dominated by organisms not having chlorophyll.

INTRODUCTION

Background

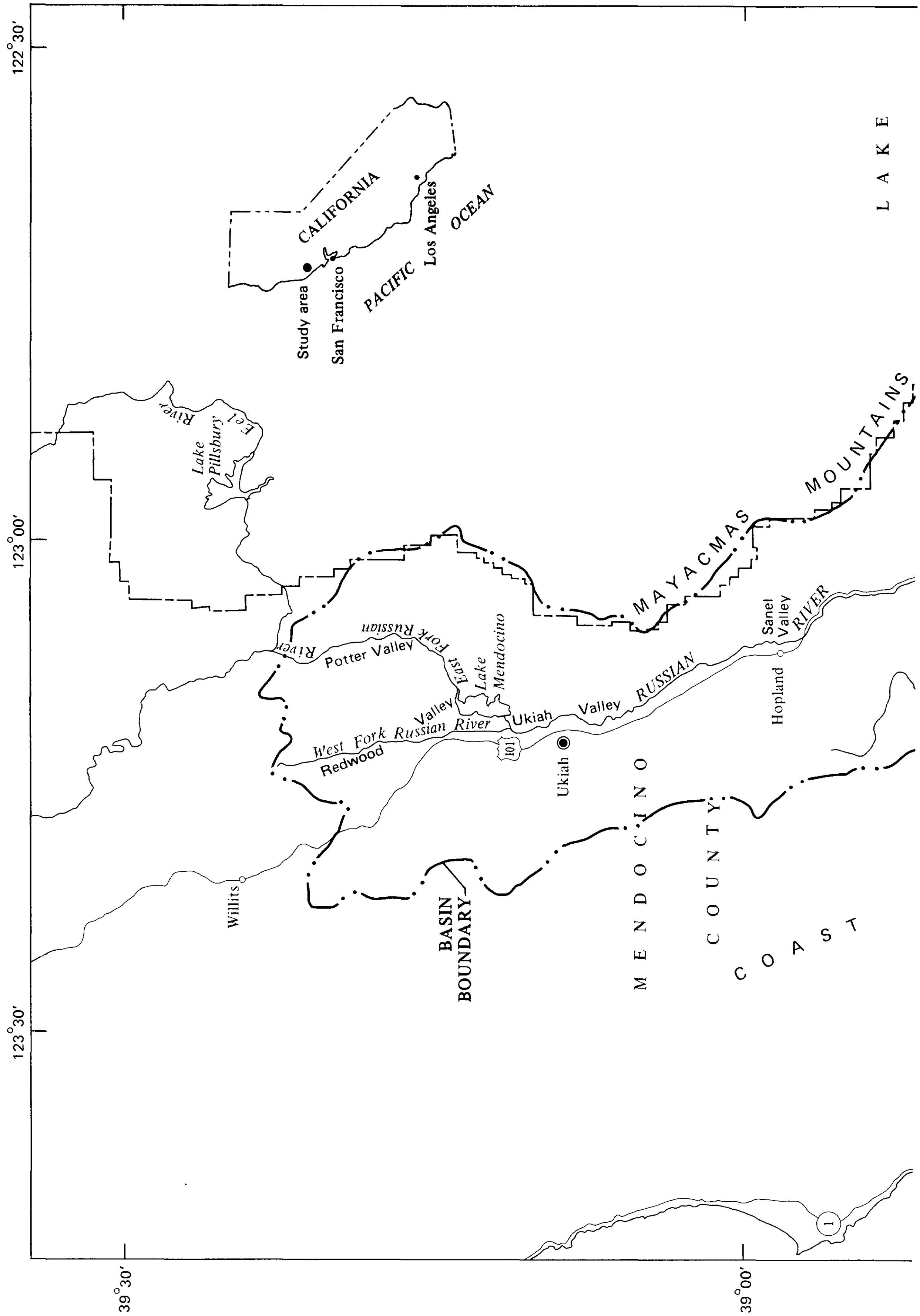
In 1973 the California Regional Water Quality Control Board, North Coast Region (Regional Board), began a water-quality sampling program of the Russian River basin (fig. 1) to determine if basin waters were of suitable quality for agricultural, municipal, recreational, and instream uses. During the summer of 1974, fecal-coliform bacteria concentrations in the main stem of the river and one of its tributaries generally exceeded water-quality objectives. As a result of these findings, several wastewater-discharge requirements were promulgated from 1975 to 1977. These requirements prohibit wastewater discharge to the main stem and tributaries of the Russian River from May 15 to September 30. Wastewater discharges are also prohibited at other times of the year when the flow of the Russian River at Healdsburg (11464010) is less than 1,000 ft^3/s or when the dilution ratio of river water to wastewater is less than 100 to 1.

During the time these revised wastewater-discharge requirements were being implemented, the Russian River was identified as 1 of 28 rivers in California to be included in a statewide network of water-quality sampling stations (California Department of Water Resources, 1976). Inclusion of the Russian River in this network of stations, bacterial and algal problems in the river during 1974, and a need to evaluate the effect of revised wastewater-discharge requirements on the quality of water in the basin, led the Regional Board to decide to do an intensive water-quality study of the Russian River and some of its tributaries. This study, which began in 1975, was primarily a continuation of the 1974 sampling program but with special emphasis on sampling during the low-flow, high recreational-use season when water-quality problems had been most apparent.

During 1977 the U.S. Geological Survey (Survey), under a cooperative agreement with the California State Water Resources Control Board (State Board), joined the Regional Board in the study. The Regional Board and the Survey jointly participated in water-quality sampling from May 1977 to October 1978.

Purpose and Scope

The objectives of this report are to document water-quality and streamflow conditions in the Russian River basin and to determine the extent and cause(s) of any water-quality impairment in the basin during the low-flow season (May to October). This part of the year was chosen for sampling because water quality is most likely to impact beneficial water uses during the low-flow season. Most of the agricultural, municipal, and recreational water uses occur during the low-flow season. The principal source of information for this report was the streamflow and water-quality data collected jointly by the Survey and Regional Board during 1977 and 1978. Data collected by the Regional Board from 1973 to 1977, was used to characterize pre-1977 water-quality conditions. Land use and other physiographic information were also compiled and their effects on water quality during the low-flow season were examined.



122°30'
123°00'
123°30'
39°30'
39°00'
CALIFORNIA
Study area
San Francisco
Los Angeles
PACIFIC OCEAN
LAKE
Eel River
Lake Pillsbury
MAYACMAS MOUNTAINS
East Fork Russian River
Potter Valley
Lake Mendocino
Sanel Valley
RUSSIAN RIVER
Hopland
Ukiah Valley
Ukiah
West Fork Russian River
Redwood Valley
101
Willits
BASIN BOUNDARY
MENDOCINO COUNTY COAST
1

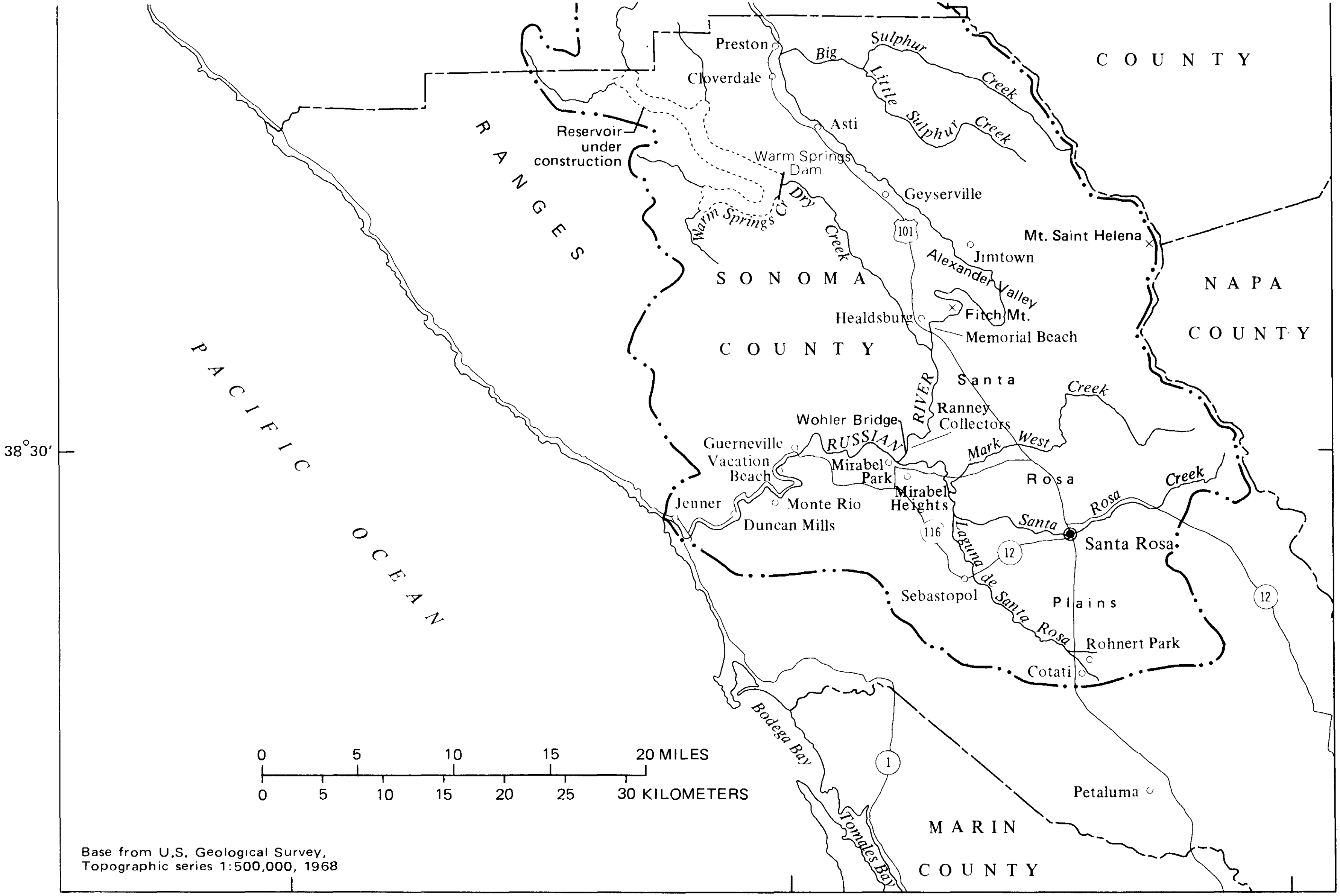


FIGURE 1. – Location of study area and principal features of the Russian River basin.

Acknowledgments

The authors express their appreciation to Robert R. Klamt, Kristine Henderson, Leslie James, Judy Nosechi, Candi Parker, Theresa Wistrom, and Robert Jouganatos of the Regional Board staff for their assistance in sampling. The authors also thank the County of Sonoma for providing wages and transportation for a field technician during three summers of the study, and gratefully acknowledge the assistance of Ken W. Lee and Diane Van Schoten, U.S. Geological Survey, Menlo Park, Calif., in the preparation of certain illustrations used in this report.

LOCATION AND DESCRIPTION OF STUDY AREA

Topography and Hydrology

The 1,485 mi^2 Russian River basin (fig. 1) is on the north coast of California primarily in Sonoma and Mendocino Counties (less than 1 percent is in Lake County). The basin is about 80 miles long and from 10 to 30 miles wide with its major axis generally paralleling the coastline. Mountains of the Coast Ranges form basin boundaries. Elevations range from sea level at the mouth of the Russian River near Jenner to 4,343 feet at the crest of Mount St. Helena in the Mayacmas Mountains. Most of the basin is mountainous with peak elevations mostly between 1,000 and 3,500 feet and slopes commonly exceeding 30 percent.

The main stem of the Russian River is about 110 miles long and flows southward from its headwaters near Redwood and Potter Valleys to Mirabel Park where the direction of flow changes to westward as the river transects a part of the Coast Ranges. Principal tributaries of the Russian River are Big Sulphur Creek and Mark West Creek from the east and Dry Creek from the west. Streamflow during the rainy season (October to May) composes most of the total annual flow of the Russian River. From May through September, most of the flow is imported water from the Eel River. Since 1910, Eel River water has been diverted from Lake Pillsbury to the East Fork of the Russian River near Potter Valley to augment summer flow of the Russian River. Coyote Dam, constructed by the U.S. Army Corps of Engineers and completed in 1959, impounds Lake Mendocino and supplements Russian River summer flow by regulated release of stored intrabasin and imported water (fig. 2).

East

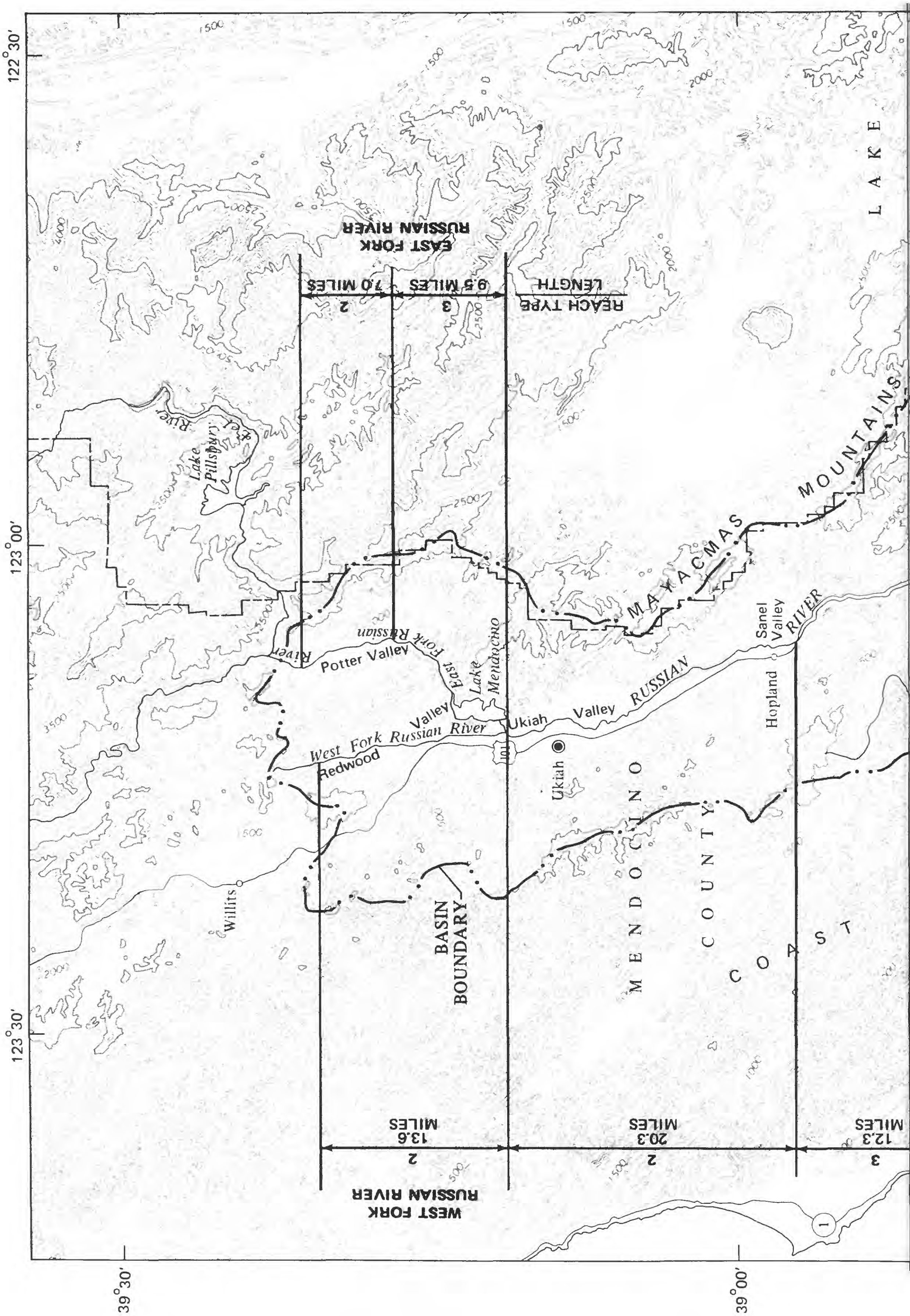
North  South

West

FIGURE 2. – Coyote Dam and Lake Mendocino.

Based on river gradient and channel characteristics, the Russian River can be divided into three distinct geomorphic reach types. As shown in figures 3 and 4, the terrain adjacent to the river alternates between flat and mountainous. Major flatland areas bordering the river are, the Santa Rosa Plains and the following valleys: Potter, Redwood, Ukiah, Sanel, and Alexander. Mountainous reaches are between Potter Valley and Ukiah, Hopland and Cloverdale, Jimtown and Healdsburg, and Mirabel Park and Jenner.

<u>Reach type 1</u> (figs. 3 and 4) includes only the mountainous reach, Mirabel Park to Jenner. This reach type has: (1) A lesser river gradient than flatland and other mountainous reaches; (2) channel width intermediate between flatland and other mountainous reaches; (3) long, deep pools with only a few riffles and some steep side slopes; and (4) loose bed material of pebbles, sand, silt, and sometimes cobbles (fig. 5). Flatland reaches comprise <u>reach type 2</u>. Characteristics of this reach type are: (1) river gradient usually less than adjoining mountainous reaches; (2) broad channel (sometimes braided) with gentle side slopes; (3) shallow pools; and (4) loose bed material of cobbles, pebbles, sand, and silt (fig. 6). <u>Reach type 3</u> consists of mountainous reaches that have: (1) river gradients usually greater than adjoining flatland reaches; (2) narrow channel with generally steep side slopes; (3) some rapids and deep pools; and (4) bedrock substrate with cobbles and some boulders in riffles and rapids and pebbles, sand, and silt in pools (fig. 7).


122°30'
123°00'
123°30'
39°30'
39°00'
EAST FORK RUSSIAN RIVER
REACH TYPE
LENGTH
3
9.5 MILES
2
7.0 MILES
WEST FORK RUSSIAN RIVER
2
13.6 MILES
2
20.3 MILES
3
12.3 MILES
LAKE
MAYACMAS MOUNTAINS
Lake Pillsbury
Eel River
River
Potter Valley
East Fork Russian
East
Lake Mendocino
Ukiah Valley
RUSSIAN RIVER
Sanel Valley
Hopland
Ukiah
West Fork Russian River
Redwood Valley
101
Willits
BASIN BOUNDARY
MENDOCINO COUNTY
COAST
1500
2000
2500
3500
4000

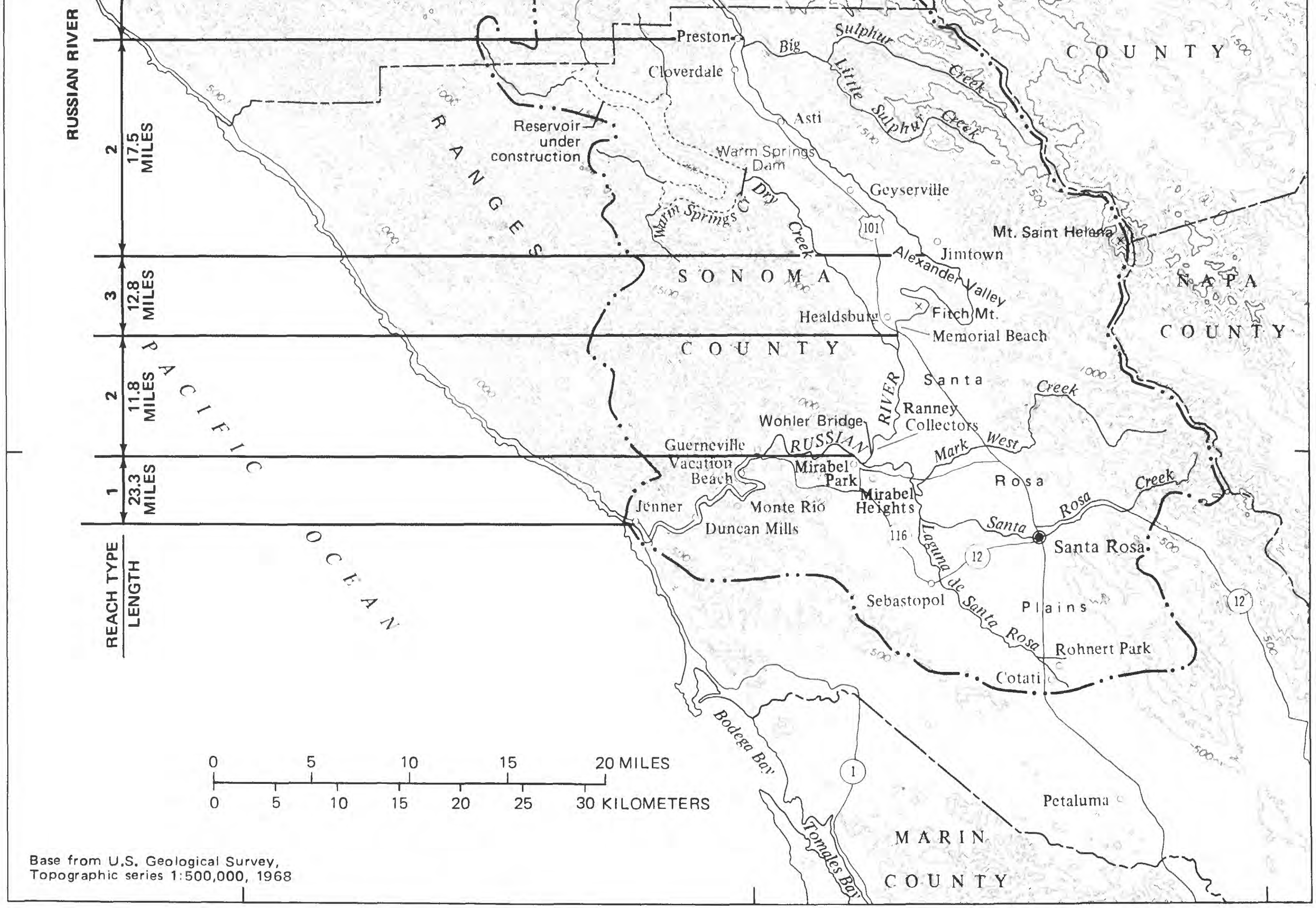


FIGURE 3. – Location of geomorphic reach types in the Russian River basin.
(Reach types are described in the text on p.7.)

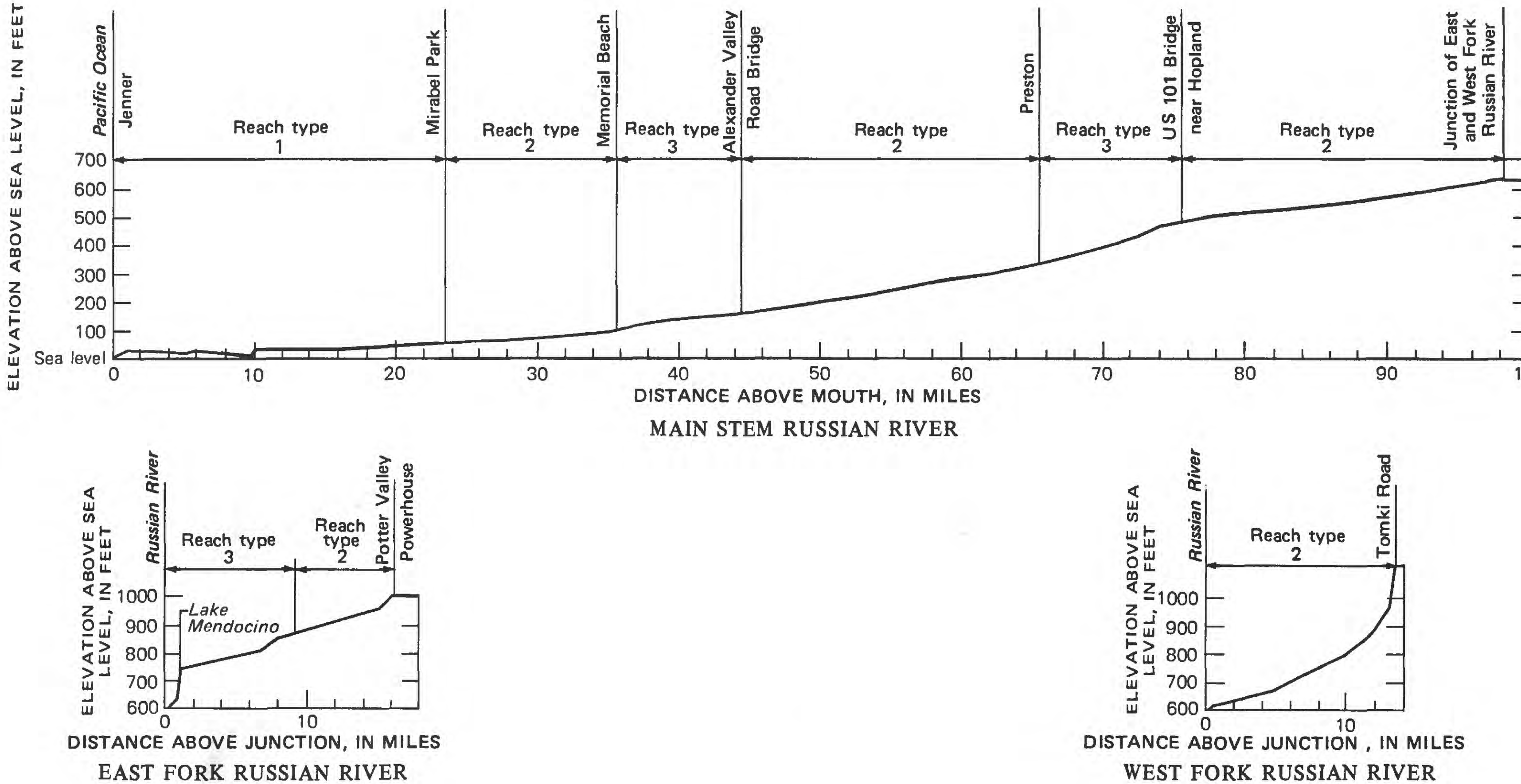


FIGURE 4. – River-gradient profile. (Reach types are described in the text on p. 7.)

FIGURE 5. — Russian River between Monte Rio and Duncan Mills showing characteristics of reach type 1.

FIGURE 6. — Russian River near Geyserville showing characteristics of reach type 2.

FIGURE 7. – Russian River at Squaw Rock (between Hopland and Cloverdale) showing characteristics of reach type 3.

Climate

During low-flow season, the climate of the Russian River basin near the coast is moist and cool because of ocean influences, particularly fog. For the main stem of the Russian River, ocean influences occur primarily from the mouth to Mirabel Park. Farther inland, the climate becomes warmer because areas upstream of Healdsburg are progressively more isolated from ocean influences by the Coast Ranges.

Mean annual precipitation varies from about 30 inches in the southern part of the basin near Santa Rosa to 50-80 inches in the Mayacmas Mountains, from Mark West Creek drainage to Big Sulphur Creek drainage, and in the western part of the basin near the coast. In the central part of the basin from Redwood and Potter Valleys to Guerneville, mean annual precipitation is about 30 to 40 inches (Rantz, 1969). Rainfall is infrequent from May to October (the dry season).

During the 1976 and 1977 drought in California, annual precipitation in the Russian River basin averaged only 22.27 inches, 38 percent of the mean annual precipitation for the period 1973-75 and 1978 (table 1). Based on 1941-70 normals, the Russian River basin received more precipitation than normal during water years 1973, 1974, and 1978. Precipitation was nearly normal during the 1975 water year.

TABLE 1. - Annual precipitation, 1973-78 water years

[Data from U.S. Department of Commerce, 1972-78. Precipitation values are in inches; E, indicates amount is wholly or partly estimated; ---, dash indicates value not available]

	Water year						Normals based on
	1973	1974	1975	1976	1977	1978	1941-70 period
Potter Valley-----	45.41	67.12	47.75	28.27	17.84	59.10	45.66
Ukiah:							
City------------	41.75	57.04	38.78	19.55	16.12	52.47	38.43
Mountains southwest of city.	54.21	66.74	50.04	28.24	22.47	64.37	---
Cloverdale--------	56.20	63.82	40.65	18.74	18.38	64.29	43.51
Healdsburg--------	50.43	62.89	40.37	18.38	17.42	63.50	---
Guerneville-------	65.23	71.58	47.16	24.93	17.70	Oct.-Apr. E67.83	---
Occidental--------	69.45	82.01	50.83	32.26	E20.13	E70.81	54.08
Santa Rosa--------	42.91	42.19	28.03	16.92	12.78	32.36	30.54
Cazadero----------	76.41	127.27	69.41	43.80	26.90	Oct.-Aug. 91.71	---
Mean for Russian River basin.	55.78	71.18	45.89	25.68	18.86	62.94	---

Geology

The Franciscan Formation and Great Valley Sequence primarily compose the geology of mountainous areas except for Sonoma Volcanics in the southeastern part of the basin. Stream channel, alluvial, and river-terrace deposits are predominant in the flatland areas upstream of Jimtown and along the Russian River from Healdsburg to Jenner. The geology of the Santa Rosa Plains is primarily composed of the Glen Ellen Formation and alluvial deposits (Blake and others, 1971; and Fox and others, 1973). Most of these geologic formations are water bearing, but the Franciscan Formation and Great Valley Sequence generally provide low yields to wells (less than 3 gal/min, California Department of Water Resources, 1975, p. 147).

Land Use and Land Cover

In general, the predominant land use in the Russian River basin is agriculture, primarily pasture, vineyards, and orchards; but the amount of urban land use is substantial and is increasing. Agriculture occurs mostly in the flatland areas bordering the Russian River or its tributaries. The main urban centers are Santa Rosa, Healdsburg, Cloverdale, and Ukiah. Important activities in these agricultural and urban areas include cultivation of crops, extraction and processing of riparian sand and gravel, retail and wholesale trade, wine production, and processing of orchard and timber crops. Recreational activities are most prevalent in the section of the Russian River from Mirabel Park to Jenner. Principal land covers are forestland and rangeland. Forestland near the coast primarily contains dense stands of redwood and fir; whereas, further inland, it contains less dense stands of fir, pine, and hardwood (mostly oaks) mixed with shrubs. Grass is the main vegetation on rangeland.

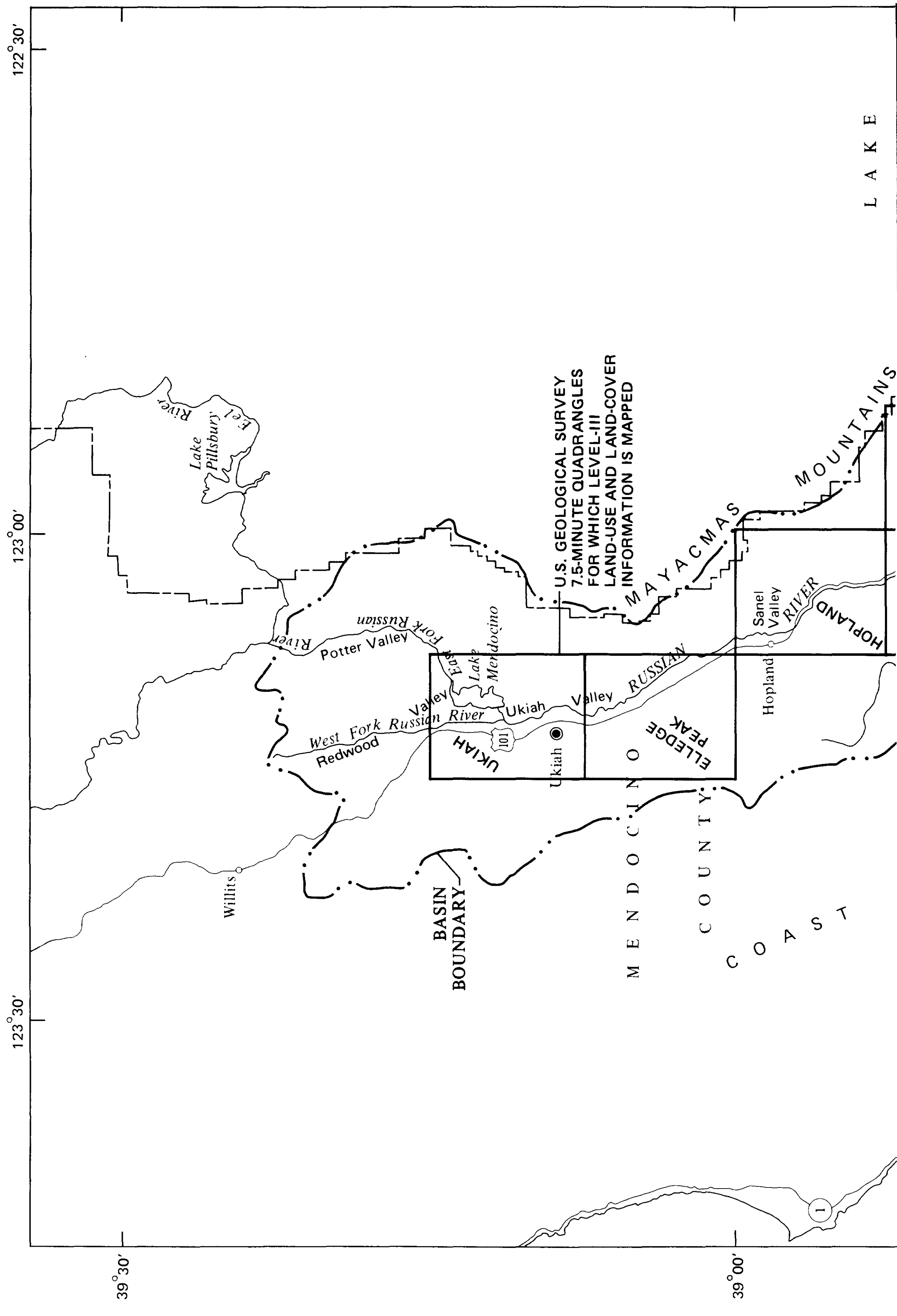
The preceding description of land use and land cover in the Russian River basin is based on the information provided in table 2. This information was compiled from land-use and land-cover mapping done by the U.S. Army Corps of Engineers, San Francisco District during 1975 for the 7½-minute quadrangles shown in figure 8. The area mapped constitutes about 50 percent of the total basin.

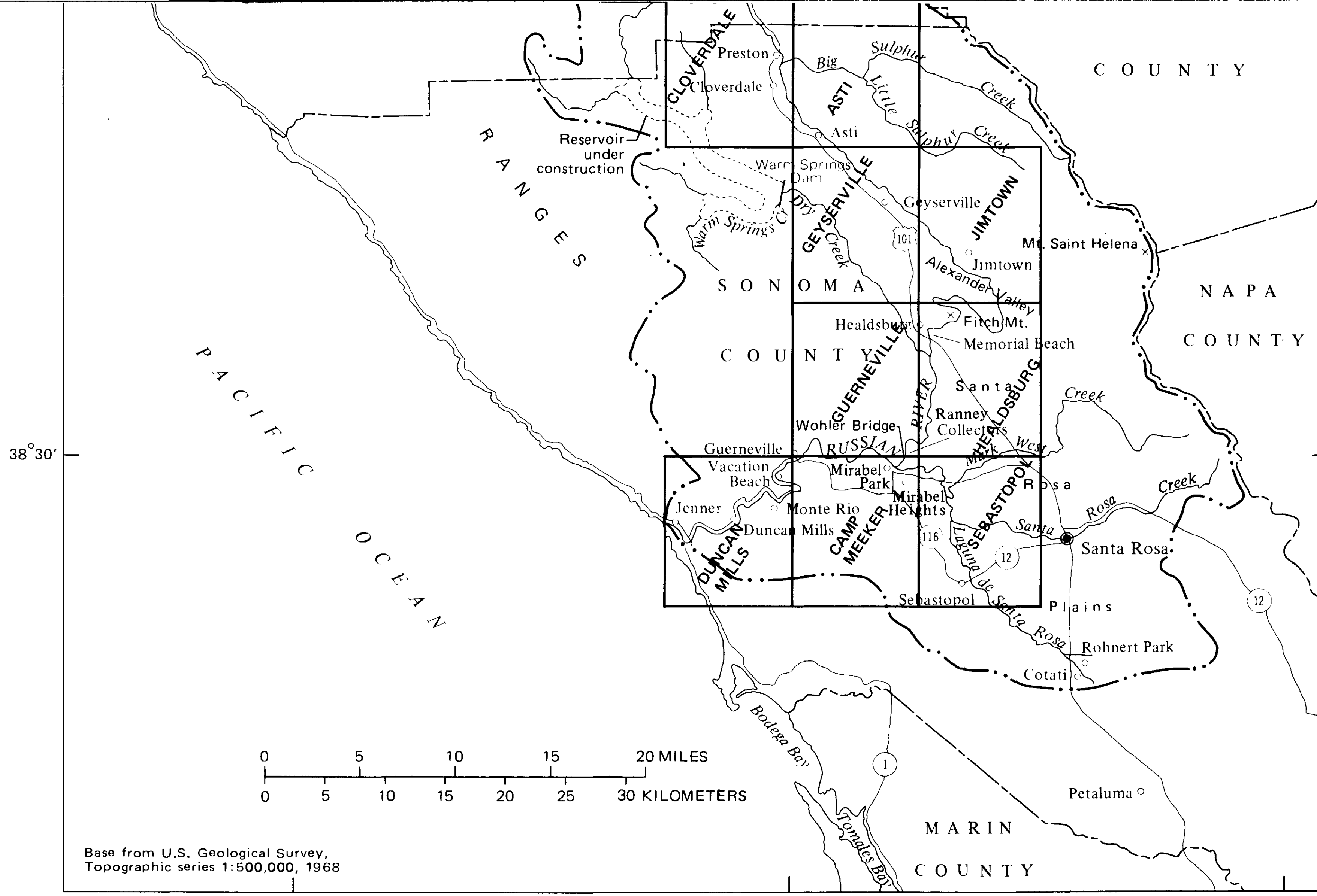
TABLE 2. - Land use and land cover for areas bordering the Russian River

Land use or land cover — Name	Area — Acres	Area — Square miles
Urban and built-up land:		
Residential		
Single-family	43,168.88	67.45
Multifamily	675.00	1.05
Mobile homes	715.44	1.12
Transient lodgings	145.41	.23
Other	136.60	.21
Commercial, institutional, and services		
Wholesale trade	54.20	.08
Retail trade	1,303.49	2.04
Business, professional, institutional, and services.	2,252.47	3.52
Cultural, entertainment, and recreational.	757.74	1.18
Military	422.74	.66
Industrial		
Heat processing	12.84	.02
Industrial park	485.10	.76
Food processing	63.55	.10
Wineries	194.16	.30
Wholesale warehousing	1,071.36	1.67
Lumber mills and lumber storage	881.05	1.38
Other	119.85	.19
Extractive		
Shaft mining	38.10	.06
Strip mines	1,502.79	2.35
Quarries	10.44	.02
Sand and gravel pits	626.15	.98
Transportation, communications, and utilities.		
Transportation	2,338.97	3.65
Telecommunications, radio, and TV facilities.	21.40	.03
Electric plants	17.28	.03
Water plants	2.40	.00
Sewage plants	282.61	.44
Solid waste disposal	60.37	.09
Marinas and port facilities	20.09	.03
Other	11.32	.02
Urban open		
Golf courses	479.91	.75
Cemeteries	188.71	.29
Parks	205.42	.32
Vacant and (or) cleared	2,541.62	3.97
Campgrounds	148.35	.23
Other	11.18	.17

TABLE 2. - Land use and land cover for areas bordering the Russian River--Continued

Land use or land cover	Area	
Name	Acres	Square miles
Agricultural land:		
Cropland and pasture	5.71	0.01
Cropland	16,207.50	25.32
Pasture	26,293.63	41.09
Orchards, groves, vineyards, and horticultural.		
Fruit and nut trees	20,208.64	31.58
Vineyards	26,003.18	40.63
Nursuries	225.86	.35
Other	650.39	1.02
Confined feeding operations		
Feedlots	71.03	.11
Poultry and egg houses	301.43	.47
Other	11.43	.02
Related facilities	2,097.50	3.28
Equipment, fodder, stock storage buildings.	500.05	.78
Other	7.49	.01
Other agricultural land	98.19	.15
Forestland:		
Harvested	1,027.80	1.61
Other	228,549.60	357.12
Rangeland	78,586.06	122.79
Wetland:		
Vegetated	193.12	.30
Bare	11.68	.02
Riparian	1,565.96	2.45
Water:		
Streams and waterways	2,486.92	3.89
Still water		
Natural lakes and ponds	16.22	.03
Reservoirs	2,373.18	3.71
Summer dam impoundments	49.16	.08
Other	75.13	.12
Manmade waterways		
Stock ponds	146.09	.23
Canals	34.75	.05
Other	77.12	.12
Barren land:	32.50	.05
Sand beaches		
River	1,139.62	1.78
Sand areas other than beaches	1,092.13	1.71
Bare exposed rock	30.5	.05
Abandoned extractive		
Quarries	27.70	.04
Sand and gravel pits	33.20	.05
Transitional (land disturbed by construction).	1,371.48	2.14


122°30′
123°00′
123°30′
39°30′
39°00′
LAKE
MAYACMAS MOUNTAINS
U.S. GEOLOGICAL SURVEY
7.5-MINUTE QUADRANGLES
FOR WHICH LEVEL-III
LAND-USE AND LAND-COVER
INFORMATION IS MAPPED
Eel River
Lake Pillsbury
Potter Valley
East Fork Russian River
Lake Mendocino
Redwood Valley
West Fork Russian River
Ukiah Valley
RUSSIAN RIVER
Sanel Valley
HOPLAND
UKIAH
ELLEDGE PEAK
Ukiah
Hopland
101
Willits
BASIN BOUNDARY
MENDOCINO COUNTY
COAST
1



38°30′

FIGURE 8. — Part of basin covered by U.S. Army Corps of Engineers Level-III land-use and land-cover information.

