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

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

Sincerely,

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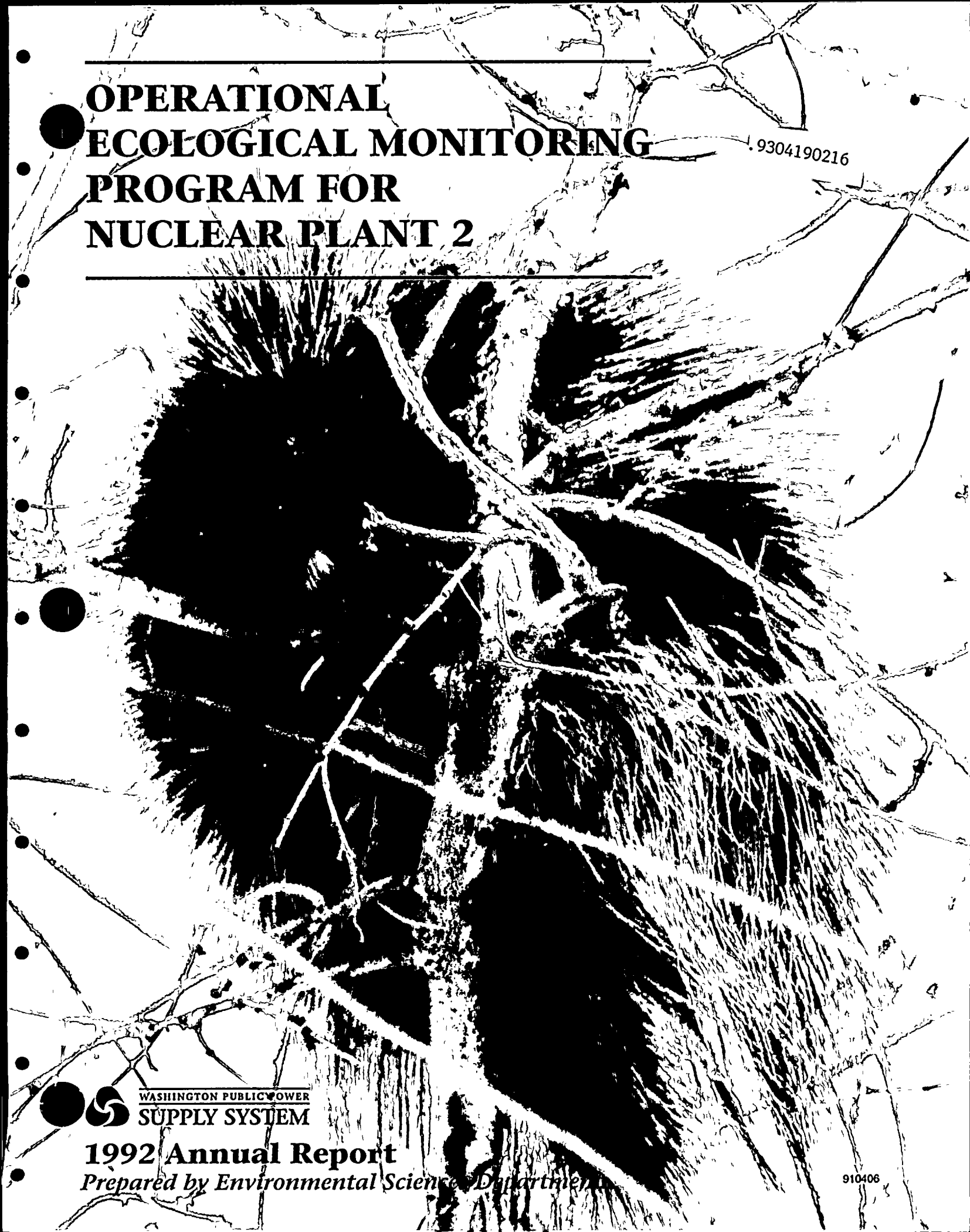

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

1992 Annual Report

Prepared by Environmental Science Department

910406

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EXECUTIVE SUMMARY

During 1992 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.

Two Daphnia pulex and four Hyalella azteca 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 1992, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

Total herbaceous cover decreased slightly in 1992. A corresponding decrease 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 1992 appear to be directly related to the growing season precipitation and temperature. Calendar year 1992 was the warmest year on record, and the seventh consecutive year with above-normal average annual temperature.

Color infrared aerial photographs along 5 flightlines were taken in May 1992. Interpretation of the color infrared photographs were done by Oregon State University, Geo Sciences Department. A comparison of 1992 photographs with those taken in 1991 shows that there has been little or no change in 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).

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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 1992.

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 1992 through December 1992.

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 for 1992, measured at the USGS stream-quality station located at river mile 388.1, near the Vernita Bridge, was 35,300 cfs (cubic feet per second), while average and maximum flows in 1992 were 100,840 and 261,000 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 and vegetation samples taken at each station.
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.

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

Specific Programs	Historical Program	Proposed Program
Cooling Tower Drift	The pattern and chemistry of the cooling tower drift model.	Terminated in 1991.
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	Originally, 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 utilizing two species. Fish Flow - through and Daphnia static bioassays (two tests/species) will be performed on an annual basis with respect to WNP-2 maintenance and referral schedules.
	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.

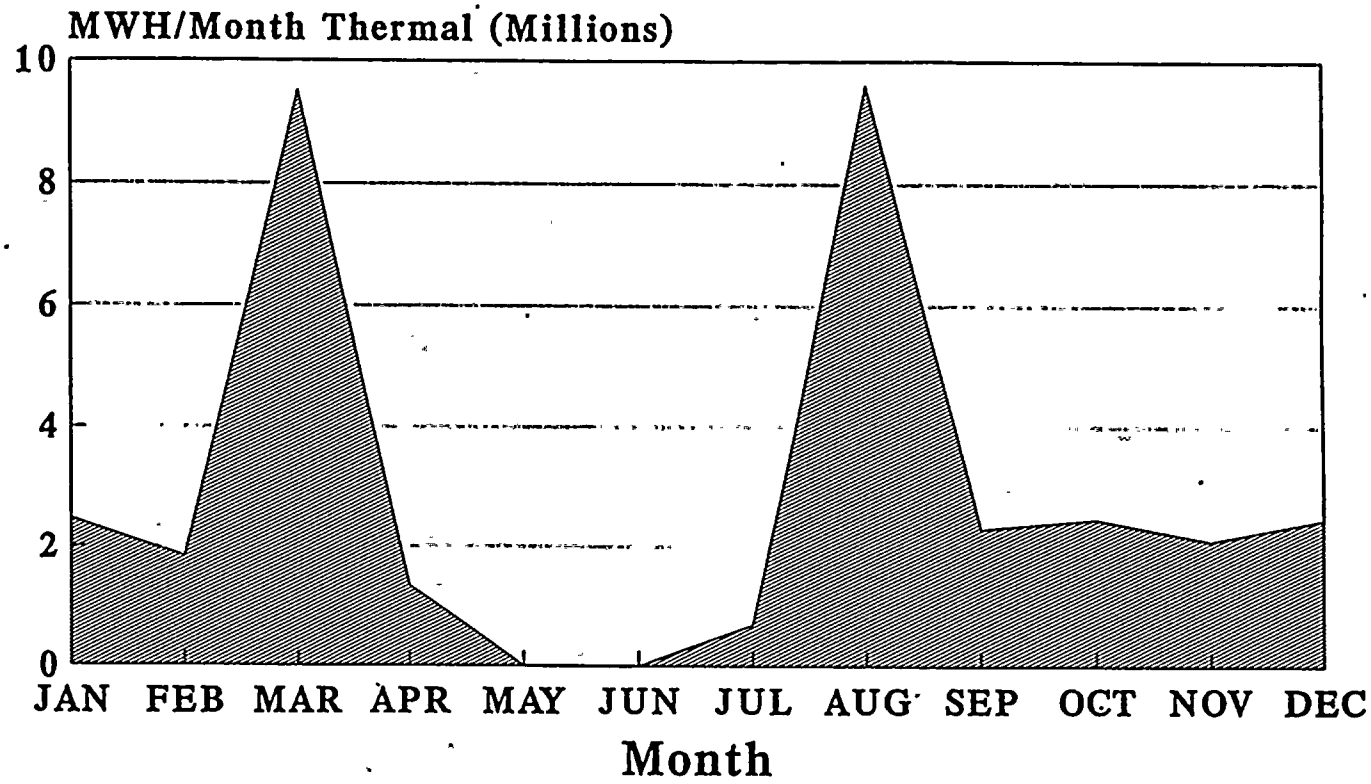

FIGURE 1-1
WNP-2 GROSS THERMAL PRODUCTION FOR 1992

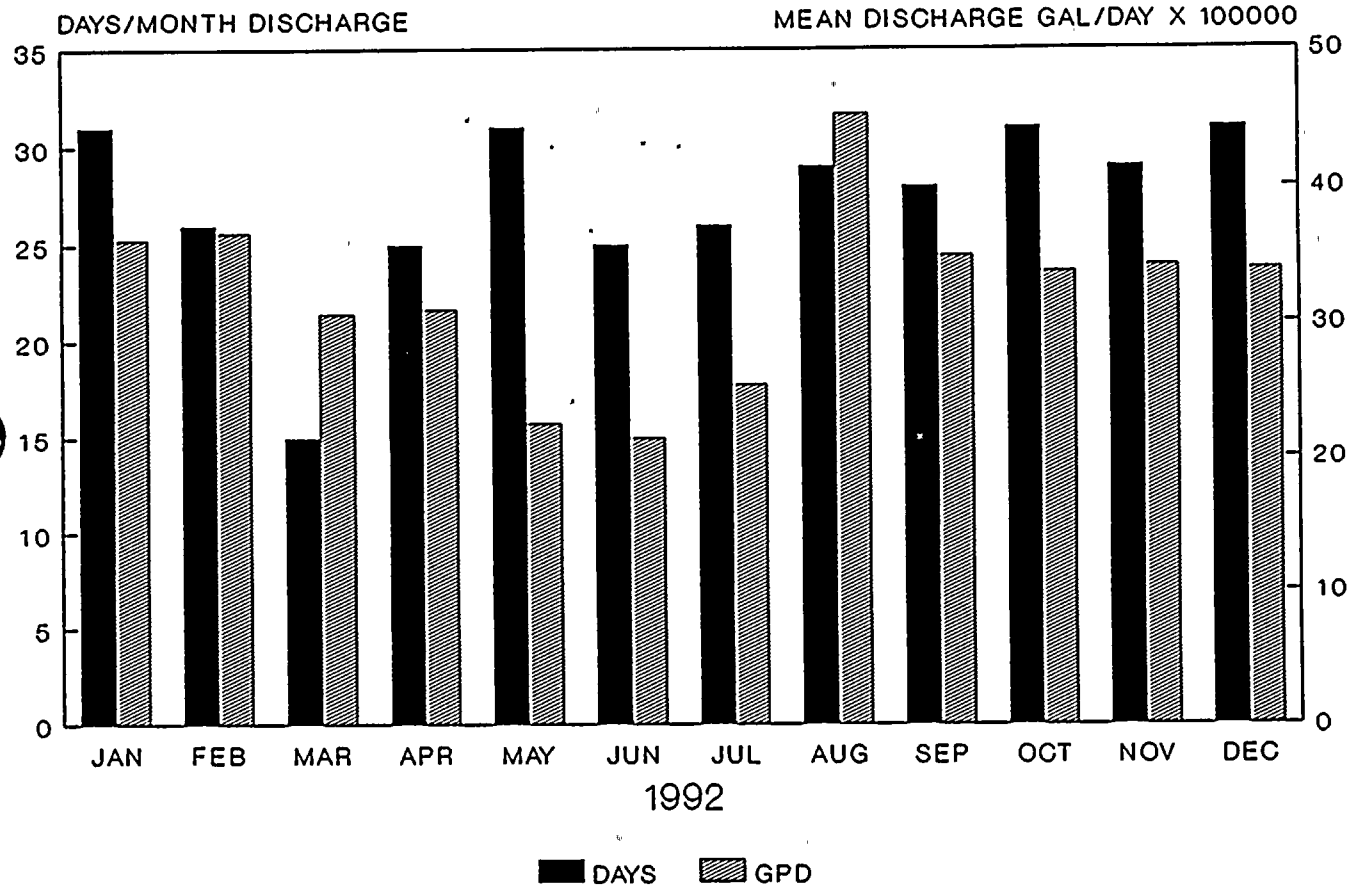

FIGURE 1-2
WNP-2 DAYS PER MONTH DISCHARGING AND MEAN MONTHLY DISCHARGE

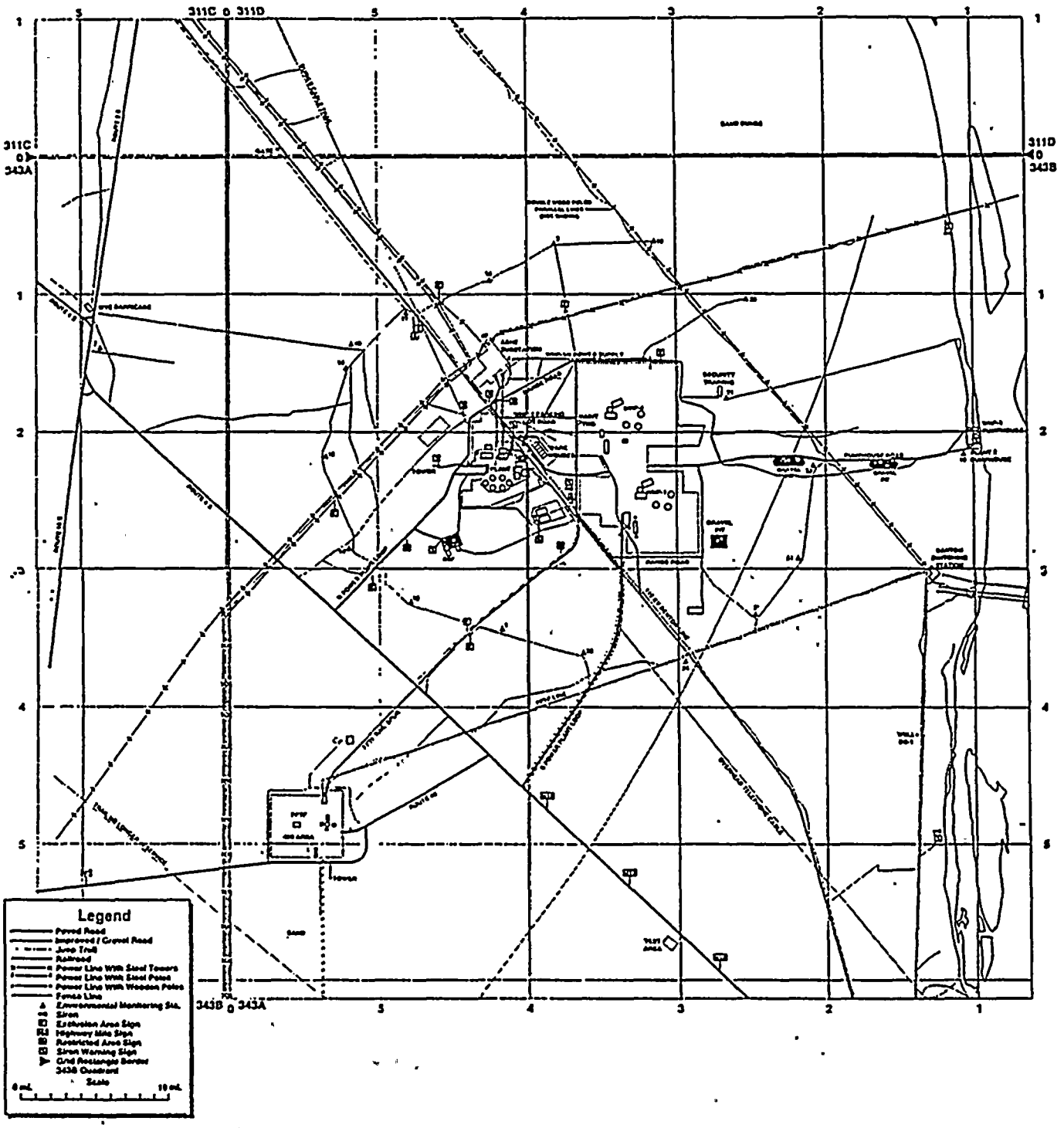

FIGURE 1-3
WNP-2 LOCATION MAP

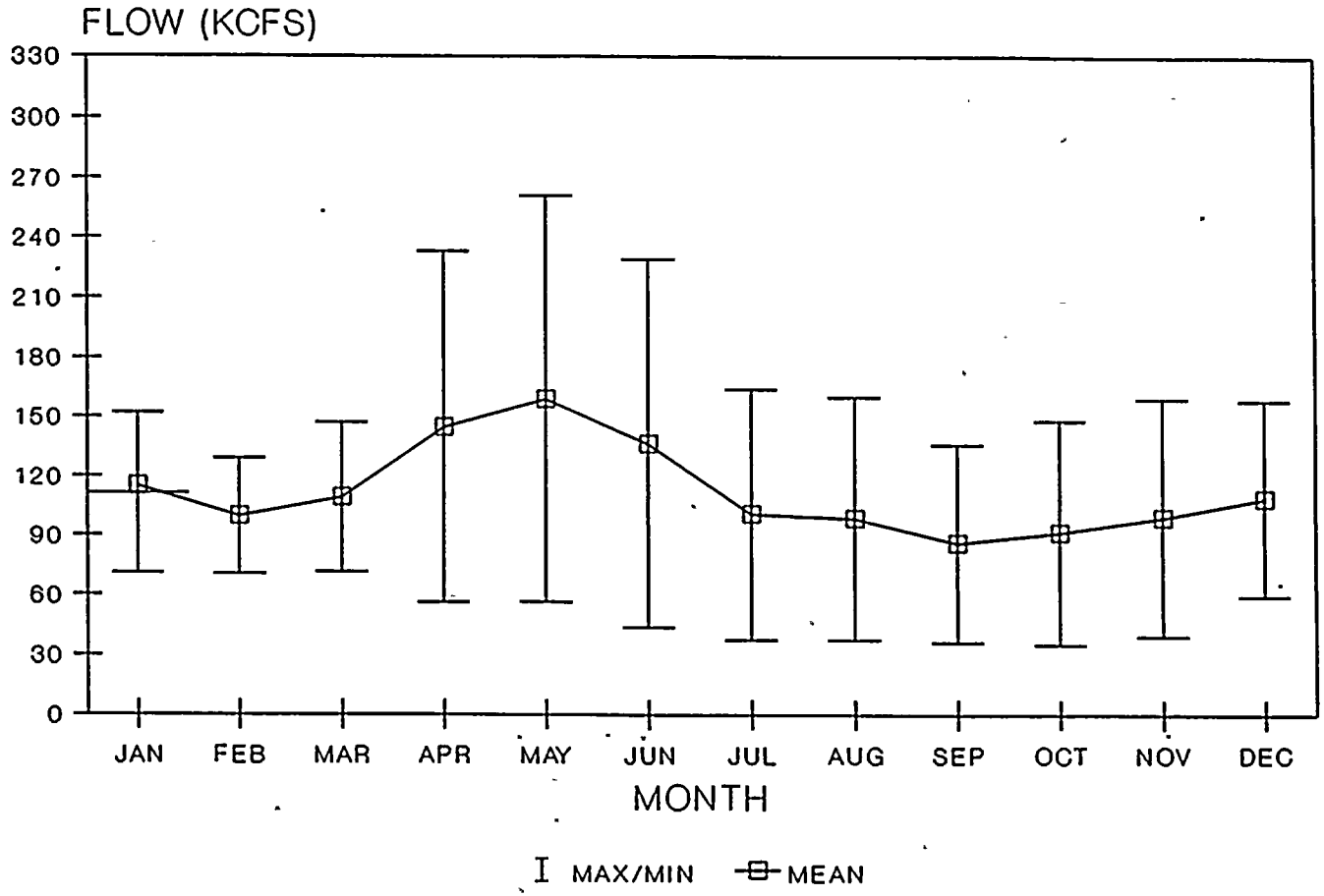

FIGURE 1-4
COLUMBIA RIVER MEAN MONTHLY FLOW FOR 1992

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.

Several porcupines, Erethizon dorsatam, were observed at various times in and around the trees near the WNP-2 river pumphouse.

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 erythrorhyrchos) 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.

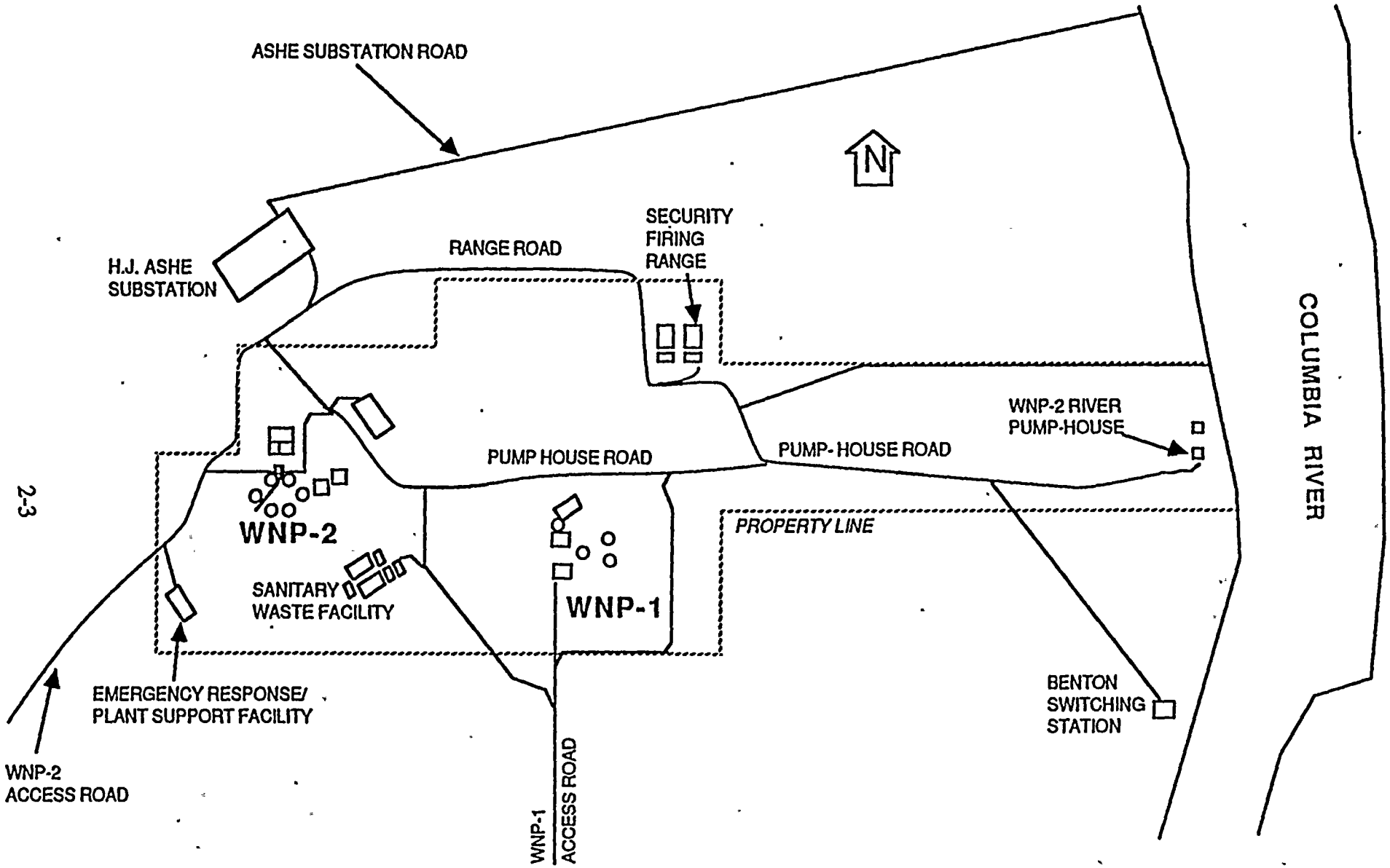

FIGURE 2-1
WNP-2 PROPERTY BOUNDARY

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. The results of bioassay tests on Hyalella azteca and Daphnia pulex are reported in section 3.1 and 3.2, respectively.

3.1 HYALELLA BIOASSAYS

3.1.1 INTRODUCTION

Four bioassays of WNP-2 cooling tower effluent were conducted during February and March 1992 on the amphipod Hyalella azteca using a static test format. Dates for Tests 1 through 4 were February 8-12, 19-23, 25-29, and March 23-27, respectively.

3.1.2 METHODS AND MATERIALS

The bioassays followed the guidance set forth in U.S. Environmental Protection Agency (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 was provided in the publication Use of the Amphipod Crustacean *Hyalella azteca* in Freshwater and Estuarine Sediment Toxicity Tests (Nebeker, 1988).

Effluent used for the tests was collected (by grab sample) from the discharge sample line located at the fish bioassay facility. Control water for Tests 1 through 3 was untreated Columbia River water collected from the fish bioassay facility. Control water for Test 4 was

prepared using the same procedure for moderately hard water as utilized in performance of the Daphnia bioassays.

Juvenile Hyalella were exposed to 100% effluent and 100% control water for a 96-hour period. Mortality checks were made one hour after the beginning of the test and daily thereafter. See Table 3-1-1 for a complete summary of test conditions.

The Hyalella used in the tests were from a stock culture obtained from the EPA Regional Laboratory, Manchester, Washington on January 15, 1992. The Supply System Environmental Laboratory maintains a breeding population of this organism. The stock cultures used in Tests 1 through 3 were maintained in Columbia River water. The stock culture used for Test 4 was maintained in the "Daphnia" culture water for 21 days prior to the start of the test.

Reference toxicant tests using cadmium chloride were performed in conjunction with Tests 2 and 4. The cadmium chloride was received from the U.S. EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Temperature and dissolved oxygen were measured in control and effluent containers at the start of each test and daily thereafter. pH, conductivity, alkalinity, and hardness were measured in control and effluent solutions at the beginning of each 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 made with a YSI Model 33 meter.

Sample holding times and analytical methods (listed in Table 3-1-2) were consistent with U.S. Environmental Protection Agency guidance (EPA, 1983).

3.1.3 RESULTS AND DISCUSSION

All three tests were successfully completed with respect to a survival rate criterion of 80% or greater. The number of mortalities and corresponding percent survival for control and effluent solutions from each test are presented in Table 3-1-3.

Temperature and dissolved oxygen measurements for control and effluent solutions remained fairly constant throughout the tests (Table 3-1-4). Measurements of physical and chemical parameters for control and effluent solutions at the beginning of each test are presented in Table 3-1-5.

The initial reference toxicant test was a range-finding test and indicated a 96-hour LC_{50} of less than 8 μg/1 cadmium chloride. The second reference test (conducted in conjunction with Test 4) was more specific and indicated a 96-hour LC_{50} of 4.00 μg/1 for cadmium chloride. This result is somewhat lower than the results reported by the EPA Laboratory at Manchester which ranged from 7.7 to 12.1 μg/1 (Stinson, 1992). The LC_{50} was determined using a computer based Trimmed Spearman Karber method. See Table 3-1-6 for a complete summary including concentrations used and resulting mortalities.

3.1.4 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.

Hamilton, M.A., R.C. Russo, and R.V. Thurston, 1977. Trimmed Spearman-Karber Method For Estimating Median Lethal Concentrations in Toxicity Bioassays. Environ. Sci. Technol. 11(7) : 714-719; Correction 12(4) : 417 (1978).

Nebeker, A.V. and Clifford E. Miller, 1988. Use of the Amphipod Crustacean Hyalella azteca in Freshwater and Estuarine Sediment Toxicity Tests, Environ. Tocica, Chem, 7:1027-1033.

Washington Department of Ecology, February 1992. Personal communication between R.E. Welch, Supply System, and M. Stinson, D.O.E.

Table 3-1-1. Bioassay Test Conditions for Hyalella azteca

Temperature:	20 ± 2 °C
Photoperiod:	16 h light/24 h
Size of test vessel:	1000 ml beaker
Volume of test solution:	1000 ml
Age of test animals:	Juveniles
No. animals/test vessel:	10
No. of replicate test vessels per concentration:	2
Total no. organisms per concentration:	20
Feeding regime:	Not fed for test duration
Aeration:	2-3 bubbles/sec
Dilution water:	Columbia River (Tests 1-3) Moderately hard (Test 4)
Test Duration:	96 hours
Effect measured:	Mortality - 80% survival in effluent

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
- Calcium	243.1
- Magnesium	215.1

Table 3-1-3. Mortalities and Percent Survival of Hyalella azteca in Control and Effluent Solutions.

Test		Number of Mortalities		Percent Survival	
No.	Date	Control	Effluent	Control	Effluent
1	2/8-2/12	2	1	90	95
2	2/19-2/23	1	1	95	95
3	2/25-2/29	2	0	90	100
4	3/23-3/27	2	2	90	90

Table 3-1-4 Temperature and Dissolved Oxygen Measurements of Hyalella azteca in Control and Effluent Solutions.

Temperature (°C)

Test No.	Date	Average		Range	
		Control	Effluent	Control	Effluent
1	2/8-2/12	21.4	21.4	20.6-21.8	20.6-21.8
2	2/19-2/23	21.5	21.5	20.7-22.0	20.7-21.8
3	2/25-2/29	21.7	21.7	21.5-22.0	21.5-22.0
4	3/23-3/27	21.8	21.8	21.7-21.9	21.7-21.9

Dissolved Oxygen (mg/L)

Test No.	Date	Average		Range	
		Control	Effluent	Control	Effluent
1	2/8-2/12	7.9	7.8	7.8-7.9	7.7-7.8
2	2/19-2/23	8.0	7.7	7.8-8.6	7.3-8.1
3	2/25-2/29	7.9	7.7	7.5-8.9	7.4-8.6
4	3/23-3/27	7.9	7.8	7.6-8.2	7.4-8.0

Table 3-1-5 Physical and Chemical Characteristics of Control and Effluent Solutions at the Beginning of Each Test

Test No.	Sample	Temp. (°C)	pH	D.O. (mg/L)	Cond. (uS/cm)	Hard. (mg/L)	Alk. (mg/L)
1	Control	20.6	7.18	7.9	147	64	61
	Effluent	20.6	7.81	7.8	681	468	131
2	Control	20.7	7.75	8.6	147	61	61
	Effluent	20.7	8.15	8.1	798	566	193
3	Control	21.9	7.53	8.8	149	58	61
	Effluent	21.9	8.07	8.6	544	348	130
4	Control	21.8	8.16	7.6	308	74	60
	Effluent	21.8	8.45	7.5	629	453	182

Table 3-1-6 Reference Toxicant Test with Hyalella azteca in Cadmium Chloride Solution

Concentration (μg/L):	2.00	4.00	8.00	16.0	32.0
Number Exposed:	20	20	20	20	20
Mortalities (at 96 h):	7	9	17	20	20

Spearman-Karber Estimates: LC_{50}: 4.00 μg/L

95% Lower Confidence: 2.39
95% Upper Confidence: 6.69

Test performed March 23-27, 1992

3.2 DAPHNIA BIOASSAYS

3.2.1 INTRODUCTION

Two bioassays of WNP-2 cooling tower effluent were performed March 25-29 and March 26-30, 1992, on the common water flea (Daphnia pulex) using a static test format.

3.2.2 METHODS AND MATERIALS

The bioassays followed the guidance set forth in 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).

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.

A reference toxicant test using cadmium chloride was performed in conjunction with Test No. 1. The cadmium chloride was received from the EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

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 made with a YSI Model 33 meter. Sample holding times and analytical methods 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 the survival rate criterion of 80% or greater. The number of mortalities and corresponding percent survival for control and effluent solutions from each test are presented in Table 3-2-3.

Temperature measurements in the control and test containers averaged 21.0°C and 20.6°C for Tests 1 and 2, respectively. Measurements of physical and chemical parameters for control and effluent solutions at the beginning of each test are presented in Table 3-2-4.

The results for the reference toxicant cadmium chloride indicate a 24-hour LC_{50} of 0.22 mg/L. This is within the expected range of 0.14 to 0.70 mg/L for Daphnia pulex (per EPA, which provided the reference toxicant). The LC_{50} was determined using a computer based Trimmed Spearman Karber method. See Table 3-2-5 for a complete summary including concentrations used and resulting mortalities.

3.2.4 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.

Hamilton, M.A., R.C. Russo, and R.V. Thurston, 1977. Trimmed Spearman-Karber Method For Estimating Median Lethal Concentrations in Toxicity Bioassays. Environ. Sci. Technol. 11(7) : 714-719; Correction 12(4) : 417 (1978).

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.

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

Parameter	EPA Method Number
Water Temperature (C)	170.1
Conductivity (uS/cm) at 25C	120.1
Dissolved Oxygen (mg/L)	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 Mortalities and Percent Survival of Daphnia pulex in Control and Effluent Solutions

Test		Number of Moralities		Percent Survival	
No.	Date	Control	Effluent	Control	Effluent
1	3/25-3/29	1	1	95	95
2	3/26-3/30	2.	1	90	95

Table 3-2-4 Physical and Chemical Characteristics of Control and Effluent Solutions at the Beginning of Each Test

Test No.	Sample	Temp. (°C)	pH	D.O. (mg/L)	Cond. (μS/cm)	Hard. (mg/L)	Alk. (mg/L)
1	Control	21.7	8.33	8.1	303	73	60
	Effluent	21.7	8.42	8.3	797	560	160
2	Control	21.8	8.31	7.9	312	73	60
	Effluent	21.8	8.52	7.8	694	491	156

Table 3-2-5 Reference Toxicant Test with Daphnia pulex in Cadmium Chloride Solution

Concentration (mg/L)	0.01	0.10	0.50	1.00	2.00
Number Exposed:	20	20	20	20	20
Mortalities (at 24 h):	0	0	20	20	20

Spearman-Karber Estimates: LC_{50} = 0.22 mg/l

Test performed March 25, 1992

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.

4.2 MATERIALS AND METHODS

Columbia River surface water was sampled monthly from January 1992 through December 1992. 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 was sampled monthly during 1992. 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 and total copper.

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

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, pH, dissolved oxygen, sulfate, orthophosphorus, ammonia-nitrogen, nitrate-nitrogen, turbidity, total alkalinity and total hardness analyses was collected in 3.8 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 one-liter polypropylene cubitainers 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 June) only station 1 (control) samples were collected.

4.2.2 Field Equipment and Measurements

Surface temperature measurements were made using a Fisher - NIST traceable thermometer. 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.

