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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

P.O. Box 968 • 3000 George Washington Way • Richland, Washington 99352

April 24, 1992

Jason J. Zeller, Manager
Energy Facility Site Evaluation Council
Mail Stop FA-11
Olympia, WA 98501-1211

Dear Mr. Zeller:

Subject: **TRANSMITTAL OF OPERATIONAL ECOLOGICAL MONITORING PROGRAM NUCLEAR PLANT 2 ANNUAL REPORT**

Enclosed are five (5) copies of the subject report.

Sincerely,

JBell

J.C. Bell
Manager
Plant Services

JCB:pg

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W.M. Dean, Project Manager, NRC
J. Witczak, Department of Ecology
R.K. Woodruff, Battelle

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OPERATIONAL ECOLOGICAL MONITORING PROGRAM FOR NUCLEAR PLANT 2

1991 Annual Report

Prepared by Environmental Sciences Department

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

910408

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EXECUTIVE SUMMARY

During 1991, there were no unusual events which resulted in significant environmental impacts from the operation of WNP-2.

There were no unanticipated or emergency discharges of water or wastewater during the reporting period.

Three fish bioassays were successfully completed with a survival rate criterion of greater than 80%. These results are in agreement with those achieved in the first NPDES flow-through test performed in October 1990.

Two Daphnia bioassays were successfully completed with a survival rate criterion of greater than 80%.

With respect to all of the measured parameters sampled under the operating conditions prevailing during 1991, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

Total herbaceous cover increased 68.94% in 1991. A corresponding increase in herbaceous phytomass was also observed. Soil and vegetation analyte concentrations were generally within the ranges observed in previous years. Changes in vegetation cover and density recorded in 1991 appear to be directly related to the growing season precipitation and temperature, with no evident signs of adverse impacts from the operation of WNP-2 cooling towers evident.

Color infrared aerial photographs along 5 flightlines were taken in May 1991. The health of the vegetation in the color infrared photographs appeared good along all five flightlines. A comparison of these photographs with those taken in 1989 show that there has been little change in the shrub health and density.

ACKNOWLEDGEMENTS

This annual report, prepared by Washington Public Power Supply System, describes the aquatic, terrestrial and water quality programs for Nuclear Project No. 2 (WNP-2).

Project Team

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1.0 INTRODUCTION

1.1 BACKGROUND

Washington Public Power Supply System (Supply System) began site preparation for Nuclear Plant Number 2 (WNP-2) near Richland, Washington in March 1973. WNP-2 loaded fuel in December 1983, reached approximately 75 percent thermal load in November 1984, and began commercial operation in December 1984.

The Site Certification Agreement (SCA) for WNP-2, executed on May 17, 1972, between the State of Washington and the Supply System, requires that ecological monitoring be conducted during the preoperational and operational phases of site development and use. The Washington State Energy Facility Site Evaluation Council (EFSEC) approved a change in 1978 to the technical scope of environmental monitoring required by the SCA (EFSEC Resolution No. 132, January 23, 1978). In 1980, the aquatic water quality portions of the preoperational monitoring program were terminated (EFSEC Resolution No. 166, March 24, 1980). The following year the preoperational and operational terrestrial monitoring program scope for WNP-2 was modified (EFSEC Resolution No. 193, May 26, 1981). Prior to operation, the council reviewed the preoperational aquatic monitoring data and approved the operational monitoring program (EFSEC Resolution No. 214, November 8, 1982).

The Supply System in 1974 retained Battelle Pacific Northwest Laboratories (BNW) to conduct the preoperational aquatic monitoring for WNP-2. The results of aquatic studies performed from September 1974 through August 1978 are presented in various reports (Battelle 1976, 1977, 1978, 1979a and 1979b). From August 1978 through March 1980 the aquatic studies were performed by Beak Consultants, Inc. (Beak 1980). In 1982 the Supply System analyzed the 1974-1980 aquatic data and presented the results and a recommended operational monitoring program to EFSEC (Mudge et. al., 1982). The operational program

was accepted with minor modifications and initiated in March 1983. Due to operational conditions, the plant did not consistently discharge liquid effluents until the fall of 1984. Figures 1-1 and 1-2 present summaries of electrical generation and monthly discharges for 1991.

Terrestrial monitoring was initiated in 1974 and was conducted by BNW until 1979 (Rickard and Gano, 1976, 1977, 1979a, 1979b). Beak Consultants, Inc. performed the vegetation monitoring program from 1980-1982 (Beak 1981, 1982a, 1982b). Since 1983, Supply System scientists have been responsible for the vegetation aspects of the program (Northstrom et.al., 1984; Supply System 1985, 1986, 1987, 1988, 1989, 1990, 1991). During 1981, the animal studies program was taken over by Supply System scientists and results were reported annually (Schleder 1982, 1983, 1984; Supply System 1985, 1986, 1987, 1988, 1989). The first comprehensive operational environmental report was prepared by Supply System scientists in 1984 (Supply System 1985).

During their regular meeting of September 14, 1987, the Energy Facility Site Evaluation Council approved Resolution No. 239, which adopted a long-term environmental monitoring program for WNP-2. This decision was based upon the council's examination of the document titled, Review of the Environmental Monitoring Program for WNP-2 with Recommendations for Design of Continuing Studies (Davis and Northstrom, 1987).

This report presents the results of the Ecological Monitoring Program (EMP) for the period January 1991 through December 1991.

1.2 THE SITE

The WNP-2 plant site is located 19 km (12 miles) north of Richland, Washington in Benton County (Figure 1-3). The Supply System has leased 441 hectares (1089 acres) from the U.S. Department of Energy's Hanford Site for WNP-2.

WNP-2 lies within the boundaries of the Columbia Basin, an extensive area south of the Columbia River between the Cascade Range and Blue Mountains in Oregon and approximately two thirds of the area lying east of the Cascades in Washington. The plant communities within the region are described as shrub-steppe communities consisting of various layers of perennial grasses overlayed by a discontinuous layer of shrubs. In general, moisture relations do not support arborescent species except along streambanks. Approximately 5 km (3.25 miles) to the east, the site is bounded by the Columbia River. In August of 1984, a range fire destroyed much of the shrub cover which occupied the site and temporarily modified the shrub-steppe associations which were formerly present.

The water quality sampling stations are located near the west bank of the Columbia River at mile 352. Sampling was limited to the main channel on the Benton County side which, near the site, averages 370 meters (1200 feet) wide at a river elevation of 105 meters (345 feet) above sea level and ranges to 7.3 meters (24 feet) deep. Sampling stations have been established in the river both upstream and downstream from the plant intake and discharge structures. The river level in this area fluctuates considerably diurnally and from day-to-day in response to release patterns at the Priest Rapids Dam (River Mile 397). These fluctuations cause large areas of river bottom to be alternately exposed and covered. The river bottom within the study area varies from exposed Ringold conglomerate to boulders, cobble, gravel, and sand. River velocities at the surface average approximately 2 meters (5 to 6 feet) per second in this area of the river, and water temperature varies from approximately 0 to 22°C.

The flow of the Columbia River at WNP-2 is controlled by releases from Priest Rapids Dam. The minimum flow, measured at the USGS stream-quality station located at river mile 388.1 near the Vernita Bridge, was 35,200 cfs (cubic feet per second), while average and maximum flows in 1991 were 142,627 and 288,000 cfs, respectively (Figure 1-4.)

The terrestrial sampling locations are all within an 8 km (5 mile) radius from WNP-2. The topography is flat to gently rolling, gradually increasing from an elevation of 114 meters (375 feet) at the riparian sampling locations to approximately 152 meters (500 feet) at more distant shrubgrass sample stations.

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Table 1-1. Summary of Historical and Long Term Environmental Monitoring Programs for WNP-2

Specific Programs	Historical Program	Proposed Program
	Asiatic clam - inspections in response to an NRC information bulletin.	Regulatory commitment has been completed. No further studies are proposed; however, incidental observations will be made when maintenance inspections of the condenser water boxes are conducted.
Water Quality Program	Samples are collected at 4 stations; an upstream control, a near field discharge, located in the center of the mixing zone, 91 meters downstream from the discharge, representing the extremity of the mixing zone and 568 meters downstream from the discharge.	Continue annual program.
Terrestrial Animal Program	Deer and Rabbits - Six plots were reduced to three as the result of fire.	Terminated in 1987
	Birds - Spring and fall surveys are conducted.	Terminated in 1987; however, weekly ground surveys are conducted to document the occurrence of unusual species.
Terrestrial Soil and Vegetation	Vegetation and soil samples are collected each spring at eight grassland and 7 shrubland sites.	Continue with slight modifications to the number of soil replicates taken at each station.

Table 1-1. Summary of Historical and Long Term Environmental Monitoring Programs for WNP-2 (Cont)

Specific Programs	Historical Program	Proposed Program
	Aerial Photography - Five flightlines covering the areas of greatest deposition according to the drift model constructed by Battelle Pacific Northwest Laboratories.	Continue annual program to assess changes in vegetation.
Cooling Tower Drift	Validation of chemistry of the cooling tower drift model.	Terminated in 1991.
Transformer Yard Drift	Transformer Yard Drift - Measure the levels of airborne salt deposition originating from the WNP-2 tower steam condensate plume.	Continue only with those sampling stations located within the WNP-2 Transformer Yard.
Aquatic Biology Program	Fish - Four static bioassays were required by EFSEC for the fish bioassays. Fish flow-through bioassays, in conjunction with Daphnia and Hyalella static assays, are currently being done in compliance with special condition S4 of the WNP-2 National Pollutant Discharge Elimination System Waste Discharge Permit.	Further testing will be done biannually on a species determined by the EFSEC.
	Impingement studies.	Regulatory commitment has been completed. No further studies are proposed; however incidental observations will be made when maintenance inspections of the intakes are conducted.

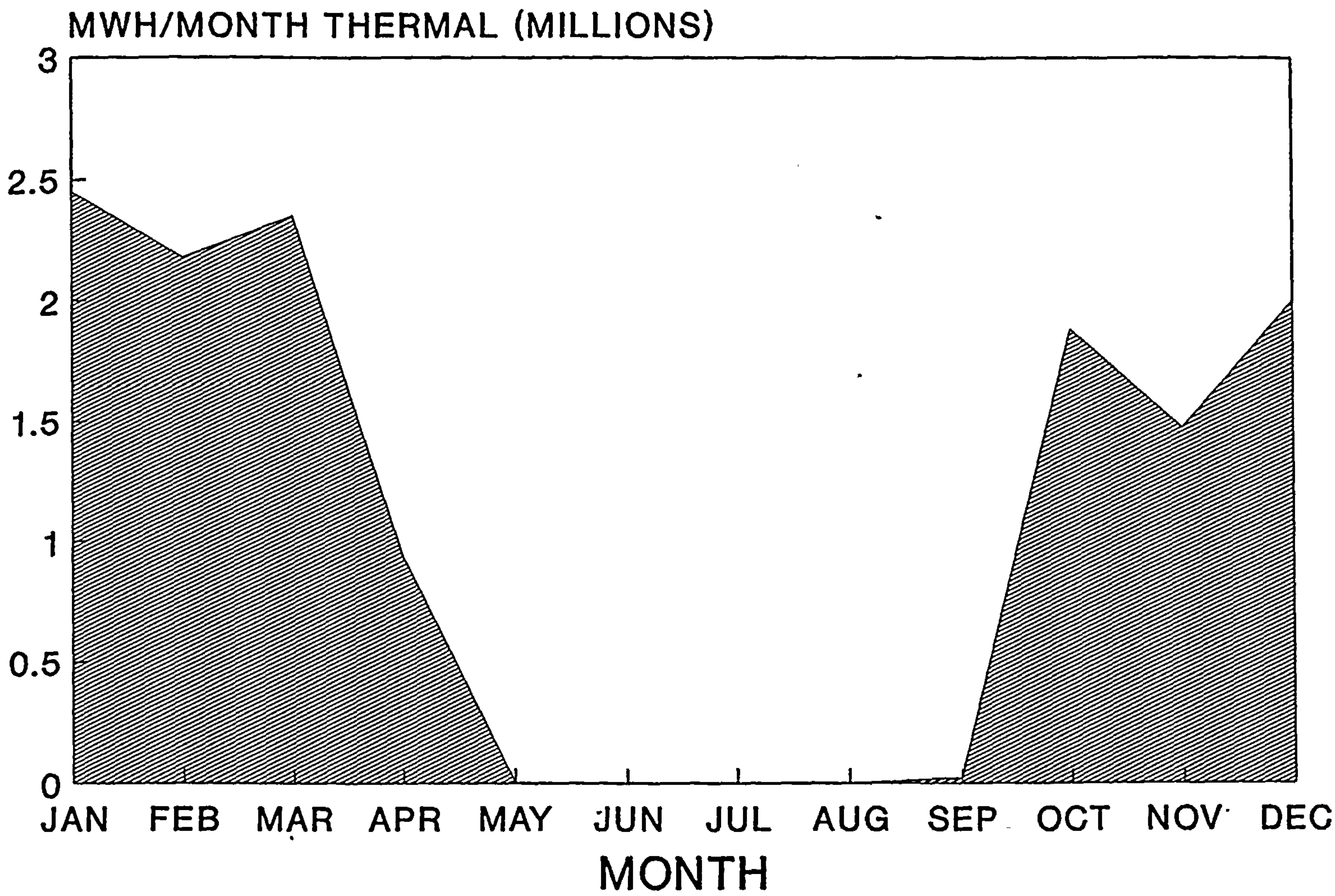

FIGURE 1-1
WNP-2 GROSS THERMAL PRODUCTION FOR 1991

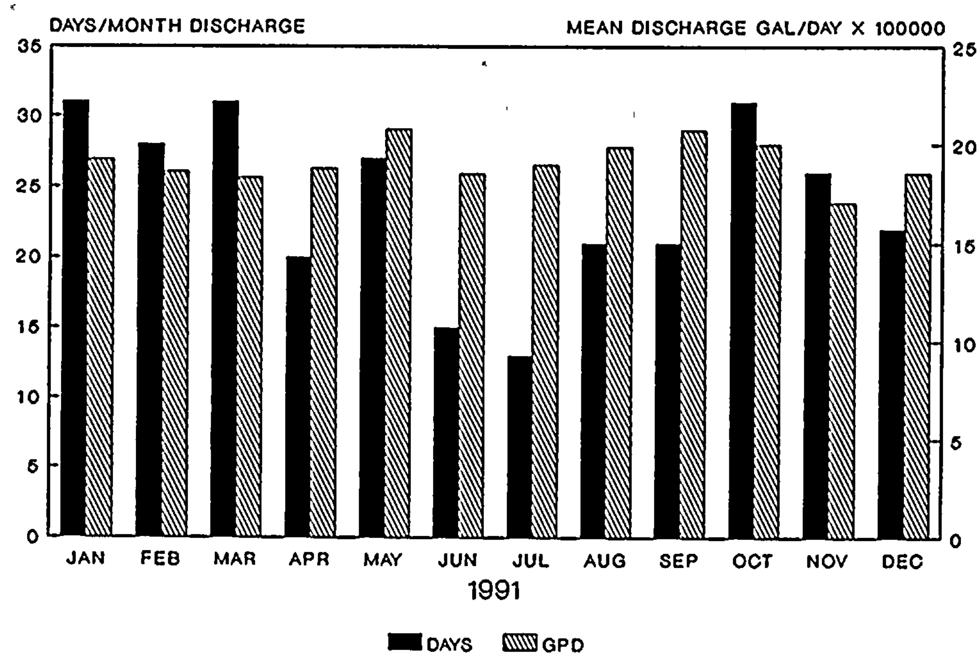

FIGURE 1-2
WNP-2 DAYS PER MONTH DISCHARGING AND MEAN MONTHLY DISCHARGE

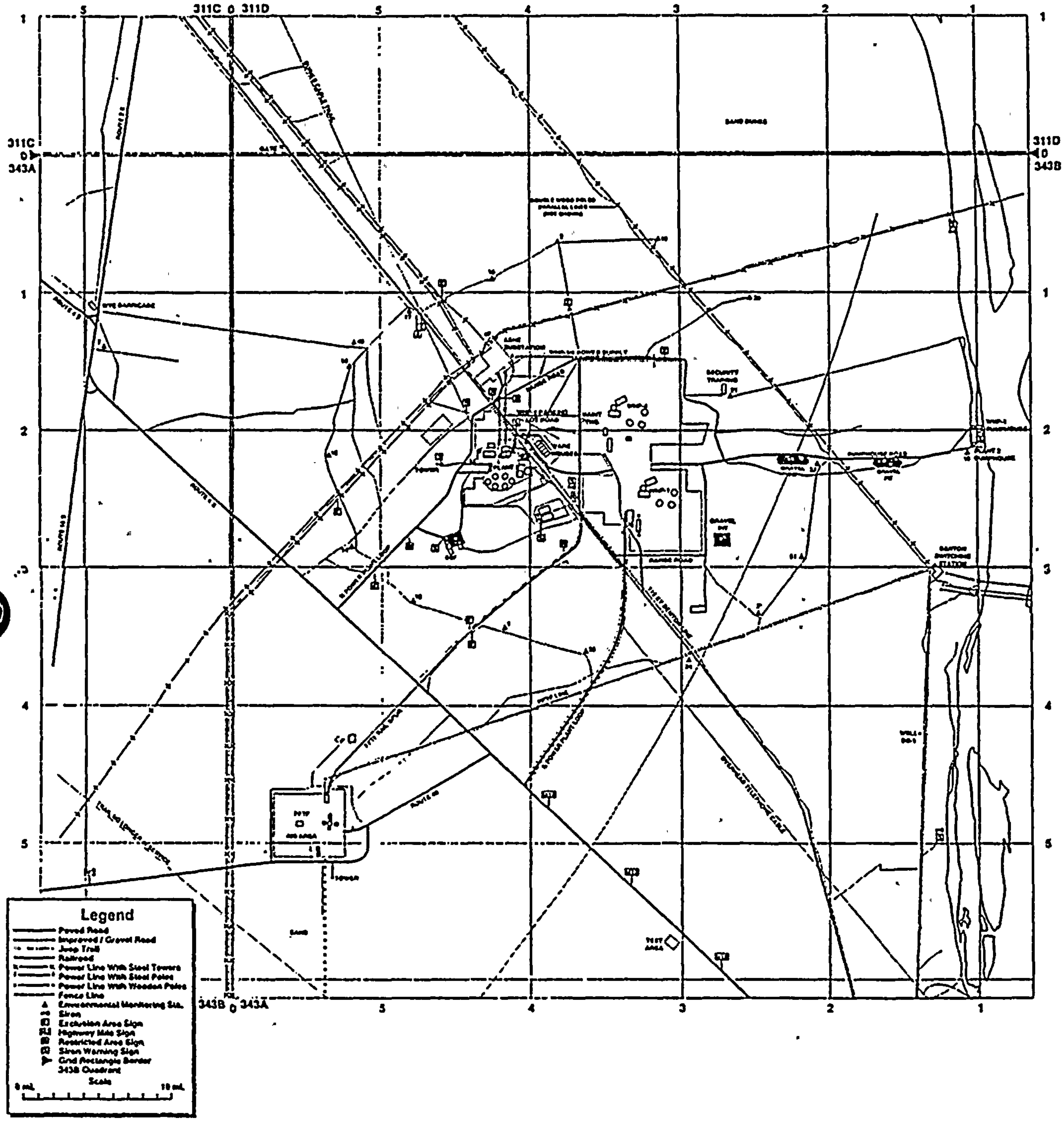

FIGURE 1-3
WNP-2 LOCATION MAP

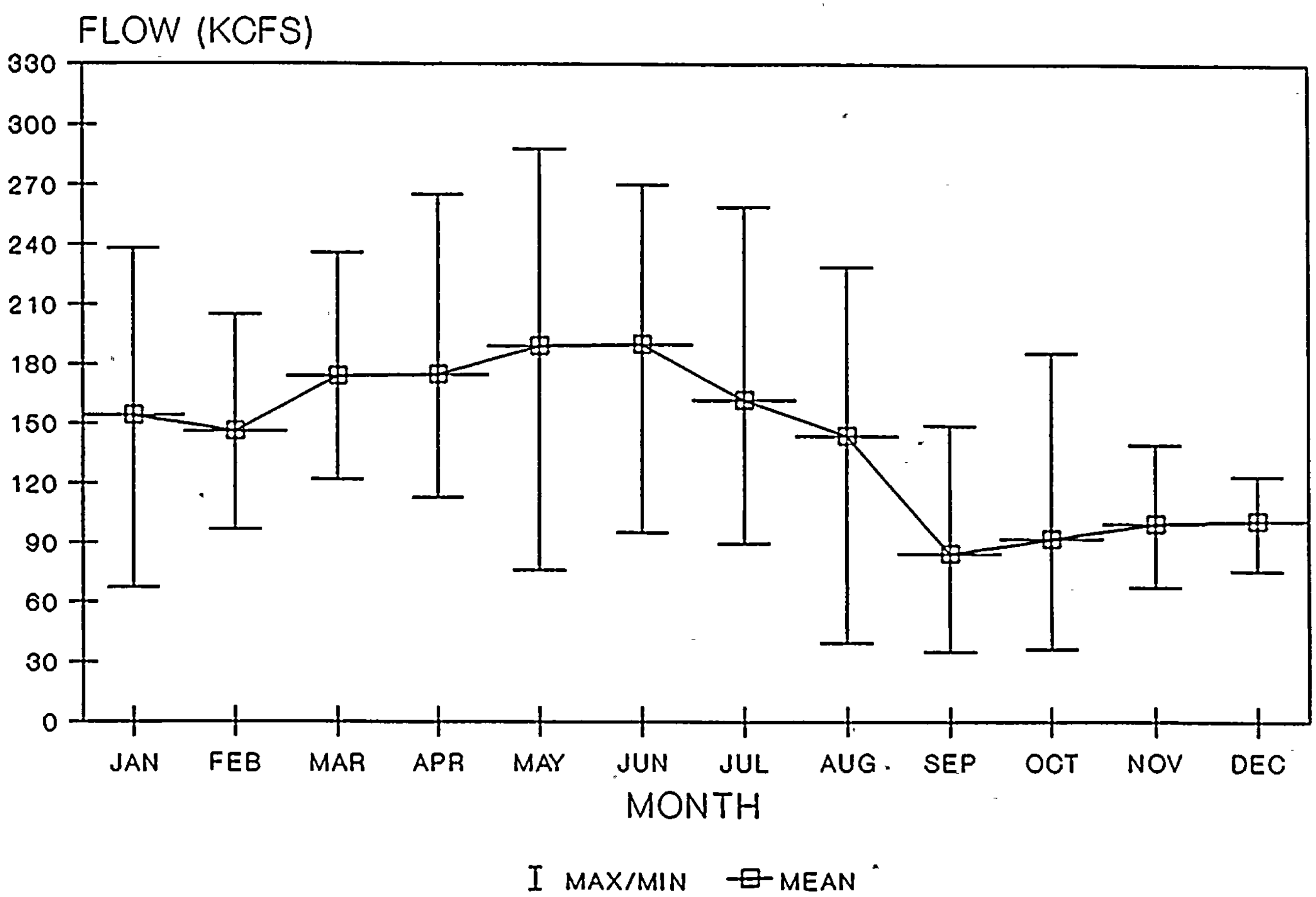

FIGURE 1-4
COLUMBIA RIVER MEAN MONTHLY FLOW FOR 1991

2.0 NOTABLE ENVIRONMENTAL OBSERVATIONS

2.1 INTRODUCTION

Any occurrence of an unusual or notable event that indicates or could result in a significant environmental impact causally related to plant operation shall be recorded and reported to the NRC within 24 hours followed by a written report. The following are examples: excessive bird impaction events, onsite plant or animal disease outbreaks, mortality or unusual occurrence of any species protected by the Endangered Species Act of 1973, fish kills, increase in nuisance organisms or conditions, and a significant, unanticipated or emergency discharge of waste water or chemical substances.

2.2 METHODS

Weekly ground surveys were conducted from January 1st through December 31st to document the occurrence of unusual species or events within the property boundary of WNP-2 (Figure 2.1). Additional information was supplied by security and environmental personnel.

2.3 RESULTS

There were no unusual or notable events which resulted in significant environmental impacts from the operation of WNP-2.

There were, however, some general observations worth noting.

The long-billed curlew (Numenius americanus) continues to be a common resident during spring periods, with several nesting pairs sighted in the shrub-steppe communities surrounding WNP-2.

The burrowing owl, Athene cunicularia, is also a springtime resident of the Hanford Reservation, with several sightings being reported from locations within WNP-2's site area boundary.

A pair of great horned owls (Bubo virginianus) were observed at different times around the WNP-2 river pumphouse. Again this year, several flocks of the American white pelican (Pelecanus erythrorhynchos) were noted frequenting the area just south of the WNP-2 river pumphouse.

There were no unanticipated or emergency discharges of water or wastewater during the reporting period.

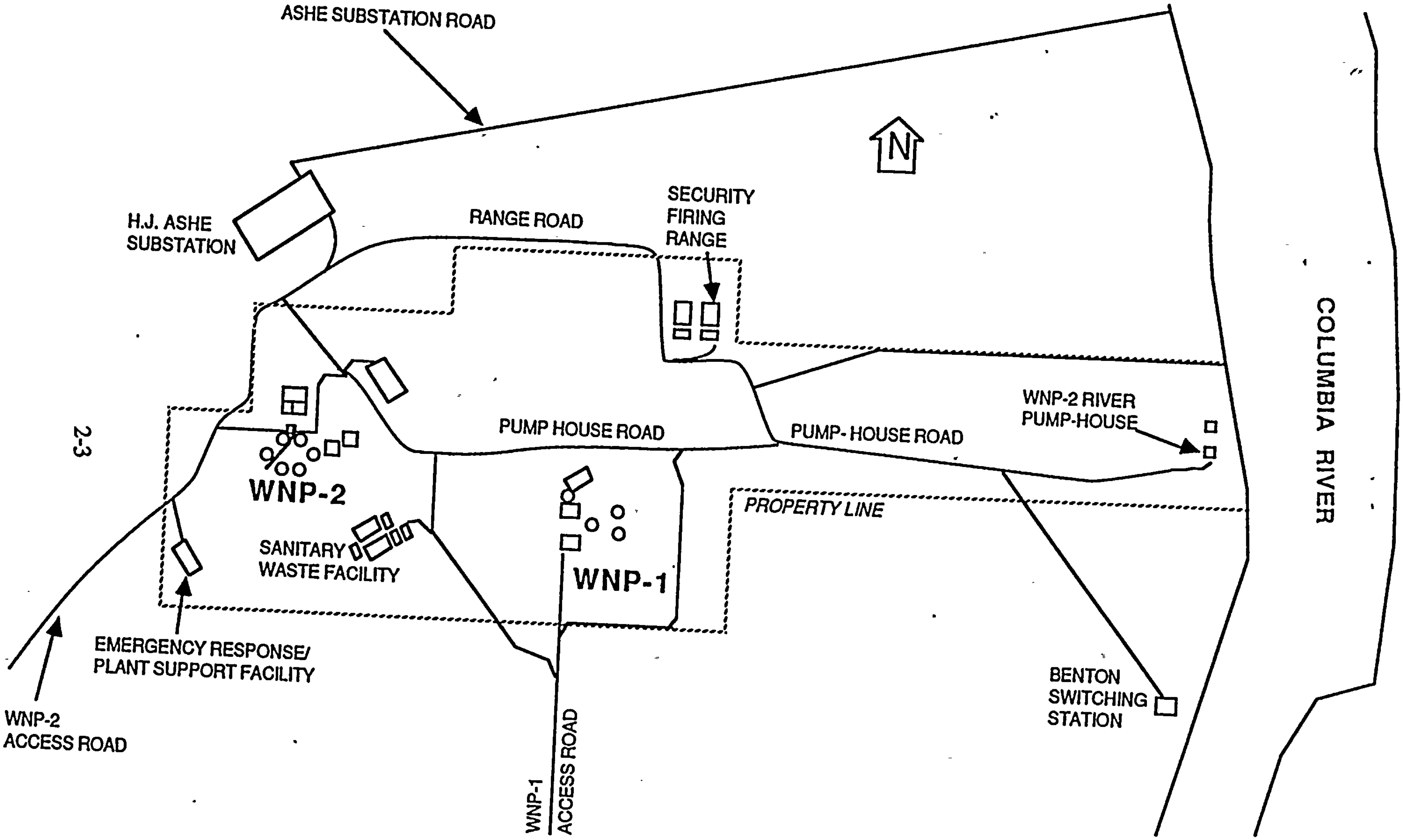

FIGURE 2-1
WNP-2 PROPERTY BOUNDARY

3.0 AQUATIC BIOASSAYS

3.0.1 INTRODUCTION

Special condition S4 of the WNP-2 National Pollutant Discharge Elimination System Permit (NPDES Permit No. WA-002515-1) requires acute biomonitoring studies on plant effluent. Specifically, the permit requires 96-hour testing in 0% (control) and 100% effluent concentrations. An 80% or greater survival rate in 100% effluent is specified as the successful test criteria. Section 3.1 reports the results of bioassay tests performed on chinook salmon (Oncorhynchus tshawytscha) using a flow-through format. The results of the bioassay tests on Daphnia pulex, using a static test format, are reported in section 3.2.

3.1 FISH BIOASSAYS

3.1.1 INTRODUCTION

Three bioassays, subjecting chinook salmon (Oncorhynchus tshawytscha) to 100% effluent concentrations, were conducted from March 30 - April 4, December 2-6, and December 9-13, 1991.

3.1.2 METHODS AND MATERIALS

The bioassays followed the guidance set forth in the EPA publications, Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms (EPA, March 1985), and, Quality Assurance Guidelines for Biological Testing (EPA, August 1978). Specific methodology is provided in References 3 and 4.

Effluent used for the tests was diverted from the discharge pipe and pumped to the test facility. Control (dilution) and holding tank water was untreated Columbia River water pumped from the makeup water pumphouse directly to the test facility.

Temperature control for the holding tank water and the 0% (control) and 100% plant effluent solutions was provided by a 200,000 BTU capacity chiller and an in-house designed temperature conditioning unit. A system of heat exchangers, flow and temperature control valves, water heater, and controllers produced a test water temperature of 12°C, controllable to within +/-1°C.

Because of supersaturation problems associated with the heating of the control water to 12°C, the April bioassay was performed at ambient river temperatures (see discussion section). The temperature conditioning unit was used to cool the plant effluent to temperatures approximating that of the control water.

The chinook salmon juveniles utilized for the bioassays were obtained from the Washington Department of Fisheries, Ringold Hatchery. The fish were acclimatized in a 2000-liter capacity holding tank for a minimum of 14 days. A commercial fish food (Bio-Dry by Bioproducts) was utilized, with food size and feeding rates identical to those used at the hatchery. Fish were not fed for 48 hours prior to handling or during the 96-hour test.

The flow-through system consisted of six 132-liter capacity glass aquaria, each containing approximately 114 liters of water. The system included three control (100% Columbia River water) and three (100% plant effluent) aquaria selected on a random basis. Flow rates were approximately 1.43 liters/minute per aquaria.

Water temperature in both the control and effluent head boxes was monitored continuously by use of an Astro-Med Dash 2 recorder.

At the beginning of each test, ten fish were distributed to each aquaria, two at a time, in a stratified random manner. The aquarium loading factor varied from approximately 2 g/liter during the two December tests to 8 g/liter during the test performed in April.

Fish were acclimatized in the aquaria with 100% control water for 48 hours prior to the introduction of plant effluent. The 96-hour test was begun by siphoning down the aquaria (including the controls) until there were approximately 23 liters of water remaining, and then plant effluent was introduced to the test aquaria. Control aquaria were allowed to refill with river water. The aquaria were checked for mortalities twice per day.

Fork lengths and wet weights were determined by anesthetizing and measuring the control fish at the end of the test (Table 3-1-1). All fish were released to the Columbia River at the conclusion of the test.

Temperature, dissolved oxygen, pH, and conductivity were measured daily in the control and effluent head boxes and each aquaria. Grab water samples were collected daily from the control and effluent head boxes and each aquaria and analyzed for calcium, magnesium, alkalinity, total copper, and total zinc.

The pH and temperature measurements were made with an IBM Model EC105-2A portable pH meter. Prior to each use, the instrument was calibrated using pH standards of 4.0, 7.0, and 10.0. If necessary, the probes were adjusted to within 0.1 unit of the standards. The temperature probe was calibrated against an NIST traceable thermometer.

Dissolved oxygen measurements were made using a Yellow Springs Instrument (YSI) Model 57 meter. The meter was air-calibrated prior to each use per manufacturer's instruction. In addition, Winkler D.O. measurements were made prior to the bioassay and results compared to the Model 57 meter.

Conductivity measurements were made with a YSI Model 33 meter. Daily measurements of conductivity standards were performed.

Sample holding times and analysis methods were consistent with EPA recommendations (EPA 1983). The specific methods are identified in Table 3-1-2.

3.1.3 RESULTS AND DISCUSSION

All three tests were successfully completed with respect to a survival rate criterion of 80% or greater. Only one fish mortality was observed, occurring approximately 88 hours into the test performed in April. These results are in agreement with the first NPDES flow-through test performed in October 1990 and several static bioassays conducted during 1984 and 1985 (WPPSS 1991 and 1986).

The bioassay completed in April had to be abandoned in February and again in March when excessive mortality rates were experienced during the 14-day holding periods. The problem was attributed to supersaturation caused by the heating of the control water to 12°C (recommended test temperature). Winter periods produce Columbia River temperatures in the 2-5°C range. Extremely high dissolved gas levels result at these low temperatures. Water quality data obtained in February indicated river temperatures of 2.5°C and dissolved oxygen levels of 14.5 mg/l. Based on Rawson's nomogram (EPA 1985 pp. 36) for oxygen saturation as a function of temperature, the Columbia River was highly saturated with respect to oxygen (105%). Measurements of dissolved oxygen levels taken at various output temperatures from the temperature conditioning unit, indicated that increasing the temperature of the river water to 12°C resulted in saturation levels approaching 140%. Of the gases involved with supersaturated water (oxygen, nitrogen, and carbon dioxide), nitrogen has the greatest adverse effect on fish. Published reports (Woods, 1974 and Esch, et.al., 1976) indicate that nitrogen levels near 110% can cause problems in juvenile salmonids. Normally, nitrogen levels (percent saturation) are at or above the corresponding dissolved oxygen levels. Based on these results, it was determined that a successful test could only be conducted at ambient river temperatures.

Water quality parameters (Table 3-1-3) basically demonstrate the difference between control (Columbia River) and test (100% effluent) water sources. Measurements remained fairly constant between tests for both control and test aquaria. Only slight variations, indicative of seasonal changes, occurred in dissolved oxygen and pH measurements for control aquaria.

Test aquaria differed only in measurements of conductivity and hardness, which is indicative of the cycles of concentration of the discharge water. For the bioassays completed on April 4, December 6, and December 13, the number of cycles of concentration averaged 5, 4, and 5, respectively.

Copper and zinc concentrations are presented in Table 3-1-4. It is interesting to note that the levels of copper in the discharge water during the test performed in December are approximately three times higher than the levels recorded from the test conducted in April, even though plant operating conditions (i.e. - cycles of concentration) were similar. Additionally, these levels are slightly higher than the copper measurements recorded during the October, 1990 test (WPPSS, 1991) in which the number of cycles of concentration approached 12. The elevated copper levels may be the result of increased corrosion of condenser tubes and system piping attributable to the long delay in the restart of the plant following the annual maintenance outage. Zinc levels remained fairly constant for all three bioassays. Discharge water zinc concentrations somewhat demonstrate the slight variations between tests in the number of cycles of concentration.

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Table 3-1-1. Size and Wet Weight of Control Fish Used In Bioassay Tests.

		Fork Length (cm)		Wet Weight (g)	
Test Date	Number	Average	Range	Average	Range
3/31-4/4	28	20.5	14.9-26.2	97.1	32.9-196.5
12/2-12/6	30	11.9	10.2-16.5	20.6	12.4-48.0
12/9-12/13	30	11.9	9.4-15.2	20.4	8.8-49.7

Table 3-1-2. Summary of Bioassay Parameters and Associated EPA Methods.

Parameter	EPA Method Number
Water Temperature (°C)	170.1
Conductivity (μs/cm) at 25°C	120.1
Dissolved Oxygen (mg/l)	360.1 360.2
pH (su)	150.1
Total Alkalinity (mg/l as $CaCO_3$)	310.1
Total Hardness (mg/l as $CaCO_3$)	130.2
Total Calcium	200.7
Total Magnesium	200.7
Total Copper (μg/l as Cu)	220.2 200.7
Total Zinc (μg/l as zn)	298.2 200.7

Table 3-1-3. Summary of Water Quality Parameters

Parameter	Control Aquaria		100% Discharge Aquaria	
Test Dates	Average	Range	Average	Range
Temperature (°C)				
3/31-4/4	6.9	6.4-7.3	8.4	7.7-8.8
12/2-12/6	11.4	11.3-11.5	12.0	11.7-12.2
12/9-12/13	11.3	11.3-11.3	11.8	11.4-12.4
Dissolved Oxygen (mg/l)				
3/31-4/4	12.6	12.1-13.3	7.4	6.6-9.2
12/2-12/6	10.1	9.7-10.3	8.0	7.8-8.4
12/9-12/13	10.4	10.0-10.7	8.0	7.4-8.4
pH				
3/31-4/4	7.84	7.76-7.99	8.52	8.33-8.75
12/2-12/6	7.61	7.45-7.67	8.55	8.48-8.63
12/9-12/13	7.64	7.42-7.81	8.45	8.33-8.58
Conductivity (μs/cm)				
3/31-4/4	97	95-100	491	380-540
12/2-12/6	101	100-105	400	363-422
12/9-12/13	101	100-102	473	420-520
Alkalinity (mg/l)				
3/31-4/4	61	59-63	147	113-162
12/2-12/6	59	58-60	156	131-166
12/9-12/13	60	58-60	152	121-193
Hardness (mg/l)				
3/31-4/4	66	64-71	337	319-365
12/2-12/6	64	61-67	242	192-266
12/9-12/13	64	61-67	287	250-333

Table 3-1-4. Summary of Total Copper and Total Zinc Measurements

Parameter	Control Aquaria		100% Discharge Aquaria	
Test Dates	Average	Range	Average	Range
Copper (μg/l)				
3/31-4/4	2.4	1.3-4.8	37.0	32.0-45.0
12/2-12/6	4.0	1.1-11.0	112.9	82.2-125.6
12/9-12/13	2.3	0.2-6.2	118.3	94.0-138.7
Zinc (μg/l)				
3/31-4/4	9.0	2.0-18.0	65.0	58.0-69.0
12/2-12/6	7.9	4.2-18.9	49.8	38.9-59.5
12/9-12/13	6.6	3.0-14.3	53.5	40.7-61.4

3.2 DAPHNIA BIOASSAYS

3.2.1 INTRODUCTION

Two bioassays of WNP-2 cooling tower effluent were performed October 30 - November 3, and November 12-16, 1991, on the common water flea (Daphnia pulex).

3.2.2 METHODS AND MATERIALS

The bioassays followed the guidance set forth in the EPA publication, Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms (EPA, March.1985), and, Quality Assurance Guidelines for Biological Testing (EPA, August 1978).

The effluent used for the test was collected (by grab sample) from the discharge sample line located at the fish bioassay facility. Control (dilution) water was prepared using the procedure for moderately hard water outlined in EPA, March 1985.

Test temperature (20° +/- 2°C) was maintained by a Revco model RI-50-555 incubator.

Less than 24-hour old Daphnia (neonates) were exposed to 100% effluent (test) and 100% dilution water (control) for a 96-hour period. Mortality checks were made at one, two, four, and eight hours after the beginning of the test and daily thereafter. See Table 3-2-1 for a complete summary of test conditions. Table 3-2-2 lists a summary of the bioassay parameters and the associated EPA methods.

The Daphnia pulex used in the test were originally obtained from a stock culture from the EPA Regional Laboratory, Manchester, WA in July 1991. The WNP-2 Environmental Laboratory now maintains a breeding population of this organism.

Temperature was measured in control and test containers at the start of the test and daily thereafter in representative containers. Dissolved oxygen, pH, conductivity, alkalinity, and hardness were measured in control and test solutions at the beginning of the test.