Population and Water Use

Water in the Russian River basin is used primarily for agricultural, urban, recreational, and instream purposes. Surface water supplies most of the water used for agricultural and urban purposes (about 70 percent of the total water used in 1975). Projections show that surface water probably will continue to be the predominant source of water used for agricultural and urban purposes in the basin. Irrigation of vineyards is the primary agricultural use. Most of the agricultural use is upstream of Healdsburg. Urban use is mainly downstream of Healdsburg, with surface water supplying about two-thirds of the urban use. Recreational use of water (primarily swimming, bathing, and boating) occurs throughout the basin, but most of it occurs downstream of Mirabel Park. Of the water used for agricultural and urban purposes, more than one-half of it is used from May to October (California Department of Water Resources, 1980).

Agricultural water users generally obtain surface water either by direct diversion or pumping. The Sonoma County Water Agency is the major purveyor of water for urban use in the Russian River basin. This agency relies on surface water obtained from Ranney collectors, located adjacent to the Russian River near Mirabel Park, to meet the water needs of the Santa Rosa area. About one-half of the water obtained from the Ranney collectors is transported out of the basin for use in southern Sonoma and northern Marin Counties.

As a result of an agreement between the Sonoma County Water Agency and the California Department of Fish and Game, minimum flows to maintain fish habitat are required at two locations on the Russian River: (1) 150 ft^3/s at the junction of the east and west forks of the Russian River, and (2) 125 ft^3/s downstream of Guerneville. Presently, these requirements are met by releases from Lake Mendocino. When the Warm Springs Dam Project (Lake Sonoma) is completed (fig. 1), additional water will be available to meet these requirements and water uses in the basin.

DATA COLLECTION AND METHODS

1973-76

During 1973 and 1974, the Regional Board collected water-quality samples between Alexander Valley and Duncan Mills near the mouth of the river (stations 11463680-11466850 and 11467002-11467210, as shown in fig. 9). Properties and constituents sampled and sampling frequencies are listed in table 3. The twice-weekly samples were collected during normal working hours, with the sequence of stations sampled reversed every week. Samples were collected by the Regional Board staff, and handled in accordance with California Department of Health Services procedures (California Department of Public Health, 1971).

Field measurements and laboratory analyses were conducted in accordance with standard methods current at that time (American Public Health Association and others, 1971). Fieldwork was done by the Regional Board staff, and laboratory analyses were done in commercial laboratories working under contract with the Regional Board and approved by the California Department of Health Services.

In 1975 and 1976, the Regional Board expanded its sampling effort (table 3) to include all but two stations (Russian River near Cloverdale (11463000 and Russian River near Guerneville 11467000) used in the joint Survey-Regional Board samplings of 1977 and 1978.

During 1975, samples were collected twice weekly; in 1976, they were collected once weekly. Because it was impractical to collect from all stations on a single day, the samples for the upper reaches of the river from the East and West Forks of the Russian River to Geyserville (11461000-11463500) were collected on one day and the remainder from Jimtown to Duncan Mills (11463680-11467210) on the next sampling day. Sampling was done during normal working hours, and the sequence of stations sampled was reversed for each sampling trip. Samples were collected and handled in the field, as they were in 1973-74, and again they were analyzed by contract laboratories using standard methods current at that time (American Public Health Association and others, 1976).

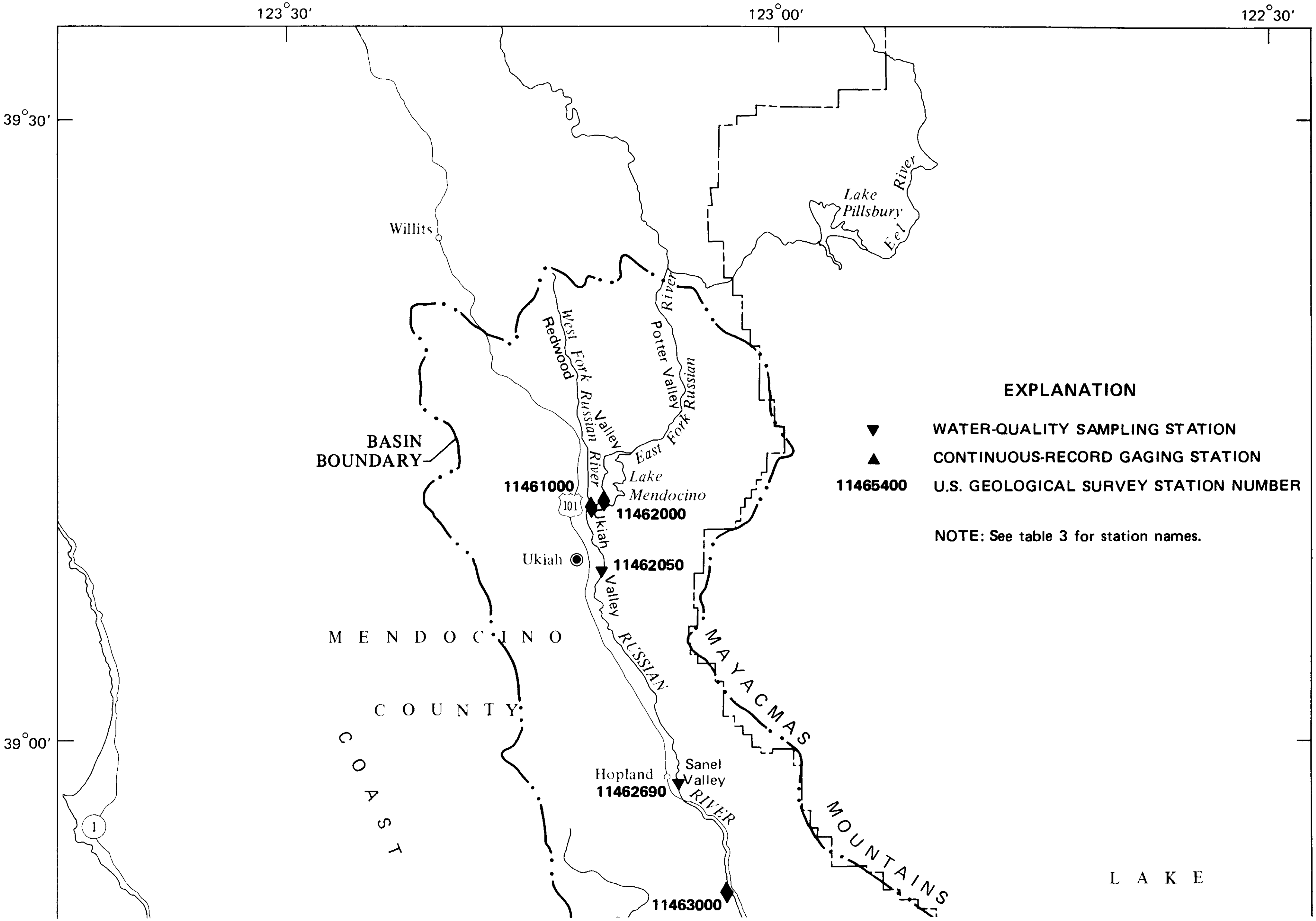
As shown in the far right column of table 3, the Survey during this period was sampling at station 11462000 as part of a cooperative study with the U.S. Army Corps of Engineers, San Francisco District, and at station 11467000 which is part of the National Stream Quality Accounting Network (NASQAN). Data collected by the Survey at these stations during the time periods shown in table 3 are included in this report.

1977 and 1978

Scheduled Sampling

From May to October (low-flow season) of 1977 and 1978, the Survey and the Regional Board jointly sampled at the 18 stations shown in figure 9 for the properties and constituents and at the sampling frequencies listed in table 4. The sampling stations were selected for the reasons given in table 4 and on the basis of the information obtained during a reconnaissance of possible sampling stations during April 1977 (table 5). The reconnaissance provided information on the general character of each station and the magnitude of any cross-sectional variation in water quality. Such information indicated the suitability of each station for streamflow measurements and water-quality sampling.

Constituent selection was based on the observation that the principal water-quality problems in the Russian River basin were bacterial contamination (California Regional Water Quality Control Board, North Coast Region, 1976) and nuisance algal growths (California Department of Water Resources, 1968).



123°30′
123°00′
122°30′
39°30′
39°00′
EXPLANATION
WATER-QUALITY SAMPLING STATION
CONTINUOUS-RECORD GAGING STATION
11465400 U.S. GEOLOGICAL SURVEY STATION NUMBER
NOTE: See table 3 for station names.
Willits
Lake Pillsbury
Eel River
River
Potter Valley
East Fork Russian
Redwood
Valley
West Fork Russian River
BASIN BOUNDARY
Lake Mendocino
11461000
11462000
101
Ukiah
11462050
Valley
RUSSIAN
RIVER
MENDOCINO
COUNTY
COAST
MAYACMAS
MOUNTAINS
Hopland
11462690
Sanel Valley
11463000
LAKE
1

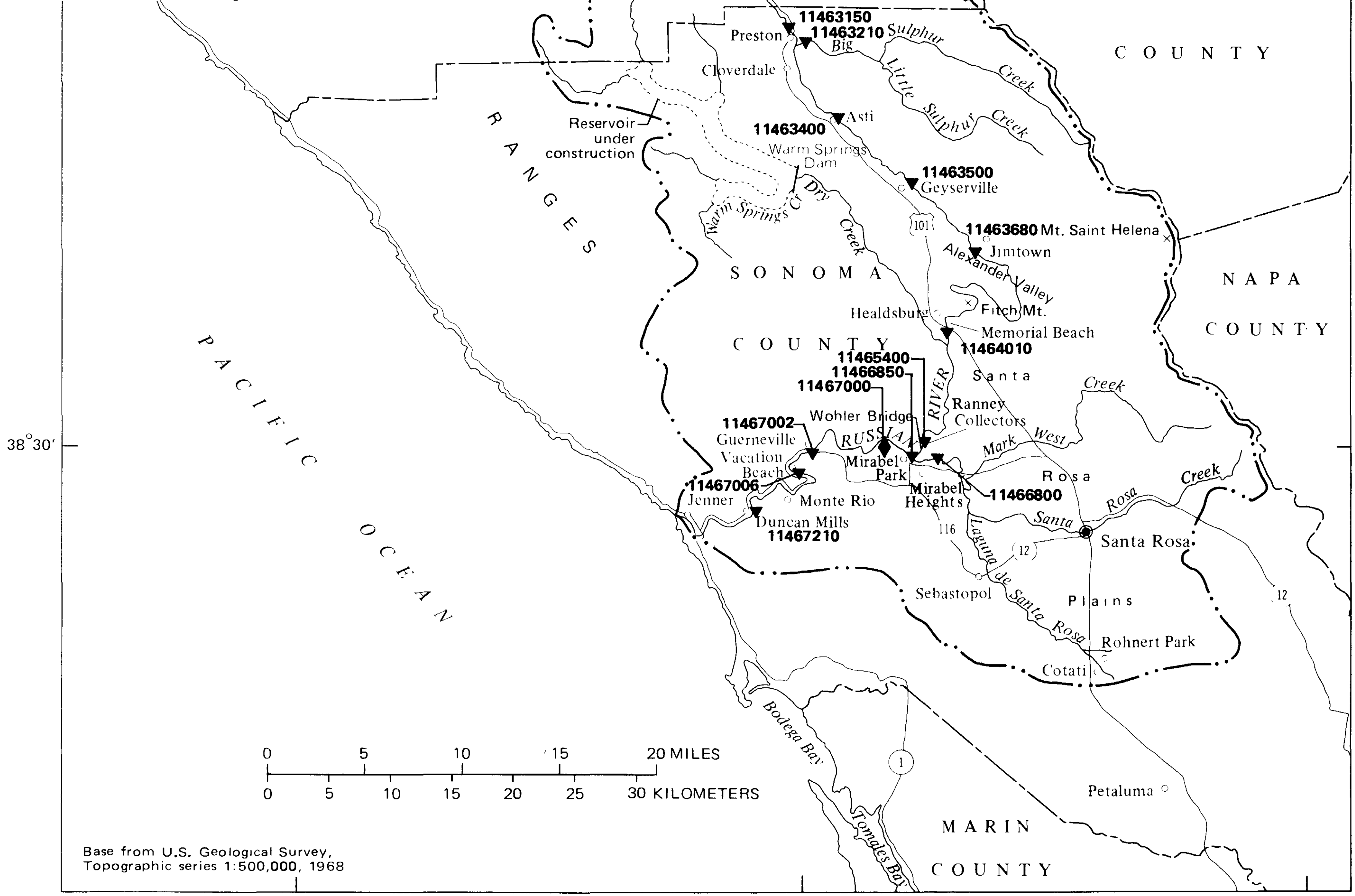


FIGURE 9. — Location of sampling stations.

TABLE 3. - Sampling program during low-flow seasons, 1973-76

[Sampling or measurement frequency, number of times per month. Field measurements, water temperature, pH, alkalinity, specific conductance, dissolved oxygen, and turbidity. Nutrients, include total NO_3, Kjeldahl nitrogen, and phosphorus, unless otherwise noted. Agency collecting data: RB, Regional Board; USGS, U.S. Geological Survey]

Dates	Station No.	Station name	Sampling or measurement frequency: Field measurements	Total coliform bacteria MPN	Fecal coliform bacteria MPN	Fecal strepto-coccal bacterial MPN	Pseudomonas aeruginos bacteria MPN	Nutrients	Phyto-plankton counts	Agency collecting data
Sept. 1974	11461000	Russian River near	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Ukiah.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	1-3	1-3	1-3	
May to Oct. 1973	11462000	East Fork Russian	3-4	-	-	-	-	0-1[1]	-	USGS.
May to Oct. 1974		River near Ukiah.	1-4	-	10	-	-	0-1[1]	-	RB, USGS.
May to Oct. 1975			4-13	7-9	7-9	0-1	0-1	1-5[1]	2-4	RB, USGS.
May to Oct. 1976			2-6	2-3	2-3	0-3	0-3	1-4[1]	1-3	RB, USGS.
Sept. 1974	11462050	Russian River at	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Ukiah.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	0-3	1-3	1-3	
Sept. 1974	11462690	Russian River at	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Hopland.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	0-3	1-3	1-3	
Sept. 1974	11463150	Russian River at	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Preston.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	0-3	1-3	1-3	
Sept. 1974	11463210	Big Sulphur Creek		-	10	-	-	-	-	
Apr. to Nov. 1975		at mouth	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976		near Cloverdale.	1-3	1-3	1-3	0-3	0-3	1-3	1-3	
Aug. to Sept. 1974	11463400	Russian River at	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Asti.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	0-3	1-3	1-3	
Sept. 1974	11463500	Russian River at	-	-	10	-	-	-	-	
Apr. to Nov. 1975		Geyserville.	4-9	4-9	4-9	0-1	0-1	2-5	2-4	
Apr. to Nov. 1976			1-3	1-3	1-3	0-3	0-3	1-3	1-3	
May to Oct. 1973	11463680	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Alexander Valley	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975		Road Bridge.	4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-3	1-3	0-2	0-2	1-3	1-3	

TABLE 3. - Sampling program during low-flow seasons, 1973-76--Continued

Dates	Station No.	Station name	Sampling or measurement frequency: Field measure-ments	Total coliform bacteria MPN	Fecal coliform bacteria MPN	Fecal strepto-coccal bacterial MPN	Pseudomonas aeruginos bacteria MPN	Nutrients	Phyto-plankton counts	Agency collecting data
May to Oct. 1973	11464010	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Healdsburg.	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-3	1-3	0-2	0-2	1-3	1-3	
May to Oct. 1973	11465400	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Wohler Bridge.	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	
July to Oct. 1973	11466800	Mark West Creek	3-5	0-1	0-1	-	-	2-4	0-1	
July to Oct. 1974		near Mirabel	4-9	2-4	0-5	-	-	2-9[3]	2-4	
Apr. to Nov. 1975		Heights.	4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	
May to Oct. 1973	11466850	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Mirabel Heights.	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	
May to Oct. 1974	11467000	Russian River	1-4	-	-	-	-	1[4]	1	USGS.
May to Oct. 1975		near Guerneville.	1-7	-	-	-	-	1	1	USGS.
May to Oct. 1976			0-3	-	-	-	-	0-1[5]	1	USGS.
May to Oct. 1973	11467002	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Johnson's Beach.	4-9	2-5	-	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	
May to Oct. 1973	11467006	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Vacation Beach.	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	
May to Oct. 1973	11467210	Russian River at	0-9	1-5	-	-	-	0-5[2]	1-5	
June to Oct. 1974		Duncan Mills.	4-9	2-5	0-5	-	-	2-9[3]	2-5	
Apr. to Nov. 1975			4-10	4-10	4-10	0-1	0-1	2-8	2-5	
Apr. to Nov. 1976			1-3	1-2	1-2	0-2	0-2	1-3	1-3	

[1]Nutrients sampled at this station: Total and dissolved NO_2, NO_3, NH_4, Kjeldahl nitrogen, total phosphorus, and dissolved orthophosphorus.
[2]Nutrients sampled at this station: Total NO_2, NO_3, NH_4, Kjeldahl nitrogen, phosphorus, and dissolved orthophosphorus.
[3]Nutrients sampled at this station: Total NO_3, Kjeldahl nitrogen, phosphorus, and dissolved orthophosphorus.
[4]Nutrients sampled at this station: Total NO_2+NO_3, Kjeldahl nitrogen, and phosphorus.
[5]Nutrients sampled at this station: Total NO_2, NO_3, NH_4, Kjeldahl nitrogen, and phosphorus.

TABLE 4. - Sampling program during 1977 and 1978

[Sampling or measurement frequency: number indicates times per month; C, continuous recorder; MJ, one sample during May or June; AS, one sample during August or September]

Station No.	Station name	Reason for station selection														
				Characterize streamflow and water quality of												
		Existing or historical gaging station	Existing or historical water-quality station	Major river branch or tributary	Main stem downstream of major river branch or tributary	Main stem or tributary downstream of major urban area	Main stem or branch in agricultural area	Main stem, branch, or tributary in recreational area	Main stem within or downstream of recreational impoundment	Main stem within or downstream of major riparian sand and gravel extraction area	Main stem at upstream limits of tidal influence	Major geomorphic reach type	Reservoir release	Downstream of geothermal area	Bacterial contamination problem	Nuisance algal growth problem
11461000	Russian River near Ukiah	X	X	X			X								X	
11462000	East Fork Russian River near Ukiah	X	X	X				X	X				X			
11462050	Russian River at Ukiah	X	X		X	X	X			X						
11462690	Russian River at Hopland		X				X					X				
11463000	Russian River near Cloverdale	X						X				X				
11463150	Russian River at Preston		X									X			X	
11463210	Big Sulphur Creek at mouth near Cloverdale.[1]		X	X										X		
11463400	Russian River at Asti		X		X		X	X							X	
11463500	Russian River at Geyserville		X				X	X		X		X				
11463680	Russian River at Alexander Valley Road Bridge		X				X	X		X		X			X	
11464010	Russian River at Healdsburg		X					X	X	X		X				
11465400	Russian River at Wohler Bridge		X				X	X	X	X					X	
11466800	Mark West Creek near Mirabel Heights		X	X		X									X	X
11466850	Russian River at Mirabel Heights		X		X	X		X	X						X	X
11467000	Russian River near Guerneville	X	X					X				X				
11467002	Russian River at Johnson's Beach		X					X	X						X	X
11467006	Russian River at Vacation Beach		X					X	X						X	X
11467210	Russian River at Duncan Mills		X								X				X	

TABLE 4. - Sampling program during 1977 and 1978--Continued

Station No.	Station name	Sampling or measurement frequency							
		Water discharge	Field measurements[2] and fecal coliform and fecal streptococcal bacteria (MF and MPN)	Nutrients[3]	Chemical oxygen demand 1977	Chemical oxygen demand 1978	Algal growth potential and phytoplankton counts, chlorophyll *a*, and biomass	*Pseudomonas aeruginosa* bacteria	Periphyton, chlorophyll *a*, and biomass
11461000	Russian River near Ukiah	C	5	2	2	-	1	1	MJ-AS
11462000	East Fork Russian River near Ukiah	C	5	2	2	-	1	1	MJ-AS
11462050	Russian River at Ukiah	5	5	2	2	-	1	1	MJ-AS
11462690	Russian River at Hopland	5	5	2	2	-	1	1	MJ-AS
11463000	Russian River near Cloverdale	C	5	2	2	-	1	1	MJ-AS
11463150	Russian River at Preston	Not possible[4]	5	2	2	-	1	1	MJ-AS
11463210	Big Sulphur Creek at mouth near Cloverdale	5	5	2	2	-	1	1	MJ-AS
11463400	Russian River at Asti	5	5	2	2	-	1	1	MJ-AS
11463500	Russian River at Geyserville	5	5	2	2	-	1	1	MJ-AS
11463680	Russian River at Alexander Valley Road Bridge	5	5	2	2	-	1	1	MJ-AS
11464010	Russian River at Healdsburg	5	5	2	2	-	1	1	MJ-AS
11465400	Russian River at Wohler Bridge	Not possible[4]	5	2	2	2	1	1	MJ-AS
11466800	Mark West Creek near Mirabel Heights	5	5	2	2	2	1	1	MJ-AS
11466850	Russian River at Mirabel Heights	5	5	2	2	2	1	1	MJ-AS
11467000	Russian River near Guerneville	C	5	2	2	-	1	1	MJ-AS
11467002	Russian River at Johnson's Beach	5	5	2	2	-	1	1	MJ-AS
11467006	Russian River at Vacation Beach	5	5	2	2	-	1	1	MJ-AS
11467210	Russian River at Duncan Mills	Not possible[4]	5	2	2	-	1	1	MJ-AS

[1]Major ions (HCO_3, Cl, SO_4, Ca, Mg, Na, K, SiO_2, B, F, Fe) sampled 2 times per month only from May to October 1977.

[2]Field measurements: specific conductance, water temperature, pH, dissolved oxygen and turbidity.

[3]Nutrients: dissolved NO_2 as N, dissolved NO_3 as N, dissolved Kjeldahl nitrogen as N, dissolved NH_4 as N, dissolved organic nitrogen as N, total NO_2 as N, total NO_3 as N, total Kjeldahl nitrogen as N, total NH_4 as N, total organic nitrogen as N, dissolved orthophosphorus as P, and total phosphorus as P.

[4]Not possible because station was in pooled, impounded, or tidally influenced section of river.

TABLE 5. - Example of completed reconnaissance sampling form showing the kind of information obtained

[LEW, left edge water; REW, right edge water; S, near surface; M, middle; B, bottom]

WATER QUALITY - RECONNAISSANCE FORM

STATION NAME: Russian River at Mirabel Heights — 7½-minute quadrangle Camp Meeker
NUMBER: 11466850 — DATE: 4/23/77 — TIME: 11:00 a.m. to 11:30 a.m.

Field measurements	Cross section points					Upstream 35-foot centroid	Downstream 30-foot centroid	Verticals								
								1 5 feet from LEW			2 Centroid			3 2 feet from REW		
	1	2	3	4	5			S	M	B	S	M	B	S	M	B
Water temperature----------------°C--	19.0	19.0	19.0	19.5	19.5	19.0	19.0	18.5	18.5	18.5	19	19	19	19	19	19
Specific conductance--µmho at 25°C--	370	370	375	379	382	364	368	---	---	---	---	---	---	---	---	---
pH----------------------------units--	8.2	8.2	8.2	8.2	8.3	---	---	---	---	---	---	---	---	---	---	---
Dissolved oxygen--------------mg/L--	---	---	---	---	---	---	---	9.8	9.9	9.9	9.8	9.9	9.8	9.8	9.8	9.8

Water discharge -- Estimated at 75 ft^3/s.
Time of travel from last station -- 10 minutes (8.2 miles) from Russian River near Guerneville (11467000).
Route -- River Road.
Station location description -- Approached from left bank, about 200 feet downstream of old dam posts downstream of Mirabel Park swimming area and boat launch. Ranney collectors on right bank.
Station character description -- Water appearance (light penetration, degree of shading, color) -- Turbid, brownish color (different from downstream stations where water appears greenish).
Substrate of streambed -- Small cobbles, sand, and silt. Steeper than right bank — Fairly flat

LEW ← 40 feet → REW

Vegetation and streambank -- At sampling station very little canopy. Mostly willows and low brush; redwoods and California bay on left bank near dam posts and recreation area.
Manmade structures -- Ranney collectors on right bank, old dam posts approximately 200 feet upstream.
Aquatic life -- Some filamentous, green periphyton.
Access -- At Mirabel Park Recreation area. Take north exit at sign (junction of River Road and Mirabel Road). Park in campground area and walk about 500 feet downstream using left bank to sampling station.
Best spot for QW -- 200 feet downstream of old dam posts, mostly level river bed, moderate water velocity.
Best spot for streamflow measurement -- same as for QW, stream velocity = 1-2 ft/s, sufficient depths in cross section for measurements.
Inflows -- Mark West Creek about ¼ mile upstream on left bank.
Other comments -- Pictures taken: 1. Sampling site. 2. Upstream area from sampling site. 3. Downstream area from sampling site.

Diel Study

In addition to the scheduled sampling shown in table 4, a diel study (intensive monitoring for a 24-hour period) was done during 1977 at two stations: Russian River at Alexander Valley Road Bridge (11463680) and Russian River near Guerneville (11467000). The diel study was done to provide an estimate of primary productivity and community metabolism in the Russian River during the low-flow season. To obtain an estimate representative of the low-flow season, late August was chosen because streamflows were fairly stable and about average for the 1977 low-flow season and recreational use was considered typical for the season. The station at Alexander Valley Road Bridge was chosen because it was at the downstream limits of a major agricultural area and geomorphic reach-type 2. The station near Guerneville was chosen because it was within the river's major recreational-use area and geomorphic reach-type 1. In addition, by choosing these stations, urban influences on river productivity and community metabolism might be assessed because the station near Guerneville is downstream of the basin's major urban center, Santa Rosa, whereas the station at Alexander Valley Road Bridge is downstream of an agricultural area and upstream of Santa Rosa.

Field Methods

Using the current-meter method (Carter and Davidian, 1968, p. 6 and 7), instantaneous discharge measurements were made at stations without continuous recorders. At continuous-record stations, water stages were measured using bubble-gage sensors with digital recorders. Water discharges were derived from the water-stage record and the stage-discharge relation developed from current-meter measurements. Portable meters were used for making field measurements of pH and specific conductance. Water-temperature measurements were made with hand-held mercury-filled thermometers that were calibrated with an ASTM (American Standards for Testing Materials) standard laboratory thermometer. Field thermometers had a full-scale accuracy of 0.5°C. Dissolved-oxygen concentrations were determined by the Alsterberg azide modification of the Winkler method (Skougstad and others, 1979, p. 611-613). Alkalinity was measured by electrometric titration (Skougstad and others, 1979, p. 517 and 518) and was done only at Big Sulphur Creek at mouth near Cloverdale (11463210) during 1977, in conjunction with major-ion sampling. The membrane filter method was the field technique used to enumerate fecal-coliform and fecal-streptococcal bacteria concentrations in water. Culture media were M-FC agar for fecal-coliform bacteria and KF streptococcus agar for fecal-streptococcal bacteria (Greeson and others, 1977, p. 53-62). Laboratory methods were also used to enumerate fecal-coliform and fecal-streptococcal bacteria as well as *Pseudomonas aeruginosa* bacteria (see laboratory methods).

Multi-electrode, water-quality monitors were used during the diel study to measure water temperature, pH, specific conductance, and dissolved-oxygen concentration (electrometric, polarographic probe method; Skougstad and others, 1979, p. 537-542).

Water samples were obtained at the centroid of flow. Grab samples were obtained for bacteria and depth-integrated samples for other properties and constituents. Centroid samples were considered representative of water-quality conditions at the sampling stations because data obtained during the reconnaissance survey of possible sampling stations indicated there was little cross-sectional variation in water quality at these stations.

Samples for dissolved constituents were filtered in the field through 0.45-μm pore-size membrane filters. Samples for cations and chemical-oxygen demand were acidified to a pH of less than 2. Samples for nutrients were chilled. Samples for phytoplankton enumeration were collected in 1-liter, narrow-mouth bottles and preserved with 40 mL of 37- to 40-percent formalin solution, 5 mL of 20-percent detergent solution, and 1 mL of cupric sulfate solution. Samples for phytoplankton cellular contents (chlorophyll and biomass) and AGP (algal growth potential) were collected in narrow-mouth, glass jugs. For phytoplankton cellular contents, a measured quantity of the water collected was filtered through a 47-mm glass-fiber filter. The filter was rolled with the phytoplankton on the inside and placed in a glass vial with a screw cap. The vial was immediately chilled with ice. Upon completion of the field trip, the chilled vials were frozen before shipment to the laboratory. For AGP, filtrate from phytoplankton filtration was refiltered using a low-water extractable, 0.22-μm pore-size membrane filter. To prevent damage to algal cells and possible release of nutrients into the sample, a vacuum of 10 inches of mercury was not exceeded during filtration. The filtrate was put into a liter bottle and immediately chilled.

Periphyton samples were collected using artificial substrates (1- by 6-inch polyethylene strips). The strips usually were nailed to the streambed in riffles at locations and depths providing appropriate light exposure for algal growth. At stations in pooled, impounded, or tidally influenced sections of the river, strips were attached to submerged objects in sunlit areas. These strips were installed at each station during May or June, and August or September. Strips were retrieved from the water after a green or brown growth was noticed. Length of exposure (colonization period) varied from station to station according to edaphic and climatic conditions at each station, and seasonal changes in these conditions. After retrieval, the strips were immediately put into glass jars and chilled.

Nutrient, major ion, and COD (chemical oxygen demand) samples were sent express mail (guaranteed 24-hour delivery time) to the U.S. Geological Survey Water Quality Laboratory in Denver, Colo. Phytoplankton, periphyton, and AGP samples were sent express mail to the U.S. Geological Survey Water Quality Laboratory in Doraville, Ga. Bacterial samples for laboratory analyses were sent to private local laboratories approved by the California Department of Health Services and chosen by the Regional Board.

Laboratory Methods

Nutrient samples were analyzed using automated colorimetric methods given in Skougstad and others (1979, p. 389-399, 407, 415-417, 433-439, 445-447, 479-481, and 491-493). Samples for calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were analyzed by atomic absorption spectrometric methods given in Skougstad and others (1979, p. 107 and 108, 177 and 178, 229 and 230, and 255-256). Automated colorimetric methods (Skougstad and others, 1979, p. 333-335, 375-377, 497-499, and 501-504) were used to analyze samples for iron (Fe), chloride (Cl), silica (SiO_2), and sulfate (SO_4). Samples for boron (B) were analyzed by a nonautomated colorimetric method (Skougstad and others, 1979, p. 315 and 316). Bicarbonate was calculated from alkalinity determinations done by the electrometric titration method (Skougstad and others, 1979, p. 517 and 518). Fluoride determinations were done by electrometric ion-selective electrode method (Skougstad and others, 1979, p. 525-528). During 1977, COD samples were analyzed by the "low-level" method (Brown, Skougstad, and Fishman 1970, p. 124-126) and during 1978, the "high-level" method was used (Skougstad and others, 1979, p. 449 and 450).

The inverted microscope method was used to enumerate phytoplankton (Greeson and others, 1977, p. 97-99). Cellular contents of phytoplankton and periphyton were determined by chromatography and fluorometry (Greeson and others, 1977, p. 217-224 and 233-241). AGP bioassays were done using an electronic particle counter to obtain counts of the test alga, Selenastrum capricornutum. Counts were made until the growth rate of the test alga was less than 5 percent per day. This was considered to be the point at which the maximum standing crop had been obtained.

Turbidity measurements were done at the Regional Board's laboratory in Santa Rosa, Calif., by the people who did the sampling, using the nephelometric method given in Skougstad and others (1979, p. 549 and 550). Samples for turbidity were chilled immediately after collection and measurements made within 24 hours.

Laboratory analyses for fecal-coliform, fecal-streptococcal, and Pseudomonas aeruginosa bacteria were done by multiple tube fermentation MPN (most probable number) methods (American Public Health Association and others, 1976, p. 916-926, 942-944, and 976-982).

RESULTS AND DISCUSSION

Temporal Variations in Streamflow and Water Quality

Changes in Streamflow and Water Quality During the Period of Study

Prior to 1975, treated wastewater was discharged to the Russian River throughout the year. In 1975, when improved wastewater treatment facilities were coming into operation, the Regional Board adopted regulations prohibiting the discharge of wastewater to the Russian River and its tributaries during the low-flow season. By 1977 no wastewater was discharged to the Russian River during the low-flow season. During 1976 and 1977, a drought occurred in California.

The flow of the Russian River during the period of this study is summarized in figures 10 and 11. Streamflows are given at only two stations because prior to 1977 either streamflow measurements were not made or water-quality samples were not collected at the other stations. Flows at Russian River near Guerneville (11467000) for the 1973 low-flow season are not shown in figure 11 because water-quality data were not collected at this station during that time. The flow of the Russian River during the 1973-75 and 1978 water years was greater than normal, but during the drought (1976-77) the flow was considerably less than normal (fig. 10). Flow at East Fork Russian River near Ukiah (11462000) was 69 percent of normal in 1976 and 31 percent of normal in 1977. Near Guerneville the flow was 17 percent of normal in 1976 and 4 percent of normal in 1977. Thus, the effect of the drought on the flow of the Russian River was more evident in the lower part of the basin than it was in the upper part of the basin where flows are regulated by Coyote Dam.

Changes in the flow of the Russian River during the 1973-78 low-flow seasons correspond to changes in annual mean flows (figs. 10 and 11). During the 1973-78 low-flow seasons, streamflow at East Fork Russian River near Ukiah and at Russian River near Guerneville varied greatly (fig. 11). During the low-flow season, streamflow was less during drought years than during non-drought years.

The effect of wastewater regulations and the drought on water quality of the Russian River is shown in figures 12-16. These data displays are for five representative stations: (1) East Fork Russian River near Ukiah (11462000); (2) Russian River at Alexander Valley Road Bridge (11463680); (3) Mark West Creek near Mirabel Heights (11466800); (4) Russian River at Mirabel Heights (11466850); and (5) Russian River at Johnson's Beach (11467002). Water-quality properties and constituents shown are the ones for which samples were obtained throughout the study period.