4.2.3 Laboratory Measurements

Total metals, sulfate, conductivity, pH, dissolved oxygen, 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 4.6°C at all surface stations on January 16th and a maximum of 19.5°C at station 11M on August 31 (Table 4-3). River temperatures measured in 1992 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 9.2 mg/L at stations 11 and 8 in August and September to 15.5 mg/L at station 8 in March.

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 1992) 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 7.35 at station 1 in October to 8.28 at station 8 in March (Table 4-5). The variation in pH between sample stations is small. The largest difference of 0.23 standard units occurred between station 1 (pH 7.76) and station 7 (pH 7.53) in September.

The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1992). pH measurements are presented graphically in Figure 4-5.

Columbia River alkalinities ranged from 49.0 to 61.0 mg/L as calcium carbonate (Table 4-6). The alkalinity measurements are presented graphically in Figure 4-6.

4.3.4 Hardness

Hardness ranged from 61.8 to 73.8 mg/L as calcium carbonate (Table 4-7). The hardness measurements are presented graphically in Figure 4-7.

4.3.5 Conductivity

Columbia River conductivity measurements ranged from 125.0 μS/cm at 25°C at station 1 in June to 150.0 μS/cm at 25°C at station 7, 11, and 8 in January (Table 4-8). The measurements are presented graphically in Figure 4-8.

4.3.6 Turbidity

In the Columbia River, measured turbidities were low and ranged from 0.5 nephelometric turbidity units (NTU) to 1.8 NTU (Table 4-9). Turbidity data is presented graphically in Figure 4-9.

4.3.7 Total Residual Chlorine (TRC)

Total residual chlorine (TRC) measurements for 1992 were less than the measured detection limit of 1.0 mg/L (Table 4-10).

4.3.8 Metals - (Total)

Columbia River nickel, lead, cadmium, and chromium concentrations were below respective detection limits for all stations during all periods. Copper concentrations ranged from <1.2 μg/L to 7.5 μg/L. Zinc measurements were below the detection limit (6.0 μg/L) for nearly all periods except at stations 7 and 11 in March, and at station 1 in April and November. In comparing the station 1 results in November with the results from the other river stations during that month the 10.8 μg/L value is inconsistent and may represent a contaminated sample. Iron concentrations ranged from 17.8 μg/l to 90.9 μg/L.

Total metals results are listed in Tables 4-11 through 4-17. Total Iron measurements are presented graphically in Figure 4-10.

4.3.9 Ammonia-Nitrogen and Nitrate-Nitrogen

Ammonia concentrations ranged from <0.010 to 0.064 mg-N/L (Table 4-18). Nitrate concentrations ranged from <0.001 to 0.18 mg-N/L. The nitrate measurements are summarized in Table 4-19. 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 during January and at station 11 in August. Oil and grease measurements are summarized in Table 4-20.

4.3.11 Total Phosphorus and Orthophosphorus

Measured total phosphorus concentrations ranged from <0.005 to 0.170 mg-P/L and are summarized. Orthophosphorus concentrations were below 0.13 mg/L for all stations and periods except station 8 in October. 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 8.1 to 10.7 mg/L (Table 4-23). Total sulfate measurements are presented graphically in Figure 4-13.

4.3.13 Total Dissolved Solids, Total Suspended Solids

The total dissolved solids (TDS) measured in the Columbia River ranged from 24.0 mg/L to 380.0 mg/L (Table 4-24). The 24.0 mg/L (recorded at station 1 in August) is uncharacteristically low with respect to other stations and historical data. Water quality program data from 1985 through 1991 indicates TDS values for station 1 averaged 83.2 mg/l. A minimum reading of 46.0 mg/L was recorded in December, 1991.

Total suspended solids concentrations were generally low and varied from <1.0 to 14.0 mg/L (Table 4-24).

Total dissolved solids and total suspended solids are presented graphically in Figures 4-14 and 4-15.

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).

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 1992, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

4.5 REFERENCES

Environmental Protection Agency. 1983. Methods for chemical analysis of water and wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, OH.

Standard Methods for Examination of Water and Waste Water, 16th Edition, APHA, AWWA, WPCF, Washington, D.C., 1985.

Washington Department of Ecology. 1992. Water Quality Standards for Surface Waters of the State of Washington. Water Quality Planning Office of Water Programs. Olympia, WA.

Washington Public Power Supply System. 1987. Operational Ecological Monitoring Program for Nuclear Plant 2. Annual Reports for 1986-1991. Richland, WA.

Table 4-1. Summary of Water Quality Parameters, Stations, and Sampling Frequencies, 1992

Parameter	1	7++	11++	11M & 11B++	8++	P.H. DIS.++
Temperature	M	M	M	M	M	M
Dissolved Oxygen	M	M	M	-	M	-
pH	M	M	M	-	M	-
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	-
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	-
Orthophosphorus	M	M	M	-	M	-
Total Phosphorus	M	M	M	-	M	-
Oil and Grease	M	M	M	-	M	-
Chlorine, Total Residual	M	M	M	-	M	-
Hardness	M	M	M	-	M	-

Symbols Key

M = Monthly
++ 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 (us/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	
Ammonia-Nitrogen, 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 pb)	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)	409A	
Filterable Residue: Total Dissolved Solids (mg/L)	160.1	
Non-Filterable Residue: Total Suspended Solids (mg/L)	160.2	

Table 4-3. Summary of Temperature Measurements for 1992

Temperature (°C)

Sample Date	1	7	11	11M	11B	8	PLANT DISCHRG
01/29/92	4.6	4.6	4.6	4.9	4.9	4.6	19.6
02/27/92	5.0	5.1	5.1	5.4	5.3	5.1	-
03/31/92	7.3	7.3	7.3	7.7	7.6	7.3	21.3
04/29/92	10.7	-	-	-	-	-	-
05/29/92	13.6	-	-	-	-	-	-
06/18/92	15.1	-	-	-	-	-	-
07/29/92	19.0	18.9	19.0	19.3	19.3	19.0	29.3
08/31/92	19.2	19.3	19.3	19.5	19.4	19.3	25.4
09/23/92	17.5	17.6	17.6	17.7	17.7	17.6	27.7
10/27/92	14.5	14.5	14.5	14.2	14.3	14.5	22.7
11/30/92	9.3	9.3	9.3	9.2	9.2	9.3	19.6
12/16/92	7.1	7.1	7.1	6.8	7.0	7.1	17.8

Table 4-4. Summary of Dissolved Oxygen Measurements for 1992.

Dissolved Oxygen (mg/L)

Sample Date	1	7	11	8
01/29/92	14.6	14.7	14.7	14.4
02/27/92	15.1	15.2	15.1	15.2
03/31/92	15.3	15.3	15.3	15.5
04/29/92	12.0	-	-	-
05/29/92	11.7	-	-	-
06/18/92	-	-	-	-
07/29/92	9.5	9.4	9.5	9.3
08/31/92	9.3	9.3	9.2	9.2
09/23/92	9.3	9.3	9.2	9.3
10/27/92	9.6	9.6	9.7	9.5
11/30/92	10.7	10.8	10.7	10.7
12/16/92	11.3	11.2	11.1	11.4

Table 4-5. Summary of pH Measurements for 1992

pH

Sample Date	1	7	11	8
01/29/92	7.48	7.63	7.55	7.56
02/27/92	7.69	7.75	7.77	7.83
03/31/92	8.27	8.26	8.18	8.28
04/29/92	8.19	-	-	-
05/29/92	7.99	-	-	-
06/18/92	7.93	-	-	-
07/29/92	7.85	7.93	7.82	7.85
08/31/92	7.84	7.80	7.84	7.91
09/23/92	7.76	7.53	7.62	7.71
10/27/92	7.35	7.37	7.41	7.37
11/30/92	7.61	7.45	7.66	7.61
12/16/92	7.54	7.58	7.52	7.64

Table 4-6. Summary of Alkalinity Measurements for 1992.

Total Alkalinity (mg/L)

Sample Date	1	7	11	8
01/29/92	61.0	61.0	61.0	60.0
02/27/92	59.5	60.0	61.0	61.0
03/31/92	60.0	61.0	61.0	61.0
04/29/92	60.0	-	-	-
05/29/92	57.0	-	-	-
06/18/92	49.0	-	-	-
07/29/92	53.0	54.0	53.0	53.0
08/31/92	56.0	57.0	57.0	56.0
09/23/92	57.0	57.0	58.0	57.0
10/27/92	53.0	55.0	55.5	55.5
11/30/92	59.0	59.0	60.0	60.0
12/16/92	59.0	60.0	61.0	61.0

Table 4-7. Summary of Total Hardness Measurements for 1992

Total Hardness (mg/L)

Sample Date	1	7	11	8
01/29/92	73.6	73.4	73.8	73.2
02/27/92	72.0	71.0	71.7	70.3
03/31/92	70.8	69.8	71.7	69.7
04/29/92	66.8	-	-	-
05/29/92	66.8	-	-	-
06/18/92	62.6	-	-	-
07/29/92	63.4	64.2	68.5	66.6
08/31/92	63.0	65.3	65.3	64.0
09/23/92	64.5	62.9	62.1	61.8
10/27/92	67.9	67.1	66.0	65.4
11/30/92	70.3	71.1	71.9	69.5
12/16/92	70.0	69.3	72.4	70.5

Table 4-8. Summary of Conductivity Measurements for 1992

Conductivity at 25°C (μS/cm)

Sample Date	1	7	11	8
01/29/92	149.0	150.0	150.0	150.0
02/27/92	146.0	145.0	145.0	146.0
03/31/92	148.0	146.0	147.0	146.0
04/29/92	145.0	-	-	-
05/29/92	139.0	-	-	-
06/18/92	125.0	-	-	-
07/29/92	126.0	125.0	126.0	126.0
08/31/92	130.0	131.0	131.0	131.0
09/23/92	131.0	132.0	132.0	131.0
10/27/92	131.0	133.0	133.0	133.0
11/30/92	137.0	137.0	138.0	137.0
12/16/92	143.0	142.0	143.0	143.0

Table 4-9. Summary of Turbidity Measurements for 1992

	Turbidity (NTU)			
Sample Date	1	7	11	8
01/29/92	0.6	0.6	0.5	0.7
02/27/92	0.7	0.8	0.5	0.6
03/31/92	0.9	1.4	1.6	1.8
04/29/92	0.4	-	-	-
05/29/92	1.2	-	-	-
06/18/92	1.3	-	-	-
07/29/92	1.5	1.7	1.7	1.6
08/31/92	0.9	0.9	0.9	0.8
09/23/92	0.5	0.7	0.7	0.7
10/27/92	1.0	1.3	1.2	0.9
11/30/92	0.8	0.8	0.8	0.9
12/16/92	0.6	0.7	0.6	0.7

Table 4-10. Summary of Total Residual Chlorine Measurements for 1992

	Total Residual Chlorine (mg/L)			
Sample Date	1	7	11	8
01/29/92	<1.0	<1.0	<1.0	<1.0
02/27/92	<1.0	<1.0	<1.0	<1.0
03/31/92	<1.0	<1.0	<1.0	<1.0
04/29/92	<1.0	-	-	-
05/29/92	<1.0	-	-	-
06/18/92	<1.0	-	-	-
07/29/92	<1.0	<1.0	<1.0	<1.0
08/31/92	<1.0	<1.0	<1.0	<1.0
09/23/92	<1.0	<1.0	<1.0	<1.0
10/27/92	<1.0	<1.0	<1.0	<1.0
11/30/92	<1.0	<1.0	<1.0	<1.0
12/16/92	<1.0	<1.0	<1.0	<1.0

Table 4-11. Summary of Copper Measurements for 1992

Copper (μg/L)

Sample Date	1	7	11	11M	11B	8	PLANT DSCHRG
01/29/92	-	-	-	1.7	2.0	-	102.0
02/27/92	1.8	2.7	2.3	1.9	1.4	2.2	-
03/31/92	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	105.5
04/29/92	<1.2	-	-	-	-	-	-
05/29/92	7.5	-	-	-	-	-	-
06/18/92	2.7	-	-	-	-	-	-
07/29/92	3.1	<1.2	<1.2	<1.2	<1.2	<1.2	348.0
08/31/92	5.7	<1.2	1.6	<1.2	<1.2	<1.2	323.0
09/23/92	2.7	3.1	2.1	<1.2	2.1	1.7	177.0
10/27/92	2.2	1.8	1.9	2.4	1.8	1.8	134.0
11/30/92	1.8	3.1	3.2	1.5	1.8	2.1	119.8
12/16/92	2.5	2.3	2.9	1.7	1.8	2.7	93.4

Table 4-12. Summary of Nickel Measurements for 1992

Nickel (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	<2.6	<2.6	<2.6	<2.6	<2.6
02/27/92	<2.6	<2.6	<2.6	<2.6	-
03/31/92	<2.6	<2.6	<2.6	<2.6	25.5
04/29/92	<2.6	-	-	-	-
05/29/92	<2.6	-	-	-	-
06/18/92	<2.6	-	-	-	-
07/29/92	<2.6	<2.6	<2.6	<2.6	6.5
08/31/92	<2.6	<2.6	<2.6	<2.6	3.2
09/23/92	<2.6	<2.6	<2.6	<2.6	4.2
10/27/92	<2.6	<2.6	<2.6	<2.6	2.6
11/30/92	<2.6	<2.6	<2.6	<2.6	<2.6
12/16/92	<2.6	<2.6	<2.6	<2.6	<2.6

Table 4-13. Summary of Zinc Measurements for 1992

Zinc (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	<6.0	<6.0	<6.0	<6.0	82.1
02/27/92	<6.0	<6.0	<6.0	<6.0	-
03/31/92	<6.0	6.7	6.7	<6.0	64.4
04/29/92	7.8	-	-	-	-
05/29/92	-	-	-	-	-
06/18/92	<6.0	-	-	-	-
07/29/92	<6.0	<6.0	<6.0	<6.0	160.8
08/31/92	<6.0	<6.0	<6.0	<6.0	171.0
09/23/92	<6.0	<6.0	<6.0	<6.0	94.4
10/27/92	<6.0	<6.0	<6.0	<6.0	119.0
11/30/92	10.8	<6.0	<6.0	<6.0	56.0
12/16/92	<6.0	<6.0	<6.0	<6.0	141.0

Table 4-14. Summary of Iron Measurements for 1992

Iron (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	25.2	26.6	27.8	25.5	376.3
02/27/92	17.8	24.4	33.3	36.6	-
03/31/92	44.4	44.4	35.5	-	204.2
04/29/92	37.7	-	-	-	-
05/29/92	67.7	-	-	-	-
06/18/92	62.3	-	-	-	-
07/29/92	62.6	57.9	72.3	48.8	206.5
08/31/92	61.5	46.3	37.2	36.9	326.0
09/23/92	68.0	67.0	58.1	50.2	491.0
10/27/92	77.8	87.7	90.9	86.3	1454.0
11/30/92	50.7	51.8	59.5	51.2	527.0
12/16/92	48.0	48.6	54.3	43.5	292.0

Table 4-15. Summary of Lead Measurements for 1992

Lead (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	<1.9	<1.9	<1.9	<1.9	<1.9
02/27/92	<1.9	<1.9	<1.9	<1.9	-
03/31/92	<1.9	<1.9	<1.9	<1.9	2.9
04/29/92	<1.9	-	-	-	-
05/29/92	<1.9	-	-	-	-
06/18/92	<1.9	-	-	-	-
07/29/92	<1.9	<1.9	<1.9	<1.9	2.7
08/31/92	<1.9	<1.9	<1.9	<1.9	14.0
09/23/92	<1.9	<1.9	<1.9	<1.9	6.2
10/27/92	<1.9	<1.9	<1.9	<1.9	2.8
11/30/92	<1.9	<1.9	<1.9	<1.9	5.8
12/16/92	<1.9	<1.9	<1.9	<1.9	2.7

Table 4-16. Summary of Cadmium Measurements for 1992.
Cadmium (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	<0.5	<0.5	<0.5	<0.5	<0.5
02/27/92	<0.5	<0.5	<0.5	<0.5	-
03/31/92	<0.5	<0.5	<0.5	<0.5	<0.5
04/29/92	<0.5	-	-	-	-
05/29/92	<0.5	-	-	-	-
06/18/92	<0.5	-	-	-	-
07/29/92	<0.5	<0.5	<0.5	<0.5	0.6
08/31/92	<0.5	<0.5	<0.5	<0.5	0.8
09/23/92	<0.5	<0.5	<0.5	<0.5	<0.5
10/27/92	<0.5	<0.5	<0.5	<0.5	<0.5
11/30/92	<0.5	<0.5	<0.5	<0.5	<0.5
12/16/92	<0.5	<0.5	<0.5	<0.5	<0.5

Table 4-17. Summary of Chromium Measurements for 1992

Chromium (μg/L)

Sample Date	1	7	11	8	PLANT DSCHRG
01/29/92	<1.9	<1.9	<1.9	<1.9	<1.9
02/27/92	<1.9	<1.9	<1.9	<1.9	-
03/31/92	<1.9	<1.9	<1.9	<1.9	<1.9
04/29/92	<1.9	-	-	-	-
05/29/92	<1.9	-	-	-	-
06/18/92	<1.9	-	-	-	-
07/29/92	<1.9	<1.9	<1.9	<1.9	3.3
08/31/92	<1.9	<1.9	<1.9	<1.9	<1.9
09/23/92	<1.9	<1.9	<1.9	<1.9	2.5
10/27/92	<1.9	<1.9	<1.9	<1.9	<1.9
11/30/92	<1.9	<1.9	<1.9	<1.9	<1.9
12/16/92	<1.9	<1.9	<1.9	<1.9	<1.9

Table 4-18. Summary of Ammonia Measurements for 1992

Ammonia (mg NH_3 - N/L)

Sample Date	1	7	11	8
01/29/92	<0.010	<0.010	<0.010	<0.010
02/27/92	<0.010	<0.010	<0.010	<0.010
03/31/92	0.022	0.020	0.017	0.014
04/29/92	0.011	-	-	-
05/29/92	0.012	-	-	-
06/18/92	0.018	-	-	-
07/29/92	0.018	0.018	0.016	0.022
08/31/92	0.011	<0.010	<0.010	<0.010
09/23/92	0.025	0.023	0.017	0.017
10/27/92	0.016	0.014	0.012	0.013
11/30/92	0.052	0.060	0.059	0.064
12/16/92	0.017	0.023	0.017	0.018

Table 4-19. Summary of Nitrate-Nitrogen Measurements for 1992

	Nitrate-Nitrogen (mg/L)			
Sample Date	1	7	11	8
01/29/92	0.180	0.170	0.170	0.170
02/27/92	0.170	0.160	0.170	0.160
03/31/92	0.120	0.120	0.120	0.120
04/29/92	0.060	-	-	-
05/29/92	<0.001	-	-	-
06/18/92	0.050	-	-	-
07/29/92	0.080	0.070	0.080	0.070
08/31/92	0.008	0.010	0.006	0.008
09/23/92	0.002	0.004	<0.001	0.001
10/27/92	0.088	0.089	0.090	0.091
11/30/92	0.156	0.156	0.150	0.148
12/16/92	0.146	0.150	0.151	0.149

Table 4-20. Summary of Oil and Grease Measurements for 1992.

	Oil & Grease (mg/L)			
Sample Date	1	7	11	8
01/29/92	3.1	3.4	1.5	2.1
02/27/92	<1.0	<1.0	<1.0	-
03/31/92	<1.0	<1.0	<1.0	<1.0
04/29/92	<1.0	-	-	-
05/29/92	<1.0	-	-	-
06/18/92	<1.0	-	-	-
07/29/92	<1.0	<1.0	<1.0	<1.0
08/31/92	<1.0	<1.0	1.8	-
09/23/92	<1.0	<1.0	<1.0	<1.0
10/27/92	<1.0	<1.0	<1.0	<1.0
11/30/92	<1.0	<1.0	<1.0	<1.0
12/16/92	<1.0	<1.0	<1.0	<1.0

Table 4-21. Summary of Total Phosphorus Measurements for 1992

	Total Phosphorus (mg/L)			
Sample Date	1	7	11	8
01/29/92	0.037	0.007	0.027	0.029
02/27/92	0.011	0.009	0.010	0.007
03/31/92	<0.005	<0.005	<0.005	<0.005
04/29/92	0.017	-	-	-
05/29/92	0.016	-	-	-
06/18/92	0.022	-	-	-
07/29/92	0.011	0.017	0.016	0.014
08/31/92	0.015	0.008	0.011	0.013
09/23/92	<0.005	0.018	<0.005	<0.005
10/27/92	0.019	0.019	0.021	0.019
11/30/92	0.007	0.009	0.012	<0.005
12/16/92	0.160	0.160	0.150	0.170

Table 4-22. Summary of Orthophosphate Measurements for 1992.

	Orthophosphate (mg/L)			
Sample Date	1	7	11	8
01/29/92	<0.13	<0.13	<0.13	<0.13
02/27/92	<0.13	<0.13	<0.13	<0.13
03/31/92	<0.13	<0.13	<0.13	<0.13
04/29/92	<0.13	-	-	-
05/29/92	<0.13	-	-	-
06/18/92	<0.13	-	-	-
07/29/92	<0.13	<0.13	<0.13	<0.13
08/31/92	<0.13	<0.13	<0.13	<0.13
09/23/92	<0.13	<0.13	<0.13	<0.13
10/27/92	<0.13	<0.13	<0.13	0.15
11/30/92	<0.13	<0.13	<0.13	<0.13
12/16/92	<0.13	<0.13	<0.13	<0.13

Table 4-23. Summary of Sulfate Measurements for 1992

	Sulfate (mg/L)			
Sample Date	1	7	11	8
01/29/92	10.3	10.3	10.4	10.3
02/27/92	10.3	10.3	10.4	10.5
03/31/92	10.4	10.4	10.5	10.4
04/29/92	10.7	-	-	-
05/29/92	9.5	-	-	-
06/18/92	8.1	-	-	-
07/29/92	9.0	9.0	9.4	9.0
08/31/92	9.2	9.2	9.3	9.3
09/23/92	9.6	10.3	10.4	9.7
10/27/92	9.7	9.7	9.8	9.7
11/30/92	9.4	9.4	9.5	9.4
12/16/92	9.5	9.6	9.8	9.5

Table 4-24. Summary of Total Dissolved and Total Suspended Solids Measurements for 1992.

Total Dissolved Solids (mg/L)

Sample Date	1	7	11	8
01/29/92	62.0	70.0	74.0	70.0
02/27/92	64.0	62.0	60.0	54.0
03/31/92	80.0	72.0	66.0	68.0
04/29/92	70.0	-	-	-
05/29/92	70.0	-	-	-
06/18/92	64.0	-	-	-
07/29/92	96.0	82.0	86.0	72.0
08/31/92	24.0	110.0	92.0	56.0
09/23/92	120.0	120.0	110.0	120.0
10/27/92	98.0	90.0	110.0	100.0
11/30/92	380.0	260.0	340.0	340.0
12/16/92	78.0	96.0	94.0	94.0

Total Suspended Solids (mg/L)

Sample Date	1	7	11	8
01/29/92	<1.0	<1.0	<1.0	<1.0
02/27/92	<1.0	<1.0	<1.0	<1.0
03/31/92	3.0	3.0	4.0	3.0
04/29/92	1.0	-	-	-
05/29/92	6.0	-	-	-
06/18/92	6.0	-	-	-
07/29/92	14.0	3.0	1.0	5.0
08/31/92	<1.0	<1.0	<1.0	1.0
09/23/92	1.0	<1.0	4.0	3.0
10/27/92	<1.0	3.0	<1.0	9.0
11/30/92	<1.0	<1.0	1.0	1.0
12/16/92	2.0	6.0	1.0	1.0

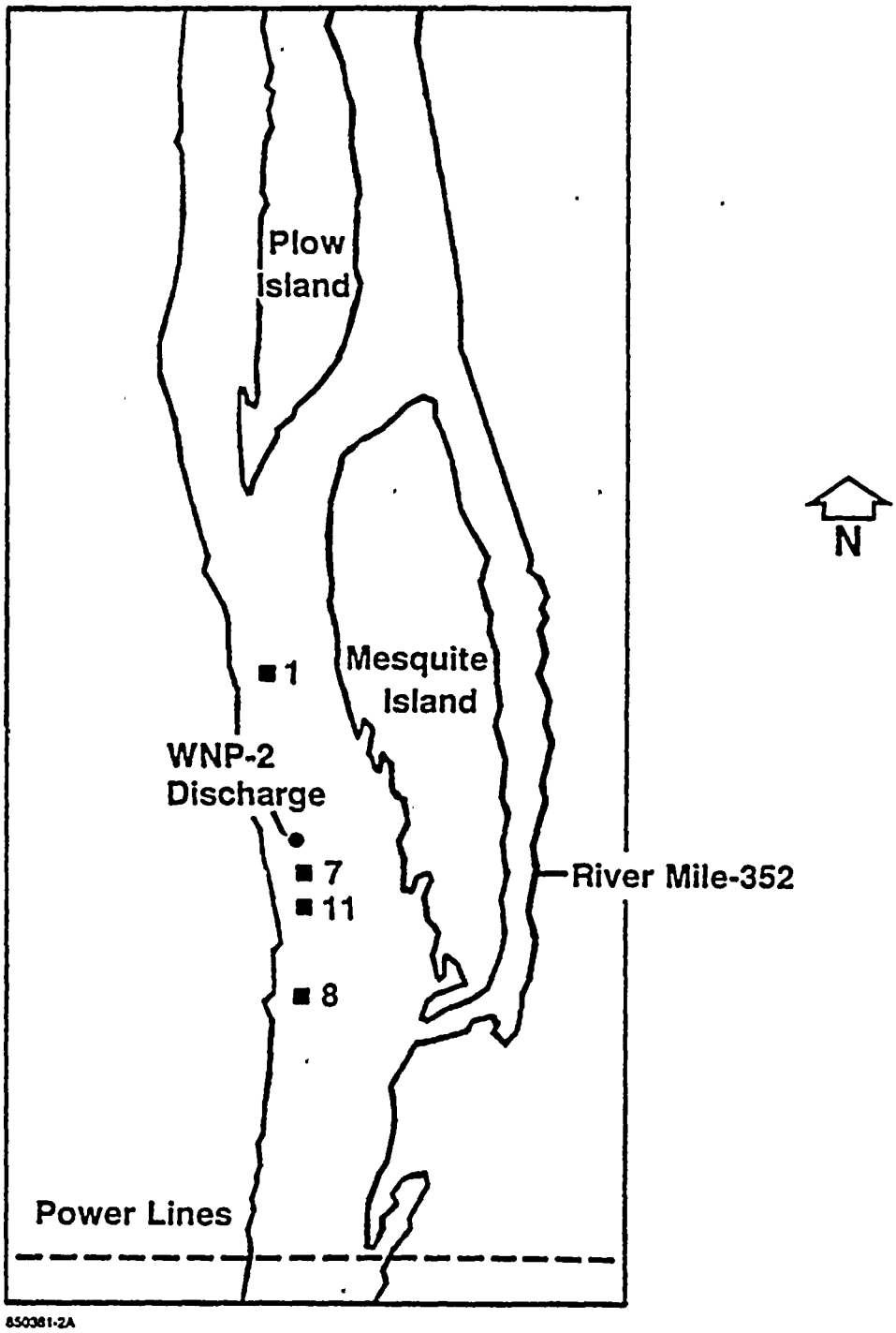

Figure 4-1. Location of Sampling Stations in the Columbia River

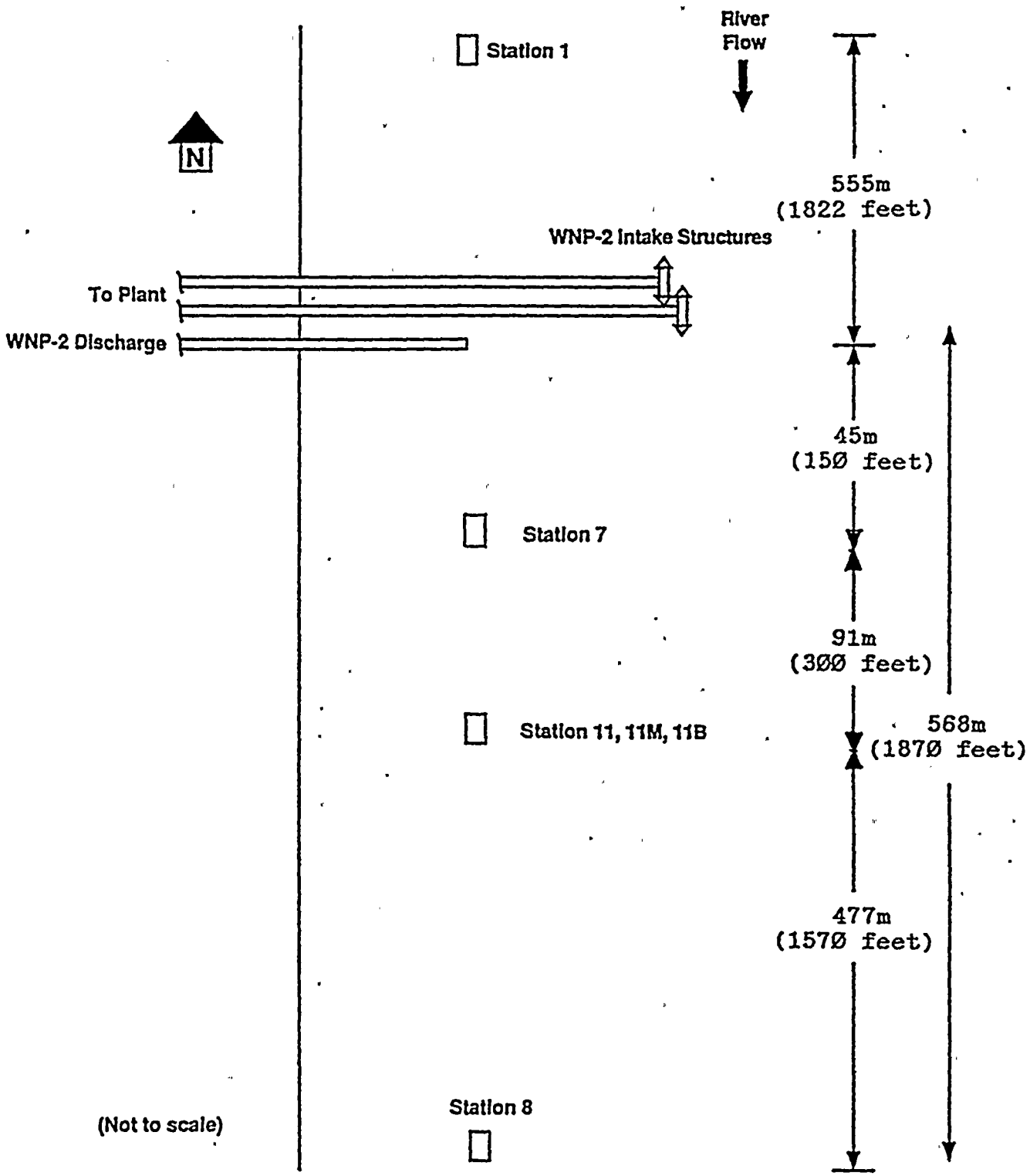

Figure 4-2. Sampling Station Locations for Water Chemistry

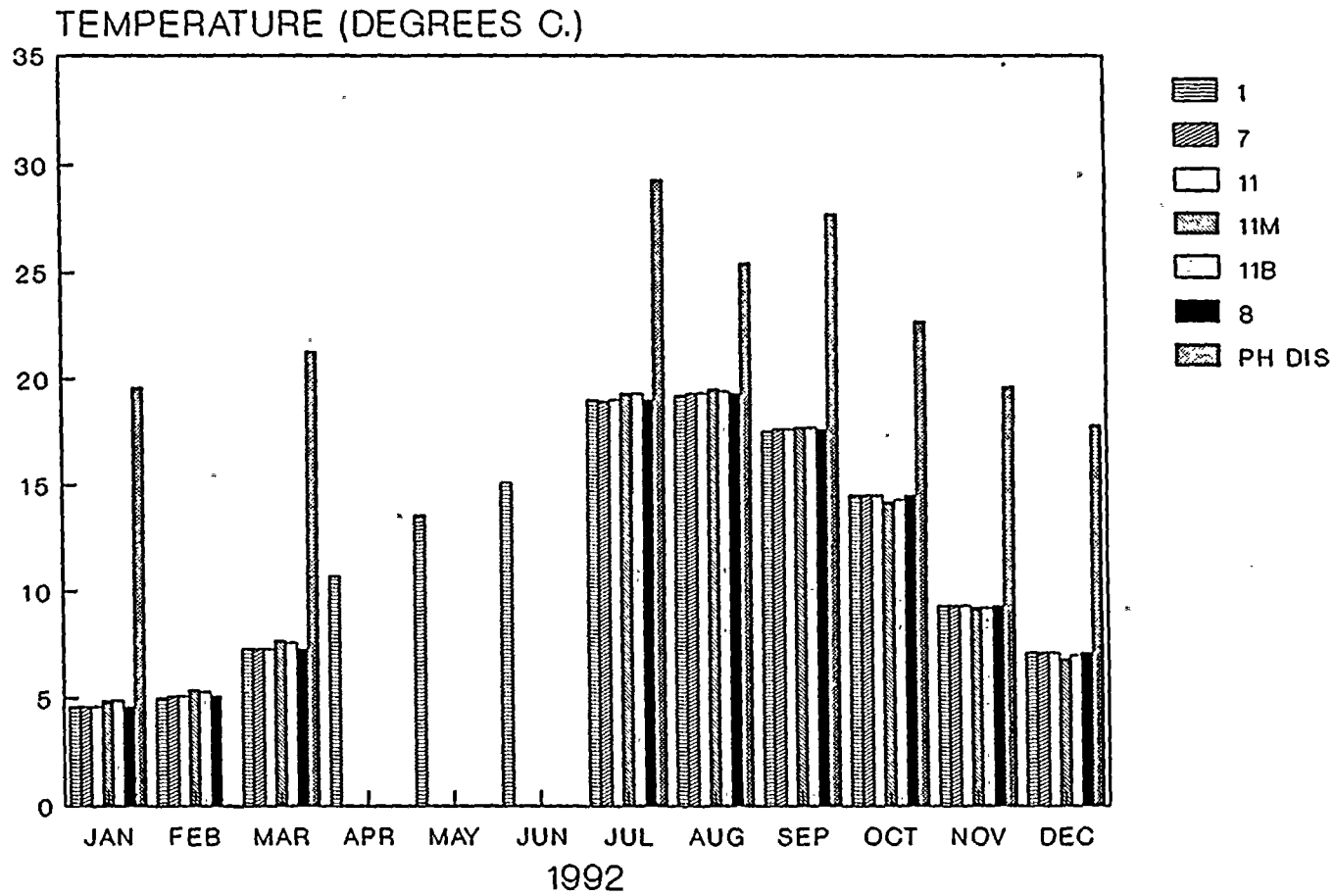

FIGURE 4-3 Columbia River and WNP-2
Discharge Temperature Measurements
During 1992