Temperature measurements were made with a Fisher-NIST traceable thermometer. pH measurements were made with an Orion model 701-A meter and Ross model 8102 electrode. Dissolved oxygen measurements were made using a Yellow Springs Instrument (YSI) model 57 meter. Conductivity measurements were consistent with U.S. Environmental Protection Agency guidance (EPA, 1983).

3.2.3 RESULTS AND DISCUSSION

The tests were successfully completed with respect to a survival criterion of 80% or greater. There was one mortality recorded in 100% plant effluent during the first test. There were no plant effluent test mortalities recorded during performance of the second bioassay.

Temperature measurements in the control and test containers averaged 20.9°C and 20.0°C for test 1 (10/30-11/3) and test 2 (11/12-11/16), respectively. Measurements of physical and chemical parameters for control and test solutions are presented in Table 3-2-3. Hardness was determined by calculation from magnesium and calcium measurements. Conductivity and hardness measurements reflect the cycles of concentration of the discharge water. The number of cycles of concentration was approximately 5 and 4 for test 1 and 2, respectively.

REFERENCES

Environmental Protection Agency, March 1985. Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA/600/4-85/013.

Environmental Protection Agency, August 1978. Quality Assurance Guidelines for Biological Testing, EPA/600/4-78/043.

Environmental Protection Agency, 1983. Methods for Chemical Analysis of Water and Wastes, EPA/600/4-79/020.

Table 3-2-2. Summary of Bioassay Parameters and Associated EPA Methods

Parameter	EPA Method Number
Water Temperature (C)	170.1
Conductivity (μs/cm) at 25C	120.1
Dissolved Oxygen (mg/1)	360.1
pH (su)	150.1
Total Alkalinity (mg/l as Calcium carbonate)	310.1
Total Hardness (mg/l as Calcium carbonate)	130.2
Total Calcium	200.7
Total Magnesium	200.7

Table 3-2-3. Physical and Chemical Parameters of Dilution (control) and Effluent (test) Solution at the Beginning of Each Test Period.

Test Date	Sample	Temp. (°C)	pH	D. O. (mg/l)	Cond. (μs/cm)	Hard. (mg/l)	Alk. (mg/l)
10/30-11/3	Dil. H_2O (control)	21.6	8.05	8.3	288	79	52
	Effluent (test)	21.6	8.28	8.4	664	296	187
11/12-11/16	Dil. H_2O (control)	21.5	8.06	8.4	298	80	53
	Effluent (test)	21.9	8.58	7.9	481	227	144

Table 3-2-1. Test Conditions for Daphnia pulex

1.	Temperature (°C):	20 +/-2°C
2.	Photoperiod:	16 h light/24 h
3.	Size of test vessel:	30 ml beaker
4.	Volume of test solution:	25 ml
5.	Age of test animals:	1-24 h (neonates)
6.	No. animals/test vessel:	5
7.	No. of replicate test vessels per concentration:	4
8.	Total no. organisms per concentration:	20
9.	Feeding regime:	Not fed first 48 h. Fed daily thereafter
10.	Aeration:	None
11.	Dilution water:	Moderately hard
12.	Test Duration:	96 hours
13.	Effect measured:	Mortality - 80% survival in effluent.

4.0 WATER QUALITY

4.1 INTRODUCTION

The water quality monitoring program documents the chemical character of the Columbia River in the vicinity of the WNP-2 discharge. The monitoring data is used to assess if chemical changes in the Columbia River result from WNP-2 cooling tower blowdown. The program is performed to comply with EFSEC Resolution No. 239.

During 1991, certain events caused a delay in plant start-up following the annual maintenance outage. As a result, discharge flow to the Columbia River only occurred from January through March and October through December sampling periods.

4.2 MATERIALS AND METHODS

Columbia River surface water was sampled monthly January 1991 through December 1991. Samples were collected near River Mile 352 from four stations numbered 1, 7, 11, and 8 (Figures 4-1, 4-2). Station 1 is upstream of the WNP-2 intake and discharge and represents the control. Station 7 is in the center of the mixing zone approximately 45 meters (150 feet) downstream of the discharge and provides a measure of nearfield discharge effects. Station 11, at 91 meters (300 feet) downstream from the discharge, represents the extremity of the mixing zone allowed by WNP-2's National Pollutant Discharge Elimination System (NPDES) permit. Substations 11M and 11B sample water from middle and bottom depths, respectively. Station 8 is approximately 568 meters (1870 feet) downstream from the discharge and represents a location where the discharge is well mixed in the Columbia River.

Plant discharge water (P.H.Dis.) was sampled monthly during 1991. Samples were collected from the discharge pipe, at a sample point located in the WNP-2 makeup water pumphouse, immediately prior to its entering the Columbia River.

With the exception of substations 11M and 11B, Columbia River samples were analyzed for temperature, dissolved oxygen (DO), pH, conductivity, turbidity, total alkalinity, total hardness, filterable residue (total dissolved solids), nonfilterable residue (total suspended solids), ammonia-nitrogen, nitrate-nitrogen, total phosphorus, orthophosphorus, sulfate, oil and grease, total residual chlorine, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium.

Substations 11M and 11B were analyzed for temperature, pH, conductivity, and total copper.

Discharge samples were analyzed for temperature, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium.

Measurements for mercury were determined on plant discharge water and on a sample collected at station 1, on a quarterly basis.

A summary of water quality parameters, stations and sample frequencies is presented in Table 4-1.

4.2.1 Sample Collection

Columbia River samples were collected by boat approximately 300 feet from the Benton County shore. Temperature is determined in-situ with portable instruments. Water for total metal, conductivity, sulfate, orthophosphorus, ammonia-nitrogen, nitrate-nitrogen, turbidity, total alkalinity and total hardness analysis was collected in one-liter polypropylene cubitainers and stored in a cooler until delivered to the Supply System's Environmental Programs Laboratory (EPL). Water for total copper analysis from Stations 11M and 11B were collected in 125 ml nalgene bottles with an All-Teflon pump and Tygon tubing. In the laboratory the metals samples were acidified to 0.5% with concentrated nitric acid.

Determinations for filterable residue, non-filterable residue, total phosphorus, and total residual chlorine were made on water samples collected in two 500 ml plastic, one 250 ml plastic, and one 250 ml colored glass, containers, respectively. Water for oil and grease analysis was skimmed from the surface into solvent rinsed borosilicate glass bottles.

Discharge samples were collected in one-liter polypropylene cubitainers and stored in a cooler until delivered to the EPL for analysis.

During the annual plant maintenance outage (April through September) only Station 1 (control) samples were collected.

4.2.2 Field Equipment and Measurements

Surface temperature and dissolved oxygen measurements were made using a Yellow Springs Instruments (YSI) Model 57 meter. Temperature was recorded to within 0.1°C after the probe had been allowed to equilibrate in the river for a minimum of one minute. The field probe was calibrated monthly against an NBS-traceable thermometer in the laboratory.

The DO meter was air-calibrated prior to each field sample date per manufacturer's instruction. In addition, Winkler DO measurements were made every month and results were compared to the field probe.

Conductivity measurements were made with a YSI model 34 meter. Prior to each sample date, measurements of conductivity standards were performed.

pH measurements were made with an IBM Model EC105-2A portable pH meter. Prior to each use the instrument was calibrated using pH standards of 4.0, 7.0, and 10.0. If necessary, the probes were adjusted to within 0.1 unit of the standards.

4.2.3 Laboratory Measurements

Total metals, sulfate, conductivity, orthophosphorus, ammonia-nitrogen, nitrate-nitrogen, turbidity, total alkalinity and total hardness were determined by Supply System Environmental Programs personnel. The remaining analyses were performed by an offsite laboratory. Sample holding times followed those recommended by the U.S. Environmental Protection Agency (EPA 1983). Analyses were performed per USEPA (1983) and ASTM approved methods (Table 4-2).

4.3 RESULTS

4.3.1 Temperature

Columbia River temperatures varied seasonally with a minimum temperature of 2.4°C at Station 11 on February 13th and a maximum of 20.8°C at Stations 1 on September 30 (Table 4-3). River temperatures measured in 1991 are presented graphically in Figure 4-3.

4.3.2 Dissolved Oxygen (DO)

DO measurements for each sample station are presented in Table 4-4. Columbia River DO concentrations ranged from 9.8 mg/l at Stations 1 and 7 in October to 14.5 mg/l at Station 7 in February.

DO concentrations were inversely related to river temperature as would be expected from solubility laws. DO levels were never below the 8 mg/l water quality standard for Class A waters (WDOE 1988), indicating good water quality with respect to dissolved oxygen throughout the year. Dissolved oxygen measurements are presented graphically in Figure 4-4.

4.3.3 pH and Alkalinity

Columbia River pH values ranged from 7.43 at Substation 11B in November to 8.65 at Station 1 in September (Table 4-5). The variation in pH between sample stations is small. The largest difference of 0.33 standard units occurred between Station 1 (pH 7.76) and Substation 11B (pH 7.43) in November.

The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1988). The measurement for Station 1 in September demonstrates naturally occurring conditions outside of this range. pH measurements, presented graphically in Figure 4-5, generally agree with historical data for the Columbia River (Silker 1964).

The alkalinity of a water is a measure of its capacity to neutralize acids and is generally due to the presence of carbonates, bicarbonates, phosphates, silicates, borates, and hydroxides. Columbia River alkalinities ranged from 50.0 to 60.5 mg/l as calcium carbonate (Table 4-6). The alkalinity measurements are presented graphically in Figure 4-6.

4.3.4 Hardness

Hardness indicates the quantity of divalent metallic cations present in the system, principally calcium and magnesium ions. Hardness ranged from 57.3 to 74.9 mg/l as calcium carbonate (Table 4-6). The hardness measurements are presented graphically in Figure 4-7.

4.3.5 Conductivity

Conductivity is a measure of the ionic content of a solution. Columbia River conductivity measurements ranged from 117.4 μs/cm at 25°C at Station 1 in June to 148.0 μs/cm at 25°C at Station 11 in February (Table 4-8). The conductivity results are very comparable to those reported in earlier studies of the Columbia River (Silker 1964). The measurements are presented graphically in Figure 4-7.

4.3.6 Turbidity

Turbidity is a measure of the suspended matter that interferes with the passage of light through water. In the Columbia River, measured turbidities were low and ranged from 0.5 nephelometric turbidity units (NTU) to 6.8 NTU (Table 4-9). Total dissolved solids, total suspended solids and turbidity data are presented graphically in Figures 4-14, 4-15, and 4-16.

4.3.7 Total Residual Chlorine (TRC)

Total residual chlorine (TRC) measurements for 1991 were less than the measured detection limit of 1.0 mg/l (Table 4-10).

TRC measurements were made using EPA method 409A. This method has a detection limit of 1.0 mg/l.

4.3.8 Metals

Total Copper

Columbia River total copper values ranged from < 1.2 μg/l to 8.0 μg/l (Table 4-9). The largest interstation difference in copper occurred between Station 1 (8.0 μg/l) and stations 7, 11, 11M and 8 (< 1.2 mg/l) in December. However, the value of 8.0 is uncharacteristic and is probably an indication of a contaminated sample rather than an actual copper measurement. Our copper results show good agreement with earlier studies. In 1962, Silker (1964) analyzed 27 Columbia River samples collected upstream of WNP-2 and reported a mean copper concentration of 4.3 μg/l. Neutron activation analysis of Columbia River water was done in 1968-1969 by Cushing and Rancitelli (1972). They reported a mean copper concentration of 1.4 μg/l. Florence and Batley (1977) state that total copper concentrations

in the range of 0.3 - 3.0 μg/l are found in many unpolluted fresh-water rivers throughout the world. The Hanford reach of the Columbia River would generally be in that category.

Plant discharge total copper concentrations ranged from 44.4 μg/l in March to 153.4 μg/l in November.

Total Nickel

Total nickel concentrations were below the detection limit (2.6 μg/l) for nearly all periods, except for station 11 in March (3.1 μg/l).

Plant discharge total nickel concentrations ranged from 3.3 μg/l in December to 19.5 μg/l in February.

Total Zinc

Individual zinc measurements ranged from < 1.0 μg/l to 18.0 μg/l (table 4-13).

Discharge water total zinc measurements ranged from 46.9 μg/l in December to 89.9 μg/l in February.

Total Iron

Columbia River iron concentrations ranged from 34.9 μg/l at Station 7 in December to 393.0 μg/l at Station 1 in May (Table 4-14).

Plant discharge total iron concentrations ranged from 274.1 μg/l in December to 2009.0 μg/l in February.

Total Lead

Total lead concentrations were low with all stations recording levels below detection limits (<1.9 μg/l) for all periods (Table 4-12).

Discharge water total lead measurements ranged from <1.9 μg/l in November and December to 9.0 μg/l in February.

Total Cadmium

Cadmium concentrations were below detection limits (<0.5 μg/l) for all stations during all periods.

Plant discharge total cadmium concentrations were below the detection limit (0.5 μg/l) for all periods (Table 4-16).

Total Chromium

Chromium concentrations were below detection limits for all periods (Table 4-17).

Plant discharge total chromium concentrations ranged from <1.9 μg/l to 10.5 μg/l.

Total zinc and total iron measurements are presented graphically in Figures 4-8 and 4-9, respectively.

Total Mercury

Columbia River mercury concentrations were below the detection limit (0.2 μg/l) for all periods (Table 4-18).

Measured total phosphorus concentrations ranged from <0.007 to 0.028 mg-P/l. Orthophosphorus concentrations were below 0.13 mg/l for all stations and periods except station 11 in March and November (Table 4-23). Total orthophosphorus measurements are summarized in Table 4-22. Total phosphorus measurements are presented graphically in figure 4-12.

4.3.12 Sulfate

Individual sulfate measurements ranged from 8.5 to 11.4 mg/l. Sulfuric acid is added at WNP-2 to control circulating water pH and a by-product is sulfate. Based on the river measurements, WNP-2 discharges are not appreciably altering river sulfate concentrations. Total sulfate measurements are presented graphically in Figure 4-13.

4.3.13 Total Dissolved Solids, Total Suspended Solids and Turbidity

Total dissolved solids or total filterable residue, TDS, is defined as that portion of the total residue that passes through a glass fiber filter and remains after ignition at 180°C for one hour. Total dissolved solids do not necessarily represent only the dissolved constituents but may also include colloidal materials and some small particulates. The TDS measured in the Columbia River ranged from 14.0 mg/l at Station 1 to 150.0 mg/l at Station 1 (Table 4-25). The three lowest measurements at stations 8, 7 and 11 in October, November and December, respectively, are uncharacteristically low with respect to other stations and may represent sampling and/or analytical errors.

Total suspended solids (TSS) or total nonfilterable residue is the material retained on a standard glass fiber filter after filtration of a well-mixed sample. TSS concentrations were generally low and varied from <1.0 to 8.0 mg/l (Table 4-25).

WNP-2 circulating water mercury concentrations ranged from <0.2 ug/1 in January and April to 0.8 μg/l in October. The circulating water system was not operating during the July sampling period.

4.3.9 Ammonia-Nitrogen and Nitrate-Nitrogen

Ammonia and nitrate are forms of nitrogen commonly found in water systems. Both nitrate and ammonia are assimilated by plants and converted to proteins. Common sources of nitrate and ammonia to the aquatic system are breakdown of organic matter in the soil, industrial discharges, fertilizers and septic tank leachate.

Ammonia concentrations ranged from <0.010 to 0.020 mg-N/l (Table 4-18). Nitrate concentrations ranged from <0.06 to 0.19 mg-N/l. The nitrate measurements are summarized in Table 4-20. The nitrate measurements are presented graphically in Figure 4-11.

4.3.10 Oil and Grease

Oil and grease values were below the detection limit of 1.0 mg/l for all stations and periods except station 1 in April and October. Oil and grease measurements are summarized in Table 4-20.

4.3.11 Total Phosphorus and Orthophosphorus

Phosphorus is a required nutrient for plant growth and, while found in certain minerals, is commonly added to streams through fertilizers, treated sewage, and septic tank leachate.

Turbidity is a measure of the suspended matter that interferes with the passage of light through water. In the columbia River, measured turbidities were low and ranged from 0.5 nephelometric turbidity units (NTU) to 6.8 NTU (Table 4-9). Total dissolved solids, total suspended solids and turbidity data are presented graphically in Figures 4-14, 4-15, and 4-16.

4.4 DISCUSSION

Plant discharge data basically demonstrates the increase in certain constituents of the blowdown due mainly to concentrating the circulating cooling water (Columbia River water). Operating conditions at WNP-2 during 1991 were characterized by a circulating water concentration of approximately 5 cycles.

In comparing river and plant discharge data, it is evident that the impact on the Columbia River is minimal with no significant interstation differences being detected.

Overall, it appears that, with respect to all the measured parameters sampled under the operating conditions prevailing during 1991, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

4.5 REFERENCES

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Table 4-1. Summary of Water Quality Parameters,

Stations, and Sampling Frequencies, 1991

Parameter	1	7++	11++	11M & 11B++	8++	Wells in Vicinity of Plant Site+	P.H. DIS.++
Quantity (flow)	-	-	-	-	-	-	-
Temperature	M	M	M	M	M	-	M
Dissolved Oxygen	M	M	M	-	M	-	-
pH	M	M	M	M	M	Q	-
Turbidity	M	M	M	-	M	-	-
Total Alkalinity	M	M	M	-	M	-	-
Filterable Residue (Total Dissolved Solid)	M	M	M	-	M	-	-
Nonfilterable Residue (Suspended Solids)	M	M	M	-	M	- -	-
Conductivity	M	M	M	M	M	-	-
Iron (Total)	M	M	M	-	M	-	M
Copper (Total)	M	M	M	M**	M	-	M
Nickel (Total)	M	M	M	-	M	-	M
Zinc (Total)	M	M	M	-	M	-	M
Lead (Total)	M	M	M	-	M	-	M
Cadmium (Total)	M	M	M	-	M	-	M
Chromium (Total)	M	M	M	-	M	-	M
Sulfate	M	M	M	-	M	-	-
Ammonia Nitrogen	M	M	M	-	M	-	-
Nitrate Nitrogen	M	M	M	-	M	Q	-
Orthophosphorus	M	M	M	-	M	Q	-
Total Phosphorus	M	M	M	-	M	Q	-
Oil and Grease	M	M	M	-	M	-	-
Chlorine, Total Residual	M	M	M	-	M	-	-
Hardness	M	M	M	-	M	-	-
Mercury (Total)	Q	-	-	-	-	-	Q

Symbols Key

M = Monthly
Q = Quarterly
+ Samples will be collected if wells are being used for drinking water.
- Analysis not required
** Samples taken in triplicate
++ Samples collected only if the plant is operating.

Table 4-2. Summary of Water Quality Parameters, EPA and ASTM Method Number

Parameter	EPA Method Number	ASTM Method Number
Water Temperature (°C)	170.1	
Turbidity, (NTU)	180.1	
Conductivity (μs/cm) at 25°C	120.1	
Dissolved Oxygen (mg/l) probe	360.1	
Dissolved Oxygen (mg/l) Modified Winkler	360.2	
pH (Standard Unit)	150.1	
Total Alkalinity (mg/l as $CaCO_3$)	310.1	
Total Hardness (mg/l as $CaCO_3$)	130.2, 6010	
Oil and Grease (mg/l)	413.2	
Nitrogen, Ammonia, Total (mg/l as N)	350.3	
Nitrate Nitrogen, Total (mg/l as N)	352.1	D4327-88
Total Phosphorus (mg/l as P)	365.2	
Ortho Phosphorus (mg/l as P)	365.2	D4327-88
Sulfate (mg/l as SO_4)	375.4	D4327-88
Total Copper (μg/l as Cu)	220.1, 220.2, 200.7	
Total Iron (μg/l as Fe)	236.1, 236.2, 200.7	
Total Nickel (μg/l as Ni)	249.1, 249.2	
Total Zinc (μg/l as Zn)	289.1, 289.2, 200.7	
Total Lead (μg/l as p6)	239.1, 239.2	
Total Cadmium (μg/l as Cd)	213.1, 213.2	
Total Chromium (μg/l as Cr)	218.1, 218.2	
Total Residual Chlorine (mg/l)	330.1	
Filterable Residue: Total Dissolved Solids (mg/l)	160.1	
Non-Filterable Residue: Total Suspended Solids (mg/l)	160.2	
Total Mercury (μg/l as Hg)	245.1	

Table 4-3. Summary of Temperature Measurements for 1991

Temperature (Degrees C)

Sample Date	1	7	11	11M	11B	8	PLANT DISCHRG
01/16/91	2.8	3.0	2.9	3.2	3.2	2.9	22.8
02/13/91	2.5	2.5	2.4	2.9	2.9	2.5	21.6
03/28/91	4.9	4.9	4.8	5.3	5.2	4.9	20.1
04/25/91	7.8	-	-	-	-	-	-
05/29/91	11.4	-	-	-	-	-	-
06/27/91	14.1	-	-	-	-	-	-
07/30/91	17.7	-	-	-	-	-	-
08/27/91	19.0	-	-	-	-	-	-
09/30/91	20.8	-	-	-	-	-	-
10/31/91	12.3	12.2	12.7	11.8	12.1	12.2	20.9
11/25/91	10.3	10.3	10.4	10.5	10.4	10.2	20.0
12/18/91	7.2	7.3	7.2	7.2	7.1	7.2	18.9

Table 4-4. Summary of Dissolved Oxygen Measurements for 1991.

Dissolved Oxygen (mg/l)

Sample Date	1	7	11	8
01/16/91	13.4	13.3	13.2	13.4
02/13/91	14.4	14.5	14.4	14.4
03/28/91	14.4	14.3	14.3	14.4
04/25/91	12.9	-	-	-
05/29/91	12.6	-	-	-
06/27/91	11.4	-	-	-
07/30/91	11.6	-	-	-
08/27/91	11.5	-	-	-
09/30/91	11.3	-	-	-
10/31/91	9.8	9.8	9.9	9.9
11/25/91	10.3	10.8	10.7	10.3
12/18/91	-	-	-	-

Table 4-5. Summary of pH Measurements for 1991

pH

Sample Date	1	7	11	11M	11B	8
01/16/91	7.92	7.86	7.83	7.76	7.84	7.85
02/13/91	7.84	7.75	7.80	7.84	7.74	7.84
03/28/91	7.82	7.79	7.82	7.72	7.90	7.83
04/25/91	8.05	-	-	-	-	-
05/29/91	7.65	-	-	-	-	-
06/27/91	7.88	-	-	-	-	-
07/30/91	8.21	-	-	-	-	-
08/27/91	7.93	-	-	-	-	-
09/30/91	8.65	-	-	-	-	-
10/31/91	7.76	7.67	7.72	7.78	7.76	7.73
11/25/91	7.76	7.54	7.61	7.71	7.43	7.72
12/18/91	7.66	7.66	7.70	7.63	7.73	7.67

Table 4-6. Summary of Alkalinity Measurements for 1991.

Total Alkalinity (mg/l)

Sample Date	1	7	11	8
01/16/91	60.5	59.0	60.0	60.0
02/13/91	57.0	57.0	57.0	59.0
03/28/91	57.0	57.0	58.0	57.0
04/25/91	55.0	-	-	-
05/29/91	52.0	-	-	-
06/27/91	50.0	-	-	-
07/30/91	51.0	-	-	-
08/27/91	53.0	-	-	-
09/30/91	55.5	-	-	-
10/31/91	52.5	52.5	53.0	52.5
11/25/91	51.0	56.0	54.0	52.5
12/18/91	55.0	55.5	56.0	55.0

Table 4-7. Total Hardness Measurements for 1991

	Total Hardness (mg/l)			
Sample Date	1	7	11	8
01/16/91	59.5	59.2	60.9	61.5
02/13/91	66.6	70.2	68.9	65.1
03/28/91	74.9	71.3	74.2	74.4
04/25/91	71.8	-	-	-
05/29/91	62.1	-	-	-
06/27/91	57.3	-	-	-
07/30/91	59.0	-	-	-
08/27/91	63.0	-	-	-
09/30/91	64.9	-	-	-
10/31/91	61.2	62.3	62.3	64.2
11/25/91	65.9	68.7	65.7	67.9
12/18/91	68.7	69.8	69.5	69.7

Table 4-8. Summary of Conductivity Measurements for 1991

	Conductivity at 25°C (μS/cm)					
Sample Date	1	7	11	11M	11B	8
01/16/91	121.0	120.1	119.1	120.8	121.1	120.3
02/13/91	145.8	147.0	148.0	146.2	145.9	145.1
03/28/91	144.0	143.0	144.0	143.0	144.0	143.0
04/25/91	146.0	-	-	-	-	-
05/29/91	127.0	-	-	-	-	-
06/27/91	117.4	-	-	-	-	-
07/30/91	119.5	-	-	-	-	-
08/27/91	130.1	-	-	-	-	-
09/30/91	135.0	-	-	-	-	-
10/31/91	126.8	126.4	127.2	127.1	127.2	126.6
11/25/91	135.0	135.0	137.0	135.0	136.0	135.0
12/18/91	139.0	140.0	140.0	140.0	140.0	140.0

Table 4-9. Summary of Turbidity Measurements for 1991

Sample Date	Turbidity (NTU) 1	7	11	8
01/16/91	1.3	1.4	1.1	1.5
02/13/91	0.7	0.7	0.7	0.7
03/28/91	1.0	1.3	1.3	1.0
04/25/91	1.9	-	-	-
05/29/91	6.8	-	-	-
06/27/91	2.2	-	-	-
07/30/91	1.7	-	-	-
08/27/91	1.1	-	-	-
09/30/91	0.8	-	-	-
10/31/91	0.5	0.5	0.5	0.6
11/25/91	0.8	0.8	0.8	0.8
12/18/91	1.3	1.3	1.1	1.4

Table 4-10. Summary of Total Residual Chlorine Measurements for 1991

Sample Date	Total Residual Chlorine (mg/l) 1	7	11	8
01/16/91	<1.0	<1.0	<1.0	<1.0
02/13/91	<1.0	<1.0	<1.0	<1.0
03/28/91	<1.0	<1.0	<1.0	<1.0
04/25/91	<1.0	-	-	-
05/29/91	<1.0	-	-	-
06/27/91	<1.0	-	-	-
07/30/91	<1.0	-	-	-
08/27/91	<1.0	-	-	-
09/30/91	<1.0	-	-	-
10/31/91	<1.0	<1.0	<1.0	<1.0
11/25/91	<1.0	<1.0	<1.0	<1.0
12/18/91	<1.0	<1.0	<1.0	<1.0

Table 4-11. Summary of Copper Measurements for 1991

Copper ($\mu g/l$)

Sample Date	1	7	11	11M	11B	8	PLANT DSCHRG
01/16/91	4.8	3.3	3.3	5.6	3.2	4.7	55.5
02/13/91	<1.2	<1.2	3.2	1.5	1.2	1.4	67.0
03/28/91	4.7	4.1	1.8	4.3	<1.2	7.1	44.4
04/25/91	2.3	-	-	-	-	-	-
05/29/91	2.1	-	-	-	-	-	-
06/27/91	<1.2	-	-	-	-	-	-
07/30/91	<1.2	-	-	-	-	-	-
08/27/91	6.1	-	-	-	-	-	-
09/30/91	<1.2	-	-	-	-	-	-
10/31/91	3.5	1.8	<1.2	1.4	<1.2	<1.2	125.9
11/25/91	<1.2	<1.2	<1.2	1.2	1.4	<1.2	153.4
12/18/91	8.0	<1.2	<1.2	<1.2	3.0	<1.2	66.4

Table 4-12. Summary of Nickel Measurements for 1991

Nickel ($\mu g/l$)

Sample Date	1	7	11	8	PLANT DSCHRG
01/16/91	<2.6	<2.6	<2.6	<2.6	11.0
02/13/91	<2.6	<2.6	<2.6	<2.6	19.5
03/28/91	<2.6	<2.6	3.1	<2.6	9.7
04/25/91	<2.6	-	-	-	-
05/29/91	<2.6	-	-	-	-
06/27/91	<2.6	-	-	-	-
07/30/91	<2.6	-	-	-	-
08/27/91	<2.6	-	-	-	-
09/30/91	<2.6	-	-	-	-
10/31/91	<2.6	<2.6	<2.6	<2.6	6.7
11/25/91	<2.6	<2.6	<2.6	<2.6	7.8
12/18/91	<2.6	<2.6	<2.6	<2.6	3.3

Table 4-13. Summary of Zinc Measurements for 1991

Sample Date	Zinc (μg/l) 1	7	11	8	PLANT DSCHRG
01/16/91	12.5	4.3	7.6	2.5	51.3
02/13/91	10.4	10.6	12.9	14.0	89.9
03/28/91	18.0	10.1	9.2	6.5	68.0
04/25/91	9.4	-	-	-	-
05/29/91	15.5	-	-	-	-
06/27/91	9.9	-	-	-	-
07/30/91	7.5	-	-	-	-
08/27/91	<1.0	-	-	-	-
09/30/91	3.3	-	-	-	-
10/31/91	<1.0	2.1	<1.0	<1.0	69.3
11/25/91	2.3	2.1	2.8	3.9	71.6
12/18/91	3.9	3.8	5.2	3.6	46.9

Table 4-14. Summary of Iron Measurements for 1991

Sample Date	Iron (μg/l) 1	7	11	8	PLANT DSCHRG
01/16/91	82.1	47.7	52.2	53.3	355.2
02/13/91	103.2	74.4	82.1	67.7	2009.0
03/28/91	90.2	76.7	93.1	73.5	393.0
04/25/91	84.7	-	-	-	-
05/29/91	393.0	-	-	-	-
06/27/91	88.0	-	-	-	-
07/30/91	108.9	-	-	-	-
08/27/91	140.0	-	-	-	-
09/30/91	84.7	-	-	-	-
10/31/91	65.7	69.9	67.9	65.2	436.4
11/25/91	63.5	50.3	59.5	64.5	490.8
12/18/91	41.7	34.9	44.2	38.6	274.1

Table 4-15. Summary of Lead Measurements for 1991

Sample Date	Lead (μg/l) 1	7	11	8	PLANT DSCHRG
01/16/91	<1.9	<1.9	<1.9	<1.9	2.0
02/13/91	<1.9	<1.9	<1.9	<1.9	9.0
03/28/91	<1.9	<1.9	<1.9	<1.9	3.4
04/25/91	<1.9	-	-	-	-
05/29/91	<1.9	-	-	-	-
06/27/91	<1.9	-	-	-	-
07/30/91	<1.9	-	-	-	-
08/27/91	<1.9	-	-	-	-
09/30/91	<1.9	-	-	-	-
10/31/91	<1.9	<1.9	<1.9	<1.9	3.3
11/25/91	<1.9	<1.9	<1.9	<1.9	<1.9
12/18/91	<1.9	<1.9	<1.9	<1.9	<1.9

Table 4-16. Summary of Cadmium Measurements for 1991.

Sample Date	Cadmium (μg/l) 1	7	11	8	PLANT DSCHRG
01/16/91	<0.5	<0.5	<0.5	<0.5	<0.5
02/13/91	<0.5	<0.5	<0.5	<0.5	<0.5
03/28/91	<0.5	<0.5	<0.6	<0.5	<0.5
04/25/91	<0.5	-	-	-	-
05/29/91	<0.5	-	-	-	-
06/27/91	<0.5	-	-	-	-
07/30/91	<0.5	-	-	-	-
08/27/91	<0.5	-	-	-	-
09/30/91	<0.5	-	-	-	-
10/31/91	<0.5	<0.5	<0.5	<0.5	<0.5
11/25/91	<0.5	<0.5	<0.5	<0.5	<0.5
12/18/91	<0.5	<0.5	<0.5	<0.5	<0.5

Table 4-17. Summary of Chromium Measurements for 1991

	Chromium (μg/l)				
Sample Date	1	7	11	8	PLANT DSCHRG
01/16/91	<1.9	<1.9	<1.9	<1.9	<1.9
02/13/91	<1.9	<1.9	<1.9	<1.9	10.5
03/28/91	<1.9	<1.9	<1.9	<1.9	2.4
04/25/91	<1.9	-	-	-	-
05/29/91	<1.9	-	-	-	-
06/27/91	<1.9	-	-	-	-
07/30/91	<1.9	-	-	-	-
08/27/91	<1.9	-	-	-	-
09/30/91	<1.9	-	-	-	-
10/31/91	<1.9	<1.9	<1.9	<1.9	<1.9
11/25/91	<1.9	<1.9	<1.9	<1.9	<1.9
12/18/91	<1.9	<1.9	<1.9	<1.9	<1.9

Table 4-18. Summary of Ammonia Measurements for 1991

	Ammonia (mg NH_3 - N/1)			
Sample Date	1	7	11	8
01/16/91	<0.010	<0.010	<0.010	<0.010
02/13/91	0.012	0.012	0.012	<0.010
03/28/91	0.018	0.018	0.017	0.016
04/25/91	0.014	-	-	-
05/29/91	0.018	-	-	-
06/27/91	<0.010	-	-	-
07/30/91	<0.010	-	-	-
08/27/91	<0.010	-	-	-
09/30/91	0.020	-	-	-
10/31/91	0.013	0.013	0.012	0.013
11/25/91	0.011	0.010	0.012	0.011
12/18/91	<0.010	<0.010	<0.010	<0.010

Table 4-19. Summary of Oil and Grease Measurements for 1991.

	Oil & Grease (mg/l)			
Sample Date	1	7	11	8
01/16/91	<1.0	<1.0	<1.0	<1.0
02/13/91	<1.0	<1.0	<1.0	<1.0
03/28/91	<1.0	<1.0	<1.0	<1.0
04/25/91	2.3	-	-	-
05/29/91	<1.0	-	-	-
06/27/91	<1.0	-	-	-
07/30/91	<1.0	-	-	-
08/27/91	<1.0	-	-	-
09/30/91	<1.0	-	-	-
10/31/91	2.3	<1.0	<1.0	<1.0
11/25/91	<1.0	<1.0	<1.0	<1.0
12/18/91	<1.0	<1.0	<1.0	<1.0

Table 4-20. Summary of Nitrate-Nitrogen Measurements for 1991

	Nitrate-Nitrogen (mg/1)			
Sample Date	1	7	11	8
01/16/91	0.13	0.13	0.13	0.13
02/13/91	0.15	0.15	0.15	0.15
03/28/91	0.15	0.14	0.14	0.15
04/25/91	0.19	-	-	-
05/29/91	0.12	-	-	-
06/27/91	0.09	-	-	-
07/30/91	0.06	-	-	-
08/27/91	0.08	-	-	-
09/30/91	0.08	-	-	-
10/31/91	0.15	0.15	0.15	0.15
11/25/91	0.16	0.16	0.19	0.15
12/18/91	0.17	0.17	0.17	0.17

Table 4-21. Summary of Total Phosphorus Measurements for 1991

Sample Date	Total Phosphorus (mg/l) 1	7	11	8
01/16/91	0.020	0.020	0.020	0.020
02/13/91	0.013	0.015	0.019	0.012
03/28/91	0.014	0.013	0.018	0.016
04/27/91	0.011	-	-	-
05/29/91	0.017	-	-	-
06/27/91	0.009	-	-	-
07/30/91	0.008	-	-	-
08/27/91	0.007	-	-	-
09/30/91	0.014	-	-	-
10/31/91	0.022	0.019	0.025	0.022
11/25/91	0.023	0.020	0.025	0.025
12/18/91	0.019	0.025	0.028	0.017

Table 4-22. Summary of Orthophosphate Measurements for 1991.

Sample Date	Orthophosphate (mg/1) 1	7	11	8
01/16/91	<0.13	<0.13	<0.13	<0.13
02/13/91	<0.13	<0.13	<0.13	<0.13
03/28/91	<0.13	<0.13	0.14	<0.13
04/25/91	<0.13	-	-	-
05/29/91	<0.13	-	-	-
06/27/91	<0.13	-	-	-
07/30/91	<0.13	-	-	-
08/27/91	<0.13	-	-	-
09/30/91	<0.13	-	-	-
10/31/91	<0.13	<0.13	<0.13	<0.13
11/25/91	<0.13	<0.13	0.15	<0.13
12/18/91	<0.13	<0.13	<0.13	<0.13

Table 4-23. Summary of Sulfate Measurements for 1991

Sulfate (mg/l)

Sample Date	1	7	11	8
01/16/91	10.0	10.0	10.0	10.1
02/13/91	10.1	10.3	10.4	10.2
03/28/91	10.1	10.1	10.1	10.5
04/25/91	-	-	-	-
05/29/91	8.1	-	-	-
06/27/91	7.2	-	-	-
07/30/91	7.4	-	-	-
08/27/91	8.2	-	-	-
09/30/91	9.0	-	-	-
10/31/91	8.5	8.5	8.7	8.5
11/25/91	9.1	9.1	11.4	10.2
12/18/91	9.0	9.5	9.6	9.1

Table 4-24. Summary of Quarterly Total Mercury Measurements for 1991.

Total Mercury (μg/l)

Sample Date	Columbia River	WNP-2 Circulating Water System
01/16/91	<0.2	<0.2
04/25/91	<0.2	<0.2
07/30/91	<0.2	-
10/31/91	<0.2	0.8

Table 4-25. Summary of Total Dissolved and Total Suspended Solids Measurements for 1991.