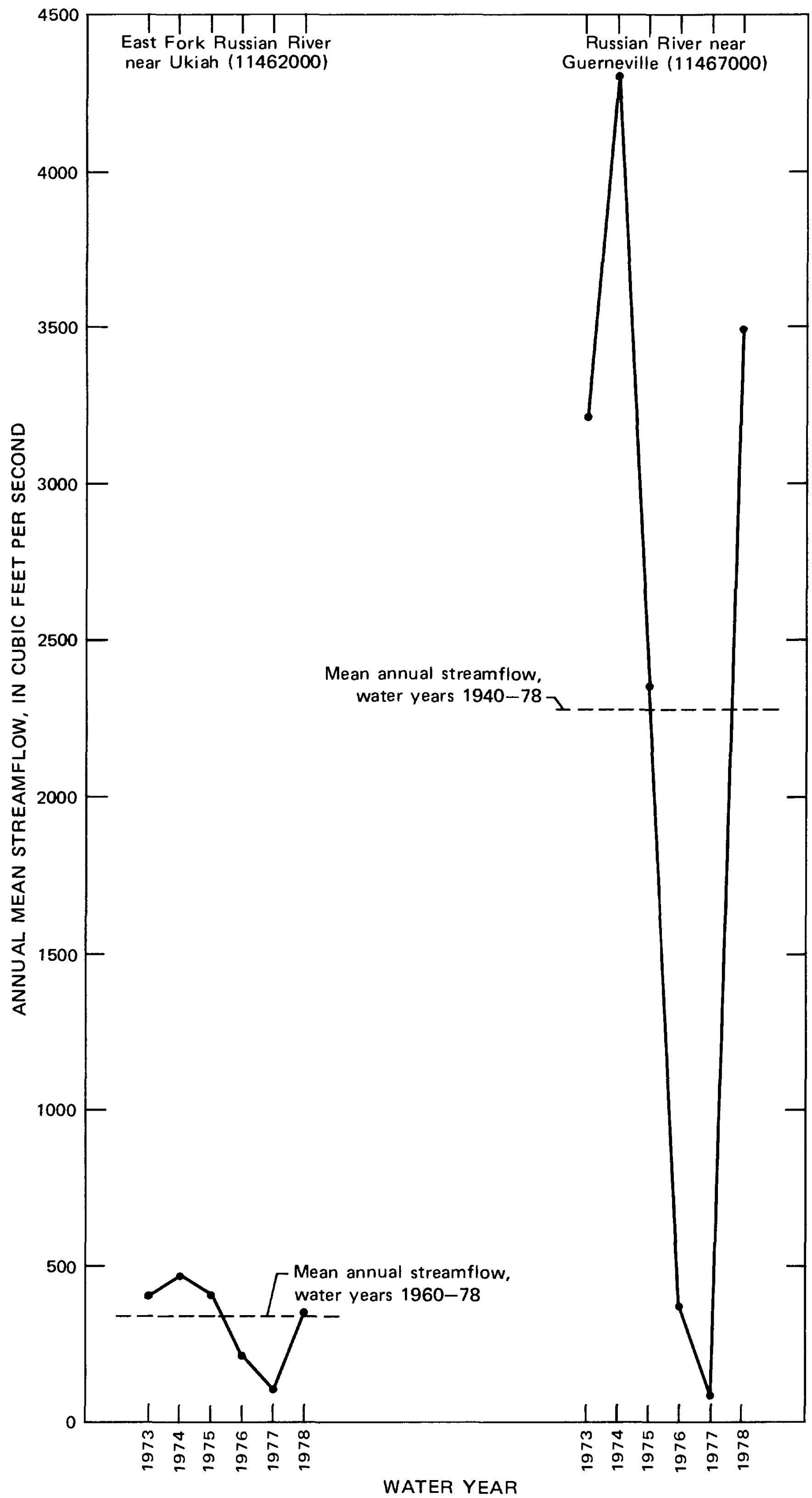


FIGURE 10. – Changes in annual mean streamflow, 1973–78 water years.

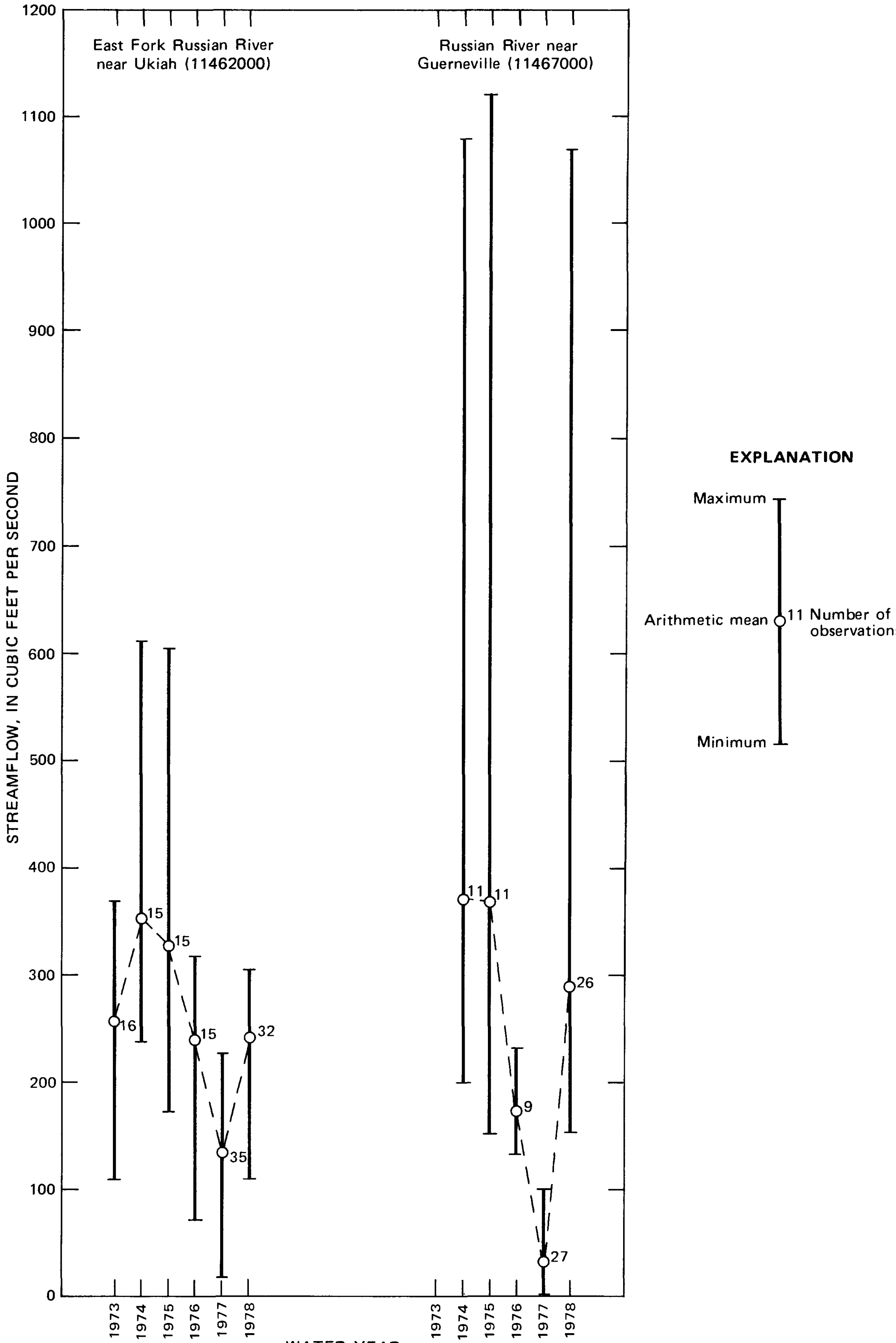


FIGURE 11. – Streamflow during the low-flow season, 1973–78 water years.

The patterns of change in water quality are nearly the same at main-stem stations: Russian River at Alexander Valley Road Bridge, Russian River at Mirabel Heights, and Russian River at Johnson's Beach (figs. 13, 15, and 16, respectively). At these stations, beginning in 1975, substantial decreases occurred in fecal-coliform bacteria, total nitrate, total ammonia plus organic nitrogen, and dissolved orthophosphorus. These decreases coincide with the initial implementation of regulations specifying no discharge of wastewater during the low-flow season.

Turbidity was less during 1977 and 1978, than during 1974. This does not appear to be related to the regulation of wastewater discharges or the drought because turbidity generally was greater at Russian River at Mirabel Heights and at Russian River at Johnson's Beach during 1976 than during other years of study.

From 1977 to 1978, there was an increase in total nitrate and total ammonia plus organic nitrogen at Russian River at Alexander Valley Road Bridge and at Russian River at Mirabel Heights. This appears to be the result of increased storm runoff and greater streamflows after the 1976-77 drought.

A large increase in phytoplankton occurred from 1976 to 1977. Another large increase occurred from 1977 to 1978 at Russian River at Mirabel Heights and Russian River at Johnson's Beach. Increases in phytoplankton from 1976 to 1977 are related to substantially less streamflow during the 1977 water year (fig. 10). Less streamflow, especially during the low-flow season (fig. 11), coupled with less turbidity can concentrate nutrients and allow greater light penetration into the water of the Russian River, thus promoting phytoplankton growth. During the 1978 low-flow season, phytoplankton concentrations remained greater than during the 1974-76 low-flow seasons. This suggests the reduction in turbidity from 1974-76 levels to 1977-78 levels (figs. 12-16) is more important than reduced streamflows in promoting phytoplankton growth.

The station, East Fork Russian River near Ukiah, is immediately downstream of Lake Mendocino and the flow at this station is water released from the lake. Thus, the water quality at this station is closely related to the water quality of and variations in volume of water released from Lake Mendocino. At Russian River at Alexander Valley Road Bridge, Russian River at Mirabel Heights, and Russian River at Johnson's Beach, specific conductance, total nitrate, turbidity, and phytoplankton values also appear to be related to the water quality of Lake Mendocino and variations in the volume of water released from this lake. The patterns of yearly change in values of these water-quality properties and constituents at these stations (figs. 13, 15, and 16) are similar to those observed at East Fork Russian River near Ukiah. However, concentrations of fecal-coliform bacteria, total ammonia plus organic nitrogen, and dissolved orthophosphorus at these stations do not appear to be related to the water quality of Lake Mendocino or to variations in the volume of water released from this lake, because the patterns of yearly change in values of these constituents are not similar to those observed at East Fork Russian River near Ukiah.

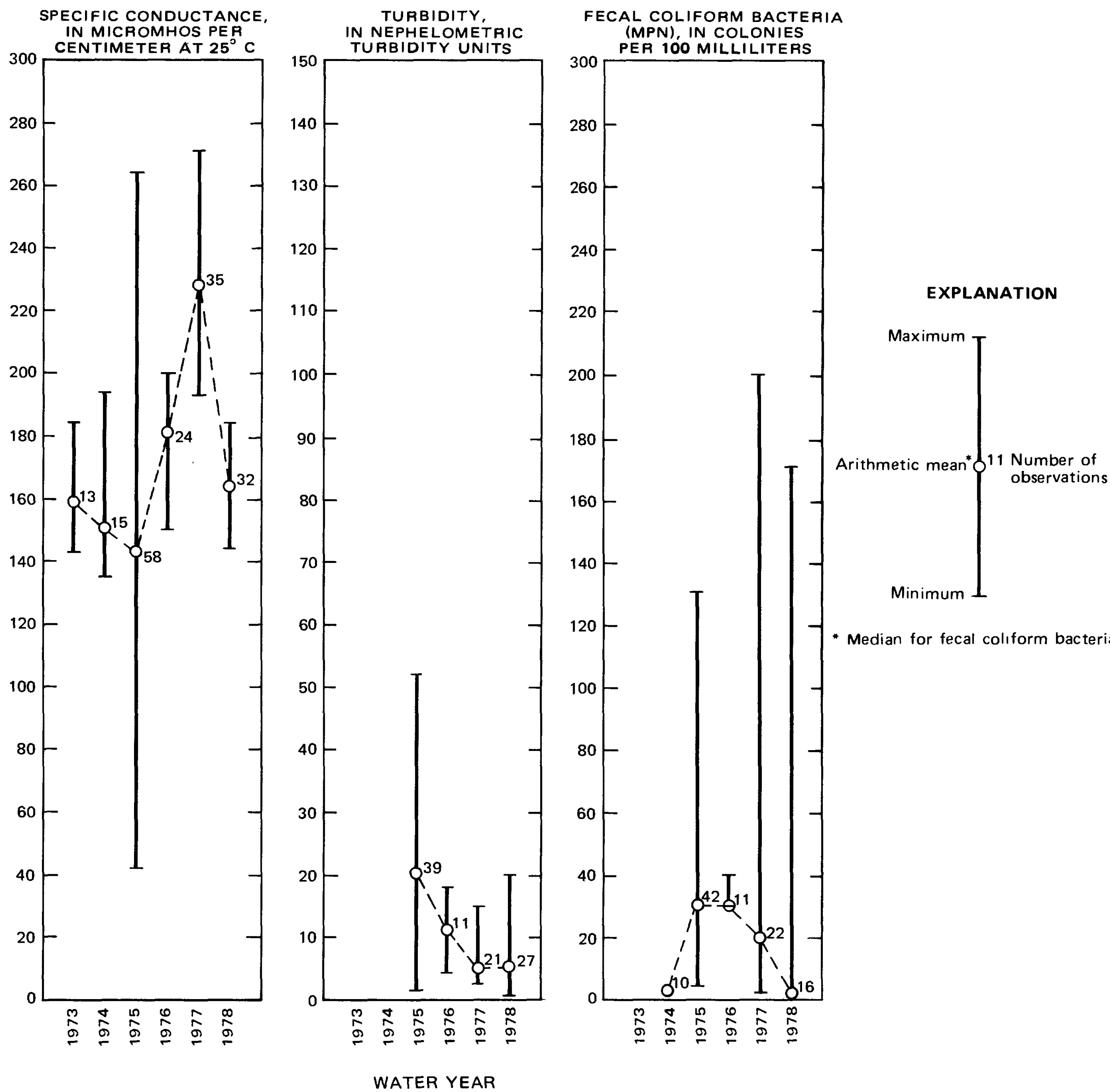


FIGURE 12. – Changes in water quality during the study period at East Fork Russian River near Ukiah (station 11462000).

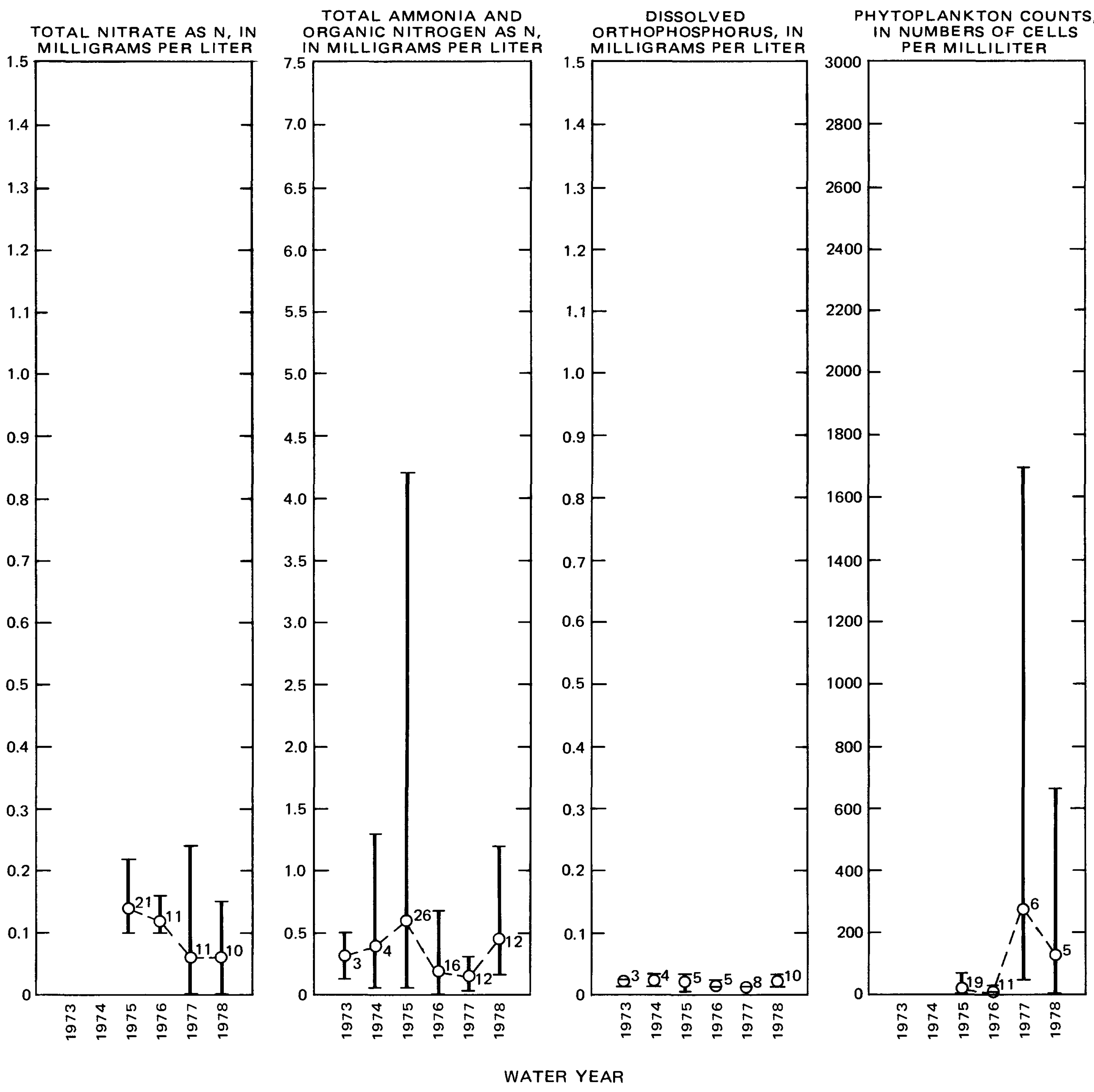


FIGURE 12. – Continued.

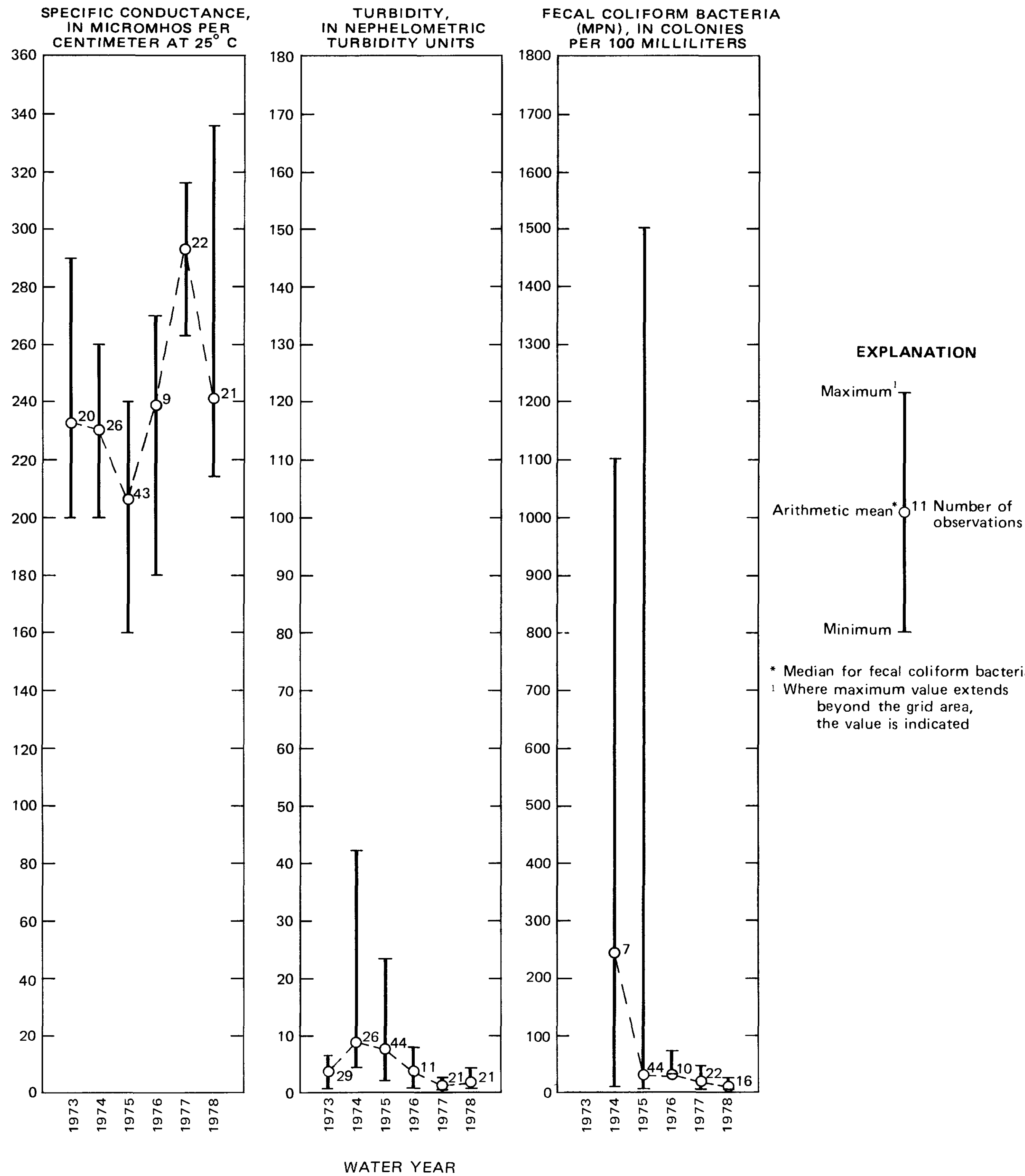


FIGURE 13. – Changes in water quality during the study period at Russian River at Alexander Valley Road Bridge (station 11463680).

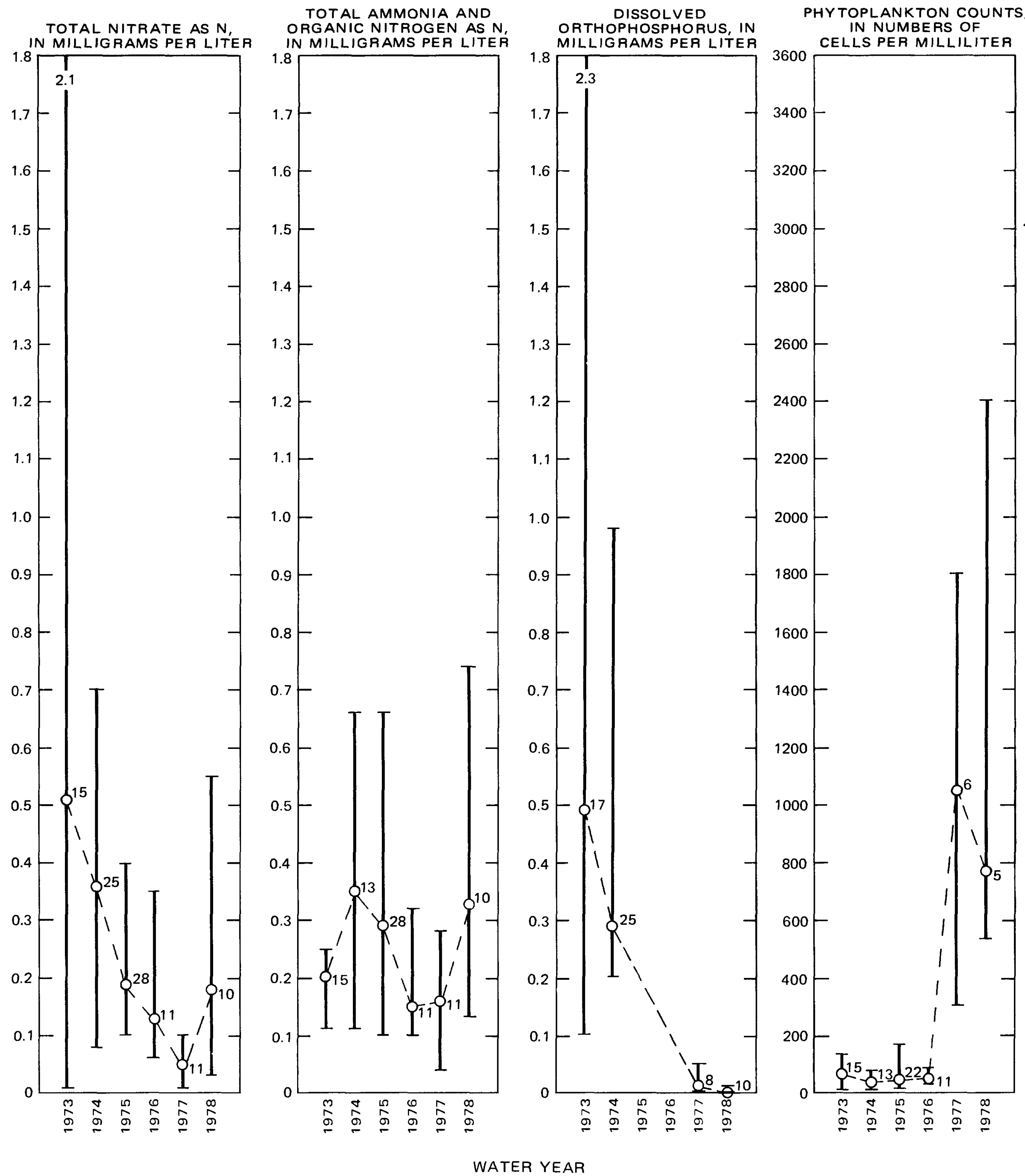


FIGURE 13. – Continued.

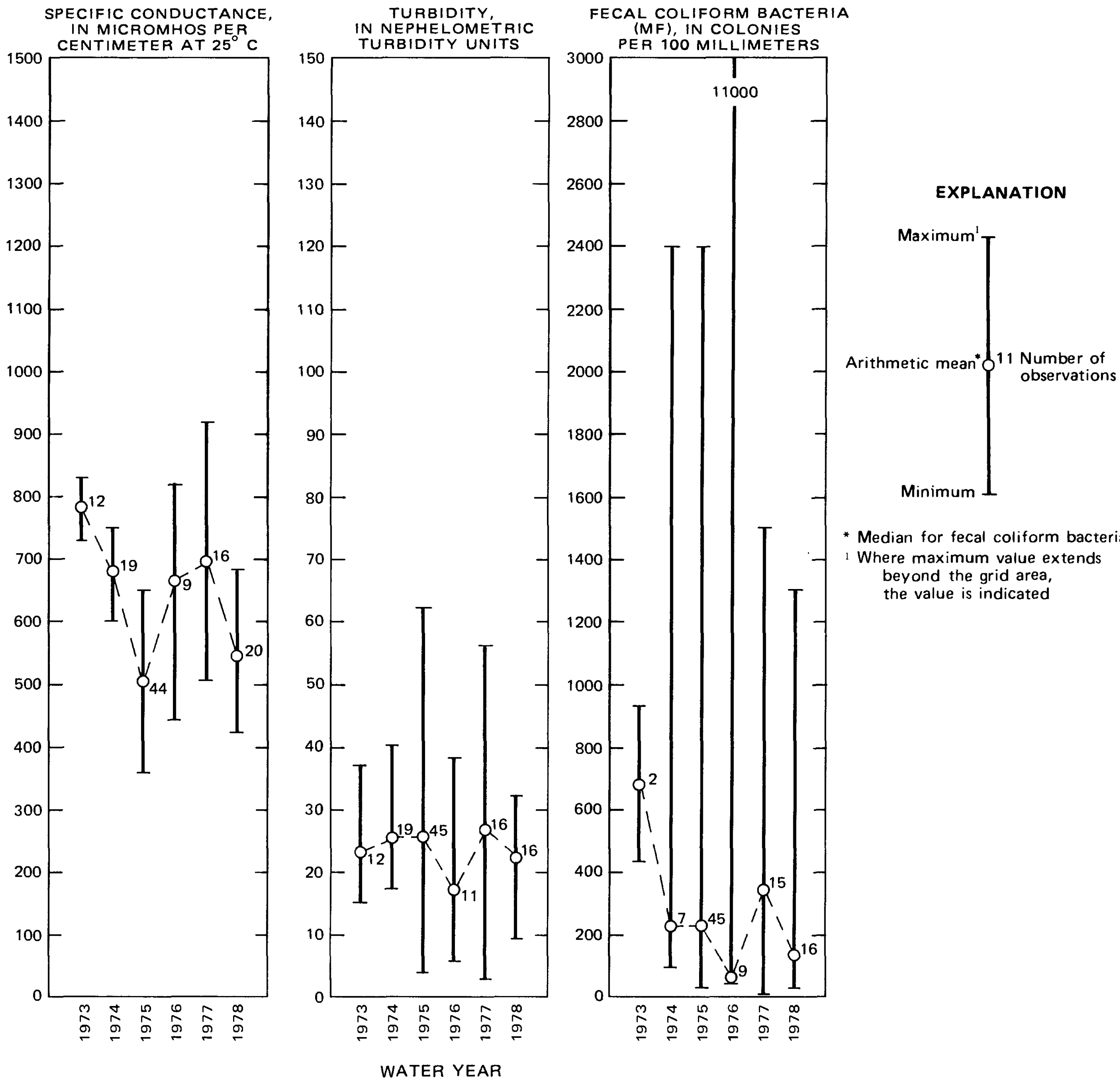


FIGURE 14. – Changes in water quality during the study period at Mark West Creek near Mirabel Heights (station 11466800).

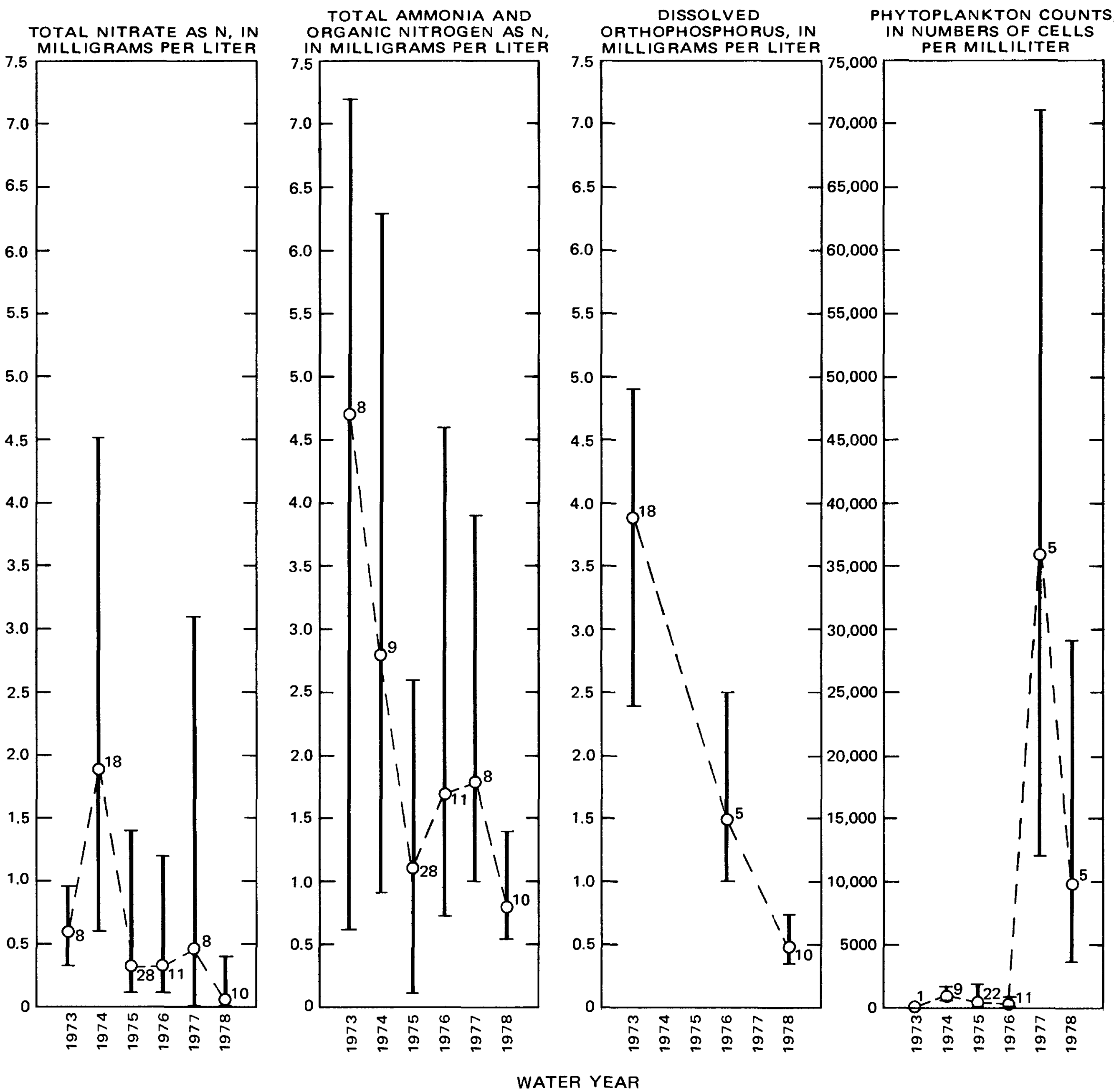


FIGURE 14. – Continued.

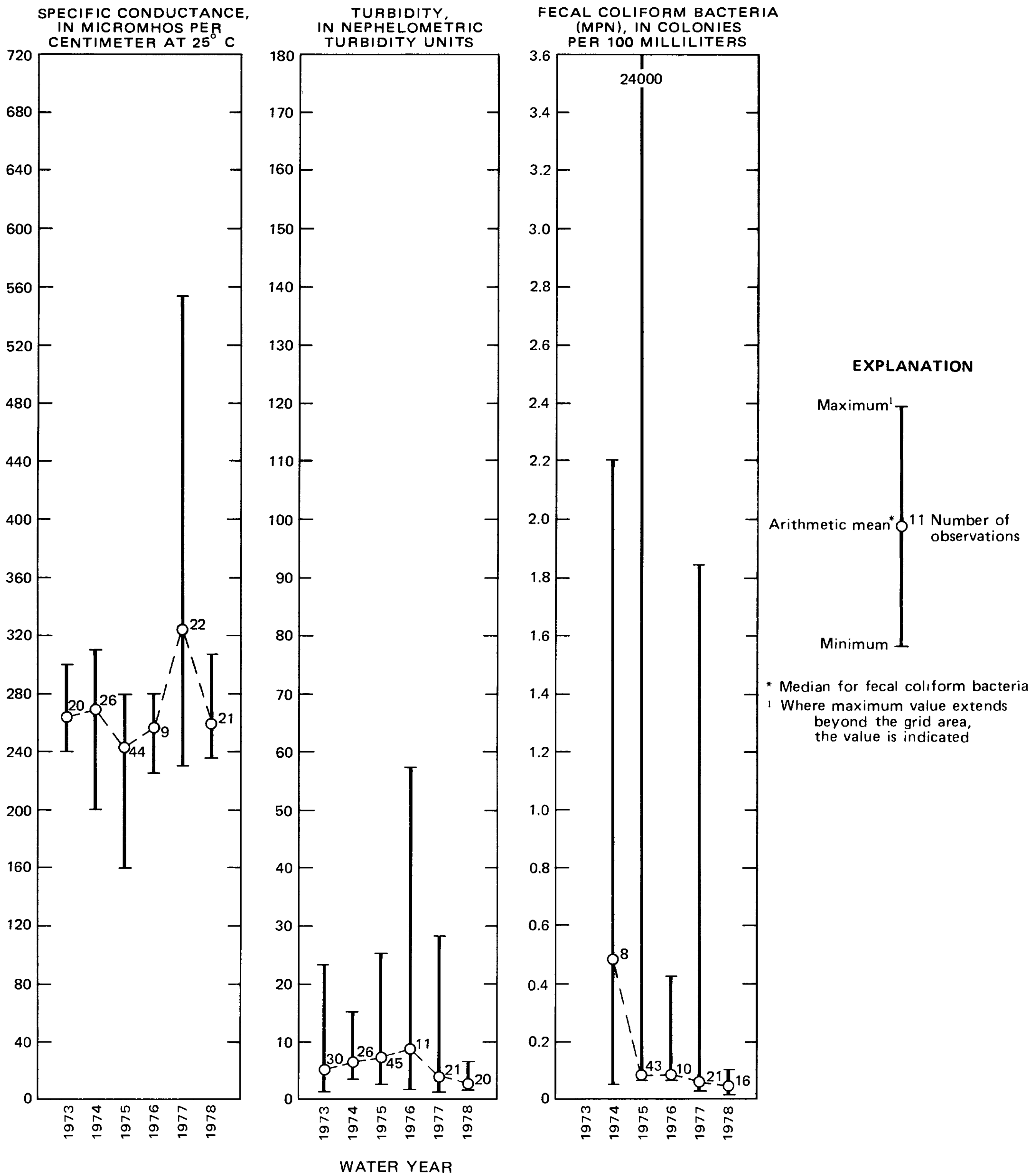


FIGURE 15. – Changes in water quality during the study period at Russian River at Mirabel Heights (station 11466850).

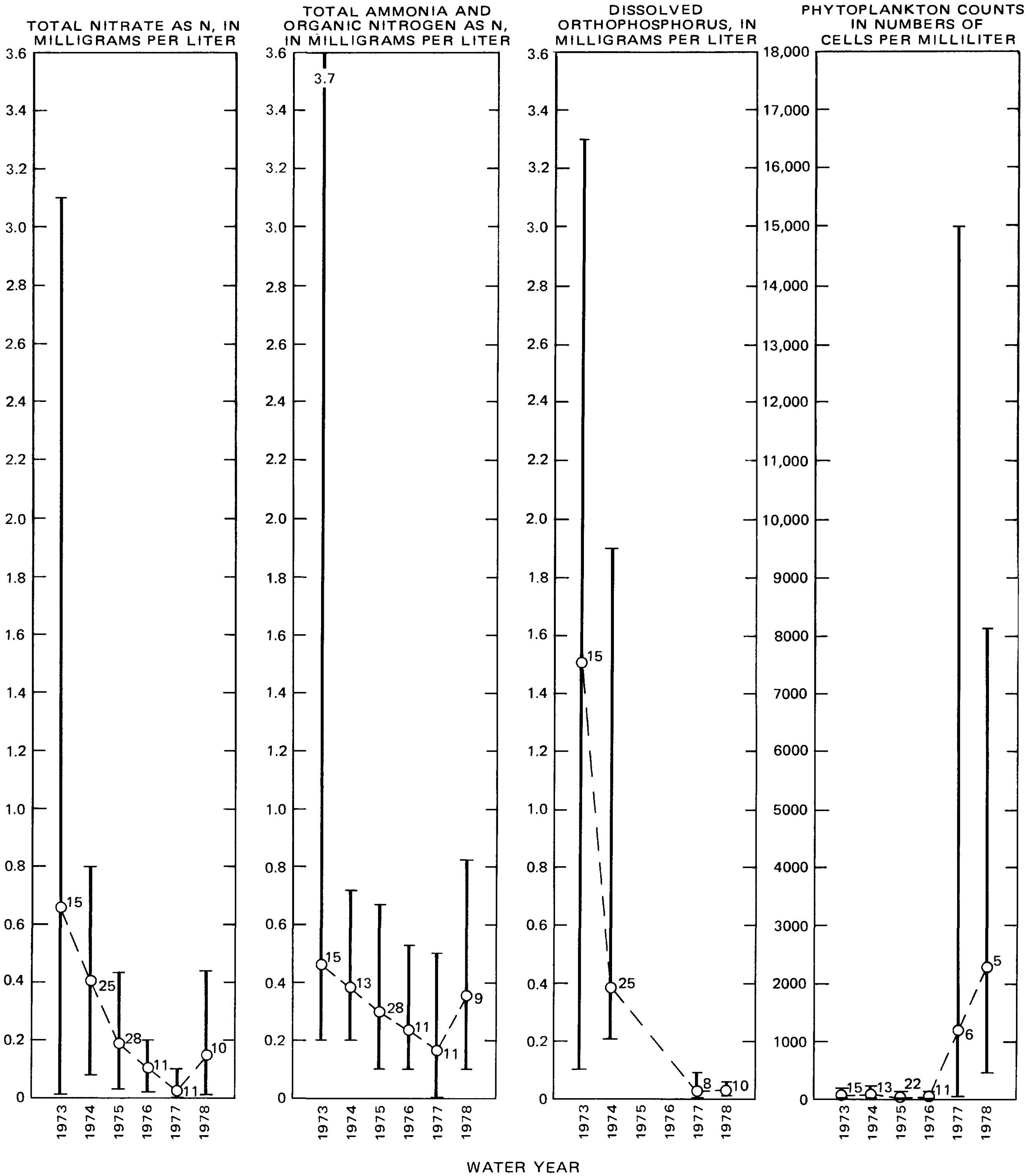


FIGURE 15. – Continued.