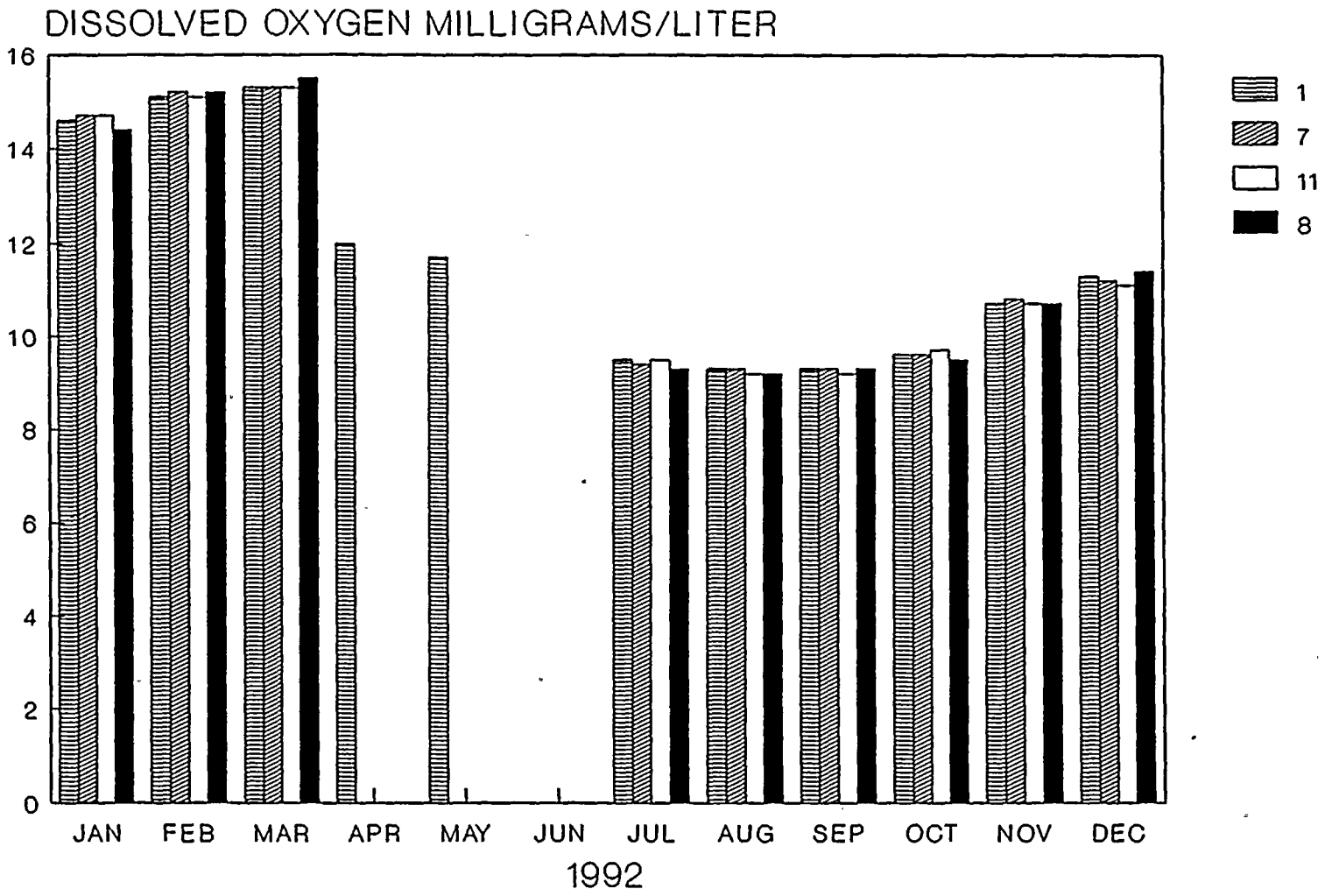

FIGURE 4-4 Columbia River Dissolved Oxygen Measurements at Four Stations During 1992

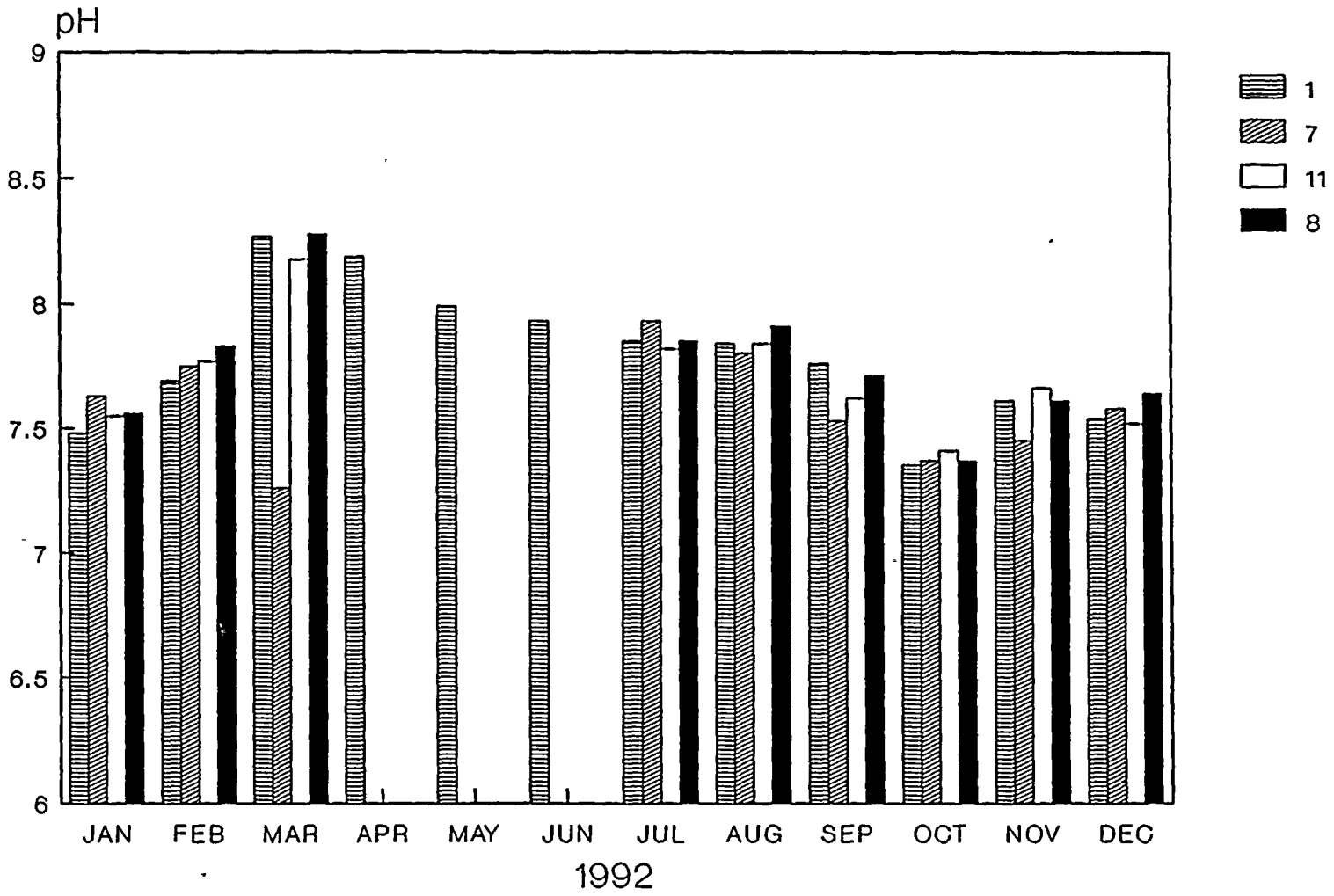

FIGURE 4-5 Columbia River pH
Measurements at Six Stations During 1992

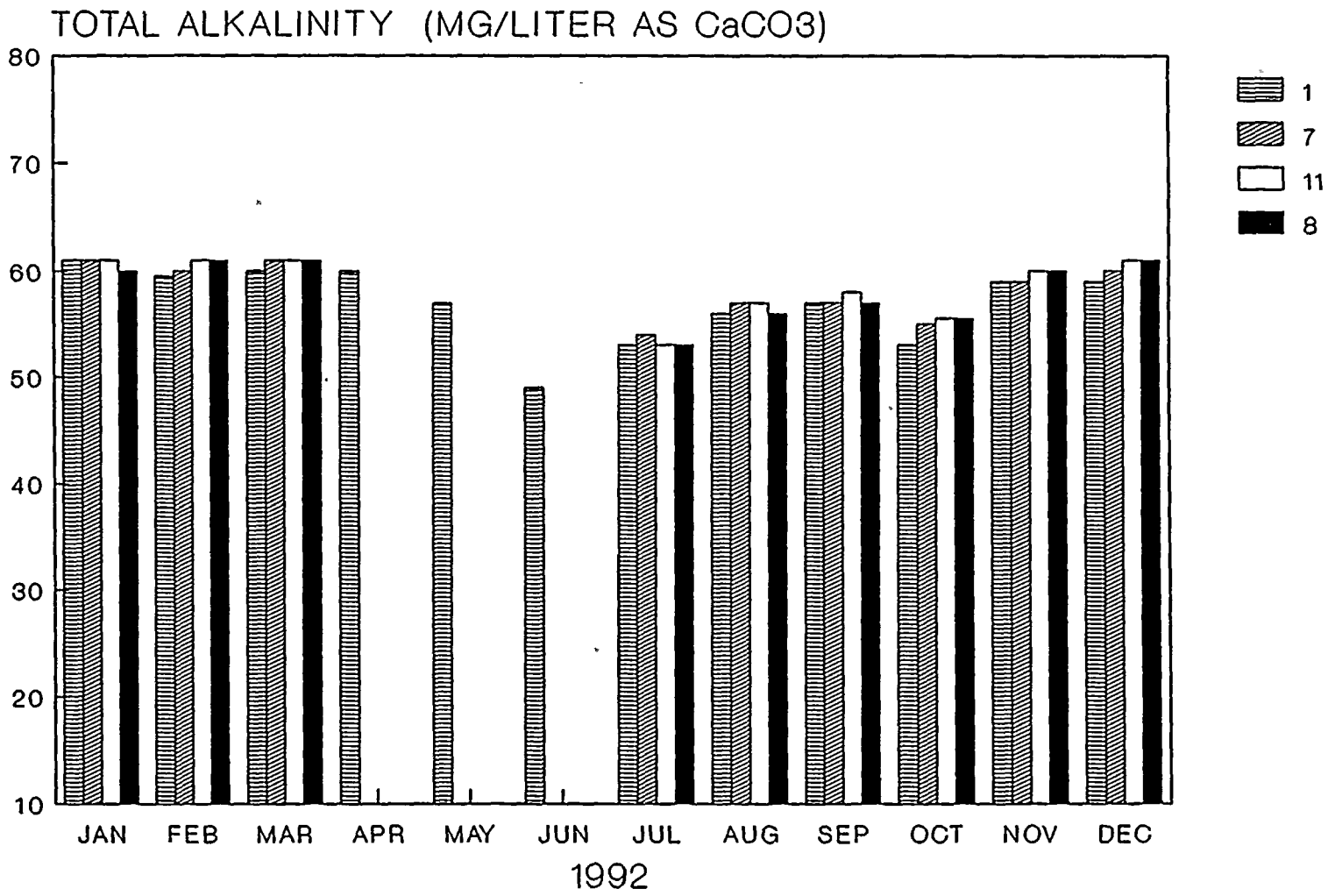

FIGURE 4-6 Columbia River Total Alkalinity Measurements at Four Stations During 1992

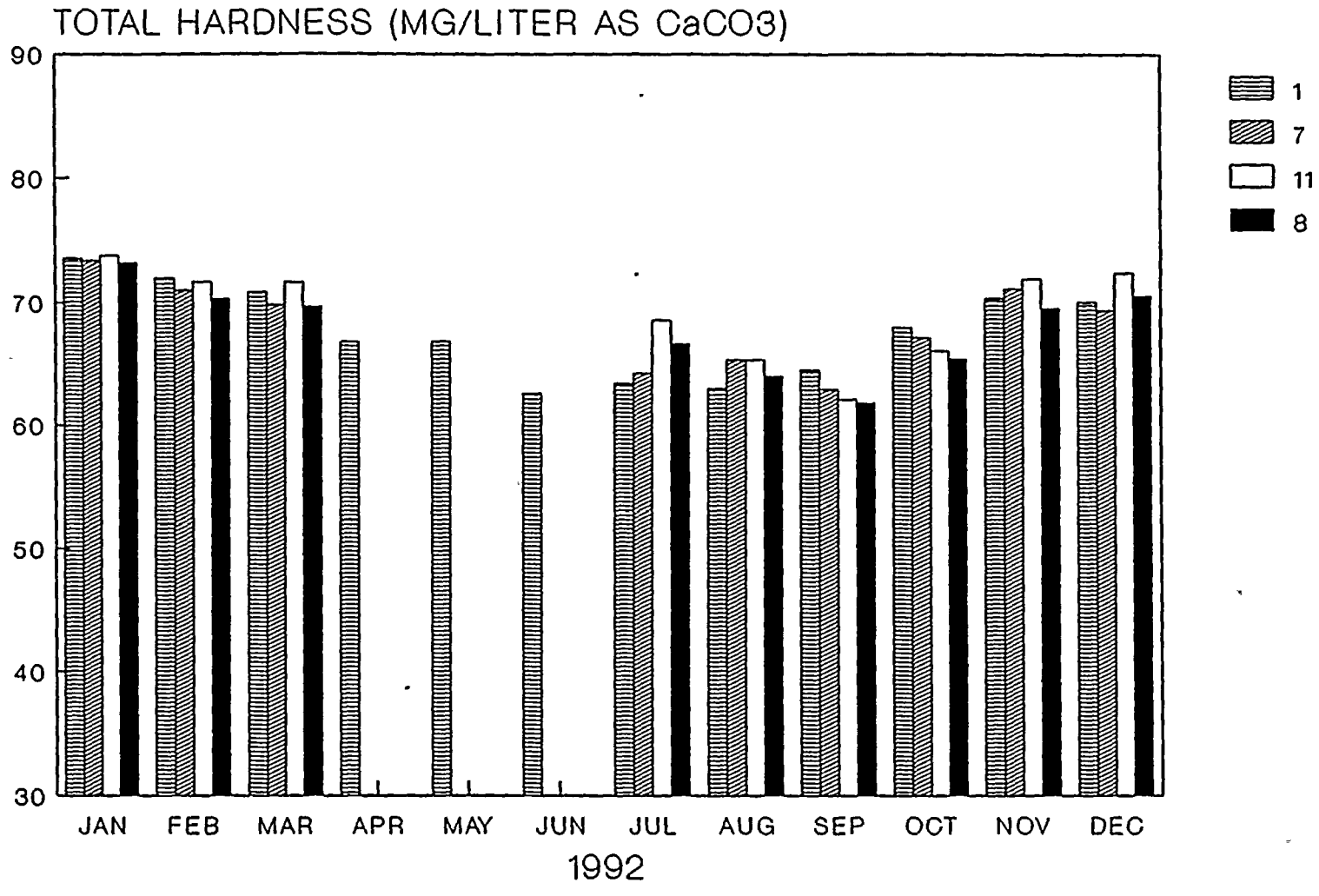

FIGURE 4-7 Columbia River Total Hardness Measurements at Four Stations During 1992

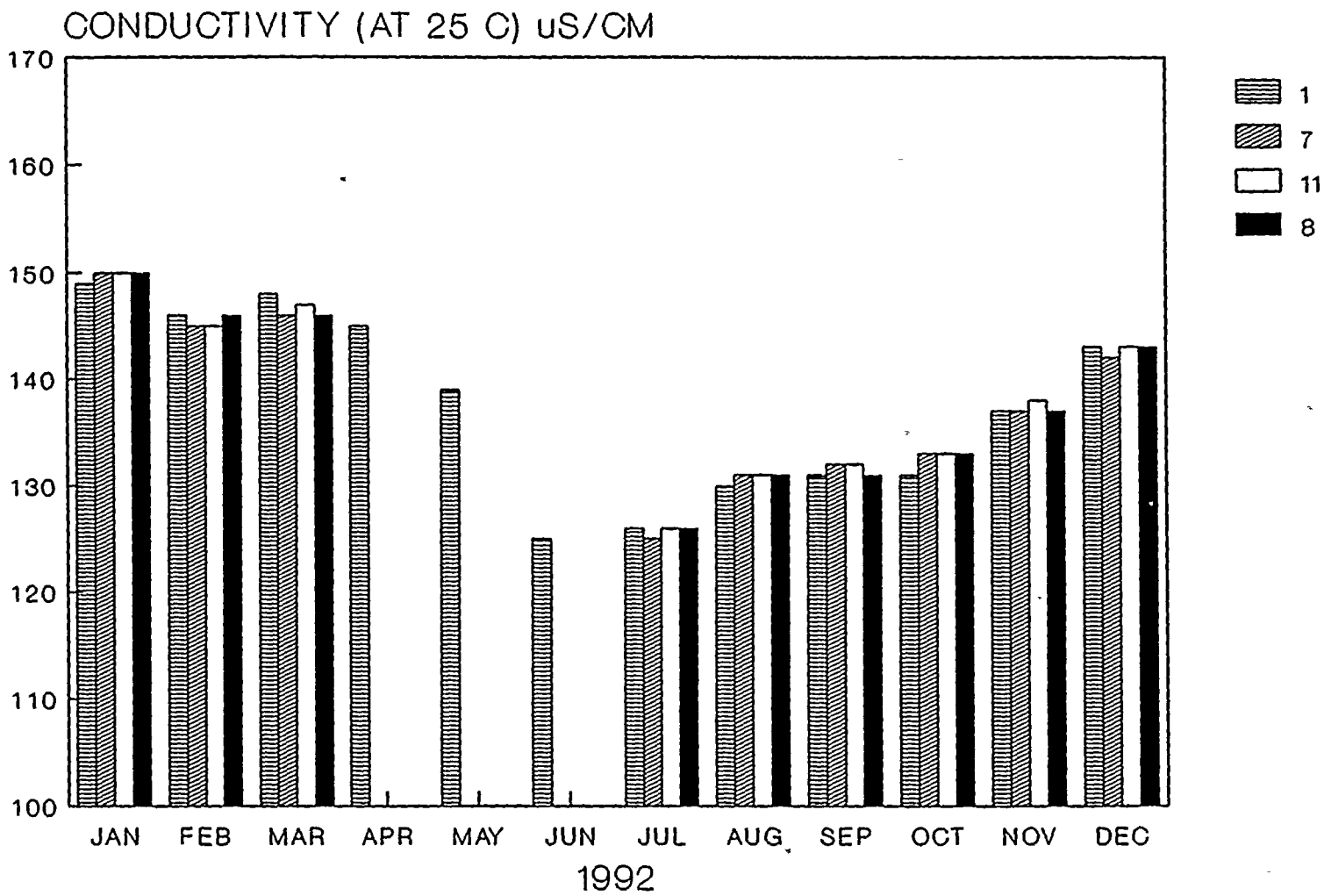

FIGURE 4-8 Columbia River Conductivity Measurements at Six Stations During 1992

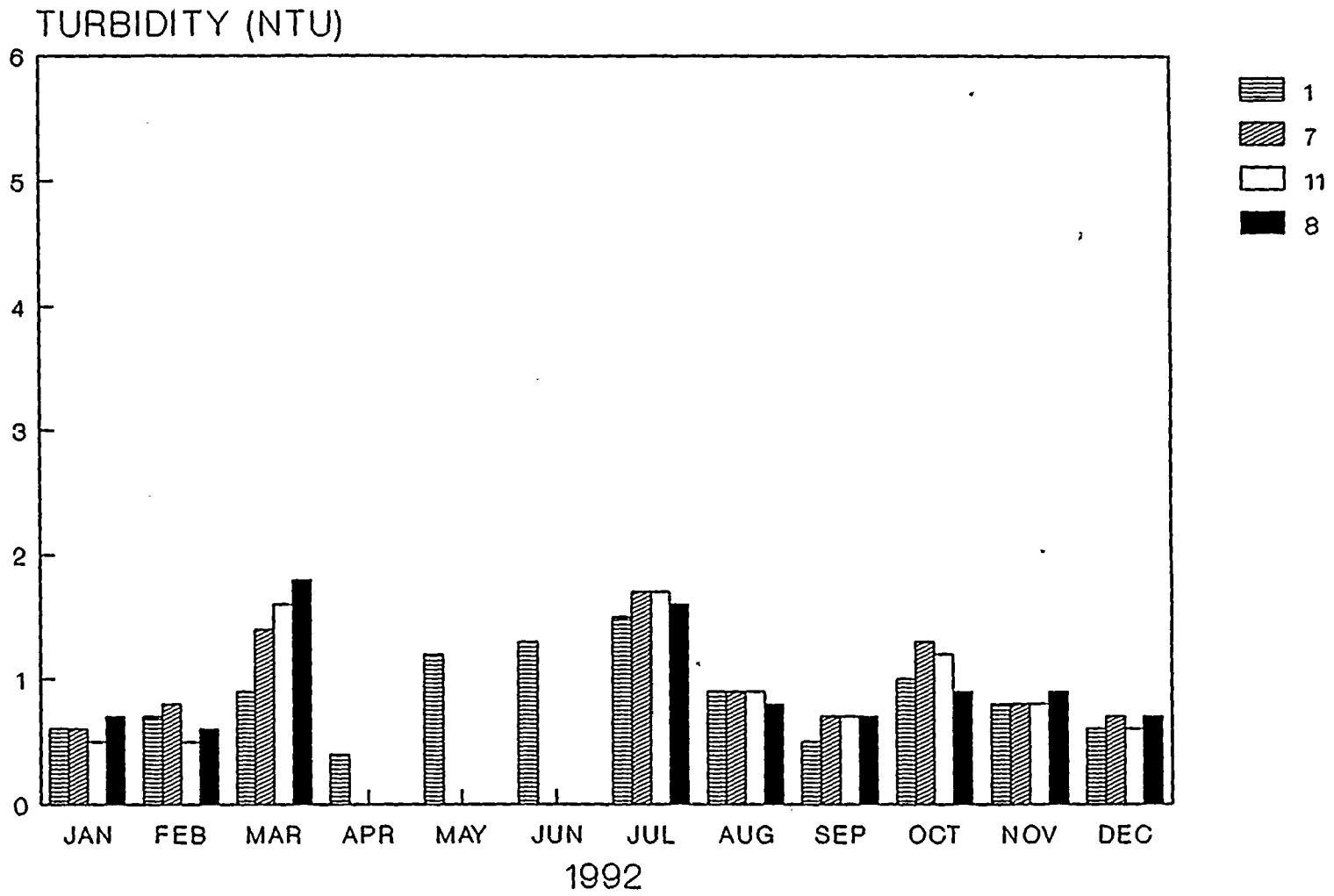

FIGURE 4-9 Columbia River Turbidity Measurements at Four Stations During 1992

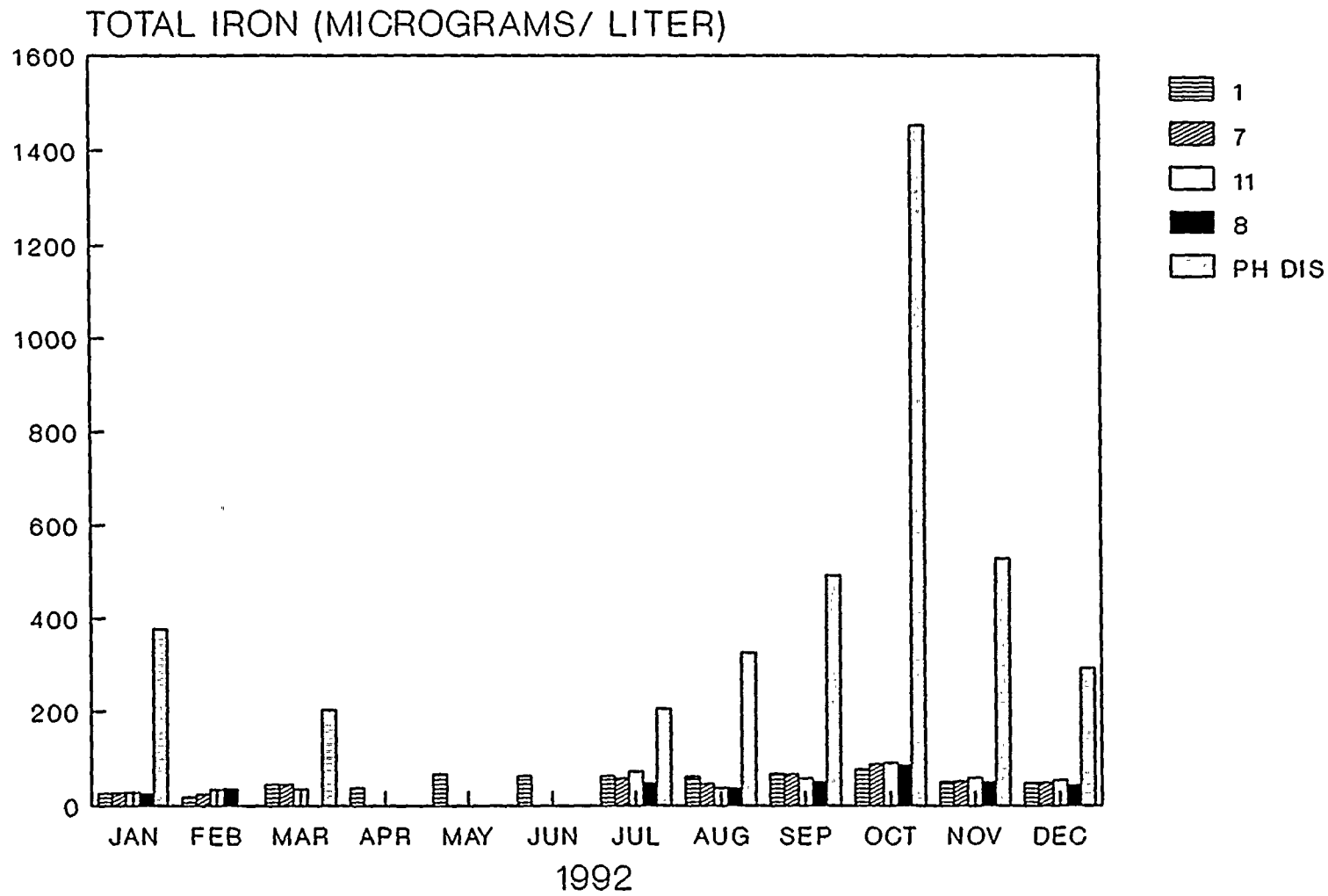

FIGURE 4-10 Columbia River and WNP-2
Discharge Total Iron Measurements
and Plant Discharge During 1992

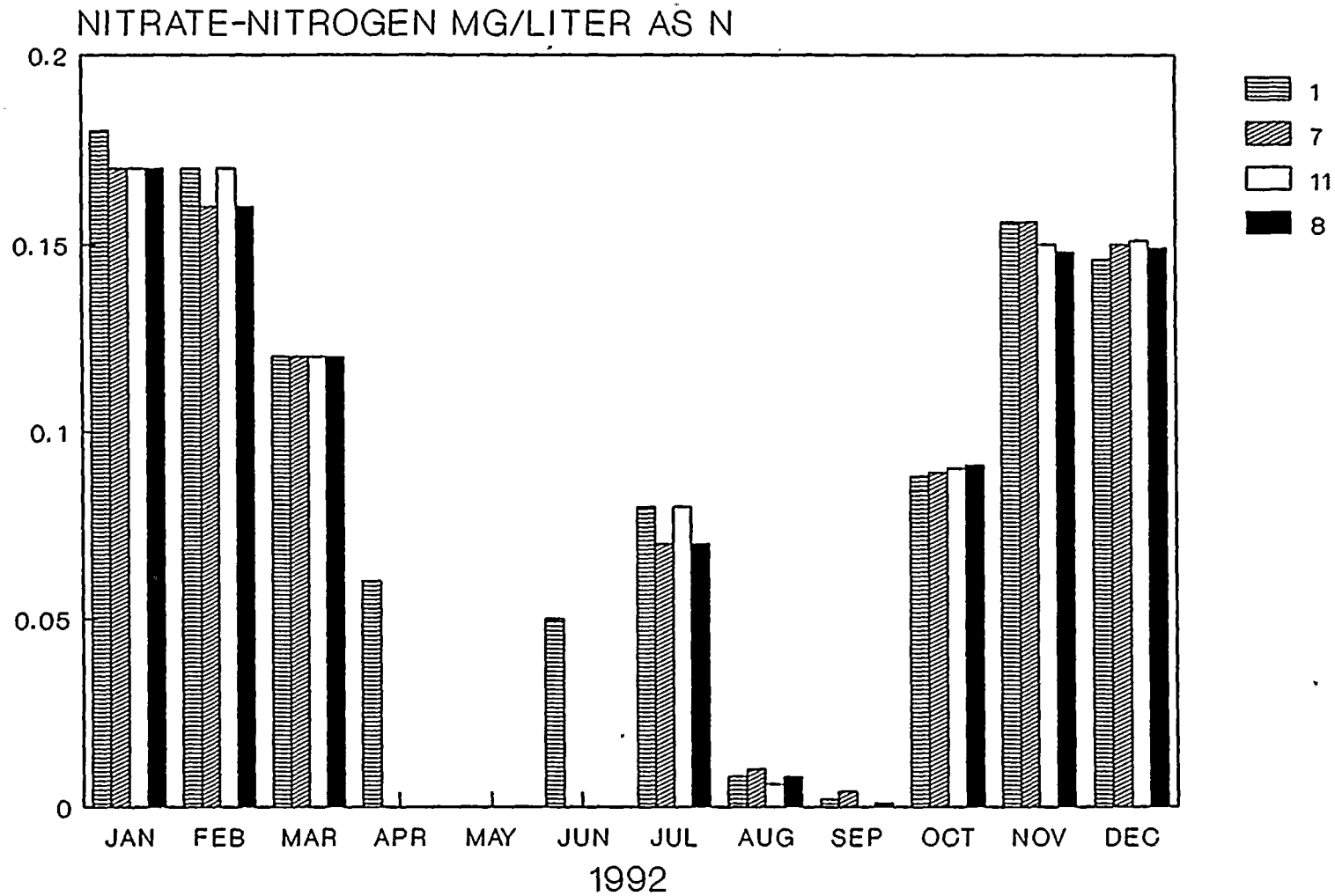

FIGURE 4-11 Columbia River Nitrate - Nitrogen Measurements at Four Stations During 1992

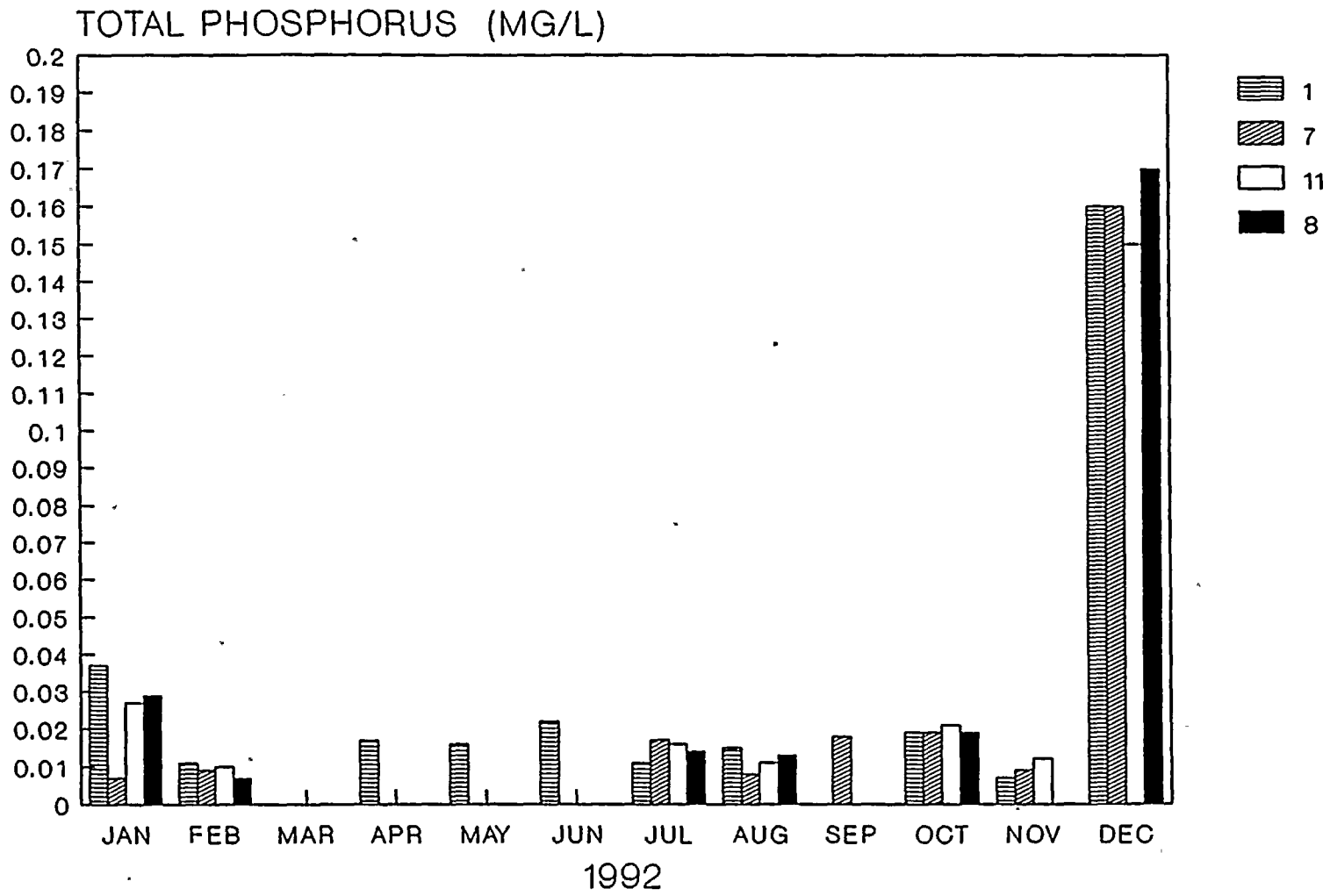

FIGURE 4-12 Columbia River Total Phosphorus Measurements at Four Stations During 1992