Total Dissolved Solids (mg/1)

Sample Date	1	7	11	8
01/16/91	94.0	94.0	99.0	106.0
02/13/91	85.0	86.0	84.0	85.0
03/28/91	150.0	120.0	140.0	74.0
04/25/91	100.0	-	-	-
05/29/91	110.0	-	-	-
06/27/91	110.0	-	-	-
07/30/91	130.0	-	-	-
08/27/91	140.0	-	-	-
09/30/91	80.0	-	-	-
10/31/91	56.0	48.0	64.0	22.0
11/25/91	76.0	28.0	64.0	68.0
12/18/91	46.0	66.0	14.0	48.0

Total Suspended Solids (mg/l)

Sample Date	1	7	11	8
01/16/91	1.0	<1.0	1.0	1.1
02/13/91	1.7	1.8	1.7	1.6
03/28/91	<1.0	4.0	2.0	<1.0
04/25/91	<1.0	-	-	-
05/29/91	9.0	-	-	-
06/27/91	2.0	-	-	-
07/30/91	3.0	-	-	-
08/27/91	2.0	-	-	-
09/30/91	4.0	-	-	-
10/31/91	1.0	<1.0	<1.0	<1.0
11/25/91	<1.0	8.0	<1.0	<1.0
12/18/91	<1.0	1.0	1.0	2.0

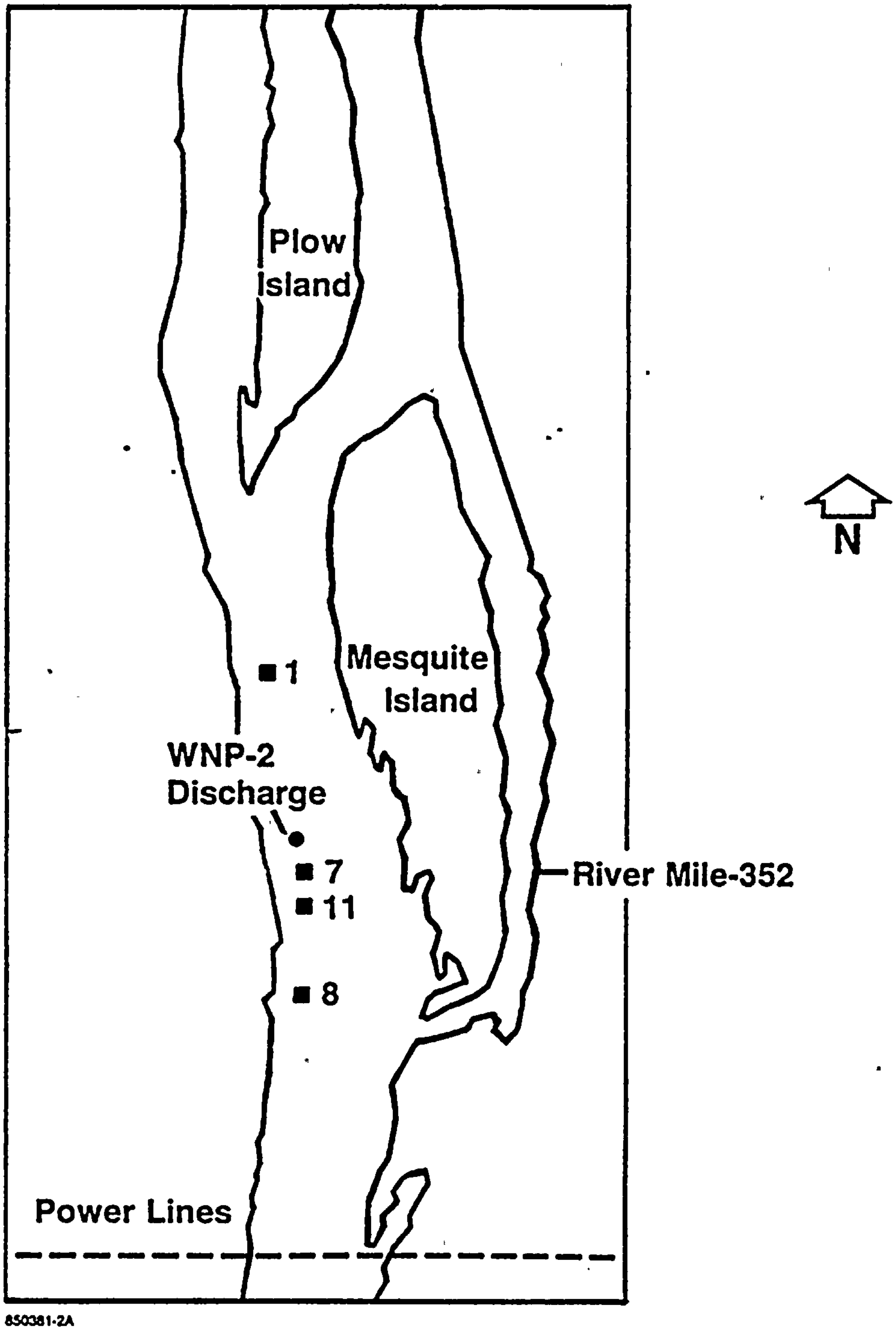

Figure 4-1. Location of Sampling Stations in the Columbia River

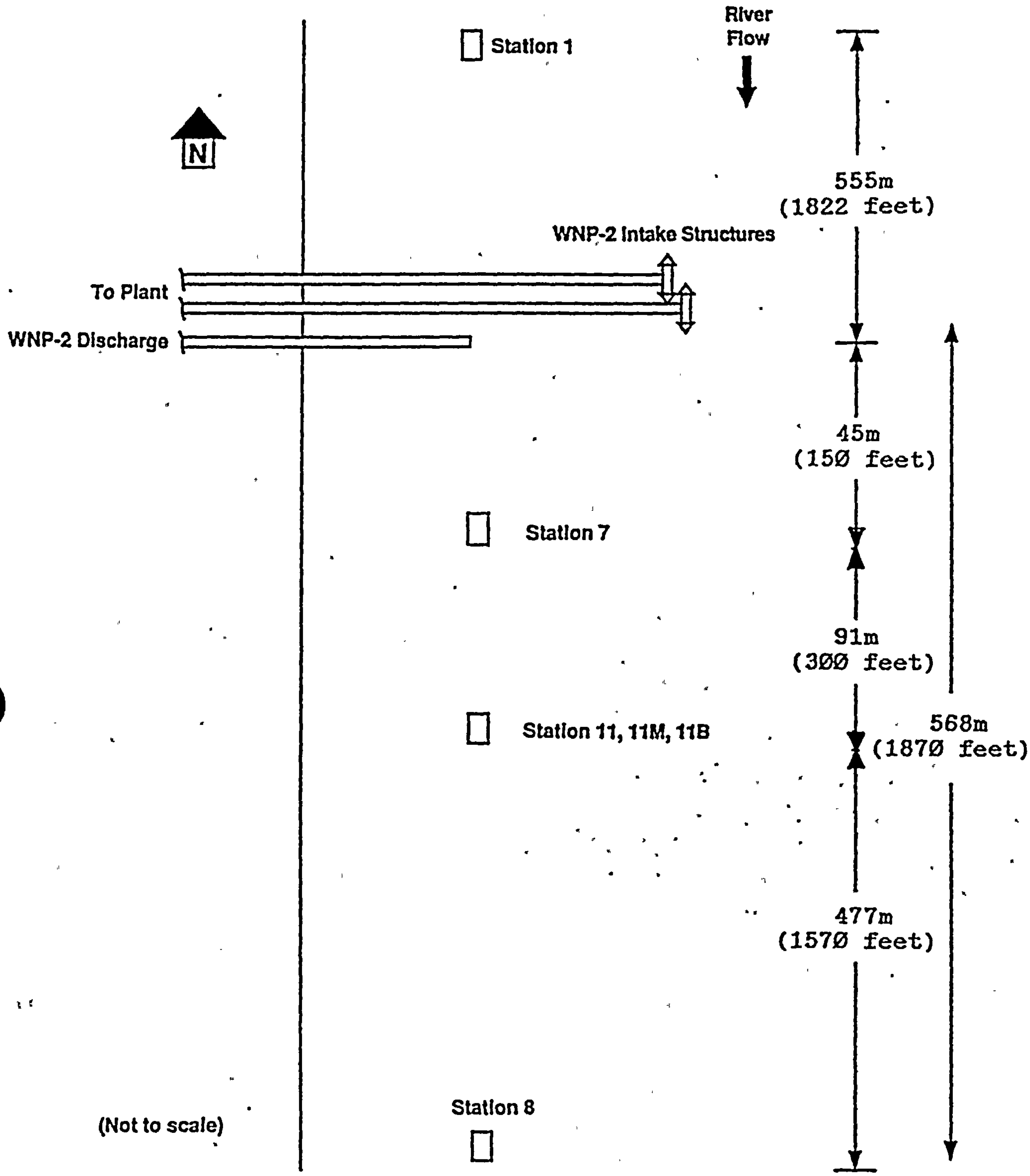

Figure 4-2. Sampling Station Locations for Water Chemistry

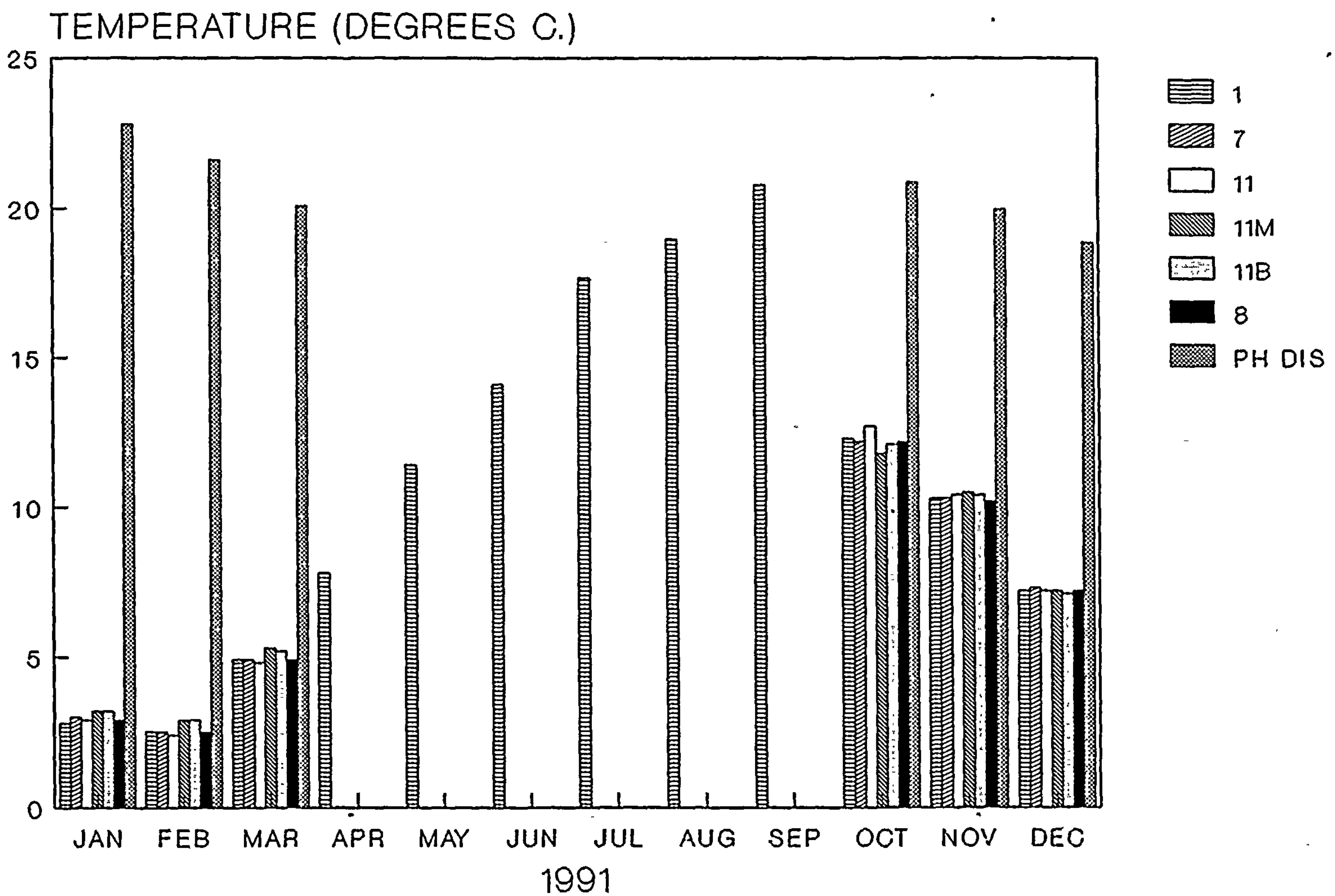

FIGURE 4-3 Columbia River and Plant Discharge Temperature Measurements During 1991

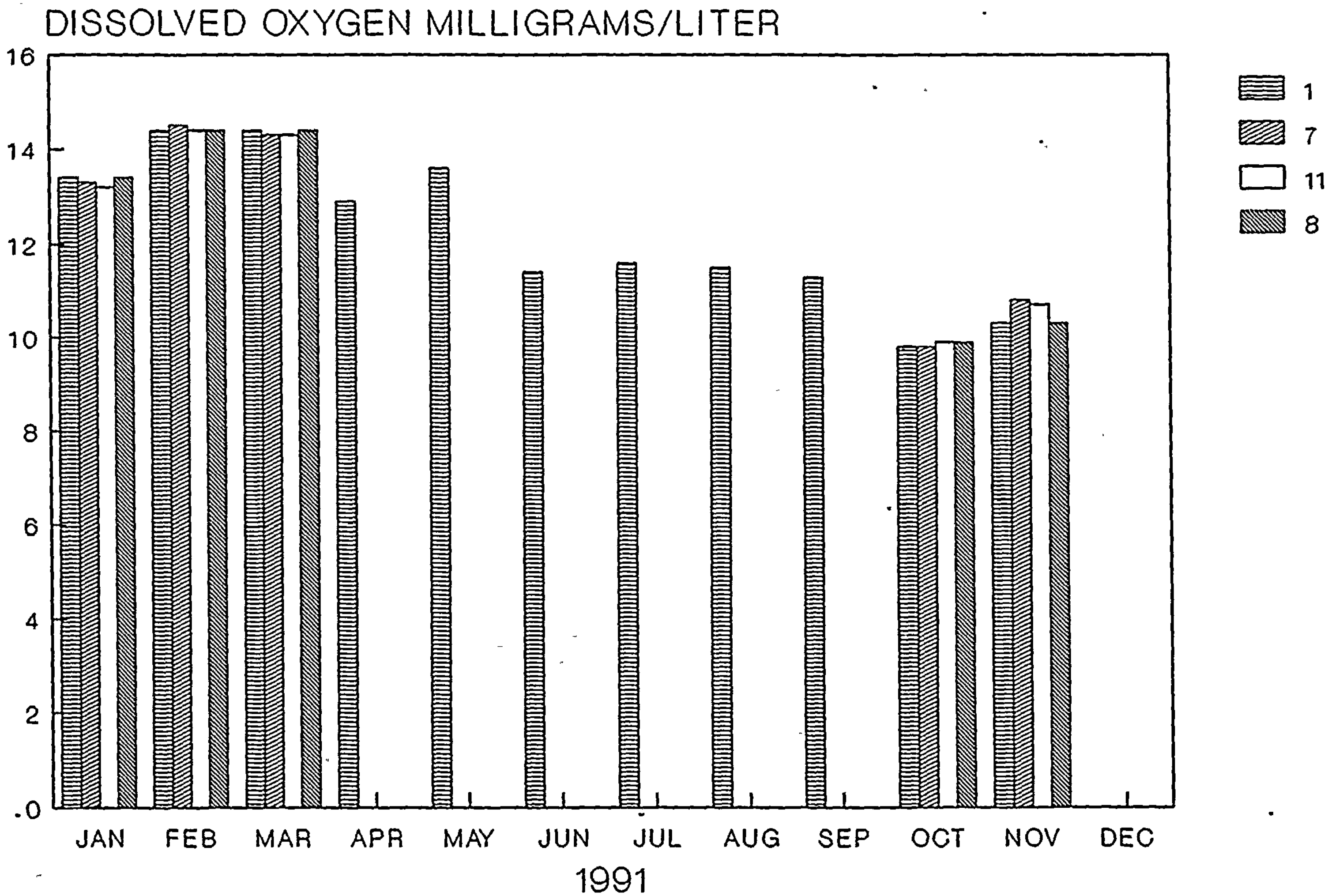

FIGURE 4-4 Columbia River Dissolved Oxygen Measurements at Four Stations During 1991

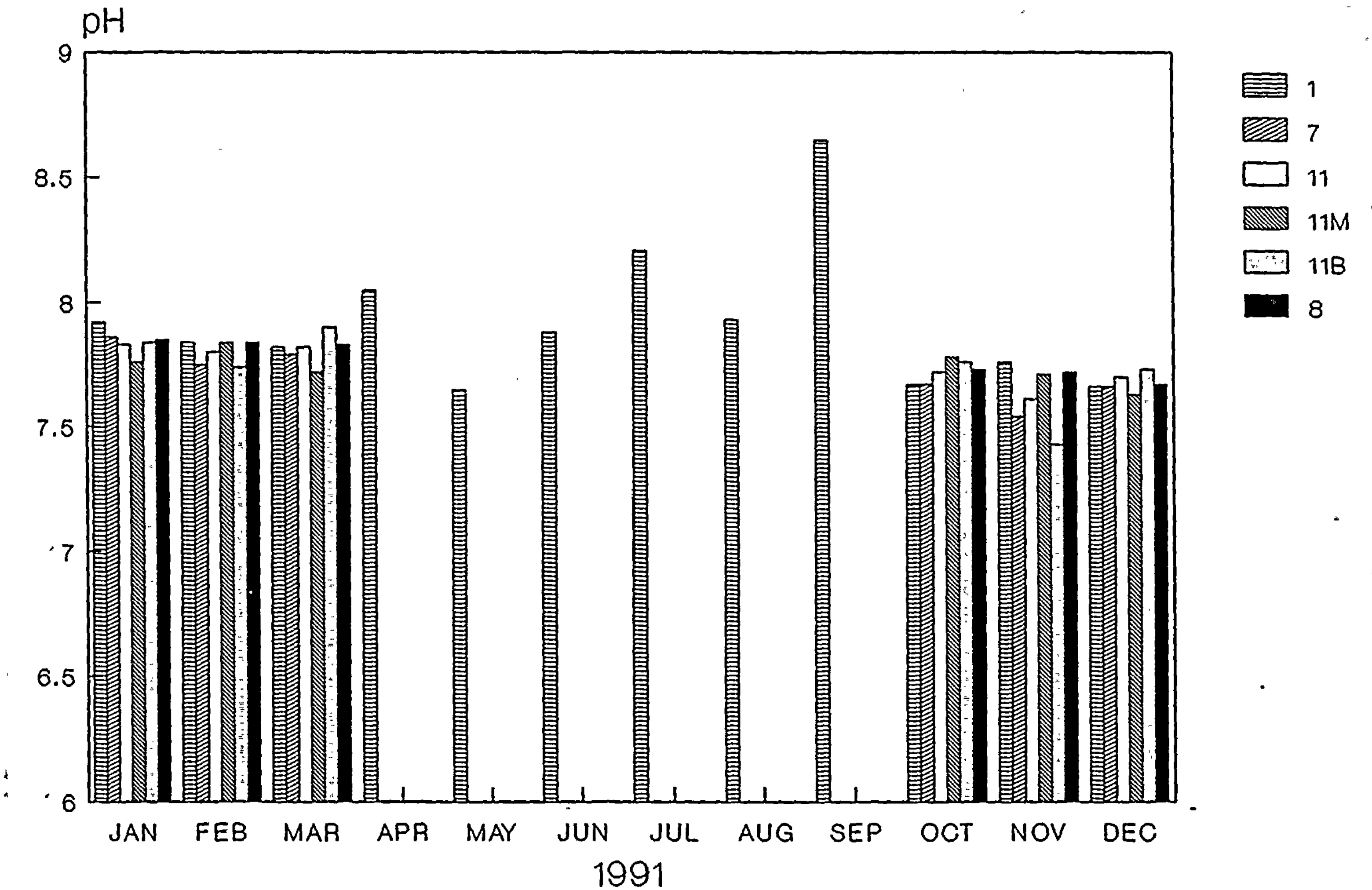

FIGURE 4-5 Columbia River pH
Measurements at Six Stations During 1991

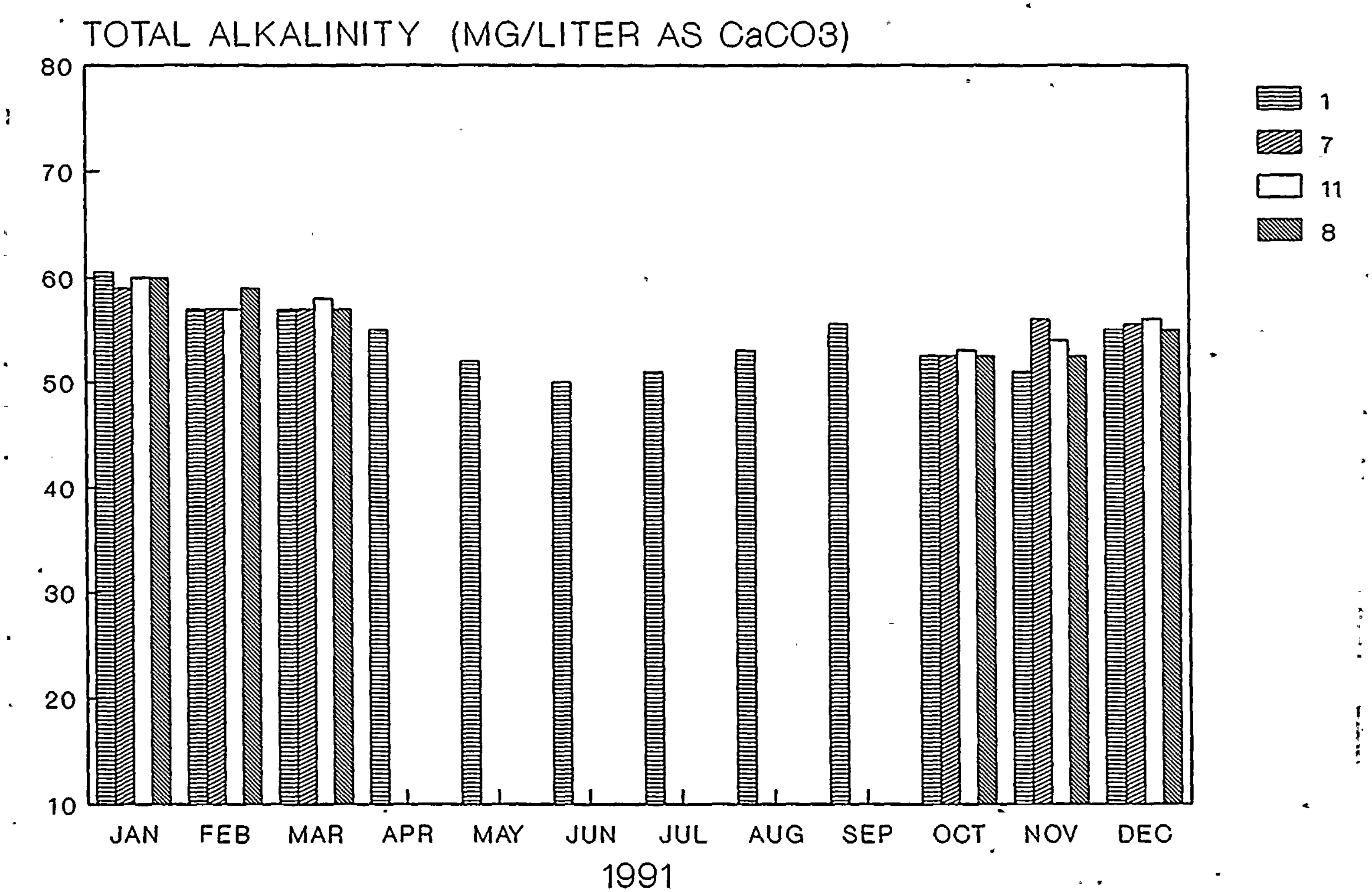

FIGURE 4-6 Columbia River Total Alkalinity Measurements at Four Stations During 1991

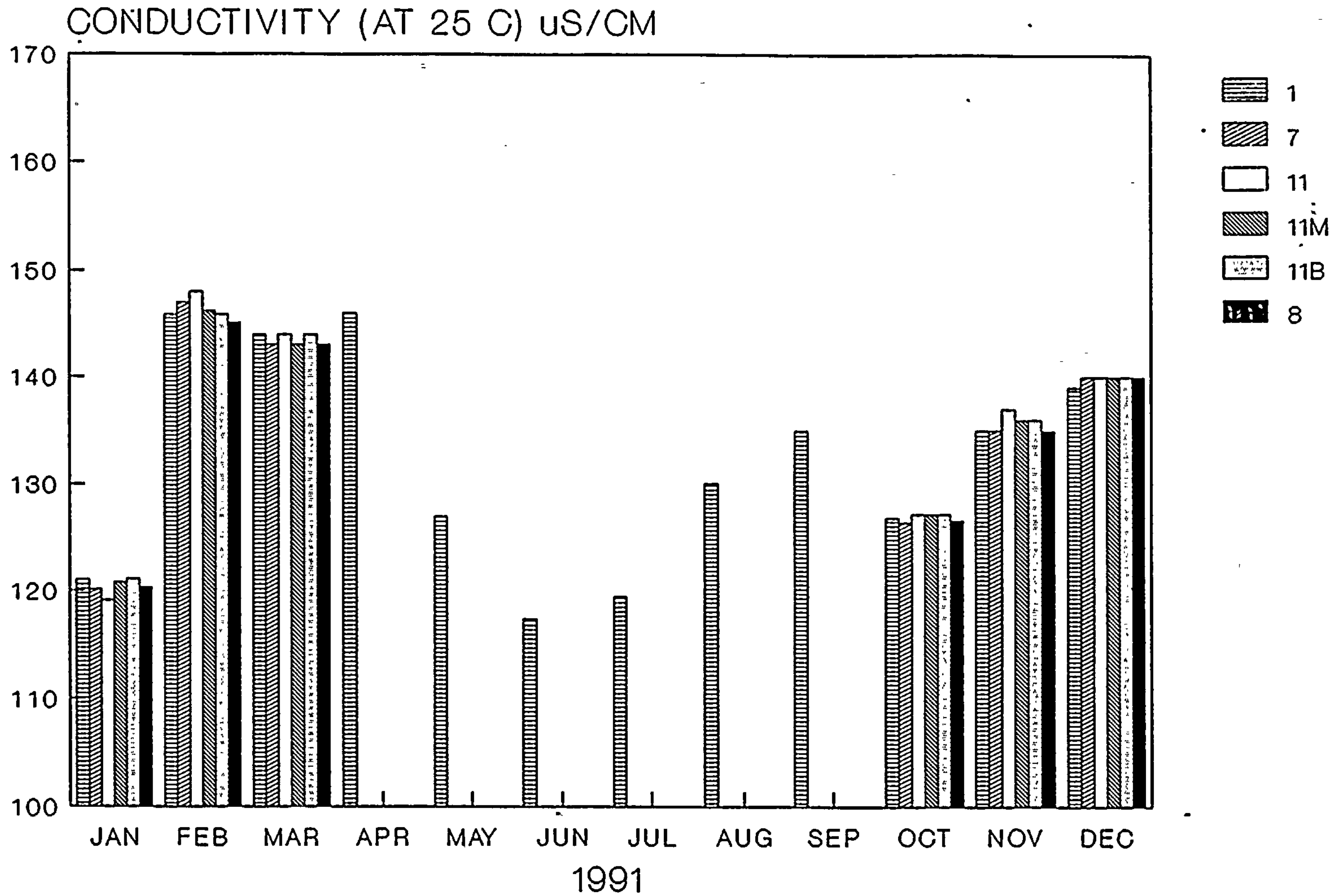

FIGURE 4-7 Columbia River Conductivity Measurements at Six Stations During 1991

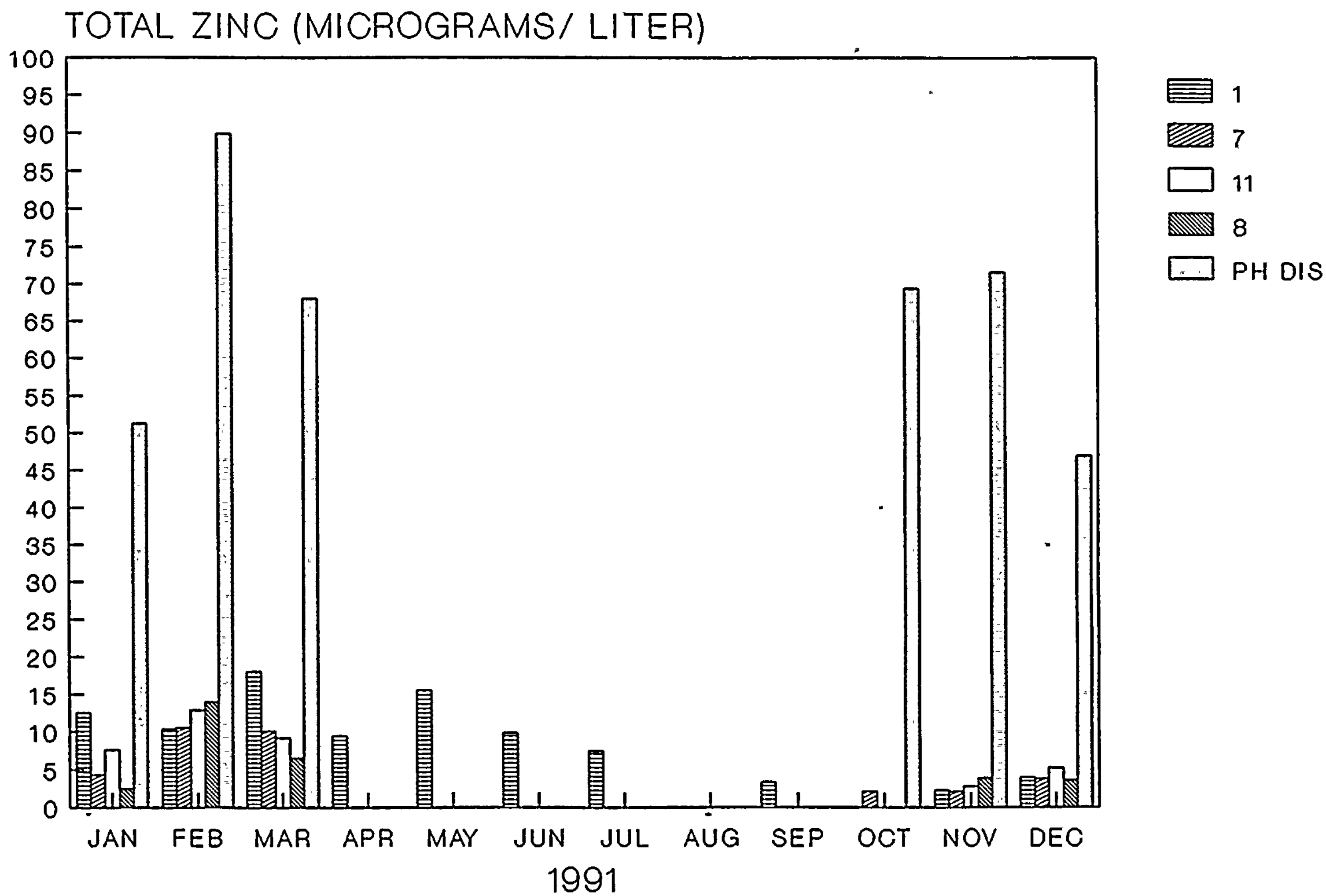

FIGURE 4-8 Columbia River and Plant
Discharge Total Zinc Measurements
During 1991

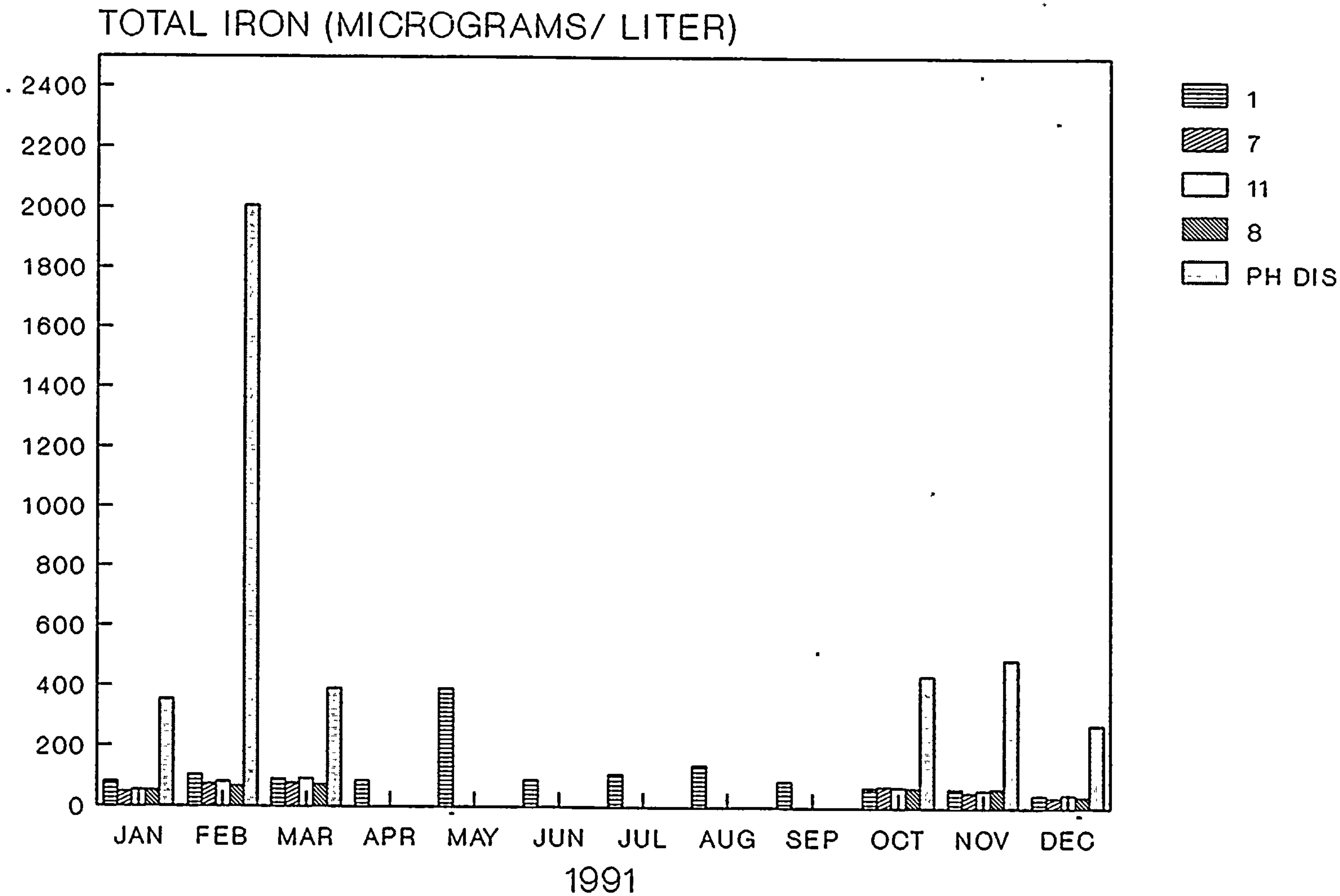

FIGURE 4-9 Columbia River and Plant
Discharge Total Iron Measurements
During 1991

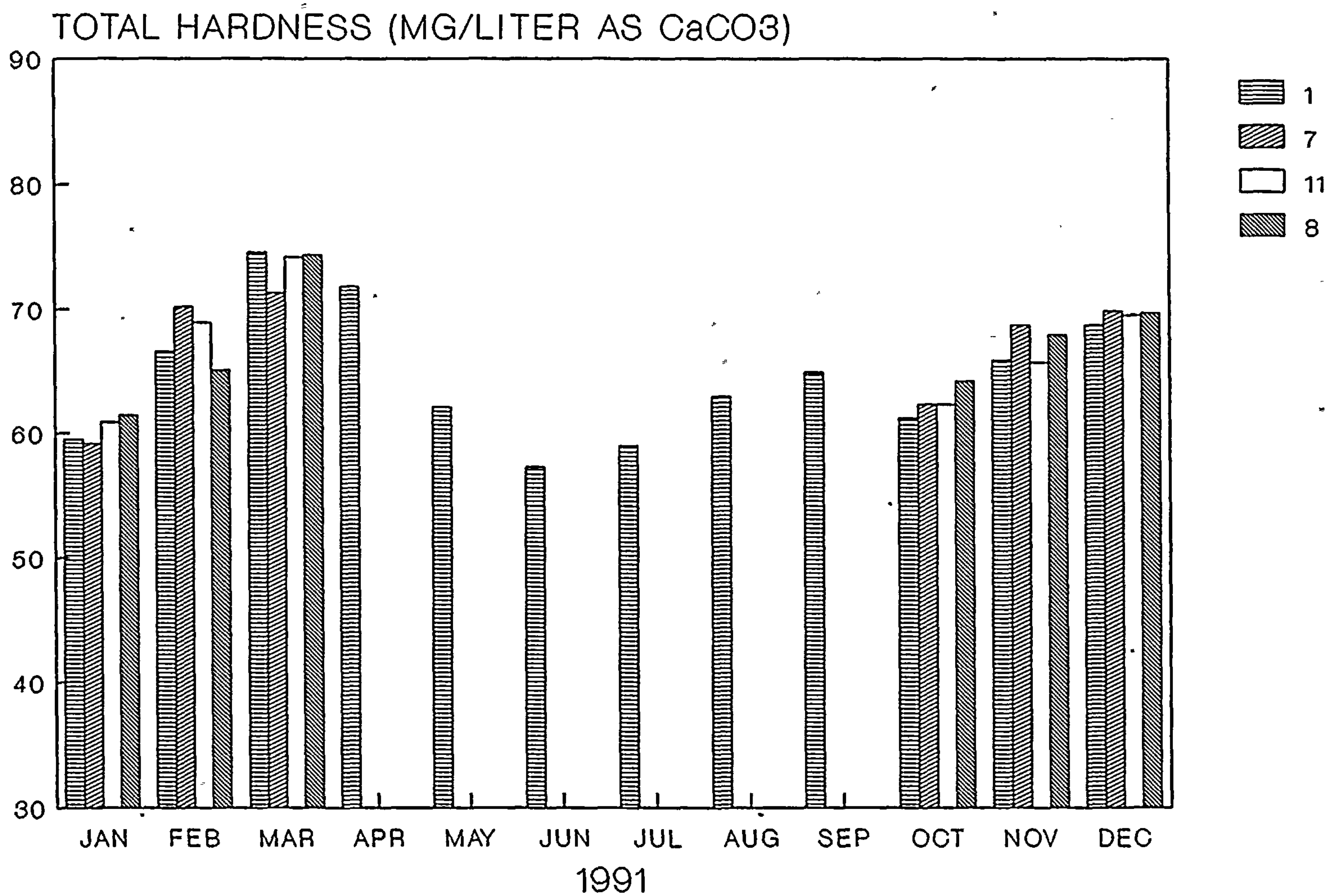

FIGURE 4-10 Columbia River Total
Hardness Measurements at Four Stations
During 1991

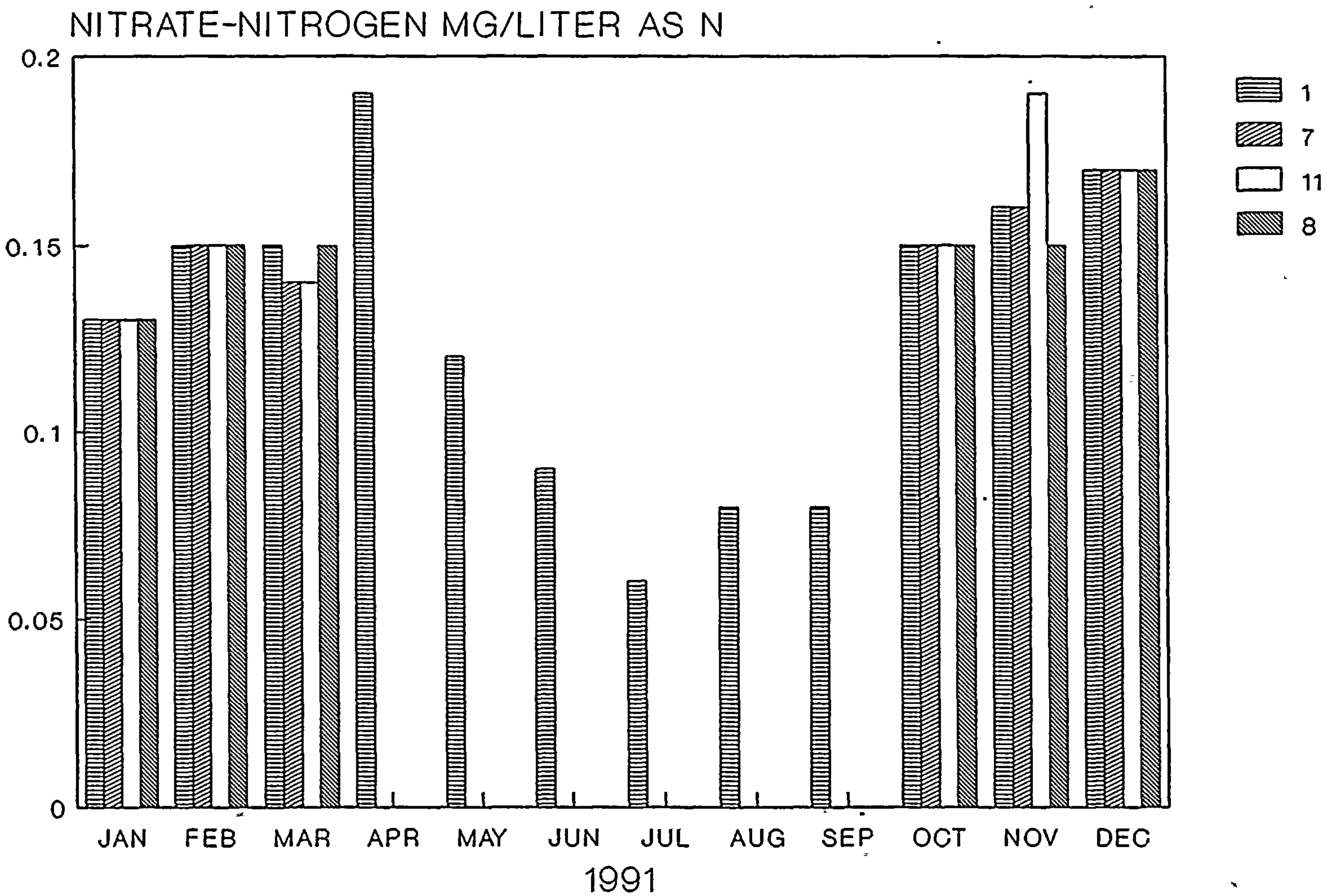

FIGURE 4-11 Columbia River Nitrate - Nitrogen Measurements at Four Stations During 1991