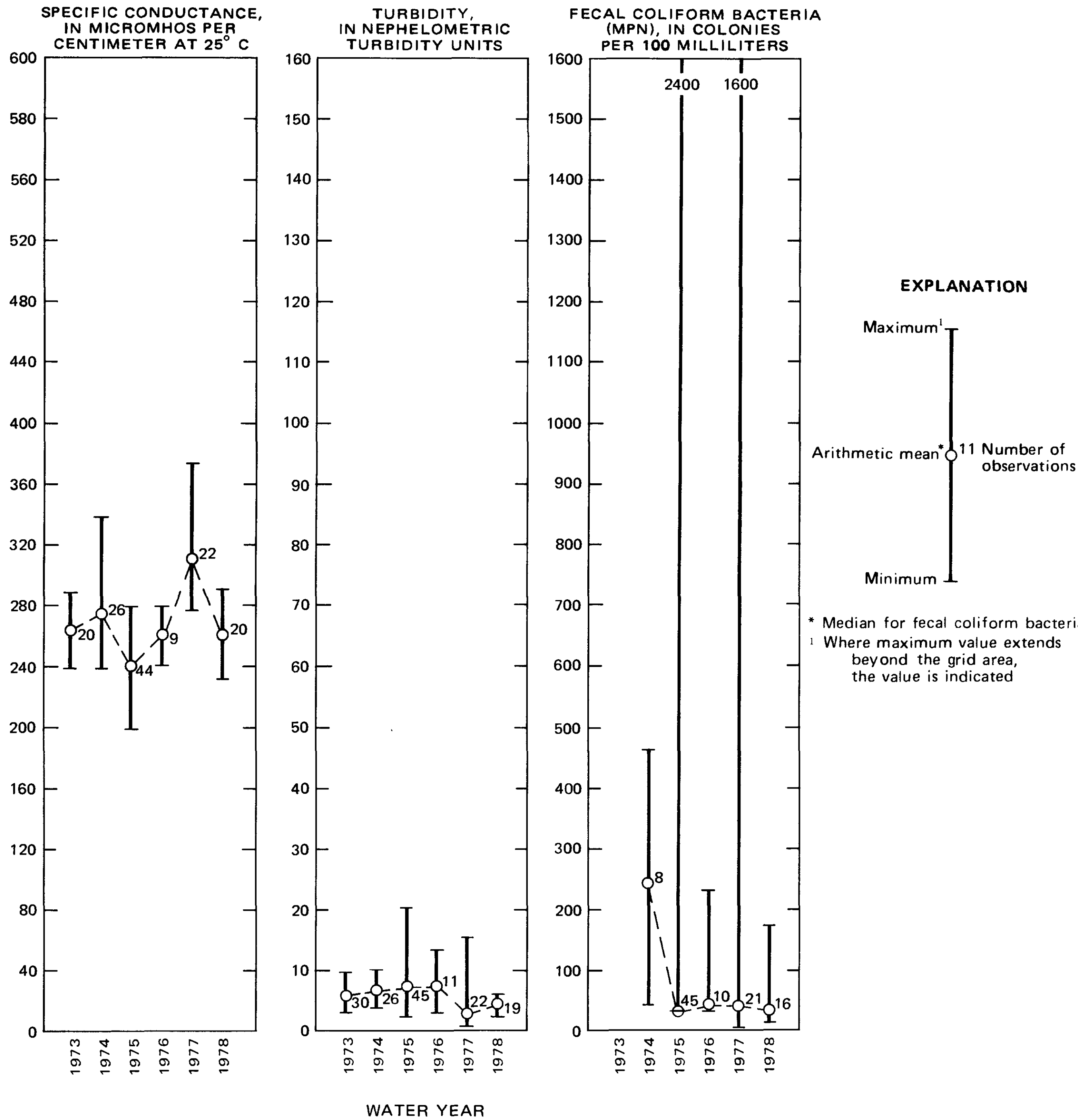


FIGURE 16. – Changes in water quality during the study period at Russian River at Johnson's Beach (station 11467002).

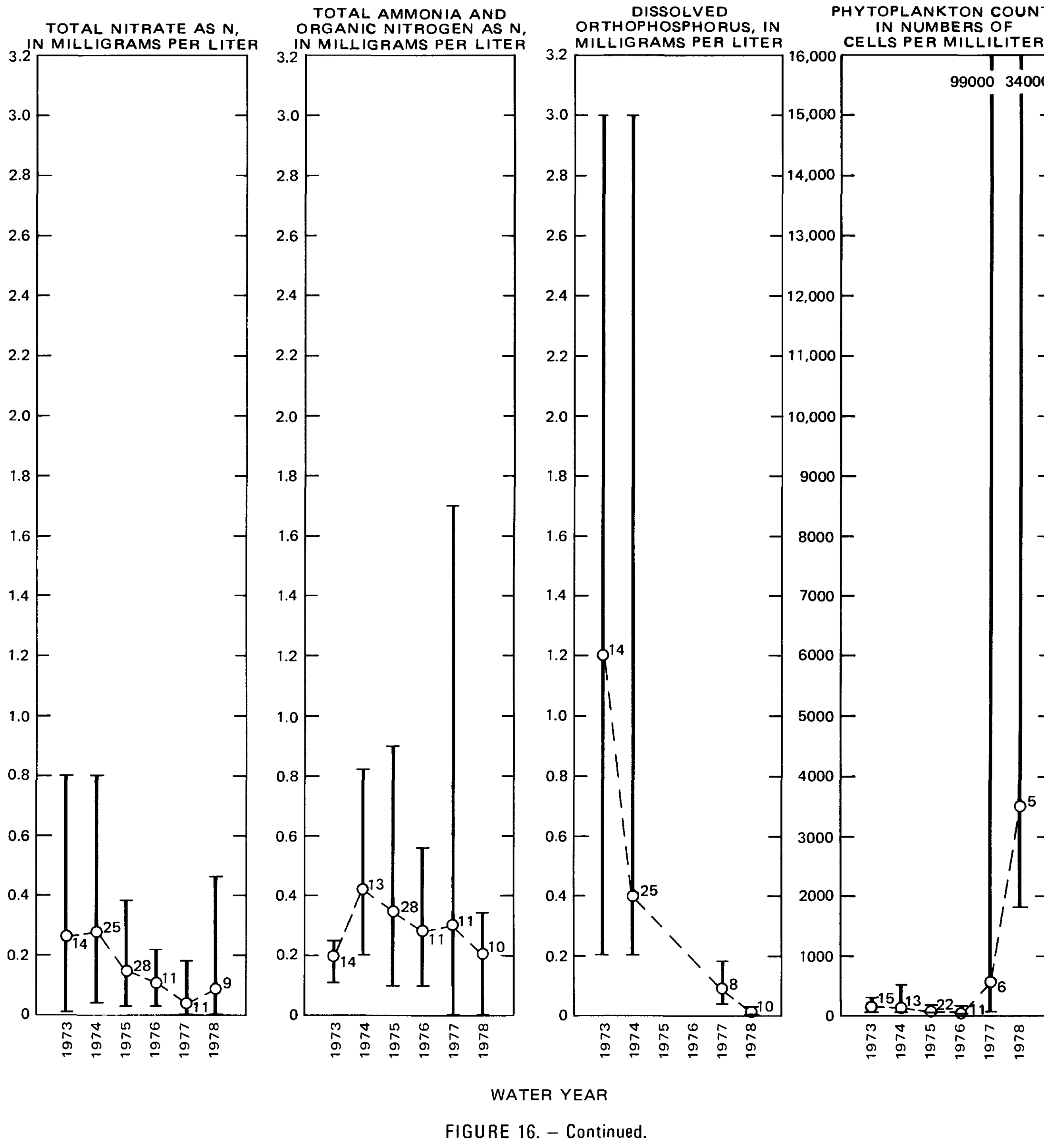


FIGURE 16. – Continued.

Except for specific conductance, dissolved orthophosphorus, and phytoplankton values, the patterns of changes in water quality at Mark West Creek near Mirabel Heights (fig. 14) are different than at other stations (figs. 12, 13, 15, and 16). The main differences are the increases in turbidity, fecal-coliform bacteria, and total nitrate from 1976 to 1977, and the increases in total ammonia plus organic nitrogen from 1975 to 1977. These increases and the greater water-quality property and constituent values at Mark West Creek near Mirabel Heights than at other stations are mostly due to the low-flow season discharge of treated wastewater into the Mark West Creek drainage until 1978 and to the greatly reduced flow of Mark West Creek during the 1976 and 1977 low-flow seasons (between 0.00 and 0.50 ft^3/s during most of the 1977 low-flow season).

During 1976 and 1977, specific conductance increased markedly at all stations shown in figures 12-16. Decreased streamflows during the 1976-77 drought are responsible for increased specific conductance during this period. Decreased streamflow concentrated dissolved solids, thus increasing specific conductance. Increased streamflows during 1978 resulted in decreased specific conductance.

Changes in Streamflow and Water Quality During the Low-Flow Seasons of the 1977 and 1978 Water Years

Changes in streamflow and water quality during the low-flow season are described for only the 1977 and 1978 water years and for only two stations: East Fork Russian River near Ukiah (11462000) and Russian River near Guerneville (11467000). Prior to 1977, either streamflow measurements were not made or water-quality samples were not collected at the other stations.

Streamflows were variable and did not follow a consistent pattern at East Fork Russian River near Ukiah and Russian River near Guerneville (figs. 17 and 18). During the low-flow season, variable streamflow is expected because water releases from Lake Mendocino depend on the variable water needs of downstream users, and these water releases comprise all the flow at East Fork Russian River near Ukiah and compose most of the flow at Russian River near Guerneville. The streamflow patterns at these two stations are dissimilar because the flow at Russian River near Guerneville is also influenced by accrual of water from tributaries, water withdrawal by water users, and water losses by evaporation that occur between these stations. During the 1977 low-flow season, mean monthly streamflows ranged from 86 to 183 ft^3/s at East Fork Russian River near Ukiah and from 23 to 39 ft^3/s at Russian River near Guerneville. During the 1978 low-flow season, mean monthly streamflows ranged from 207 to 296 ft^3/s at East Fork Russian River near Ukiah and from 167 to 809 ft^3/s at Russian River near Guerneville.

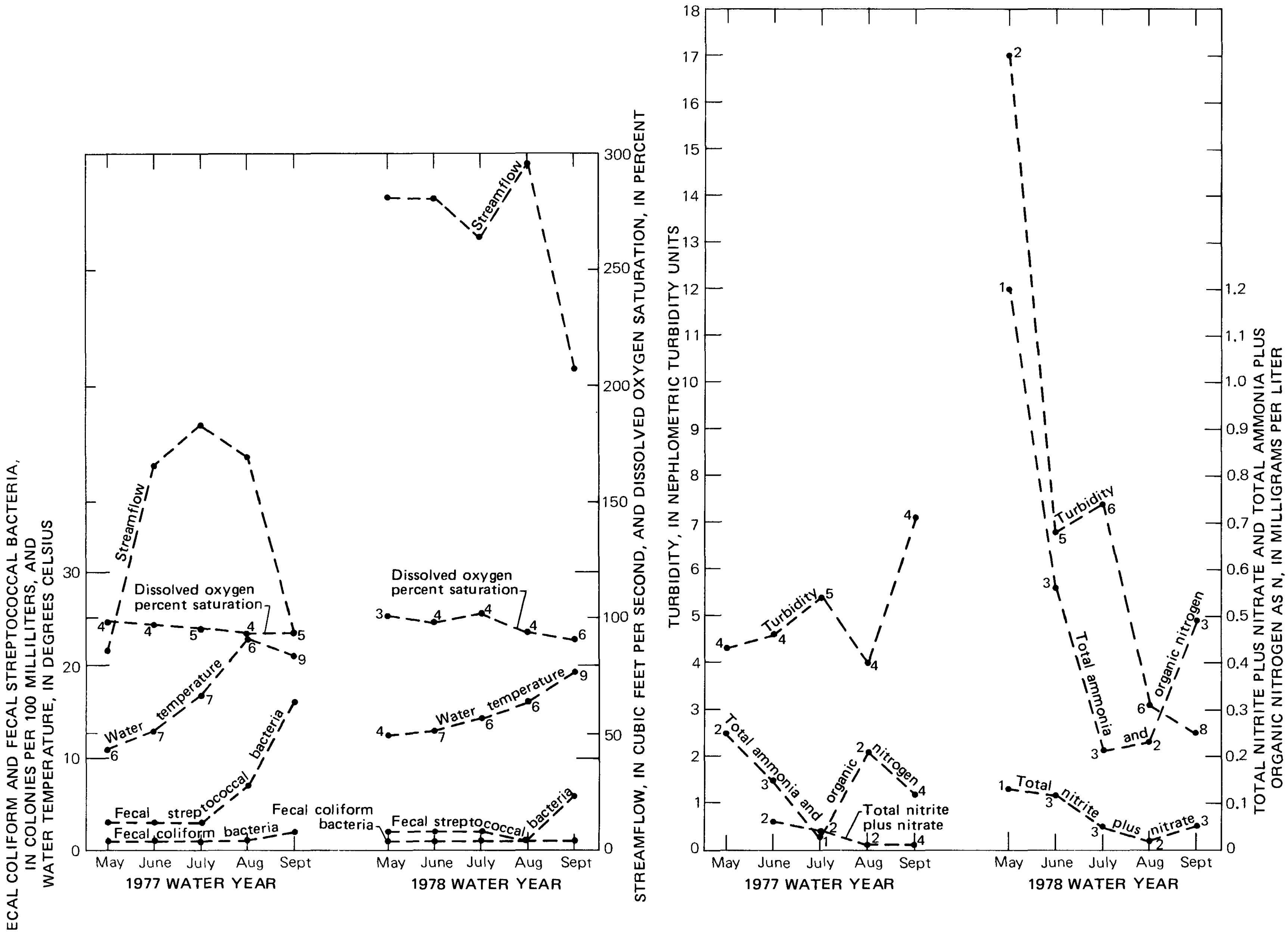
Water temperatures at East Fork Russian River near Ukiah markedly increased during the 1977 and 1978 low-flow seasons (fig. 17). This probably resulted from a greater contribution of warm water from the epilimnion (upper zone in stratified water body) to release water as the reservoir is drawn down during the low-flow season. During the 1977 and 1978 low-flow season, water temperatures at Russian River near Guerneville followed the summer pattern of air temperatures, increasing from May to July in response to greater daylight periods and more insolation and decreasing in August or September because of decreasing periods of daylight and less insolation (fig. 18). During the 1977 low-flow season, mean monthly water temperatures ranged from 10.7 to 22.7°C at East Fork Russian River near Ukiah and from 19.5 to 24.8°C at Russian River near Guerneville. During the 1978 low-flow season, mean monthly water temperatures ranged from 12.4 to 19.2°C at East Fork Russian River near Ukiah and from 20.2 to 24.3°C at Russian River near Guerneville.

Although remaining less than 90 col/100 mL, fecal-streptococcal bacteria concentrations generally increased during the 1977 and 1978 low-flow seasons (figs. 17 and 18). Fecal-coliform bacteria concentrations were less than fecal-streptococcal bacteria concentrations and increased only slightly or did not increase during the 1977 and 1978 low-flow seasons.

During the 1977 and 1978 low-flow seasons, turbidity, total ammonia plus organic nitrogen, and total nitrite plus nitrate values generally decreased except at East Fork Russian River near Ukiah where turbidity increased during the 1977 low-flow season (figs. 17 and 18). Water stored in Lake Mendocino is generally more turbid in May than in summer months because imported water from the Eel River and streams tributary to Lake Mendocino are turbid during the rainy season (October through April). As the suspended matter in Lake Mendocino settles to the bottom of the lake during the low-flow season, stored water and release water become less turbid. The increase in turbidity at East Fork Russian River near Ukiah during the 1977 low-flow season may be the result of drought conditions that produced greater than usual drawdown of Lake Mendocino.

The similarity of nitrogen and turbidity graphs in figures 17 and 18 suggests organic and inorganic nitrogen in the Russian River are associated with suspended matter.

Decreases in algal growth potential during the 1977 and 1978 low-flow seasons generally correspond to decreases in nitrogen, indicating that algal growth in the Russian River is dependent on the amount of nitrogen in the water. Algal growth potential did not follow the pattern of dissolved orthophosphorous concentrations that decreased only slightly at Russian River near Guerneville (fig. 18) and essentially did not change at East Fork Russian River near Ukiah (fig. 17). Hence, algal growth in the Russian River is not limited by the amount of phosphorus in the water. These observations are supported by correlation coefficients of 0.95 and 0.98 (number of observations = 8, significant at 0.05 level) between algal growth potential and total nitrite plus nitrate at East Fork Russian River near Ukiah and Russian River near Guerneville, respectively. Correlation coefficients between algal growth potential and dissolved orthophosphorus were 0.00 (number of observations = 8, not significant at 0.05 level) at East Fork Russian River near Ukiah and -0.34 (number of observations = 9, not significant at 0.05 level) at Russian River near Guerneville.


FECAL COLIFORM AND FECAL STREPTOCOCCAL BACTERIA, IN COLONIES PER 100 MILLILITERS, AND WATER TEMPERATURE, IN DEGREES CELSIUS
STREAMFLOW, IN CUBIC FEET PER SECOND, AND DISSOLVED OXYGEN SATURATION, IN PERCENT
Streamflow
Dissolved oxygen percent saturation
Water temperature
Fecal streptococcal bacteria
Fecal coliform bacteria
May June July Aug Sept
1977 WATER YEAR
1978 WATER YEAR
TURBIDITY, IN NEPHLOMETRIC TURBIDITY UNITS
TOTAL NITRITE PLUS NITRATE AND TOTAL AMMONIA PLUS ORGANIC NITROGEN AS N, IN MILLIGRAMS PER LITER
Turbidity
Total ammonia and organic nitrogen
Total nitrite plus nitrate

EXPLANATION

Monthly medians are given for fecal coliform and fecal streptococcal bacteria, others are monthly arithmetic means. Number next to the mean is number of values used to calculate the mean. Streamflow points are mean daily for each month shown.

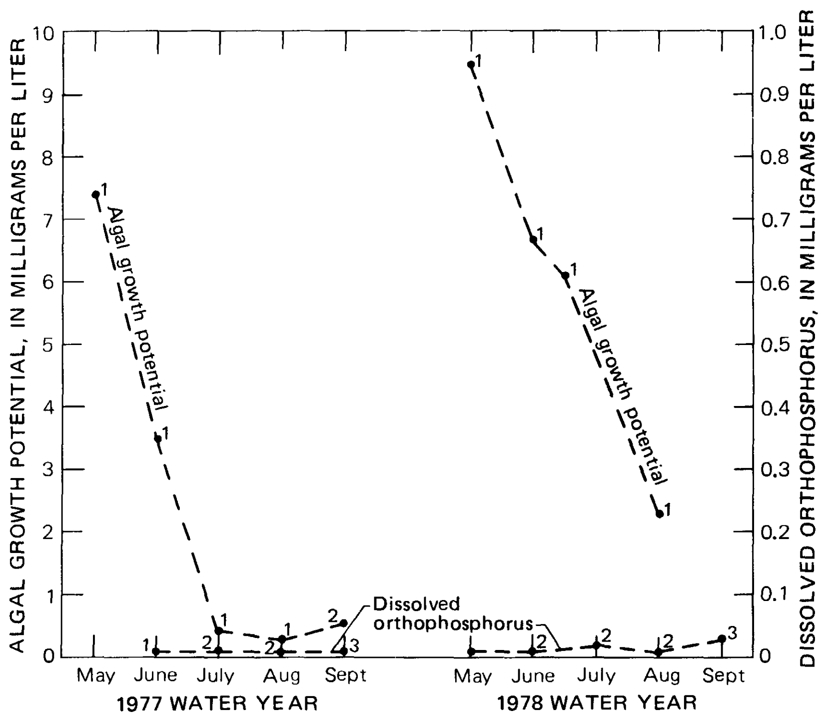
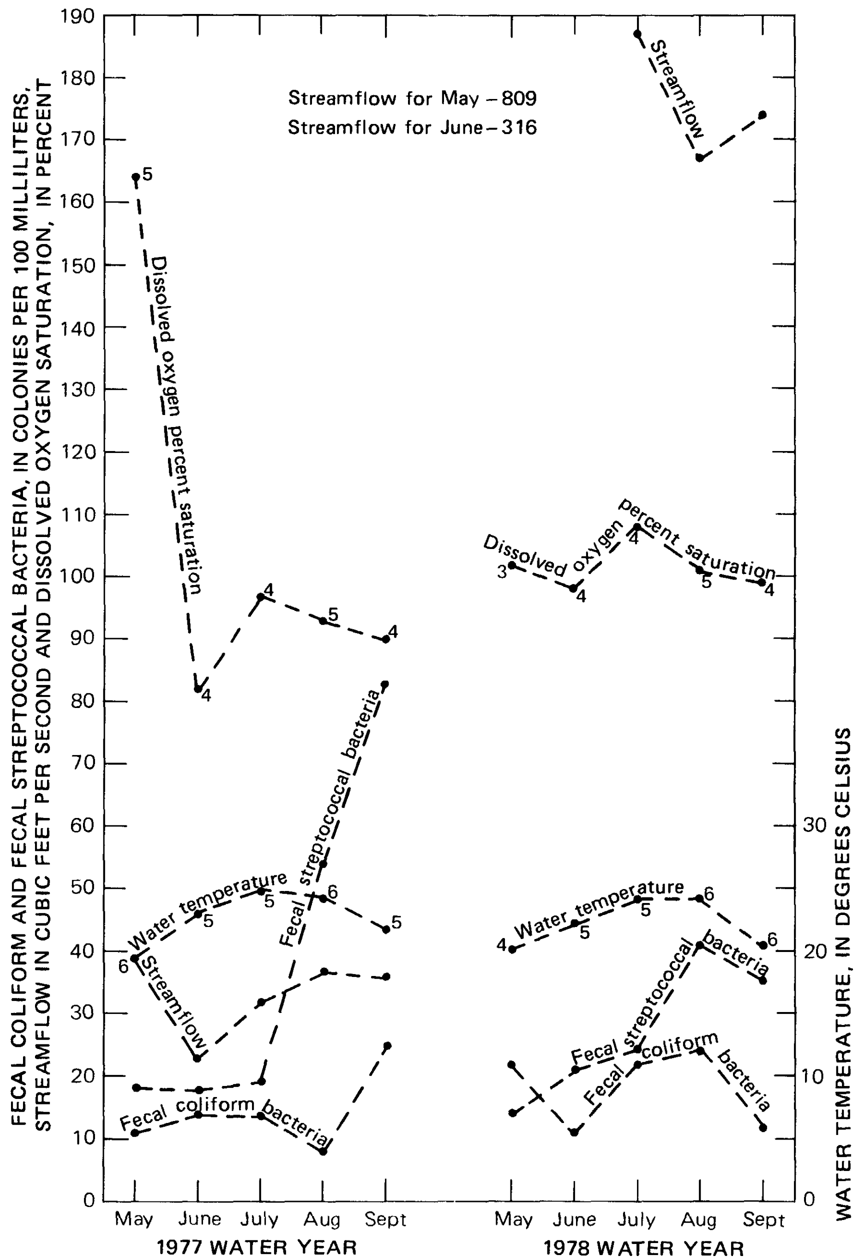
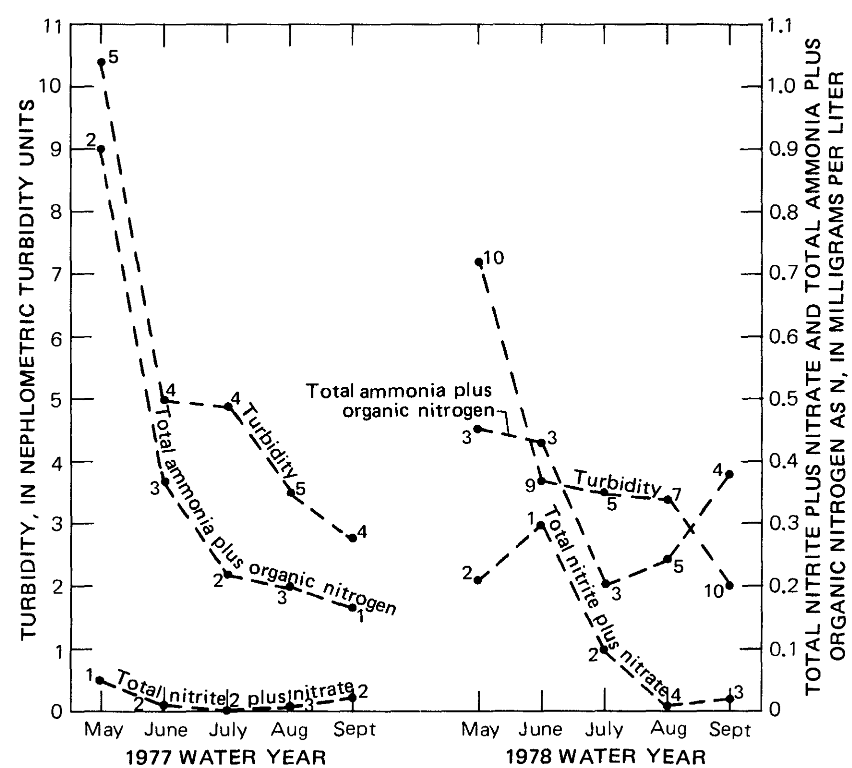
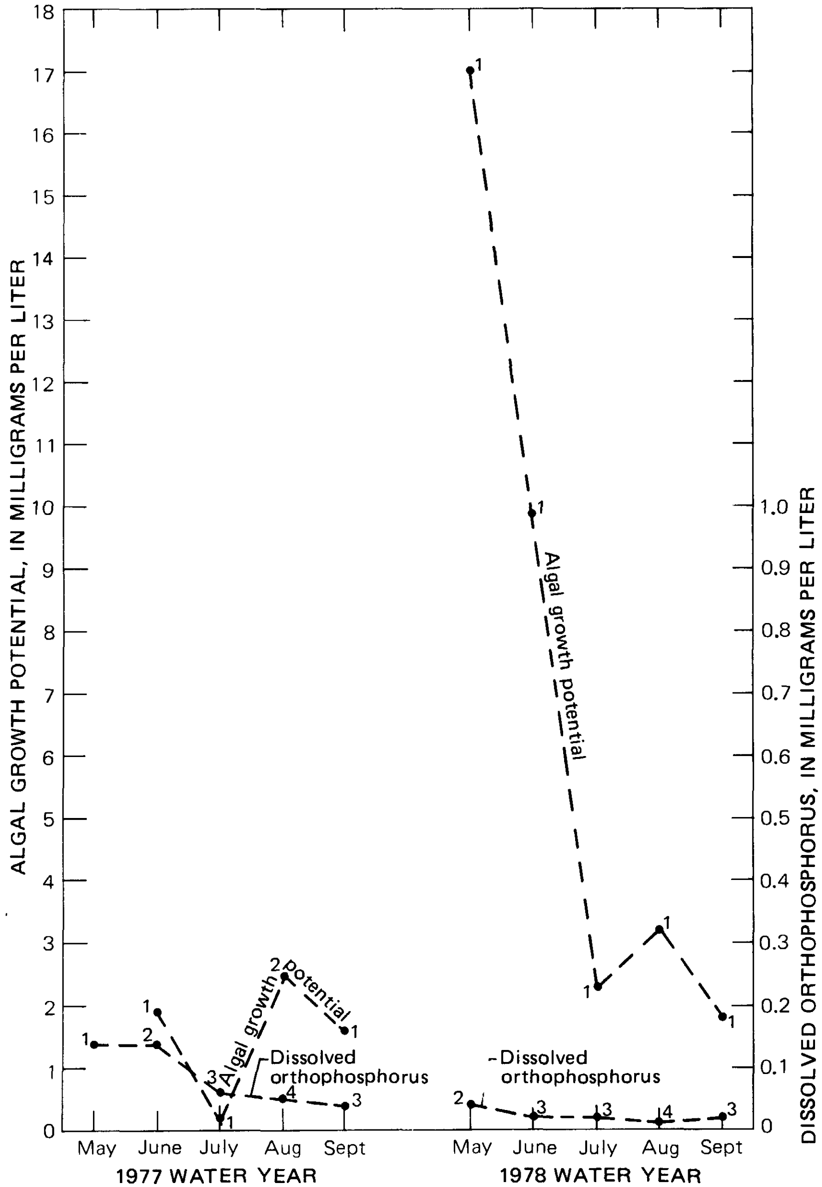


FIGURE 17. – Changes in streamflow and water quality at East Fork Russian River near Ukiah (11462000) during the low-flow seasons of 1977 and 1978 water years.


FECAL COLIFORM AND FECAL STREPTOCOCCAL BACTERIA, IN COLONIES PER 100 MILLILITERS, STREAMFLOW IN CUBIC FEET PER SECOND AND DISSOLVED OXYGEN SATURATION, IN PERCENT
WATER TEMPERATURE, IN DEGREES CELSIUS
Streamflow for May – 809
Streamflow for June – 316
Dissolved oxygen percent saturation
Streamflow
Water temperature
Fecal streptococcal bacteria
Fecal coliform bacteria
May
June
July
Aug
Sept
1977 WATER YEAR
1978 WATER YEAR


TURBIDITY, IN NEPHLOMETRIC TURBIDITY UNITS
TOTAL NITRITE PLUS NITRATE AND TOTAL AMMONIA PLUS ORGANIC NITROGEN AS N, IN MILLIGRAMS PER LITER
Turbidity
Total ammonia plus organic nitrogen
Total nitrite plus nitrate
May
June
July
Aug
Sept
1977 WATER YEAR
1978 WATER YEAR



EXPLANATION

Monthly medians are given for fecal coliform and fecal streptococcal bacteria, others are monthly arithmetic means. Number next to the mean is number of values used to calculate the mean. Streamflow points are mean daily for each month shown.

FIGURE 18. – Changes in streamflow and water quality at Russian River near Guerneville (11467000) during the low-flow seasons of 1977 and 1978 water years.

At East Fork Russian River near Ukiah mean monthly dissolved-oxygen saturation decreased from 98 to 93 percent during the 1977 low-flow season and from 101 to 91 percent during the 1978 low-flow season (fig. 17).

These decreases may have been due to increasing oxygen demand of material in the bottom waters of Lake Mendocino induced by the marked increase in water temperature shown in figure 17. At Russian River near Guerneville, changes in dissolved-oxygen saturation during the 1977 low-flow season appear to be related to streamflows (fig. 18). Changes in streamflow during this period of unusually low streamflows greatly affected the amount of streambed under water and the amount of light reaching the submerged streambed. Photoinhibition may occur when too much light reaches periphyton. Thus, during the 1977 low-flow season, the extent of the periphytic community and; hence, oxygen production were regulated by streamflow. Also, physical aeration of the water is directly related to the amount of water turbulence and, at Russian River near Guerneville, the amount of water turbulence is directly related to streamflow. During 1978, streamflows at Russian River near Guerneville were much greater than during 1977 and were large enough to provide sufficient streambed coverage and physical aeration to keep mean monthly dissolved-oxygen saturation between 98 and 108 percent.

Areal Variations in Streamflow and Water Quality

The approach used in this section of the report is: (1) to identify those attributes of the basin that may be affecting the streamflow and water quality of the Russian River during low-flow periods; (2) to select stations that are in or just downstream of the attributes identified; and (3) to determine whether data collected at these stations are different from data collected at other stations in the basin. Data distributions for the properties and constituents compared among stations are graphically represented by box plots which were prepared from information computed using the UNIVARIATE procedure in a computerized statistical analysis system called SAS (Helwig and Council, 1979). Statistical tests were used to determine if property and constituent values were alike among stations compared. A nonparametric statistical procedure, Kruskal-Wallis (Chi-square approximation) test, was used if the data sets compared were not normally distributed. A parametric statistical procedure, ANOVA (Analysis of Variance) Model II, single classification test (Dixon and Massey, 1969, p. 109-119 and p. 150-162) was used if the data sets compared were normally distributed. Depending on the number of observations in the data set, the Shapiro-Wilk W-statistic ($N \leq 50$) or a modified version of the Kolmogorov-Smirnov D-statistic ($N > 50$) (Stephens, 1974) was used to test whether or not data sets compared were distributed normally. SAS procedure NPARIWAY with option WILCOXON was used for the Kruskal-Wallis tests and GLM with statement LSMEANS and option PDIFF was used for ANOVA tests.

Comparisons were based on data collected during water years 1973 through 1978 unless data were collected during dissimilar time periods or at dissimilar sampling frequencies. When 1973 through 1978 water-year data could not be used for comparisons, only 1977 and 1978 water-year data were used because similar data collections were done at all sampling stations during those water years. During low-flow periods, the effect of the following basin attributes on the streamflow and water-quality of the Russian River will be discussed: (1) Geomorphology; (2) Tributaries; (3) West Fork of Russian River; (4) Principal Water Diversion; (5) Recreational Impoundments; (6) Land Use; (7) The Tide; and (8) Climate.

Effect of Geomorphology on Water Quality of the Russian River

As described previously in this report, the Russian River can be divided into three distinct geomorphic reach types (figs. 3 and 4). A comparison of property and constituent values among stations at locations representative of these geomorphic reach types is shown in figure 19 (at end of report). Generally, property or constituent values were alike for the stations compared. Dissolved othophosphorus, phytoplankton counts, water temperature, and turbidity were significantly greater at Russian River near Guerneville (11467000, in reach type 1) than at the other stations compared (in reach types 2 and 3).

Phytoplankton counts at Russian River near Guerneville (11467000) were greater than at other stations compared in figure 19. This may be the result of less riverbed gradient, slower flows, and more pools in geomorphic reach type 1 than in others. Such conditions facilitate the utilization of nutrients by algae and promote their growth; thus, accounting for the lesser nitrate values at Russian River near Guerneville than at Russian River near Hopland (11462690) and Russian River near Cloverdale (11463000). The reason for the lesser nitrate values at Russian River near Geyserville (11463500) than at Russian River near Hopland and at Russian River near Cloverdale is not known. Higher water temperatures at Russian River near Guerneville also helped to produce more algae. Slower flows and more pools in reach type 1 contribute to higher water temperatures at Russian River near Guerneville than at other stations compared in figure 19, but cold-water releases from Lake Mendocino were primarily responsible for the significantly lower water temperatures at the other stations.

Greater orthophosphorus and turbidity values at Russian River near Guerneville than at other stations compared in figure 19 were due to attributes other than geomorphology (tributaries and recreational impoundments) and will be discussed later in this report.

The reason for the lesser pH values at Russian River at Hopland than at other stations compared in figure 19, is not known. Lesser streamflows at Russian River near Guerneville than at other stations compared in figure 19 were due to water withdrawals upstream and will be discussed later in this report.

Effect of Tributaries on Water Quality of the Russian River

The principal tributaries that contribute flow to the Russian River during most, if not all, of the low-flow season are Big Sulphur Creek and Mark West Creek (fig. 1). Big Sulphur Creek drains a prominent geothermal area and Mark West Creek drains the major urban area in the basin, Santa Rosa and nearby communities.

The impact of Big Sulphur Creek on the water quality of the Russian River is shown by examining the difference in water quality between Russian River at Preston (11463150) (1 mile upstream of Big Sulphur Creek) and Russian River at Asti (11463400) (5 miles downstream of Big Sulphur Creek). Greater specific conductance and pH values at Russian River at Asti than at Russian River at Preston were caused by Big Sulphur Creek inflow (fig. 20 at end of report). Because of the geothermic activity and the geology of the Big Sulphur Creek drainage, specific conductance values were greater at the Big Sulphur Creek station (11463210) than at Russian River at Preston and Russian River at Asti. Greater pH values at the Big Sulphur Creek station than at Russian River at Preston and Russian River at Asti were due to lesser flows and turbidity and to greater nitrate concentrations of Big Sulphur Creek. These conditions enhanced periphyton growth (fig. 31), and increased pH as the result of CO_2 uptake by periphyton. Big Sulphur Creek was less turbid than the Russian River because turbid bottom releases from Lake Mendocino (fig. 21) compose most of the flow of the Russian River during the low-flow season.

Nitrate and fecal-streptococcal bacteria concentrations were greater at the Big Sulphur Creek station than at Russian River at Preston and Russian River at Asti (fig. 20). Cattle and pets from nearby residential areas could be the source of the greater nitrate and fecal-streptococcal bacteria concentrations at the Big Sulphur Creek station. Cattle and pets were observed to drink from, wade in, and occasionally defecate in Big Sulphur Creek near the sampling station.

The increase in water temperature and dissolved oxygen from Russian River at Preston (11463150) to Russian River at Asti (11463400) was not due to Big Sulphur Creek, but rather to decreased water depth and more water turbulence at station 11463400 than at station 11463150, where the water was pooled.

Even though most property and constituent values were greater at the Mark West Creek station than at the main-stem stations, the creek's effect on the Russian River was limited to increasing specific conductance and orthophosphorus values and phytoplankton counts from Russian River at Wohler Bridge (11465400) to Russian River at Mirabel Heights (11466850) (fig. 20). Mark West Creek's effect on the Russian River was tempered by the much greater flows of the Russian River. Lesser dissolved-oxygen saturation at the Mark West Creek station than at the main-stem stations was related to greater COD (chemical oxygen demand) values at the Mark West Creek station than at the main-stem stations. Until 1978, treated wastewater was discharged to the Mark West Creek drainage during the low-flow season. These discharges were mostly responsible for the greater property and constituent values in Mark West Creek than in the Russian River.