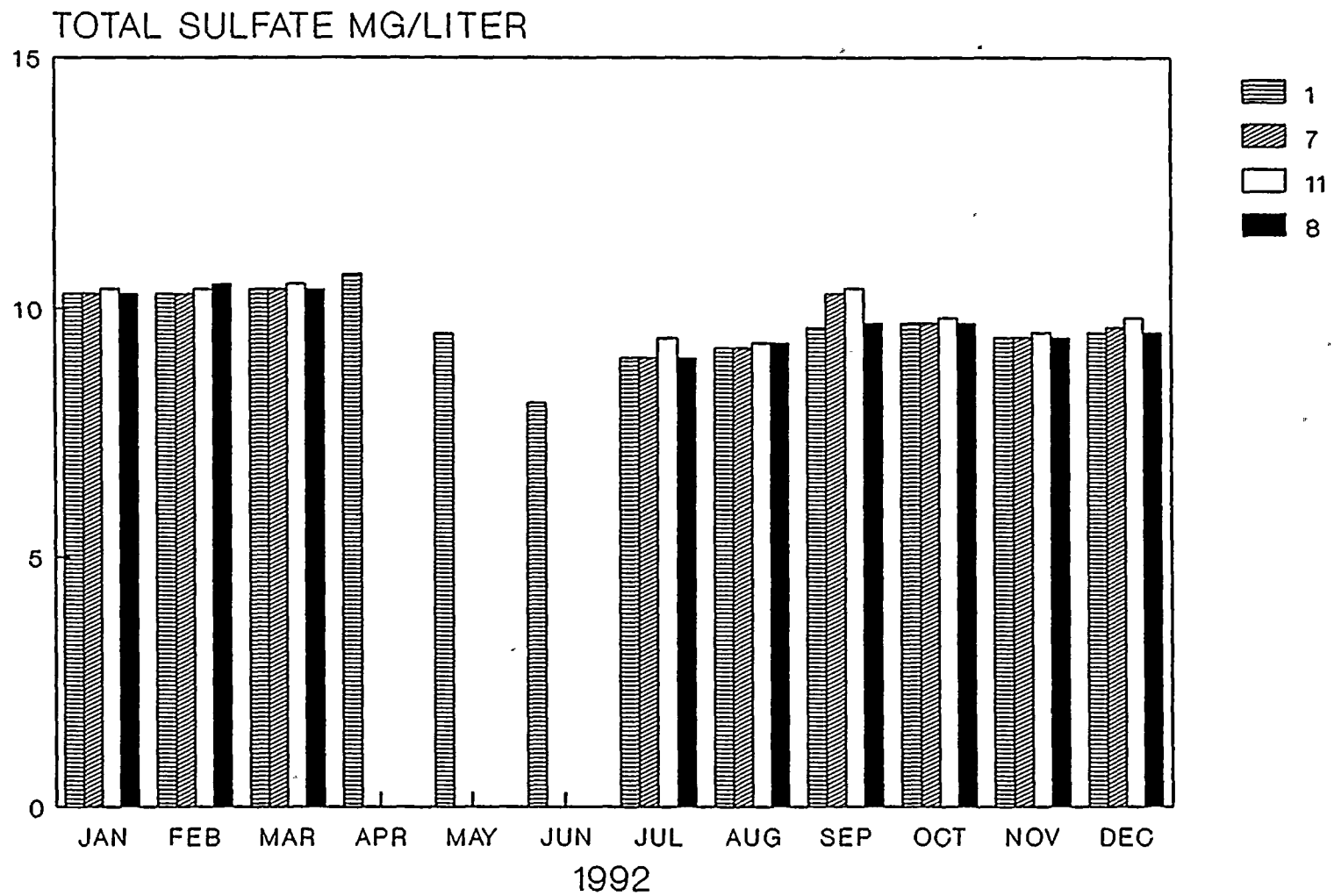

FIGURE 4-13 Columbia River Total Sulfate Measurements at Four Stations During 1992

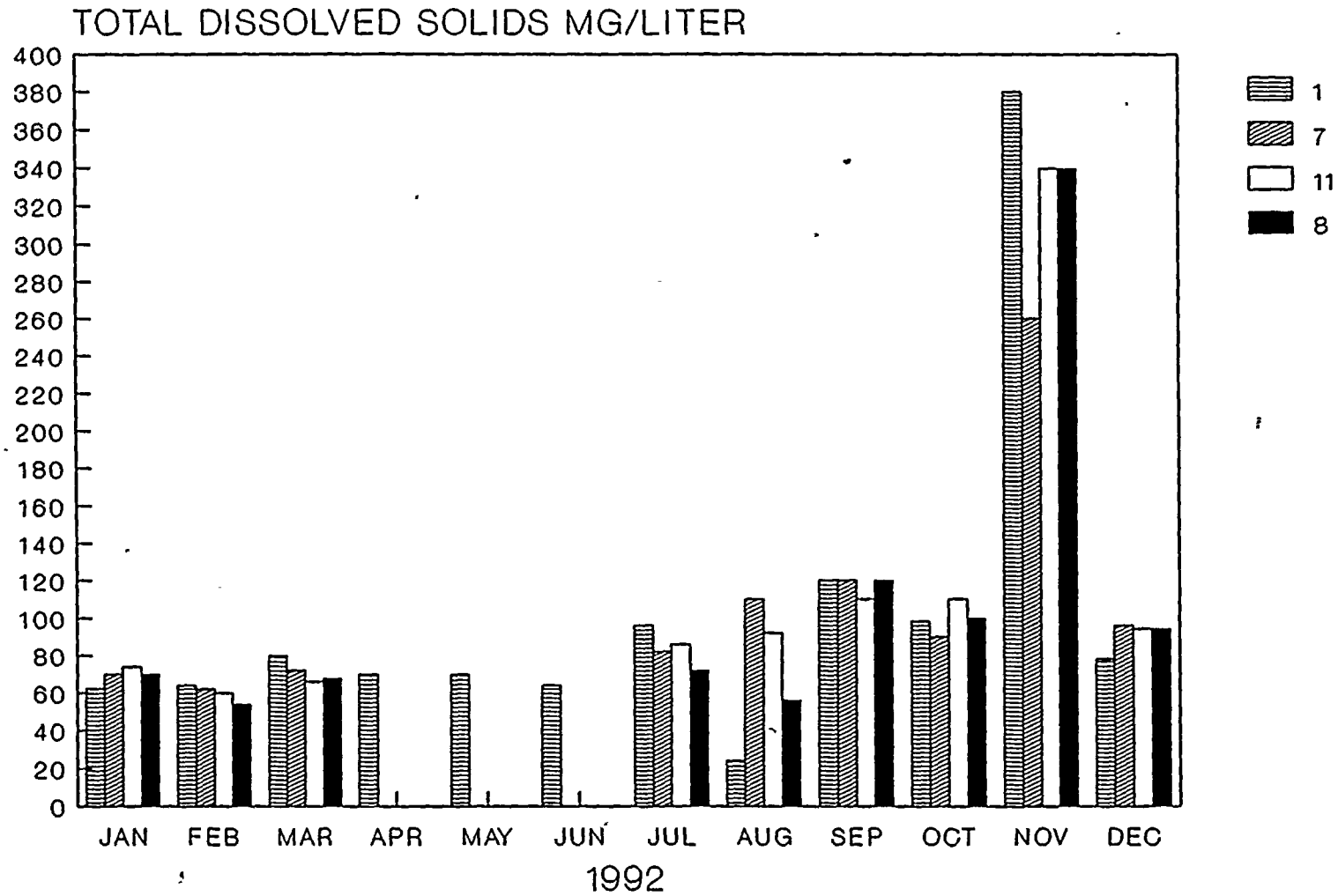

FIGURE 4-14 Columbia River Total Dissolved Solids Measurements at Four Stations During 1992

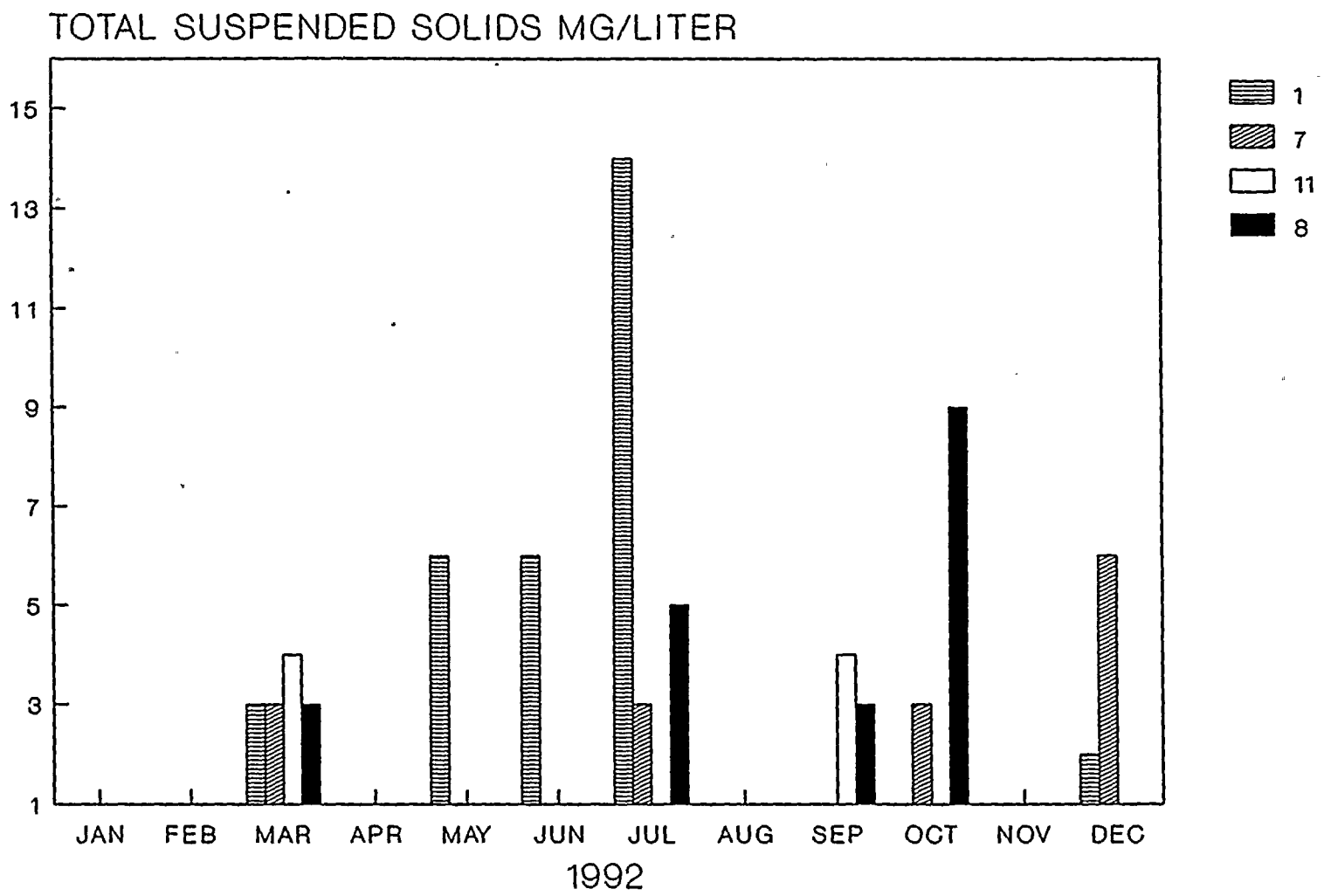

FIGURE 4-15 Columbia River Total Suspended Solids Measurements at Four Stations During 1992

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, two 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 nephelometry 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 1992 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 1975-1992. Many of the graphs will depict a preoperational, operational and 1992 status. The preoperational data is that which was collected annually prior to WNP-2 becoming fully operational (1980-1984). Operational data is that which was collected after 1984 but not including the current year (1992), which is listed separately.

5.3.1 Herbaceous Cover

Herbaceous cover data for 1992 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 72.94% in 1992 which represents a slight decrease of 3.16% from 1991 (75.32%). As in previous years, the dominant annual grass was Bromus tectorum with 43.88% cover, a 33.74% increase over last year. Poa sandbergii was the dominant perennial grass at ten of the fifteen stations. Agropyron spicatum averaged 0.23% cover, a 35.29% increase over last year (0.17%).

There was a 19.1% decrease in total annual forb cover for 1992. Sisymbrium altissimum was the dominant species with 4.05% followed by Holosteum umbellatum (2.85%). Descurainia pinnata (.82%) increased 46% over last year (.56%).

Perennial forb cover for 1992 was 3.41%. The perennial forb cover continues to increase as demonstrated by a 74.87% increase over 1991 (1.95%). The dominant species continued to be Cymopterus terebinthinus (1.00%) followed by Oenothera pallida (0.95%) with a more than 130% increase in cover from 1991 (0.41%).

Species frequency values (%) continue to increase for annual forbs (Table 5-5). The annual forbs with the highest frequency values were Holosteum umbellatum with 96% at station G06 and Draba verna at station S03 with 92%. The greatest diversity of species was observed at station S02 (18). The most significant change in total species per site was observed at station G01. Eleven species were observed in 1992, an increase of 6 species over 1991(5). No significant decreases in species were observed at the individual stations.

Growing season (August - March) precipitation increased 23.66% from 1991 (8.03 cm vs 9.93 cm). The total precipitation for the year was 20.07 cm. Calendar year snowfall totaled 23.4 inches, 21.0 inches of which fell in December, the snowiest on record. Mean temperature during the growing season was 10.8°C with the average temperature for the year being 13.38°C.

5.3.2 Herbaceous Phytomass

Mean production of herbaceous phytomass in 1992 was 96.9 g/m^2, a 31.7% decrease from the previous (141.95 g/m^2). At grassland and shrub stations the phytomass production averaged 84.2 g/m^2 and 109.6 g/m^2 respectively. Mean herbaceous phytomass production at grassland stations and at shrub stations for 1975 through 1992 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 1992 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 1992 show a 42.36% increase over 1991 (2.05% versus 1.44%). Shrub density increased at all five of the representative stations. Shrub density data for 1992 is summarized in Table 5-8, while shrub density data at each station from 1980 through 1992 is presented in Figure 5-10. Shrub cover data for 1992 is summarized in Table 5-9, while Figure 5-11 presents mean shrub cover values measured from 1975 through 1992. Shrub cover and density for 1992 at the five original shrub stations are presented graphically in Figure 5-12.

5.3.4 Soil Chemistry

The results of the 1992 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. Calcium, magnesium and potassium concentrations at station S07 are slightly higher than those observed at 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 1992 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

Calendar year 1992 was the warmest year on record. The average temperature was 13.5°C (56.4°F), 1.73°C above normal (53.3°F). A slight decrease in herbaceous phytomass was observed at 10 of the 15 stations. Mean Frequency vales for each of the sampling station's were not significantly affected by the decrease in phytomass The remaining analyses were generally within the ranges previously observed. Changes in vegetation cover and density recorded in 1992 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 eight 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.

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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 1992 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	Evening-primrose Family

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 bitterbrush

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

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Annual Grasses																		
Bromus tectorum	x	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	x
Festuca sp.		x		x														
Perennial Grasses																		
Agropyron cristatum							x	x	x	x	x	x	x	x	x	x	x	x
Agropyron desystachyum			x			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	x
Koeleria cristata				x		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	x
Poa sandbergii							x	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	x
Stipa comata		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stipa thurberiana					x													
Annual Forbs																		
Franseria acanthicarpa	x		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	x
Amsinckia menziesii							x	x										
Chenopodium leptophyllum			x												x	x	x	x
Cryptantha pterocarya		x		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	x
Descurainia pinnata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 5-2. Vascular Plants Observed During 1975-1992 Field Work

Table 5-2. Vascular Plants Observed During 1975-1992 Field Work

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Draba verna	X	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	X
Gilia minutiflora					X				X		X	X	X	X	X	X	X	X
Gilia sinuata						X		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	X
Lagophylla ramosissima						X												
Layia glandulosa			X		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	X
Microsteris gracilis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Orobanche californica													X	X			X	X
Phacelia hastata							X	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	X
Phacelia sp.		X																
Plantago patagonica	X	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	X
Polemonium micranthum	X			X														
Salsola kali	X	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	X
Tragopogon dubius				X			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	X
Antennaria dimorpha						X	X	X	X	X	X	X	X	X	X	X	X	X

Table 5-2. (Cont'd)

Table 5-2. Vascular Plants Observed During 1975-1992 Field Work

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Arenaria franklinii var. franklinii						x	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	x
Astragalus lyallii			x															
Astragalus purshii	x	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	x
Astragalus sp.				x														
Balsamorhiza carvana	x	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	x
Brodiaea howellii				x														
Calochortus macrocarpus	x				x									x	x	x	x	x
Comandra umbellata	x		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	x
Cryptantha leucophaea						x	x	x	x		x	x						
Cymopterus terebinthinus	x			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	x
Erigeron diverrens								x										
Fritillaria pudica									x	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	x
Penstemon acuminatus							x	x	x	x	x	x	x	x	x	x	x	x

Table 5-2. (Cont'd

Table 5-2. Vascular Plants Observed During 1975-1992 Field Work

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Penstemon sp.						x												
Phlox longifolia	x	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	x
Rumex venosus				x		x	x	x	x	x	x	x	x	x	x	x	x	x
Sphaeralcea munroana								x	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	x
Chrysothamnus nauseosus	x	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	x
Eriogonum niveum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gravia spinosa															x		x	x
Leptodactylon pungens									x	x								
Opuntia polyacantha	x			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	x
Ribes aureum											x	x	x	x	x	x	x	x

Table 5-2. (Cont'd

Table 5-3 Herbaceous Cover for Fifteen Sampling Stations - 1992

	O01	O02	O03	O04	O05	O06	O07	O08	S01	S02	S03	S04	S05	S06	S07	O01-S07	O01-O04	S01-S05	S01-S05
Annual Grasses																			
Bromus tectorum	48.70	64.25	53.15	34.24	45.60	41.65	66.15	55.15	30.30	30.20	42.60	55.60	51.60	23.85	15.20	43.88	50.09	42.06	46.07
Festuca octoflora	0.00	0.00	0.00	0.00	0.40	0.15	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.05	0.00	0.06	0.00	0.07	0.04
Total Annual Grass Cover	48.70	64.25	53.15	34.24	46.00	41.80	66.15	55.15	30.30	30.20	42.60	55.95	51.60	23.90	15.20	43.95	50.09	42.13	46.11
Perennial Grasses																			
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70	0.00	0.00	1.19	0.00	0.00	0.26	0.00	0.78	0.39
Oryzopsis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.06	0.03
Poa sandbergii	25.60	20.00	0.00	11.95	18.60	1.90	5.95	8.40	3.25	11.65	11.40	5.40	0.00	29.70	33.80	11.17	14.39	6.34	10.36
Stipa comata	0.00	0.00	0.00	20.25	0.00	8.30	0.00	0.40	0.00	1.00	0.00	0.00	1.20	1.60	0.00	2.18	5.06	0.44	2.75
Total Perennial Grass Cover	25.60	20.00	0.00	32.20	18.60	10.20	5.95	8.80	3.25	15.65	11.40	5.40	2.39	31.30	33.80	14.97	19.45	7.62	13.53
Annual Forbs																			
Amsinckia lycopsoides	0.10	0.00	0.00	0.10	0.95	0.00	7.90	0.10	3.70	0.15	0.00	0.05	4.60	0.05	0.05	1.18	0.05	1.70	0.88
Chenopodium leptophyllum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.01
Cryptantha circumscissa	0.00	0.00	0.00	0.00	0.05	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.04	0.02
Descurainia pinnata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.15	0.00	0.05	12.10	0.83	0.00	0.06	0.03
Draba verna	2.00	1.00	1.20	2.35	2.35	2.75	1.30	0.60	1.95	1.70	4.05	1.55	1.65	0.00	0.00	1.63	1.64	2.18	1.91
Erodium cicutarium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.01
Fraseria acanthocarpa	0.00	0.00	5.10	0.00	0.05	0.55	0.10	0.10	0.20	0.60	0.00	0.05	0.15	0.00	0.00	0.46	1.28	0.20	0.74
Gilia minutiflora	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
Holosteum umbellatum	2.95	0.35	3.80	1.00	2.85	5.65	3.45	9.05	3.05	1.70	2.60	2.00	4.30	0.00	0.00	2.85	2.03	2.73	2.38
Layia glandulosa	0.00	0.00	0.00	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	0.01	0.01
Mentzelia albicaulis	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Microsteris gracilis	0.10	0.40	0.45	0.00	0.40	0.30	0.05	0.35	0.45	0.15	1.15	1.45	0.50	0.00	0.00	0.38	0.24	0.74	0.49
Phacelia linearis	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.95	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.21	0.11
Plantago patagonica	2.25	0.35	0.00	2.80	0.00	0.00	0.00	0.55	0.00	0.00	3.10	0.00	0.75	0.00	0.25	0.67	1.35	0.77	1.06
Salsola kali	0.60	1.10	0.00	0.00	0.20	0.55	0.00	0.00	0.05	0.10	0.00	0.05	0.20	0.00	0.00	0.19	0.43	0.08	0.25
Sisymbrium altissimum	5.25	4.95	4.50	1.00	1.75	0.25	3.65	6.60	3.80	0.30	1.00	11.15	1.25	4.60	10.70	4.05	3.93	3.50	3.71
Total Annual Forb Cover	13.15	8.15	15.05	7.15	7.65	10.20	8.80	17.25	9.85	5.55	11.95	16.40	8.95	4.65	23.05	11.19	10.88	10.54	10.71
Perennial Forbs																			
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.48	0.24
Aster canescens	0.05	0.00	0.00	0.00	0.60	0.10	0.45	0.00	1.05	0.10	0.00	1.20	0.40	0.00	0.00	0.26	0.01	0.55	0.28
Astragalus purshii	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	0.00
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.09	0.00	0.01	0.01
Balsamorhiza careyana	0.00	0.00	0.00	0.00	0.35	1.55	0.00	0.00	0.00	0.00	0.00	2.95	0.35	0.00	0.00	0.35	0.00	0.66	0.33
Comandra umbellata	0.00	0.00	0.00	0.00	0.35	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	0.07
Cymopterum terebinthinus	0.05	0.05	0.00	0.00	0.00	9.00	0.00	0.00	0.00	5.90	0.00	0.05	0.00	0.00	0.00	1.00	0.03	1.19	0.61
Oenothera pallida	0.00	0.00	0.30	0.35	0.30	0.35	0.85	1.95	7.50	2.30	0.00	0.00	0.30	0.00	0.00	0.95	0.16	2.02	1.09
Phlox longifolia	0.00	0.15	0.00	0.40	0.30	0.30	0.05	1.85	0.60	0.00	1.55	0.00	0.00	0.65	0.00	0.39	0.14	0.43	0.28
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	0.10	0.25	0.30	0.75	1.95	12.55	1.35	3.85	9.15	10.70	2.25	4.25	1.05	0.65	0.00	3.28	0.35	5.48	2.92
Total Herbaceous Cover	87.55	92.65	68.50	74.34	74.20	74.75	82.25	85.05	52.55	62.10	68.20	82.00	63.99	60.50	72.05	73.38	80.76	65.77	73.26

Table 5-4 Mean Herbaceous Cover for 1975 through 1992

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					108.55	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 1992

Table 5-4 Mean Herbaceous Cover for 1975 through 1992 (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	23.71
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.	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	33	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
AG	1992	30.30	30.20	42.60	55.95	51.60	42.13	23.90	15.20	35.67	48.70	64.25	53.15	34.24	50.09	46.00	41.80	66.15	55.15	51.18	43.95	45.67
PG	1992	3.25	15.65	11.40	5.40	2.39	7.62	31.30	33.80	14.74	25.60	20.00	0.00	32.20	19.45	18.60	10.20	5.95	8.80	15.17	14.97	12.88
AF	1992	9.85	5.55	11.95	16.40	8.95	10.54	4.65	23.05	11.48	13.15	8.15	15.05	7.15	10.87	7.65	10.20	8.80	17.25	10.93	11.19	10.69
PF	1992	9.15	10.70	2.25	4.25	1.05	5.48	0.65	6.00	4.01	0.10	0.25	0.30	0.75	0.35	1.95	12.55	1.35	3.85	2.64	3.28	3.20
ALL	1992	52.55	62.10	68.20	82.00	63.99	65.77	60.50	72.70	65.90	87.55	92.65	68.50	74.34	80.76	74.20	74.75	82.25	85.05	79.92	73.39	72.44

Table 5-4 Mean Herbaceous Cover for 1975 through 1992 (continued)

Table 5-5 Mean Frequency Values (%) by Species for Each Sampling Station - 1992

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
Annual Grasses															
Bromus tectorum	100	100	100	100	98	100	100	100	100	90	100	100	100	88	98
Festuca octoflora					16	8						14		2	
Perennial Grasses															
Agropyron spicatum										14			4		
Oryzopis hymenoides										2					
Poa sandbergii	96	96		92	64	8	26	36	22	46	72	34		68	94
Stipa comata				72		30		6		10			8	8	
Annual Forbs															
Amsinckia lycopsoides	4			4	8		66	4	32	16		2	30	2	2
Chenopodium leptophyllum					2	6			6				2		
Cryptantha circumscissa															
Cryptantha pterocarya															
Descurainia pinnata									2	2	2			2	68
Draba verna	80	40	28	64	74	60	52	24	78	48	92	52	66		
Franseria acanthacarpa			66		2	22	4	4	8	14		2	6		
Gilia sinuata															
Holosteum umbellatum	60	4	72	30	56	96	78	84	82	48	74	40	82		
Layia glandulosa									2						
Mentzelia albicaulis							8								
Microsteris gracilis	4	16	18		16	12	2	14	18	6	26	48	20		
Phacelia linearis							2		4	38					
Plantago patagonica	50	14		52				12			84		30		
Salsola kali	24	44			8	22			2	4		2	8		
Sisymbrium altissimum	76	84	36	12	30	10	48	60	46	12	30	78	20	40	54
Tragopogon dubius													2		
Perennial Forbs															
Achillea millefolium										10					
Aster canescens	2				4	4	8		12	4		10	6		
Astragalus purshii					2										
Astragalus sclerocarpus						2		2				2			
Balsamorhiza careyana					4	4						12	4		
Brodiaea douglasii					2										
Comandra umbellata					4										
Crepis atrabarba															
Cynopterus terebinthinus	2	2				26				16		2			
Oenothera pallida			2	4	2	4	6	28	30	16			2		
Phlox longifolia		6		6	2	2	2	8	4		4			6	
Rumex venosus															
Total Species Per Site	11	10	7	10	18	17	13	13	16	18	9	14	16	8	6

Table 5-6 Mean Terrestrial Phytomass for 1992

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/05	G01	4-7	18.3	183.4
05/05	G01	8-2	8.2	81.8
05/05	G01	12-6	25.3	252.7
05/05	G01	20-9	10.8	108.0
05/05	G01	36-5	8.6	86.0
		AVG	14.2	142.4
		STD	6.6	66.2

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/04	G02	4-7	9.8	98.3
05/04	G02	8-2	6.7	67.1
05/04	G02	12-6	18.7	187.2
05/04	G02	20-9	14.5	145.1
05/04	G02	36-5	4.9	49.2
		AVG	10.9	109.4
		STD	5.1	50.7

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/05	G03	4-7	10.8	108.1
05/05	G03	8-2	5.1	51.2
05/05	G03	12-6	11.7	116.5
05/05	G03	20-9	9.1	91.1
05/05	G03	36-5	4.7	46.4
		AVG	8.3	82.7
		STD	2.9	28.8

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/05	G04	4-7	4.2	42.4
05/05	G04	8-2	7.5	74.8
05/05	G04	12-6	7.4	74.0
05/05	G04	20-9	1.8	17.9
05/05	G04	36-5	9.1	90.7
		AVG	6.0	60.0
		STD	2.6	26.2

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/08	G05	4-7	2.7	27.1
05/08	G05	802	5.4	54.3
05/08	G05	12-6	10.1	100.6
05/08	G05	20-9	4.8	48.1
05/08	G05	36-5	4.2	41.9
		AVG	5.4	54.4
		STD	2.5	24.8

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/06	G06	4-7	5.6	56.4
05/06	G06	8-2	8.5	84.9
05/06	G06	12-6	3.5	35.4
05/06	G06	20-0	4.2	42.2
05/06	G06	36-5	2.8	28.2
		AVG	4.9	49.4
		STD	2.0	20.0

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/07	G07	4-7	10.5	105.1
05/07	G07	8-2	11.6	116.4
05/07	G07	12-6	12.8	128.3
05/07	G07	20-9	9.6	96.1
05/07	G07	36-5	6.1	61.1
		AVG	10.1	101.4
		STD	2.3	22.9

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/05	G08	4-7	4.3	72.8
05/05	G08	8-2	6.8	68.4
05/05	G08	12-6	5.8	58.2
05/05	G08	20-9	8.9	88.6
05/05	G08	36-5	8.4	83.6
		AVG	7.4	74.3
		STD	1.1	10.8

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/07	S01	4-7	2.4	24.0
05/07	S01	8-2	7.2	72.4
05/07	S01	12-6	6.7	67.1
05/07	S01	20-9	2.6	25.5
05/07	S01	36-5	5.7	57.1
		AVG	4.9	49.2
		STD	2.1	20.6

Table 5-6 Mean Terrestrial Phytomass for 1992 (continued)

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/14	S02	4-7	6.9	69.4	05/07	S03	4-7	4.2	41.9	05/08	S04	4-7	11.3	113.0
05/14	S02	8-2	29.6	295.9	05/07	S03	8-2	4.5	44.5	05/08	S04	8-2	5.5	54.7
05/14	S02	12-6	3.4	33.7	05/07	S03	12-6	6.1	60.8	05/08	S04	12-6	2.9	28.6
05/14	S02	20-9	11.9	119.4	05/07	S03	20-9	14.9	148.7	05/08	S04	20-9	14.3	143.4
05/14	S02	36-5	21.9	219.3	05/07	S03	36-5	15.8	157.5	05/08	S04	36-5	6.2	61.6
		AVG	14.8	147.5			AVG	9.1	90.7			AVG	8.0	80.3
		STD	9.7	97.0			STD	5.1	51.5			STD	4.2	41.8

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/12	S05	4-7	6.2	61.8	05/06	S06	4-7	2.5	25.4	05/06	S07	4-7	22.1	220.8
05/12	S05	8-2	7.5	75.1	05/06	S06	8-2	4.0	39.7	05/06	S07	8-2	18.0	180.0
05/12	S05	12-6	9.4	93.5	05/06	S06	12-6	18.7	187.3	05/06	S07	12-6	11.8	118.3
05/12	S05	20-9	23.2	232.1	05/06	S06	20-9	20.1	200.6	05/06	S07	20-9	24.2	242.1
05/12	S05	36-5	9.2	91.7	05/06	S06	36-5	5.4	53.5	05/06	S07	36-5	17.5	175.1
		AVG	11.1	110.8			AVG	10.1	101.3			AVG	18.7	187.3
		STD	6.2	61.7			STD	7.6	76.3			STD	4.3	42.6

Phytomass Summary

MEAN G01-G08 84.2 Grams/sq. meter
MEAN S01-S07 109.6 Grams/sq. meter

Table 5-7 Comparison of Herbaceous Phytomass (g/m2) for 1975 through 1992

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
G01	359	108	21	166	64	160	200	90	77	94	70	50	83	34	174.3	13.6	87.7	142.4
G02	302	258	11	162	37	68	255	60	137	116	27	61	77	14	65.7	4.1	97.2	109.4
G03	-	-	-	-	-	53	261	62	64	133	12	32	134	16	105.1	64.0	161.6	82.7
G04	-	-	-	-	-	79	159	113	82	67	37	35	90	61	49.5	73.2	67.6	60.0
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43.2	36.8	171.8	54.4
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61.0	39.8	101.4	49.4
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113.1	29.1	168.4	101.4
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	112.3	10.0	137.3	74.3
S01	126	137	4	173	21	36	180	98	171	104	5	35	62	59	53.9	32.8	225.1	49.2
S02	144	98	7	128	28	63	115	24	232	57	1	112	144	73	72.8	78.3	58.2	147.5
S03	88	177	7	115	16	43	31	22	54	95	27	25	48	15	67.0	28.2	87.6	90.7
S04	-	-	-	-	-	78	52	39	68	93	11	176	108	24	39.8	30.9	185.2	80.3
S05	-	-	-	-	-	71	81	184	136	43	61	42	145	19	103.7	43.4	111.3	110.3
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72.7	34.0	225.1	101.3
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	149.5	6.1	226.0	187.3

Table 5-7 Comparison of Herbaceous Phytomass (g/m^2) for 1975 through 1992

Table 5-8 Summary of Shrub Density for 1992

Station	Species	1	2	3	4	Total	S/Ha	S/a
S01	Artemisia tridentata	1	0	4	0	5	50	20
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	2	1	0	1	4	40	16
						9	90	36
						Total	S/Ha	S/a
S02	Artemisia tridentata	0	1	0	0	1	10	4
	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
						1	10	4
						Total	S/Ha	S/a
S03	Artemisia tridentata	9	16	8	17	50	500	200
	Chrysothamnus nauseosus	2	1	2	2	7	70	28
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						57	570	228
						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	3	2	1	6	60	24
	Chrysothamnus viscidiflorus	0	0	2	0	2	20	8
	Purshia tridentata	1	3	3	0	7	70	28
						15	150	60

Table 5-8 Summary of Shrub Density for 1992

Table 5-9 Summary of Shrub Cover (%) at Five Stations for 1992

Shrub Cover (%)						
Shrubs	S01	S02	S03	S04	S05	X
Artemisia tridentata	0.00	6.24	7.01	6.02	0.00	1.45
Chrysothamnus nauseosus	0.00	0.00	1.08	0.00	1.24	0.46
Chrysothamnus viscidiflorus	0.00	0.00	0.00	0.00	0.12	0.62
Purshia tridentata	0.61	0.00	0.00	0.00	0.00	0.12
Total Shrub Cover	0.61	0.24	8.09	6.02	1.36	2.05