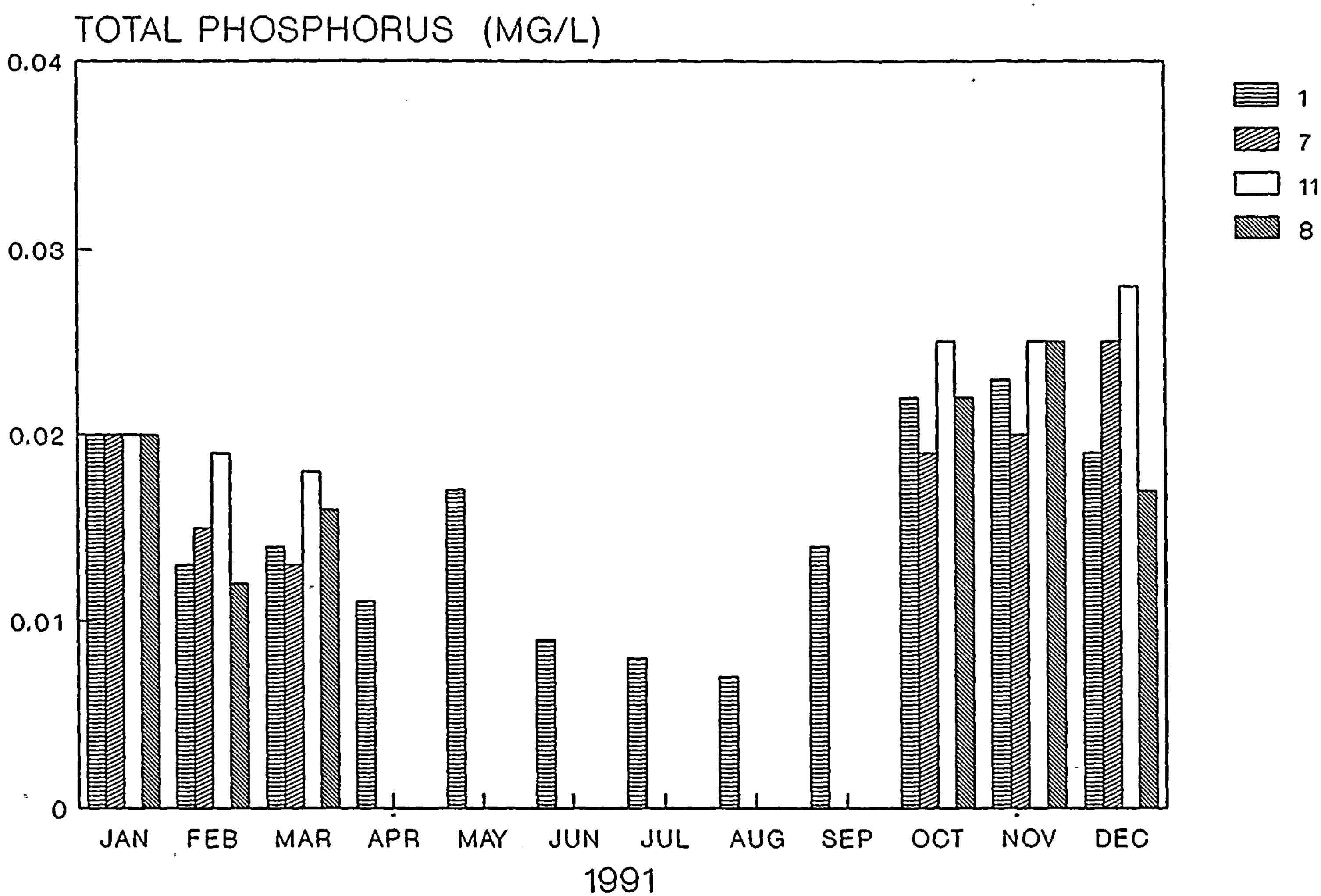

FIGURE 4-12 Columbia River Total Phosphorus Measurements at Four Stations During 1991

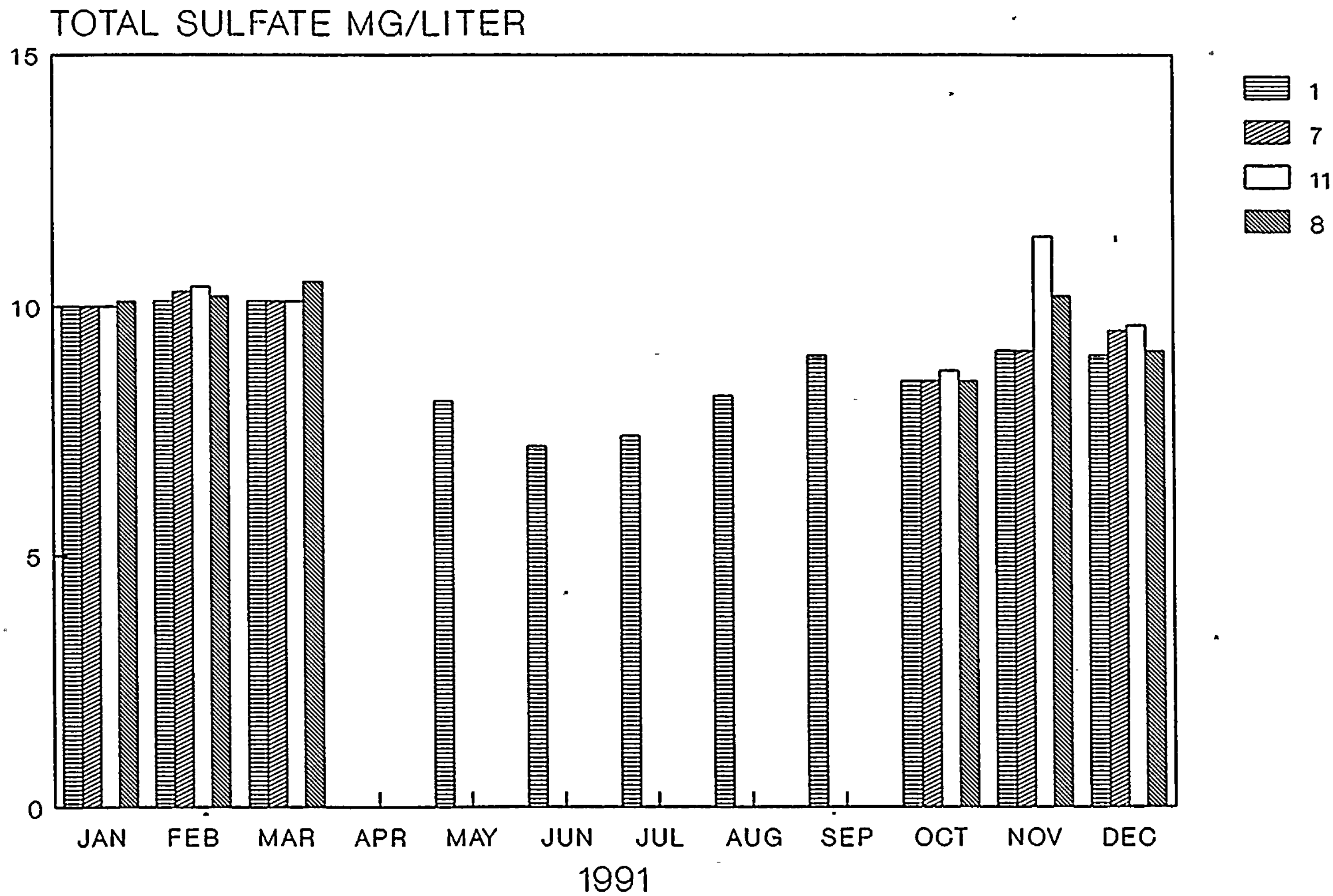

FIGURE 4-13 Columbia River Total Sulfate Measurements at Four Stations During 1991

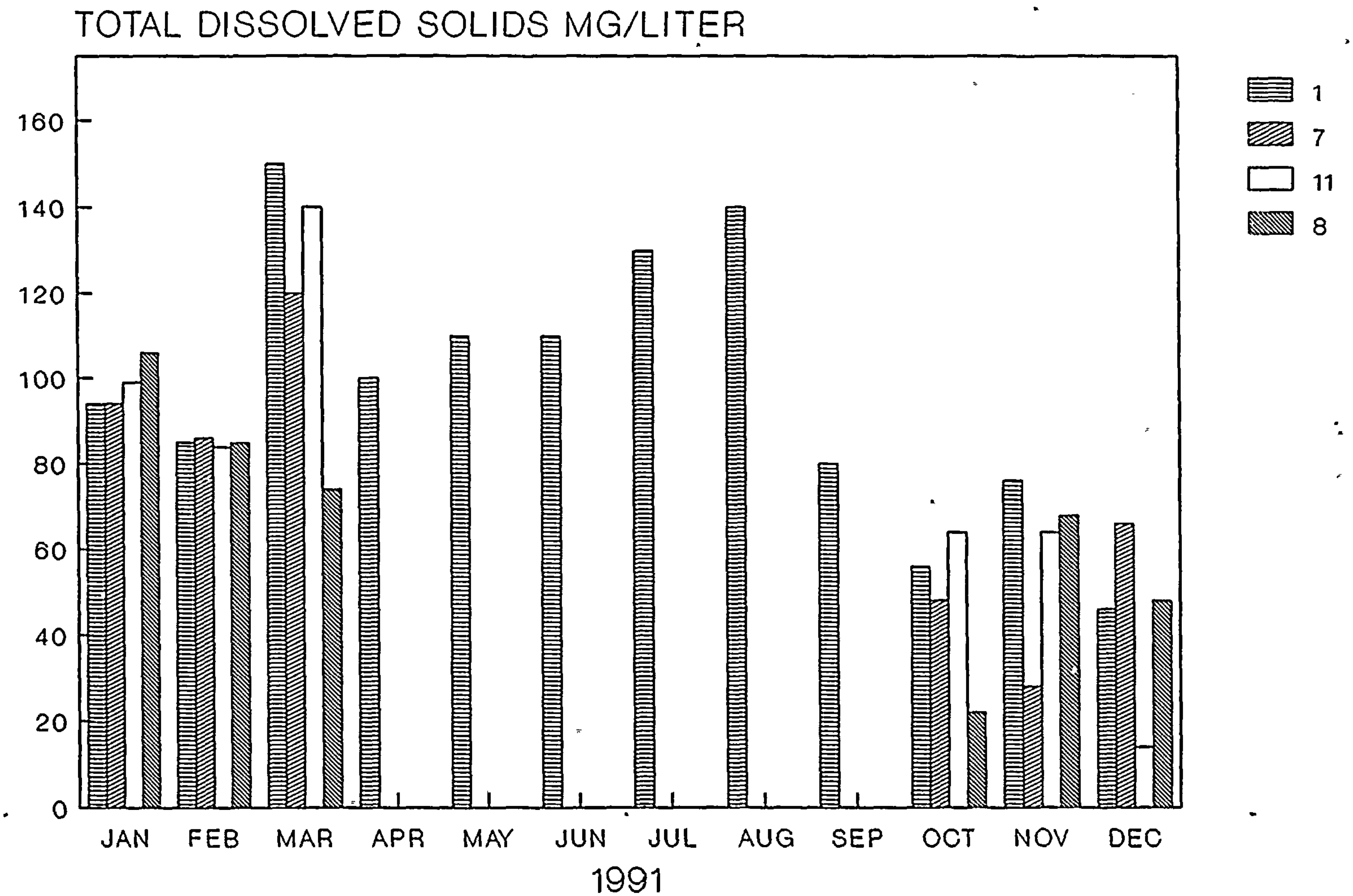

FIGURE 4-14 Columbia River Total Dissolved Solids Measurements at Four Stations During 1991

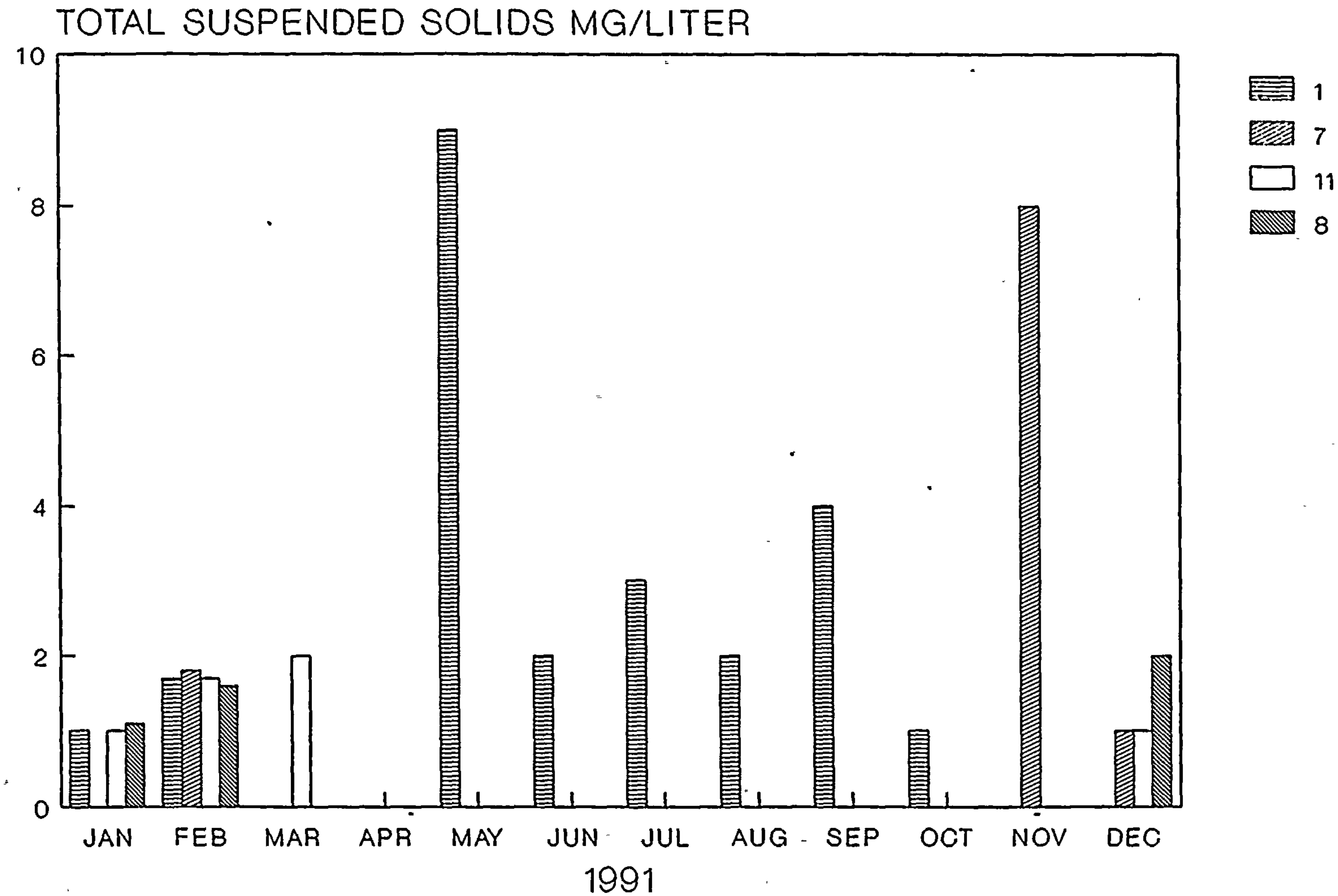

FIGURE 4-15 Columbia River Total Suspended Solids Measurements at Four Stations During 1991

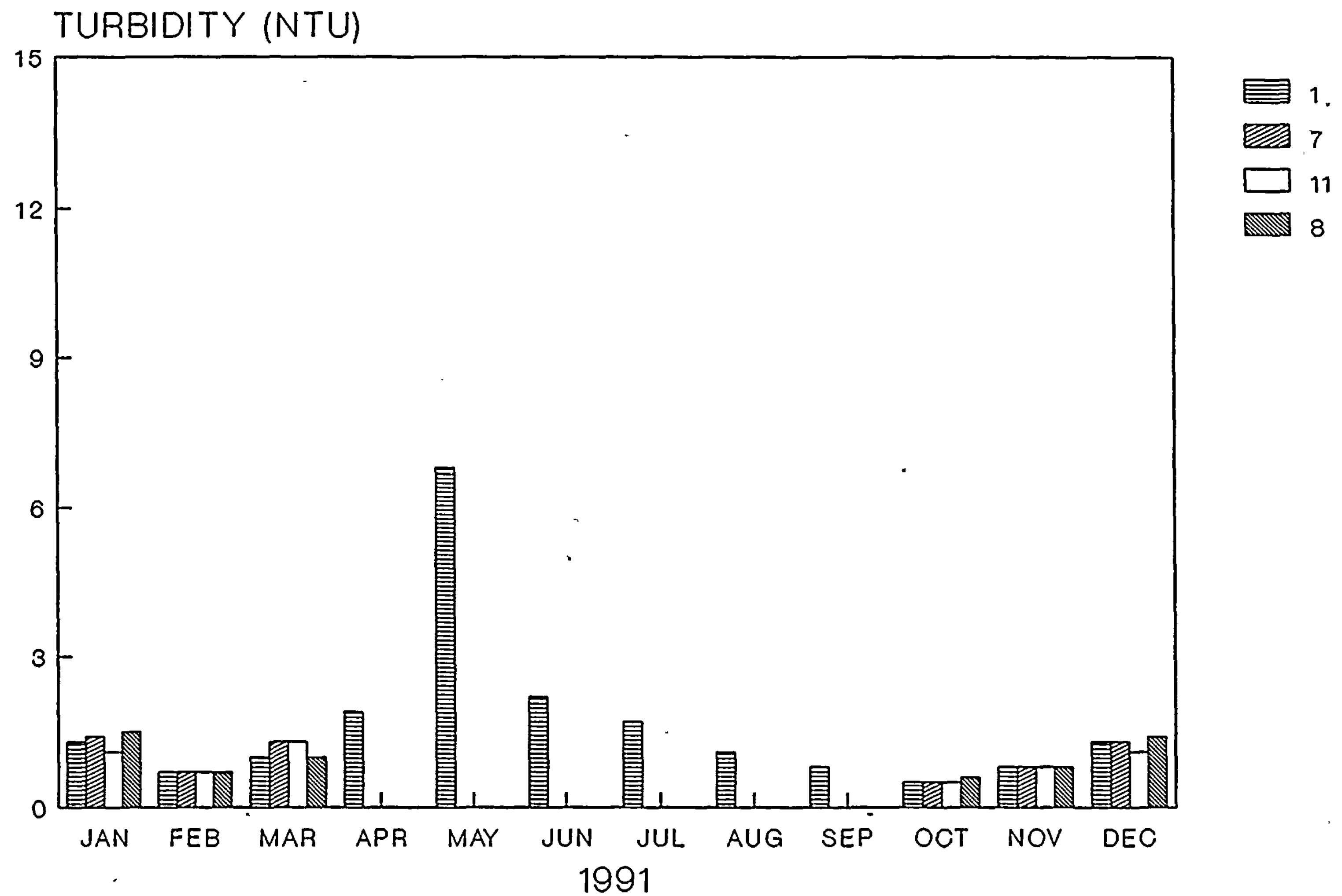

FIGURE 4-16 Columbia River Turbidity Measurements at Four Stations During 1991

5.0 COOLING TOWER DRIFT STUDIES

5.1 INTRODUCTION

The cooling tower drift studies were designed to identify any impact of cooling tower operation upon the surrounding plant communities, as well as any edaphic impacts. The program includes the measurement of herbaceous and shrub canopy cover, shrub density, herbaceous phytomass, vegetation chemistry and soil chemistry. Soil chemical parameters measured include pH, carbonate, bicarbonate, sulfate, chloride, sodium, potassium, calcium, magnesium, copper, zinc, lead, chromium, nickel, cadmium, and conductivity. Vegetation chemistry includes extractable sulfate, chloride and total copper. This study provides operational data for comparison with preoperational data and meets the requirements of Washington State Energy Facility Site Evaluation Council (EFSEC) Resolution 239, dated September 14, 1987.

In past years, sampling was conducted in May at each of nine permanent stations, four grassland Stations G01-G04 and five shrub Stations S01-S05. In 1988, preliminary data was obtained for six additional stations. In 1989, the additional six stations were added to the sampling program, four grassland sites G05, G06, G07 and G08 and 2 shrub Stations S06 and S07. Two of these Stations, S06 and S07 are on the east side of the Columbia River in Franklin County. Figure 5-1 shows the location of each station. The orientation of the various components including transects and productivity plots within each community are depicted in Figure 5-2.

5.2 MATERIALS AND METHODS

5.2.1 Herbaceous Canopy Cover

Fifty microplots (20 cm x 50 cm) were placed at 1-m intervals on alternate sides of the herbaceous transect (Figure 5-2). Canopy cover was estimated for each species occurring

within a microplot using Daubenmire's (1968) cover classes. Data were recorded on a standard data sheet.

Quality assurance was accomplished by twice sampling three randomly selected microplots on each herbaceous transect. The entire transect was resampled if cover estimates for any major species (>50 percent frequency) differed by more than one cover class.

All vegetation studies including cover, density, productivity, and chemistry were sampled, as in previous years, at the peak of the cheatgrass growth cycle known as the purple stage (Klemmedson and Smith 1964).

5.2.2 Herbaceous Phytomass

Phytomass sampling was conducted concurrently with cover sampling. Phytomass sampling plots were randomly located within an area adjacent to the permanent transects or plots (Figure 5-2). At each station, all live herbaceous vegetation rooted in five randomly located microplots (20 x 50 cm) was clipped to ground level and placed in paper bags. Each bag was stapled shut and labeled with station code, plot number, date and personnel.

Sample bags were transported to the laboratory, opened, and placed in a drying oven until a consistent weight was obtained. Following drying, the bags were removed singly from the oven and their contents immediately weighed to the nearest 0.1 g. Laboratory quality assurance consisted of independently reworking 10 percent of the phytomass samples to assess data validity and reliability.

5.2.3 Shrub Canopy Cover

Five 50-m lines were used to measure shrub canopy cover in each of the seven shrub plots (Figure 5-2). Whenever a shrub was crossed by a tape stretched between the end posts, its species and the distance (cm) at which it intercepted the line were recorded. For each shrub plot, intercept distances of each species along all five lines were summed to give a total intercept distance. From this, a shrub canopy cover value (percent) was obtained by dividing total intercept distance by total line length.

Quality assurance procedures consisted of twice sampling one major species along a randomly selected shrub transect. Resampling was conducted if intercept lengths differed by more than 10 percent.

5.2.4 Shrub Density

Individual live shrubs were counted and recorded by species within each of the four strips delineated by shrub intercept transects (Figure 5-2). Number of shrubs per strip were summed to obtain shrub density by species for the entire 1000 m^2 plot. Sampling was concurrent with cover sampling.

Quality assurance consisted of resampling one randomly selected species within one strip. Resampling was conducted if the count difference exceeded one individual.

5.2.5 Soil Chemistry

At each of the fifteen grassland and shrub stations, five soil samples were collected from the top 15 cm of soil with a clean stainless steel trowel. The samples were placed in 250 ml sterile plastic cups with lids, labeled and refrigerated at 4°C. Sixteen parameters were analyzed in each sample including pH, bicarbonate, carbonate, conductivity, sulfate, chloride, copper, zinc, nickel, cadmium, lead, chromium, calcium, magnesium, sodium and

potassium. Samples were analyzed for pH, bicarbonate, carbonate, sulfate, chloride and conductivity according to Methods of Soil Analysis (1965). Samples for chromium, cadmium and lead were analyzed by graphite furnace atomic absorption spectroscopy according to Methods for Chemical Analysis of Water and Wastes (USEPA 1983). The remaining elements were analyzed by inductively coupled plasma emission spectroscopy, ICPES (EPA 1983). Aliquots of soil for trace metal analyses were digested according to Gilman (1989). Preservation times and conditions, when utilized, were according to EPA (1983).

Laboratory quality control comprised 10% - 20% of the sample analysis load. Routine quality control samples included internal laboratory check standards, reagent blanks, and prepared EPA or NIST controls.

5.2.6 Vegetation Chemistry

Samples of Bromus tectorum, Poa sandbergii, Artemisia tridentata and Purshia tridentata were collected at each station. Two species were substituted at some of the stations due to absence of one or more of those listed above. Substitute species were Phlox longifolia and Sisymbrium altissimum. Samples were collected as close to the soil sampling station as possible. Sufficient quantities of leafy material of each species were collected to yield at least five grams of dry weight. The clipped material was sealed in a plastic bag, labeled and refrigerated at 4°C until sample preparation.

In the laboratory, the clipped plant tissue was oven dried to a constant weight, ground in a Wiley mill and digested according to Gilman (1989). Sulfate was analyzed by nephalometry and chloride by mercuric chloride titration according to USEPA (1983). Copper was analyzed by ICPES according to USEPA (1983).

5.3 RESULTS AND DISCUSSION

During the 1991 season, 59 plant taxa were observed in the study area. These are presented in Table 5-1. Table 5-2 lists by year the species of vascular plants observed during field activities from 1975-1991. Many of the graphs will depict a preoperational, operational and 1991 status. The preoperational data is that which was collected annually prior to WNP-2, becoming fully operational (1980-1984). Operational data is that which is collected after 1984 but not including the current year (1991), which is listed separately.

5.3.1 Herbaceous Cover

Herbaceous cover data for 1991 are summarized in Tables 5-3 and 5-4. Figures 5-3 and 5-4 provide a comparison of shrub and grassland sites (annual grasses - AG, perennial grasses - PG, annual forbs - AF, and perennial forbs - PF) with the data of previous years. There is a noticeable trend of the herbaceous cover reverting back to its original state prior to the fire of 1984.

Total herbaceous cover averaged 76.97% in 1991 which represents a 68.94% increase from 1990 (45.56%). As in previous years, the dominant annual grass was Bromus tectorum with 32.81% cover, a 27.2% increase over last year. Poa sandbergii was the dominant perennial grass at thirteen of the fifteen stations. Stipa comata averaged 2.38% cover, a 22.69% increase over last year (1.94%).

Total annual forb cover increased markedly, from 5.8% in 1990 to 14.77% in 1991 (a 154.7% increase). Sisymbrium altissimum was the dominant species with 8.54% followed by Holosteum umbellatum (2.55%) and Descurainia pinnata with .56%.

Perennial forb cover increased 13.64% over 1990 (1.98%). The dominant species continued to be Cymopterus terebinthinus (0.86%) and Balsamorhiza careyana (0.42%). Oenothera pallida increased markedly, from 0.04% in 1990 to 0.41% in 1991.

Species frequency values (%) are noticeably higher than in the previous years data for annual forbs (Table 5-5). The highest frequency value for Sisymbrium altissimum for 1990 was 46% at station GO7. This year the highest frequency value is 76% at station SO4. Stations GO7 and SO4 frequency values for 1990 were 22% and 42% respectively. The greatest diversity of species was observed at station SO2 (21). Station SO7 increased in diversity of species from 2 in 1990 to 7 in 1991. Station SO7 also shows a mean frequency value of 50% for Descurainia pinnata. The total species per site increased at ten of the fifteen stations. A small population of Fritillaria pudica was observed at station SO4 for the first time. No significant decreases in species were observed at the individual stations.

Growing season precipitation increased 17.56% from 1990 (6.83 cm vs 8.03 cm), with the total precipitation for 1991 being 17.14 cm. Mean temperature during the growing season was 4.46°C with the average temperature for the year being 12.44°C.

5.3.2 Herbaceous Phytomass

Mean production of herbaceous phytomass in 1991 was 141.95 g/m^2, a noticeable increase from last year (34.95 g/m^2). At grassland and shrub stations the phytomass production averaged 124.1 g/m^2 and 159.8 g/m^2 respectively. Mean herbaceous phytomass production at grassland stations and at shrub stations for 1975 through 1991 is shown graphically in Figure 5-5 (Stations G05, G06, G07, G08, S06 and S07 were not added until 1989) and is summarized in Table 5-6. Table 5-7 presents mean phytomass values for each station in each year since 1975. Mean herbaceous phytomass and percent herbaceous cover for each station from 1980 through 1991 are presented graphically in Figures 5-6 through 5-9.

5.3.3 Shrub Cover and Density

There are four shrub species in the study area: Artemisia tridentata, Purshia tridentata, Chrysothamnus nauseosus and Chrysothamnus viscidiflorus. Eriogonum niveum (a subshrub) and Opuntia polyacantha (a cactus) are also present, however, they are not included in the cover data. During a 1984 August range fire, all viable shrubs were completely destroyed at Stations SO2 and SO4, while the only individuals surviving at Station SO1 were isolated clumps of low growing Eriogonum niveum.

Shrub density and cover data continue to reflect recovery from the 1984 fire. Percent cover measurements taken in 1991 are very similar to those measured in 1990 with an overall slight decrease in average cover (1.44% versus 1.56%). Shrub density increased slightly at Station SO3, and decreased at Stations SO1, SO4, and SO5. Shrub density data for 1991 is summarized in Table 5-8, while shrub density data at each station from 1980 through 1991 is presented in Figure 5-10. Shrub cover data for 1991 is summarized in Table 5-9, while Figure 5-11 presents mean shrub cover values measured from 1975 through 1991. Shrub cover and density for 1991 at the five original shrub stations are presented graphically in Figure 5-12.

5.3.4 Soil Chemistry

The results of the 1991 soil chemical analyses are presented in Table 5-10 and are shown graphically in Figures 5-13 through 5-20.

Most metallic element concentrations were within the ranges observed in previous years. The cadmium and chromium concentrations of Station SO7 are slightly higher than those observed at the other stations.

Bicarbonate was similar to that observed in past data. Conductivity was generally within previous ranges at all stations. There is no concentration of carbonate, due to the pH level of the samples (< 8.3). The pH value has to be above 8.3 in order for carbonate to be present. There was no significant change in pH at any of the stations. Chloride and sulfate concentrations were within their expected ranges.

5.3.5 Vegetation Chemistry

The results of the 1991 vegetation chemical analyses are presented in Table 5-11 and shown graphically in Figures 5-21 through 5-30.

Total vegetation copper, extractable chloride and extractable sulfate concentrations were generally within the ranges previously observed in all of the species examined.

5.4 SUMMARY AND CONCLUSIONS

The 68.94% increase in mean herbaceous cover for 1991 (Figure 5-4) is directly associated with the 17.56% increase in precipitation during the 1990-91 growing season. A substantial increase in herbaceous phytomass was observed at all stations, except SO2 and GO4. The annual forb Sisymbrium altissimum was very abundant this year. The noticeable increase in herbaceous cover was due to the growth of this species. The remaining analyses were generally within the ranges previously observed. Changes in vegetation cover and density recorded in 1991 appear to be climatically (average growing season temperature 6.1°C and total precipitation 8.03 cm) induced with no sign of adverse impacts from the operation of WNP-2 cooling towers evident.

No adverse trends or impacts upon soil or vegetation chemistry are apparent from the seven years of operation.

5.5 REFERENCES

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Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, OH.

Gilman, Lee B. 1989. Microwave Sample Preparation. CEM Corporation.

Klemmedson, J. O. and J. G. Smith, 1964. Cheat Grass (Bromus tectorum L.) Bot. Rev. 30; 226-262.

Table 5-1. Vascular Plants Observed During 1991 Field Work

	Common Name
APIACEAE	Parsley Family
Cymopterus terebinthinus (Hook.) T.&G. var. terebinthinus	Turpentine cymopterus
Lomatium macrocarpum (Nutt.) Coult & Rose	Large-fruit lomatium
ASTERACEAE	Aster Family
Achillea millefolium L.	Yarrow
Antennaria dimorpha (Nutt.) T&G	Low pussy-toes
Artemisia tridentata Nutt.	Big sagebrush
Balsamorhiza careyana Gray	Carey's balsamroot
Chrysothamnus nauseosus (Pall.) Britt	Gray rabbitbrush
Chrysothamnus viscidiflorus (Hook.) Nutt	Green rabbitbrush
Crepis atrabarba Heller	Slender hawksbeard
Franseria acanthicarpa Hook.	Bur ragweed
Layia glandulosa (Hook.) H&A	White daisy tidytips
Tragopogon dubius Scop.	Yellow salsify
Aster canescens (Pursh)	Hoary Aster
BORAGINACEAE	Borage Family
Amsinckia lycopsoides Lehm.	Tarweed fiddleneck
Cryptantha circumscissa (H&A) Johnst.	Matted cryptantha
Cryptantha pterocarya (Torr.) Greene	Winged cryptantha
BRASSICACEAE	Mustard Family
Descurainia pinnata (Walt.) Britt.	Western tansymustard
Draba verna L.	Spring draba
Erysimum asperum (Nutt.) DC.	Prairie rocket
Sisymbrium altissimum L.	Tumblemustard
CACTACEAE	Cactus Family
Opuntia polyacantha Haw.	Starvation cactus

Table 5-1. (Continued)

	Common Name
CARYOPHYLLACEAE	Pink Family
Arenaria franklinii Dougl. var. franklinii	Franklin's sandwort
Holosteum umbellatum L.	Jagged chickweed
CHENOPODIACEAE	Chenopod Family
Grayia spinosa	
Salsola kali L.	Russian thistle
FABACEAE	Pea Family
Astragalus purshii Dougl.	Wooly-pod milk-vetch
Astragalus sclerocarpus Gray	Stalked-pod milk-vetch
Psoralea lanceolata Pursh	Lance-leaf scurf-pea
HYDROPHYLLACEAE	Waterleaf Family
Phacelia hastata Dougl.	Whiteleaf phacelia
Phacelia linearis (Pursh) Holz.	Threadleaf phacelia
LILIACEAE	Lily Family
Brodiaea douglasii Wats.	Douglas' brodiaea
Calochortus macrocarpus Dougl.	Sego lily
Fritillaria pudica (Pursh) Spreng.	Chocolate lily
LOASACEAE	Blazing-star Family
Mentzelia albicaulis Dougl. mentzelia	White-stemmed
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach	White-stemmed globe-mallow
ONAGRACEAE Family	Evening-primrose

Table 5-1. (Continued)

	Common Name
Oenothera pallida Lindl. var. pallida	White-stemmed evening-primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat
POACEAE	Grass Family
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron dasystachyum (Hoak.) Scribn.	Thick-spiked wheatgrass
Agropyron spicatum (Pursh) Scribn. & Smith	Bluebunch wheatgrass
Bromus tectorum L.	Cheatgrass
Festuca octoflora Walt.	Six-weeks fescue
Koeleria cristata Pers.	Prairie Junegrass
Oryzopsis hymenoides (R&S) Ricker	Indian ricegrass
Poa sandbergii Vasey	Sandberg's bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush squirreltail
Stipa comata Trin & Rupr.	Needle-and-thread
POLEMONIACEAE	Phlox Family
Gilia minutiflora Benth.	Gilia
Gilia sinuata Dougl.	Shy gilia
Microsteris gracilis (Hook.) Greene var. humilior (Hook.) Cronq.	Pink microsteris
Phlox longifolia	Long-leaf phlox
POLYGONACEAE	Buckwheat Family
Eriogonum niveum Dougl.	Snow buckwheat
Rumex venosus Pursh	Wild begonia
RANUNCULACEAE	Buttercup Family
Delphinium nuttallianum Pritz. ex Walpers	Larkspur
ROSACEAE	Rose Family
Purshia tridentata (Pursh) DC.	Antelope bitterbursh

Table 5-1. (Continued)

	Common Name
SANTALACEAE	Sandalwood Family
Comandra umbellata (L.) Nutt.	Bastard toad-flax
SAXIFRAGACEAE	
Ribes aureum Pursh	Golden current
SCROPHULARIACEAE	Figwort Family
Penstemon acuminatus Dougl.	Sand-dune penstemon
VALERIANACEAE	Valerian Family
Plectritis macrocera T&G	Longhorn plectritis

Table 5-2. Vascular Plants Observed During 1975-1991 Field Work

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Annual Grasses																	
Bromus tectorum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Festuca octoflora	X					X	X	X	X	X	X	X	X	X	X	X	X
Festuca sp.		X		X													
Perennial Grasses																	
Agropyron cristatum							X	X	X	X	X	X	X	X	X	X	X
Agropyron dasystachyum			X			X	X	X	X	X	X	X	X	X			X
Agropyron spicatum						X	X	X	X	X	X	X	X	X	X	X	X
Koeleria cristata				X		X	X	X	X	X	X	X	X	X	X	X	X
Oryzopsis hymenoides	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poa sandbergii							X	X	X	X	X	X	X	X	X	X	X
Poa scabrella							X	X	X	X		X	X				
Sitanion hystrix						X		X	X	X	X	X	X	X	X	X	X
Stipa comata		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stipa thurberiana					X												

Table 5-2. (Cont'd)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Annual Forbs																	
Franseria acanthicarpa	X		X	X	X			X	X	X	X	X	X	X	X	X	X
Amsinckia lycopsoides	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Amsinckia menziesii							X	X									
Chenopodium leptophyllum			X												X	X	X
Cryptantha pterocarya		X		X		X	X	X	X	X	X	X	X	X	X	X	X
Cryptantha circumscissa	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Descurainia pinnata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Draba verna	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Epilobium paniculatum	X	X	X	X	X												
Erysimum asperum							X	X	X	X	X	X	X	X	X	X	X
Gilia minutiflora					X				X		X	X	X	X	X	X	X
Gilia sinuata						X		X	X	X	X	X	X	X	X	X	X
Holosteum umbellatum	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lagophylla ramosissima						X											
Layia glandulosa			X		X			X	X	X	X	X	X	X	X	X	X
Mentzelia albicaulis			X		X			X	X	X	X	X	X	X	X	X	X
Microsteris gracilis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Orobanche californica													X	X			X
Phacelia hastata							X	X	X	X	X	X	X	X	X	X	X
Phacelia linearis				X		X	X	X	X	X	X	X	X	X	X	X	X
Phacelia sp.		X															
Plantago patagonica	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plectritis macrocera		X							X		X	X	X	X	X	X	X

Table 5-2. (Cont'd

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Polemonium micranthum	X			X													
Salsola kali	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sisymbrium altissimum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tragopogon dubius				X			X	X	X	X	X	X	X	X	X	X	X
Perennial Forbs																	
Achillea millefolium	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
Antennaria dimorpha						X	X	X	X	X	X	X	X	X	X	X	X
Arenaria franklinii var. franklinii						X	X	X	X	X	X	X	X	X	X	X	X
Aster canescens (Machaeranthera canescens)		X			X				X	X	X	X	X	X	X	X	X
Astragalus lyallii			X														
Astragalus purshii	X	X				X	X	X	X	X	X	X	X	X	X	X	X
Astragalus sclerocarpus						X	X	X	X	X	X	X	X	X	X	X	X
Astragalus sp.				X													
Balsamorhiza careyana	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brodiaea douglasii	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brodiaea howellii				X													
Calochortus macrocarpus	X				X									X	X	X	X
Comandra umbellata	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crepis atrabarba		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cryptantha leucophaea						X	X	X	X		X	X					

Table 5-2. (Cont'd

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cymopterus terebinthinus	X			X		X	X	X	X	X	X	X	X	X	X	X	X
Delphinium sp.				X					X	X	X	X	X	X	X	X	X
Erigeron divergens								X									
Fritillaria pudica									X	X	X	X	X	X	X	X	X
Lomatium macrocarpum	X		X		X	X	X	X	X	X	X	X	X	X	X	X	
Lomatium sp.				X													
Oenothera pallida	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Penstemon acuminatus							X	X	X	X	X	X	X	X	X	X	X
Penstemon sp.						X											
Phlox longifolia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Psoralea lanceolata	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Rumex venosus				X		X	X	X	X	X	X	X	X	X	X	X	X
Sphaeralcea munroana								X	X		X	X	X	X	X	X	X
Shrubs, subshrubs, cacti																	
Artemisia tridentata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chrysothamnus nauseosus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chrysothamnus viscidiflorus	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Eriogonum niveum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grayia Spinosa															X		X
Leptodactylon pungens									X	X							
Opuntia polyacantha	X			X		X	X	X	X	X	X	X	X	X	X	X	X
Purshia tridentata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ribes aureum											X	X	X	X	X	X	X