Effect of the West Fork on Water Quality of the Main Stem

During the low-flow season, water in the main stem of the Russian River is primarily releases from Lake Mendocino. Flow at East Fork Russian River near Ukiah (11462000) is from Lake Mendocino and averaged 187 ft^3/s during the 1977 and 1978 low-flow seasons. The West Fork of the Russian River also contributes some flow during most of the low-flow season and averaged 3.8 ft^3/s during the 1977 and 1978 low-flow seasons. As shown in figure 21 (at end of report), the West Fork had no effect on the water quality at Russian River at Ukiah (11462050) even though there were differences in water quality between the East and West Forks. The West Fork had no effect on main-stem water quality because its flow composed only a very small portion of the main-stem flow during the low-flow season (2 percent of the flow at Russian River at Ukiah, 11462050).

During the low-flow season, the West Fork of the Russian River had greater specific conductance values than the East Fork of the Russian River (fig. 21). This was not caused by geologic factors because the geology of the Eel River basin and the East and West Forks of the Russian River are very similar, but rather, is because the East Fork station is downstream of Lake Mendocino. Water in Lake Mendocino comes mostly from the Eel River and the headwaters of the East Fork during the high-flow season (October to May). This water characteristically has lesser specific conductance values than low-flow season water. Values of pH were greater in the West Fork because of substantially less flow, turbidity, and higher water temperatures than in the East Fork. Such conditions facilitate algal growth, thus increasing pH. The differences in water temperature and turbidity between the East and West Forks were due to the lower flows of the West Fork and the cold and turbid water released from Lake Mendocino.

Fecal-coliform and fecal-streptococcal bacteria concentrations were less at East Fork Russian River near Ukiah (11462000) than at Russian River near Ukiah (11461000) and Russian River at Ukiah (11462050). Concentrations of these bacteria were less at station 11462000 than at any other location sampled during this study. Apparently, these bacteria are either present in low concentrations in imported water and native East Fork water or settle out of the water and (or) die in the reservoir.

Effect of Principal Water Diversion on Water Quality of the Russian River

Ranney collectors located adjacent to the Russian River in the vicinity of Mirabel Park are the main water-withdrawal structures in the basin. The Ranney collectors withdraw water from the alluvium of the river channel (fig. 22). An inflatable dam across the river impounds water and facilitates percolation of water into the riverbed alluvium. This impoundment and the indirect withdrawal of water from the river by the Ranney collectors had little effect on the water quality of the Russian River other than to increase pH and water temperature (fig. 23 at end of report). The reason is not known for the increase in turbidity from Russian River at Alexander Valley Road Bridge (11463680) to Russian River near Guerneville (11467000). The increase in orthophosphorus from Russian River at Wohler Bridge (11465400) to Russian River near Guerneville (11467000) was because of high concentrations of this constituent in Mark West Creek (see previous discussion on the effect of tributaries on the water quality of the Russian River). The increase in phytoplankton counts from station 11463680 to station 11467000 was due to the diversion impoundment and other summer impoundments between these stations, as well as basin geomorphology and the influence of Mark West Creek (see previous discussion on these topics in this report). Impoundment of water facilitates phytoplankton growth by providing a more stable environment than does a flowing stream. As expected, streamflow was less downstream of the Ranney collectors than it was upstream.

FIGURE 22. – Ranney collectors near Mirabel Park.

Effect of Recreational Impoundments on Water Quality of the Russian River

The principal recreational impoundments on the Russian River are located at Memorial Beach, Vacation Beach (fig. 1), and Johnson's Beach (at Guerneville, fig. 24). To determine if these impoundments and the recreational activities associated with them have any effect on the water quality of the Russian River during the low-flow season, the water quality upstream of these impoundments was compared with the water quality downstream of these impoundments (fig. 25 at end of report). Water temperature, pH, and fecal-coliform bacteria were less and turbidity was greater at Russian River at Alexander Valley Road Bridge (11463680, upstream of Memorial Beach and other recreational impoundments in the Fitch Mountain area) than at Russian River at Healdsburg (11464010, downstream of Memorial Beach). Water impoundments and climatic factors (discussed later) probably were responsible for increased pH and water temperatures downstream of Memorial Beach. Water-contact recreation probably was responsible for the greater fecal-coliform bacteria concentrations downstream of Memorial Beach. Reasons for greater turbidity at station 11463680 than at station 11464010 are not known.

Except for greater fecal-coliform bacteria concentrations and lesser turbidity at Russian River at Johnson's Beach (11467002), there was no observable difference in water quality between station 11467000 (upstream of Johnson's Beach and Vacation Beach) and stations 11467002 and 11467006 (downstream of Johnson's Beach and Vacation Beach, respectively). Water-contact recreation probably was responsible for the increase in fecal-coliform bacteria concentrations from Guerneville to Johnson's Beach. Fecal-coliform bacteria concentrations were not significantly different at Guerneville and Vacation Beach, probably because water-contact recreation was less at Vacation Beach than at Johnson's Beach. Reasons for lesser turbidity at Johnson's Beach than at Guerneville and Vacation Beach are not known.

FIGURE 24. — Recreational impoundment at Johnson's Beach in the community of Guerneville.

Effect of Land Use on Water Quality of the Russian River

The main land uses in the Russian River basin are agriculture and urban. To determine if these land uses have any impact on water quality of the Russian River during the low-flow season, property and constituent values were compared between Russian River at Alexander Valley Road Bridge (11463680) and Russian River at Mirabel Heights (11466850) (fig. 26 at end of report). Station 11463680 is at the downstream limits of one of the major agricultural areas of the basin (Alexander Valley) and station 11466850 is immediately downstream of Mark West Creek which drains the principal urban area in the basin, Santa Rosa, and nearby communities.

Greater specific conductance and pH values and greater concentrations of fecal-coliform and fecal-streptococcal bacteria and orthophosphorus at station 11466850 than at station 11463680, reflect the influence of urban, low-flow, wastewater discharges to the Russian River, prior to 1976 (also, see the discussion on the effect of tributaries on the water quality of the Russian River). The decrease in flow between these stations was the result of water withdrawal by Ranney collectors in the vicinity of Mirabel Park.

Agricultural land use had little or no effect on the water quality of the Russian River during the low-flow season because most property and constituent values were not significantly different between Russian River near Geyserville (11463500), which is in Alexander Valley, and Russian River near Cloverdale (11463000), which is upstream of this agricultural area (fig. 19).

Tidal Influences on Water Quality of the Russian River

Russian River at Duncan Mills (11467210), near the mouth of the Russian River, is in a tidal reach. Water flow at this station is dependent on tidal fluctuations, but usually backwater conditions due to tidal inflow were found when sampling. As shown in figure 27 at end of report, the water quality at this station is very similar to that at Russian River at Vacation Beach (11467006), 6 miles upstream from the mouth of Austin Creek, which is near the upstream limit of tidal reach. The only significant differences in water quality between these stations were lower water temperatures and lesser dissolved-oxygen saturation at the station in the tidal reach. Lower water temperatures at the tidal reach station were expected because this station is closer to the ocean and its temperature-moderating influences, such as fog and cool breezes. Lesser dissolved-oxygen saturation at the tidal reach station than at Russian River at Vacation Beach may have been the result of lower water temperatures and, hence, less primary productivity. Greater specific conductance values at the tidal reach station were expected because of the likelihood of saltwater inflow with the tide. Apparently, the tide seldom brings enough saltwater from the ocean to Russian River at Duncan Mills to produce a significant difference in specific conductance values between this station and Russian River at Vacation Beach.

Effect of Climate on Water Quality of the Russian River

The climate of the Russian River basin during the low-flow season varies from place to place according to the degree of ocean influence. To determine if climatic differences have any effect on water quality of the Russian River, property and constituent values were compared at stations in areas representative of the spectrum of ocean influences received (fig. 28 at end of report). As expected, there was a significant increase in water temperature from Russian River at Hopland (11462690) to Russian River at Healdsburg (11464010). As cold water released from Lake Mendocino proceeds downstream, it is warmed in climatic areas receiving little ocean influence. Water temperatures did not increase downstream of Healdsburg because air temperatures were cooler in this climatic area with much ocean influence.

Of the stations compared in figure 28, values of pH were least at the station closest to Lake Mendocino and in the climatic area most isolated from ocean influences because the lower water temperatures there inhibited aquatic plant growth and thus kept pH values lower. Greater phytoplankton counts at Russian River near Guerneville (11467000) probably were due to higher water temperatures, slower flows, and a greater amount of pooled and impounded water in this reach of the river. The increase in specific conductance from Russian River at Hopland (11462690) to Russian River at Healdsburg (11464010) may have been related to climatic factors, but most likely was due to tributary inflows like Big Sulphur Creek that have greater dissolved-solids concentrations than does the main stem of the Russian River. The decreased flow of the Russian River between Healdsburg and Guerneville was caused by water withdrawal by Ranney collectors in the vicinity of Mirabel Park, not by local climatic conditions.

Problem Areas and Times of Water-Quality Degradation

State water-quality objectives have been established for the Russian River basin to maintain water suitable for present and anticipated beneficial uses. Objectives for some of the properties and constituents sampled in this study are given in table 6. Objectives for other properties and constituents sampled in this study have not been established.

Sampling stations where water-quality objectives were not attained are shown in table 7. If property and constituent values from Mark West Creek are compared to objectives for the Russian River downstream of its confluence with Mark West Creek (table 6), then fecal-coliform bacteria, specific conductance, and dissolved-oxygen values from Mark West Creek were not in accordance with objectives most of the time during the period of this study. It is likely that this condition was mostly caused by fecal-coliform bacteria, dissolved salts, and oxygen-demanding substances in wastewater received by this creek from the Santa Rosa area.

Many of the stations sampled during this study were not sampled during the 1973 low-flow season. Thus, except for what has been stated for Mark West Creek, not much is notable in table 7 for the 1973 low-flow season. The rest of this discussion will be presented on a property or constituent and yearly basis, because the areas where water-quality objectives were not attained vary from one low-flow season to another, depending on the property or constituent examined.

TABLE 6. - Water-quality objectives for the Russian River basin

[Source is California State Water Resources Control Board, 1975b]

Property or constituent	Objective: Russian River upstream of confluence with Mark West Creek				Objective: Russian River downstream of confluence with Mark West Creek			
	Minimum	Median	90-percent value	Maximum	Minimum	Median	90-percent value	Maximum
Fecal coliform bacteria--MPN or col/100 mL	--	50	400	--	--	50	400	--
Specific conductance--μmho at 25°C	--	250	320	--	--	285	375	--
Dissolved oxygen--mg/L	7.0	7.5	--	--	7.0	7.5	--	--
pH--units	6.5	--	--	8.5	6.5	--	--	8.5
Nitrite and nitrate as N--mg/L	--	--	--	10.0	--	--	--	10.0
Turbidity[1]--NTU	Shall not be increased more than 20 percent above naturally occurring background levels				Shall not be increased more than 20 percent above naturally occurring background levels			

[1]For this study "naturally occurring background levels" were defined to be maximum observed at each station during the 1977 and 1978 low-flow seasons. They are given below:

Station	Maximum	Station	Maximum
11461000	9.5	11463680	4.0
11462000	20	11464010	4.0
11462050	13	11465400	6.3
11462690	8.0	11466800	56
11463000	7.0	11466850	28
11463150	6.8	11467000	16
11463200	6.0	11467002	15
11463400	4.9	11467006	15
11463500	4.9	11467210	8.0

During the 1974 low-flow season, fecal-coliform bacteria concentrations at most stations were not in accordance with objectives (table 7). During this period, wastewater was still being discharged to the Russian River and its tributaries and was probably the major source of the unacceptable concentrations of fecal-coliform bacteria. Even though rainfall and streamflow were much greater than normal during the 1974 water year (table 1, and fig. 10), land-surface runoff was not the major cause of unacceptable concentrations of fecal-coliform bacteria during the 1974 low-flow season. Rainfall and streamflow during the 1978 water year (table 1, and fig. 10) were also much greater than normal, but concentrations of fecal-coliform bacteria during the 1978 low-flow season did not exceed objectives except at Mark West Creek. Also, during the 1975 water year, rainfall and streamflow were near normal; but, except for Mark West Creek, fecal-coliform objectives were not exceeded during the 1975 low-flow season (table 7). The most likely cause of the decrease in fecal-coliform bacteria concentrations from the 1974 to the 1975 low-flow season, was the initiation in 1975 of regulations specifying no discharge of wastewater to the Russian River during the low-flow season.

Specific-conductance values at most stations exceeded objectives during the 1977 low-flow season (table 7); indicating that dissolved solids increased as a result of the concentrating effect of lower flows during the second year of the drought. Even without the lower flows, specific-conductance values of Big Sulphur Creek and Mark West Creek consistently exceeded objectives during this study. If the specific-conductance objectives for the Russian River apply to Big Sulphur Creek, these objectives may not be attainable for this tributary because dissolved-solids and specific-conductance values are determined from natural sources: geology and geothermal activity. If such objectives apply to Mark West Creek, attainment of these objectives for this creek will probably depend on the capacity of the creek to recover from the effect of wastewater discharged during low-flow seasons prior to 1978.

During the 1977 low-flow season, nonattainment of pH and dissolved-oxygen objectives was also more prevalent and probably was also caused by lower than normal streamflows. The nitrite and nitrate objective was not exceeded at any of the stations during this study.

The turbidity objective is difficult to interpret because the phrase "naturally occurring background levels" is not defined. For this study, the maximum turbidity values observed at each station during the 1977 and 1978 low-flow season were selected as the maximum, naturally occurring background level for the low-flow season (table 6). Such an interpretation is reasonable, considering no wastewater was discharged to the Russian River during the 1977 and 1978 low-flow seasons and streamflows ranged from much lower to much higher than normal during the 1977 and 1978 water years, respectively.

Using this interpretation means that during the 1977 and 1978 low-flow season observed turbidity values at each station were less than or equal to the maximum limit. Hence, all stations were in accordance with turbidity objectives during the 1977 and 1978 low-flow seasons. The main human activities that could have caused nonattainment of turbidity objectives during previous low-flow seasons were wastewater discharges into the Russian River and its tributaries and gravel excavation.

TABLE 7. - Stations where State water-quality objectives were not attained,

1973-78 low-flow seasons

[Explanation: X, objective exceeded, first number is number of times objective exceeded, second number is number of samples, dash indicates station not sampled for property or constituent, blank indicates objective not exceeded]

Station number	and name	Fecal coliform bacteria: Median	Fecal coliform bacteria: 90-percent value	Specific conductance: Median	Specific conductance: 90-percent value	Dissolved oxygen: Minimum	Dissolved oxygen: Median	pH: Minimum	pH: Maximum	Nitrite and nitrate as N: Maximum	Turbidity
1973											
11461000	Russian River near Ukiah	-	-	-	-	-	-	-	-	-	-
11462000	East Fork Russian River near Ukiah	-	-					-	-		-
11462050	Russian River at Ukiah	-	-	-	-	-	-	-	-	-	-
11462690	Russian River at Hopland	-	-	-	-	-	-	-	-	-	-
11463000	Russian River near Cloverdale	-	-	-	-	-	-		-	-	-
11463150	Russian River at Preston	-	-	-	-	-	-	-	-	-	-
11463210	Big Sulphur Creek at mouth near Cloverdale	-	-	-	-	-	-	-	-	-	-
11463400	Russian River at Asti	-	-	-	-	-	-	-	-	-	-
11463500	Russian River at Geyserville	-	-	-	-	-	-	-	-	-	-
11463680	Russian River at Alexander Valley Road Bridge	-	-								8/29
11464010	Russian River at Healdsburg	-	-								3/29
11465400	Russian River at Wohler Bridge	-	-								
11466800	Mark West Creek near Mirabel Heights	X	X	X	X	8/11	X				
11466850	Russian River at Mirabel Heights	-	-						1/30		
11467000	Russian River near Guerneville	-	-	-	-	-	-	-	-	-	-
11467002	Russian River at Johnson's Beach	-	-						2/30		
11467006	Russian River at Vacation Beach	-	-						4/30		
11467210	Russian River at Duncan Mills	-	-			3/29			1/30		4/30

TABLE 7. - Stations where State water-quality objectives were not attained, 1973-78 low-flow seasons--Continued

Station number	and name	Fecal coliform bacteria		Specific conductance		Dissolved oxygen		pH		Nitrite and nitrate as N	Turbidity
		Median	90-percent value	Median	90-percent value	Minimum	Median	Minimum	Maximum	Maximum	
1974											
11461000	Russian River near Ukiah	X	X	-	-	-	-	-	-	-	-
11462000	East Fork Russian River near Ukiah										-
11462050	Russian River at Ukiah			-	-	-	-	-	-		-
11462690	Russian River at Hopland			-	-	-	-	-	-		-
11463000	Russian River near Cloverdale	-	-	-	-	-	-	-	-	-	-
11463150	Russian River at Preston	X		-	-	-	-	-	-		-
11463210	Big Sulphur Creek at mouth near Cloverdale			-	-	-	-	-	-		-
11463400	Russian River at Asti	X		-	-	-	-	-	-		-
11463500	Russian River at Geyserville			-	-	-	-	-	-		-
11463680	Russian River at Alexander Valley Road Bridge	X	X					-	-		23/26
11464010	Russian River at Healdsburg							-	-		9/26
11465400	Russian River at Wohler Bridge	X	X					-	-		2/26
11466800	Mark West Creek near Mirabel Heights	X	X	X	X	8/19		-	-		
11466850	Russian River at Mirabel Heights	X	X					-	-		
11467000	Russian River near Guerneville	-	-								-
11467002	Russian River at Johnson's Beach	X						-	-		
11467006	Russian River at Vacation Beach	X	X					-	-		1/26
11467210	Russian River at Duncan Mills	X	X			1/26		-	-		4/26

TABLE 7. - Stations where State water-quality objectives were not attained, 1973-78 low-flow seasons--Continued

Station number and name		Property or constituent and objective									
		Fecal coliform bacteria		Specific conductance		Dissolved oxygen		pH		Nitrite and nitrate as N	Turbidity
		Median	90-percent value	Median	90-percent value	Minimum	Median	Minimum	Maximum	Maximum	
1975											
11461000	Russian River near Ukiah					3/24					7/39
11462000	East Fork Russian River near Ukiah										14/39
11462050	Russian River at Ukiah								1/42		20/39
11462690	Russian River at Hopland										30/39
11463000	Russian River near Cloverdale	-	-	-	-	-	-	-	-	-	-
11463150	Russian River at Preston										30/39
11463210	Big Sulphur Creek at mouth near Cloverdale			X	X						6/39
11463400	Russian River at Asti										29/39
11463500	Russian River at Geyserville										26/39
11463680	Russian River at Alexander Valley Road Bridge										30/44
11464010	Russian River at Healdsburg										26/45
11465400	Russian River at Wohler Bridge					1/45					10/45
11466800	Mark West Creek near Mirabel Heights	X	X	X	X	9/45					
11466850	Russian River at Mirabel Heights										
11467000	Russian River near Guerneville	-	-								-
11467002	Russian River at Johnson's Beach										3/45
11467006	Russian River at Vacation Beach										2/45
11467210	Russian River at Duncan Mills					1/45					9/45

TABLE 7. - Stations where State water-quality objectives were not attained, 1973-78 low-flow seasons--Continued

Station number	and name	Property or constituent and objective									
		Fecal coliform bacteria		Specific conductance		Dissolved oxygen		pH		Nitrite and nitrate as N	Turbidity
		Median	90-percent value	Median	90-percent value	Minimum	Median	Minimum	Maximum	Maximum	
1976											
11461000	Russian River near Ukiah			X	X	1/11		-	-		
11462000	East Fork Russian River near Ukiah										
11462050	Russian River at Ukiah										
11462690	Russian River at Hopland							-	-		5/11
11463000	Russian River near Cloverdale	-	-	-	-	-		-	-		-
11463150	Russian River at Preston							-	-		4/11
11463210	Big Sulphur Creek at mouth near Cloverdale			X	X			-	-		2/11
11463400	Russian River at Asti							-	-		4/11
11463500	Russian River at Geyserville							-	-		3/10
11463680	Russian River at Alexander Valley Road Bridge					1/11		-	-		5/11
11464010	Russian River at Healdsburg							-	-		
11465400	Russian River at Wohler Bridge							-	-		3/11
11466800	Mark West Creek near Mirabel Heights	X	X	X	X			-	-		
11466850	Russian River at Mirabel Heights							-	-		3/11
11467000	Russian River near Guerneville	-	-								-
11467002	Russian River at Johnson's Beach							-	-		
11467006	Russian River at Vacation Beach							-	-		1/11
11467210	Russian River at Duncan Mills							-	-		1/11

TABLE 7. - Stations where State water-quality objectives were not attained, 1973-78 low-flow seasons--Continued

Station number	and name	Fecal coliform bacteria		Specific conductance		Dissolved oxygen		pH		Nitrite and nitrate as N	Turbidity
		Median	90-percent value	Median	90-percent value	Minimum	Median	Minimum	Maximum	Maximum	
1977											
11461000	Russian River near Ukiah			X	X	4/11			2/10		
11462000	East Fork Russian River near Ukiah										
11462050	Russian River at Ukiah								1/21		
11462690	Russian River at Hopland										
11463000	Russian River near Cloverdale										
11463150	Russian River at Preston								2/21		
11463210	Big Sulphur Creek at mouth near Cloverdale			X	X				10/22		
11463400	Russian River at Asti			X					3/22		
11463500	Russian River at Geyserville			X					3/21		
11463680	Russian River at Alexander Valley Road Bridge			X		1/22					
11464010	Russian River at Healdsburg			X					2/21		
11465400	Russian River at Wohler Bridge			X	X				6/21		
11466800	Mark West Creek near Mirabel Heights	X	X	X	X	11/16	X		3/15		
11466850	Russian River at Mirabel Heights			X		1/22			2/22		
11467000	Russian River near Guerneville			X		2/27			6/27		
11467002	Russian River at Johnson's Beach			X		2/22			3/22		
11467006	Russian River at Vacation Beach			X					3/22		
11467210	Russian River at Duncan Mills			X	X	1/22			5/22		

TABLE 7. - Stations where State water-quality objectives were not attained, 1973-78 low-flow seasons--Continued

Station number	and name	Fecal coliform bacteria		Specific conductance		Dissolved oxygen		pH		Nitrite and nitrate as N	Turbidity
		Median	90-percent value	Median	90-percent value	Minimum	Median	Minimum	Maximum	Maximum	
1978											
11461000	Russian River near Ukiah			X		3/16			4/15		
11462000	East Fork Russian River near Ukiah					1/21					
11462050	Russian River at Ukiah										
11462690	Russian River at Hopland										
11463000	Russian River near Cloverdale								1/17		
11463150	Russian River at Preston								2/17		
11463210	Big Sulphur Creek at mouth near Cloverdale			X	X				10/19		
11463400	Russian River at Asti								3/19		
11463500	Russian River at Geyserville								2/19		
11463680	Russian River at Alexander Valley Road Bridge								1/21		
11464010	Russian River at Healdsburg										
11465400	Russian River at Wohler Bridge					1/21					
11466800	Mark West Creek near Mirabel Heights	X		X	X	10/20	X				
11466850	Russian River at Mirabel Heights										
11467000	Russian River near Guerneville										
11467002	Russian River at Johnson's Beach										
11467006	Russian River at Vacation Beach										
11467210	Russian River at Duncan Mills								1/18		

Aquatic Community Metabolism

Aquatic community metabolism is related to primary productivity (the rate of formation of organic substances by producer organisms) and respiration (the rate of breakdown of organic substances to oxidation products, particularly carbon dioxide by consumer and producer organisms to obtain energy for life processes). Information about aquatic community metabolism for the Russian River is important because nuisance growths of algae (the principal components of the aquatic community responsible for primary productivity) have occurred in the past. Knowledge about the relative amounts of primary production and respiration in the Russian River during the low-flow season can help determine the general trophic (nutritional) status of the river, the propensity for nuisance algal growths to occur, and the likelihood of dissolved-oxygen reduction to levels, below which certain aquatic species die.

Changes in dissolved-oxygen concentration in water over a diel (24-hour period) can be used to estimate aquatic community metabolism because oxygen is produced during photosynthesis and utilized during respiration. The rate of change of dissolved oxygen per unit area of aquatic environment is related to primary productivity and respiration by the equation (Greeson and others, 1977, p. 269):

$$Q = P - R \pm D + A$$

where

Q = rate of change (gain or loss) of dissolved oxygen per unit area (net primary productivity),

P = rate of gross primary productivity per unit area,

R = rate of oxygen utilization (respiration) per unit area,

D = rate of oxygen uptake or loss by diffusion per unit area, depending on whether the water is undersaturated or oversaturated with oxygen with respect to the air, and

A = rate of supply of oxygen from drainage accrual.

To obtain an estimate of community metabolism in the Russian River during the low-flow season, a diel study was done during August 1977 at two stations: Russian River at Alexander Valley Road Bridge (11463680) and Russian River near Guerneville (11467000). The diel study involved continuously monitoring water temperature, pH, specific conductance, and dissolved oxygen using multi-electrode water-quality monitors. The electrodes were submersed in the water at the centroid of flow and mid-depth with an electrical cable connecting them to a readout module placed on the river bank. Electrode readings displayed on the readout module were recorded at 15-minute to 2-hour intervals. At the start of the study, electrodes were calibrated onsite. At the start and periodically throughout the study, electrode readings were compared to portable meter readings taken at a number of points across the flow width. Electrode and meter readings were the same. Water-discharge measurements were made at the start and end of the study. Water discharge, based on these measurements at both stations, varied little, throughout the study.

Data from the diel study at both stations were analyzed using a Fortran computer program (Primary Production, J330) developed by Stephens and Jennings (1976). The single-station option of the program was used which calculates daytime net production, night respiration, and 24-hour community metabolism for flowing water at a single location. Diffusion was expressed as a coefficient and was calculated according to the Bennett and Rathbun (1972) method using average water depth and velocity. The arithmetic difference between daytime net production and night respiration was 24-hour community metabolism (equivalent to Q in the equation previously given).

This approach to computing community metabolism assumes: (1) incoming water has a metabolic history similar to outflowing water; (2) reaeration is constant over a 24-hour period; (3) a known or no horizontal exchange of oxygen; (4) production only occurs during daytime, whereas, night changes in dissolved oxygen (after correcting for diffusion) are because of respiration; and (5) a sufficient plant biomass exists to create a daytime increase in dissolved oxygen due to photosynthesis. In addition, no assumption about daytime respiration is made; that is, it is not assumed that daytime respiration is equal to night respiration, thus, gross primary productivity cannot be calculated. Furthermore, at the stations studied there should be little or no turbulence and any accrual or loss of water must be known. These assumptions and requirements seem to have been satisfied for the two stations studied: river characteristics upstream of these stations were similar to those at the stations, streamflow was nearly constant and nonturbulent through out the study, there was little or no cross-sectional variation in properties monitored (indicating a well-mixed condition), and a sufficient plant biomass was present to provide a daytime increase in dissolved oxygen due to photosynthesis (fig. 29).

Diel community metabolism values computed for the stations Russian River at Alexander Valley Road Bridge (11463680) and Russian River near Guerneville (11467000) were -11.14 and -12.21 g $O_2/(m^2/d)$, respectively. The P/R (Production/Respiration Ratio) values for these stations were -0.20 and -0.85, respectively. These values show that more respiration than production occurred at both stations during the diel study. In other words, some photosynthetic production of oxygen occurred, but it was not sufficient to offset respiration. Thus, either the oxygen demand of the water or the oxygen demand of the biota and sediment was high. The latter seems more likely because COD values were usually low (<15 mg/L) throughout the main stem of the Russian River during the 1977 low-flow season.

These results indicate that heterotrophic (oxygen utilizing) aquatic communities predominate at both stations studied. In addition, depletion of dissolved oxygen to levels deleterious to some aquatic plants and animals appears to be a likely possibility, especially in pooled sections of the river where reaeration is less. But, the likelihood of nuisance algal growths occurring, given the persistence of conditions during the diel study, appears to be low.

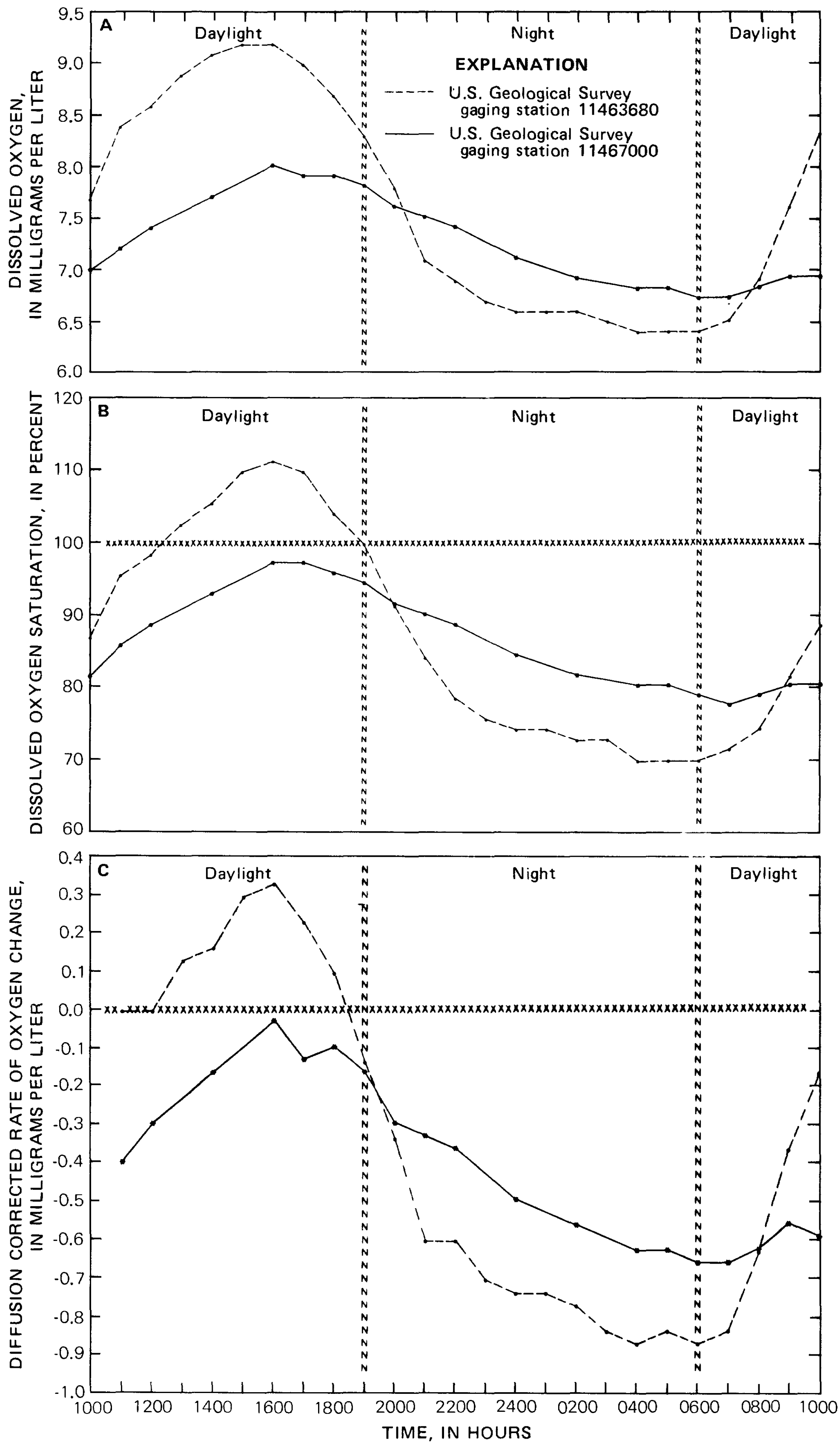


FIGURE 29. – Changes in water quality during the diel study.

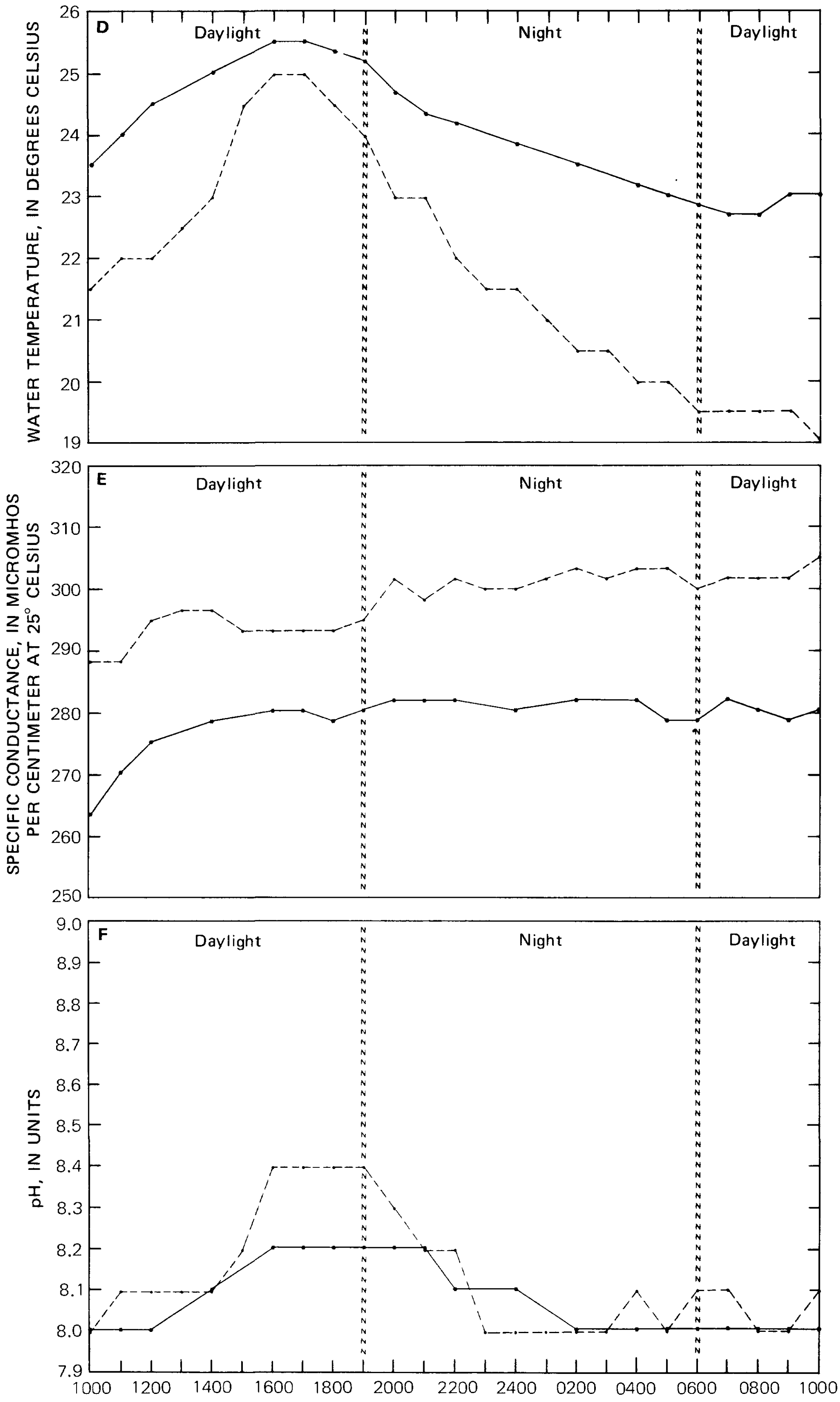


FIGURE 29. – Continued.

Changes in the properties monitored during the diel study are shown in figure 29. For all properties except specific conductance, the values increased during daylight hours and decreased during the night. In a stream whose water quality is controlled by microbial processes, these are the usual diel patterns observed because of the daylight (increased productivity and solar heating) to darkness (decreased productivity and heat loss) cycle. Dissolved-oxygen changes had greater amplitude at Russian River at Alexander Valley Road Bridge (11463680) than at Russian River near Guerneville (11467000) indicating a more dynamic aquatic community existed at the upstream station (11463680). Dissolved-oxygen values during most of the daylight period were greater at the upstream station. At the upstream station, daylight dissolved-oxygen sometimes exceeded 100 percent saturation resulting in positive values for diffusion corrected rate of change of dissolved oxygen (fig. 29). At night, dissolved-oxygen values at the upstream station (11463680) were usually less than those at the downstream station (11467000). Changes in specific conductance and pH followed similar patterns at both stations.

Periphyton

Periphyton is the community of microorganisms that is attached to or lives upon submerged objects in water. This definition of periphyton includes bacteria, fungi, protozoa, and rotifers, but periphyton usually consists primarily of algae. Periphyton is discussed separately from other properties and constituents in this report because samples were obtained only during 1977 and 1978, and then a maximum of 2 samples per station per year were collected. Periphyton is important to study in the Russian River because dislodged periphytic algae contribute significantly to the amount of floating algae present in the water during low-flow seasons and attached algae probably account for much of the primary production in the Russian River. Samples were collected to provide an estimate of seasonal and yearly changes in periphyton composition and cellular contents. Because the length of exposure (colonization period) varied, results are expressed on a weight/area/day basis to provide values comparable between years, between seasons, and among stations (table 8).

As shown in table 8 and figure 30, the biomass chlorophyll-*a* ratio, AI (autotrophic index), was markedly greater during 1977 than during 1978. Figures 31 and 32 and table 8 show that this difference in AI was due to appreciably greater chlorophyll-*a* values during 1978; organic weight (biomass) values do not appear to be much different during 1977 and 1978. During 1977, AI values were greater than 500 with most values considerably larger than 1000, which means that the periphyton was predominantly composed of organisms not having chlorophyll (for example, bacteria, fungi, protozoa, and rotifers) and (or) that an appreciable amount of nonliving organic matter was present. If the latter was the case, the source of the nonliving organic matter was not the water because the water at all stations except Mark West Creek near Mirabel Heights (11466800) was nearly always low in turbidity (<10 NTU) and organic matter (COD values <20 mg/L) during the 1977 and 1978 low-flow seasons. AI values are usually between 50 and 100 for water not receiving waste material (clean-water streams) (Weber, 1973). Yet, for the Russian River during 1977, chlorophyll-*a* values were very low ($<0.1(mg/m^2)/d$) and organic weight values were not particularly high. The primary determinant of the high AI values during 1977 was the low chlorophyll-*a* values, not high organic weights.

AI values during 1978 were seldom greater than 1000 with most values less than 500 (fig. 30). These values were closer to those expected for clean-water streams and indicate that algae were more prevalent in the periphyton during 1978 and were probably the predominant organisms when AI values were less than 100. Streamflows were greater during 1978 than 1977 (figs. 10 and 11). This might be the reason for the difference in composition of the periphyton during those years. Greater streamflows during the rainy season would probably result in more organic material being deposited on the streambed and thus increase nutrient availability to algae. Also, and probably more important, greater streamflows during the 1978 low-flow season would make more habitat available for periphyton (more streambed covered by water) and because of greater water depth, the likelihood of excessive light exposure (photooxidation) suppressing periphyton growth would be less.