Table 5-9 Summary of Shrub Cover (%) at Five Stations for 1992

TABLE 5-10 SUMMARY OF SOIL CHEMISTRY FOR 1992

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
pH (1:2 soil-water)	6.87	6.82	7.14	6.75	6.77	6.83	6.83	6.85	6.93	7.35	6.96	6.84	6.73	6.98	7.64
Conductivity (1:2 soil-water) microsiemens/cm	24.5	65.0	77.0	18.0	26.5	24.0	38.0	24.0	24.0	74.5	23.0	25.5	29.5	28.5	63.0
Sulfate ug/gm	10.01	9.59	10.13	10.37	10.13	9.98	9.85	10.09	10.28	9.66	10.32	10.20	10.18	9.81	9.01
Chloride ug/gm	3.00	4.00	4.00	10.00	3.00	7.00	0.00	4.00	4.00	1.00	6.00	5.00	2.00	5.00	5.00
Copper ug/gm	11.40	10.10	12.00	8.90	11.40	11.20	16.80	9.64	12.50	10.00	14.60	9.90	9.10	11.00	19.90
Lead ug/gm	9.09	10.11	7.39	5.85	8.36	6.09	7.70	4.87	6.66	4.88	5.74	6.71	7.21	7.46	9.72
Cadmium ug/gm	0.130	0.16	0.030	0.06	0.05	0.04	0.08	0.08	0.10	0.05	0.07	0.49	0.11	0.47	0.29
Chromium ug/gm	10.90	9.30	8.20	7.60	8.80	6.30	5.90	5.82	6.40	10.30	7.20	8.50	6.50	12.30	16.80
Nickel ug/gm	8.80	7.70	6.90	6.70	9.10	8.20	7.40	7.92	8.60	9.30	8.30	8.10	6.70	8.10	12.70
Zinc ug/gm	49.73	49.00	49.30	37.63	46.57	45.23	50.54	40.78	51.58	32.33	48.96	42.34	45.41	44.50	57.49
Sodium %	0.027	0.026	0.027	0.026	0.033	0.032	0.028	0.027	0.035	0.025	0.033	0.032	0.030	0.026	0.033
Potassium %	0.265	0.207	0.188	0.139	0.205	0.150	0.174	0.157	0.195	0.105	0.187	0.177	0.143	0.221	0.287
Calcium %	0.281	0.317	0.351	0.284	0.329	0.299	0.327	0.272	0.325	0.431	0.331	0.321	0.311	0.335	0.734
Bicarbonate (meq/HC03/gm)	0.0026	0.0050	0.0052	0.0020	0.0028	0.0024	0.0040	0.0022	0.0048	0.0044	0.0026	0.0022	0.0026	0.0030	0.0092
Magnesium %	0.493	0.449	0.436	0.373	0.465	0.401	0.427	0.390	0.486	0.386	0.452	0.454	0.401	0.477	0.807

Table 5-10 Summary of Soil Chemistry for 1992

Table 5-11 Summary of Vegetation Chemistry for 1992

	SITE	POSA	BRTE	SIAL	PHLO	PUTR	ARTR	CHVI	GRSP
Copper (ug/gm)	G01	3.60	3.60	3.80	3.60				
	G02	3.40	3.60	3.60	3.60				
	G03	3.40	3.60	0.00					
	G04	0.00	0.00	0.00	0.00				
	G05	0.00	0.00				0.00		
	G06	3.20	3.57					4.00	
	G07	3.40	3.40				4.00	3.80	
	G08	3.20	3.20	4.00	4.00				
	S01	3.60	3.80	3.80	3.80				
	S02	3.60	3.60	3.80	3.80				
	S03	5.80	6.00		5.80		6.00		
	S04	5.80	6.00	5.80	5.80		0.00		
	S05	5.80	8.60			9.00	6.20		
	S06	8.40	8.80				9.00		8.60
	S07		8.40				8.80		8.40
Extractable Sulfate (%)	G01	0.012	0.013	0.043	0.012				
	G02	0.012	0.012	0.011	0.011				
	G03	0.011	0.012	0.060		0.012			
	G04	0.012	0.011	0.069	0.011				
	G05	0.014	0.011			0.012	0.011		
	G06	0.012	0.012				0.011	0.011	
	G07	0.011	0.012				0.012	0.021	
	G08	0.012	0.014	0.040	0.011				
	S01	0.012	0.012	0.039	0.011				
	S02	0.012	0.014	0.00	0.012	0.012			
	S03	0.0011	0.012		0.011		0.012		
	S04	0.014	0.011	0.038	0.012				
	S05	0.011	0.010			0.013	0.011		
	S06	0.010	0.011				0.010		0.080
	S07		0.010				0.010		0.041
Extractable Chloride (%)	G01	0.10	0.13	0.17	0.08				
	G02	0.07	0.14	0.20	0.06				
	G03	0.11	0.04	0.20		0.03			
	G04	0.11	0.10	0.13	0.06				
	G05	0.09	0.03			0.04	0.28		
	G06	0.08	0.11				0.19	0.21	
	G07	0.11	0.08				0.19	0.18	
	G08	0.10	0.09	0.14	0.04				
	S01	0.03	0.09	0.12	0.06				
	S02	0.11	0.08		0.07	0.03			
	S03	0.12	0.08		0.07		0.24		
	S04	0.10	0.17	0.36	0.07				
	S05	0.09	0.10			0.05	0.22		
	S06	0.09	0.11				0.28		0.67
	S07		0.11				0.20		0.47

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

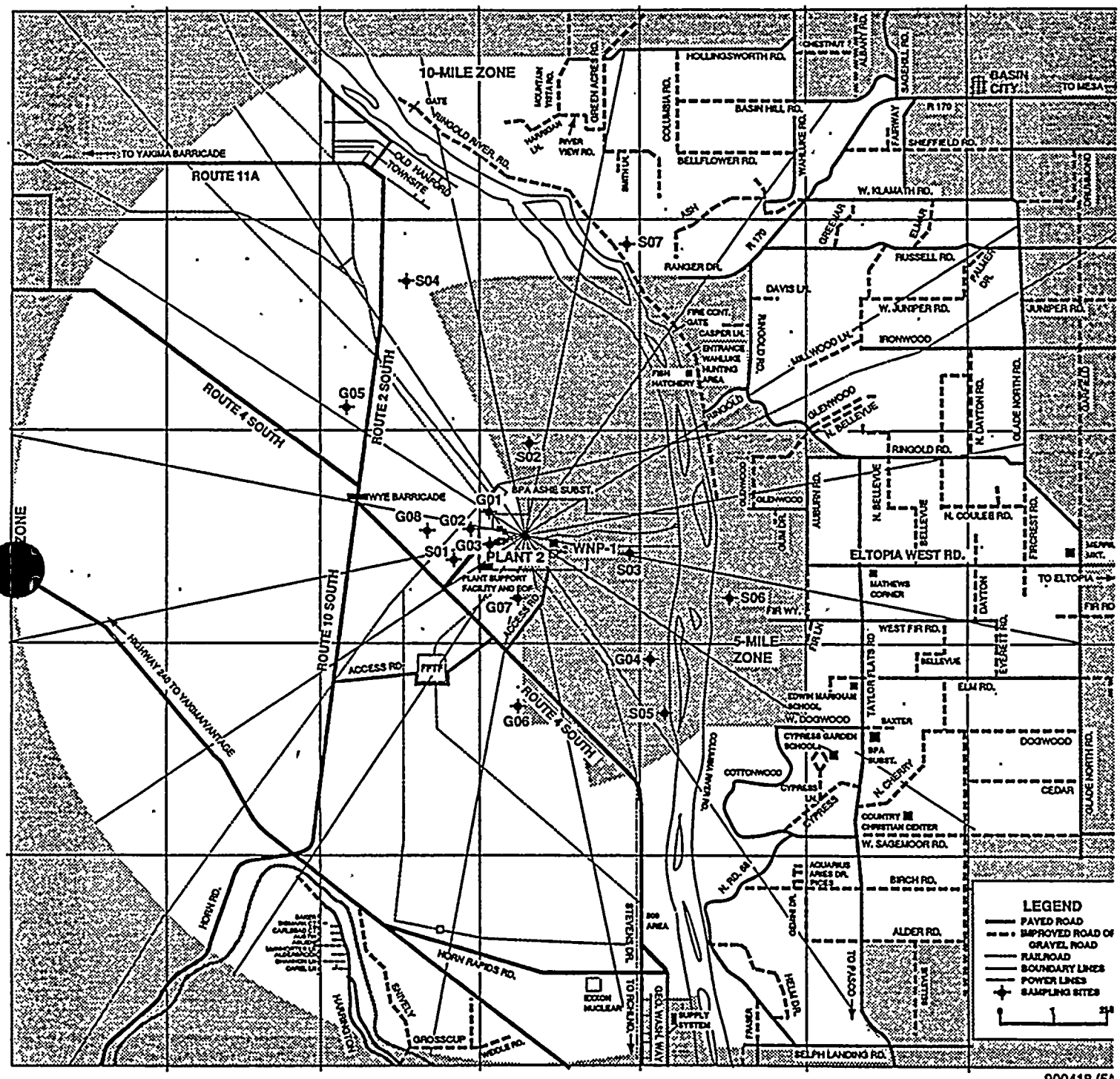
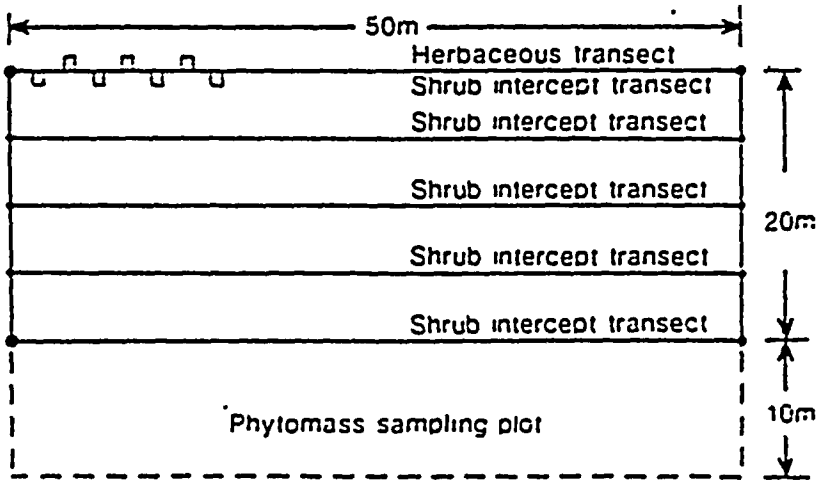


Figure 5-1 Soil and Vegetation Sampling Location Map.

Shrub Community



Herbaceous Community

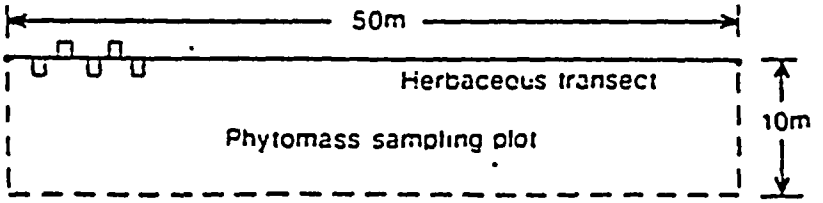
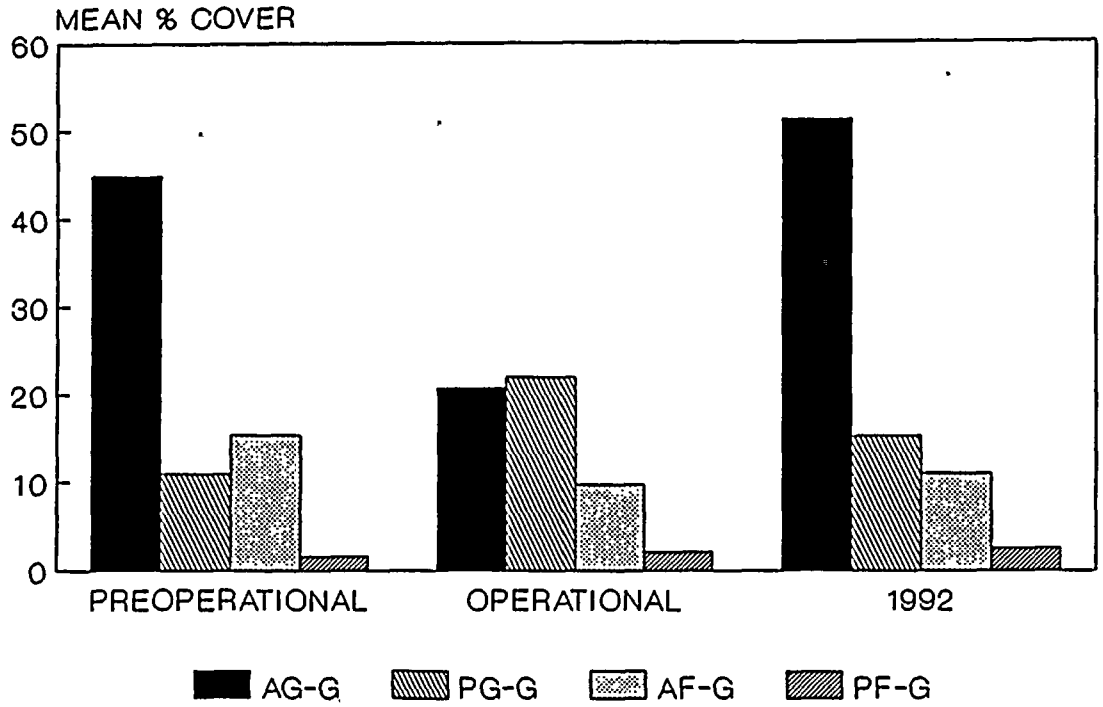


Figure 5-2 Layout of Vegetation and Soil Sampling Plots



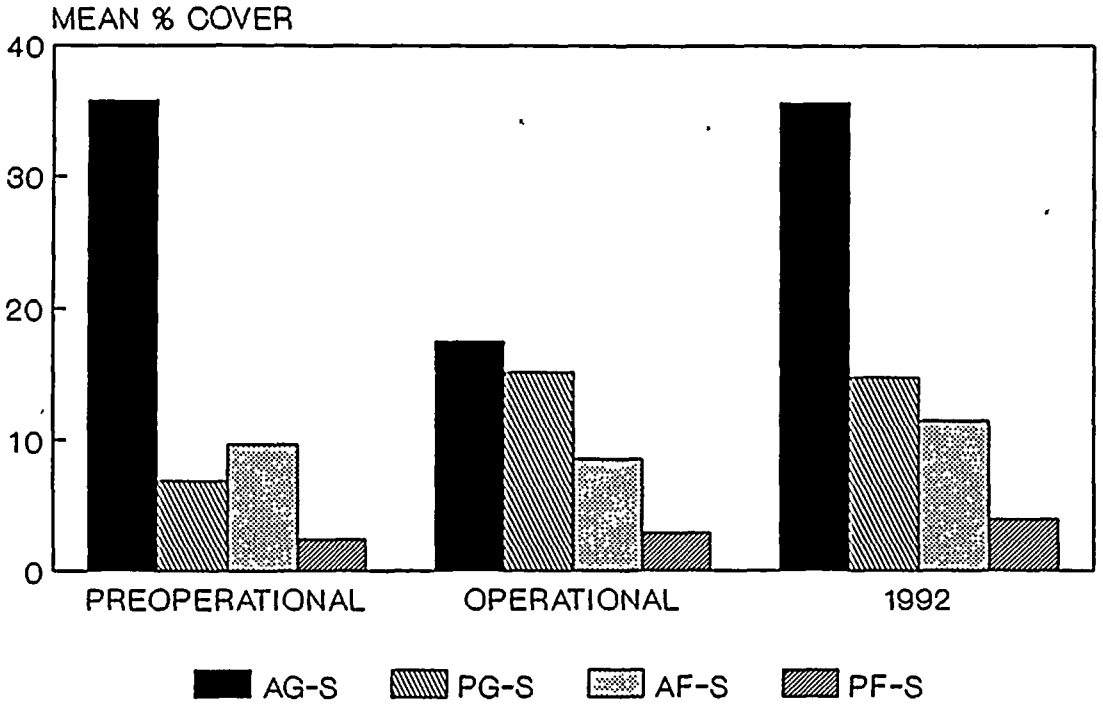


Figure 5-3 Mean Herbaceous Cover for 1975 through 1992

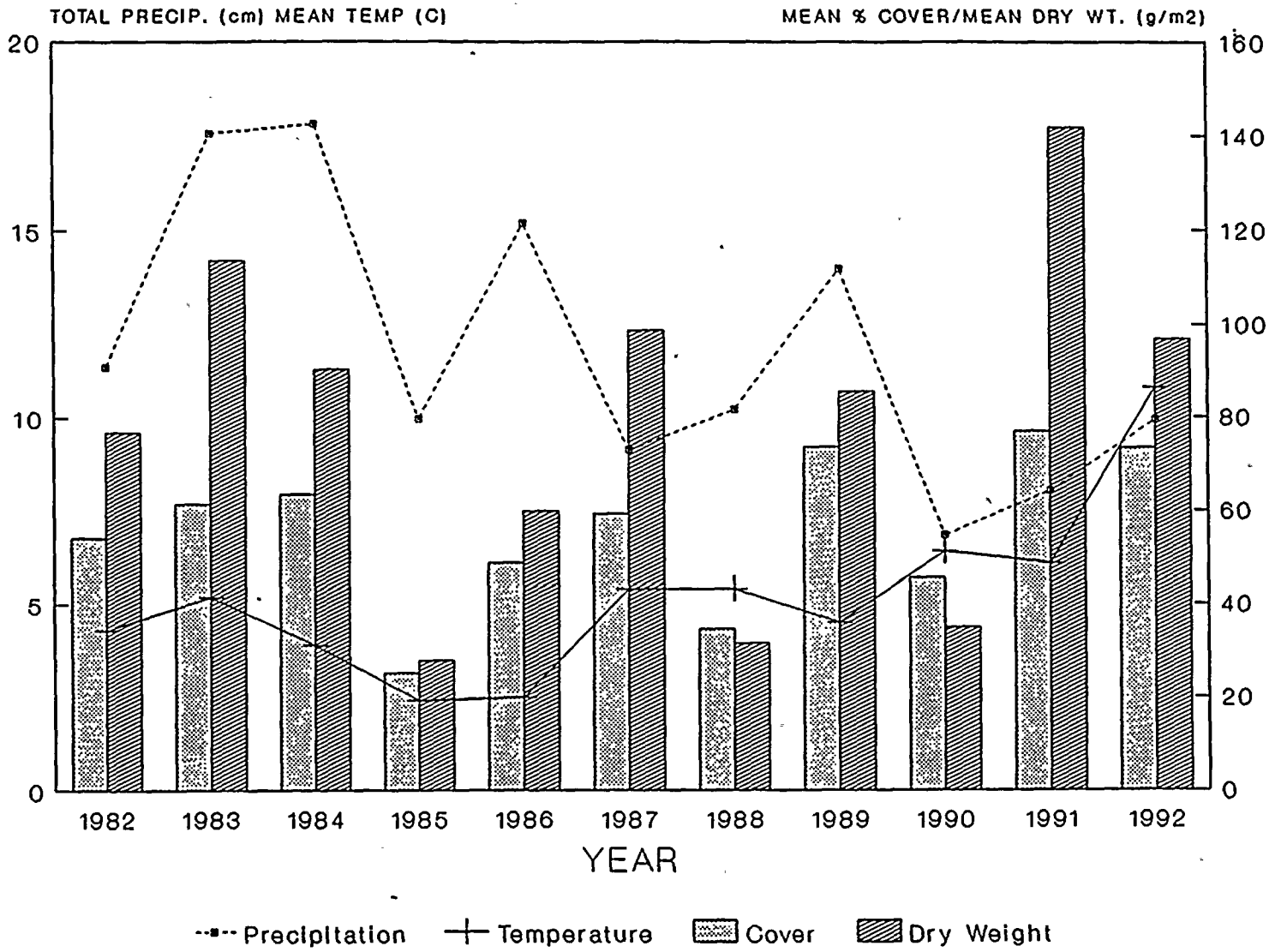
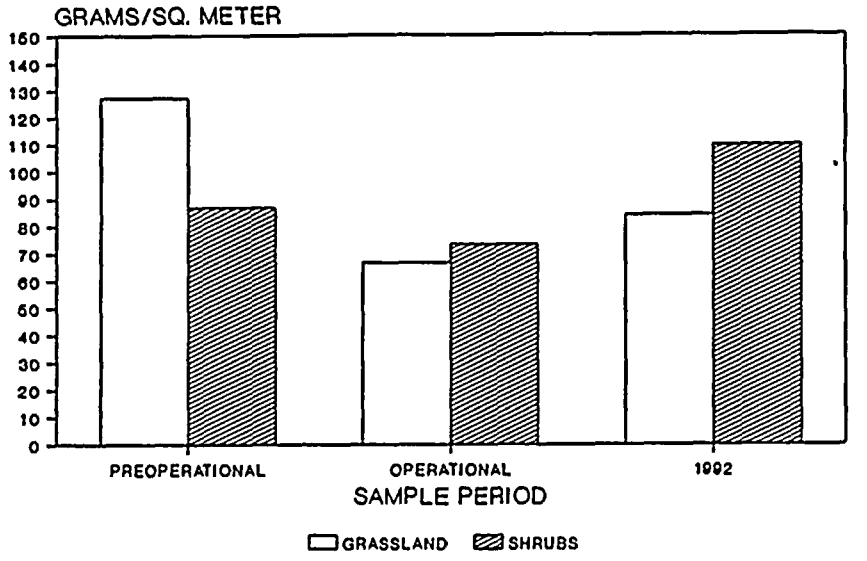


Figure 5-4 Mean Herbaceous Cover, Mean Dry Weight (g/m^2), Total Precipitation, and Mean Temperature from 1982 through 1992



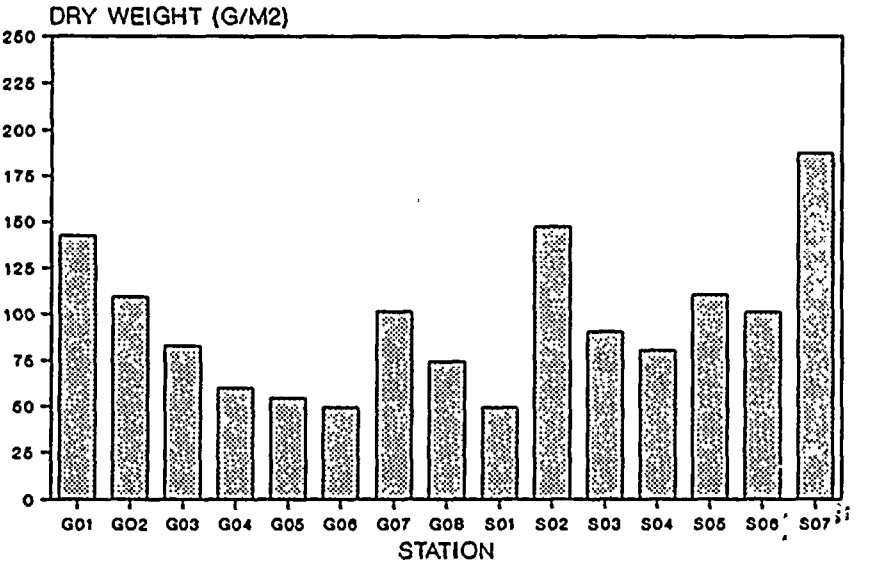


Figure 5-5 Mean Herbaceous Phytomass at Grassland and Shrub Stations for 1975 through 1992

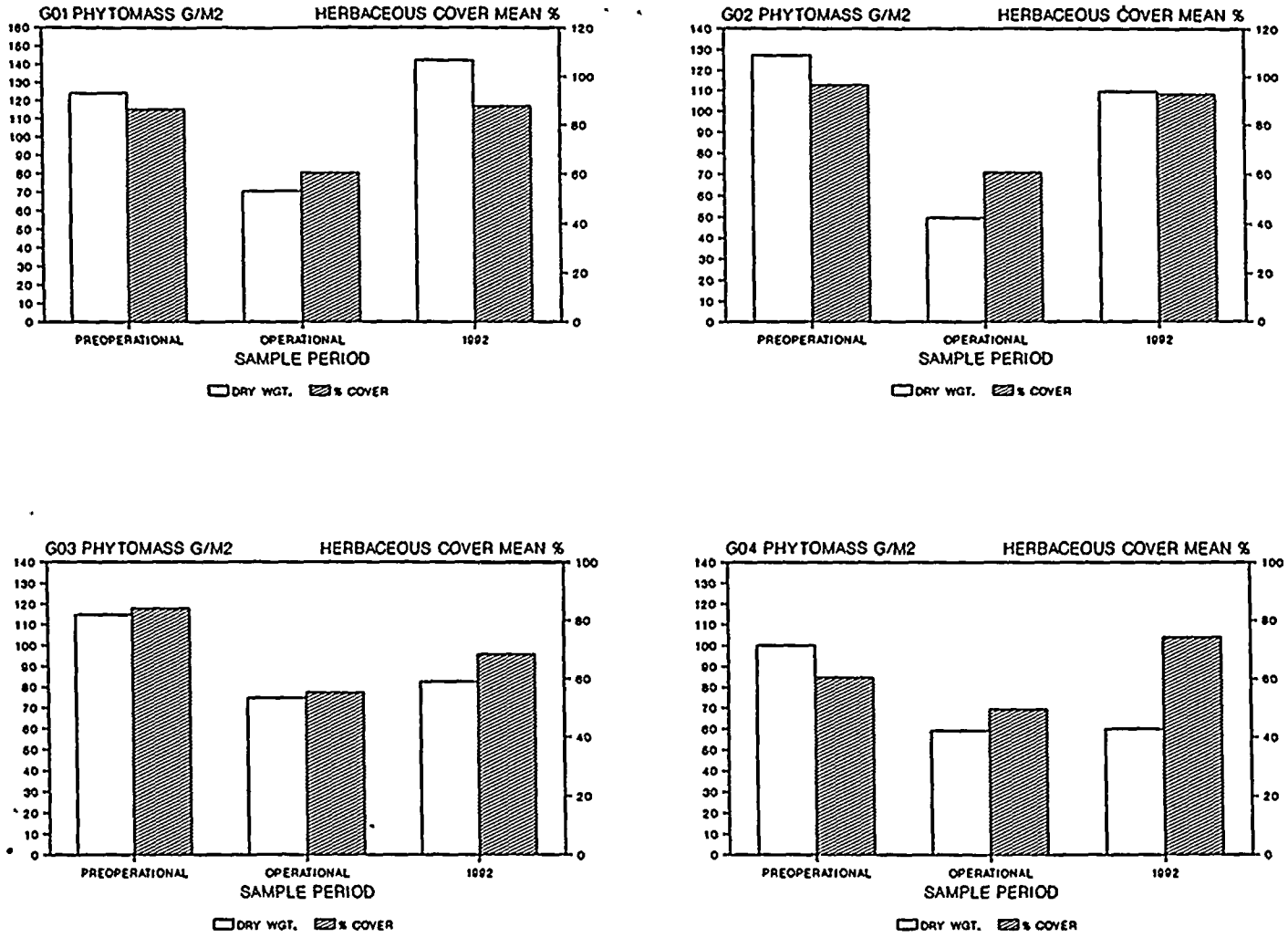


Figure 5-6 Mean Herbaceous Cover and Phytomass for Stations GO1 to GO4 for 1980 through 1992

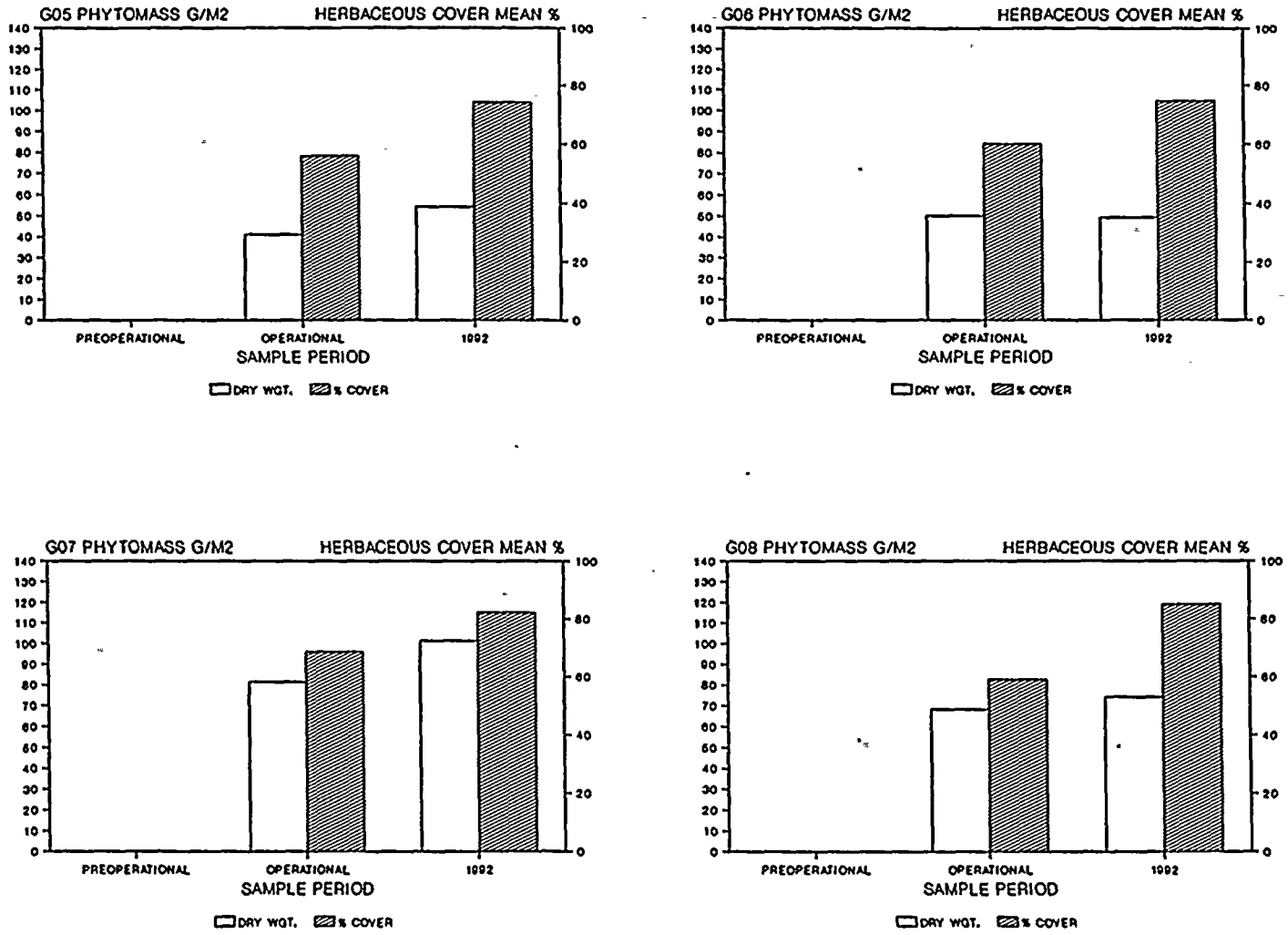


Figure 5-7 Mean Herbaceous Cover and Phytomass for Stations GO5 to GO8 for 1980 through 1992

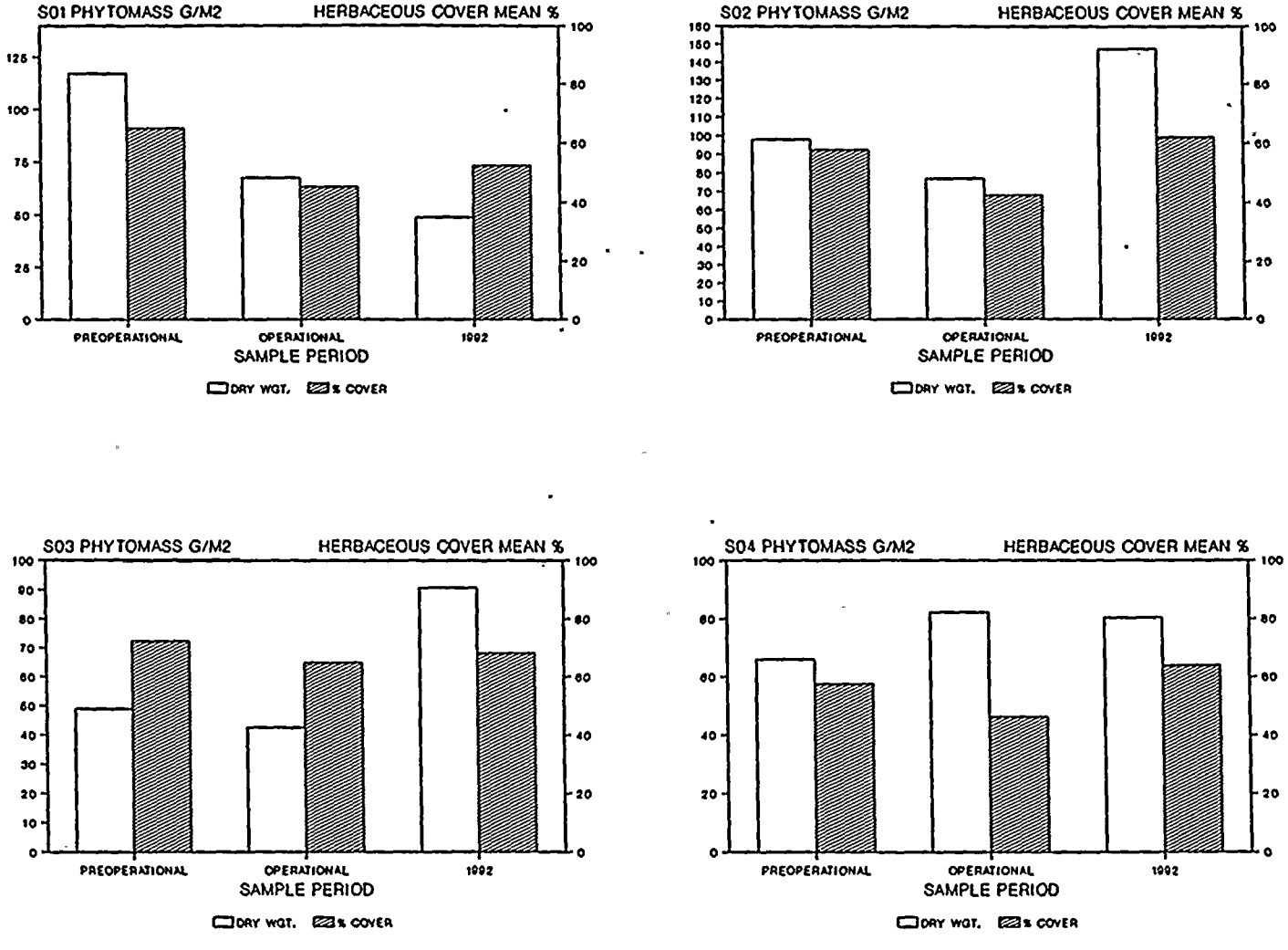


Figure 5-8 Mean Herbaceous Cover and Phytomass for Stations SO1 to SO4 for 1980 through 1992