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07	AVERAGE G01-S07	AVERAGE G01-G04	AVERAGE S01-S05	AVG. G01-4, S01-S05
Annual Grasses																			
Bromus tectorum	26.15	20.80	65.55	18.90	36.35	35.35	48.30	38.25	40.25	15.25	40.05	38.05	45.15	17.85	5.90	32.81	32.85	35.75	34.46
Festuca octoflora	0.00	0.00	0.00	0.00	0.60	1.90	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.20	0.00	0.10	0.06
Total Annual Grass Cover	26.15	20.80	65.55	18.90	36.95	37.25	48.30	38.25	40.25	15.25	40.05	38.55	45.15	17.85	5.90	33.01	32.85	35.85	34.52
Perennial Grasses																			
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.75	0.00	0.00	0.17	0.00	0.51	0.28
Oryzopsis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.69	0.38
Poa sandbergii	41.75	50.55	1.35	21.30	23.55	4.90	18.90	22.40	7.60	20.65	26.35	14.45	0.00	36.10	60.60	23.36	28.74	13.81	20.44
Stipa comata	0.00	0.00	0.00	17.40	0.00	7.90	0.00	0.45	0.00	6.15	0.00	0.00	1.55	2.30	0.00	2.38	4.35	1.54	2.79
Total Perennial Grass Cover	41.75	50.55	1.35	38.70	23.55	12.80	18.90	22.85	7.60	32.05	26.35	14.45	2.30	38.40	60.60	26.15	33.09	16.55	23.90
Annual Forbs																			
Amsinckia lycopsoides	0.00	0.05	0.45	0.00	0.00	0.00	0.00	0.00	3.90	0.05	0.00	0.00	1.50	0.05	0.00	0.40	0.13	1.09	0.66
Chenopodium leptophyllum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	1.15	0.05	0.00	0.00	0.08	0.00	0.25	0.14
Cryptantha circumscissa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	2.80	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.57	0.32
Descurainia pinnata	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.85	0.10	0.00	0.15	0.05	0.05	0.00	0.08	0.01	0.23	0.13
Draba verna	0.10	0.25	1.65	0.65	1.20	1.70	1.70	2.15	0.60	0.15	1.35	0.10	1.00	0.00	0.00	0.84	0.66	0.64	0.65
Erysimum asperum	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.30	0.17
Franseria acanthacarpa	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.15	0.20	0.00	0.00	0.00	0.11	0.18	0.18	0.18
Gilia sinuata	0.00	0.00	0.00	0.00	1.15	3.65	4.90	2.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.01	0.01
Holosteum umbellatum	0.00	2.05	8.20	0.40	0.00	0.00	0.00	0.00	2.70	0.55	1.55	0.10	8.60	0.00	0.00	1.61	2.66	2.70	2.68
Layia gladulosa	0.00	0.00	0.00	0.00	0.30	1.05	0.60	1.75	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.06	0.03
Mentzelia albicaulis	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.75	1.55	0.00	0.00	0.05	0.00	0.00	0.19	0.00	0.47	0.26
Microsteris gracilis	0.00	0.00	2.35	0.00	0.00	0.00	0.00	0.40	1.90	0.15	0.30	0.70	0.90	0.00	0.00	0.45	0.59	0.79	0.70
Phacelia linearis	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.10	1.10	0.00	0.00	0.05	0.00	0.00	0.09	0.00	0.25	0.14
Plantago pategonica	0.05	0.30	0.00	0.45	0.05	0.10	1.15	0.55	0.00	1.85	2.25	0.00	0.30	0.00	0.00	0.47	0.20	0.88	0.58
Salsola kali	0.00	0.05	0.00	0.00	0.25	0.00	0.00	0.00	0.00	3.10	0.00	1.80	0.05	0.35	0.05	0.38	0.01	0.99	0.56
Sisymbrium altissimum	0.10	1.50	0.00	0.30	2.90	0.00	25.83	12.80	24.50	2.10	11.15	33.10	9.05	4.10	0.65	8.54	0.48	15.98	9.09
Total Annual Forb Cover	0.25	4.15	12.90	1.85	5.90	6.90	34.73	19.80	32.35	15.00	16.75	37.30	20.10	4.50	0.70	14.21	15.14	15.88	16.07
Perennial Forbs																			
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.56	0.31
Astragalus purshii	0.00	0.00	0.00	0.00	0.45	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.04	0.00	0.01	0.01
Aster canescens	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Balsamorhiza careyana	0.00	0.00	0.00	0.00	2.45	0.60	0.00	0.00	0.00	0.00	0.00	2.30	0.30	0.00	0.00	0.38	0.00	0.52	0.29
Comandra umbellata	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Crepis atrabarba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.05	0.00	0.14	0.08
Cymopterus terebinthinus	0.00	0.05	0.00	0.00	0.00	6.25	0.00	0.00	0.00	3.45	0.00	0.05	0.00	0.00	0.00	0.65	0.01	0.70	0.39
Oenothera pallida	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	4.45	0.10	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.91	0.51
Phlox longifolia	0.00	0.00	0.00	0.90	0.75	0.30	0.05	0.10	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.22	0.23	0.25	0.24
Rumex venosus	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Total Perennial Forb Cover	0.00	0.10	0.00	0.90	3.95	8.55	0.05	0.20	4.45	6.35	1.95	2.35	0.35	0.00	0.00	1.95	0.25	3.09	1.83
Total Herbaceous Cover	68.15	75.60	79.80	60.35	70.35	65.50	101.98	81.10	84.65	68.65	85.10	92.65	67.90	60.75	67.20	75.32	81.33	71.37	76.32

Table 5-3 Herbaceous Cover for Fifteen Sampling Stations - 1991

Table 5-4 Mean Herbaceous Cover for 1975 through 1991

CLASS	YEAR	S01	S02	S03	S04	S05	S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
AG	1975	49.90	35.30	43.80						43.00	43.90	43.00								43.45	43.18	43.18
PG	1975	0.60	2.00	4.50						2.37	3.70	5.50								4.60	3.26	3.26
AF	1975	14.60	11.70	11.70						12.67	29.50	13.00								21.25	16.10	16.10
PF	1975	4.30	0.90	1.80						2.33	1.50	2.10								1.80	2.12	2.12
ALL	1975	69.40	49.90	61.80						60.37	78.60	63.60								71.10	64.66	64.66
AG	1976	50.70	40.90	34.30						41.97	71.20	51.60								61.40	49.74	49.74
PG	1976	0.40	10.50	10.30						7.07	4.40	3.10								3.75	5.74	5.74
AF	1976	5.50	5.30	7.20						6.00	11.90	8.50								10.20	7.68	7.68
PF	1976	0.00	0.50	0.20						0.23	0.00	0.20								0.10	0.18	0.18
ALL	1976	56.60	57.20	52.00						55.27	87.50	63.40								75.45	63.34	63.34
AG	1977	1.35	0.65	1.90						1.30	5.20	1.45								3.33	2.11	2.11
PG	1977	0.35	11.30	8.28						6.64	3.25	2.90								3.08	5.22	5.22
AF	1977	0.25	0.05	0.90						0.40	2.40	9.35								5.88	2.59	2.59
PF	1977	0.55	0.60	1.42						0.86	0.05	6.30								3.18	1.78	1.78
ALL	1977	2.50	12.60	12.50						9.20	10.90	20.00								15.45	11.70	11.70
AG	1978	51.00	67.00	51.00						56.33	68.00	42.00								55.00	55.80	55.80
PG	1978	3.00	18.00	11.00						10.67	8.00	7.00								7.50	9.40	9.40
AF	1978	38.00	10.00	33.00						27.00	23.00	25.00								24.00	25.80	25.80
PF	1978	8.00	0.00	5.00						4.33	2.00	3.00								2.50	3.60	3.60
ALL	1978	100.00	95.00	100.00						98.33	101.00	77.00								89.00	94.60	94.60
AG	1979	25.00	29.00	9.00						21.00	31.00	10.00								20.50	20.80	20.80
PG	1979	1.00	18.00	11.00						10.00	7.00	5.00								6.00	8.40	8.40
AF	1979	2.00	4.00	10.00						5.33	43.00	33.00								38.00	18.40	18.40
PF	1979	11.00	0.00	3.00						4.67	0.00	7.00								3.50	4.20	4.20
ALL	1979	39.00	51.00	33.00						41.00	81.00	55.00								68.00	51.80	51.80
AG	1980	50.40	51.80	24.30	56.20	56.40	47.82			47.82	64.30	77.80	73.80	12.30	57.05					57.05	51.92	51.92
PG	1980	1.00	7.20	23.30	10.90	0.10	8.50			8.50	28.30	64.00	0.10	26.60	29.75					29.75	17.94	17.94
AF	1980	7.60	4.20	22.50	3.40	14.10	10.36			10.36	7.30	5.00	28.70	4.90	11.48					11.48	10.86	10.86
PF	1980	2.20	2.20	4.70	4.60	1.80	3.10			3.10	0.40	0.00	0.00	4.60	1.25					1.25	2.28	2.28
ALL	1980	61.20	65.40	74.80	75.10	72.40	69.78			69.78	100.30	146.80	102.60	48.40	99.53					99.53	83.00	83.00
AG	1981	74.80	54.60	66.50	49.80	76.20	64.38			64.38	77.40	84.00	88.40	48.90	74.68					74.68	68.96	68.96
PG	1981	0.10	4.70	14.30	5.80	0.00	4.98			4.98	19.60	25.90	0.00	36.70	20.55					20.55	11.90	11.90
AF	1981	5.30	3.50	18.20	1.20	12.50	8.14			8.14	15.90	11.90	17.50	5.90	12.80					12.80	10.21	10.21
PF	1981	0.00	3.20	0.70	4.90	0.50	1.86			1.86	0.20	0.00	0.00	1.90	0.53					0.53	1.27	1.27
ALL	1981	80.20	66.00	99.70	61.70	89.20	79.36			79.36	113.10	121.80	105.90	93.40	108.55					108.5 5	92.33	92.33
AG	1982	51.50	25.80	36.60	32.70	20.00	33.32			33.32	42.20	45.50	51.00	22.90	40.40					40.40	36.47	36.47
PG	1982	0.40	6.40	17.90	4.30	0.80	5.96			5.96	11.20	11.60	0.10	31.30	13.55					13.55	9.33	9.33
AF	1982	4.60	4.20	7.50	1.60	17.30	7.04			7.04	9.70	4.60	4.60	4.10	5.75					5.75	6.47	6.47
PF	1982	0.20	4.30	0.70	6.20	1.00	2.48			2.48	0.30	0.00	1.30	3.80	1.35					1.35	1.98	1.98
ALL	1982	56.70	40.70	62.70	44.80	39.10	48.80			48.80	63.40	61.70	57.00	62.10	61.05					61.05	54.24	54.24

Table 5-4 Mean Herbaceous Cover for 1975 through 1991 (continued)

CLASS	YEAR	S01	S02	S03	S04	S05	S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01 5
AG	1983	53.80	37.60	33.65	36.75	31.85	38.73			38.73	49.50	39.55	62.75	17.55	42.35					42.34	40.33	40.33
PG	1983	2.15	7.70	14.45	6.40	1.29	6.40			6.40	2.10	15.75	0.00	25.50	10.84					10.84	8.37	8.37
AF	1983	8.20	7.85	12.55	3.45	22.35	10.88			10.88	18.70	8.85	8.65	6.65	10.71					10.71	10.81	10.81
PF	1983	0.70	3.10	1.05	4.40	1.95	2.24			2.24	0.65	0.05	2.10	4.00	1.70					1.70	2.00	2.00
ALL	1983	64.85	56.25	61.70	51.00	57.44	58.25			58.25	70.95	64.20	73.50	53.70	65.59					65.59	61.51	61.51
AG	1984	41.50	32.75	39.35	36.30	36.50	37.28			37.28	60.85	71.30	60.85	9.60	50.65					50.65	43.22	43.22
PG	1984	1.85	8.80	11.55	8.55	0.40	6.23			6.23	1.20	4.45		25.00	10.22					10.22	6.87	7.73
AF	1984	12.35	8.10	11.10	4.00	13.40	9.79			9.79	20.65	9.70	19.45	7.95	14.44					14.44	11.86	11.86
PF	1984	0.30	4.00	0.75	6.55	0.65	2.45			2.45	0.70	0.20	1.10	1.25	0.81					0.81	1.72	1.72
ALL	1984	56.00	53.65	62.75	55.40	50.95	55.75			55.75	83.40	85.65	81.40	43.80	73.56					73.56	63.67	63.67
AG	1985	2.10	2.15	14.60	4.95	27.05	10.17			10.17	8.00	8.10	18.30	7.25	10.41					10.41	10.28	10.28
PG	1985	1.05	4.70	17.85	2.40	1.85	5.57			5.57	9.20	17.95	0.00	13.90	10.26					10.26	7.66	7.66
AF	1985	0.70	1.35	9.40	2.30	4.75	3.70			3.70	18.20	8.15	7.55	3.05	9.24					9.24	6.16	6.16
PF	1985	0.00	1.35	1.15	3.00	0.25	1.15			1.15	0.80	0.10	2.35	0.90	1.04					1.04	1.10	1.10
ALL	1985	3.85	9.55	43.00	12.65	33.90	20.59			20.59	36.20	34.30	28.20	25.10	30.95					30.95	25.19	25.19
AG	1986	17.45	1.95	7.20	11.45	13.05	10.22			10.22	9.40	4.65	13.25	7.35	8.66					8.66	9.53	9.53
PG	1986	2.20	10.75	17.25	9.85	1.30	8.27			8.27	19.85	38.65	0.00	26.00	21.13					21.13	13.98	13.98
AF	1986	25.40	16.65	38.10	10.25	16.70	21.42			21.42	27.65	34.15	25.45	8.70	23.99					23.99	22.56	22.56
PF	1986	1.15	5.35	2.30	9.15	1.25	3.84			3.84	1.80	1.95	0.05	2.55	1.59					1.59	2.84	2.84
ALL	1986	46.20	34.70	64.85	40.70	32.30	43.75			43.75	58.70	79.40	38.75	44.60	55.36					55.36	48.91	48.91
AG	1987	28.90	9.95	7.80	19.05	33.40	19.82			19.82	23.85	9.45	51.65	4.65	22.40					22.40	20.97	20.97
PG	1987	3.60	21.90	42.65	19.55	2.30	18.00			18.00	32.45	58.79	0.05	45.95	34.31					34.31	25.25	25.25
AF	1987	12.56	8.50	10.80	6.55	11.40	9.96			9.96	10.30	11.32	14.00	3.25	9.72					9.72	9.85	9.85
PF	1987	5.00	6.00	2.00	10.40	1.75	5.03			5.03	0.90	1.90	0.15	1.55	1.13					1.13	3.29	3.29
ALL	1987	50.06	46.35	63.25	55.55	48.85	52.81			52.81	67.50	81.46	65.85	55.40	67.55					67.55	59.36	59.36
AG	1988	13.80	5.05	8.10	13.80	10.15	10.18	10.40	12.24	10.51	22.95	10.10	16.75	4.80	13.65	11.95	19.20	15.85	10.40	14.00	12.32	11.72
PG	1988	1.75	8.40	11.95	9.40	3.35	6.97	16.85	17.50	9.89	17.85	21.70	0.05	30.20	17.45	9.50	12.05	10.45	14.30	14.51	12.34	11.63
AF	1988	6.08	5.25	3.60	3.10	4.00	4.41	0.00	0.35	3.20	6.30	16.15	7.55	1.80	7.95	1.20	1.45	12.35	6.12	6.61	5.16	5.98
PF	1988	11.55	15.75	2.10	4.85	3.25	7.50	0.10	0.00	5.37	0.20	2.00	0.00	4.40	1.65	15.25	8.70	2.45	4.34	4.34	4.79	4.90
ALL	1988	33.18	34.45	25.75	31.15	20.75	29.06	27.35	30.09	28.96	47.30	49.95	24.35	41.20	40.70	37.90	41.40	41.10	32.52	39.47	34.60	34.23
AG	1989	21.85	12.50	12.45	10.25	32.90	17.99	15.00	47.65	21.80	22.50	13.20	65.85	3.05	26.15	22.35	35.10	38.05	12.05	26.52	24.05	21.62
PG	1989	8.30	29.55	64.00	13.00	1.25	23.22	30.35	37.50	26.28	60.40	59.60	0.05	49.55	42.40	36.75	16.20	32.05	48.95	37.94	32.54	31.74
AF	1989	12.50	6.95	13.05	6.45	11.10	10.01	0.85	5.15	8.01	12.85	5.90	42.20	2.85	15.95	8.85	13.55	13.05	13.95	14.15	11.48	12.65
PF	1989	4.45	14.50	4.40	8.20	0.55	6.42	0.10	0.00	4.60	3.85	1.10	0.05	3.00	2.00	6.45	10.40	12.90	10.60	6.04	5.23	4.46
ALL	1989	47.10	63.50	93.90	37.90	45.80	57.64	46.30	90.30	60.69	99.60	79.80	108.15	58.45	86.50	74.40	75.25	96.05	85.55	84.66	73.31	70.47
AG	1990	36.80	16.80	17.50	32.40	53.35	31.37	12.90	5.45	25.03	18.60	7.75	61.55	13.65	25.39	23.80	35.45	36.55	19.75	27.01	26.06	28.71
PG	1990	3.30	12.85	18.35	12.70	0.05	9.45	18.40	17.55	11.89	18.70	0.00	0.00	30.00	12.18	11.90	10.70	9.30	12.10	11.59	11.73	10.66
AF	1990	7.95	2.60	8.15	4.55	8.90	6.43	0.10	0.00	4.61	7.75	2.35	15.70	3.35	7.290.3	2.75	6.90	8.95	7.00	6.84	5.80	6.81
PF	1990	0.40	9.55	1.75	3.90	0.05	3.313	0.00	0.00	2.24	0.00	0.05	0.05	1.20	3	3.95	8.55	0.05	0.20	1.76	1.98	1.88
ALL	1990	48.45	41.80	45.30	53.55	62.35	50.29	31.40	23.00	43.69	45.05	10.15	77.30	48.20	45.18	42.40	61.60	53.85	39.05	47.20	45.56	48.02
AG	1991	40.25	15.25	40.05	38.55	48.15	35.85	17.85	5.90	25.14	26.15	20.80	65.55	18.90	32.85	36.95	37.25	48.30	38.25	36.52	33.81	34.52
PG	1991	7.60	32.05	26.35	14.45	2.30	11.14	38.40	60.60	25.96	41.75	50.55	1.35	38.70	29.09	23.55	12.80	0.00	22.85	23.94	26.14	11.12
AF	1991	36.25	15.00	16.75	37.30	21.60	24.29	4.85	7.30	19.86	0.25	4.20	13.35	1.85	4.92	4.75	6.30	35.13	16.65	10.31	14.77	16.26
PF	1991	4.45	6.35	1.95	2.35	0.30	3.08	0.30	0.00	2.24	0.00	0.10	0.60	0.90	0.25	3.35	12.20	0.05	1.70	2.29	2.25	1.88
ALL	1991	88.55	63.65	85.10	89.65	72.35	74.36	61.40	73.80	76.36	61.15	75.65	80.25	60.35	66.11	68.60	68.55	83.48	79.45	72.19	76.97	63.78

Table 5-5 Mean Frequency Values (%) by Species for Each Sampling Station - 1991

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
Annual Grasses															
Bromus tectorum	100	100	100	86	98	98	100	98	92	66	98	100	100	76	78
Festuca octoflora					24	8						20			
Perennial Grasses															
Agropyron spicatum										6			2	10	
Oryzopis hymenoides										6		2			
Poa sandbergii	100	98	14	94	74	16	62	76	20	48		50		68	96
Stipa comata				84		28		8		18			4	6	
Annual Forbs															
Amsinckia lycopsoides		2	8		4		20	2	14	2			10		
Chenopodium Leptophyllum							2					10	2		2
Cryptantha circumscissa					2	4			2	8					
Cryptantha pterocarya															
Descurainia pinnata				2			4		14	4		6	2	6	50
Draba verna	4	10	56	26	2	28	14	20	24	6	34	4	40		
Franseria acanthacarpa			28			2	6		2	12		6	8		
Gilia sinuata															
Holosteum umbellatum		16	98	16	22	84	64	50	78	22	42	4	86		
Layia glandulosa									2						
Mentzelia albicaulis					4				2	22				2	
Microseris gracilis			64		2	34	12	22	66	6	12	28	26		
Phacelia linearis					4				4	24			2		
Plantago patagonica	2	12		18	2			8		8	70		12		2
Salsola kali		2			10					44		52	2	4	2
Sisymbrium altissimum	4	12		21	20	18	50	62	54	8	54	76	44	20	6
Tragopogon dubius															
Perennial Forbs															
Achillea millefolium										8					
Aster canescens															
Astragulus purshii															
Astragulus sclerocarpus						2									
Balsamorhiza careyana					4	4						14	2		
Brodiaea douglasii															
Comandra umbellata					4										
Crepis Atrabarba											8				
Cynopterus terebinthinus		2				22				6					
Oenothera pallida								16	24	4					
Phlox longifolia				6	2	2	2	2			10			2	
Rumex venosus		2													
Total Species Per Site	5	10	7	9	17	14	11	11	15	21	8	14	16	9	7

Table 5-6 Mean Terrestrial Phytomass for 1991

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/10	G01	3-9	13.8	137.8	05/09	G02	3-9	5.3	53.1	05/14	G03	3-9	18.6	185.8
05/10	G01	21-6	6.2	61.9	05/09	G02	21-6	10.8	107.5	05/14	G03	21-6	20.9	209.1
05/10	G01	24-12	13.5	135.2	05/09	G02	24-12	7.7	76.5	05/14	G03	24-12	13.0	129.8
05/10	G01	27-7	4.7	47.3	05/09	G02	27-7	13.9	139.4	05/14	G03	27-7	12.0	119.5
05/10	G01	41-5	5.6	56.1	05/09	G02	41-5	11.0	109.6	05/14	G03	41-5	16.4	163.9
		AVG	8.8	87.7			AVG	9.7	97.2			AVG	16.2	161.6
		STD	4.0	40.2			STD	3.0	29.7			STD	3.4	33.6

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/09	G04	3-9	3.7	36.9	05/16	G05	3-9	8.6	85.6	05/15	G06	3-9	17.0	170.0
05/09	G04	21-6	11.8	118.3	05/16	G05	21-6	27.3	272.8	05/15	G06	21-6	5.2	51.6
05/09	G04	24-12	2.9	29.3	05/16	G05	24-12	31.1	310.5	05/15	G06	24-12	4.3	42.9
05/09	G04	27-7	11.3	113.4	05/16	G05	27-7	8.6	85.6	05/15	G06	27-7	11.0	110.3
05/09	G04	41-5	4.0	40.1	05/16	G05	41-5	10.4	104.4	05/15	G06	41-5	13.2	132.3
		AVG	6.8	67.6			AVG	17.2	171.8			AVG	10.1	101.4
		STD	4.0	39.6			STD	9.9	98.8			STD	4.8	48.3

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/16	G07	3-9	16.3	163.3	05/16	G08	3-9	5.9	58.5
05/16	G07	21-6	10.4	103.6	05/16	G08	21-6	21.8	218.2
05/16	G07	24-12	29.9	299.3	05/16	G08	24-12	15.4	153.8
05/16	G07	27-7	15.8	158.0	05/16	G08	27-7	9.3	93.4
05/16	G07	41-5	11.8	117.9	05/16	G08	41-5	16.3	162.8
		AVG	16.8	168.4			AVG	13.7	137.3
		STD	6.9	69.3			STD	5.6	55.9

Table 5-6 Mean Terrestrial Phytomass for 1991 (continued)

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/17	S01	3-9	15.1	150.9
05/17	S01	21-6	11.2	111.5
05/17	S01	24-12	33.5	335.0
05/17	S01	27-7	40.4	404.2
05/17	S01	41-5	12.4	124.1
		AVG	22.5	225.1
		STD	12.1	120.6

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/20	S02	3-9	13.1	130.7
05/20	S02	21-6	8.0	80.4
05/20	S02	24-12	2.1	21.3
05/20	S02	27-7	5.3	52.5
05/20	S02	41-5	0.6	6.1
		AVG	5.8	58.2
		STD	4.4	44.4

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
06/02	S03	3-9	11.2	111.9
06/02	S03	21-6	10.4	103.7
06/02	S03	24-12	11.0	109.9
06/02	S03	27-7	5.9	58.9
06/02	S03	41-5	5.4	53.8
		AVG	8.8	87.6
		STD	2.6	25.7

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/31	S04	3-9	17.8	177.6
05/31	S04	21-6	15.1	150.7
05/31	S04	24-12	9.6	96.4
05/31	S04	27-7	23.9	238.8
05/31	S04	41-5	26.3	262.7
		AVG	18.5	185.2
		STD	6.0	60.0

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
06/02	S05	3-9	18.8	187.5
06/02	S05	21-6	6.7	67.2
06/02	S05	24-12	14.3	143.2
06/02	S05	27-7	3.3	33.2
06/02	S05	41-5	12.5	125.3
		AVG	11.1	111.3
		STD	5.5	54.9

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/20	S06	3-9	37.2	372.3
05/20	S06	21-6	3.4	33.8
05/20	S06	24-12	32.0	320.2
05/20	S06	27-7	30.3	303.0
05/20	S06	41-5	9.6	96.4
		AVG	22.5	225.1
		STD	13.4	134.1

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/20	S07	3-9	21.7	217.2
05/20	S07	21-6	20.6	205.5
05/20	S07	24-12	31.0	309.7
05/20	S07	27-7	31.5	315.4
05/20	S07	41-5	8.2	82.0
		AVG	22.6	226.0
		STD	8.5	85.1

		Phytomass Summary
MEAN G01-G08	124.1	Grams/sq. meter
MEAN S01-S07	159.8	Grams/sq. meter
MEAN B01-B05	0.0	Grams/sq. meter

Table 5-7 Comparison of Herbaceous Phytomass (g/m^2) for 1975 through 1991

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
G01	359	108	21	166	64	160	200	90	77	94	70	50	83	34	174.3	13.6	87.7
G02	302	258	11	162	37	68	255	60	137	116	27	61	77	14	65.7	4.1	97.2
G03	-	-	-	-	-	53	261	62	64	133	12	32	134	16	105.1	64.0	161.6
G04	-	-	-	-	-	79	159	113	82	67	37	35	90	61	49.5	73.2	67.6
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43.2	36.8	171.8
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61.0	39.8	101.4
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113.1	29.1	168.4
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	112.3	10.0	137.3
S01	126	137	4	173	21	36	180	98	171	104	5	35	62	59	53.9	32.8	225.1
S02	144	98	7	128	28	63	115	24	232	57	1	112	144	73	72.8	78.3	58.2
S03	88	177	7	115	16	43	31	22	54	95	27	25	48	15	67.0	28.2	87.6
S04	-	-	-	-	-	78	52	39	68	93	11	176	108	24	39.8	30.9	185.2
S05	-	-	-	-	-	71	81	184	136	43	61	42	145	19	103.7	43.4	111.3
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72.7	34.0	225.1
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	149.5	6.1	226.0

Table 5-8 Summary of Shrub Density for 1991

Station	Species	1	2	3	4	Total	S/Ha	S/a
S01	Artemisia tridentata	1	0	3	0	4	40	16
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	2	0	1	3	30	12
						7	70	28
						Total	S/Ha	S/a
S02	Artemisia tridentata	1	1	0	0	2	20	8
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						2	20	8
						Total	S/Ha	S/a
S03	Artemisia tridentata	6	19	10	23	58	580	232
	Chrysothamnus nauseosus	2	2	2	2	8	80	32
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						66	660	264
						Total	S/Ha	S/a
S04	Artemisia tridentata	0	1	1	4	6	60	24
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						6	60	24
						Total	S/Ha	S/a
S05	Artemisia tridentata	0	0	0	0	0	0	0
	Chrysothamnus nauseosus	0	0	5	1	6	60	24
	Chrysothamnus viscidiflorus	0	0	0	1	1	10	4
	Purshia tridentata	1	3	3	0	7	70	28
						14	140	56

Table 5-9 Summary of Shrub Cover (%) at five Stations for 1991

Shrub Cover (%)

Shrubs	S01	S02	S03	S04	S05	X
Artemisia tridentata	0.00	0.20	5.78	0.00	0.00	1.20
Chrysothamnus nauseosus	0.00	0.00	0.63	0.00	0.20	0.17
Chrysothamnus viscidiflorus	0.00	0.00	0.00	0.00	0.09	0.02
Purshia tridentata	0.32	0.00	0.00	0.00	0.00	0.06
Total Shrub Cover	0.32	0.20	6.41	0.00	0.29	1.44

Table 5-10 Summary of Soil Chemistry for 1991

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
pH (1:2 soil-water)	6.71	6.58	7.02	6.60	6.65	6.65	6.77	6.68	6.81	6.82	6.46	6.77	6.68	6.82	6.76
Conductivity (1:2 soil-water) microsiemens/cm	43.5	39.5	63.5	20.6	13.6	42.2	28.7	20.7	49.6	14.6	48.3	21.2	28.0	25.8	44.4
Sulfate ug/gm	3.00	3.11	2.44	3.08	2.42	3.06	3.2	3.38	3.20	3.28	2.49	3.22	3.10	3.08	3.28
Chloride ug/gm	16.00	17.60	13.20	15.20	20.8	18.8	26.4	13.2	12.00	6.00	18.40	12.40	17.60	11.6	21.2
Copper ug/gm	13.72	11.40	11.80	9.32	8.48	10.44	9.84	12.44	15.80	7.76	10.36	10.72	12.12	17.88	16.64
Lead ug/gm	4.88	4.51	2.99	1.98	2.95	2.64	4.37	2.12	2.84	1.84	3.67	2.40	3.19	3.61	4.02
Cadmium ug/gm	0.140	0.220	0.090	0.080	0.170	0.080	0.120	0.060	0.060	0.130	0.130	0.210	0.230	0.190	0.380
Chromium ug/gm	10.7	8.1	6.5	6.6	7.9	8.2	7.2	8.9	6.5	9.4	8.3	10.0	4.2	14.6	13.9
Nickel ug/gm	17.16	14.64	15.36	12.08	14.44	14.84	13.48	16.36	15.28	15.56	14.52	13.64	12.52	16.28	16.84
Zinc ug/gm	54.84	67.96	50.56	43.52	33.84	46.16	47.44	43.96	78.68	27.84	52.44	45.64	51.40	62.60	61.16
Sodium %	0.028	0.031	0.026	0.025	0.024	0.026	0.025	0.03	0.037	0.020	0.027	0.026	0.029	0.027	0.036
Potassium %	0.352	0.241	0.236	0.198	0.236	0.142	0.167	0.157	0.189	0.087	0.172	0.164	0.189	0.241	0.244
Calcium %	0.294	0.307	0.328	0.289	0.259	0.284	0.287	0.239	0.314	0.311	0.287	0.288	0.277	0.356	0.409
Bicarbonate (meq/HC03/gm)	0.0022	0.0039	0.0038	0.0016	0.0010	0.0012	0.0019	0.0016	0.0022	0.0013	0.0028	0.0017	0.0015	0.0027	0.0042
Magnesium %	0.424	0.416	0.392	0.352	0.365	0.365	0.359	0.343	0.420	0.304	0.356	0.334	0.308	0.434	0.563

Table 5-11 Summary of Vegetation Chemistry for 1991

	SITE	POSA	BRTE	SIAL	PHLO	PUTR	ARTR	CHVI	GRSP
Copper (ug/gm)	G01	4.00	14.00	4.00	4.00				
	G02	4.00	10.00	4.00	4.00				
	G03	4.00	4.00	4.00	4.00				
	G04	2.00	4.00	4.00	4.00				
	G05	8.00	4.00			4.00	8.00		
	G06	2.00	4.00				8.40	6.00	
	G07	4.00	4.00	4.00	4.00				
	G08	2.00	2.00	2.00	2.00				
	S01	2.00	2.00	2.00	4.00				
	S02	4.00	4.00			4.00	2.00		
	S03	8.00	6.00		4.00		8.00		
	S04	2.00	4.00	4.00	2.00				
	S05	2.00	4.00			4.00	8.00		
	S06	2.00	6.00				4.00	6.00	4.00
	S07	2.00	4.00				8.00		4.00
Extractable Sulfate (%)	G01	0.012	0.049	0.013	0.015				
	G02	0.012	0.037	0.013	0.029				
	G03	0.044	0.045	0.221	0.012				
	G04	0.012	0.047	0.175	0.012				
	G05	0.036	0.042			0.021	0.012		
	G06	0.012	0.044				0.039	0.034	
	G07	0.015	0.032	0.161	0.015				
	G08	0.012	0.037	0.153	0.018				
	S01	0.011	0.032	0.104	0.015				
	S02	0.014	0.012			0.017	0.017		
	S03	0.012	0.015		0.016		0.016		
	S04	0.014	0.021	0.075	0.012				
	S05	0.014	0.012			0.013	0.012		
	S06	0.062	0.036				0.062	0.022	0.097
	S07	0.061	0.062				0.054		0.041
Extractable Chloride (%)	G01	0.15	0.21	0.31	0.12				
	G02	0.26	0.23	0.39	0.12				
	G03	0.28	0.07	0.28	0.28				
	G04	0.19	0.11	0.30	0.30				
	G05	0.12	0.08			0.05	0.48		
	G06	0.2	0.15				0.60	0.43	
	G07	0.2	0.17	0.28	0.09				
	G08	0.18	0.14	0.73	0.09				
	S01	0.09	0.22	0.18	0.10				
	S02	0.22	0.13			0.06	0.30		
	S03	0.11	0.42		0.05		0.35		
	S04	0.15	0.17	0.15	0.04				
	S05	0.07	0.11			0.05	0.40		
	S06	0.19	0.19				0.41	0.6	1.11
	S07	0.16	0.28				0.66		0.07

POSA Poa sandbergii
BRTE Bromus tectorum
SIAL Sisymbrium altissimum
PHLO Phlox longifolia
PUTR Purshia tridentata
ARTR Artemisia tridentata
CHVI Chrysothamnus viscidiflorus
GRSP Grayia spinosa