Seasonal differences in periphyton chlorophyll-a and organic weight are hard to determine because of the number of missing values. Early and late summer chlorophyll-a values generally appear to be similar, whereas early and late summer organic weights generally appear to be different (figs. 31 and 32). This indicates that during the 1977 and 1978 low-flow seasons, the algal portion of the periphyton was more stable than the heterotrophic portion of the periphyton in the Russian River.

Chlorophyll-a, organic weight, and AI values did vary from station to station, but no consistent pattern was apparent during 1977 and 1978.

All algae contain chlorophyll-a, but green algae and euglenophytes also contain chlorophyll-b. Thus, the ratio between chlorophyll-a and chlorophyll-b can help to determine the proportion of green algae and euglenophytes in periphyton. The ratio of chlorophyll-a to chlorophyll-b during 1978 generally was about twice that of 1977 (table 8), indicating that green algae and (or) euglenophytes composed a lesser portion of the periphyton during 1978 than during 1977. Early and late summer ratios were generally similar, indicating that the proportion of green algae and (or) euglenophytes in the periphyton did not change during the 1977 and 1978 low-flow seasons. Ratios are low (≤5.00) at Russian River at Ukiah (11462050), Russian River at Hopland (11462690), Russian River at Wohler Bridge (11465400), and Russian River at Johnson's Beach (11467002). This indicates that green algae and (or) euglenophytes were significant components of the periphyton at these stations.

TABLE 8. - Periphyton-cellular contents

Station number	Station name	Date polyethylene strip retrieved	Days of exposure	Organic weight ((mg/m²)/d)	Chlorophyll-a ((mg/m²)/d)	Chlorophyll-b ((mg/m²)/d)	Biomass (organic weight) Chlorophyll-a ratio	Chlorophyll-a Chlorophyll-b ratio
11461000	Russian River near Ukiah.	June 21, 1977	40	36.8	0.000	0.002	--	--
		July 19, 1978	34	135	.164	.020	827	8.20
		Oct. 12, 1978	31	19.4	.219	.043	88	5.09
11462000	East Fork Russian River near Ukiah.	June 21, 1977	40	83.0	.007	.001	12,340	7.00
		Sept. 8, 1977	29	51.4	.010	.000	4,967	--
		Sept. 12, 1978	77	14.3	.025	.009	570	2.78
11462050	Russian River at Ukiah.	June 21, 1977	40	57.8	.018	.028	3,300	.64
		Sept. 8, 1977	29	341.4	.003	.002	107,610	1.50
		Oct. 12, 1978	31	11.3	.007	.004	1,662	1.75
11462690	Russian River at Hopland.	June 3, 1977	22	--	.000	.000	--	--
		Sept. 8, 1977	29	167	.007	.006	24,200	1.17
11463000	Russian River near Cloverdale.	June 2, 1977	21	136	.015	--	9,137	--
		Sept. 8, 1977	29	338	.023	.000	14,800	--
		July 6, 1978	21	56.2	1.02	.167	55	6.11
11463150	Russian River at Preston.	June 22, 1977	42	85.7	.011	.027	7,826	.41
		Sept. 27, 1977	48	56.2	.014	.004	3,930	3.5
		July 18, 1978	33	78.8	.839	.094	94	8.93
11463210	Big Sulphur Creek at mouth near Cloverdale	Sept. 7, 1977	29	30.0	.031	.002	967	15.50
		July 6, 1978	22	545	2.43	.000	225	--
		Oct. 12, 1978	30	140	.757	.083	185	9.12
11463400	Russian River at Asti.	June 2, 1977	22	--	.023	.027	--	.85
		Sept. 7, 1977	29	445	.002	.002	268,800	1.00
		July 6, 1978	22	17.9	.007	.000	2,627	--
		Oct. 12, 1978	30	96.7	1.44	.050	67	28.80
11463500	Russian River at Geyserville.	June 2, 1977	22	368	.023	.009	16,200	2.56
		Sept. 7, 1977	29	283	.024	.003	11,570	8.00
		July 6, 1978	22	236	.841	.034	281	24.74
		Oct. 13, 1978	30	633	1.25	.273	505	4.58
11463680	Russian River at Alexander Valley Road Bridge	June 23, 1977	43	59.1	.014	.005	4,233	2.80
		Sept. 7, 1977	29	317	.066	.000	4,842	--
		July 7, 1978	23	161	1.34	.130	120	10.31
		Oct. 11, 1978	29	70.7	1.43	.121	49	11.82

TABLE 8. - Periphyton cellular contents--Continued

Station number	Station name	Date polyethylene strip retrieved	Days of exposure	Organic weight ((mg/m²)/d)	Chlorophyll-a ((mg/m²)/d)	Chlorophyll-b ((mg/m²)/d)	Biomass (organic weight) Chlorophyll-a ratio	Chlorophyll-a Chlorophyll-b ratio
11464010	Russian River at Healdsburg.	June 1, 1977	22	--	0.005	0.003	--	1.67
		Sept. 7, 1977	29	345	.000	.000	--	--
		July 25, 1978	19	184	1.62	.117	114	13.85
		Oct. 11, 1978	29	63.8	1.57	.120	41	13.08
11465400	Russian River at Wohler Bridge.	May 25, 1977	15	393	.005	.003	85,510	1.67
		Sept. 28, 1977	51	33.3	.005	.001	6,439	5.00
		July 7, 1978	23	82.6	.232	.084	356	2.76
11466800	Mark West Creek near Mirabel Heights.	July 1, 1977	22	--	.009	.004	--	2.25
		July 7, 1978	23	47.8	.428	.110	112	3.89
		Oct. 11, 1978	29	138	.321	.045	429	7.13
11466850	Russian River at Mirabel Heights.	May 24, 1977	14	307	.024	.006	12,680	4.00
		July 6, 1978	21	176	1.58	.123	111	12.85
		Oct. 11, 1978	30	370	.620	.055	597	11.27
11467000	Russian River near Guerneville.	July 21, 1977	38	--	.052	.032	--	1.62
		Sept. 6, 1977	29	81.4	.059	.002	1,372	29.5
		Oct. 11, 1978	30	297	1.25	.105	238	11.90
11467002	Russian River at Johnson's Beach.	Sept. 20, 1977	43	14.6	.022	.006	653	3.67
11467006	Russian River at Vacation Beach.	May 31, 1977	22	--	.000	.000	--	--
		July 18, 1978	33	93.9	.165	.025	568	6.60
11467210	Russian River at Duncan Mills.	Sept. 20, 1977	43	69.5	.002	.000	32,860	--
		July 6, 1978	21	30.0	.093	.017	321	5.47
	Mean------------------------------	1977		178	0.016	0.006	30,200	4.72
		1978		154	.819	.076	427	9.59
	Standard error of mean------------	1977		30.5	.003	.002	13,350	1.52
		1978		33.1	.137	.013	120	1.42
	Number of samples-----------------	1977		23	29	28	21	20
		1978		24	24	24	24	22

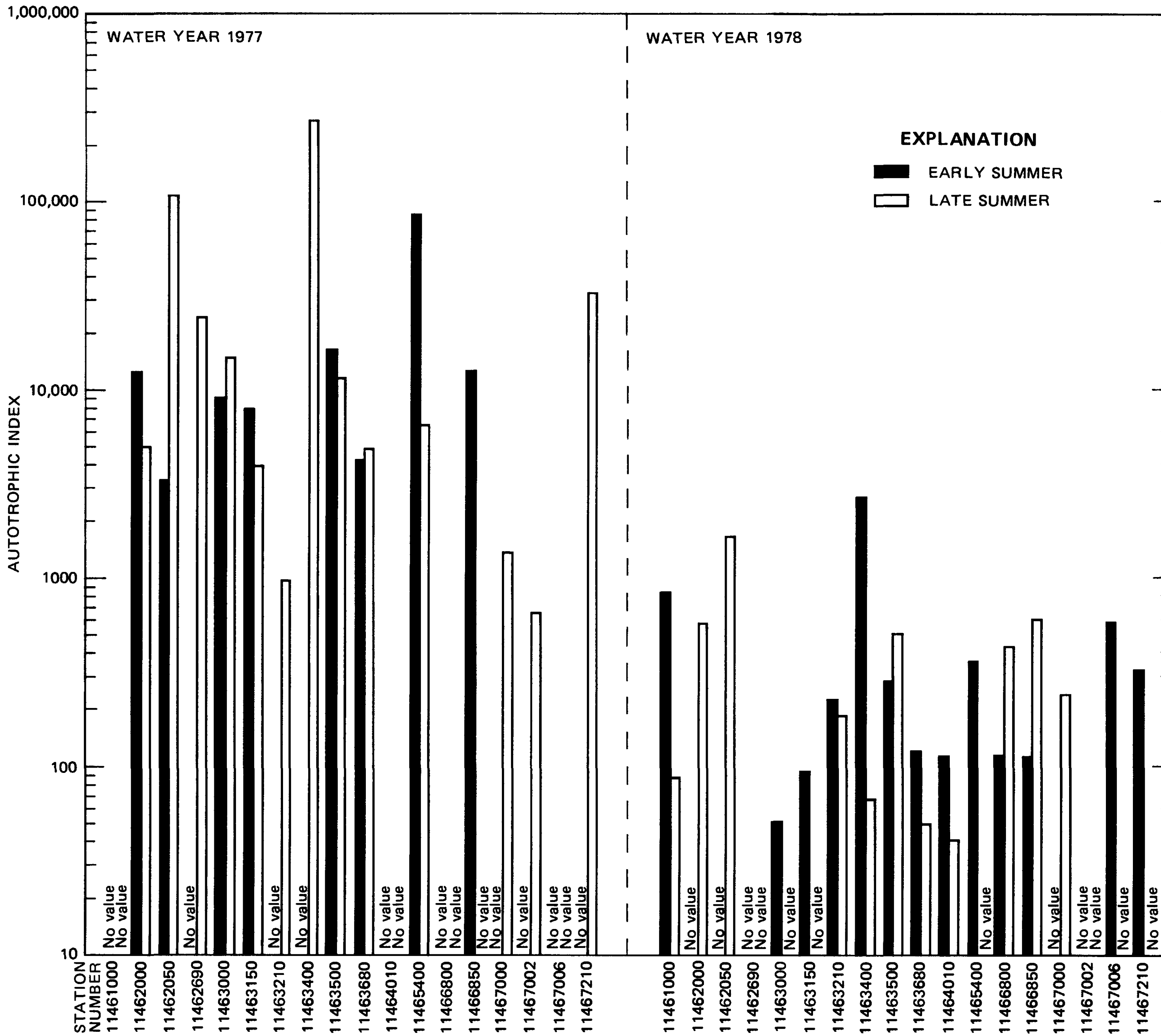


FIGURE 30. – Changes in periphyton autotrophic index.

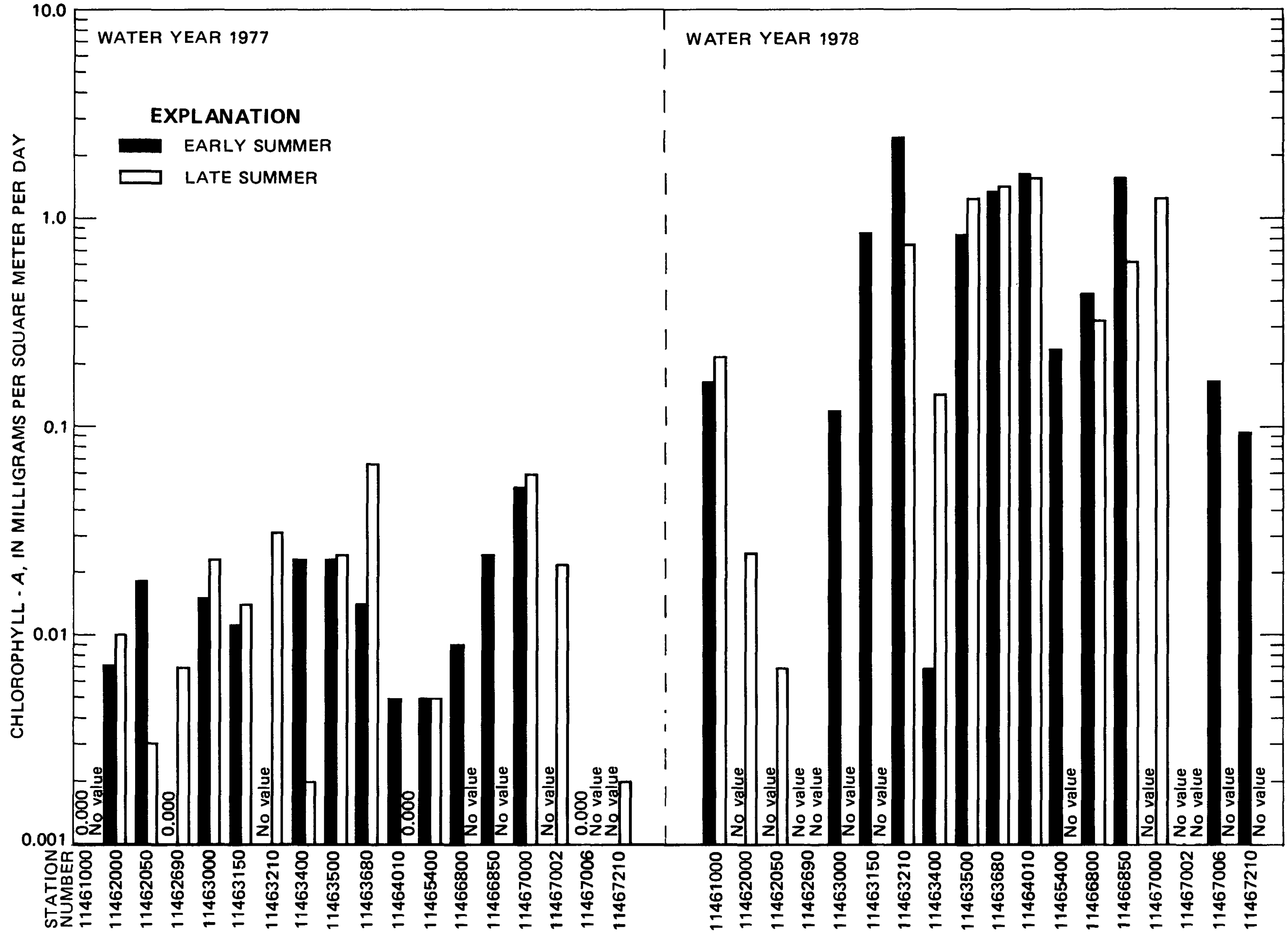


FIGURE 31.– Changes in periphyton chlorophyll - *a*.

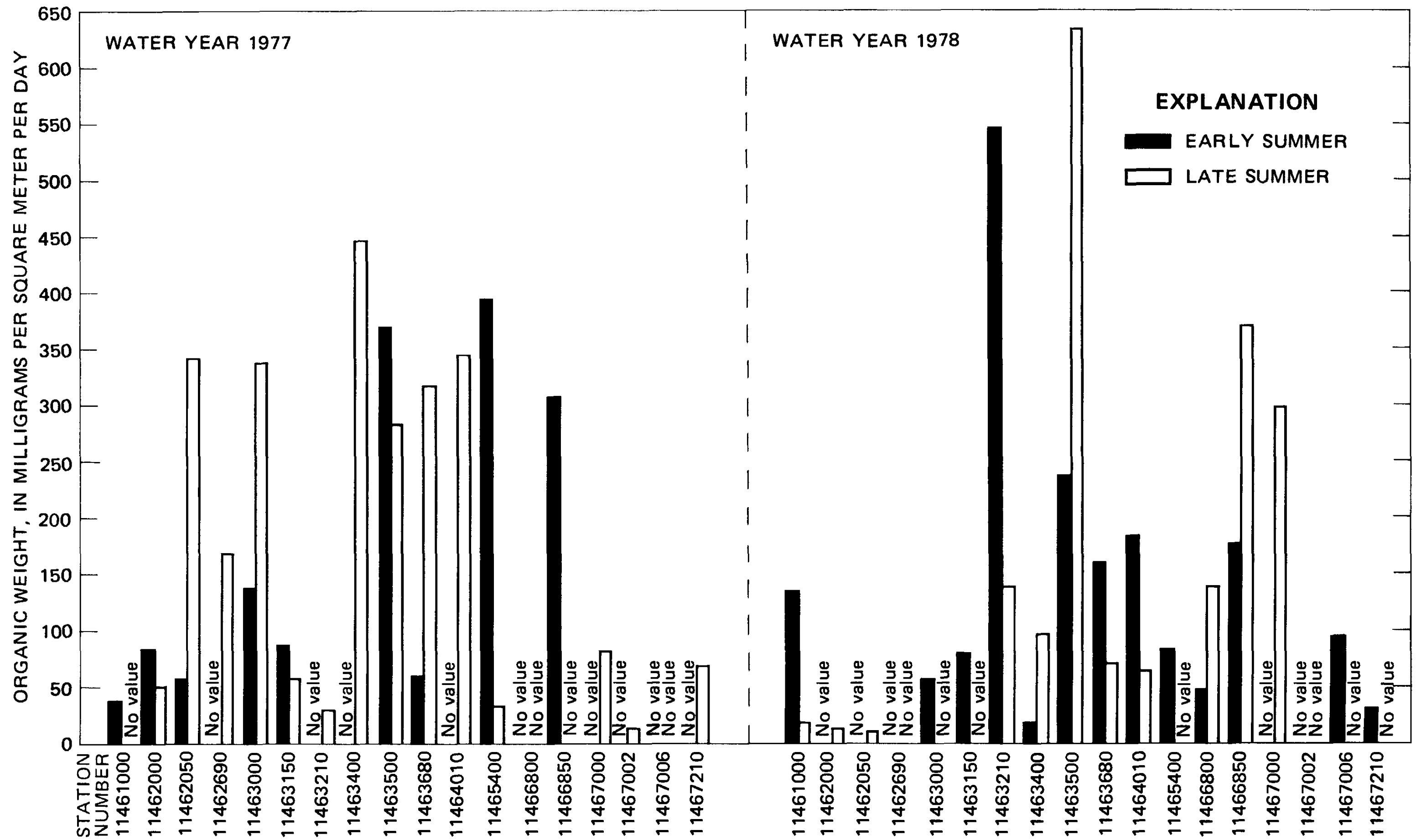


FIGURE 32. — Changes in periphyton organic weight.

SUMMARY AND CONCLUSIONS

During the low-flow season (May to October), water quality and streamflow in the Russian River basin were studied during water years 1973 through 1978 to document water-quality and streamflow conditions in the basin and to determine the extent and cause(s) of any water-quality impairment. The most important factors affecting surface-water quality and streamflow in the Russian River basin during the 1973-78 low-flow seasons were wastewater discharges, their abatement beginning in 1975, and the drought during 1976 and 1977.

During the 1974 low-flow season, concentrations of fecal-coliform bacteria, at most sampling stations, were not in accordance with water-quality objectives. Fecal-coliform bacteria, nitrate, ammonia plus organic nitrogen, and orthophosphorus decreased markedly after 1974, coinciding with the implementation of regulations stipulating no discharge of wastewater during the low-flow season. After 1974, water-quality objectives for fecal-coliform bacteria were met at all stations except Mark West Creek near Mirabel Heights (11466800). Until 1978, the Mark West Creek drainage continued to receive wastewater during the low-flow season from the basin's principal urban area, Santa Rosa and nearby communities.

Rainfall and streamflows in the Russian River basin were much less than normal during the drought (water years 1976 and 1977). The effect of the drought on the flow of the Russian River was more evident in the lower part of the basin (near Guerneville) than it was in the upper part of the basin (near Ukiah) where flows are regulated by Coyote Dam.

Abnormally low rainfall and streamflows in the basin during the drought resulted in some improvement in water quality. Generally, turbidity and inorganic and organic nitrogen were least during the 1977 low-flow season.

Deleterious effects of the drought on the quality of surface water in the basin were increases in specific conductance and pH and decreases in dissolved oxygen that, at most stations, resulted in these water-quality properties not being in accordance with water-quality objectives during the 1977 low-flow season.

Water releases from Lake Mendocino compose most of the flow of the Russian River during the low-flow season. These releases appear to influence specific conductance, total nitrate, turbidity, and phytoplankton values in the Russian River because the patterns of yearly change in values of these water-quality properties and constituents were similar to those in water releases from Lake Mendocino. However, concentrations of fecal-coliform bacteria, total ammonia plus organic nitrogen, and dissolved orthophosphorus in the Russian River do not appear to be influenced by water releases from Lake Mendocino because the patterns of yearly change in values of these water-quality properties and constituents were not similar to those in water releases from Lake Mendocino.

A large increase in phytoplankton occurred from 1976 to 1977. This increase in phytoplankton probably was due to a reduction in water turbidity and streamflow during that time.

During the 1977 and 1978 low-flow seasons, the flow of the Russian River was variable and did not follow a consistent pattern. This was due to variable water releases from Lake Mendocino to meet the variable water needs of downstream users.

During the 1977 and 1978 low-flow seasons, the temperature of release water from Lake Mendocino increased. This probably resulted from a greater contribution of warm water from the epilimnion (upper zone in a stratified water body) to release water, as the reservoir was drawn down during the low-flow season.

Fecal-streptococcal bacteria concentrations increased during the 1977 and 1978 low-flow seasons. Fecal-coliform bacteria concentrations were less than fecal streptococcal bacteria concentrations and increased only slightly or did not increase during the 1977 and 1978 low-flow seasons.

During the 1977 and 1978 low-flow seasons, turbidity, total ammonia plus organic nitrogen, and total nitrite plus nitrate values generally decreased. The similarity in the pattern of nitrogen and turbidity changes during 1977 and 1978 suggests that organic and inorganic nitrogen in the Russian River are associated with suspended matter.

Algal growth in the Russian River depends on the amount of nitrogen in the water and is not limited by the amount of phosphorus in the water. Decreases in algal growth potential during the 1977 and 1978 low-flow seasons generally correspond to decreases in nitrogen. Algal growth potential did not follow the pattern of dissolved orthophosphorus concentrations that changed only slightly during the 1977 and 1978 low-flow seasons. Correlation coefficients between algal growth potential and total nitrite plus nitrate were greater than or equal to 0.95. Correlation coefficients between algal growth potential and dissolved orthophosphorus were zero or negative.

During the 1977 low-flow season, the extent of the periphytic community and, hence, oxygen production were regulated by streamflow. At Russian River near Guerneville (11467000), dissolved oxygen changed from a high of 164 percent saturation in May 1977 when the flow was 39.0 ft^3/s to 82 percent saturation in June 1977 when the flow was 22.6 ft^3/s. During this period of unusually low streamflows, changes in streamflow greatly affected the amount of streambed under water and the amount of light reaching the submerged streambed. Photoinhibition may occur when too much light reaches periphyton. Also, physical aeration of the water was reduced at lower streamflows.

During this study, basin geomorphology, diversion of water and diversion impoundments, recreational impoundments and associated human activities, land use (other than wastewater discharges), and tidewater had little effect on the low-flow water quality of the Russian River. Only in reach type 1 (from Mirabel Park to Jenner) did basin geomorphology appear to affect water quality. Less riverbed gradient, slower flows, and more pools in this reach of the river probably helped to promote phytoplankton growth, therefore, greater phytoplankton counts were observed in this reach of the river than in others. Water diversion did decrease the flow of the river, but water-quality changes were limited to increased pH and water temperatures resulting from water impoundment behind the inflatable dam near the Ranney collectors. The only effect of recreational impoundments on water quality appeared to be a slight increase in fecal-coliform bacteria concentrations downstream of some of these impoundments. Water-contact recreation in the vicinity of these impoundments was probably responsible for the observed increased fecal-coliform bacteria concentrations.

Big Sulphur Creek and Mark West Creek did affect water quality of the Russian River during the low-flow season. Specific conductance and pH values of the Russian River were greater downstream of Big Sulphur Creek. Dissolved-solids and specific-conductance values of this creek are determined by geology and geothermal activity. Greater pH values in Big Sulphur Creek than in the Russian River probably were due to the lesser flows and turbidity and greater nitrate concentrations. These conditions enhance algal growth and increase pH as a result of CO_2 uptake. Specific-conductance values and concentrations of orthophosphorus and phytoplankton in the Russian River were greater downstream of Mark West Creek. Due mostly to the influence of wastewater discharges, Mark West Creek had greater values of most water-quality properties and constitutuents than did the Russian River.

The West Fork of the Russian River had no effect on water quality of the main stem because its flow composed a very small proportion of the flow of the main stem during the low-flow season.

During the low-flow season, local climatic conditions have an important impact on the water temperature of the Russian River. As cold water released from Lake Mendocino proceeds downstream, it is markedly warmed in climatic areas receiving little ocean influence. Releases of cold bottom water from Lake Mendocino probably maintain downstream water temperatures within the range of tolerance of certain aquatic organisms (for example, salmon and trout), inhibit aquatic community respiration, and minimize nuisance growths of phytoplankton and periphyton.

Results of the diel study indicate that in the Russian River during the low-flow season, photosynthetic production of oxygen is not sufficient to offset respiration. Thus, depletion of dissolved oxygen to levels deleterious to some aquatic plants and animals appears to be likely. The section of the river most likely to be affected is the reach downstream of Mirabel Park that has the least gradient, slowest water velocities, most pooled sections, and, therefore, least potential for reaeration by physical mechanisms such as diffusion. The likelihood of nuisance algal growths occurring appears to be low if the heterotroph-dominated aquatic community that was present during the diel study persists. This conclusion is supported by periphyton data that indicate periphyton at most stations during the 1977 and 1978 low-flow seasons was dominated by organisms not having chlorophyll.

EVALUATION OF DATA-COLLECTION PROGRAM

The data-collection program used in this study consisted of scheduled sampling and special monitoring (diel study) during that part of each year in which streamflow and water quality are most likely to impact beneficial water uses; that is, the low-flow season. Data collected were useful for documenting streamflow and water-quality conditions in the basin and for determining the extent and cause of water-quality impairment.

Because the water quality of the Russian River has markedly improved as a result of controlling the primary cause of water-quality impairment in the basin (discharge of wastewater during the low-flow season) the primary reason for continuing data collection has been eliminated. Nevertheless, some data collection could be done to alert water managers to changing streamflow and water-quality conditions.

Adequate areal coverage could be provided by measuring streamflow and sampling at East Fork Russian River near Ukiah (11462000), Russian River at Alexander Valley Road Bridge (11463680), and Russian River near Guerneville (11467000). These stations are at key locations on the Russian River (reservoir release, boundary between mostly agricultural and mostly urban areas, and high recreational-use area, respectively). The properties and constituents, and sampling frequencies used in this study would be sufficient to alert water managers to changing water-quality conditions.

In addition, diel and other special studies could be done to quantify the likelihood of dissolved-oxygen depletion and nuisance algal growths in sensitive reaches of the river, especially the low-gradient, slow-water-velocity reach downstream of Mirabel Park.

One or two key stations, East Fork Russian River near Ukiah (11462000) and (or) Russian River near Guerneville (11467000), could be sampled during the high-flow season for the properties and constituents sampled for during the low-flow season. Data provided by this sampling would be helpful in documenting high-flow water quality and its effect, if any, on low-flow water quality.

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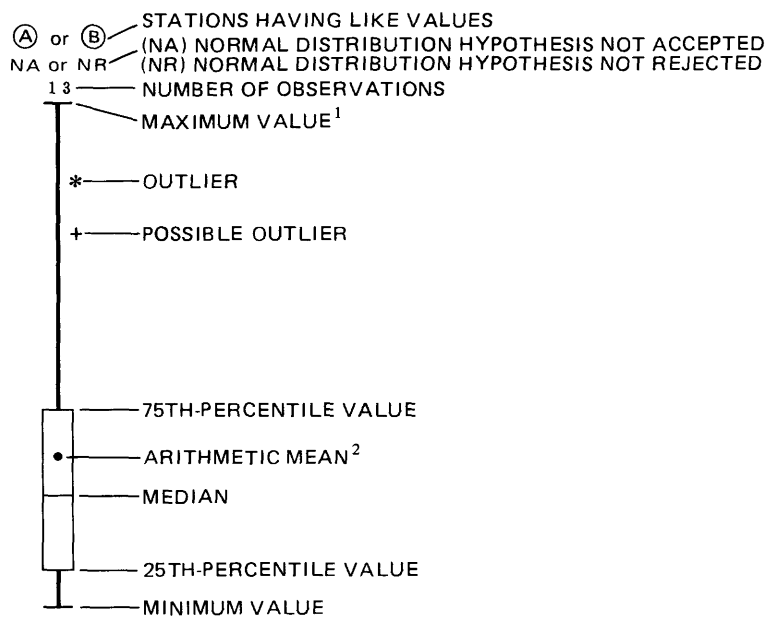
FIGURES 19-21, 23, 25-28

EXPLANATION



Ⓐ or Ⓑ Indicate stations having like values of the property or constituent compared as determined by a Kruskal-Wallis test when data for one or more of the stations compared are not a random sample from a normally distributed population and by a one-way analysis of variance test when data for all stations compared are random samples from normally distributed populations. Ninety-five percent confidence level used for all tests

NA Hypothesis that data are a random sample from a normally distributed population is not accepted at the 95-percent confidence level based on the Shapiro-Wilk W-statistic when the number of observations is less than or equal to 50 and based on a modified version of the Kolmogorov-Smirnov D-statistic when the number of observations is greater than 50

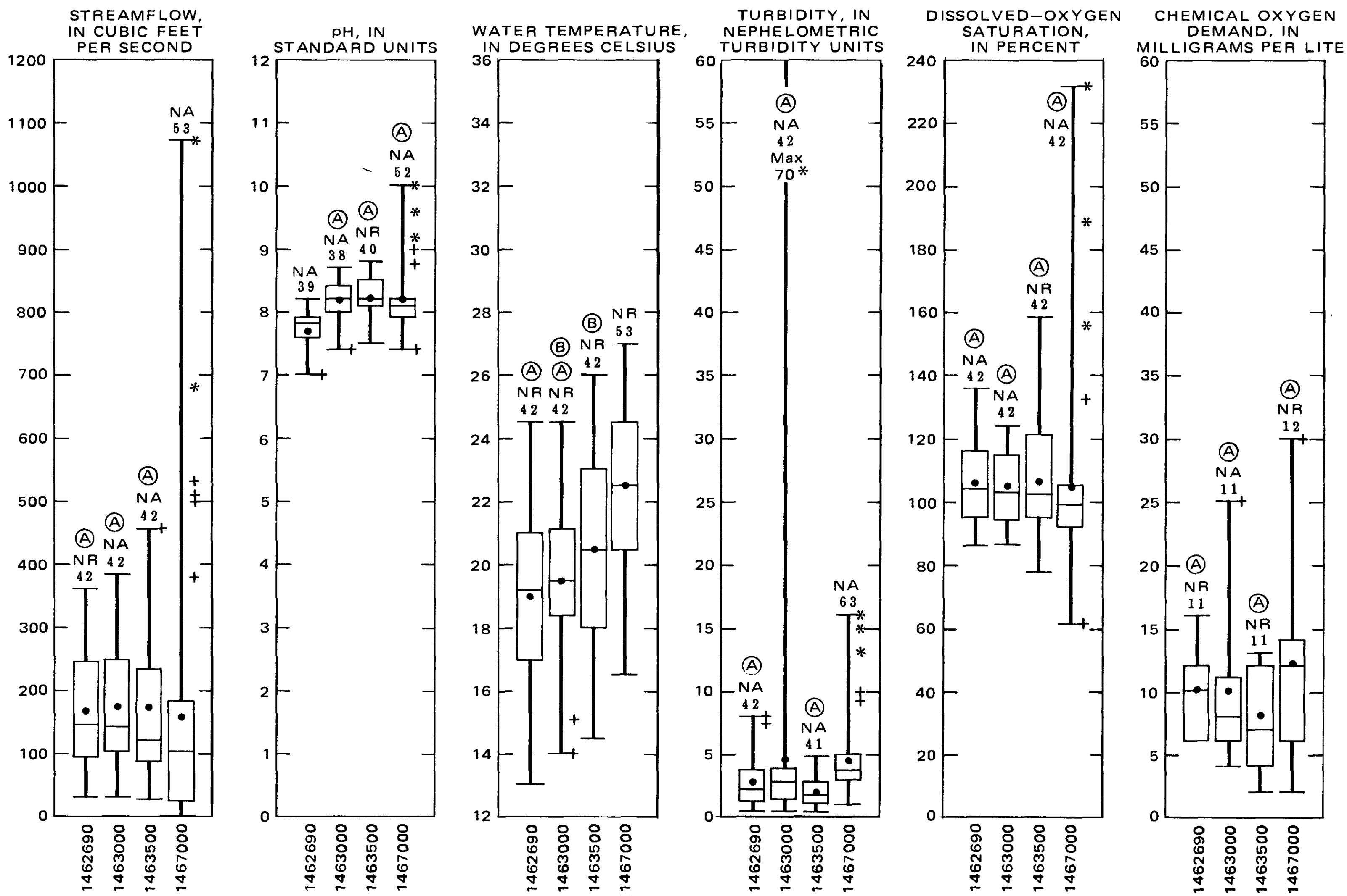
NR Hypothesis that data are a random sample from a normally distributed population is not rejected at the 95-percent confidence level based on the Shapiro-Wilk W-statistic when the number of observations is less than or equal to 50 and based on a modified version of the Kolmogorov-Smirnov D-statistic when the number of observations is greater than 50

* Outlier: Value is greater than 75th percentile or less than 25th percentile by more than 3 times the interquartile range (75th percentile minus 25th percentile)

+ Possible outlier: Value is greater than 75th percentile or less than 25th percentile by more than 1.5 times the interquartile range

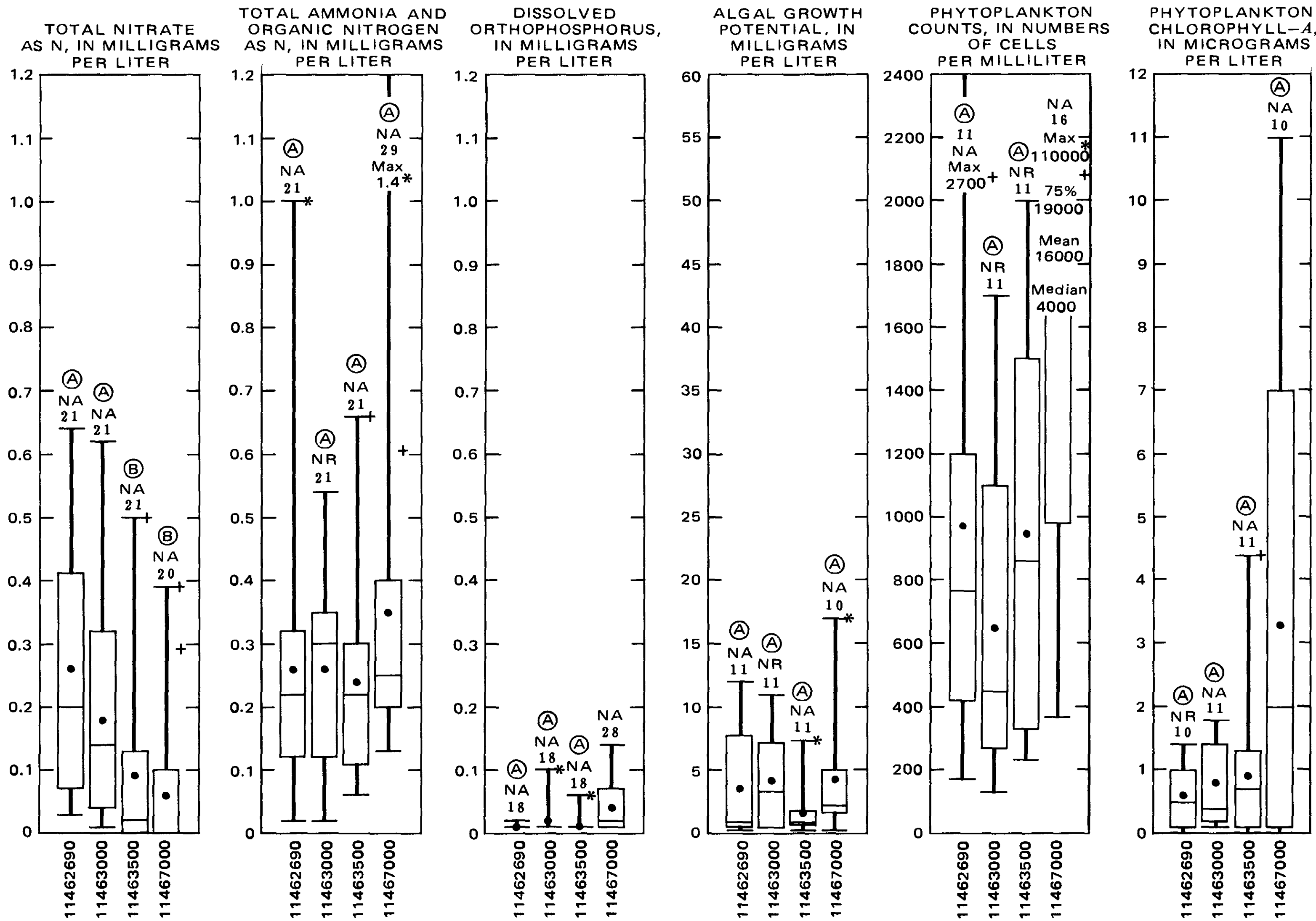
1 Where maximum and (or) mean value extends beyond the grid area, the values are indicated by Max and Mean

2 Geometric mean for pH



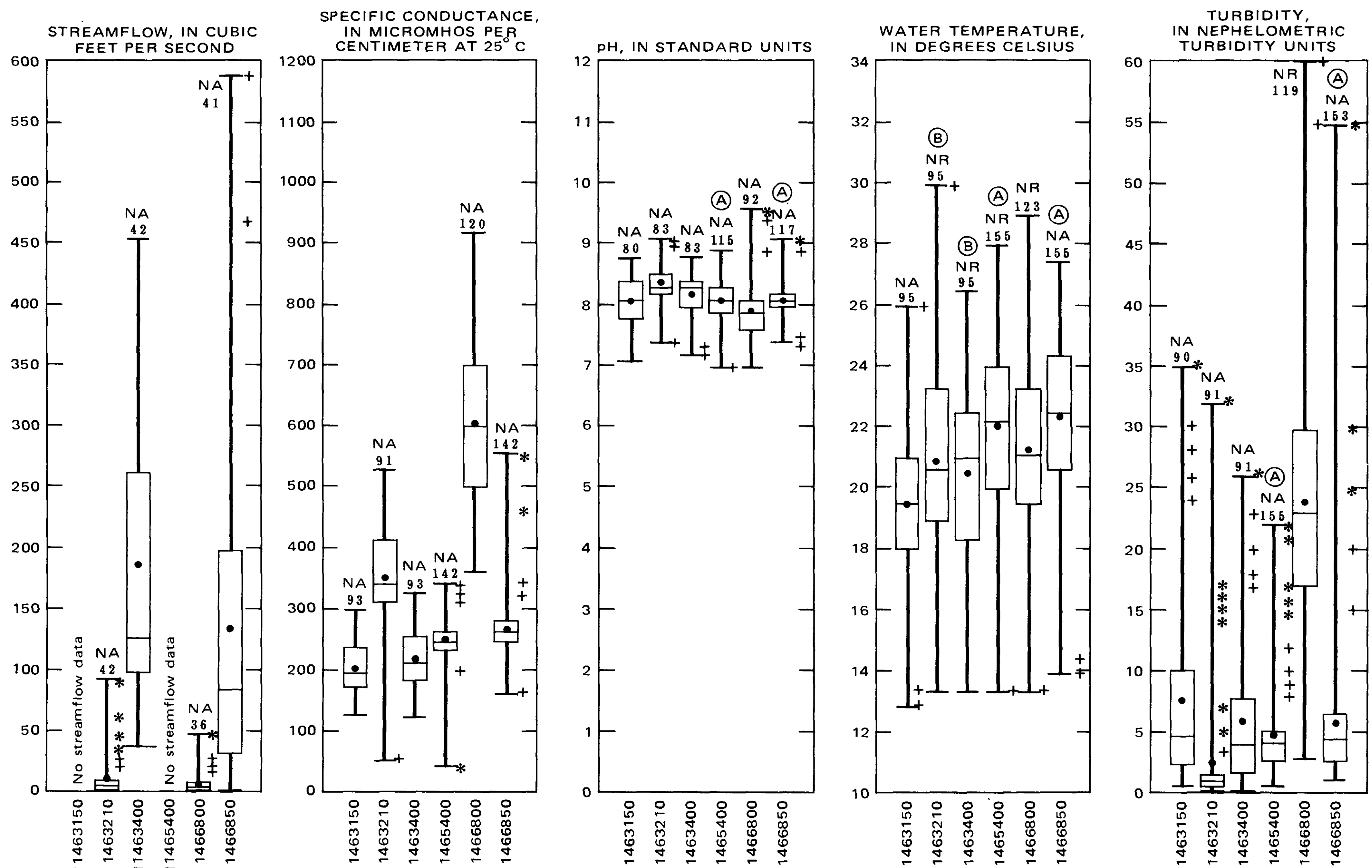
11462690 — Russian River at Hopland (flatland reach - reach type 2)
11463000 — Russian River near Cloverdale (mountainous reach with moderate gradient - reach type 3)
11463500 — Russian River at Geyserville (flatland reach - reach type 2)
11467000 — Russian River near Guerneville (mountainous reach with low gradient - reach type 1)

FIGURE 19. — Comparison of water quality and streamflow among stations at locations representative of geomorphic reach types (comparison based on 1977 and 1978 water year data).