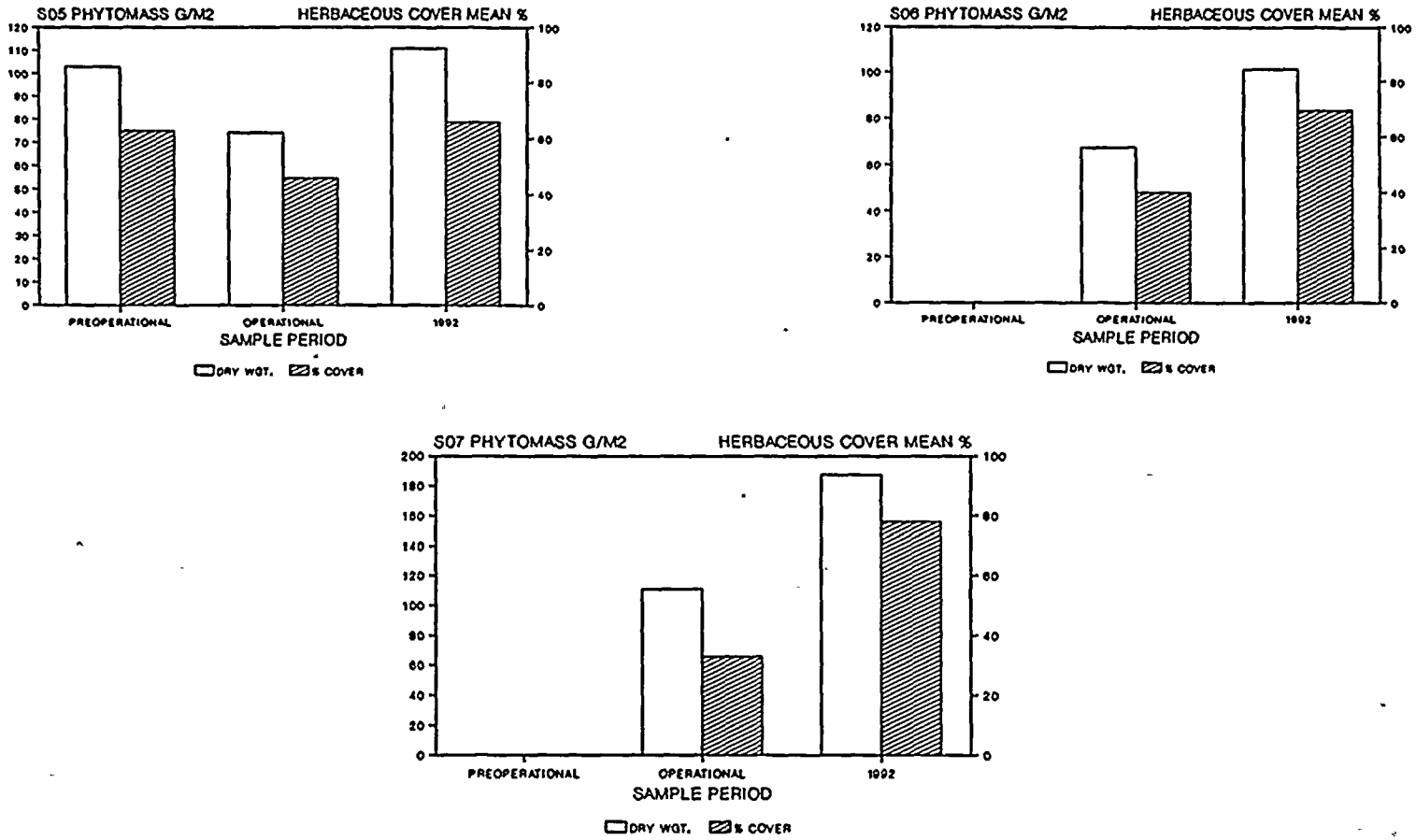


Figure 5-9 Mean Herbaceous Cover, and Phytomass for Stations SO5 for 1980 through 1992 and Stations SO6 and SO7 for 1989 through 1992

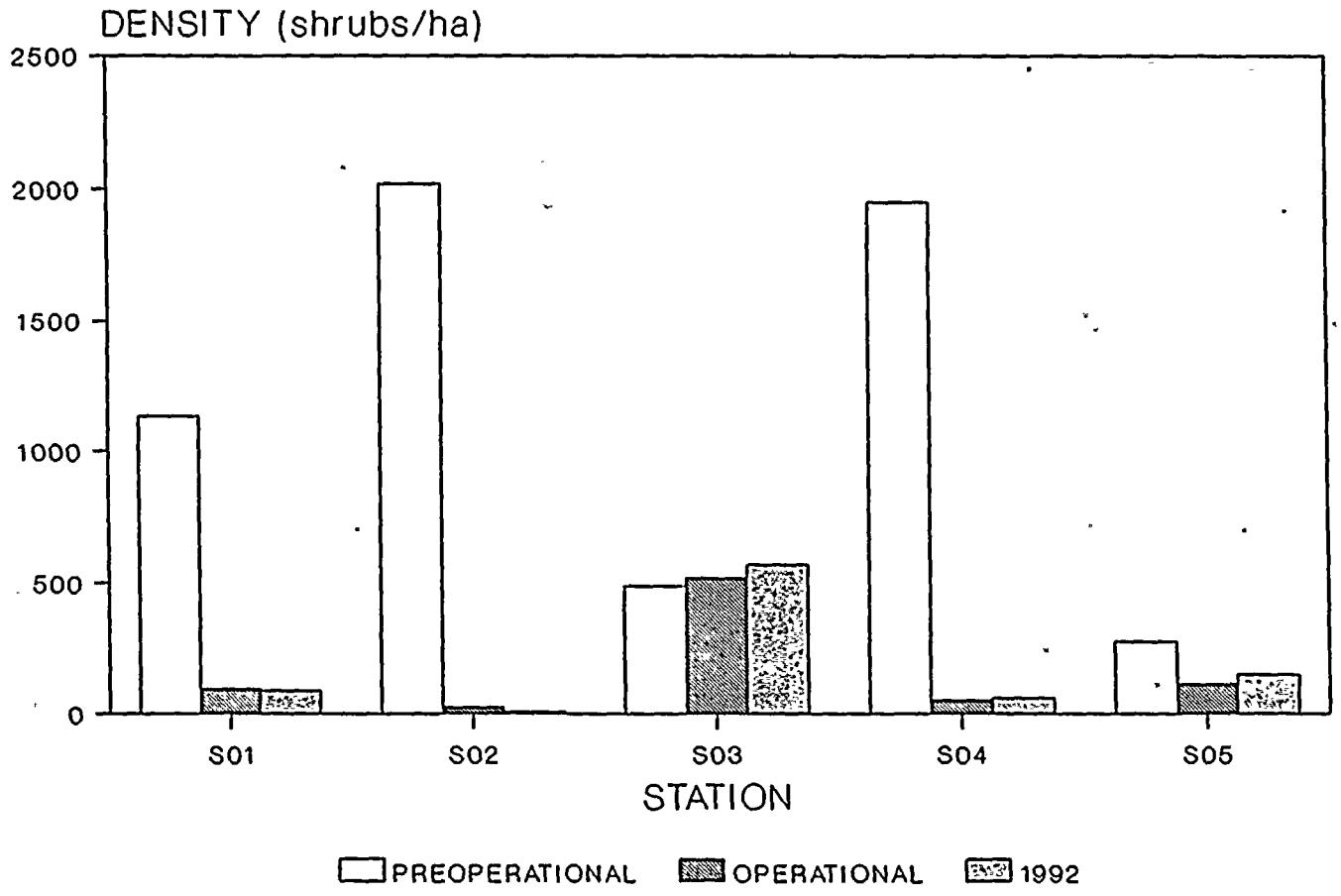


Figure 5-10 Shrub Density at Five Stations for 1975 through 1992

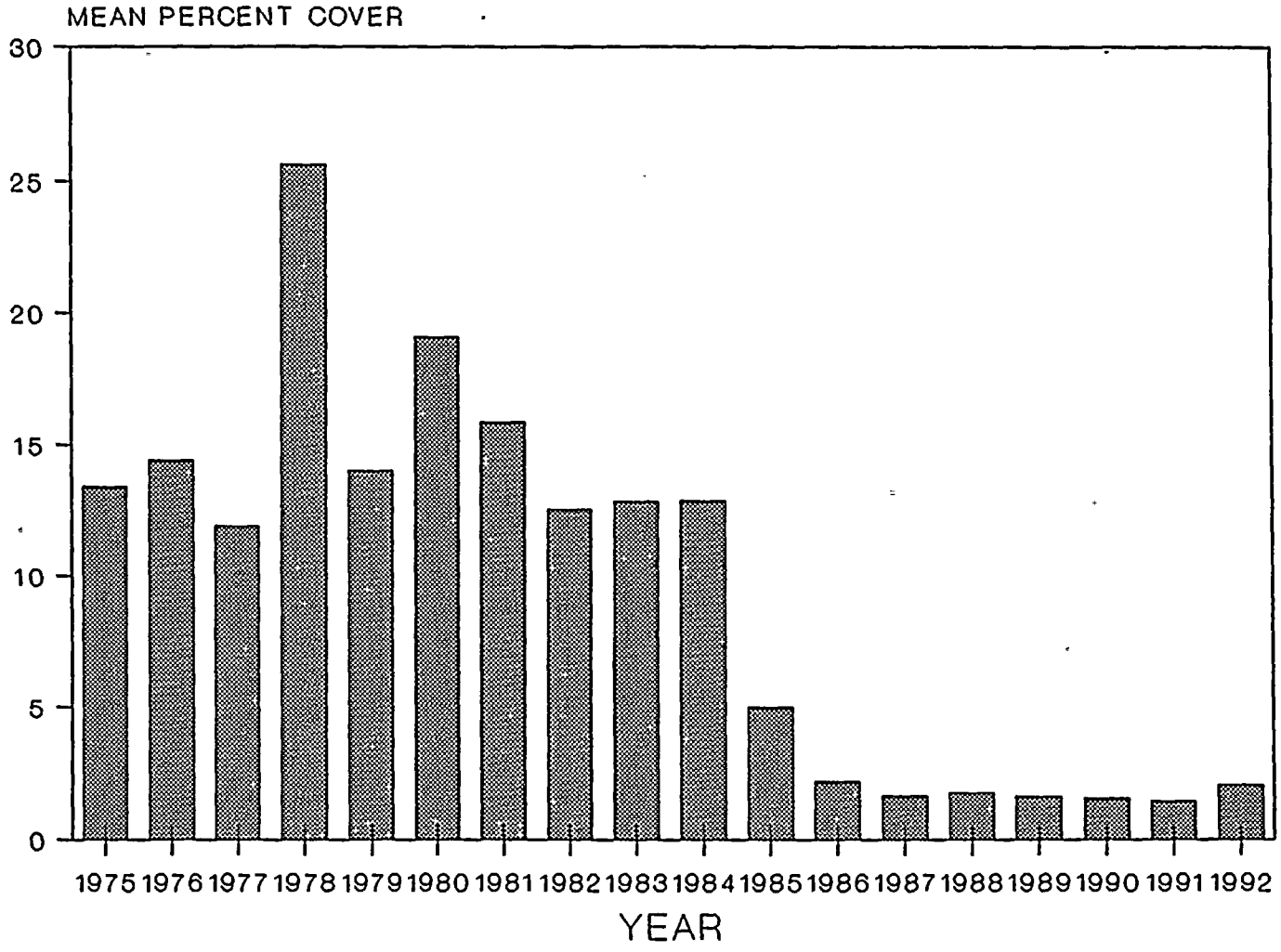


Figure 5-11 Mean Total Shrub Cover for 1975 through 1992

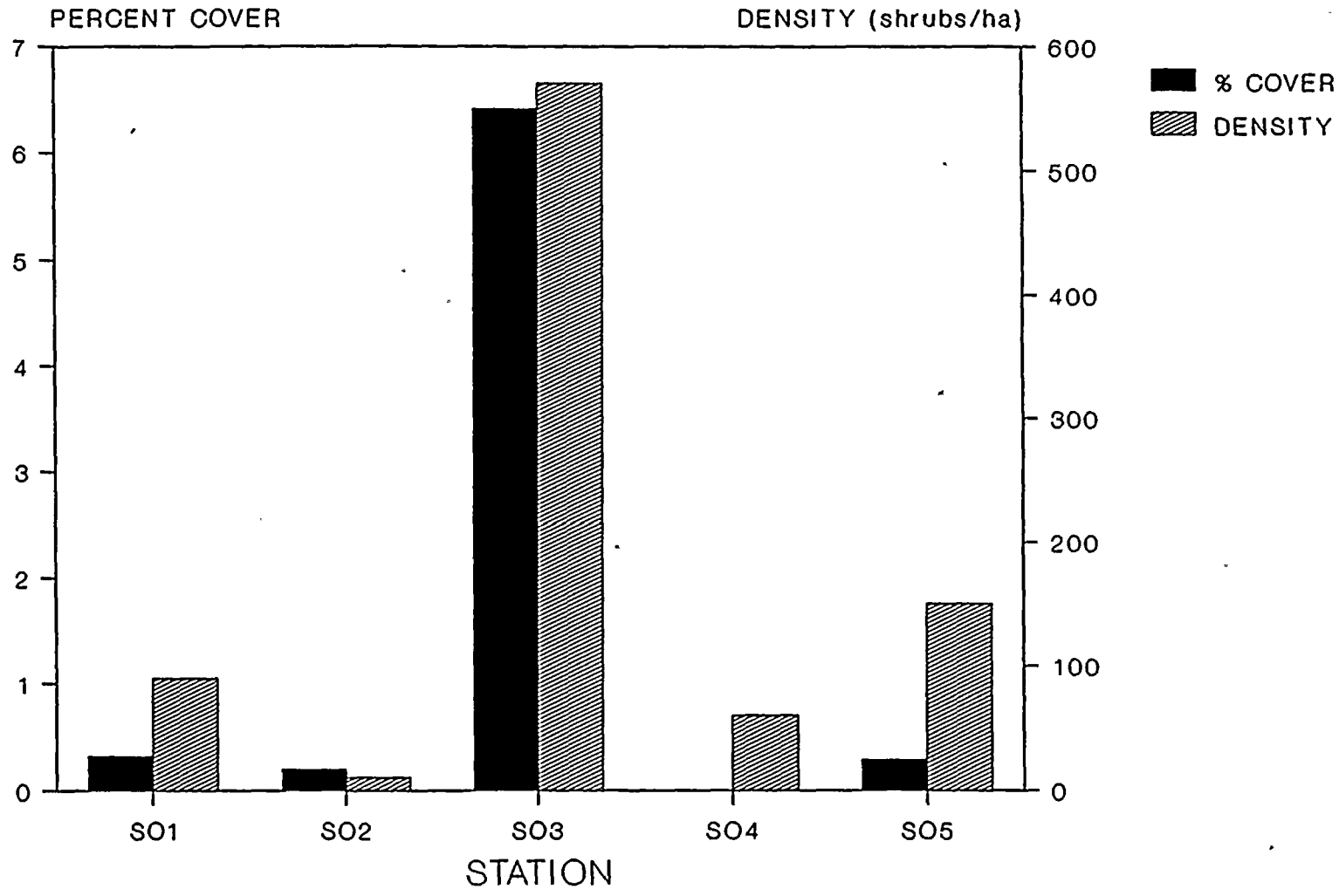
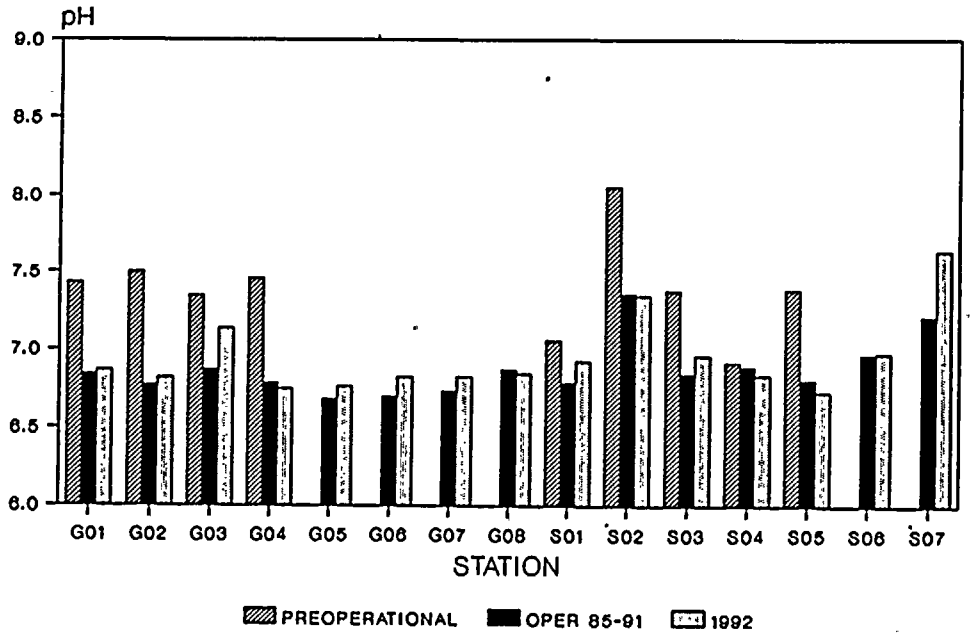


Figure 5-12 Shrub Cover and Density for Five Stations for 1992



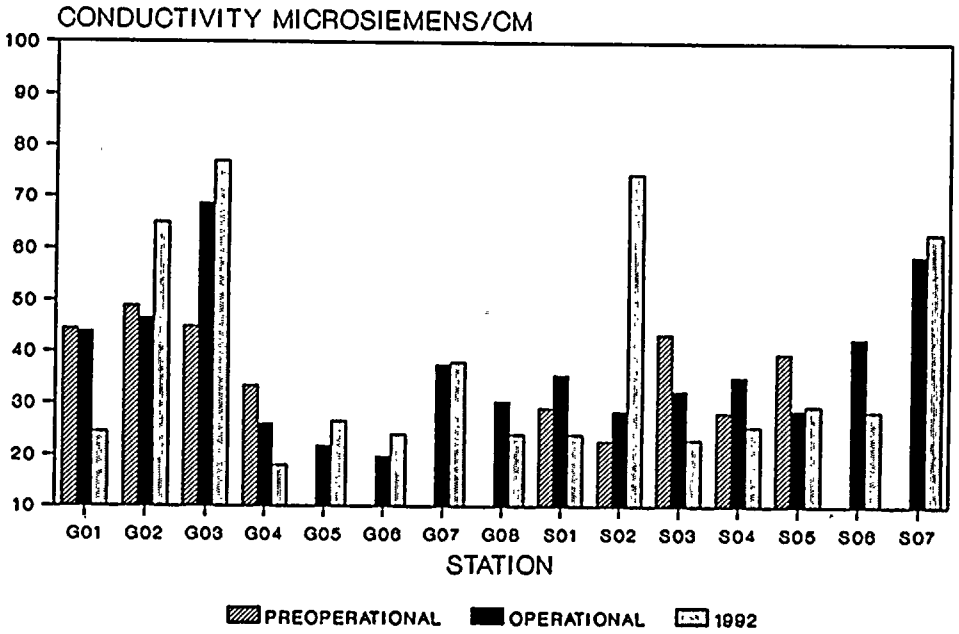
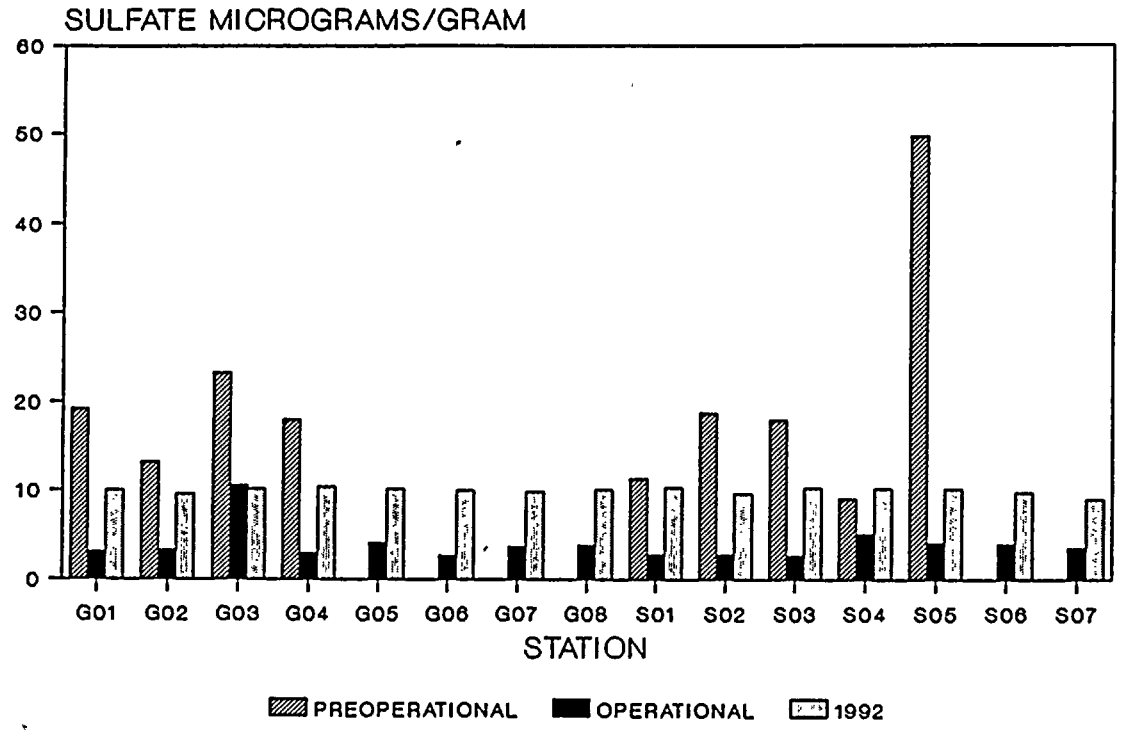


Figure 5-13 Soil pH and Conductivity for 1980 through 1992



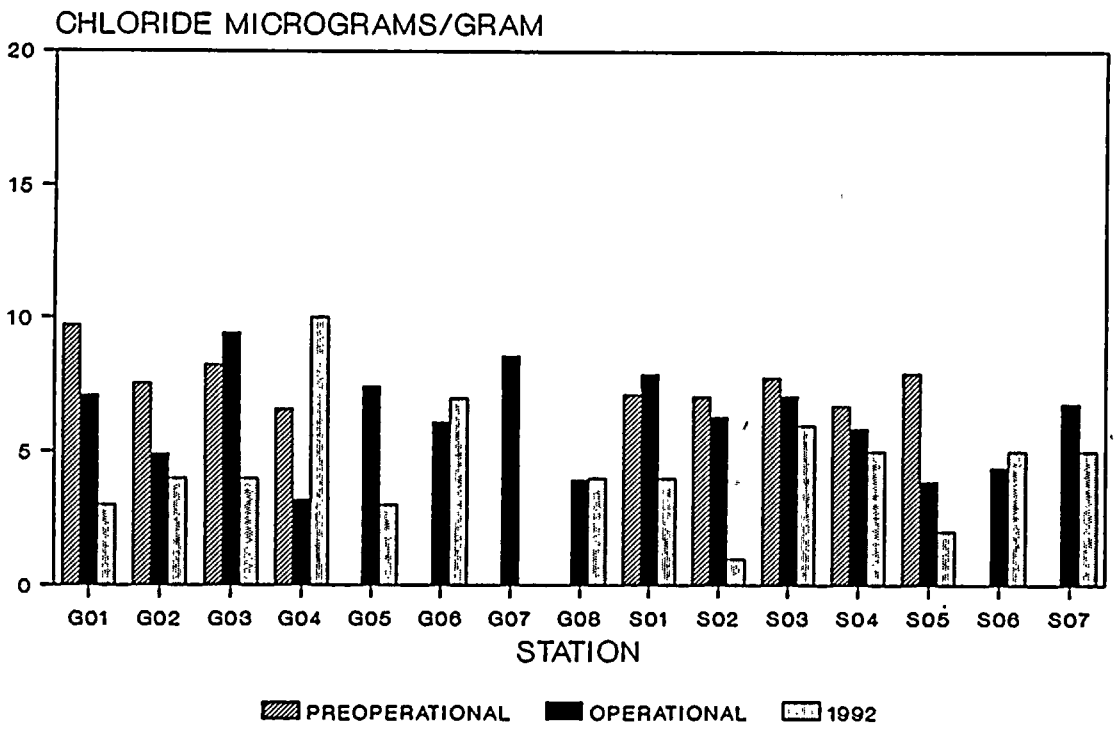
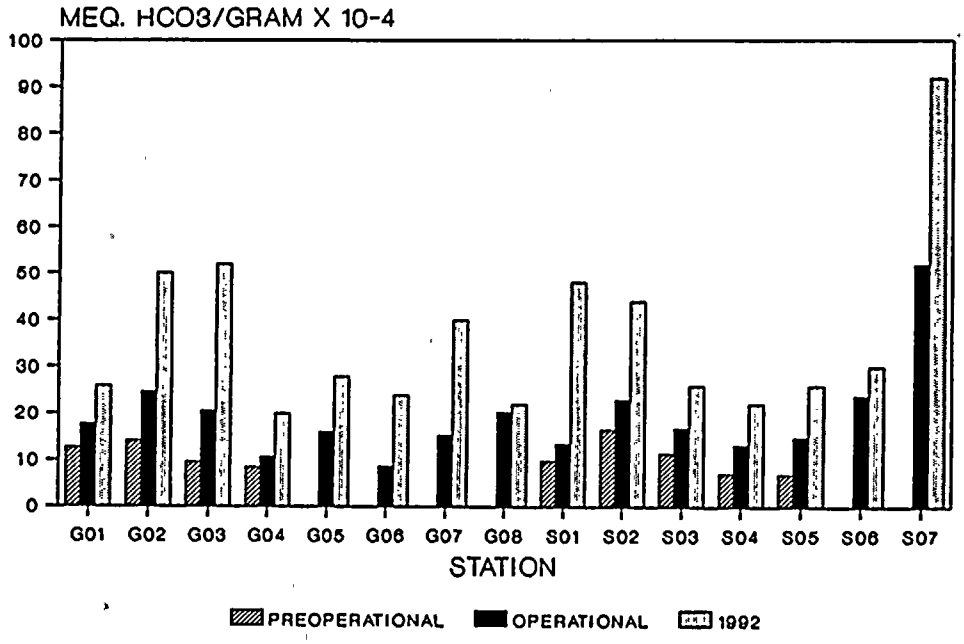


Figure 5-14 Soil Sulfate and Chloride for 1980 through 1992



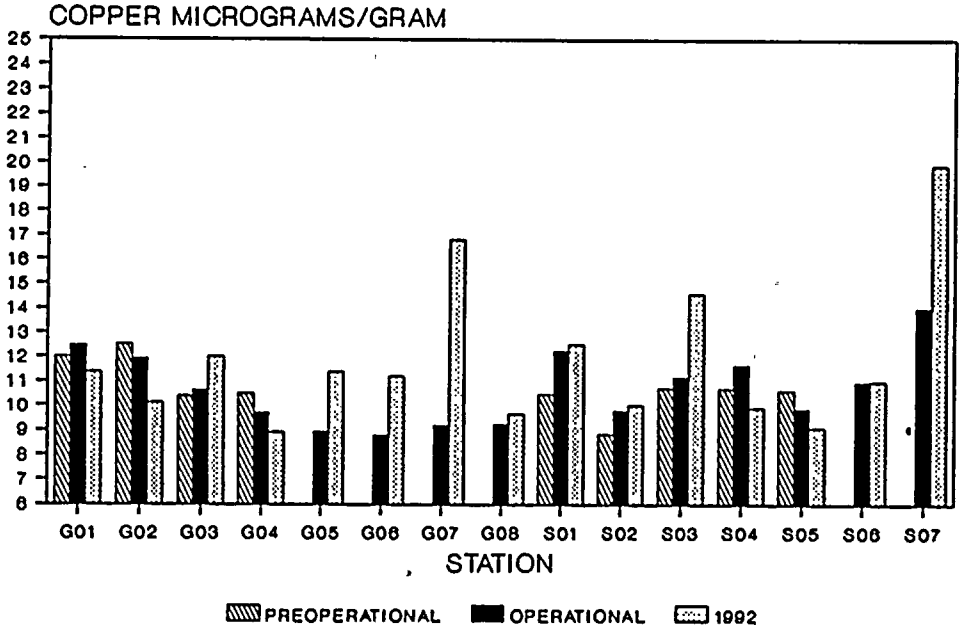
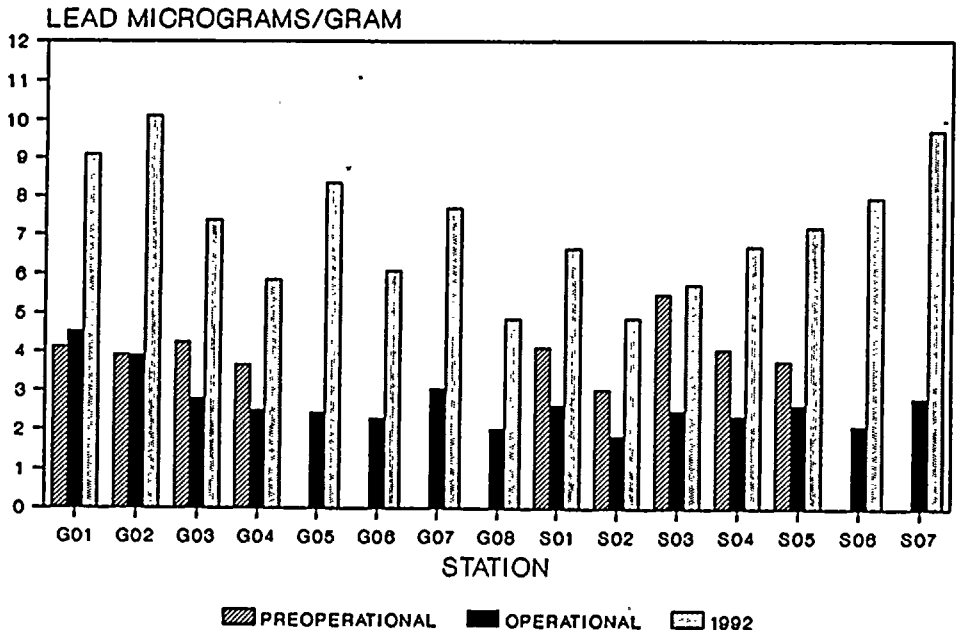


Figure 5-15 Soil Bicarbonate and Copper for 1980 through 1992



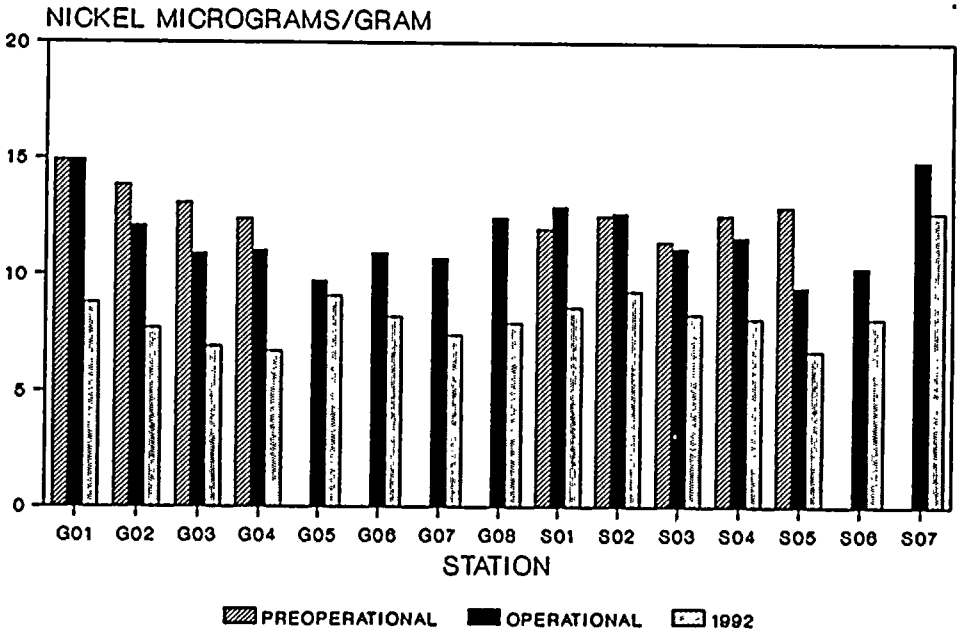
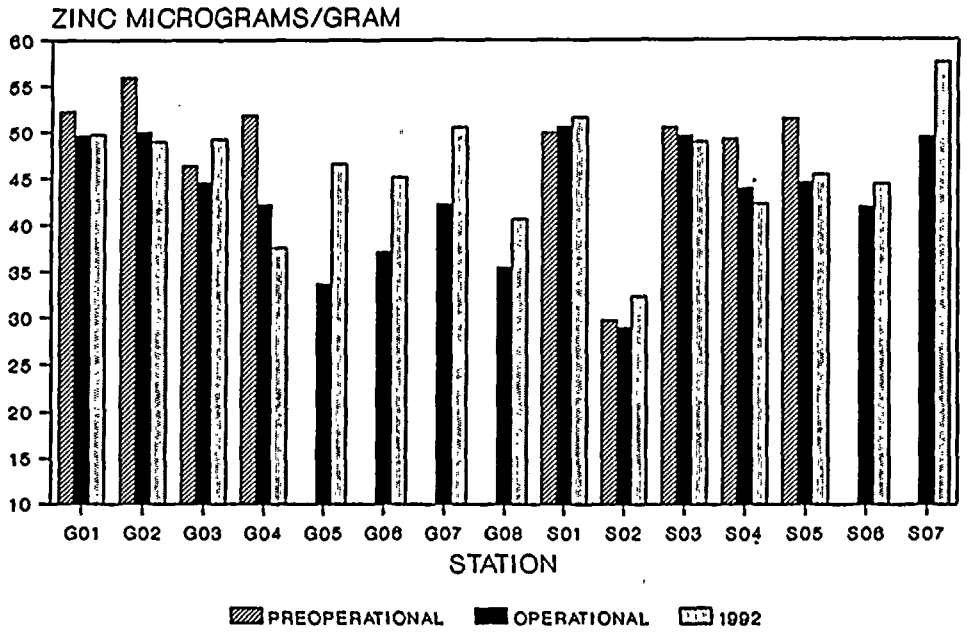