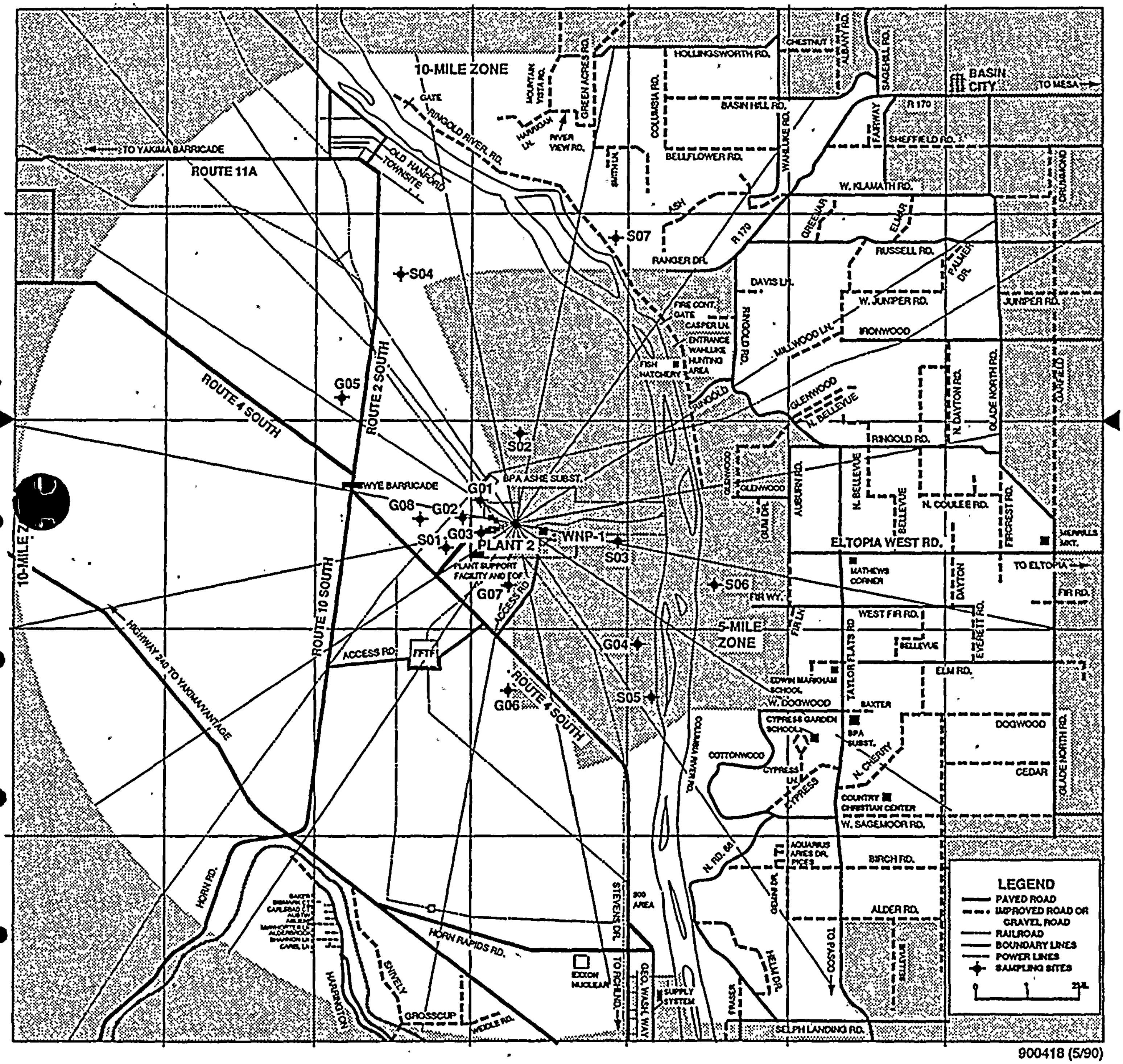


Figure 5-1 Soil and Vegetation Sampling Location Map

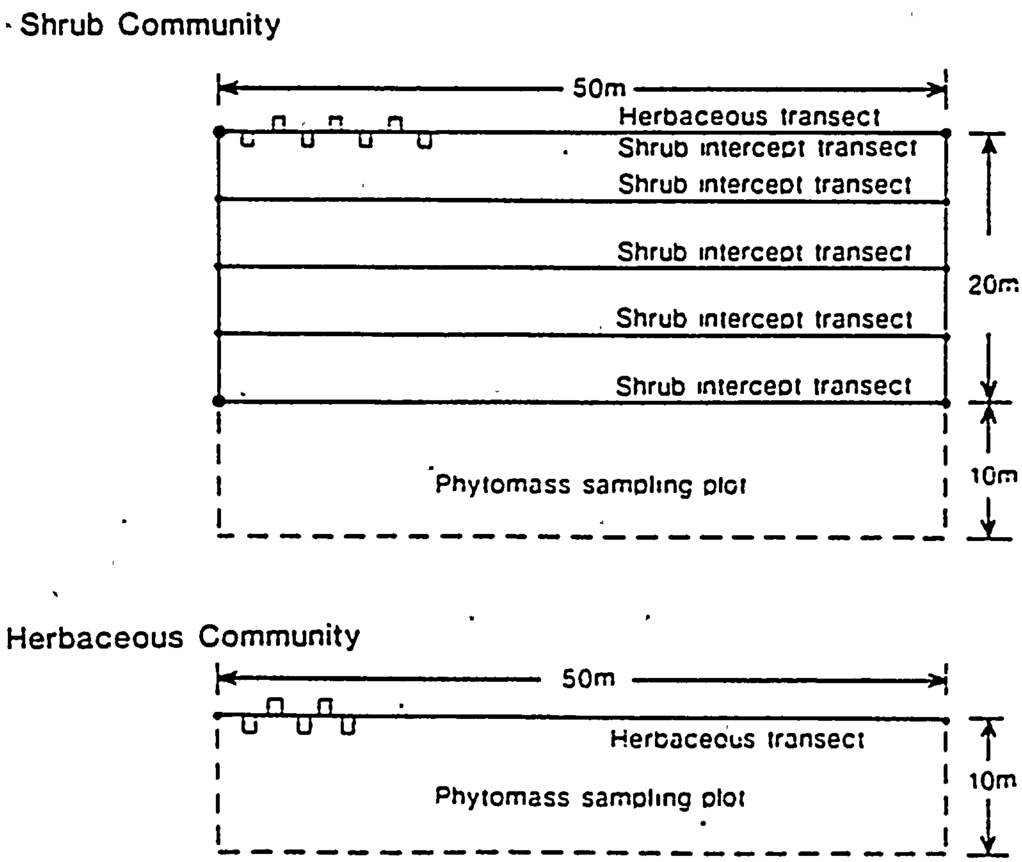


Figure 5-2 Layout of Vegetation and Soil Sampling Plots

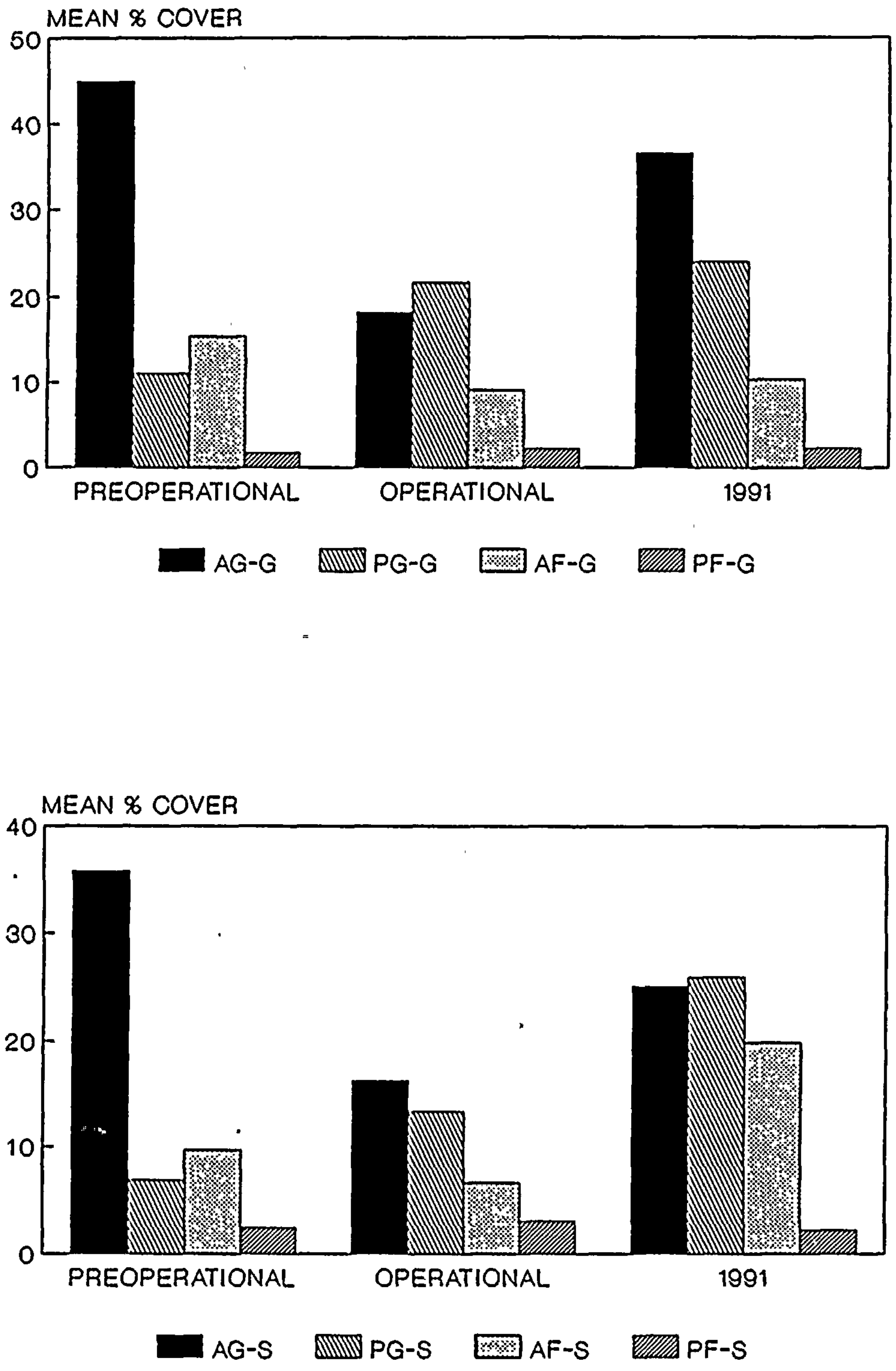


Figure 5-3 Mean Herbaceous Cover for 1975 through 1991

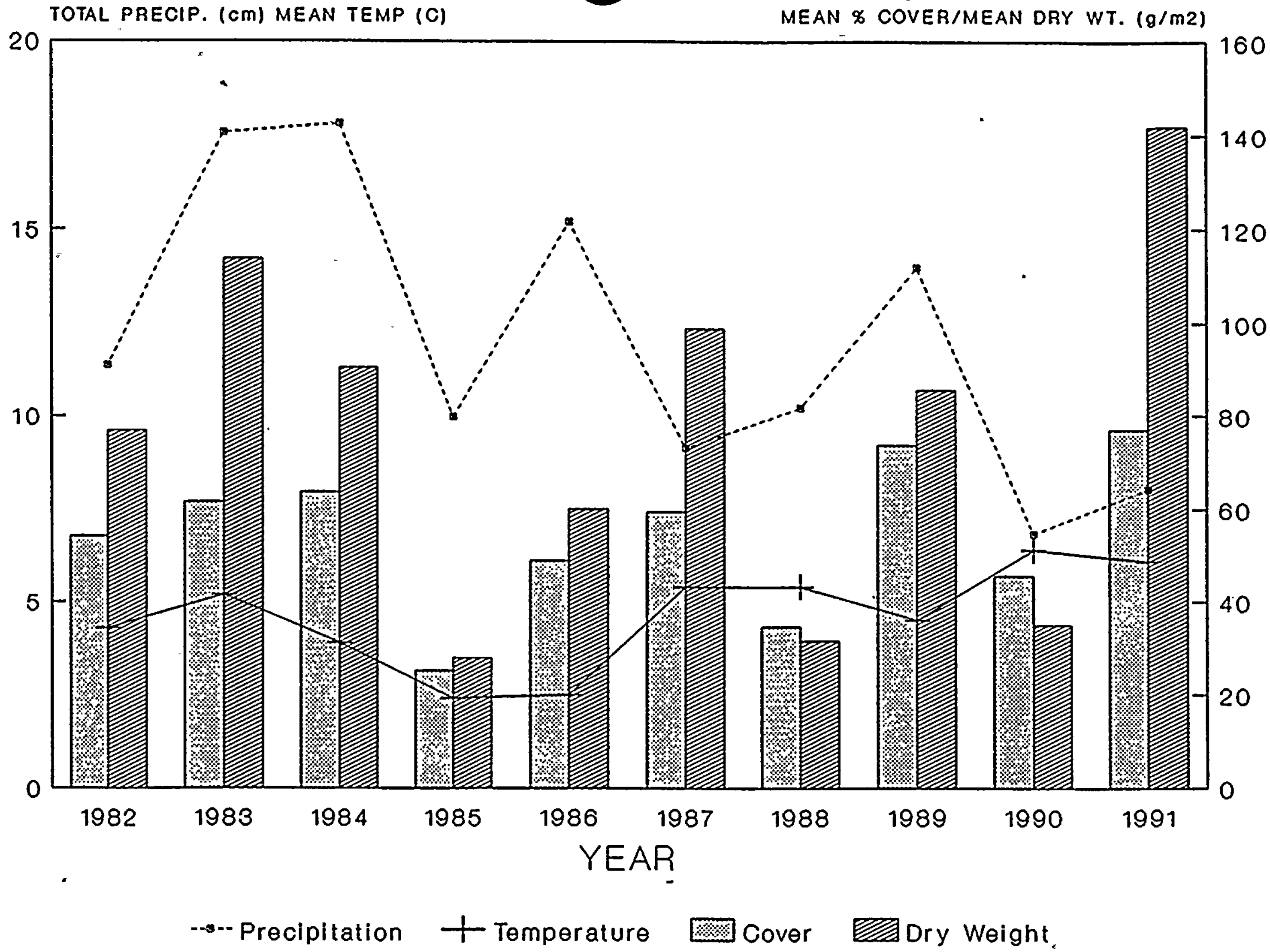
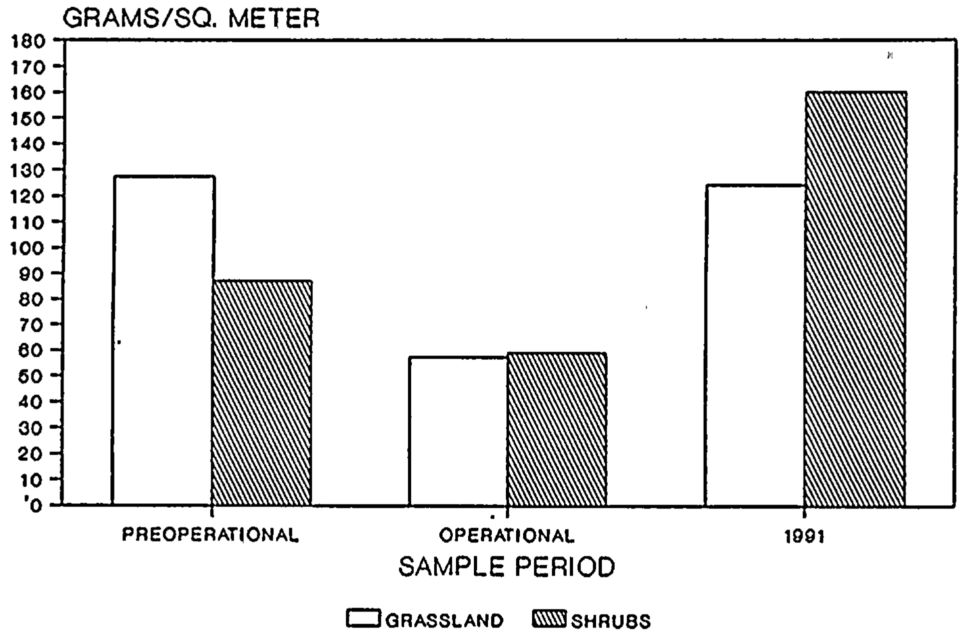


Figure 5-4 Mean Herbaceous Cover, Mean Dry Weight (g/m^2), Total Precipitation, and Mean Temperature from 1982 through 1991



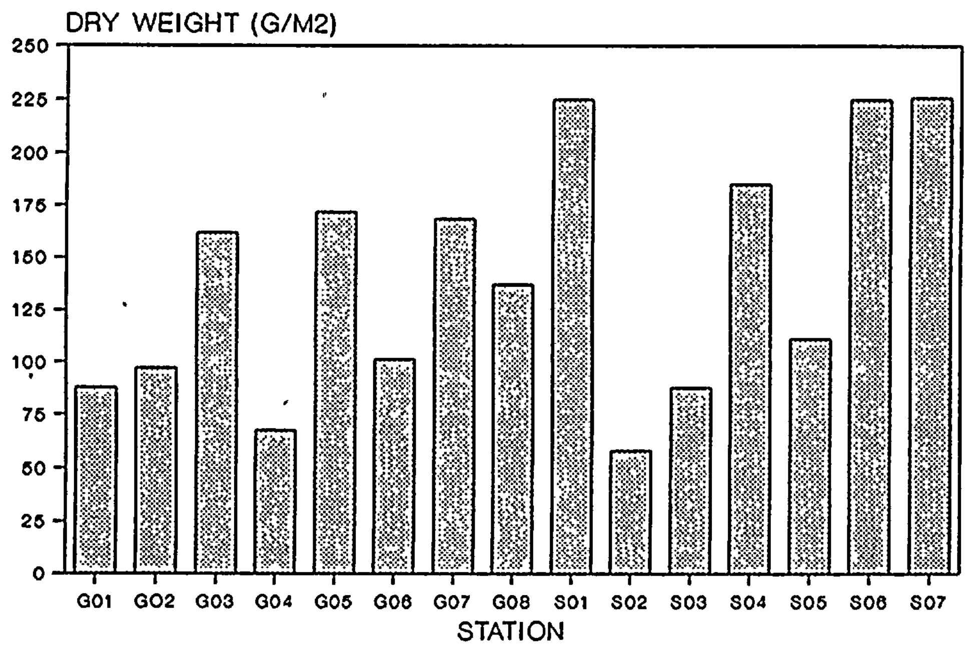


Figure 5-5 Mean Herbaceous Phytomass at Grassland and Shrub Stations for 1975 through 1991

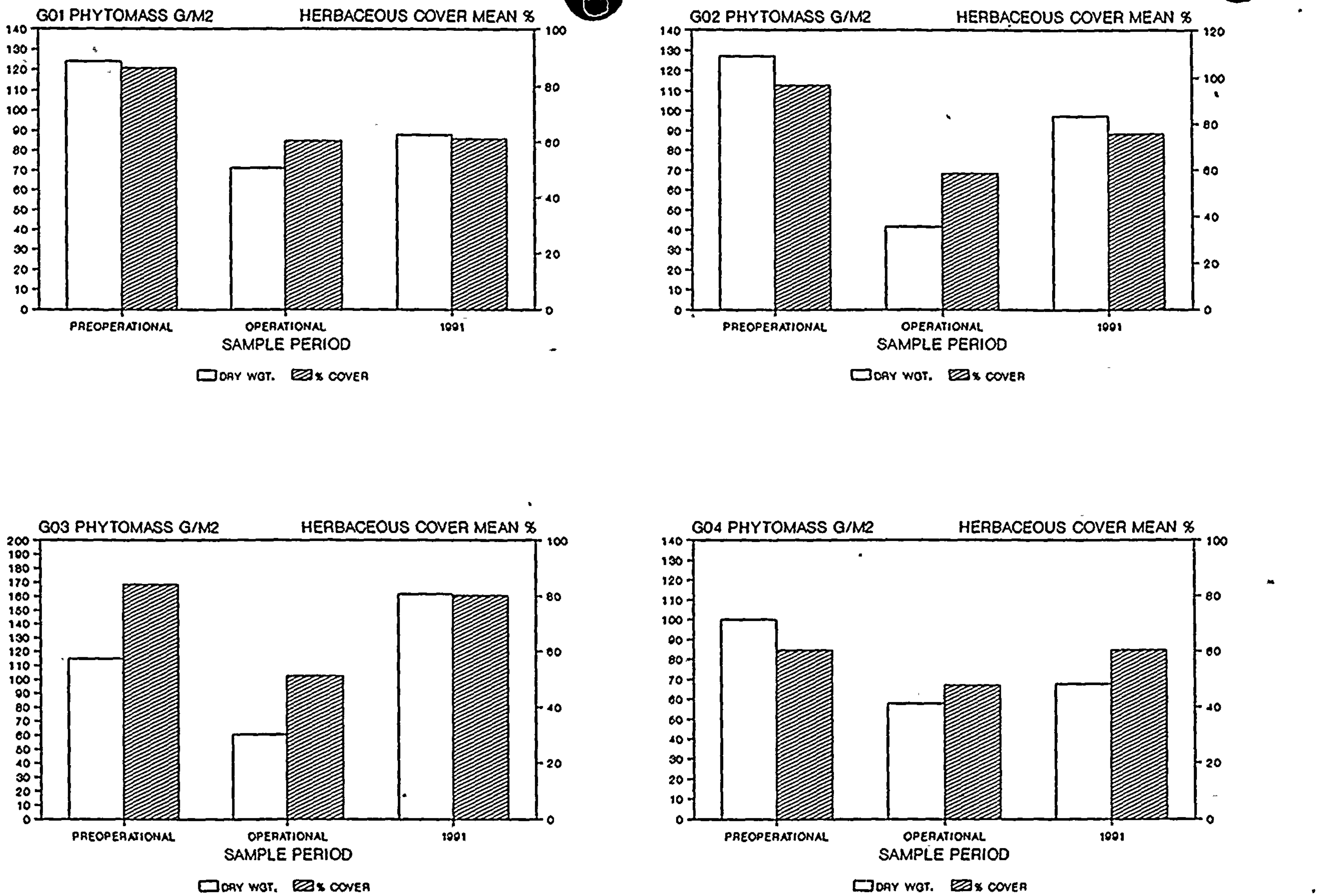


Figure 5-6 Mean Herbaceous Cover and Phytomass for Stations GO1 to GO4 for 1980 through 1991

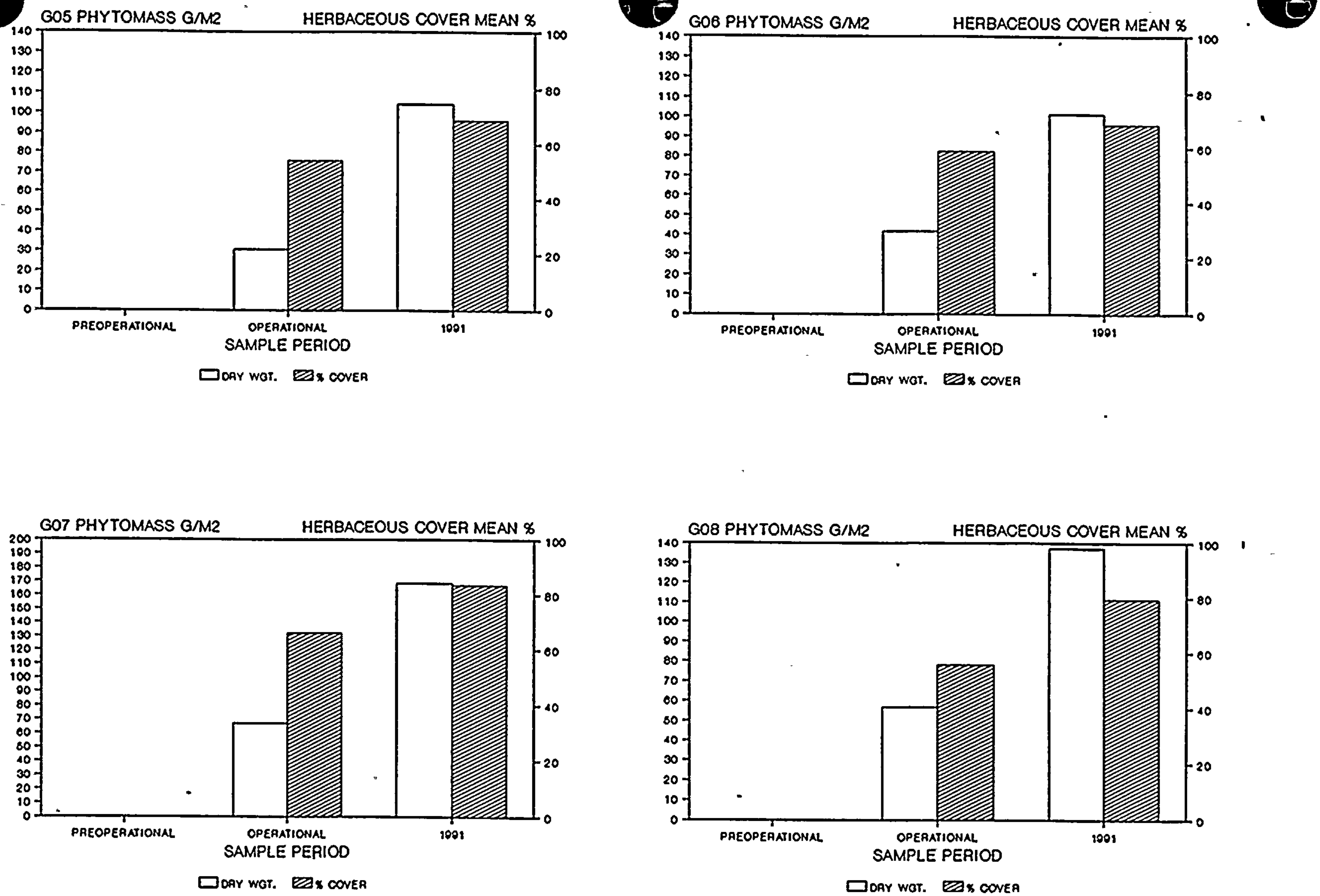


Figure 5-7 Mean Herbaceous Cover and Phytomass for Stations GO5 to GO8 for 1980 through 1991

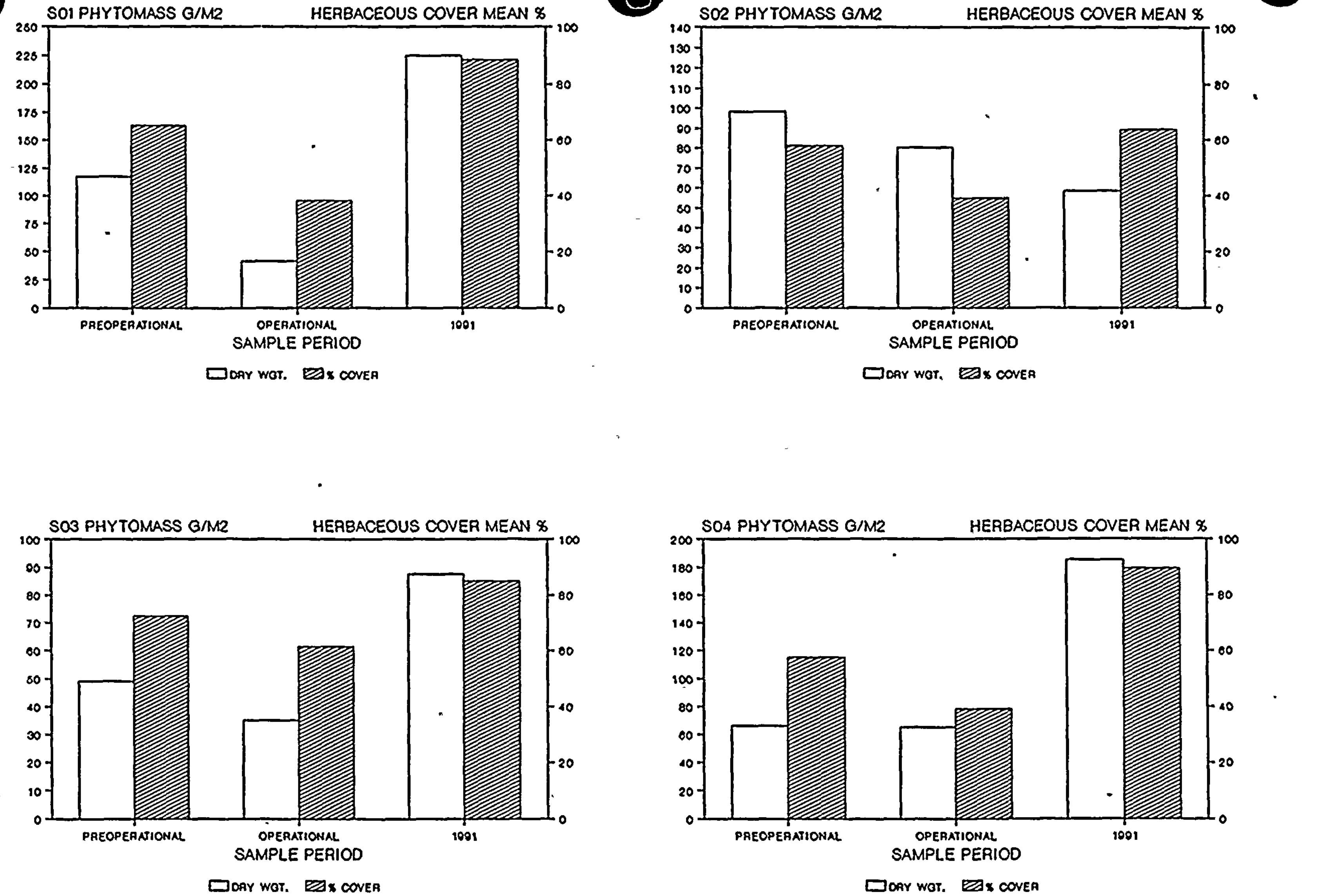
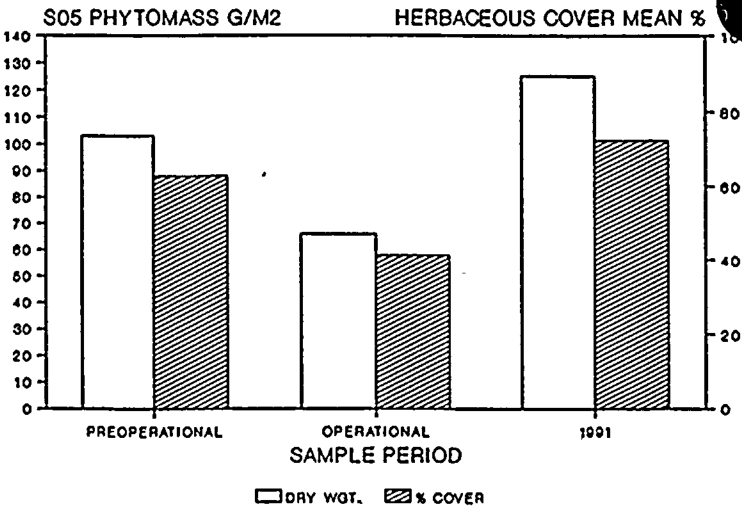
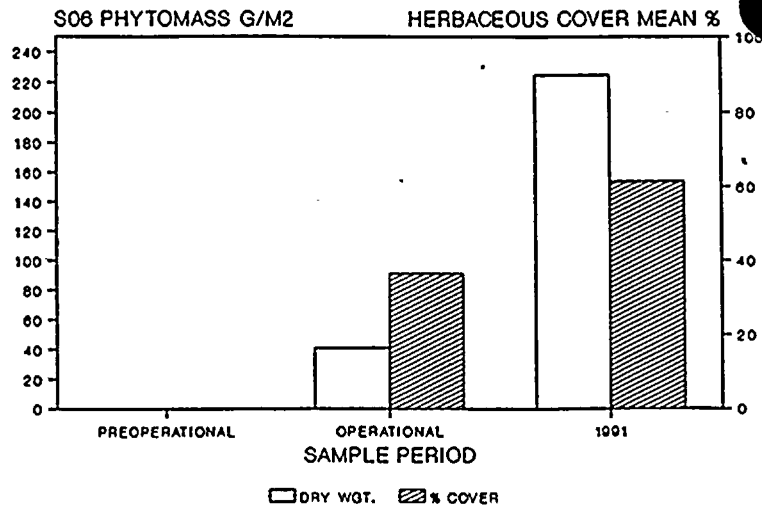


Figure 5-8 Mean Herbaceous Cover and Phytomass for Stations SO1 to SO4 for 1980 through 1991





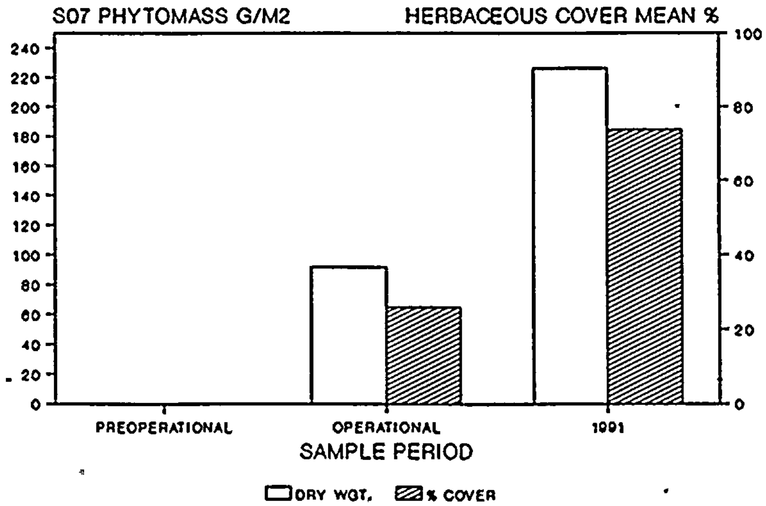


Figure 5-9 Mean Herbaceous Cover, and Phytomass for Stations SO5 for 1980 through 1990 and Stations SO6 and SO7 for 1980 through 1991

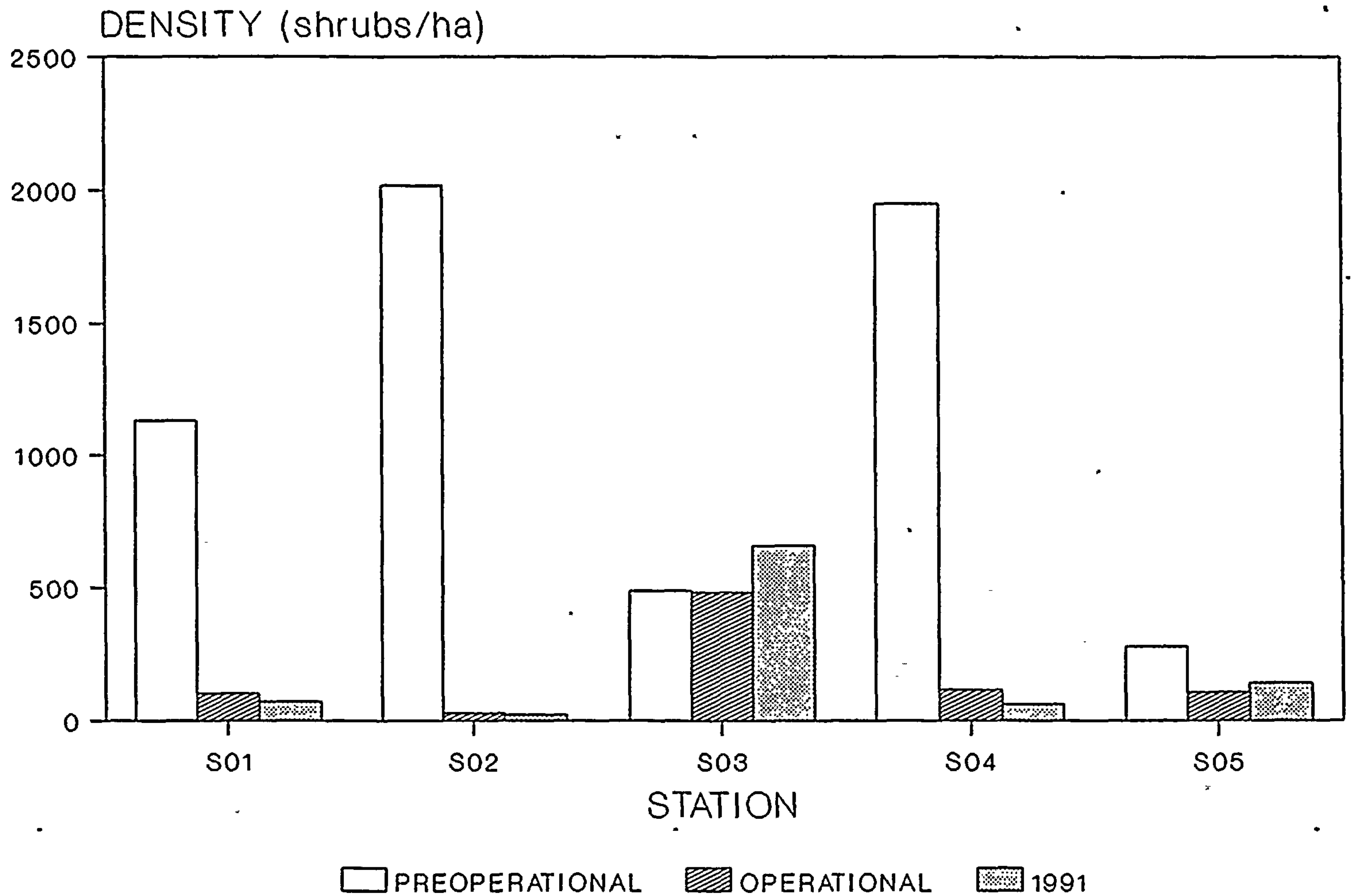


Figure 5-10 Shrub Density at Five Stations for 1975 through 1991

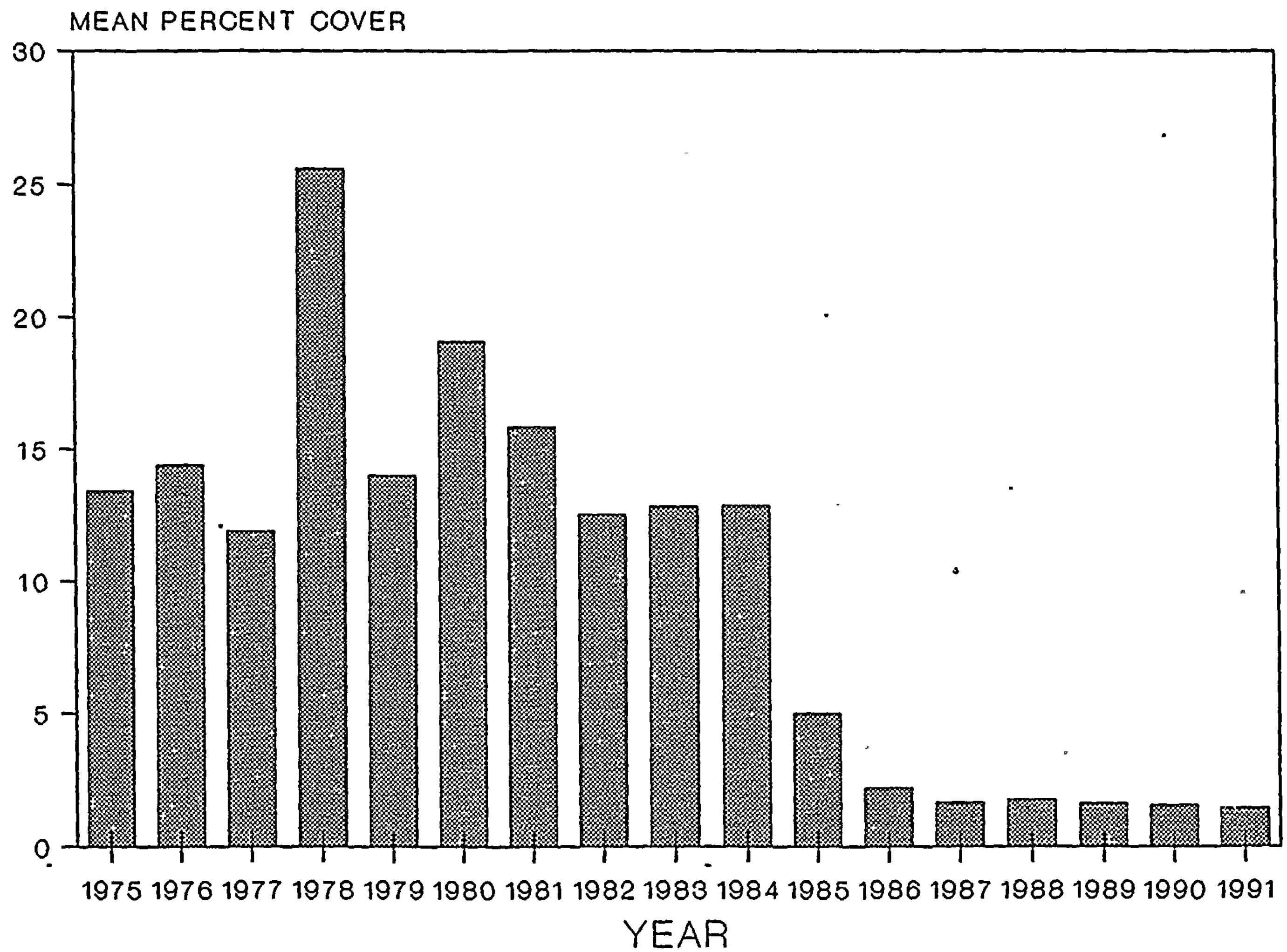


Figure 5-11 Mean Total Shrub Cover for 1975 through 1991

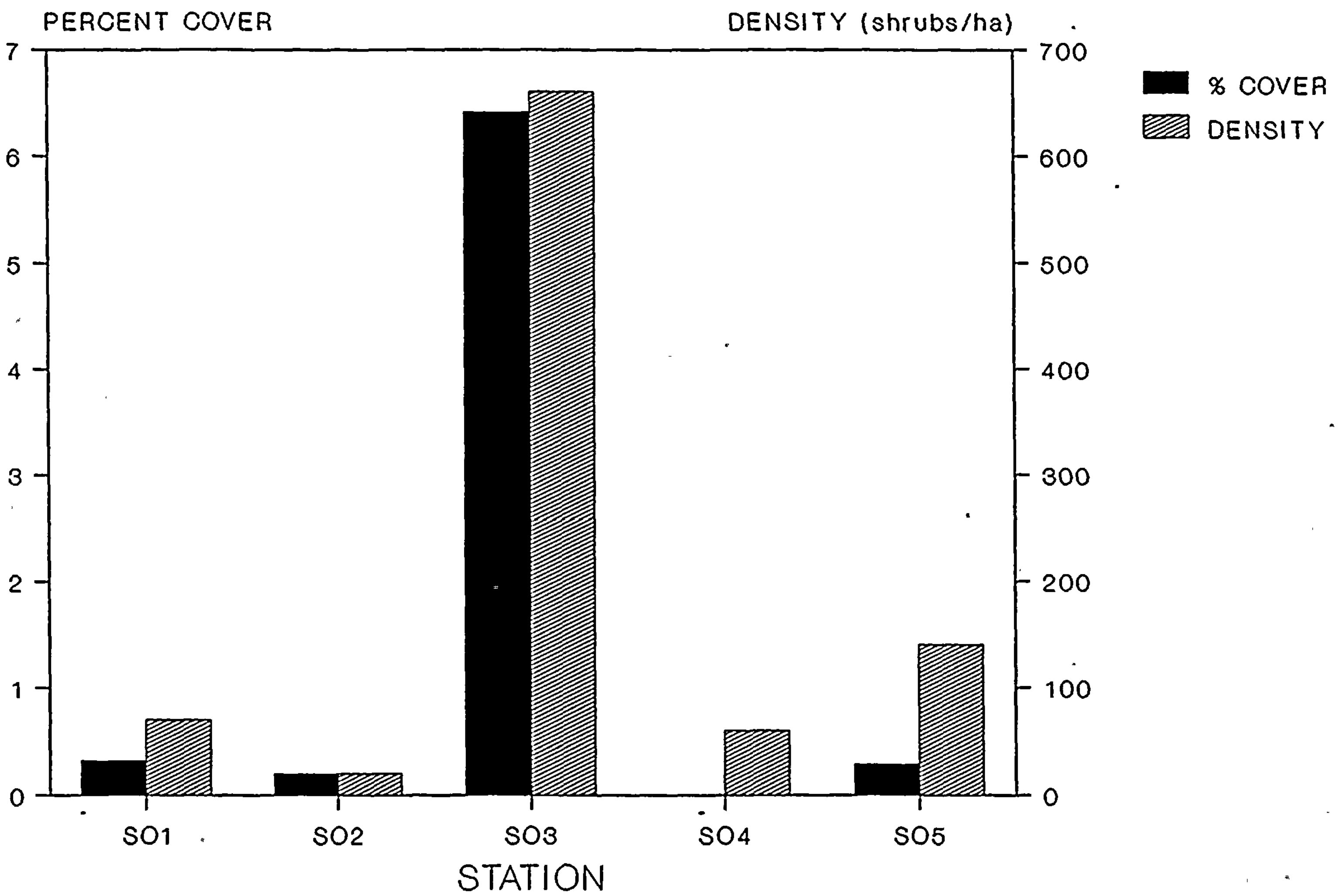
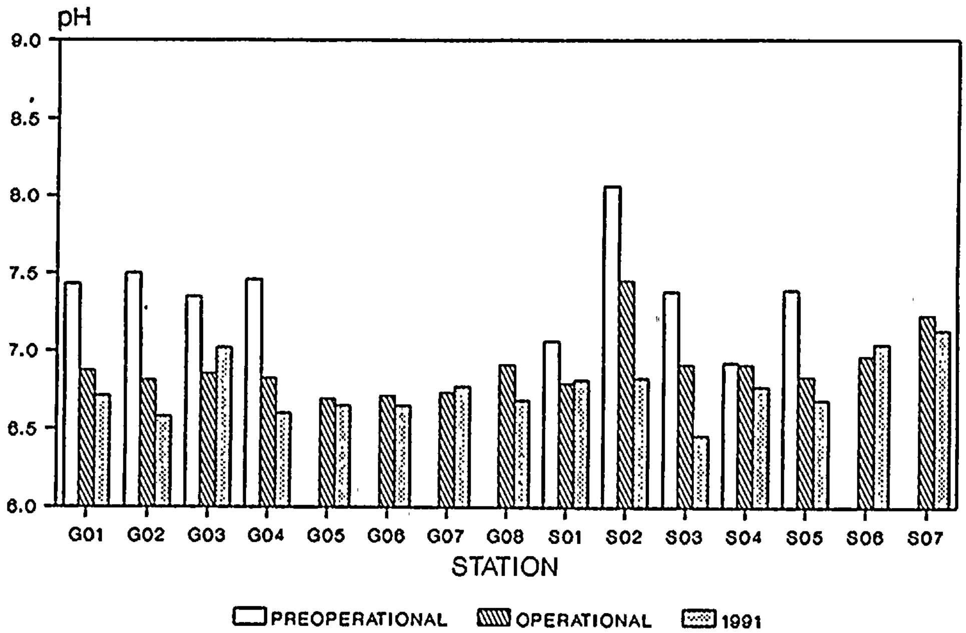