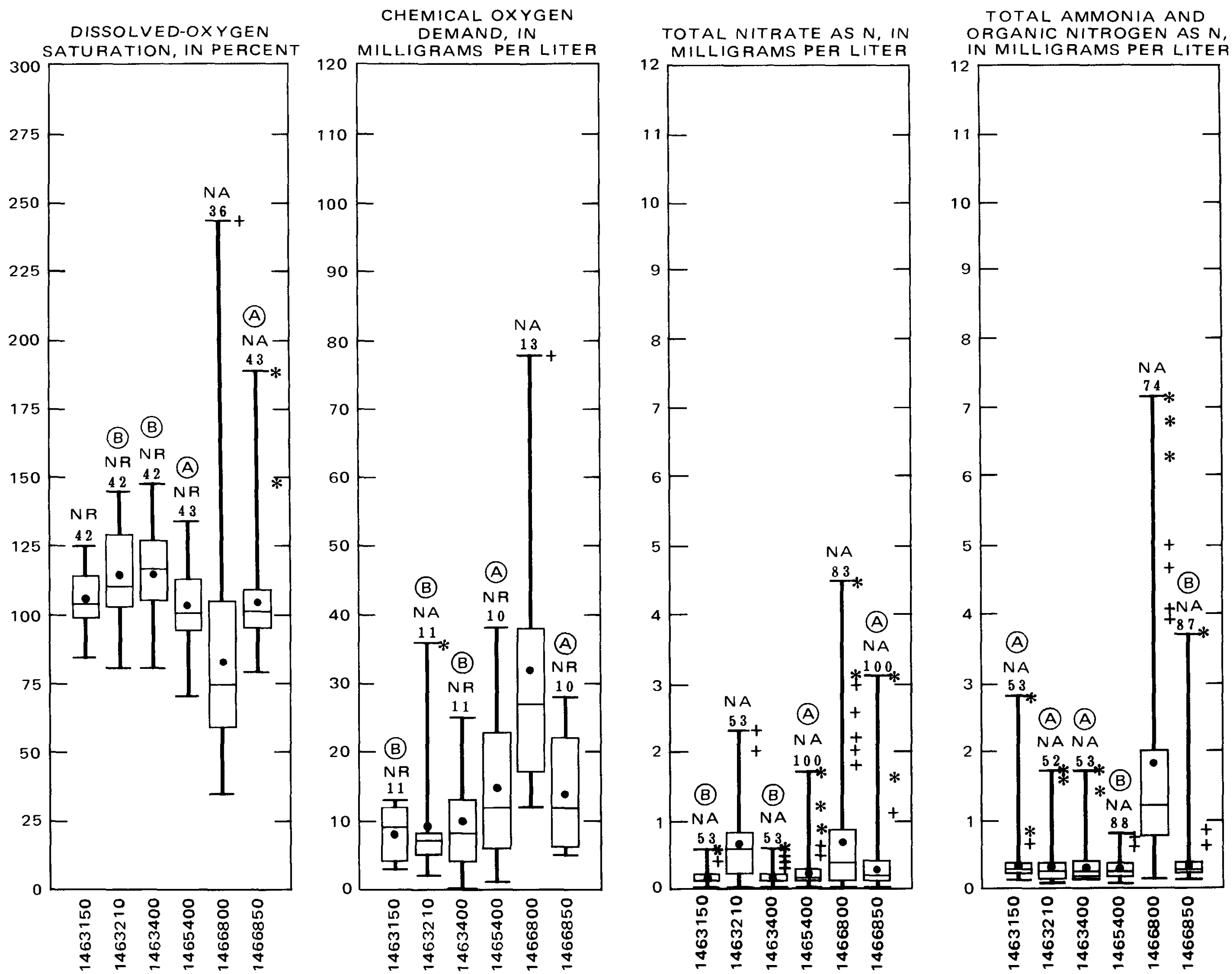
11462690 — Russian River at Hopland (flatland reach - reach type 2)
11463000 — Russian River near Cloverdale (mountainous reach with moderate gradient - reach type 3)
11463500 — Russian River at Geyserville (flatland reach - reach type 2)
11467000 — Russian River near Guerneville (mountainous reach with low gradient - reach type 1)

FIGURE 19. — Continued.



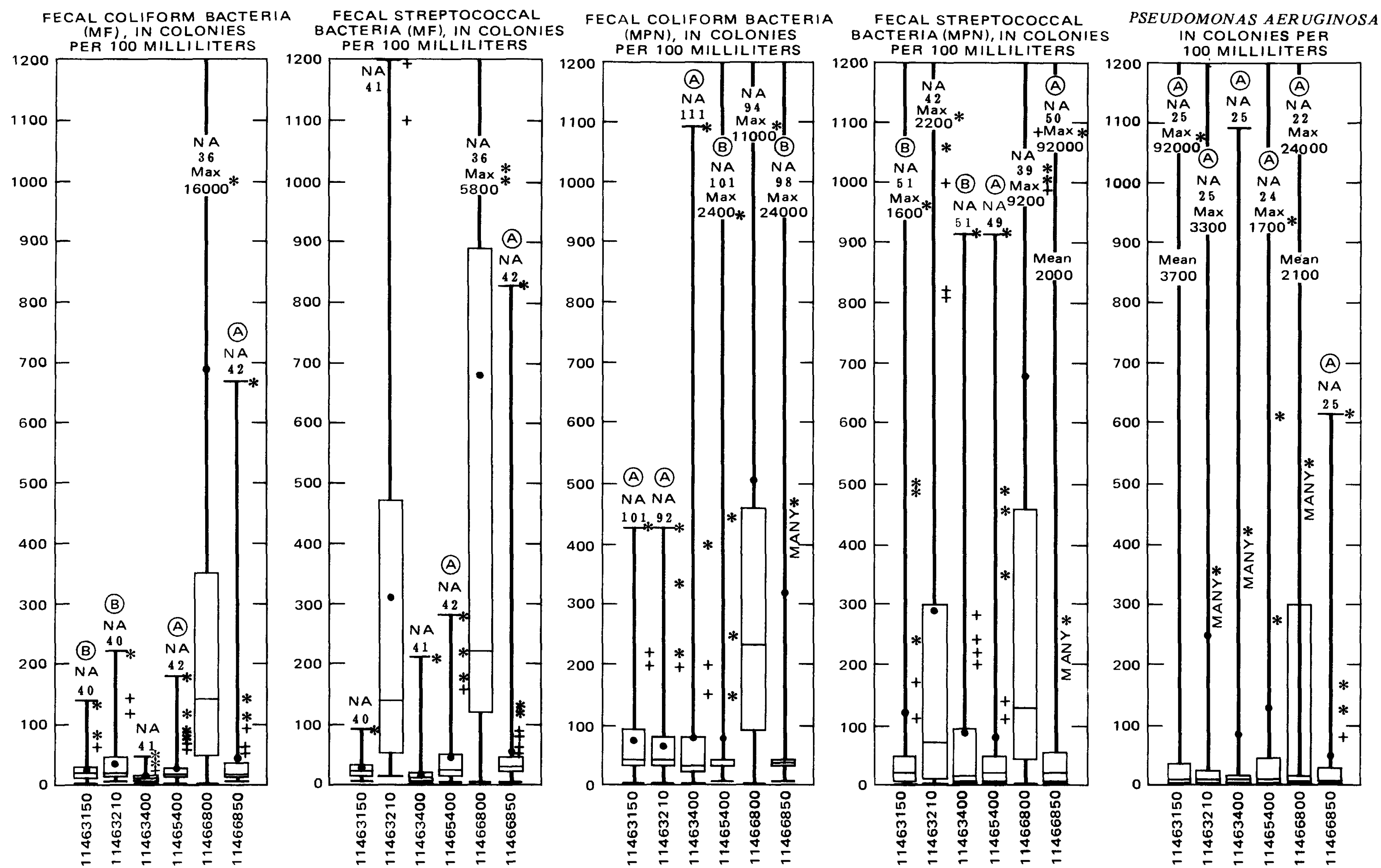
11463150 – Russian River at Preston
11463210 – Big Sulphur Creek at mouth near Cloverdale
11463400 – Russian River at Asti
11465400 – Russian River at Wohler Bridge
11466800 – Mark West Creek near Mirabel Heights
11466850 – Russian River at Mirabel Heights

FIGURE 20.– Comparison of water quality and streamflow between tributary stations and main-stem stations (comparison based on 1973-78 water year data).



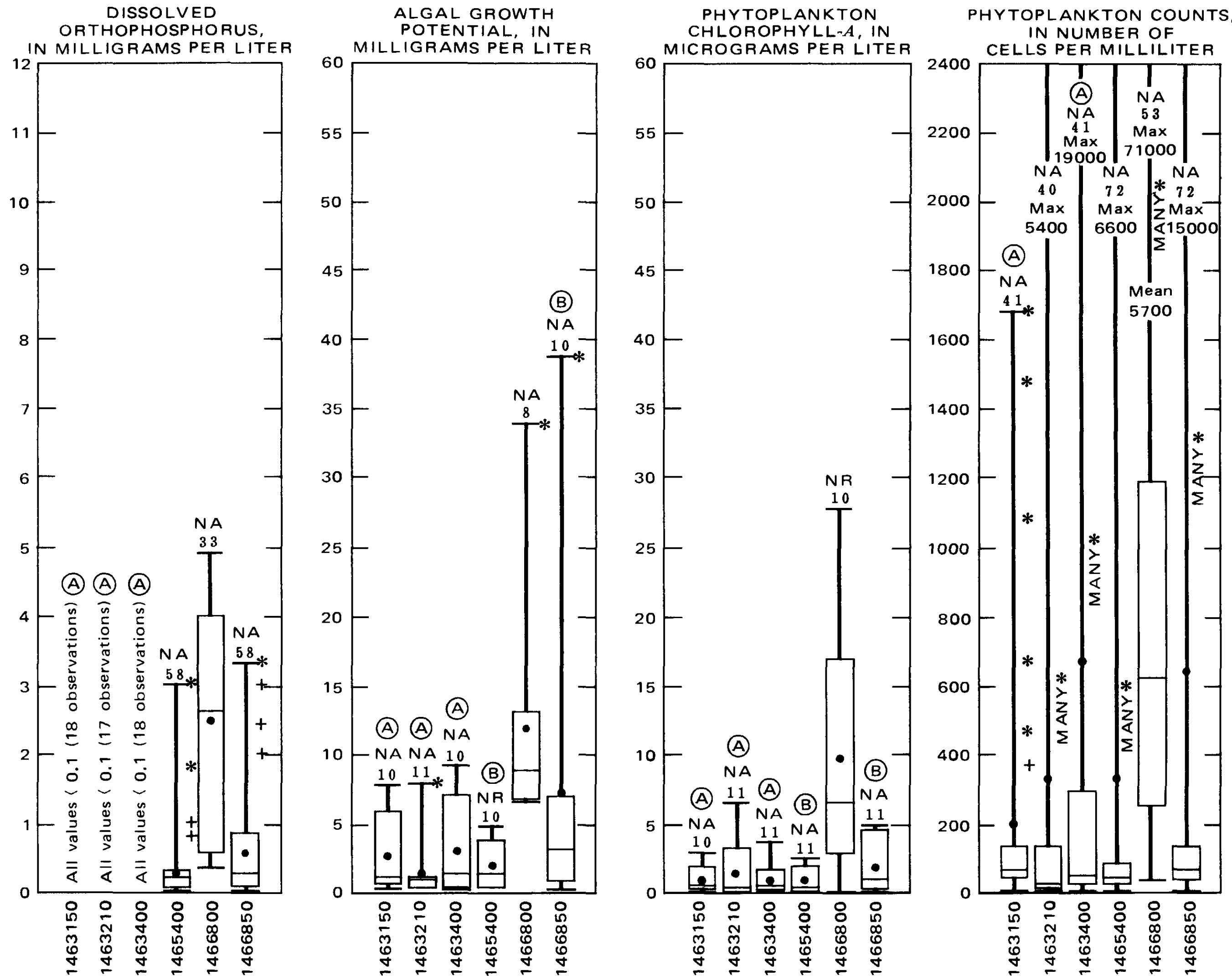
11463150 – Russian River at Preston
11463210 – Big Sulphur Creek at mouth near Cloverdale
11463400 – Russian River at Asti
11465400 – Russian River at Wohler Bridge
11466800 – Mark West Creek near Mirabel Heights
11466850 – Russian River at Mirabel Heights

FIGURE 20. – Continued.



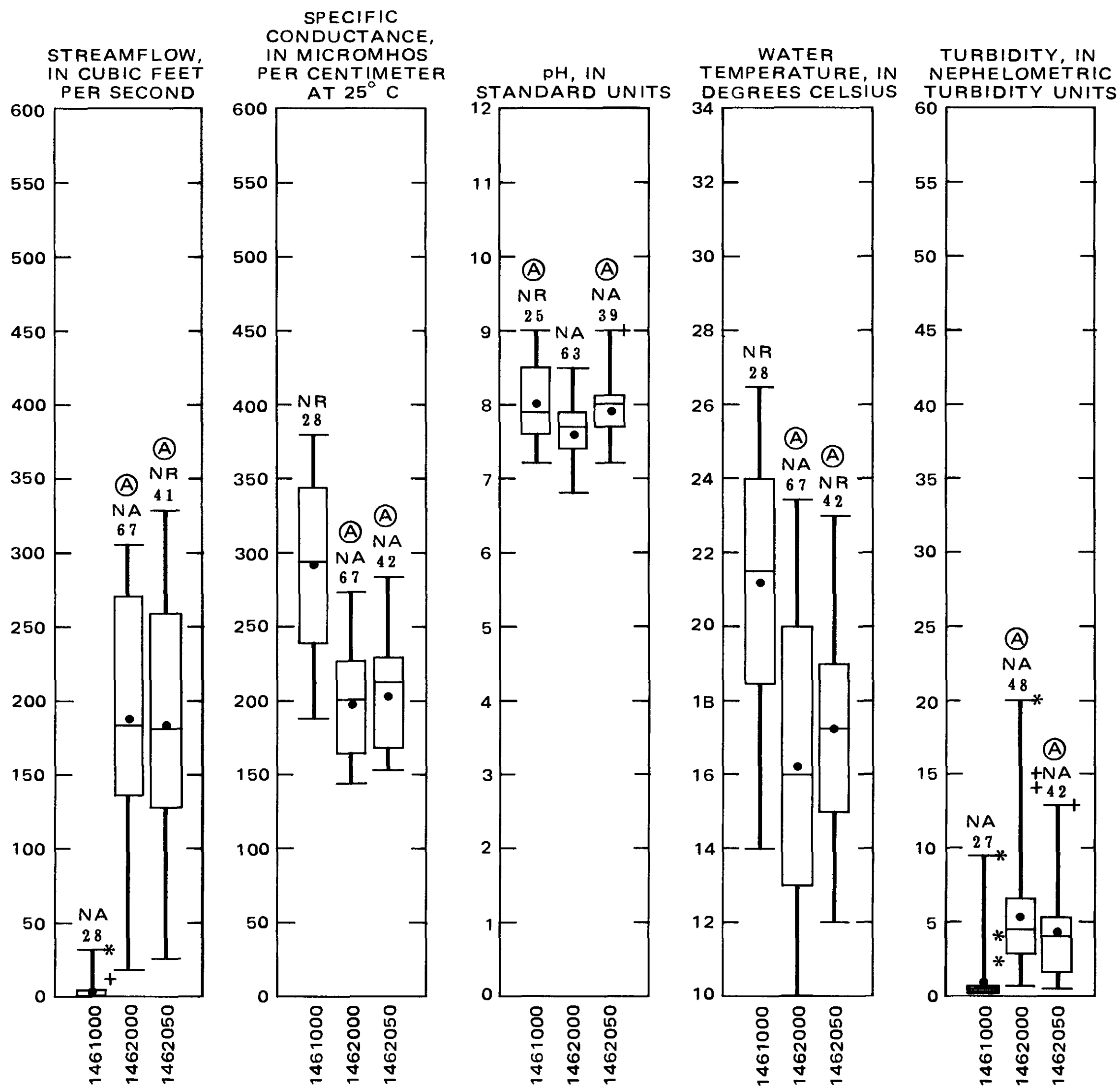
11463150 – Russian River at Preston
11463210 – Big Sulphur Creek at mouth near Cloverdale
11463400 – Russian River at Asti
11465400 – Russian River at Wohler Bridge
11466800 – Mark West Creek near Mirabel Heights
11466850 – Russian River at Mirabel Heights

FIGURE 20. – Continued.



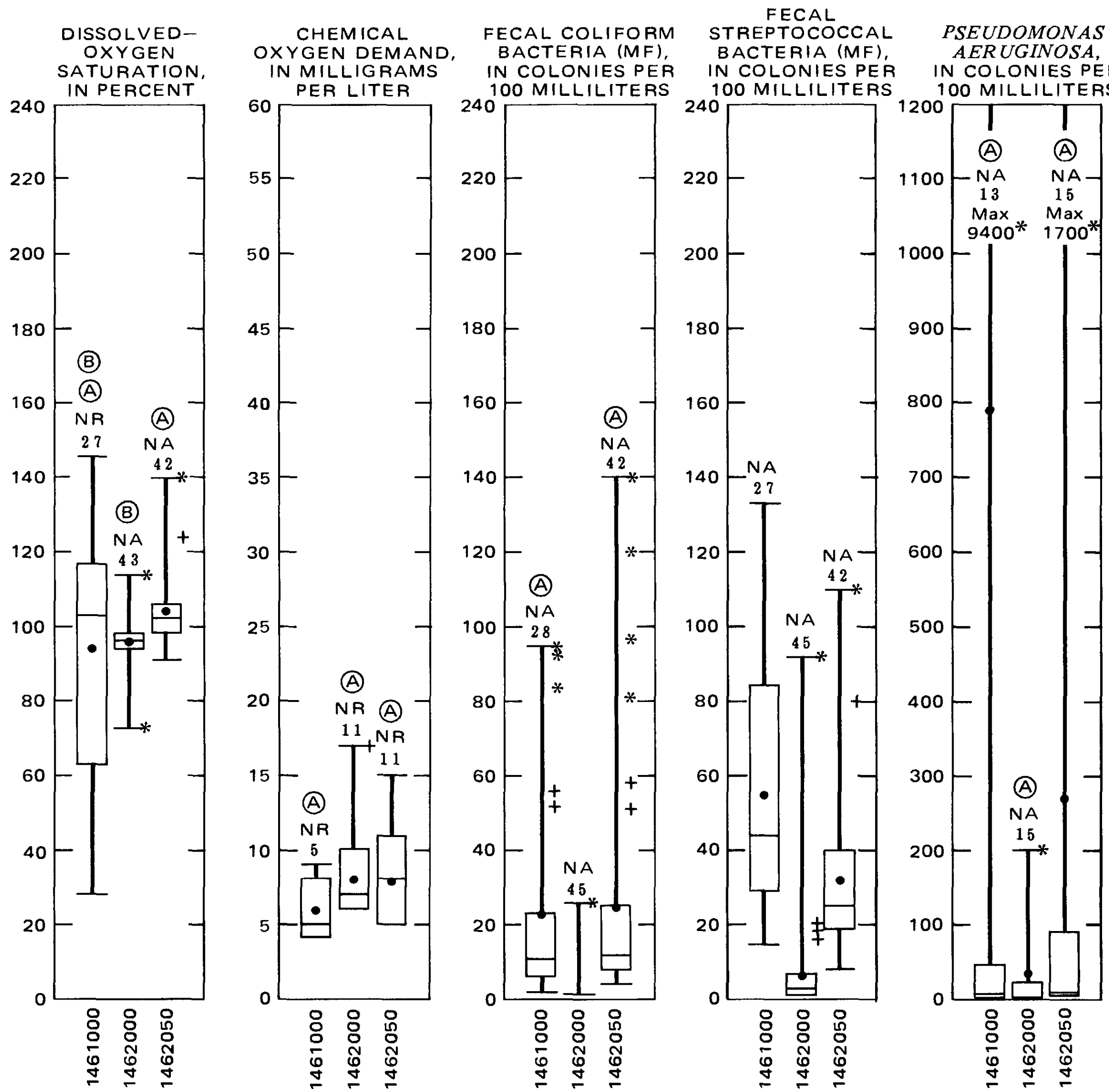
11463150 – Russian River at Preston
11463210 – Big Sulphur Creek at mouth near Cloverdale
11463400 – Russian River at Asti
11465400 – Russian River at Wohler Bridge
11466800 – Mark West Creek near Mirabel Heights
11466850 – Russian River at Mirabel Heights

FIGURE 20. – Continued.



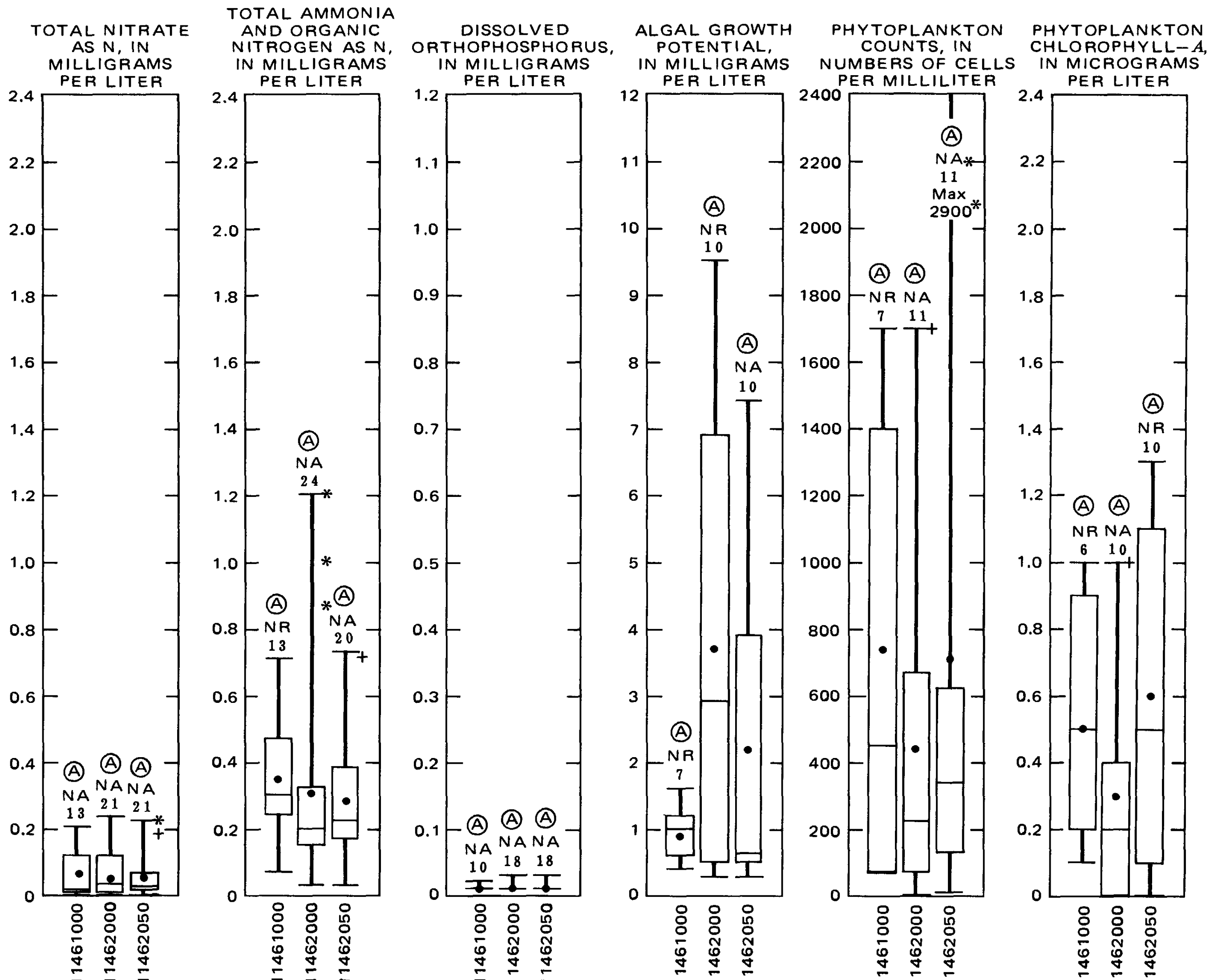
11461000 – Russian River near Ukiah (West Fork)
11462000 – East Fork Russian River near Ukiah (Lake Mendocino release)
11462050 – Russian River at Ukiah (main stem downstream of forks)

FIGURE 21. – Comparison of water quality and streamflow between the East and West Forks of the Russian River and the main stem downstream of the forks (comparison based on 1977 and 1978 water year data).



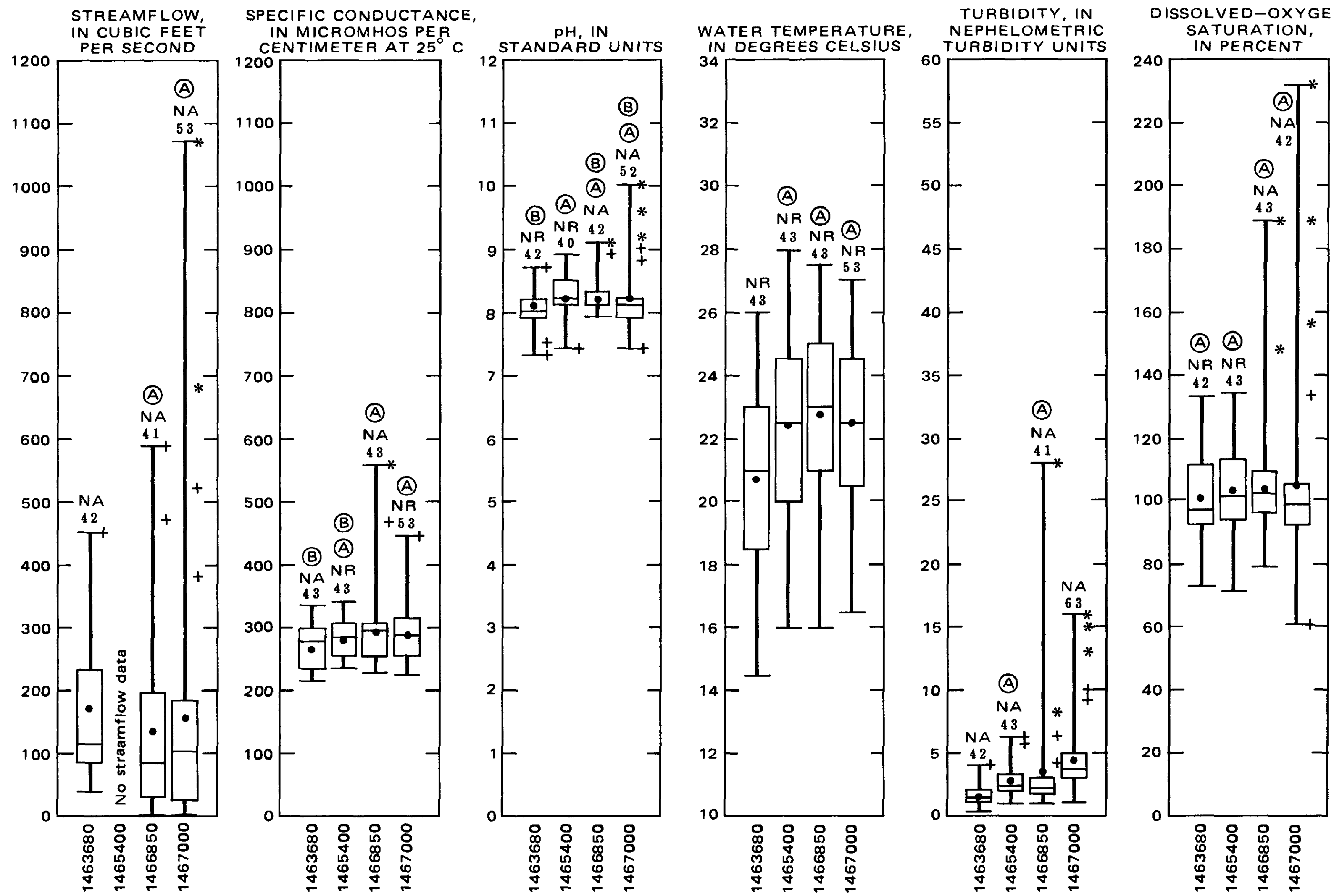
11461000 – Russian River near Ukiah (West Fork)
11462000 – East Fork Russian River near Ukiah (Lake Mendocino release)
11462050 – Russian River at Ukiah (main stem downstream of forks)

FIGURE 21. – Continued.



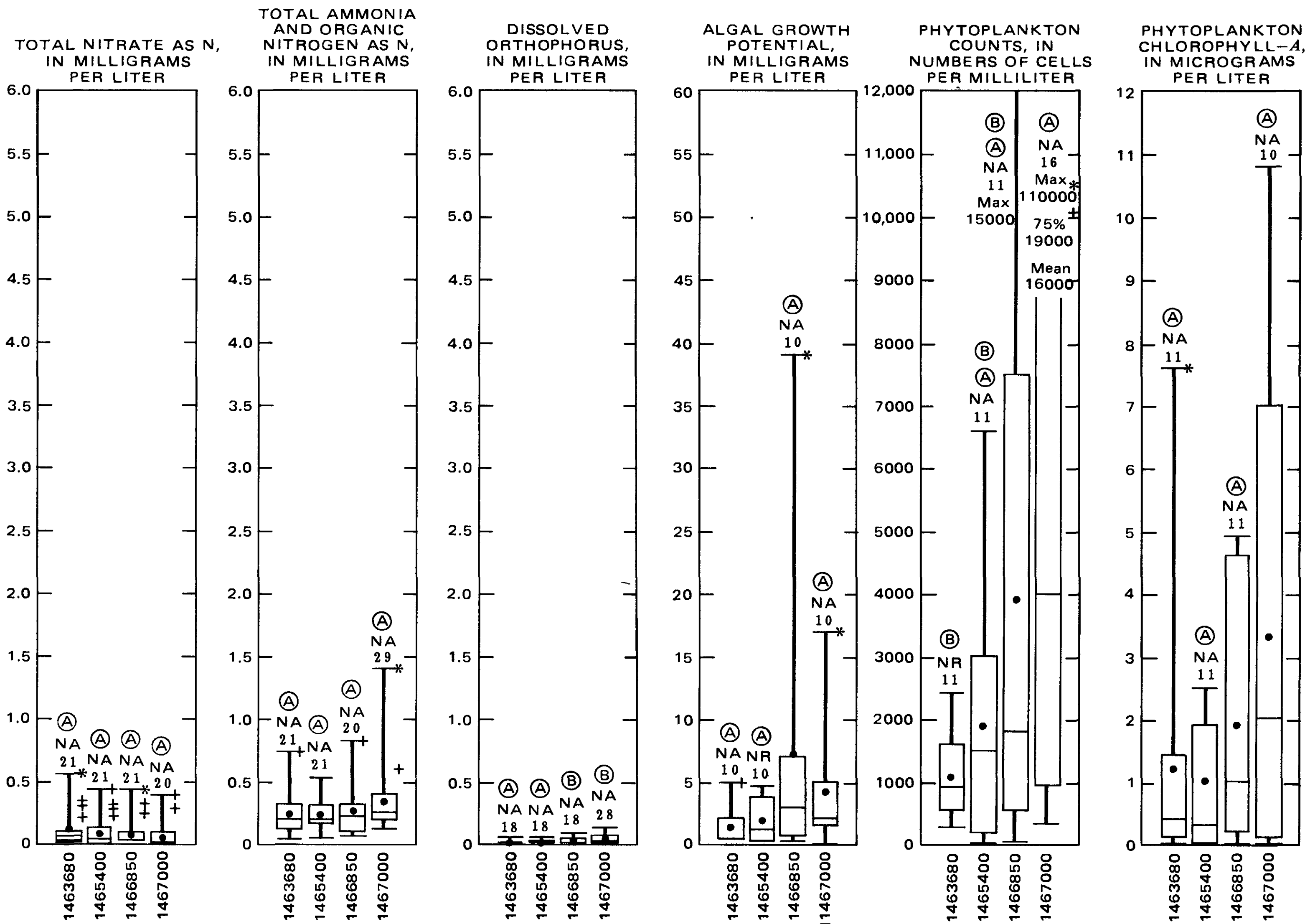
11461000 – Russian River near Ukiah (West Fork)
11462000 – East Fork Russian River near Ukiah (Lake Mendocino release)
11462050 – Russian River at Ukiah (main stem downstream of forks)

FIGURE 21. – Continued.



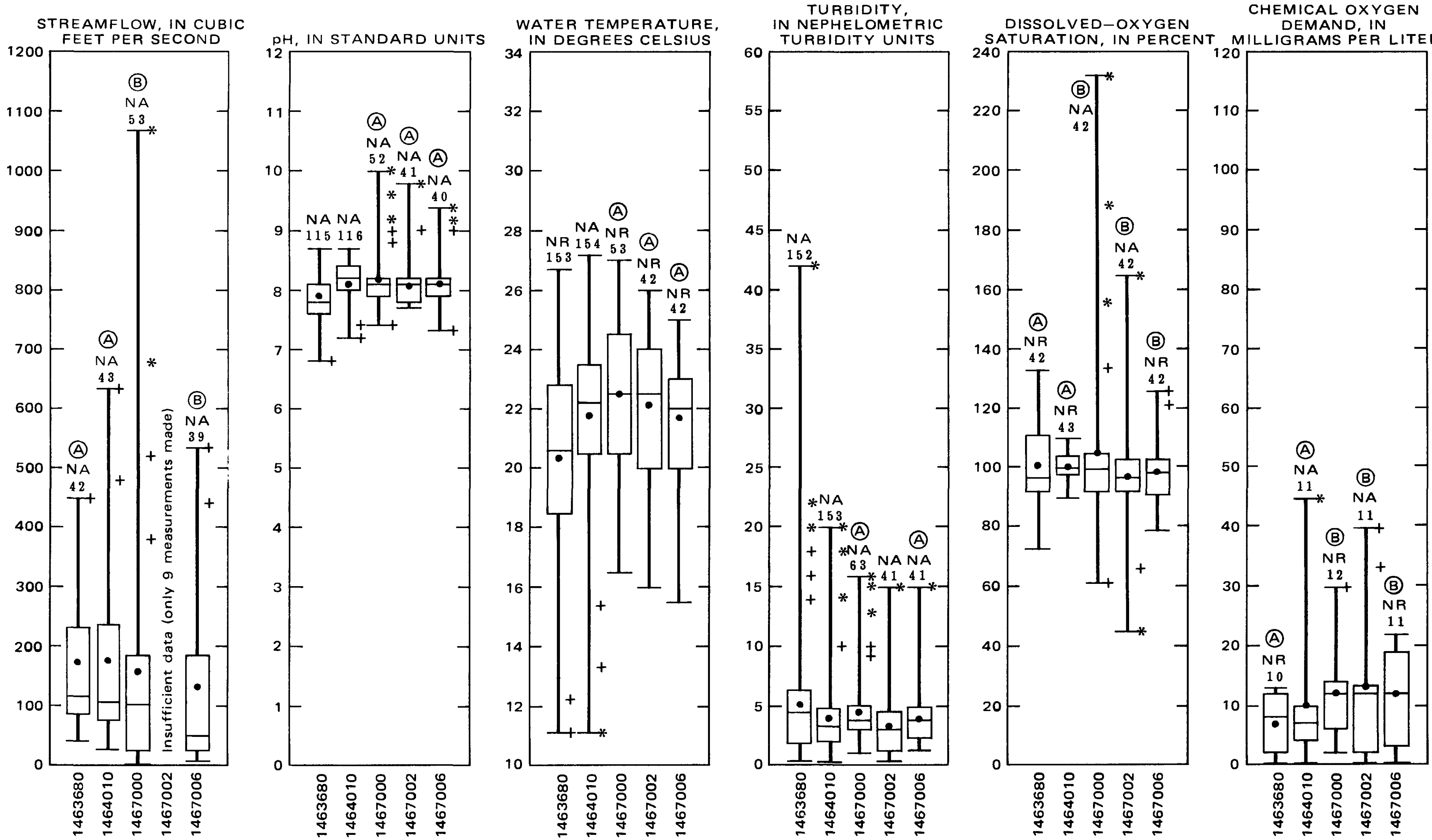
11463680 – Russian River at Alexander Valley Road Bridge (upstream of diversion and summer recreation impoundments)
11465400 – Russian River at Wohler Bridge (within diversion impoundment)
11466850 – Russian River at Mirabel Heights (within diversion area)
11467000 – Russian River near Guerneville (*downstream of diversion area*)

FIGURE 23. – Comparison of water quality and streamflow at stations upstream, in, and downstream of principal water diversion reach of river (comparison based on 1977 and 1978 water year data).