Figure 5-16 Soil Lead and Nickel for 1980 through 1992



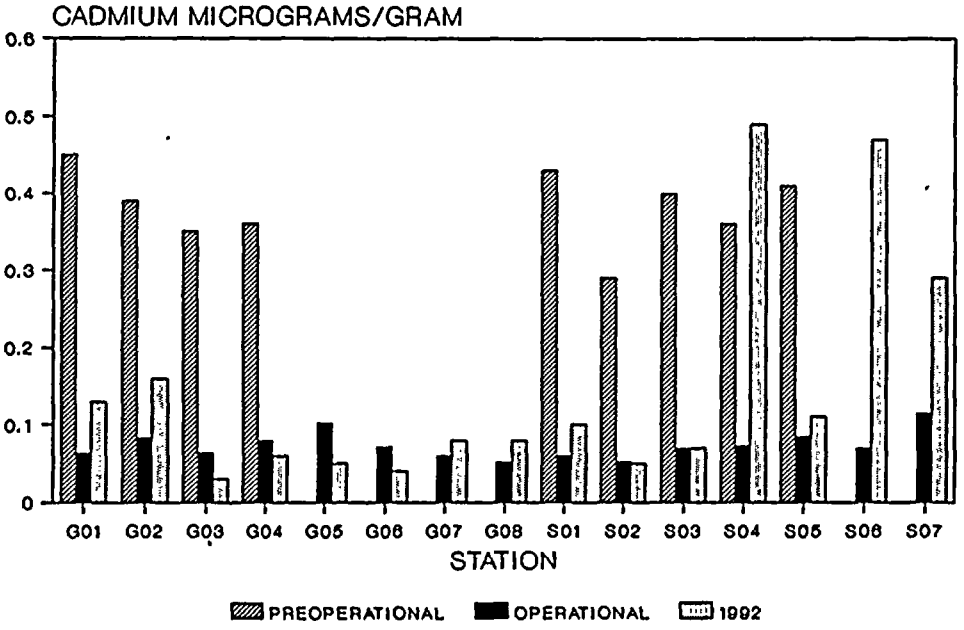
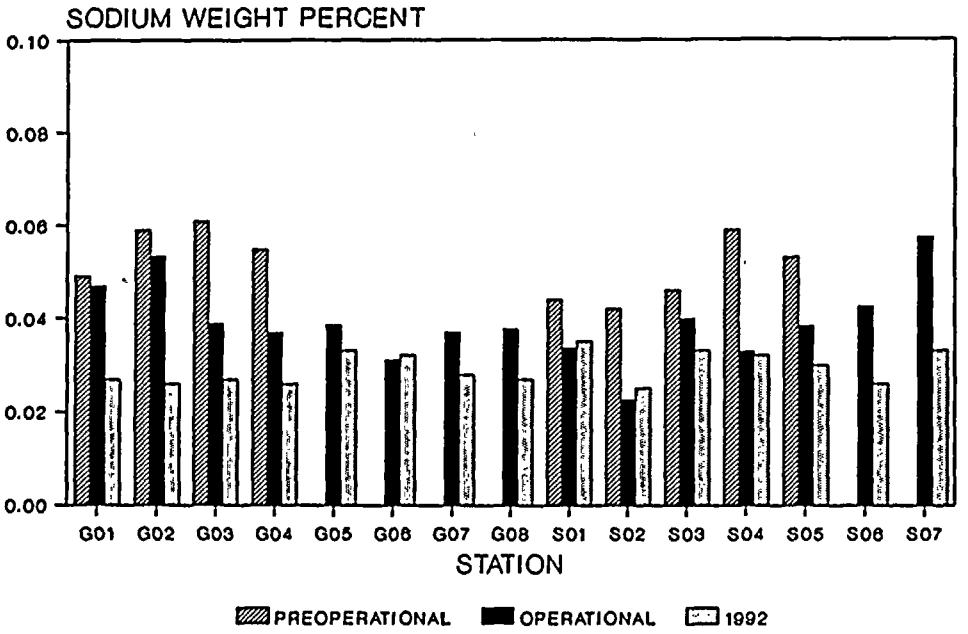


Figure 5-17 Soil Cadmium and Zinc for 1980 through 1992



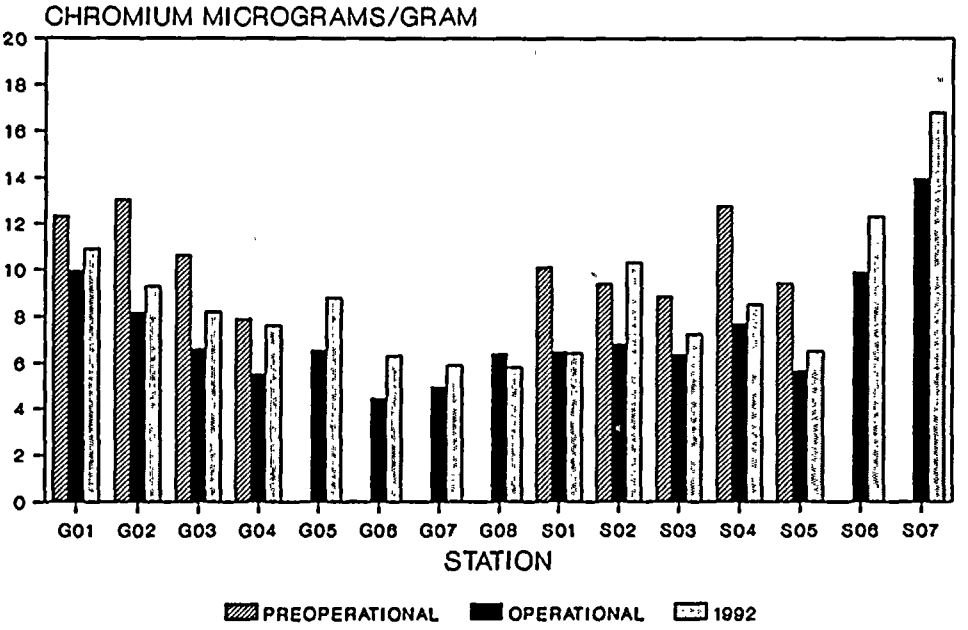
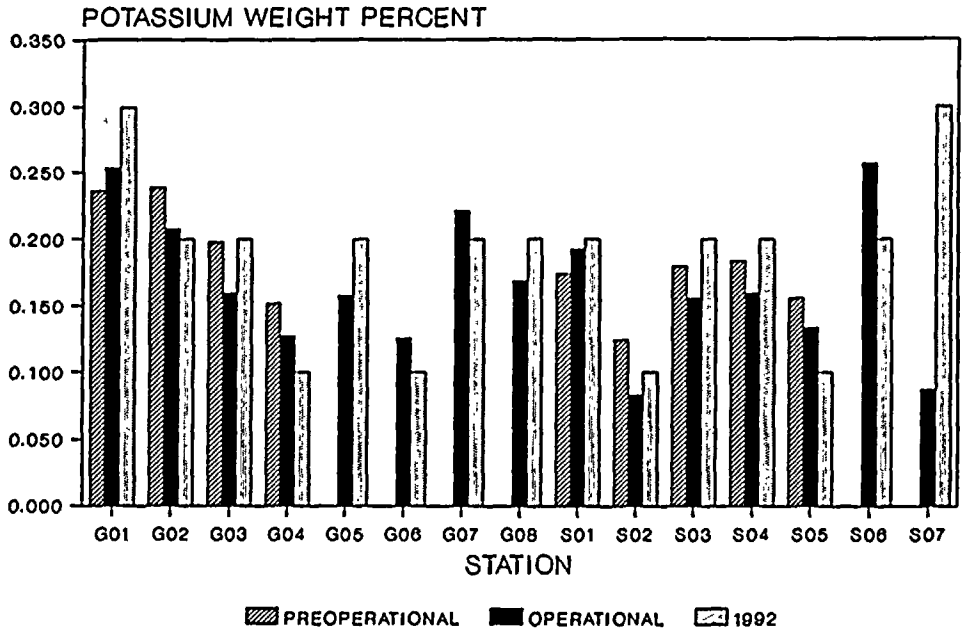


Figure 5-18 Soil Chromium and Sodium for 1980 through 1992



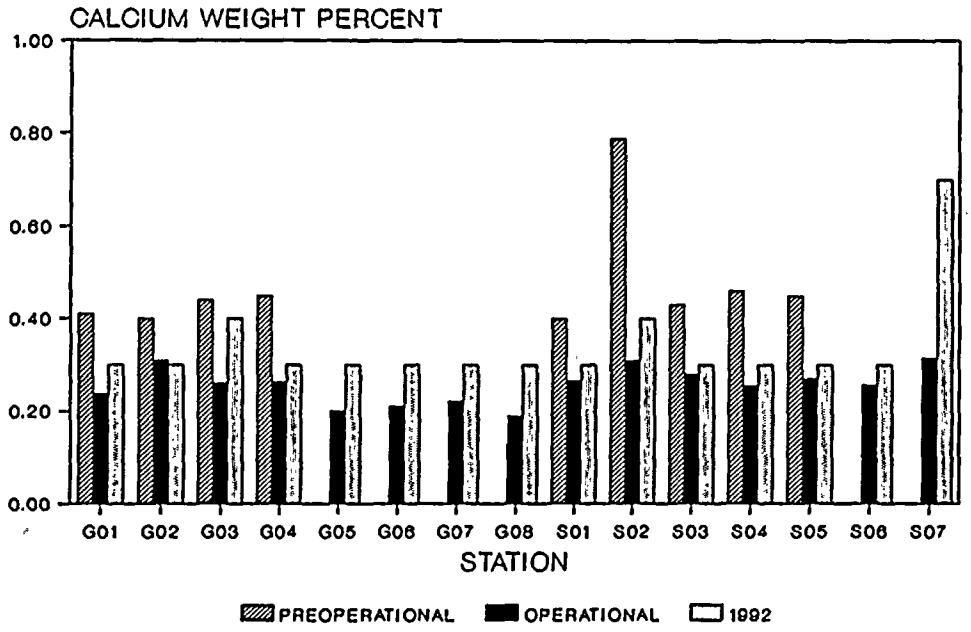


Figure 5-19 Soil Potassium and Calcium for 1980 through 1992

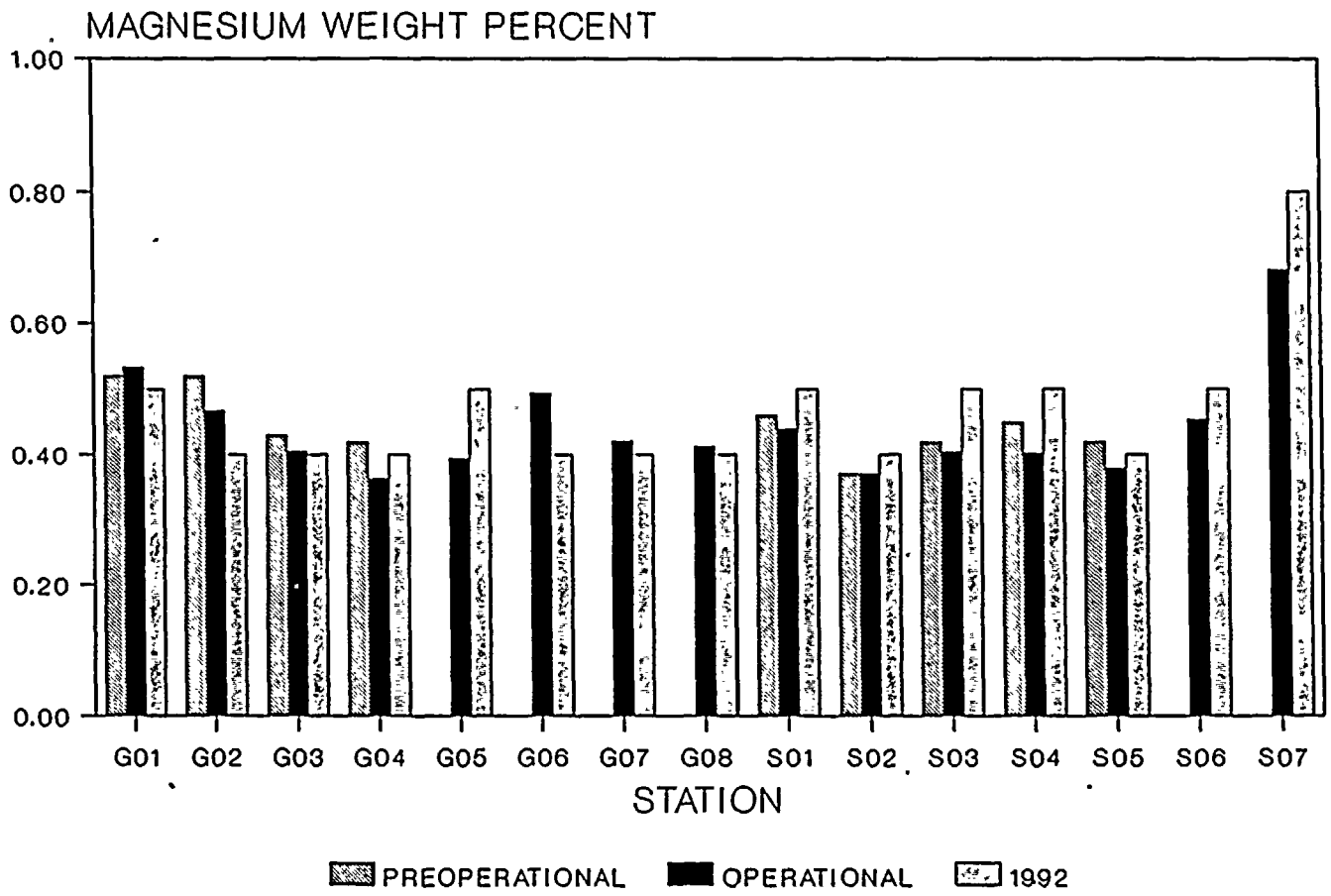
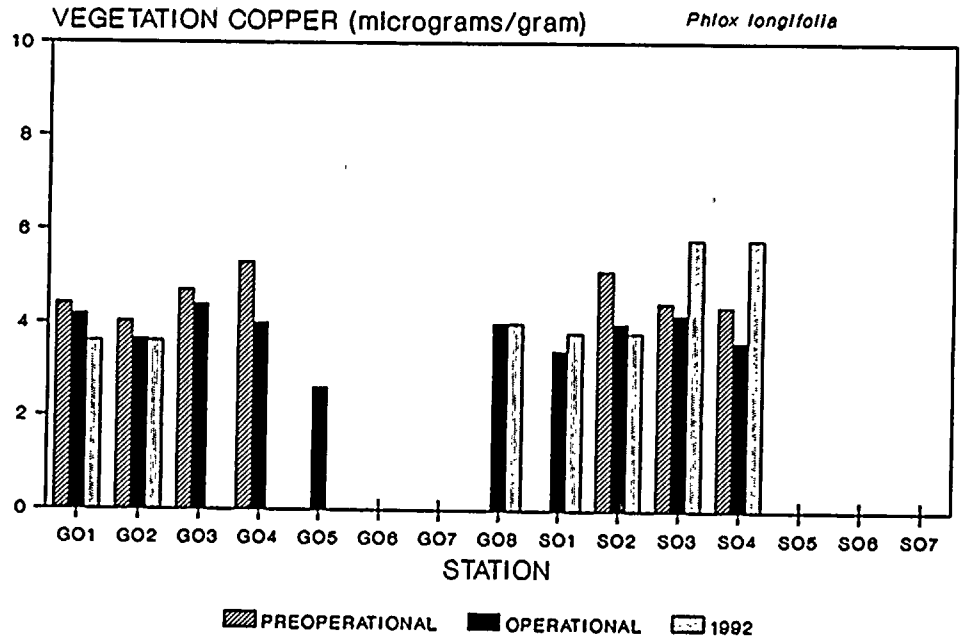


Figure 5-20 Soil Magnesium for 1980 through 1992



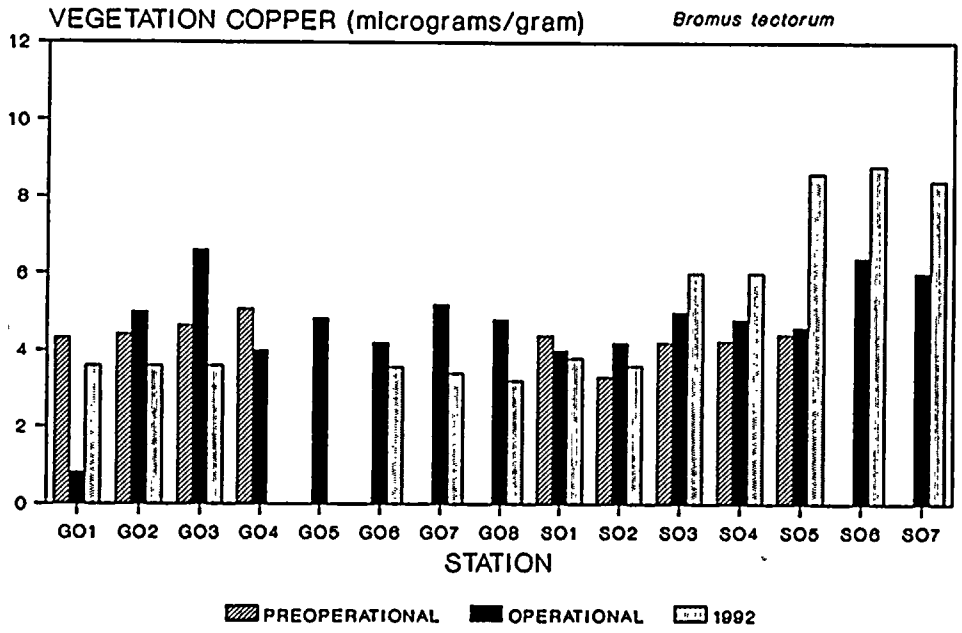
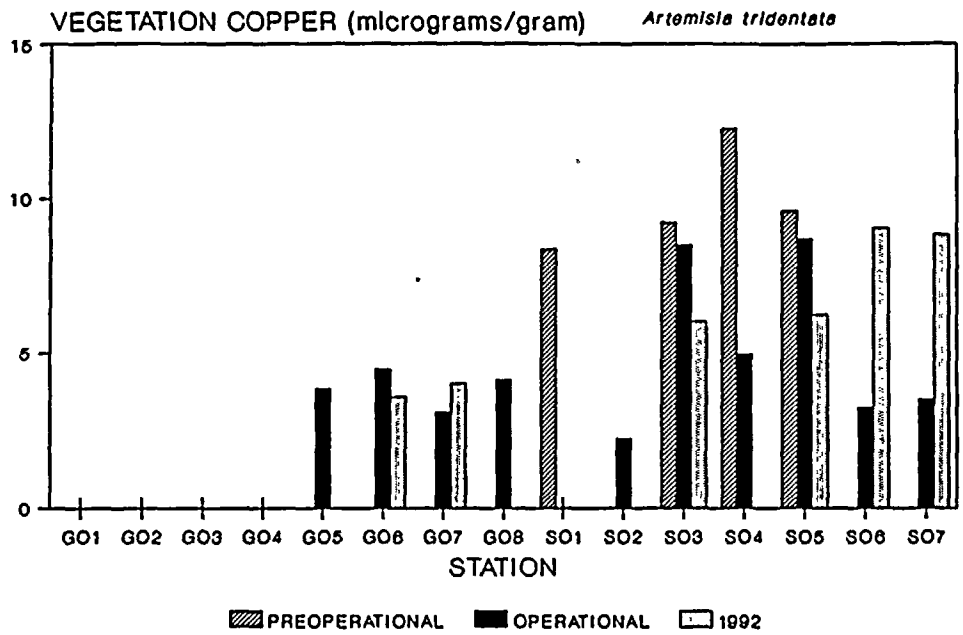


Figure 5-21 Copper Concentrations (ug/g) in Phlox longifolia and Bromus tectorum by Station for 1980 through 1992



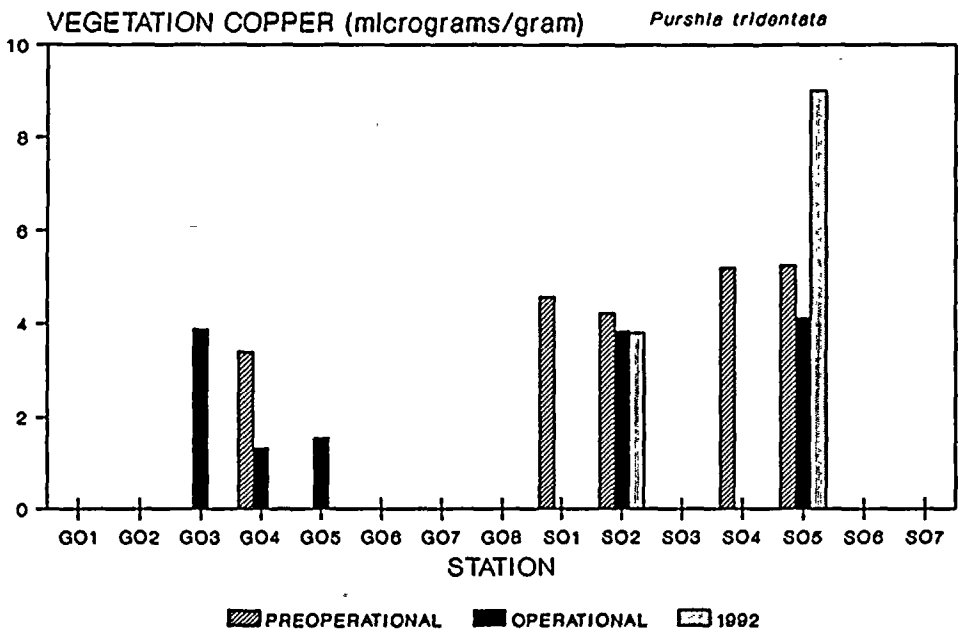
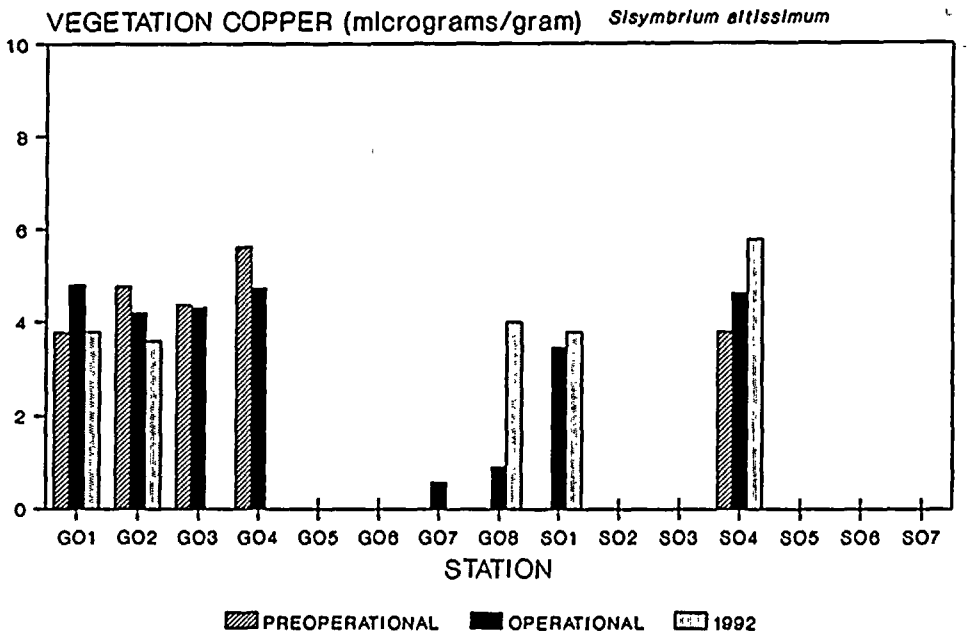


Figure 5-22 Copper Concentrations (ug/g) in Artemisia tridentata and Purshia tridentata by Station for 1980 through 1992



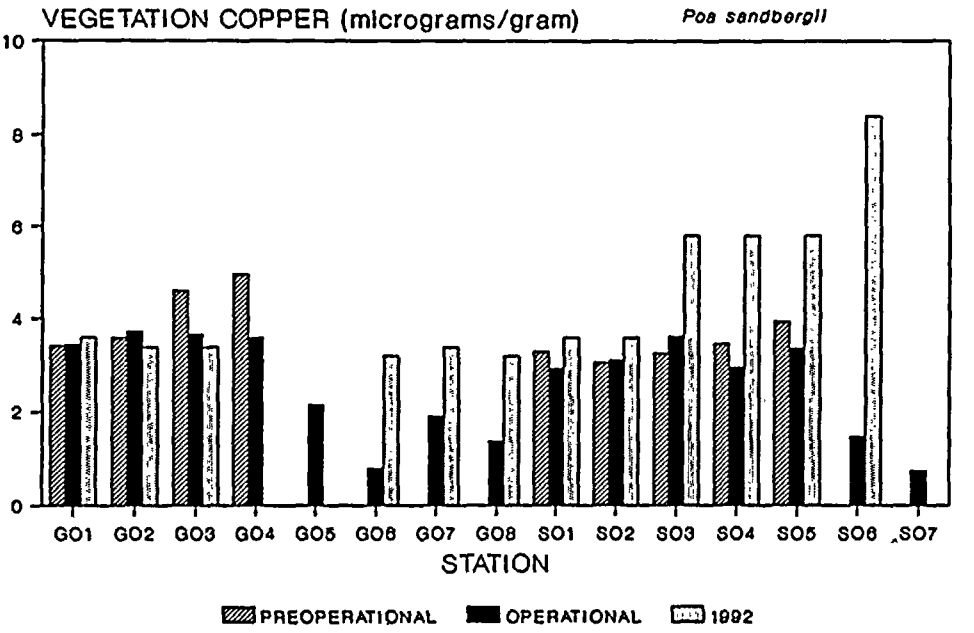
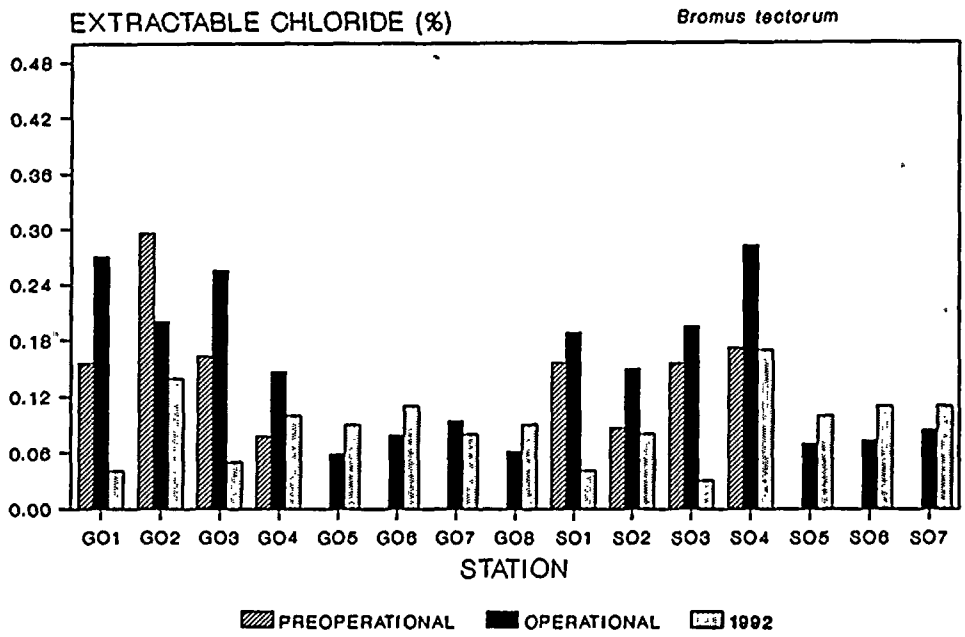


Figure 5-23 Copper Concentrations (ug/g) in Sisymbrium altissimum and Poa sandbergii by Station for 1980 through 1992



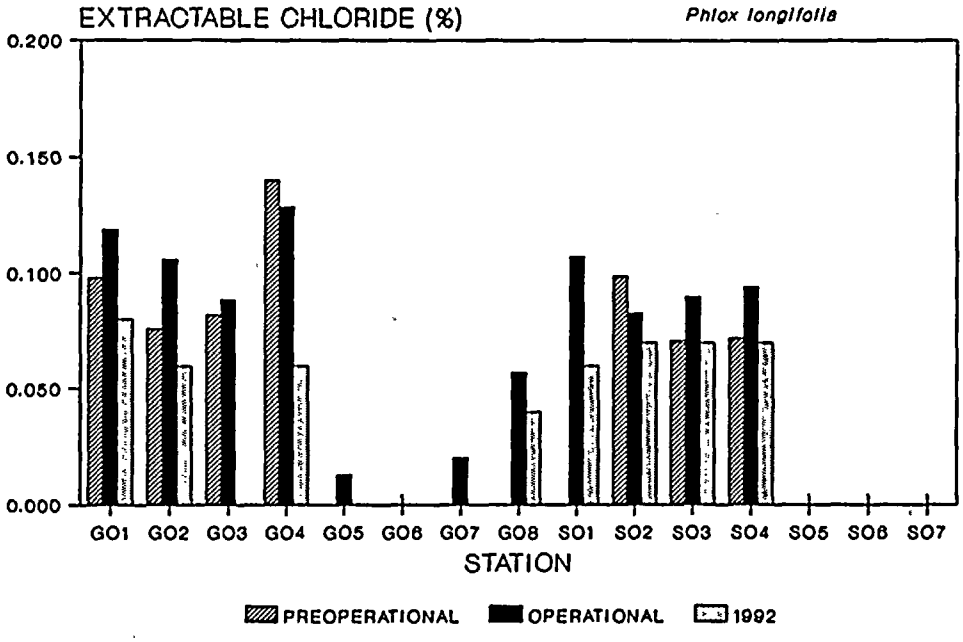
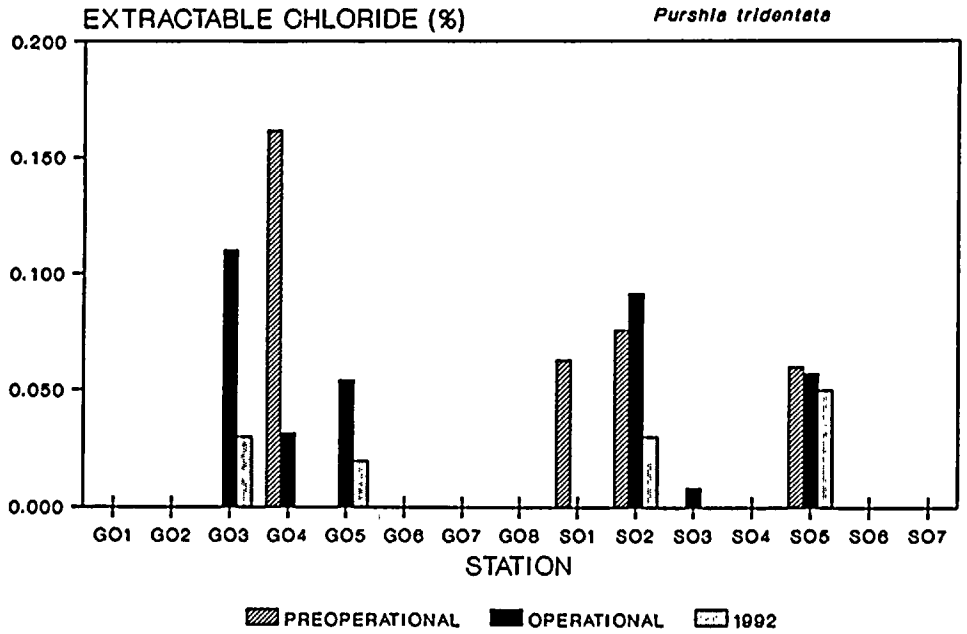


Figure 5-24 Chloride Concentrations (%) in Bromus tectorum and Phlox longifolia by Station for 1980 through 1992



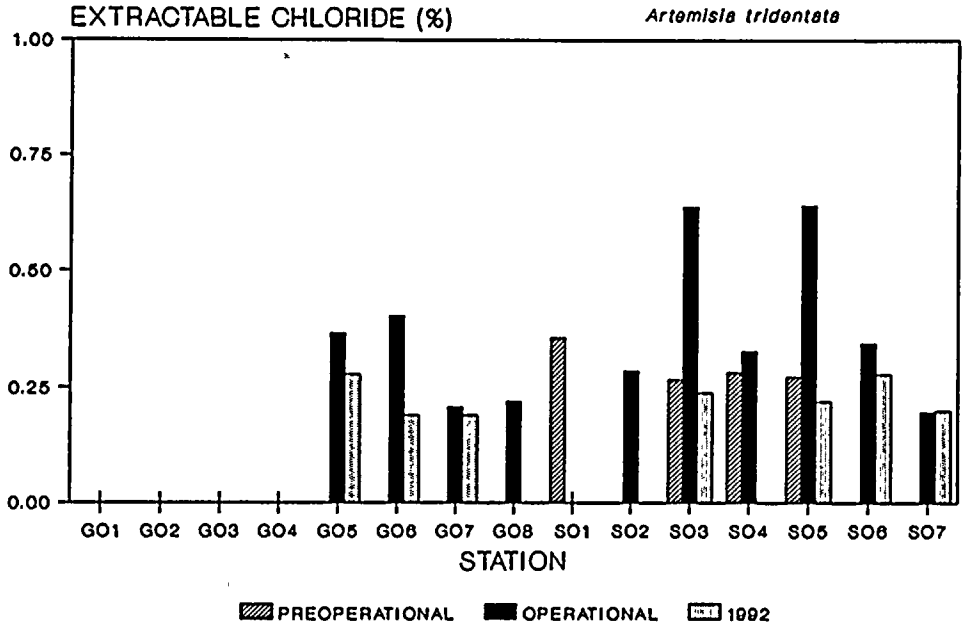
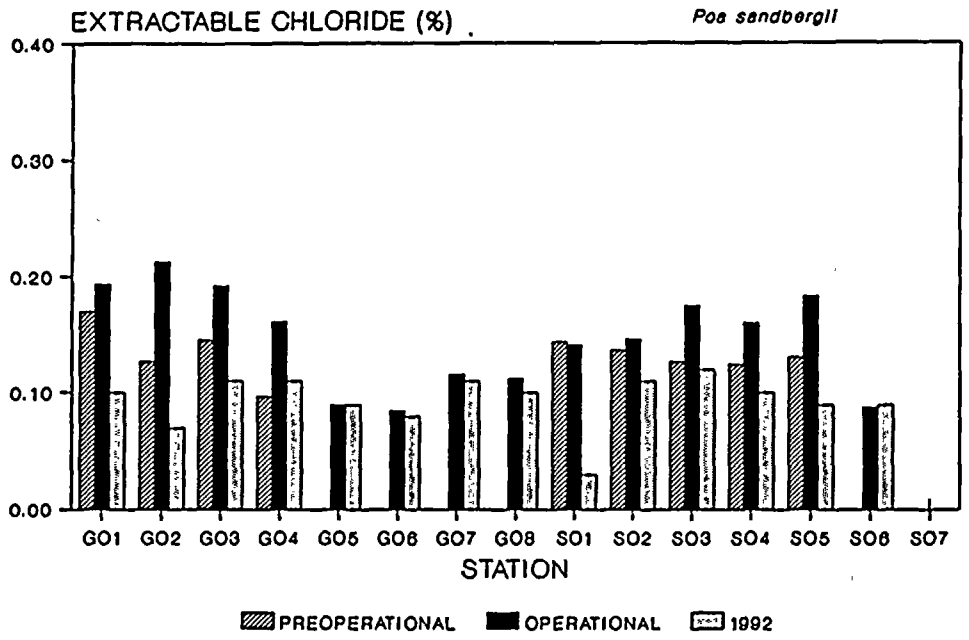