Figure 5-12 Shrub Cover and Density for Five Stations for 1991



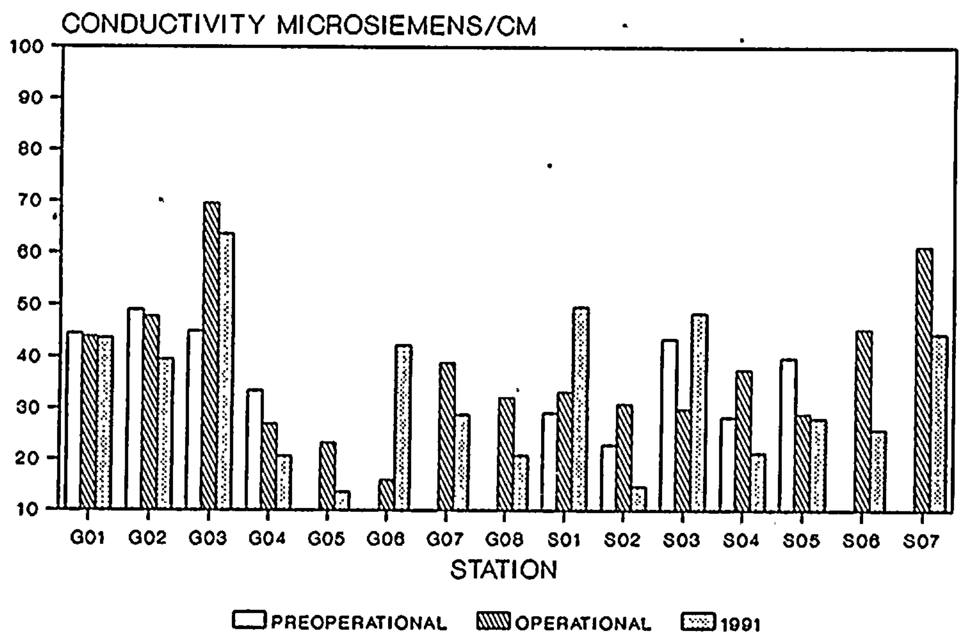
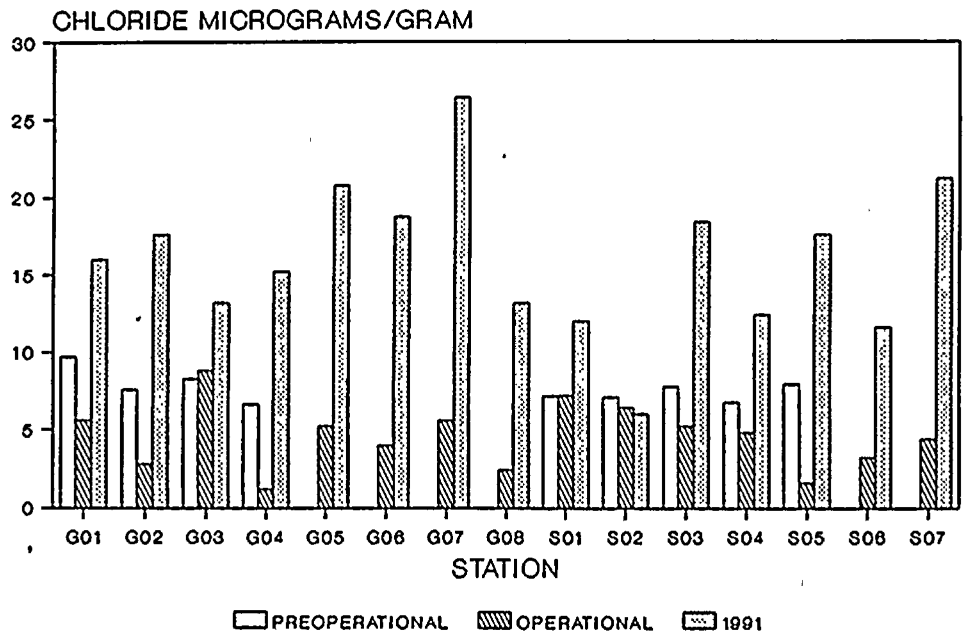


Figure 5-13 Soil pH and Conductivity for 1980 through 1991



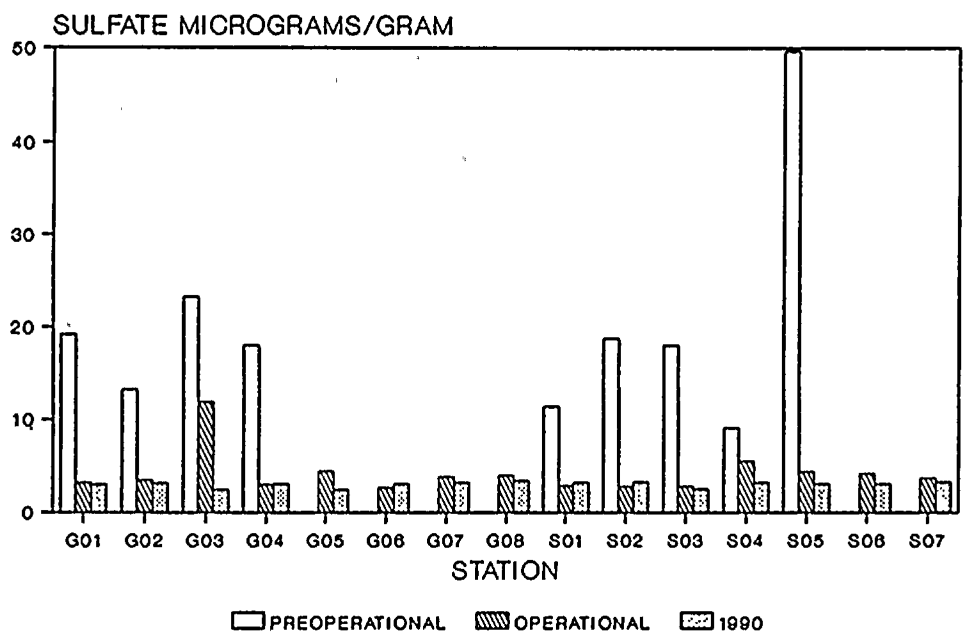
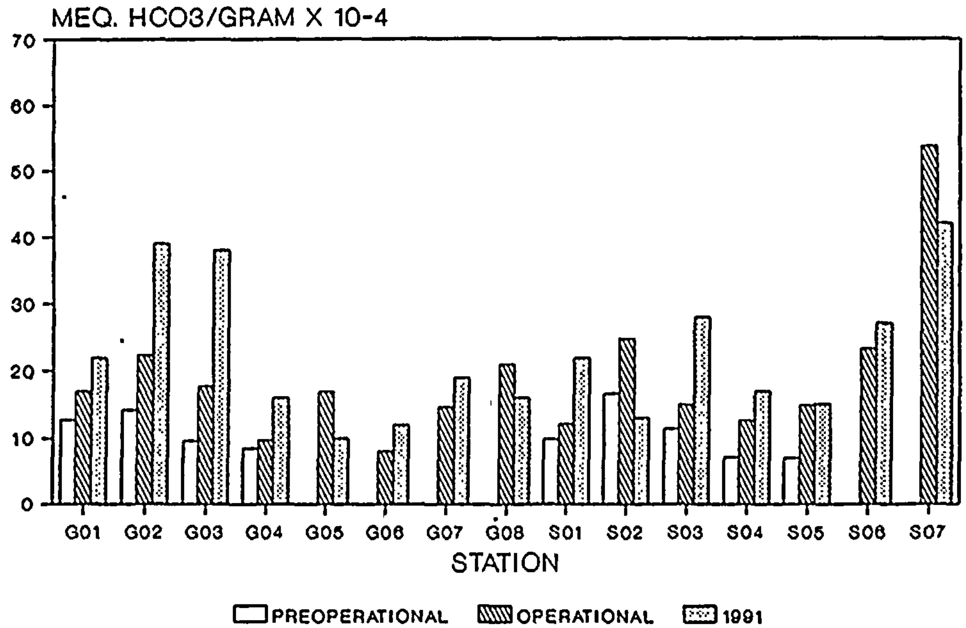


Figure 5-14 Soil Sulfate and Chloride for 1980 through 1991



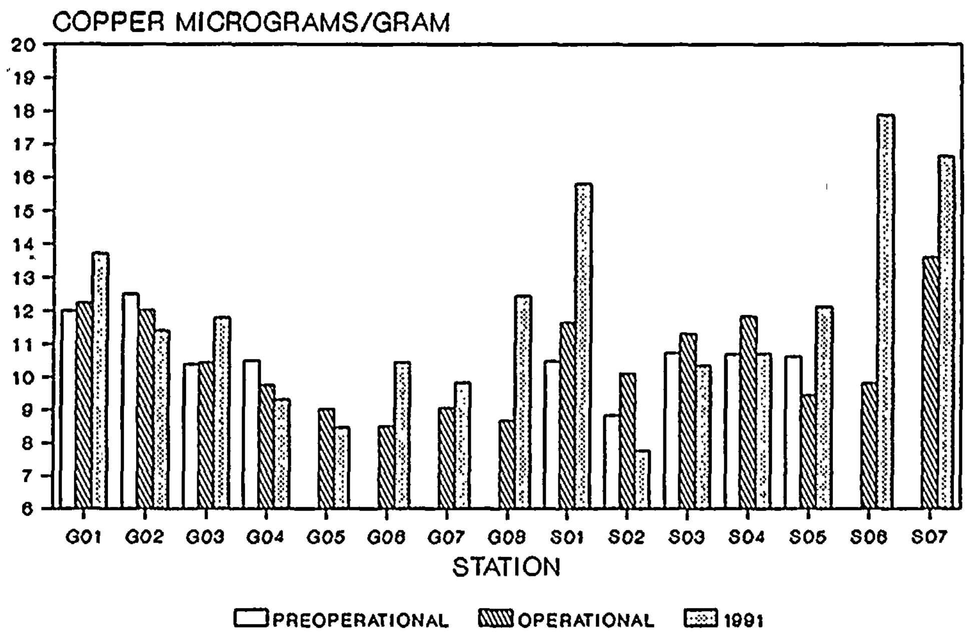
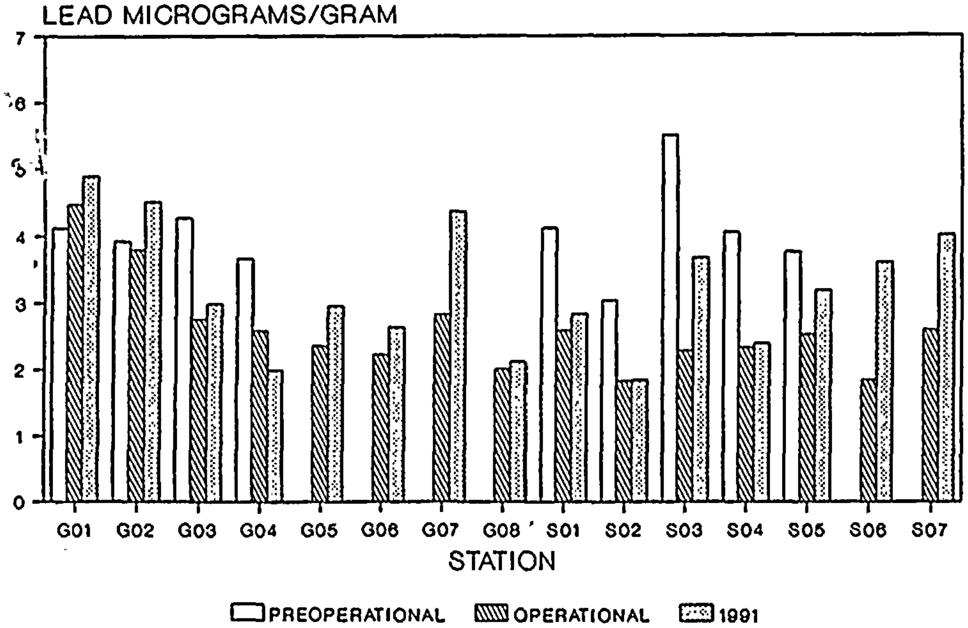


Figure 5-15 Soil Bicarbonate and Copper for 1980 through 1991



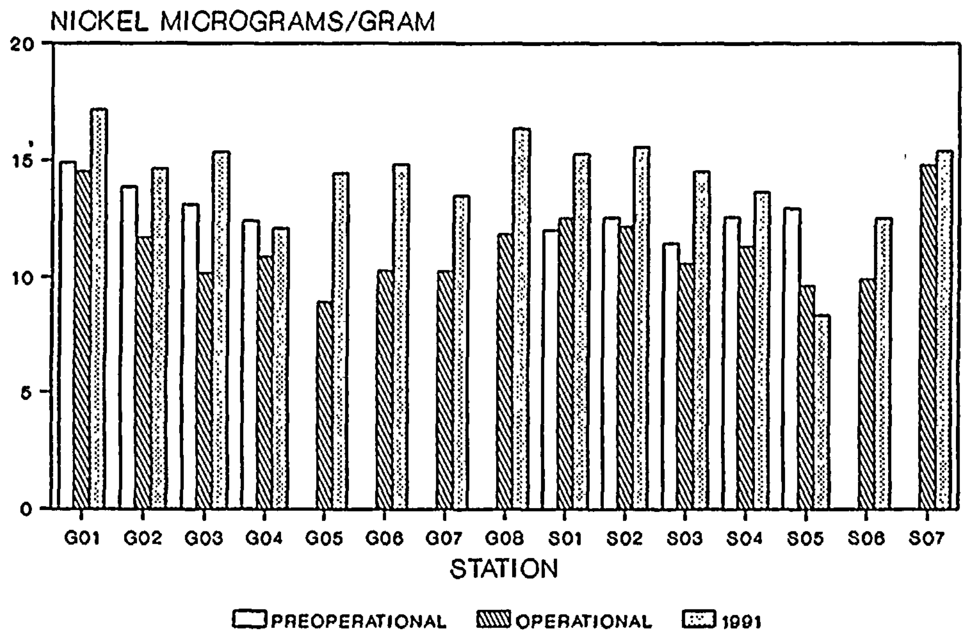
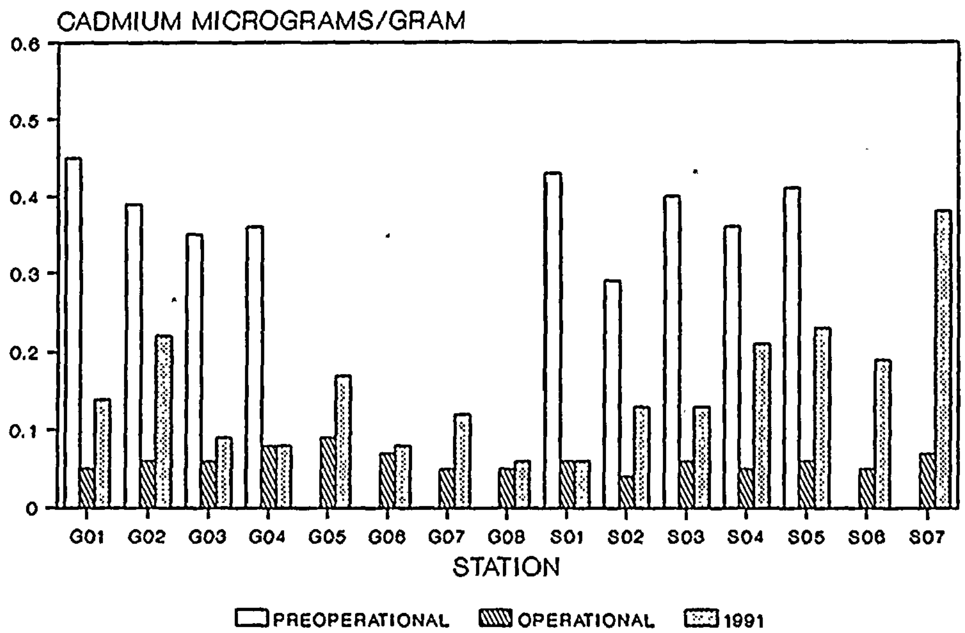


Figure 5-16 Soil Lead and Nickel for 1980 through 1991



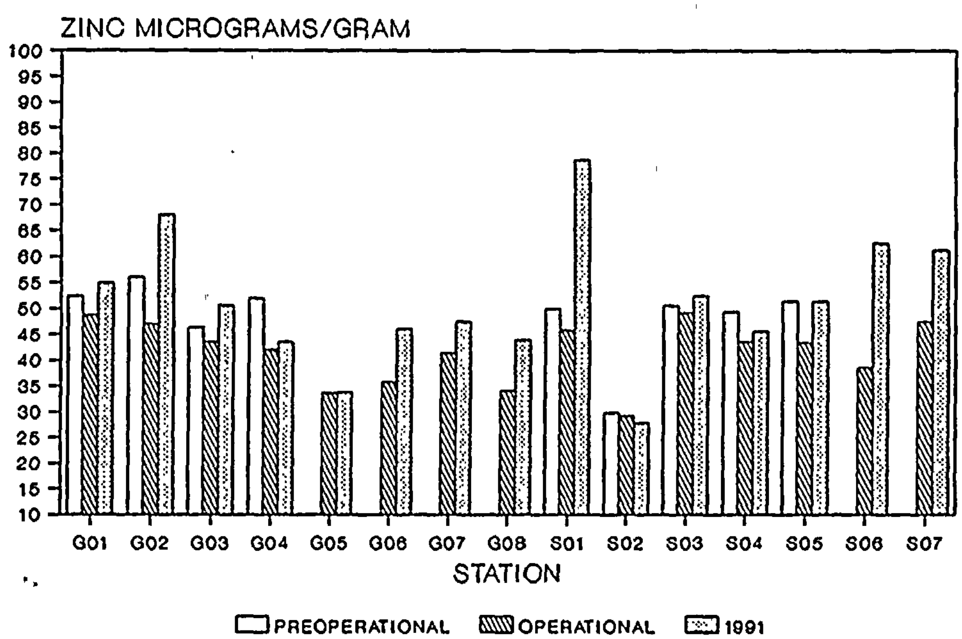
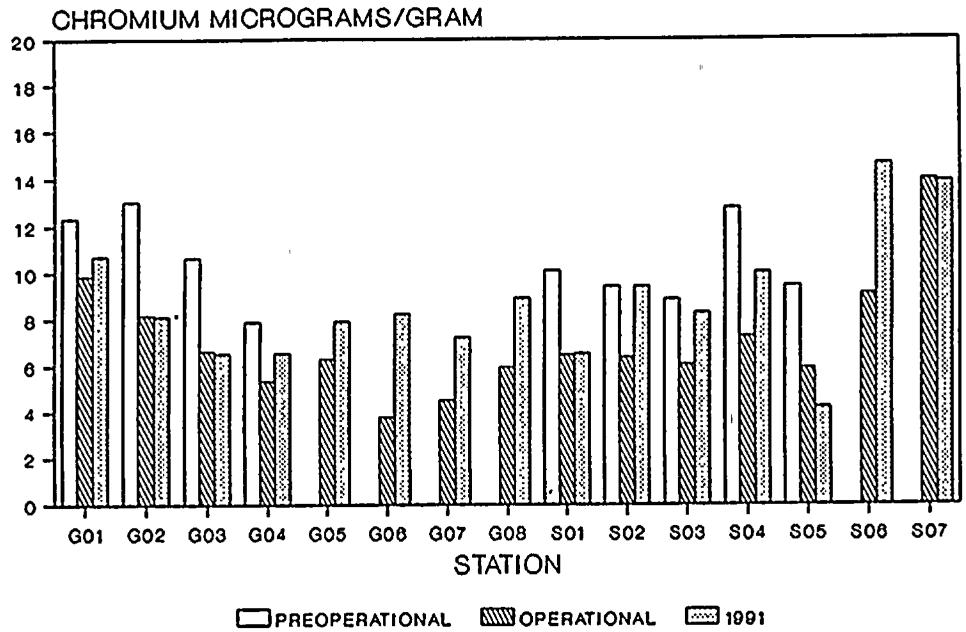


Figure 5-17 Soil Cadmium and Zinc for 1980 through 1991



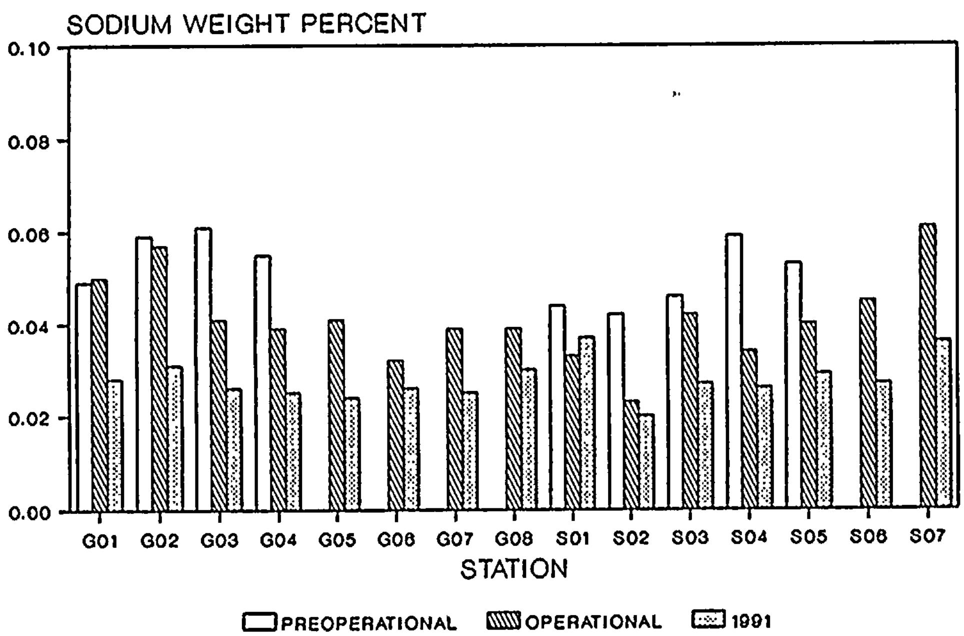


Figure 5-18 Soil Chromium and Sodium for 1980 through 1991

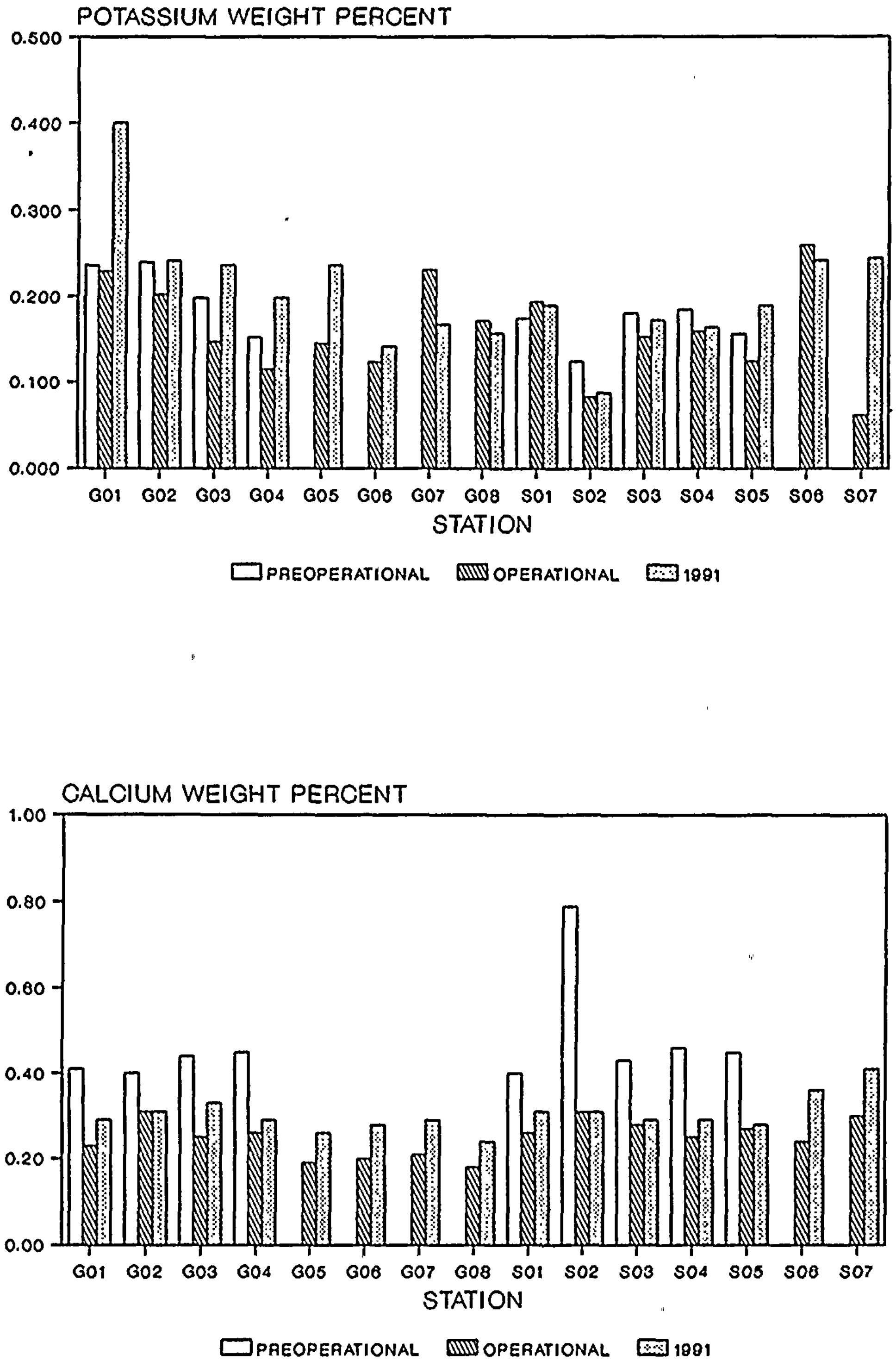


Figure 5-19 Soil Potassium and Calcium for 1980 through 1991

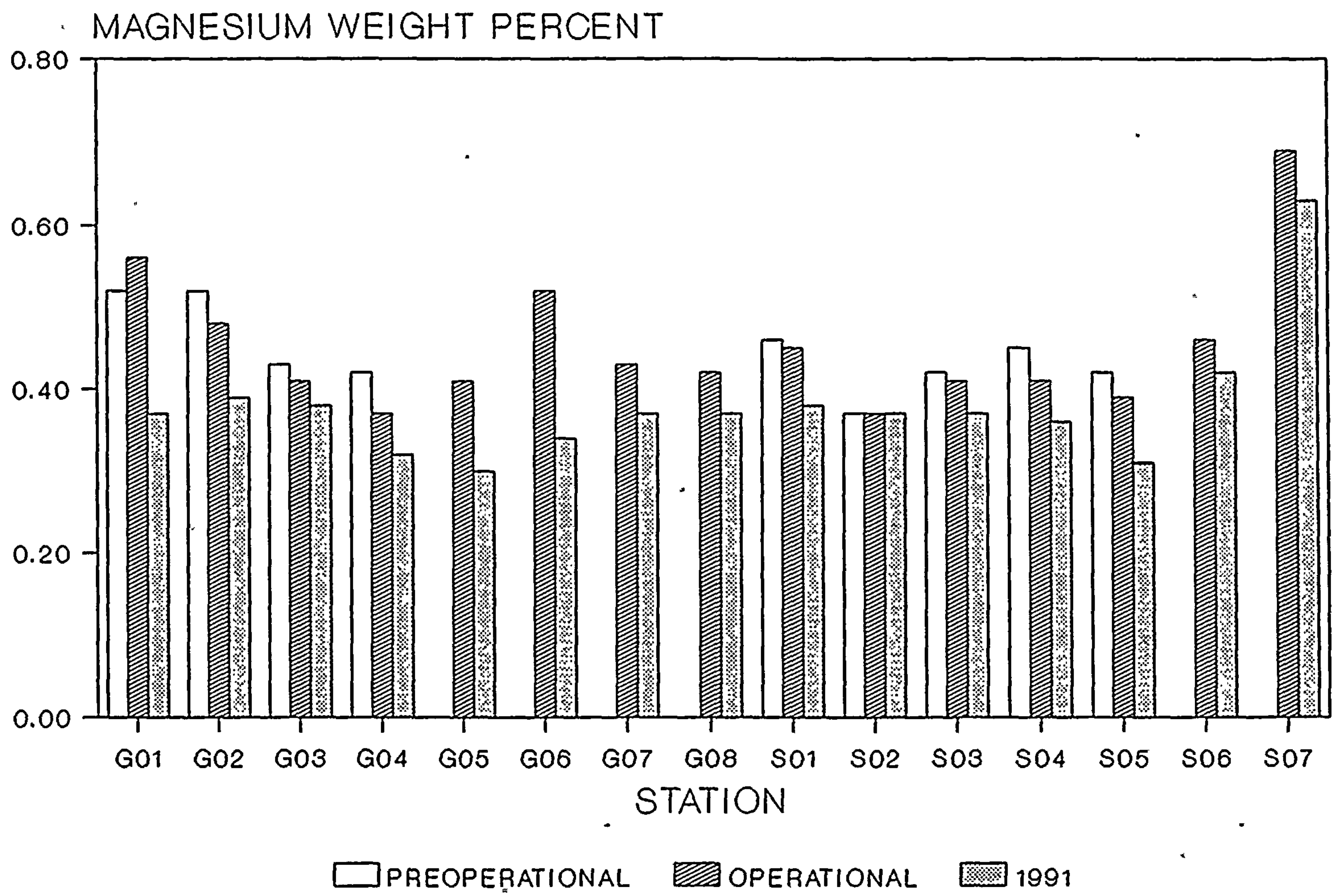


Figure 5-20 Soil Magnesium 1980 through 1991

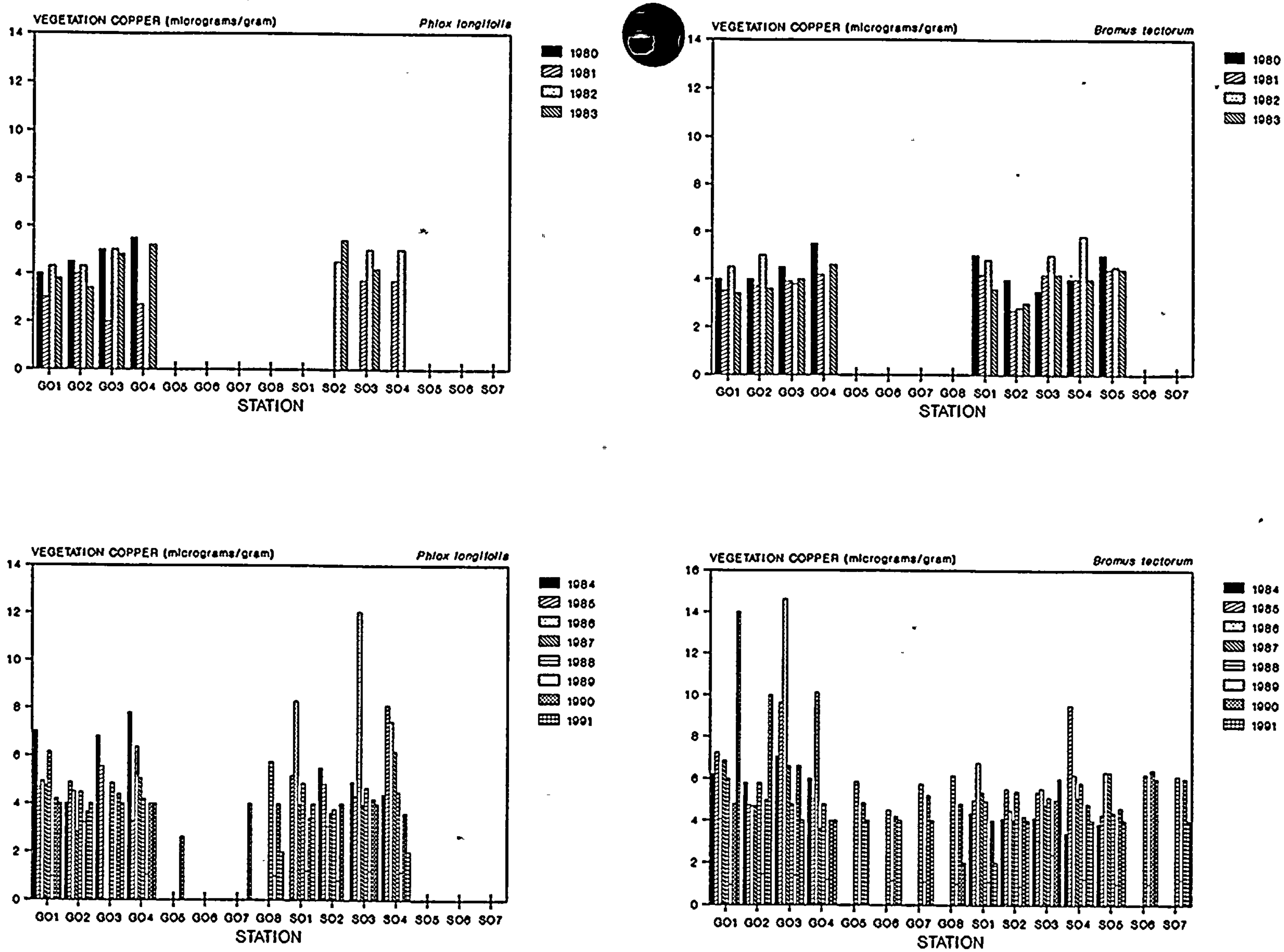


Figure 5-21 Copper Concentrations (ug/g) in Phlox longifolia and Bromus tectorum for 1980 through 1991

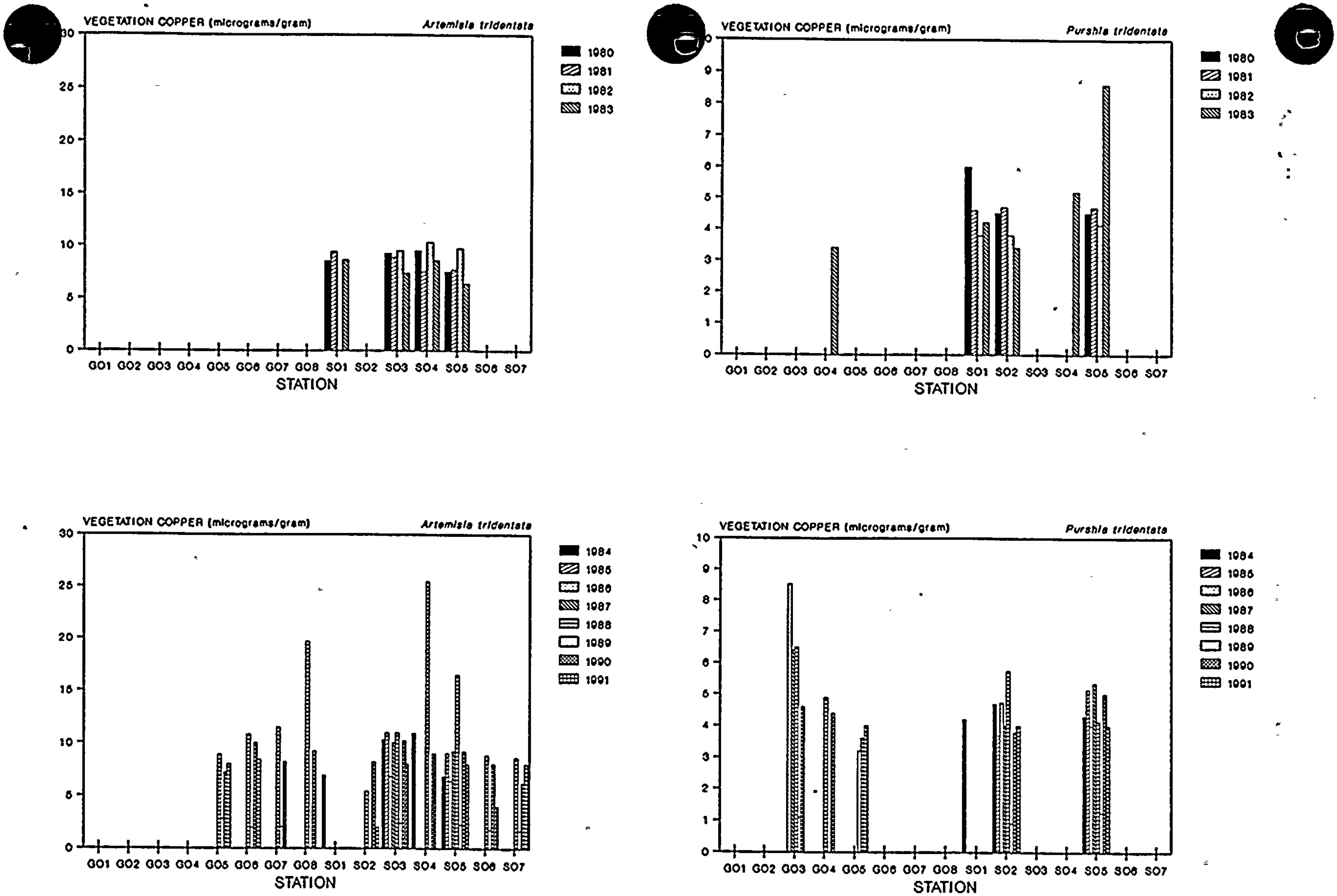


Figure 5-22 Copper Concentrations (ug/g) in Artemisia tridentata and Purshia tridentata for 1980 through 1991

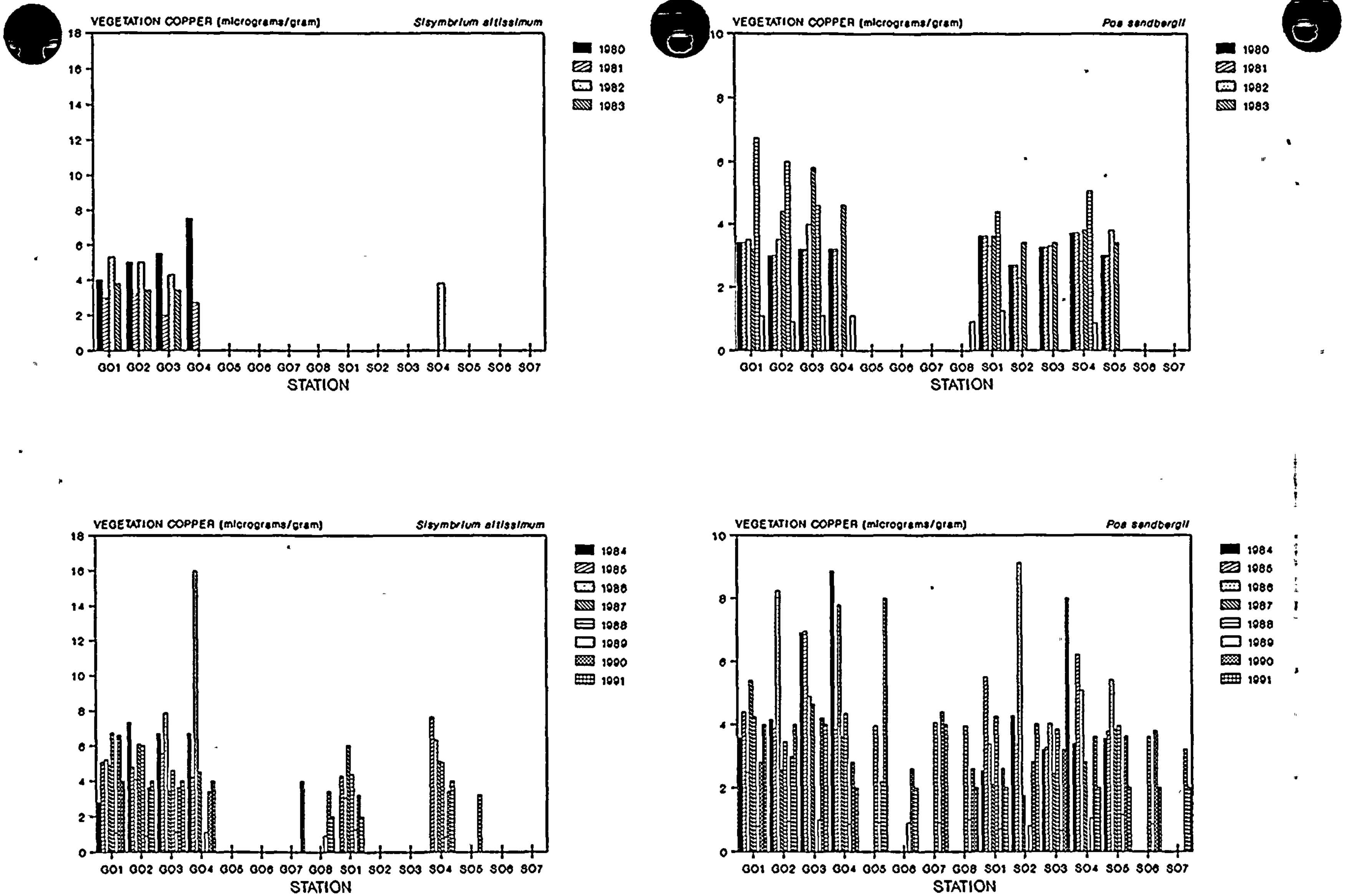


Figure 5-23 Copper Concentrations (ug/g) in
Sisymbrium altissimum and Poa sandbergil for
1980 through 1991