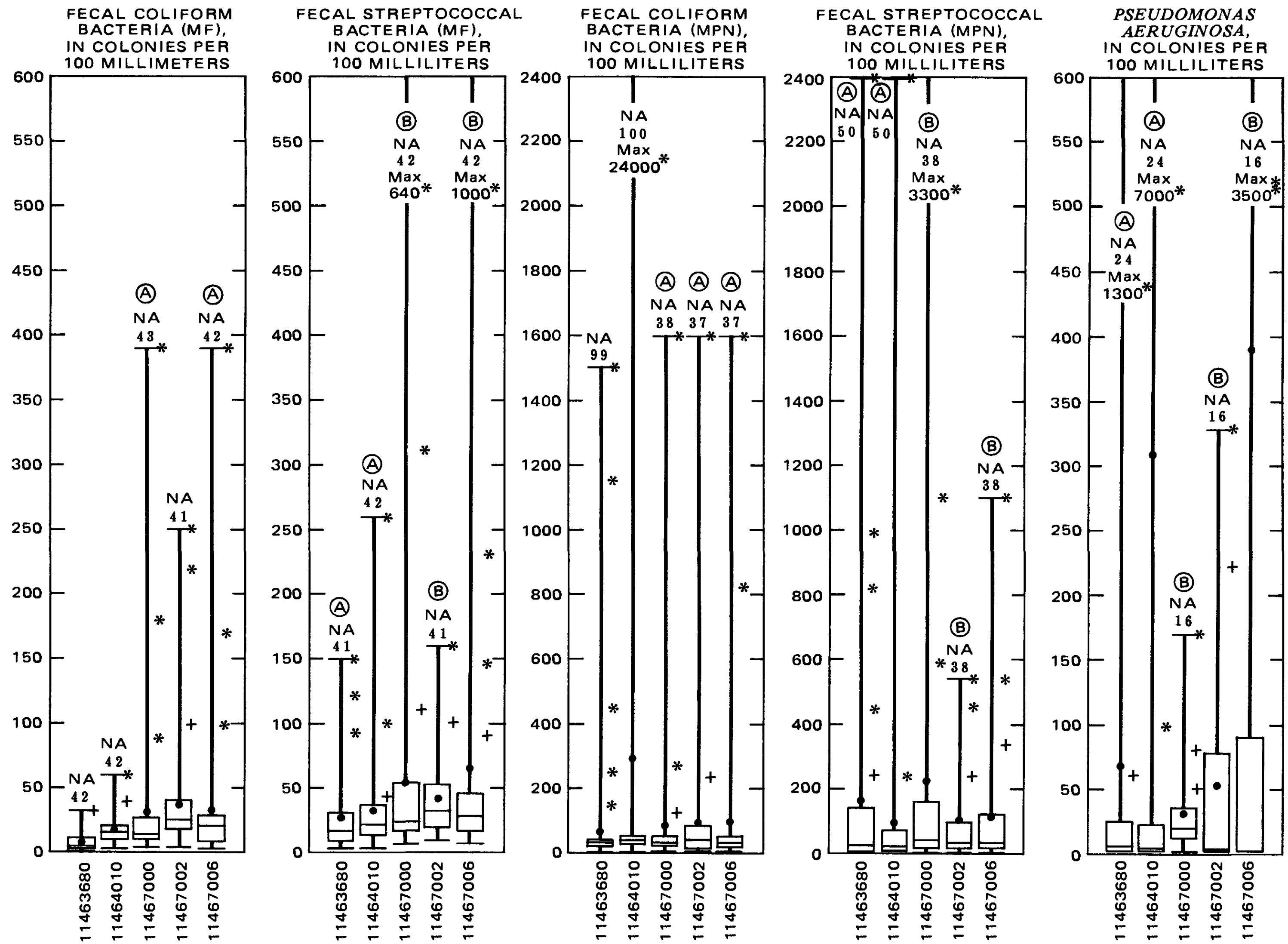
11463680 – Russian River at Alexander Valley Road Bridge (upstream of diversion and summer recreation impoundments)
11465400 – Russian River at Wohler Bridge (within diversion impoundment)
11466850 – Russian River at Mirabel Heights (within diversion area)
11467000 – Russian River near Guerneville (downstream of diversion area)

FIGURE 23. – Continued.



Comparison based on 1973-78 water year data.
11463680 – Russian River at Alexander Valley Road Bridge (upstream of recreation impoundment)
11464010 – Russian River at Healdsburg (downstream of recreational impoundment)
Comparison based on 1977 and 1978 water year data.
11467000 – Russian River near Guerneville (upstream of recreational impoundment)
11467002 – Russian River at Johnson's Beach (downstream of recreational impoundment)
11467006 – Russian River at Vacation Beach (downstream of recreational impoundment)

FIGURE 25. – Comparison of water quality and streamflow upstream and downstream of recreational impoundments.



Comparison based on 1973-78 water year data.

11463680 – Russian River at Alexander Valley Road Bridge (upstream of recreational impoundment)

11464010 – Russian River at Healdsburg (downstream of recreational impoundment)

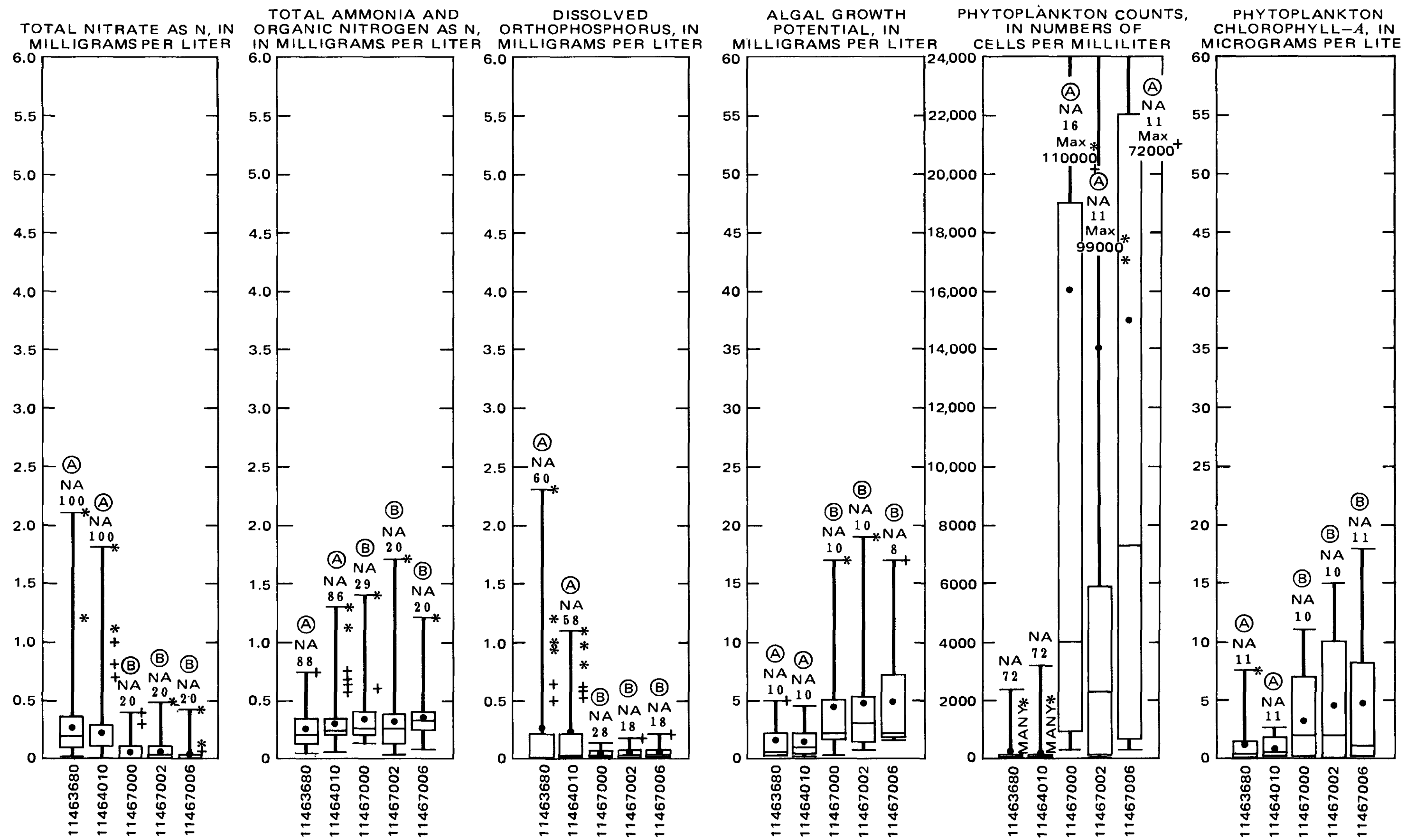
Comparison based on 1977 and 1978 water year data.

11467000 – Russian River near Guerneville (upstream of recreational impoundment)

11467002 – Russian River at Johnson's Beach (downstream of recreational impoundment)

11467006 – Russian River at Vacation Beach (downstream of recreational impoundment)

FIGURE 25. – Continued.



Comparison based on 1973-78 water year data.

11463680 – Russian River at Alexander Valley Road Bridge (upstream of recreation impoundment)

11464010 – Russian River at Healdsburg (downstream of recreational impoundment)

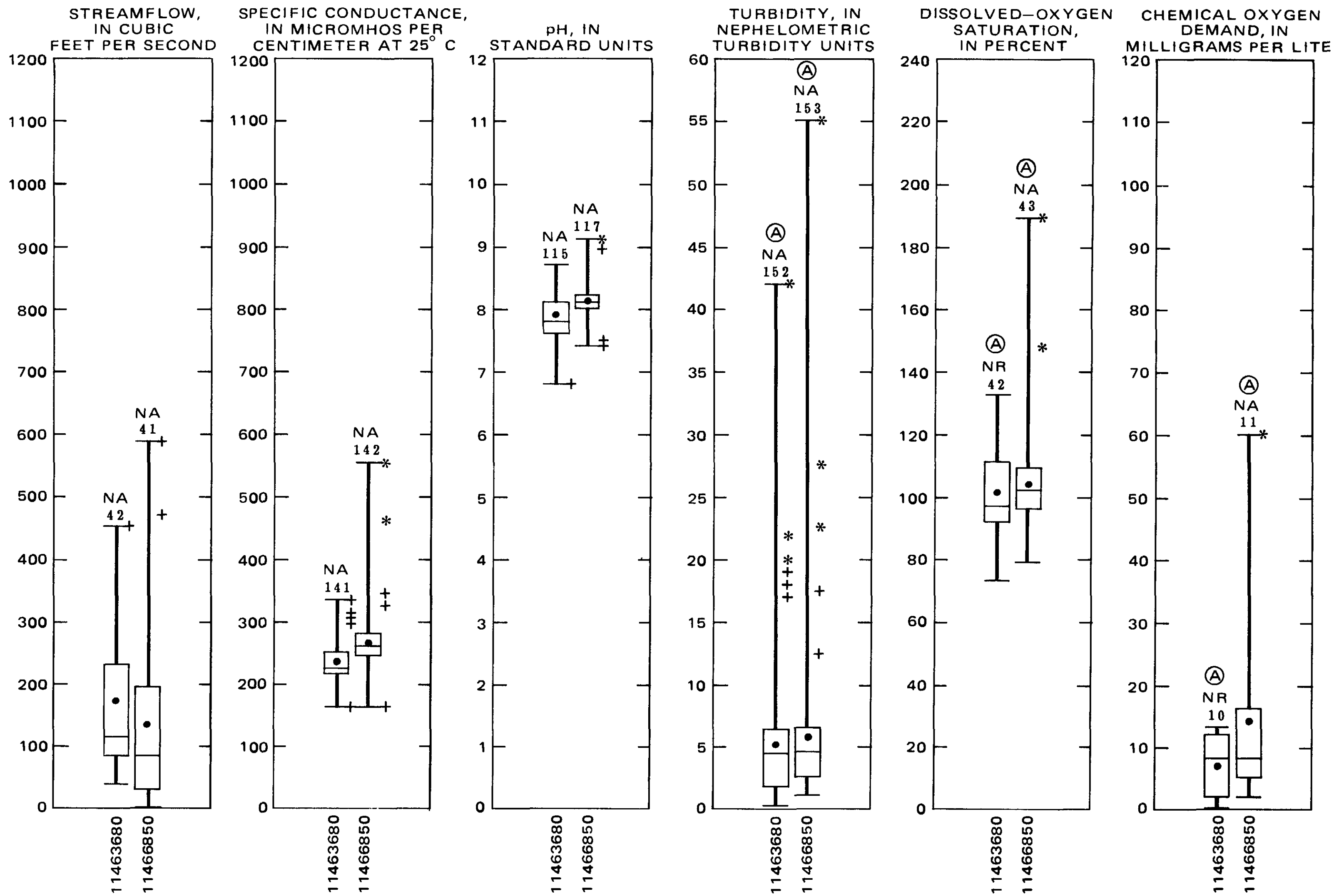
Comparison based on 1977 and 1978 water year data.

11467000 – Russian River near Guerneville (upstream of recreational impoundment)

11467002 – Russian River at Johnson's Beach (downstream of recreational impoundment)

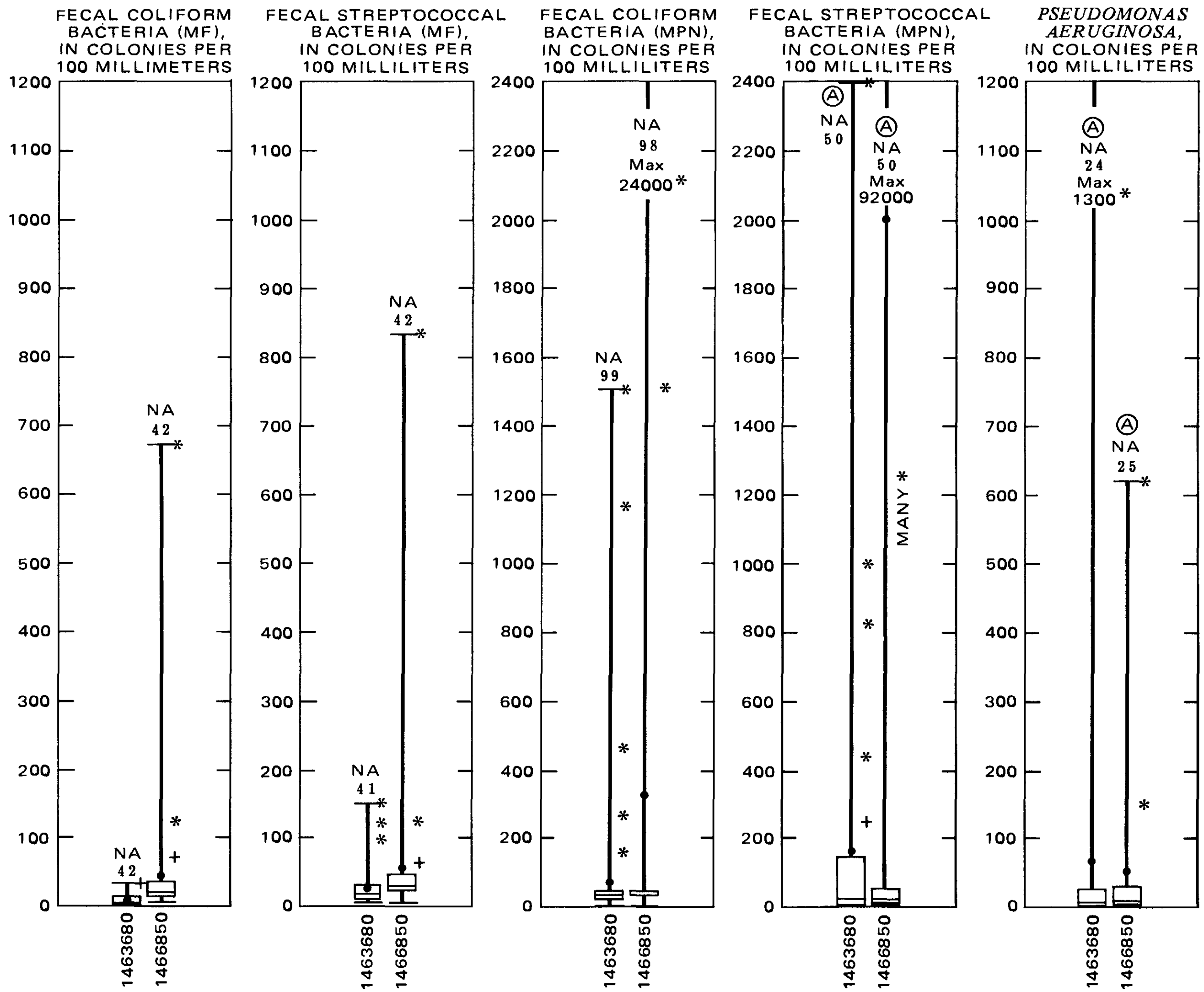
11467006 – Russian River at Vacation Beach (downstream of recreational impoundment)

FIGURE 25. – Continued.



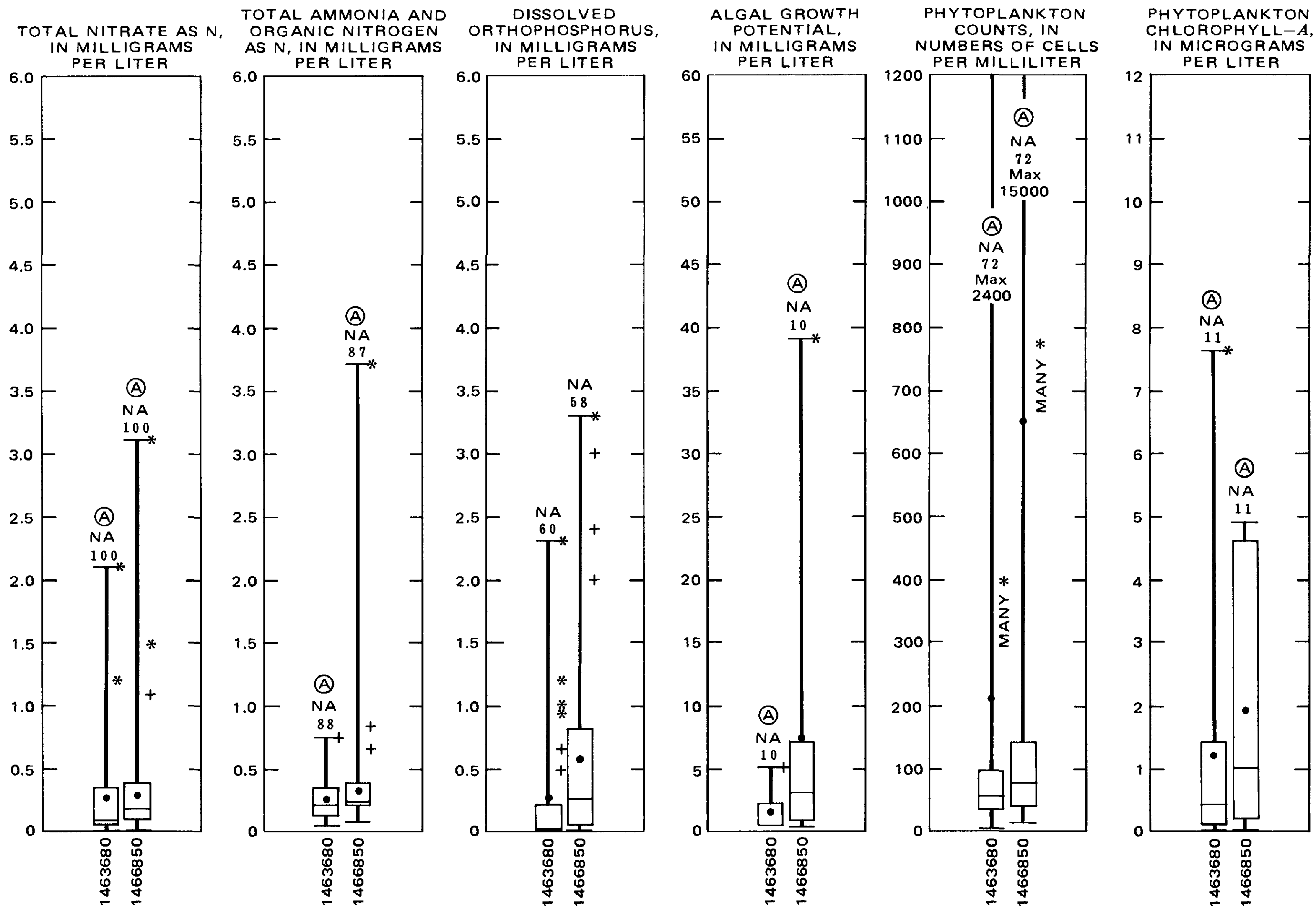
11463680 — Russian River at Alexander Valley Road Bridge (agricultural reach)
11466850 — Russian River at Mirabel Heights (downstream of principal urban area in basin)

FIGURE 26. — Comparison of water quality and streamflow at a station in an agricultural reach with a station in a reach downstream of an urban area (comparison based on 1973-78 water year data).



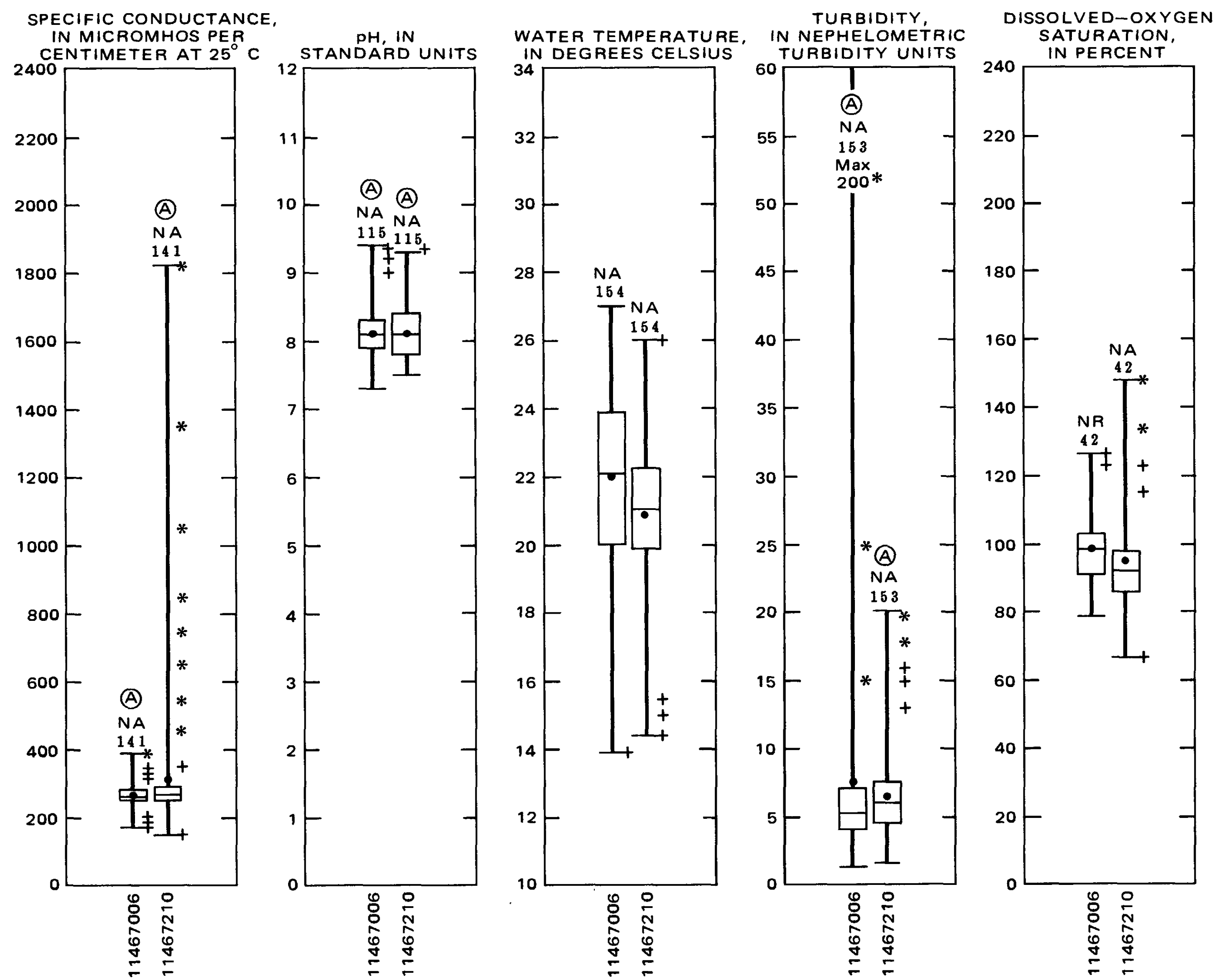
11463680 — Russian River at Alexander Valley Road Bridge *(agricultural reach)*
11466850 — Russian River at Mirabel Heights *(downstream of principal urban area in basin)*

FIGURE 26. — Continued.



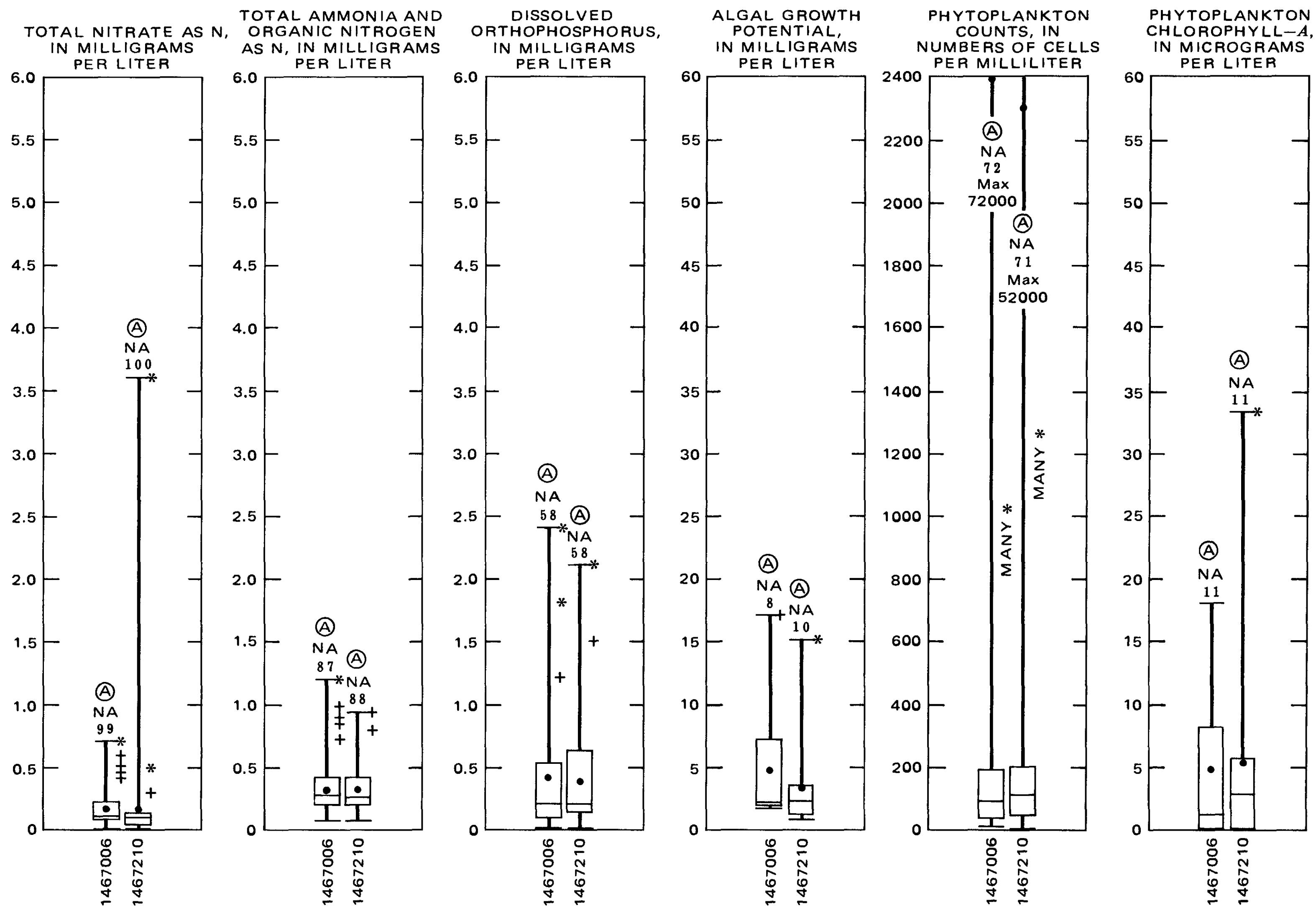
11463680 — Russian River at Alexander Valley Road Bridge (agricultural reach)
11466850 — Russian River at Mirabel Heights (downstream of principal urban area in basin)

FIGURE 26. — Continued.



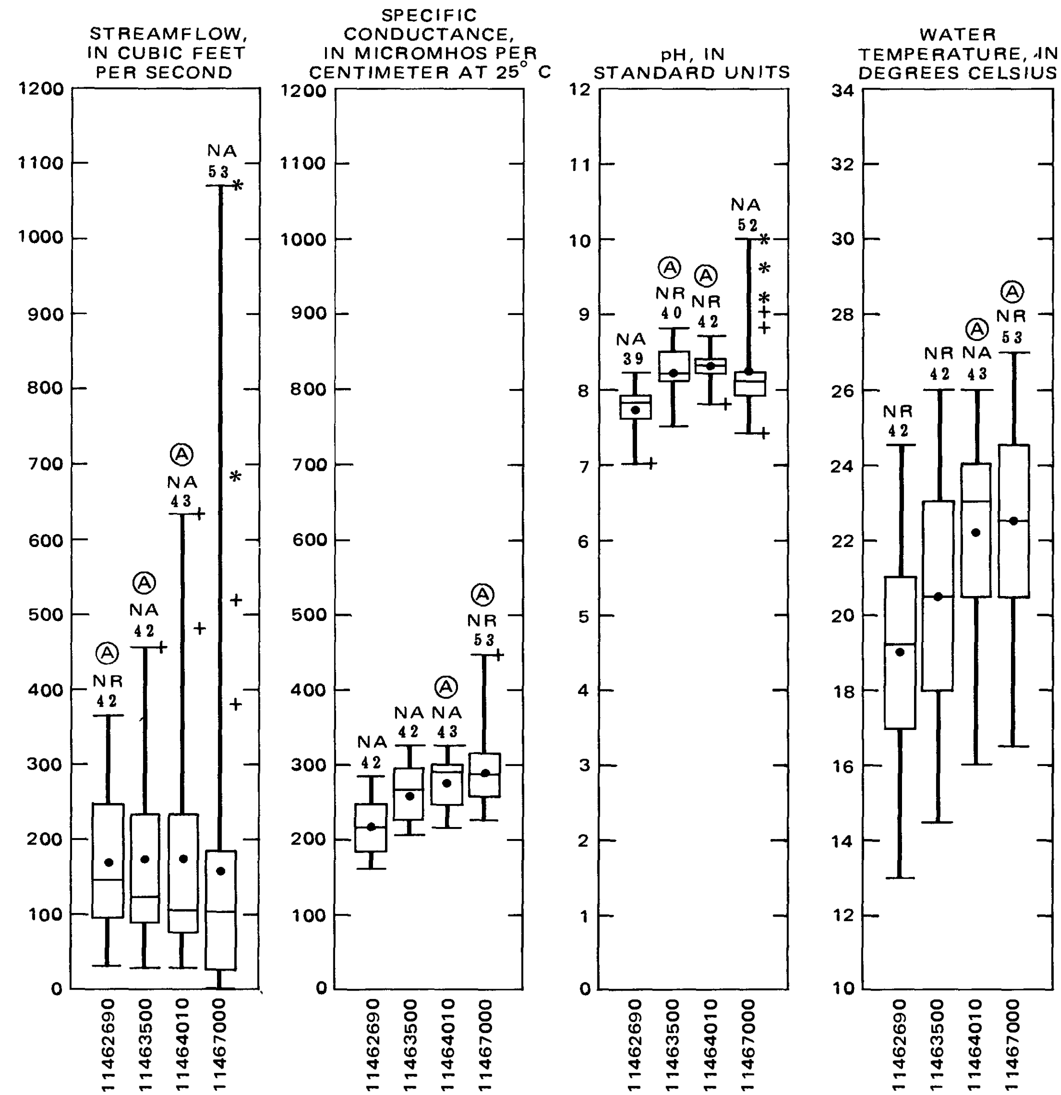
11467006 — Russian River at Vacation Beach (upstream of tidally influenced reach)
11467210 — Russian River at Duncan Mills (within tidally influenced reach)

FIGURE 27. — Comparison of water quality at a station in tidal reach with a station upstream of tidal reach (comparison based on 1973-78 water year data).



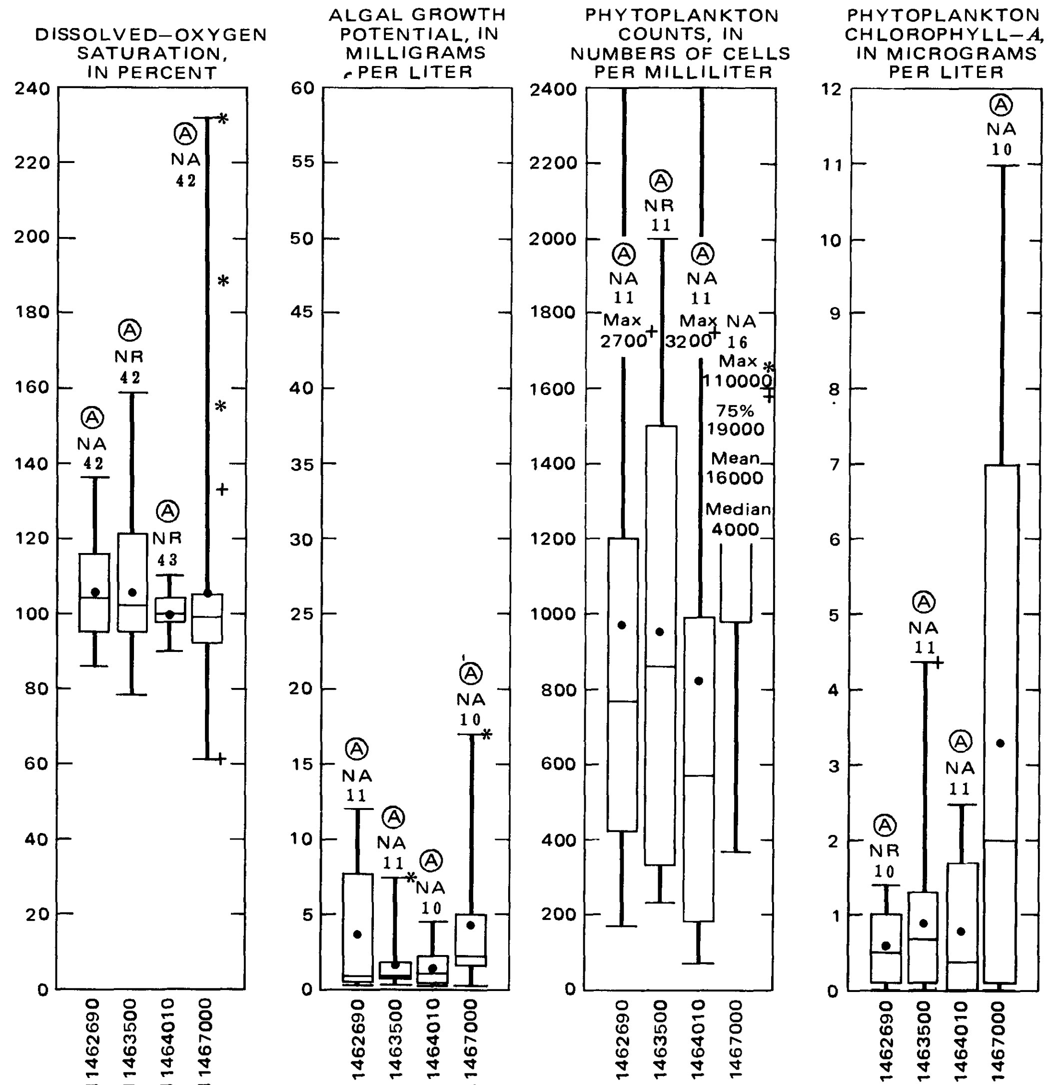
11467006 — Russian River at Vacation Beach (upstream of tidally influenced reach)
11467210 — Russian River at Duncan Mills (within tidally influenced reach)

FIGURE 27. — Continued.



11462690 — Russian River at Hopland (in climatic area most isolated from ocean influence)
11463500 — Russian River at Geyserville (in climatic area with little ocean influence)
11464010 — Russian River at Healdsburg (in climatic area with moderate ocean influence)
11467000 — Russian River near Guerneville (in climatic area with much ocean influence)

FIGURE 28. — Comparison of water quality and streamflow among stations in different climatic areas of the basin (comparison based on 1977 and 1978 water year data).



11462690 — Russian River at Hopland (in climatic area most isolated from ocean influence)
11463500 — Russian River at Geyserville (in climatic area with little ocean influence)
11464010 — Russian River at Healdsburg (in climatic area with moderate ocean influence)
11467000 — Russian River near Guerneville (in climatic area with much ocean influence)

FIGURE 28. — Continued.