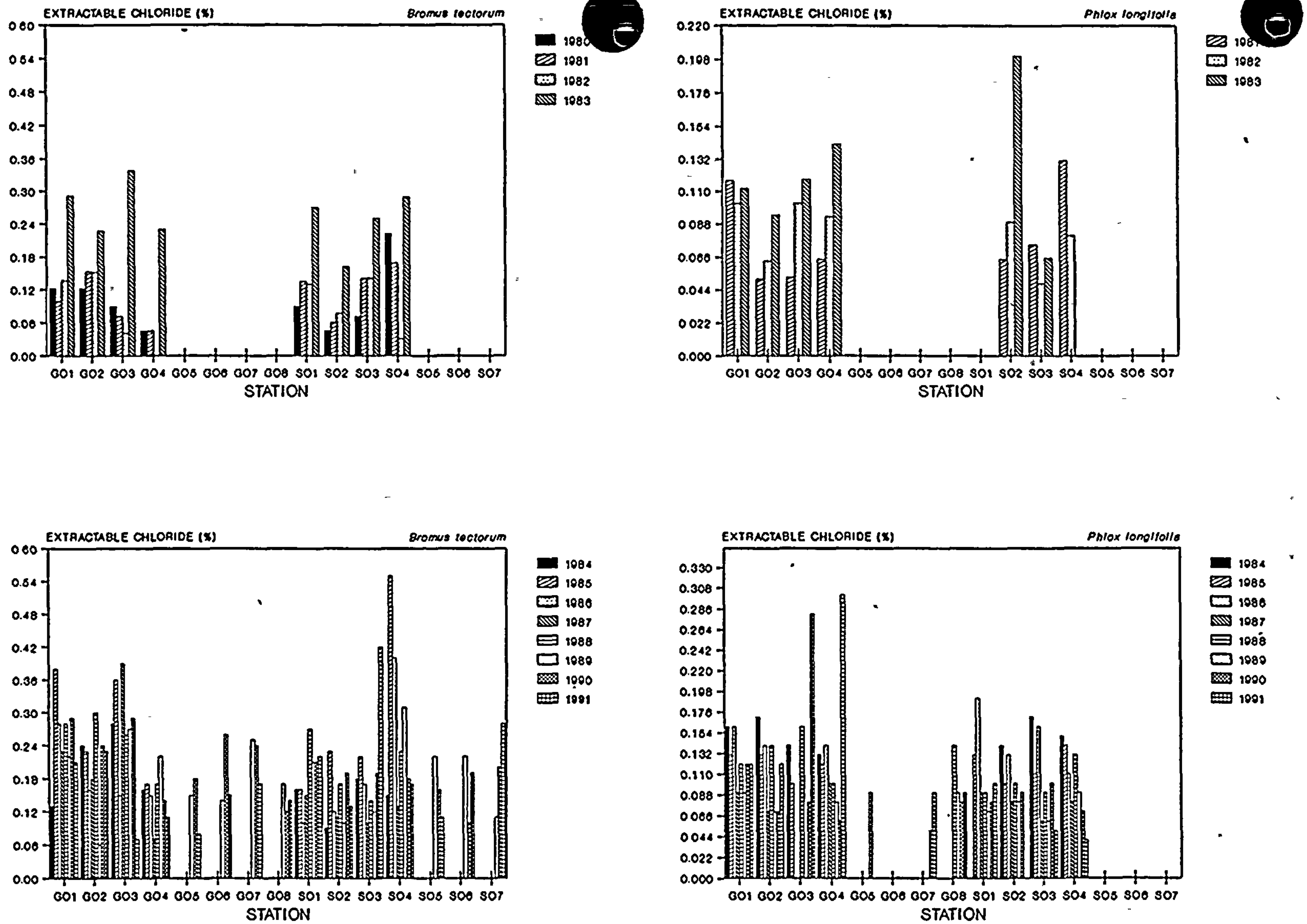


Figure 5-24 Chloride Concentration (%) in <u>Bromus tectorum</u> and <u>Phlox longifolia</u> for 1980 through 1991

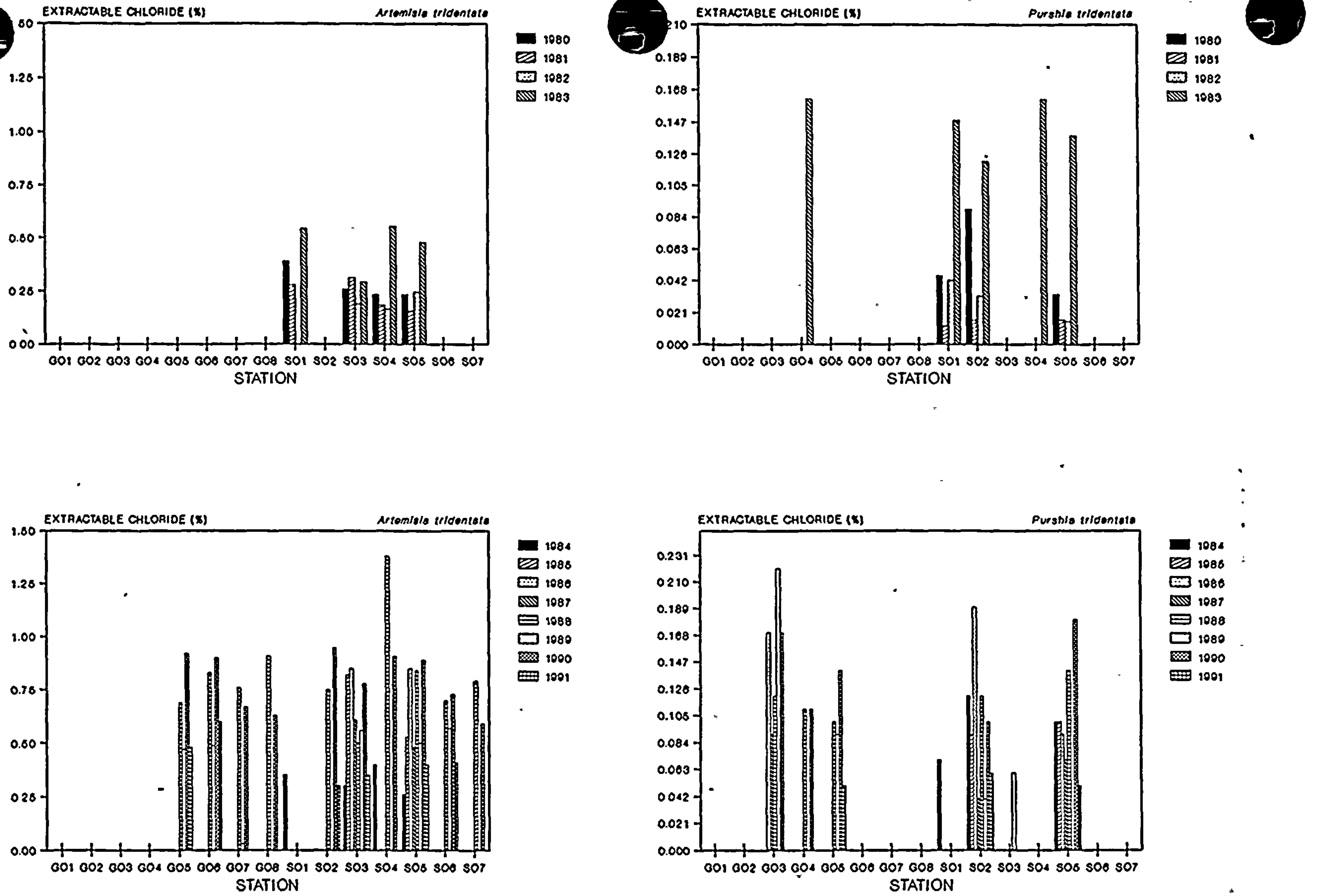


Figure 5-25 Chloride Concentration (%) in <u>Artemisia</u> <u>tridentata</u> and <u>Purshia</u> <u>tridentata</u> for 1980 through 1991

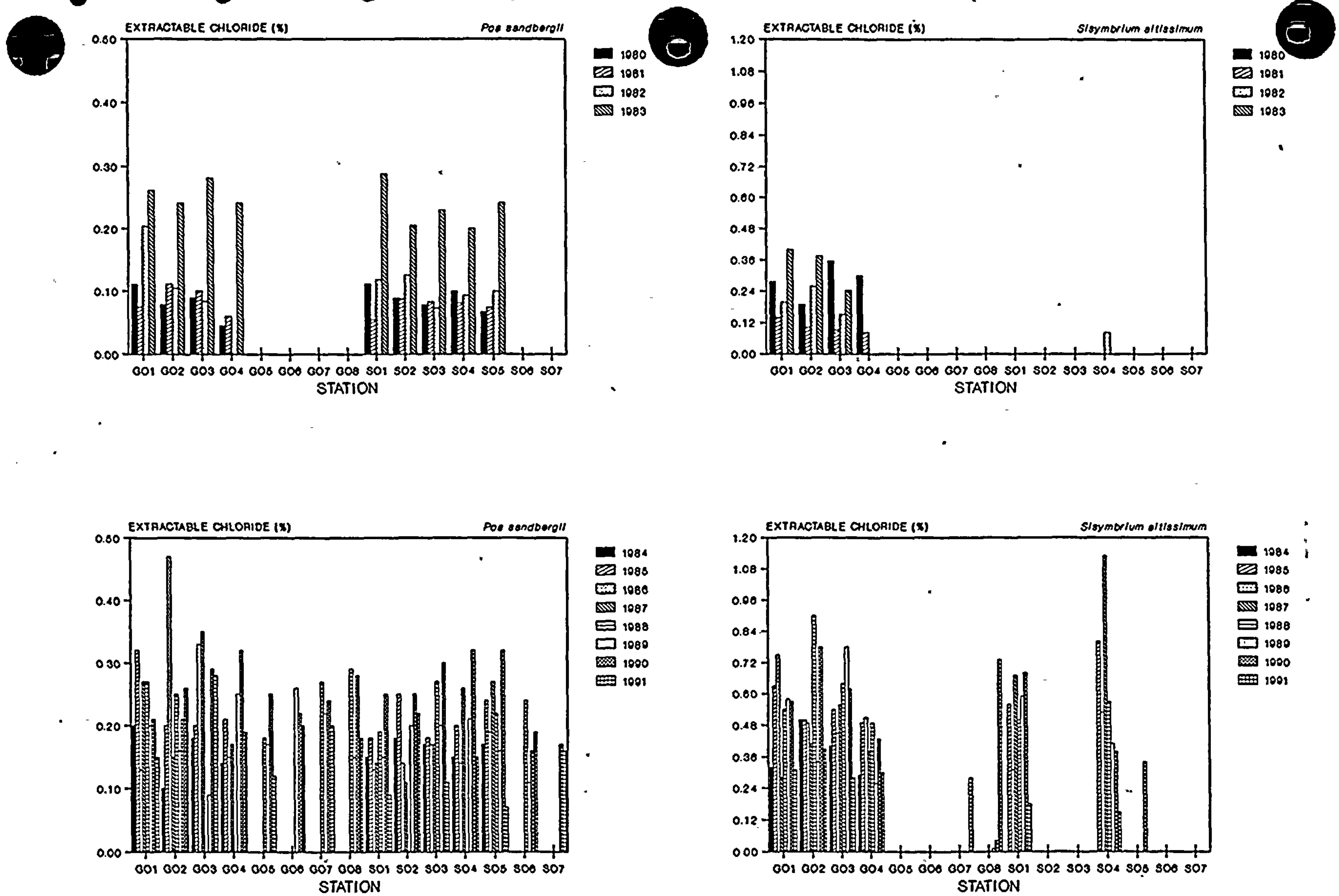


Figure 5-26 Chloride Concentration (%) in Poa sandbergil and Sisymbrium altissimum for 1980 through 1991

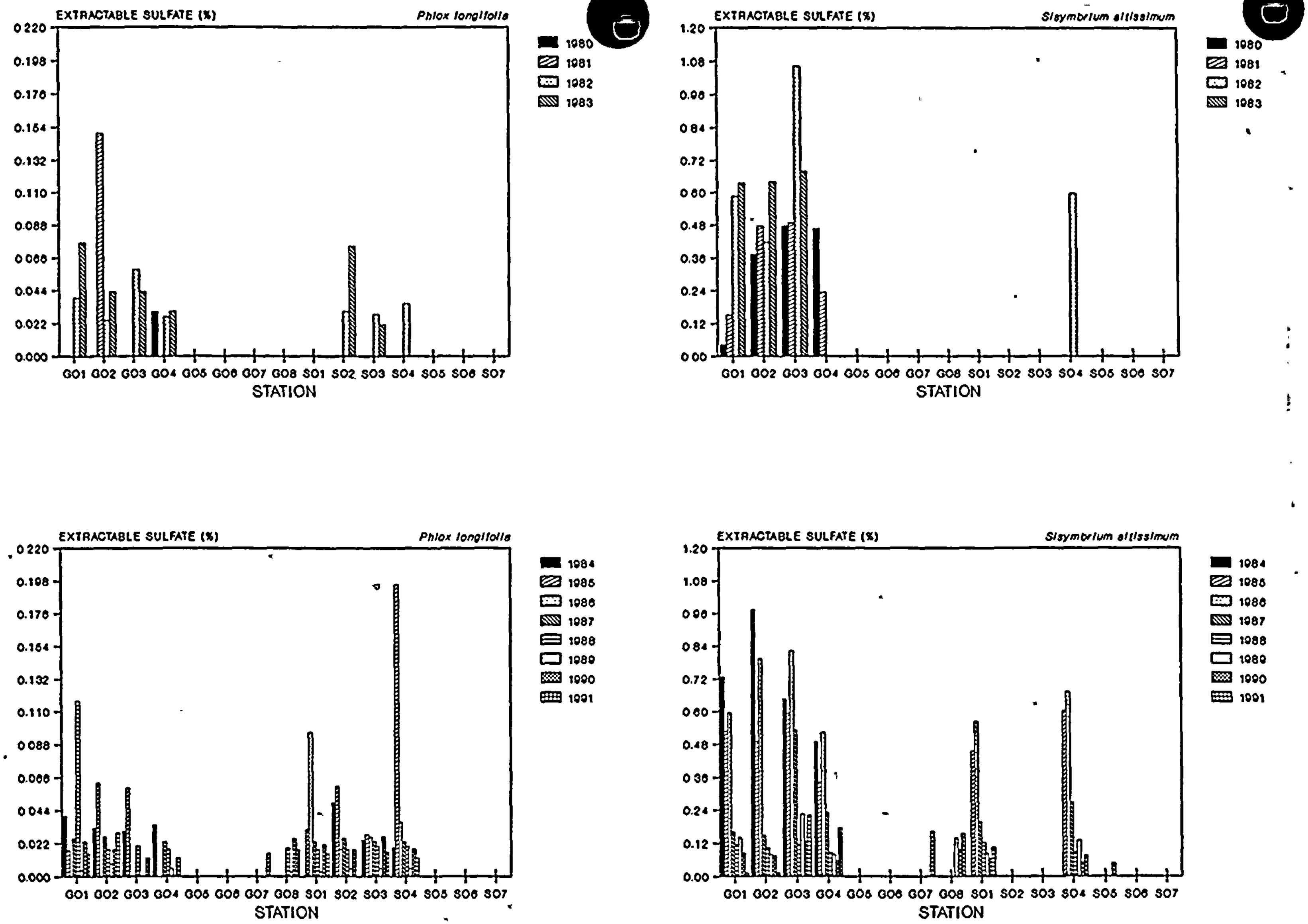


Figure 5-27 Sulfate Concentration (%) in Phlox longifolia and Sisymbrium altissimum for 1980 through 1991

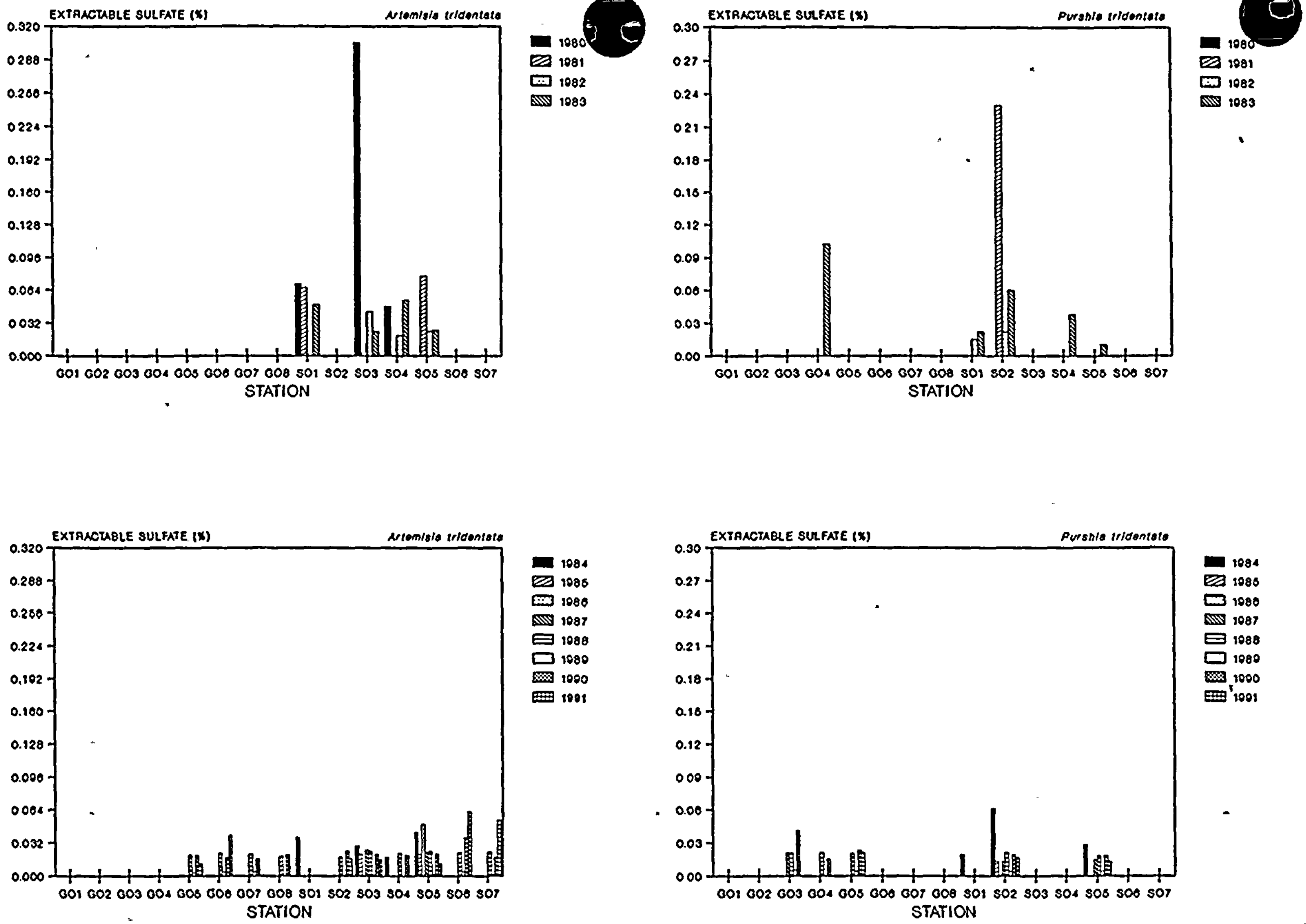


Figure 5-28 Sulfate Concentration (%) in Artemisia tridentata and Purshia tridentata for 1980 through 1991

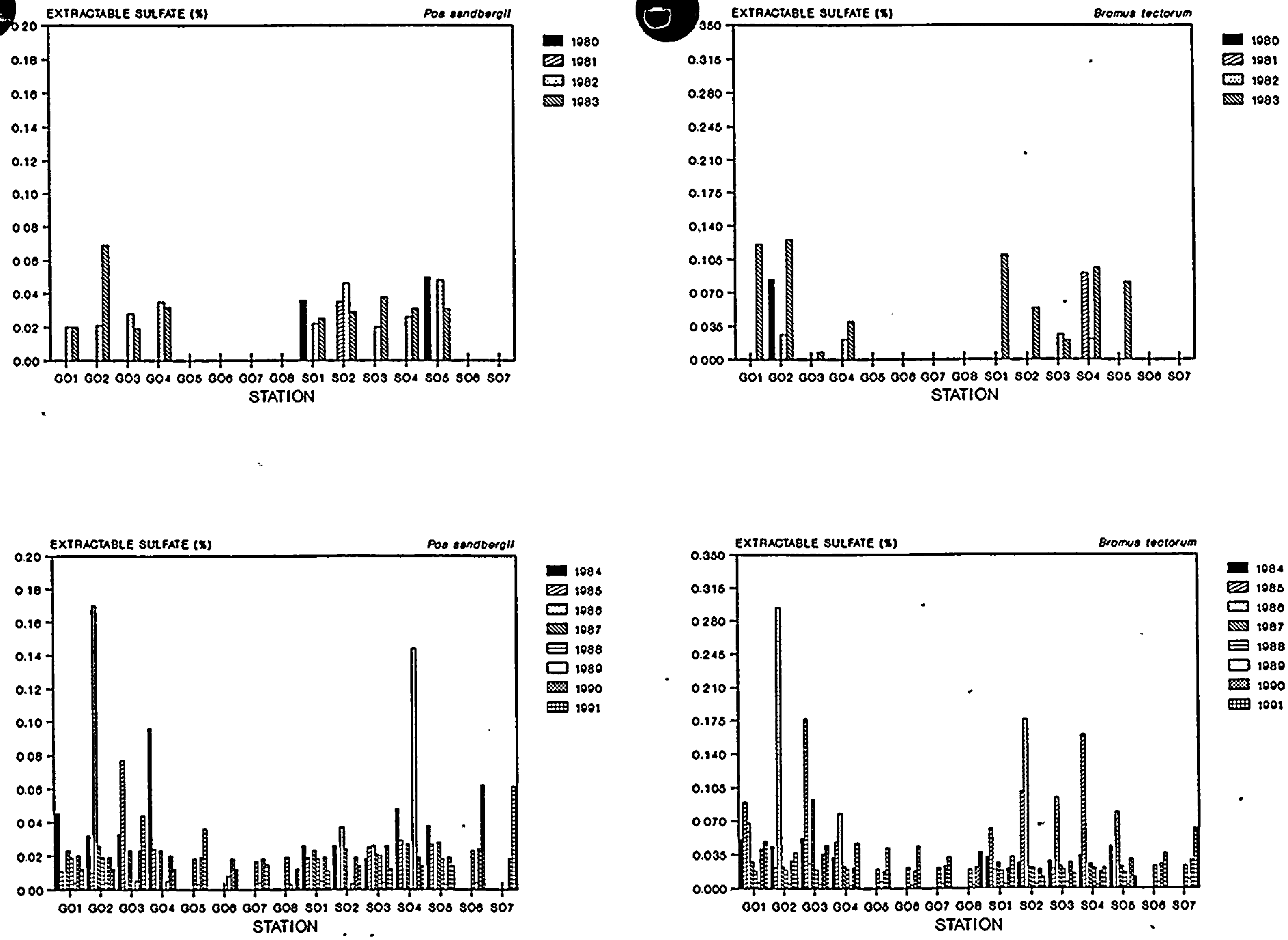


Figure 5-29 Sulfate Concentration (%) in Poa sandbergil and Bromus tectorum for 1980 through 1991

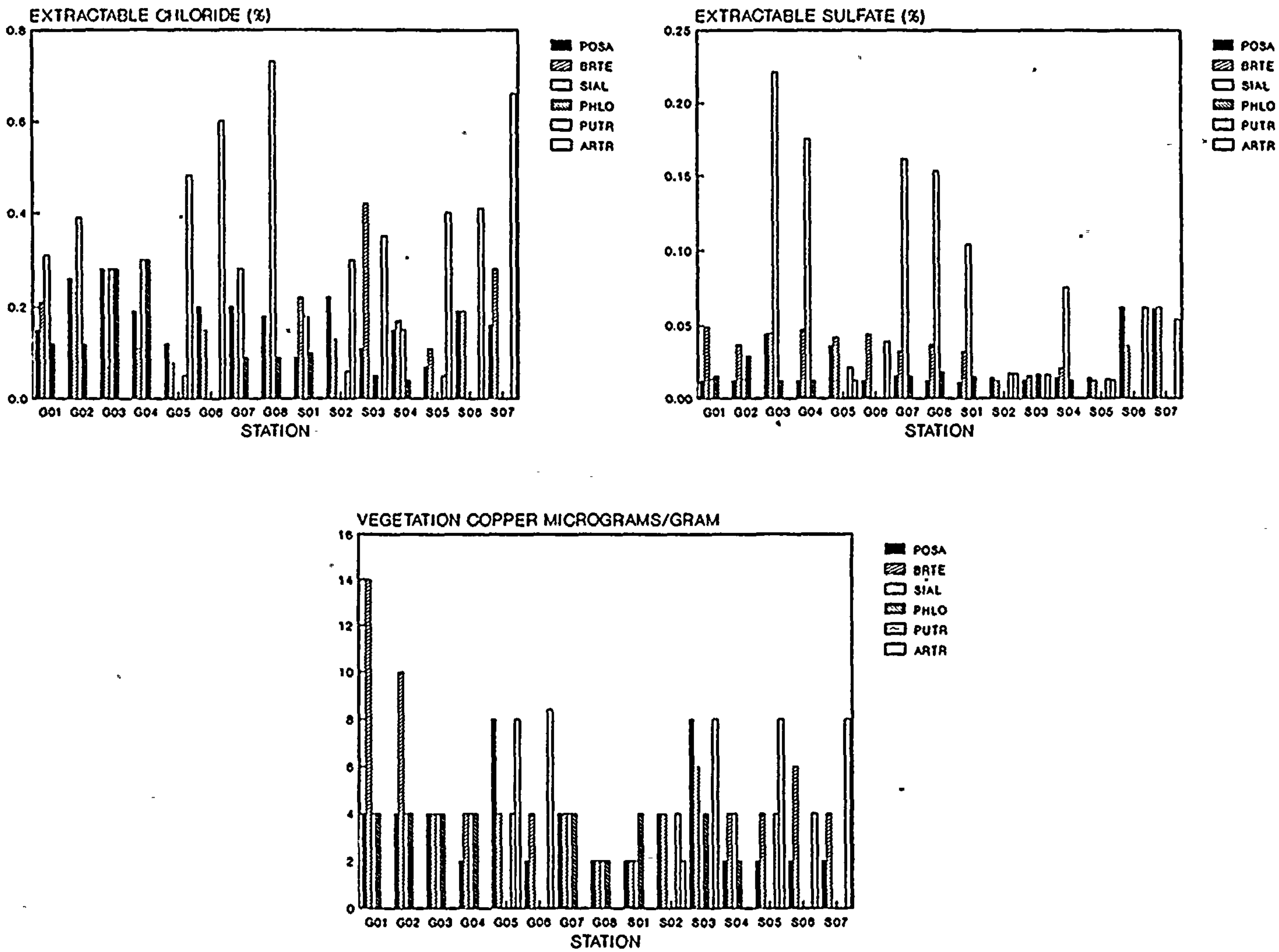


Figure 5-30 Total Vegetation Copper, Chloride and Sulfate for 1991

6.0 INTAKE STRUCTURE FOULING SURVEYS

6.0

The regulatory commitment for this study has been satisfied and no further studies are planned. No fish were found impinged during any of the inspections and algal growth was moderate. Incidental observations will be made when maintenance inspections of the intakes are conducted.

7.0 AERIAL PHOTOGRAPHY PROGRAM

7.1 INTRODUCTION

The aerial photography program began in June of 1988 to monitor the vegetation surrounding WNP-2 for impact due to cooling tower operation. Aerial photographs taken with color infrared (CIR) film, allow large areas to be monitored and to detect signs of possible stress before it becomes visible to the human eye. In addition to examination for stress, the photographs will be compared with those taken in following years to look for changes in vegetation patterns and evidence of cumulative damage. This program is performed to comply with Washington State Energy Facility Site Evaluation Council (EFSEC) Resolution No. 239, dated September 14, 1987.

7.2 MATERIALS AND METHODS

This program was developed using guidelines published in NUREG/CR-1231 (Shipley, et.al., 1980). This report outlined the basic requirements for an aerial monitoring program and suggested types of film, photograph scales, frequency of photograph acquisition and the size of prints.

Five flightlines (Figure 7.1) were planned to cover the areas of greatest deposition according to the drift model constructed by Battelle Pacific Northwest Laboratories (Droppo et.al., 1976). Two flightlines, approximately 7 miles (11.2 Km) in length, run in a general north-south direction. These flightlines run between the two areas of greatest deposition according to the model. The other three flightlines of approximately 5 miles (8.1 Km) in length, run in an east-west direction and were placed to cross gradients of deposition. The five flightlines were flown at an altitude of 1,550 feet (477m) above mean sea level. The flightline coordinates are stored in the long-range navigation (LORAN) system in the contractors airplane. This allows the same lines to be photographed in following years.

The photographs were taken with Kodak Aerochrome 2443 color infrared film in a Hasselblad ELM 70mm camera. A Planar lens with a 80mm focal length was used with a number 12 Wratten filter attached. The scale is 1:6,000 in a 70mm x 70mm format. The relatively large scale of 1:6,000 was chosen as being large enough to differentiate the types of shrubs in the areas surrounding WNP-2. The 70mm size was chosen over the larger nine inch by nine inch format for ease of handling and the storage of the nearly 300 photographs.

Color infrared (CIR) film was chosen over natural color or black and white film because the symptoms of stress on vegetation may show in the infrared wavelengths before it becomes apparent in the visible wavelengths. CIR film is easier to interpret than black and white infrared because the shades of color are easier to differentiate than the subtler shades of gray in the monochromatic infrared. Healthy vegetation will show as a dark red or magenta color. Stressed vegetation will show lighter shades of red to white. Interpretation of the photographs is done on a light table and viewed with magnifying glass or stereo microscope. A plastic sheet is put over the photographs to protect the film and to allow areas of interest to be marked with a grease pencil. Each photograph is examined and signs of stress are noted by flightline number and frame number. The photographs are taken with an overlap of 50% to make it possible to view them in stereo if desired. The 50% overlap was maintained during the acquisition by controlling the shutter with an intervelometer.

The photographs were used in the placing of the samplers for the cooling tower drift study. The samplers were placed on portions of the two north-south flightlines. In future overflights, the stations may be used to ground truth the photographs. Markers will be placed next to the samplers to make the stations easier to find on the photographs. The ground truthing will consist of a survey of an area or areas on a flightline and an examination of the vegetation for other signs of stress.

7.3 RESULTS AND DISCUSSION

The overflight was performed by the contractor, Photography Plus, of Umatilla, Oregon on May 15 and the photographs received on June 12, 1991. The initial examination of the flight lines was to determine the quality of the photographs, which was found to be generally good except for a few frames that apparently had been exposed to light. A second, more detailed examination followed for the purpose of interpretation.

Flight line 1 was flown from the south-southeast to the north-northwest and is approximately 7 miles (11.3 Km) in length. The first three-quarters of the flight line is primarily scattered small plants such as Phlox longifolia and Salsola kali. The medium sized shrubs, Chrysothamnus nauseosus and C. visidiflorus, and the larger Artemisia tridentata and Purshia tridentata usually occurring as small clusters for the medium sized shrubs and isolated individuals for the larger shrubs. Some grass growth, noted on the photographs as a reddish tinge, occurs mostly between the stabilized dunes. The last quarter of the flight line has a higher density of small and medium sized plants and shrubs. Many of the small shrubs were determined in 1989 to be immature A. tridentata. Other plants on the edges of active dunes may be Agropyron spicatum, Stipa comata or Rumex venosus. Some clusters of medium sized shrubs were also noted, most probably both species of Chrysothamnus and smaller individuals of A. tridentata. Active grass in this area seemed minimal.

Flight line 2 was flown from the southeast to the northwest and is also approximately 7 miles in length. This flight line begins at the southward turn of the railroad tracks (Figure 7-1) where a large area of large and medium shrubs occurs. The majority of the large are A. tridentata with some P. tridentata. Like flight line 1, most of this flight line covers areas with few medium and large sized shrubs and has a low to medium density of small shrubs and plants. Many of the forbs were associated with disturbed areas such as roads, railroads, gravelpits and fence lines. The last quarter of the flight line has an increase in density of small and medium sized plants and shrubs similar to that noted in flight line 1.

Flight line 3 was flown from the west to the east and is approximately 5 miles (8.1 Km) in length and covers the area approximately 1 mile north of Plant 2. Most of this flight line has a low density of scattered plants and small shrubs with some clusters of medium-sized shrubs and few large shrubs. Grasses and other forbs were noted in the immediate area of the Ashe Substation.

Flight line 4 was also flown from west to east. It intersects the area of Plant 2 at the cooling towers. The area at the beginning of this flight line is populated with scattered forbs and small to medium sized shrubs. Small shrubs, grasses and other forbs were noted in the areas surrounding powerline towers. The middle half of the flight line is in the immediate area of Plant 2. This area has forbs, such as S. kali, associated with it. The last quarter of the flight line has a medium to high density of medium and large sized shrubs. These are primarily C. nauseosus and A. tridentata.

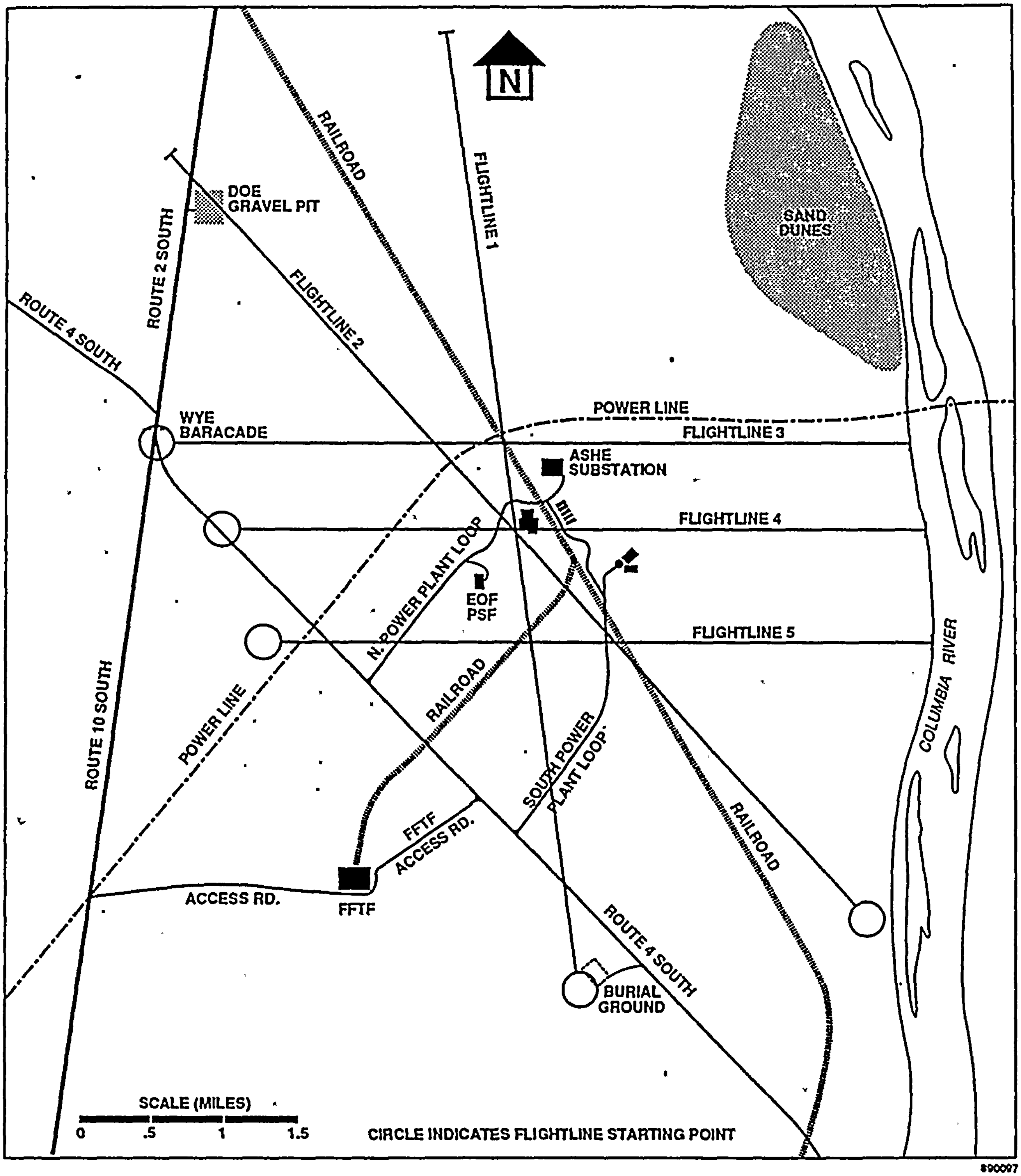
Flight line 5, flown west to east, covers the area approximately 3/4 of a mile south of Plant 2. This flight line has the most consistent vegetation density with most frames showing small and medium plants and shrubs. The last half of the flight line has an increase in the number of large shrubs, primarily A. tridentata.

Overall, the health of vegetation in all five flight lines appeared good. It was noted in an area just south of the cooling towers that the several large P. tridentata appeared to be stressed. Subsequent investigation showed that the Purshia had been damaged by the cold weather in December and January and that stress to this species was evident in other frames. A comparison of these photographs with those taken in 1989 shows little change in the shrubs. Grasses and other small forbs appeared healthy but less dense than in 1989. Overall, no adverse impact was evident from the operation of Plant 2.

7.4 REFERENCES

Shipley, B.L., S.B. Pahwa, M.D. Thompson and R.B. Lantz. 1980. NUREG/CR-1231. Remote sensing for detection and monitoring of salt stress on vegetation: evaluation and guidelines. Final report, September 1976-March 1979. Nuclear Regulatory Commission, Washington, D.C.

Droppo, J.G., C.E. Hane and R.K. Woodruff. 1976. Atmospheric effects of circular mechanical draft cooling towers at Washington Public Power Supply System Nuclear Power Plant Number Two. Battelle Pacific Northwest Laboratories, Richland, WA.



CIRCLE INDICATES FLIGHT LINES STARTING POINT

Figure 7-1. Aerial Photography Flight lines

8.0 DISTRIBUTION

Supply system

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Mail Drop 280

L.J. Garvin III, Manager
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Mail Drop 280

W.A. Kiel
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