Figure 5-25 Chloride Concentrations (%) in Artemisia tridentata and Purshia tridentata by Station for 1980 through 1992



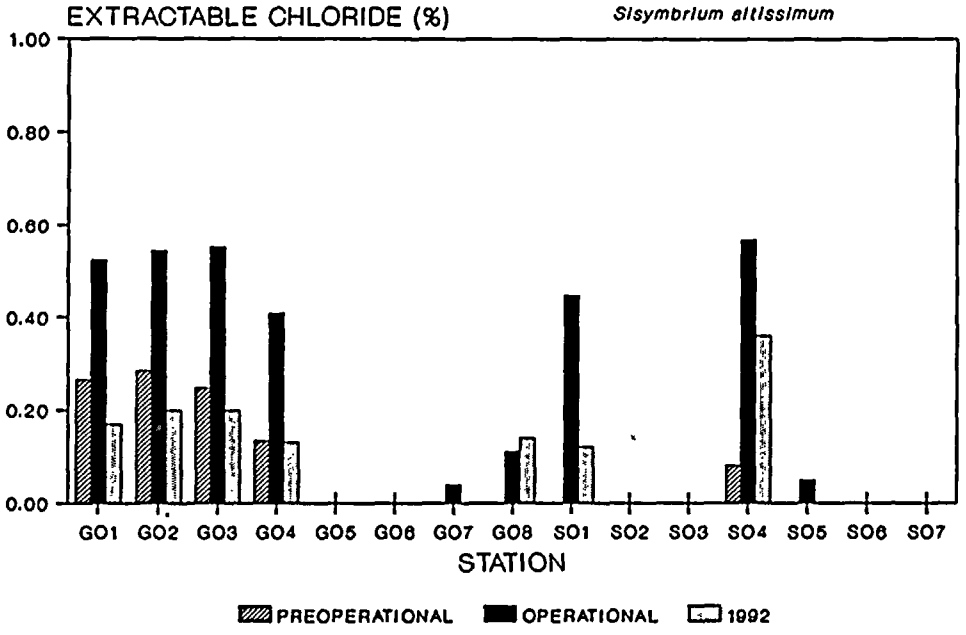
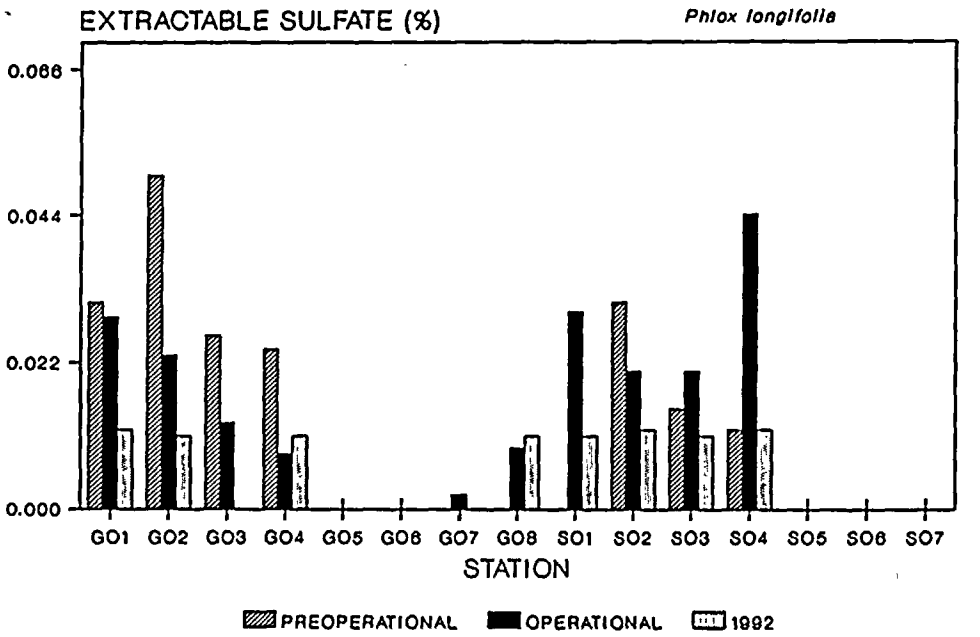


Figure 5-26 Chloride Concentrations (%) in Poa sandbergii and Sisymbrium altissimum by Station for 1980 through 1992



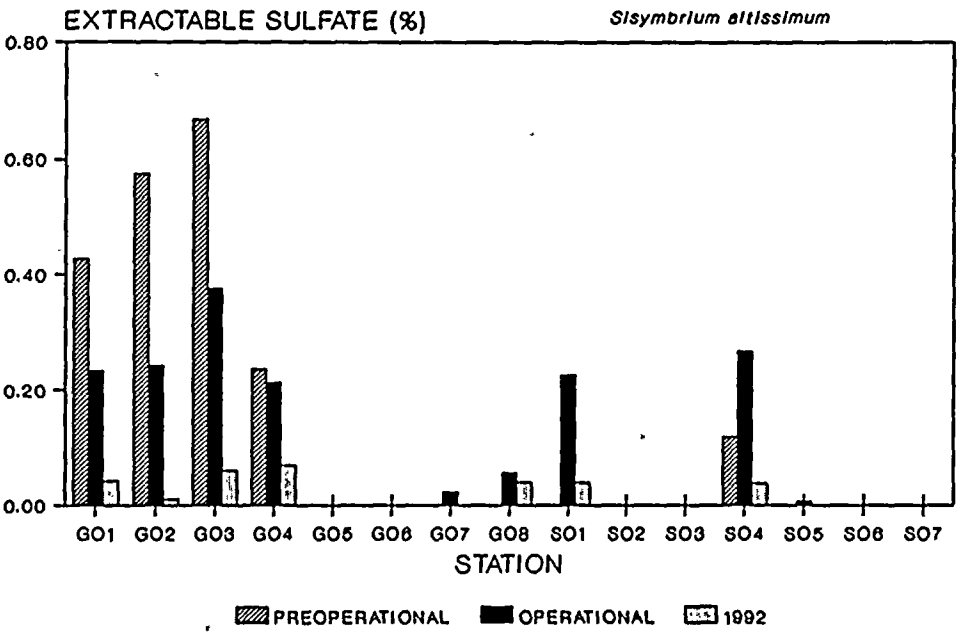
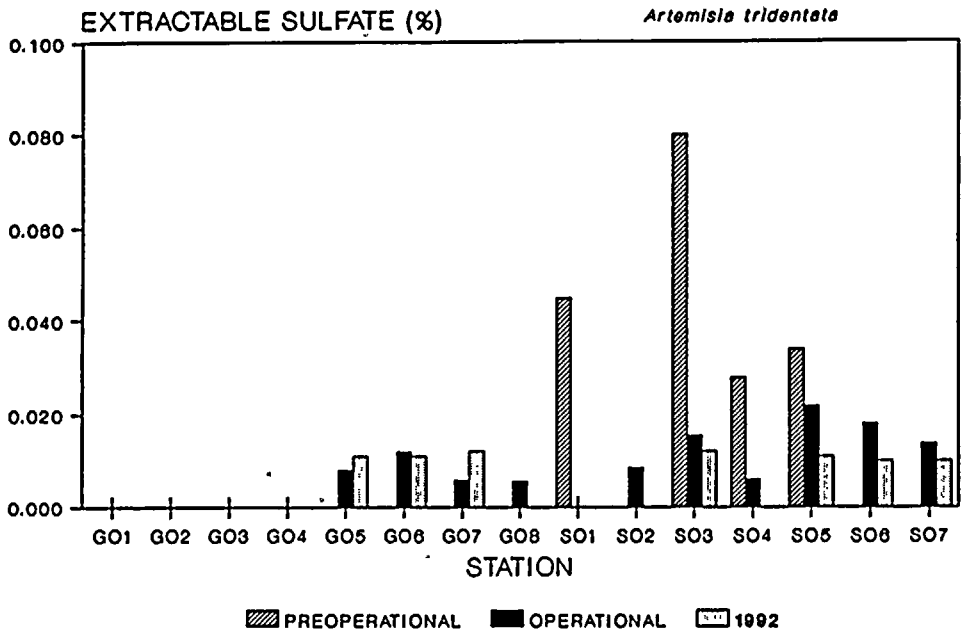


Figure 5-27 Sulfate Concentrations (%) in Phlox longifolia and Sisymbrium altissimum by Station for 1980 through 1992



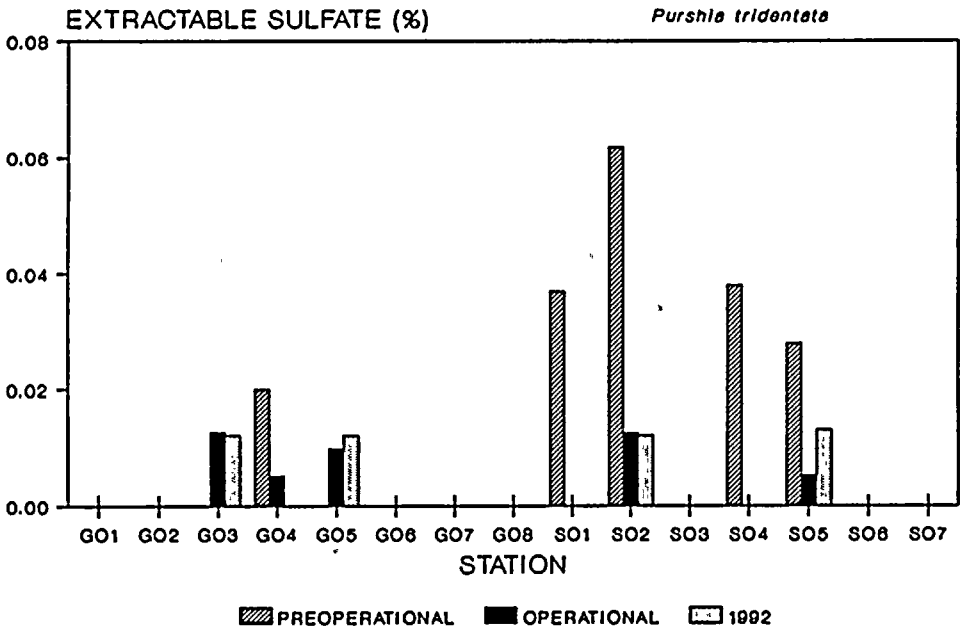
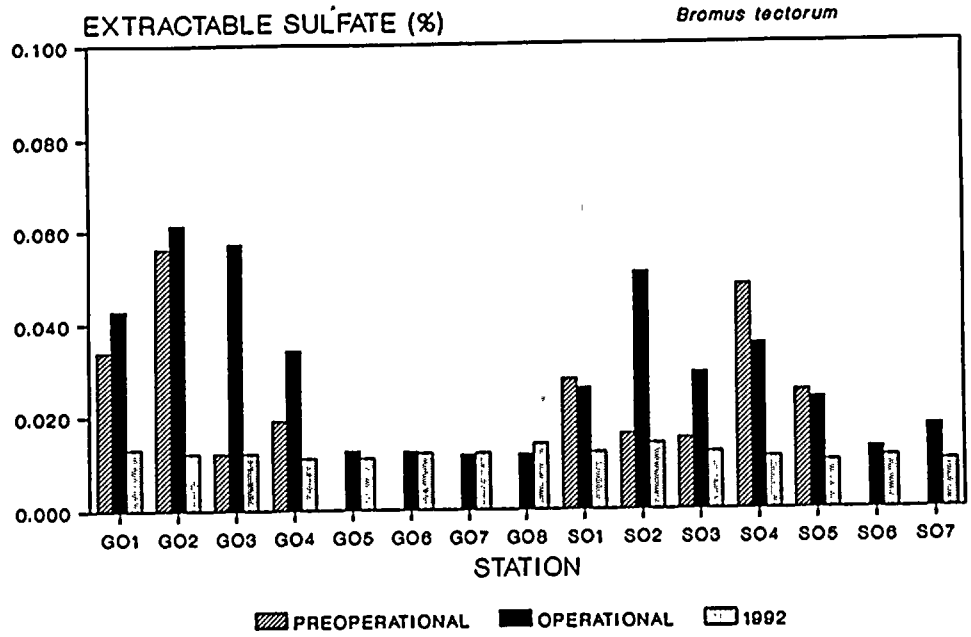


Figure 5-28 Sulfate Concentrations (%) in Artemisia tridentata and Purshia tridentata by Station for 1980 through 1992



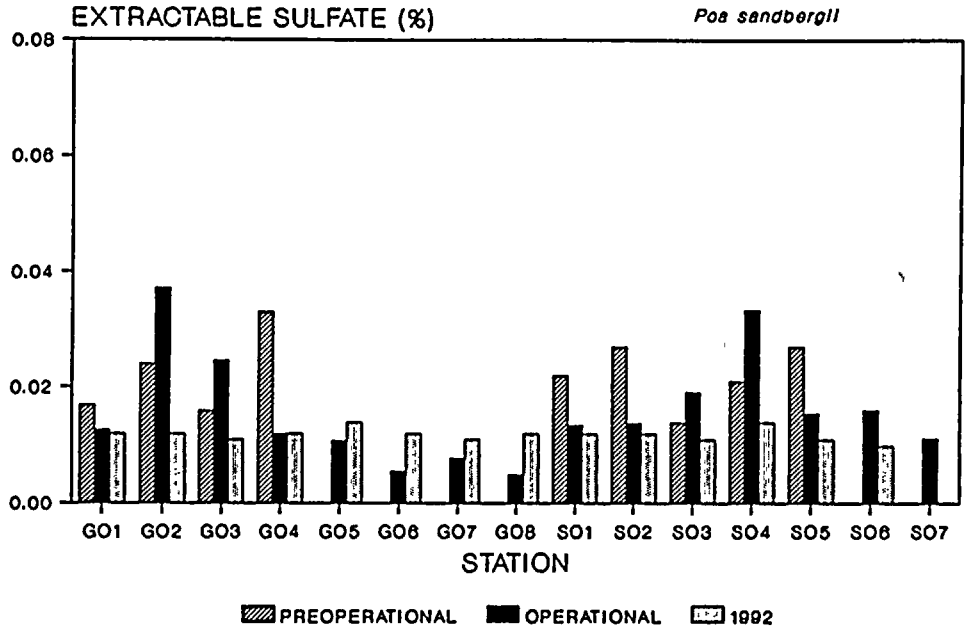
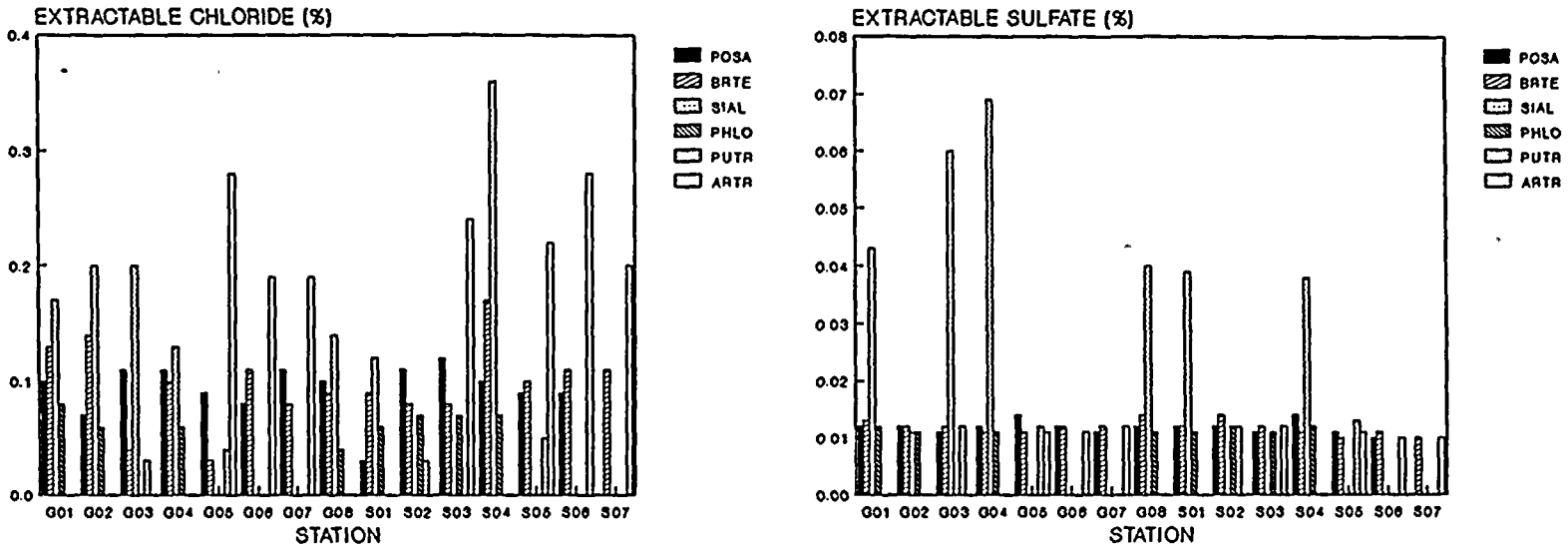


Figure 5-29 Sulfate Concentrations (%) in Poa sandbergii and Bromus tectorum by Station for 1980 through 1992



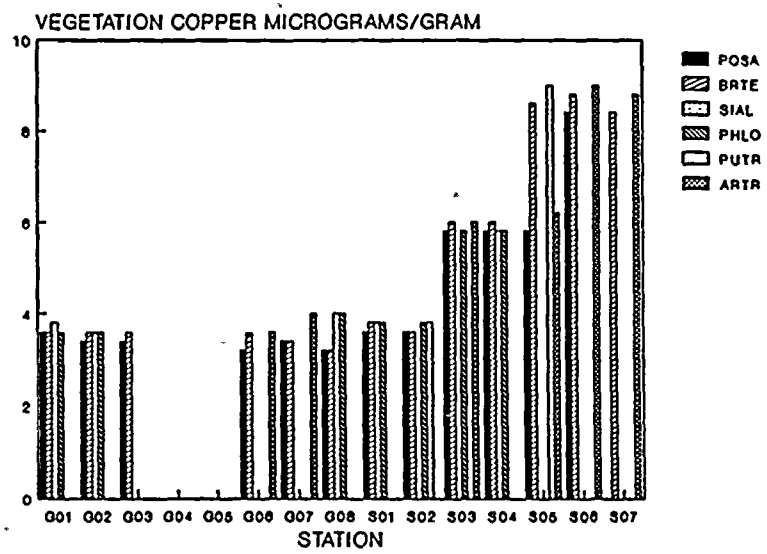


Figure 5-30 Total Vegetation Copper, Chloride and Sulfate for 1992

6.0 INTAKE STRUCTURE FOULING SURVEYS

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 are 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 provide the opportunity to detect signs of possible stress before it becomes visible to the human eye. In addition to examination for stress, the photographs are compared with those taken in previous 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), which outlines 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, each 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, each 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 by Photography Plus Inc. 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.

The photos were initially evaluated for flightline alignment and film quality. A visual analysis was performed to determine vegetation health and vigor, identify vegetative communities, compare upwind and downwind sites, and compare the 1992 film to the 1991 film. Selected scenes were converted to digital format and computer enhanced for further analysis. A map of the vegetation plots and flightlines shows the location of digitized test sites (Figure 7-2). This map was constructed from field notes, global position surveys, and the USGS Wooded Island Quadrangle. Interpretation of photographs and visual analysis is done by Oregon State University, Department of GeoSciences.

7.3 VISUAL ANALYSIS

The film quality was judged to be good. The color balance and contrast were sufficient for interpretation of plant health and vigor.

Based on the flightline map supplied by the photography contractor, the 1992 aerial coverage of each flightline appears to be within acceptable limits. One camera problem was experienced resulting in a short re-flight of a portion of flightline one. There was no loss of coverage.

7.3.1 Flightline #1

The borrow pits on the south side of Hwy SO 4 showed strong PSA. This is typical of most disturbed sites, such as the mounds of soil found near the borrow pits.

Despite the difficulty in interpreting the film from 1991, the vegetative patterns appear to be unchanged in the past year. However, the PSA appears to be much stronger in 1992. Nearly all areas of disturbed soil exhibit moderate to strong PSA.

Within the compound, the vegetation near the metal quonset hut, located near the southwest corner of the cooling water towers, exhibits PSA equal to that expected from a well-watered lawn. The grass appears to be growing on a mound of soil and is not in a location which would suggest purposeful watering. A northeast wind would be required to blow water from the coolers to this location.

Outside the compound, near the northwest corner, is an area of disturbed soil that exhibits rows of PSA. This is obviously human induced, but the reason is not clear. The spacing of the rows is too wide for a crop and the area does not appear to be tended.

In addition to disturbed soil sites, PSA is commonly found bordering old roads and trails in the rangeland. It is most often found on the east side of the roads and trails, a condition likely related to the prevailing westerly winds.

7.3.2 Flightline #2

The greatest accumulation of tumble weed, (Salsola kali), was noted on the east side of the sand fence which lies adjacent to the railroad tracks. This accumulation presumably occurs during the winter months when the winds come from the east.

Large shrubs, Purshia, were quite visible due to the large scale of the photography; however, no photosynthetic activity was detected (these shrubs rarely show CIR reflectance).

The vegetation and PSA noted along this flightline were consistently found to the east of the roads, railroad tracks, and trails. One of the largest accumulations of PSA was found to the east of the sand fence adjacent to the railroad tracks.

Northwest of South Power Plant Loop Road was a large, dense area of vegetation which showed strong PSA. This signature could be that of small grasses.

An increased density of PSA was found near the rock pile north of the railroad tracks southeast of 603 #3, near the edge of nearly all sand dunes, and near the base of most power poles.

7.3.3 Flightline #3

The alignment of Flightline 3 differs from that of the 1991 season, in that it is further to the south.

Again, the majority of the dense PSA was found to the east of the roads and trails. However, east of the power substation there is less roadside vegetation than in the majority of the photo coverage.

7.3.4 Flightline #4

The light colored Phlox, blooming vegetation visible as white spots on this and most of the other flightlines, can be seen in the 1991 photography as well.

PSA was noted within the compound of Flightline 4. Small patches of low-density PSA were most common.

Patches of PSA were found near the sand dunes west of the power lines in both the 1991 and 1992 films. Very few correlation such as this were found between the 1991 and 1992 films.

The banding of the riparian vegetation near the river can be seen in both years; however, the PSA is much stronger in the 1992 film despite the vegetation being further away from the water.

7.3.5 Flightline #5

At the beginning of Flightline 5, a large patch of the light colored blooming vegetation was noted near the highway where the powerline crosses.

The majority of PSA was again noted to the east of all roads, railroad tracks, and trails.

A small, rectangular pattern of very strong PSA wa noted between the railroad tracks and the river. This patch appears on both the 1991 and 1992 films.

The road which parallels the river exhibited the widest band of PSA of all roads in this overflight. Again, the PSA was found on the east side of the road.

The widest banding of PSA within the riparian vegetation was noted at the end of Flightline 5.

7.4 IMAGE PROCESSING

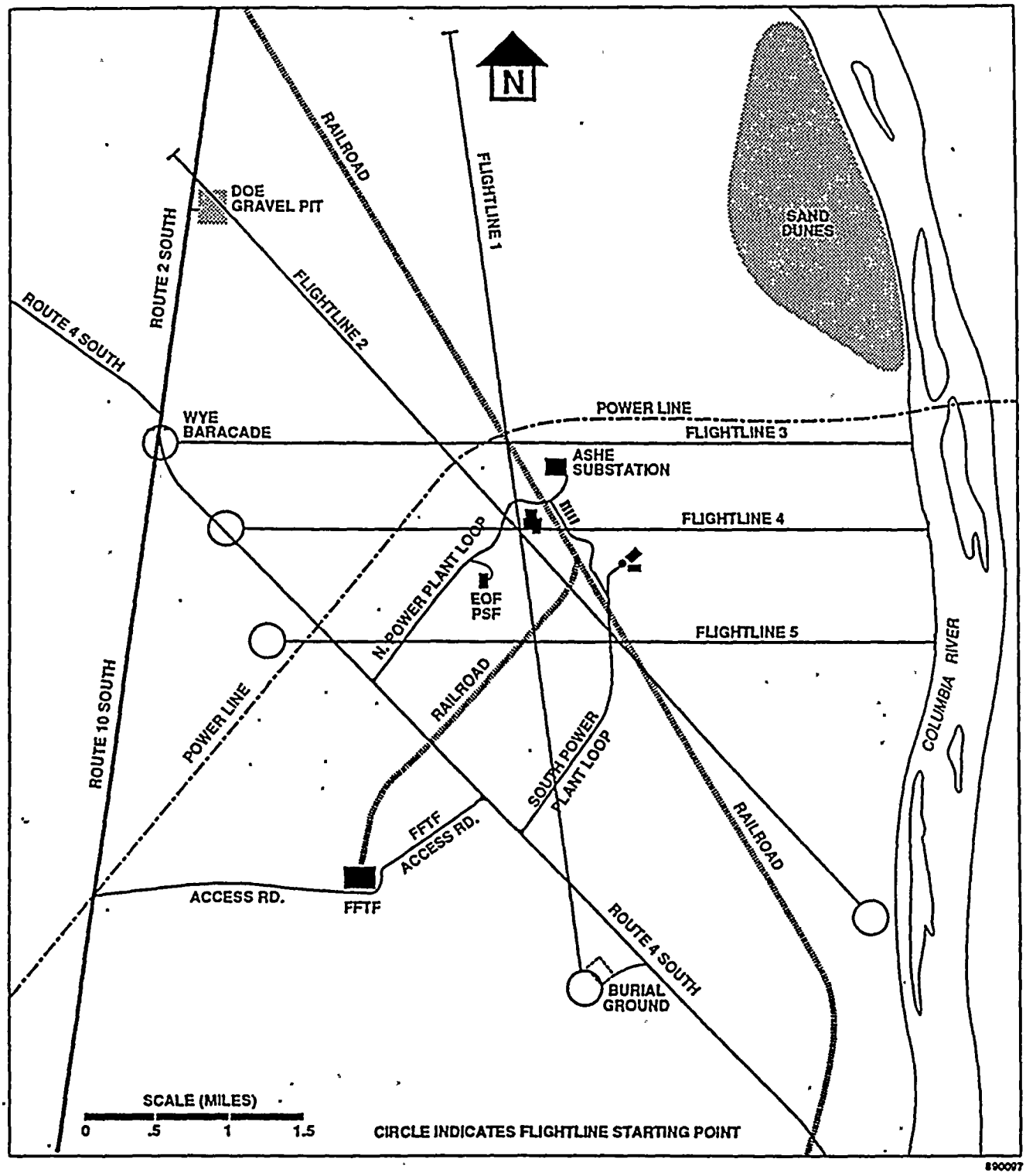
Airphotos of selected ground sites (Figure 7-2) were scanned using the Eikonix Digital Scanner. Each frame was scanned with a red, blue, and green filter to extract multispectral information. The film used for the aerial photography was color infrared. With this film, most images in the original scene are shown on the film in a false color; greens appear blue, reds appear green, and photosynthesizing vegetation (which has a high reflectance of near infrared energy) appears red (white sand appears white, black asphalt appears black).

Using the near infrared and red reflectance information, we created a Normalized Difference Vegetation Index (NDVI) Image. Actively photosynthetic vegetation strongly reflects near infrared light and absorbs red light. Higher NDVI values indicate greater photosynthetic activity and a greater mass of photosynthetic vegetation. An NDVI Image of Site A can be seen in Figure 7-3. This image clearly shows the location and extent of increased photosynthetic activity in shades of yellow (highest activity) and red. In this semi-arid environment, opportunistic vegetation, such as cheat grass (Bromus tectorum) and tumble mustard (Sisymbrium altissimum), quickly colonize recently disturbed areas. As can be seen in Figure 7-3, these two species exhibit much higher NDVI values than the surrounding range vegetation.

Using field data from an on-site inspection, April 17, 1992, multiple training sites for each image were selected and digitized. These training sites represent visually identifiable areas of specific homogenous ground cover. Training sites were located on several different scanned images. The spectral information for each training site was extracted, and an individual response signature was developed for each class of ground cover. A comparison and explanation of these spectral signatures is shown in Figure 7-4.

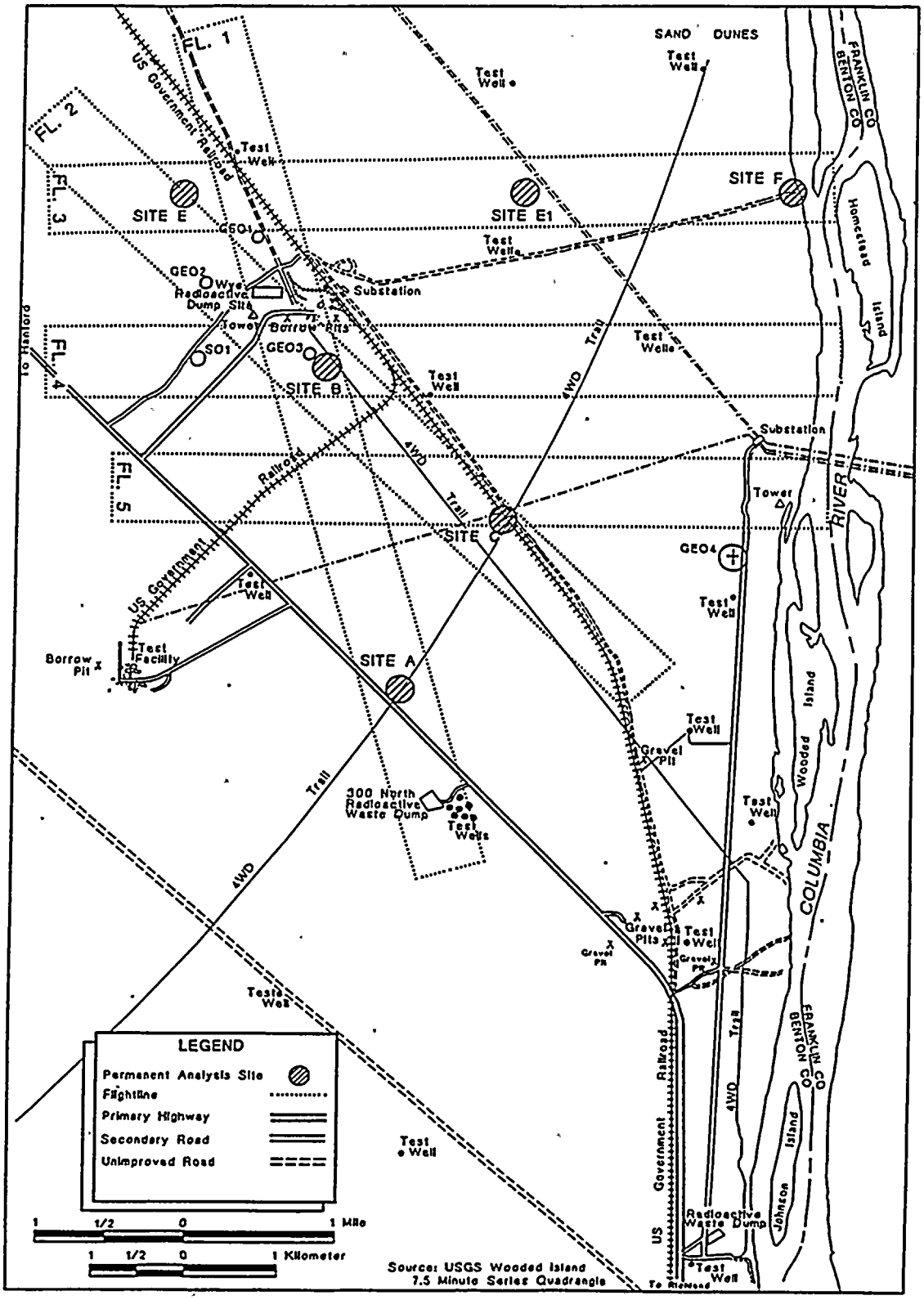
7.5 CONCLUSION

We have been able to identify distinctive range vegetation and analyze their photosynthetic reflectance characteristics at this time of the year. From our comparison of 1991 to 1992 films, no clear distinctions could be made due to the poor quality of the 1991 films. A comparison of 1992 training sites revealed that no significant differences in vegetative cover characteristics exist among monitored sites. Our interpretation shows no significant vegetative health differences between sites located upwind and downwind from the cooling towers of Power Generator Number 2.



CIRCLE INDICATES FLIGHTLINES STARTING POINT

Figure 7-1. Aerial Photography Flightlines



Vegetation Plots and Flightlines
Figure 7-2. Location of Digitized Test Sites

Photograph 4. NDVI (Normal Difference Vegetation Index) classified image of Site A. This classification highlights photosynthetic activity relative to CIR reflectance values. Note the relative high value of tumble mustard (yellow) and lesser values of cheat grass (red).

Figure 7-3. NDVI (Normal Difference Vegetation Index)

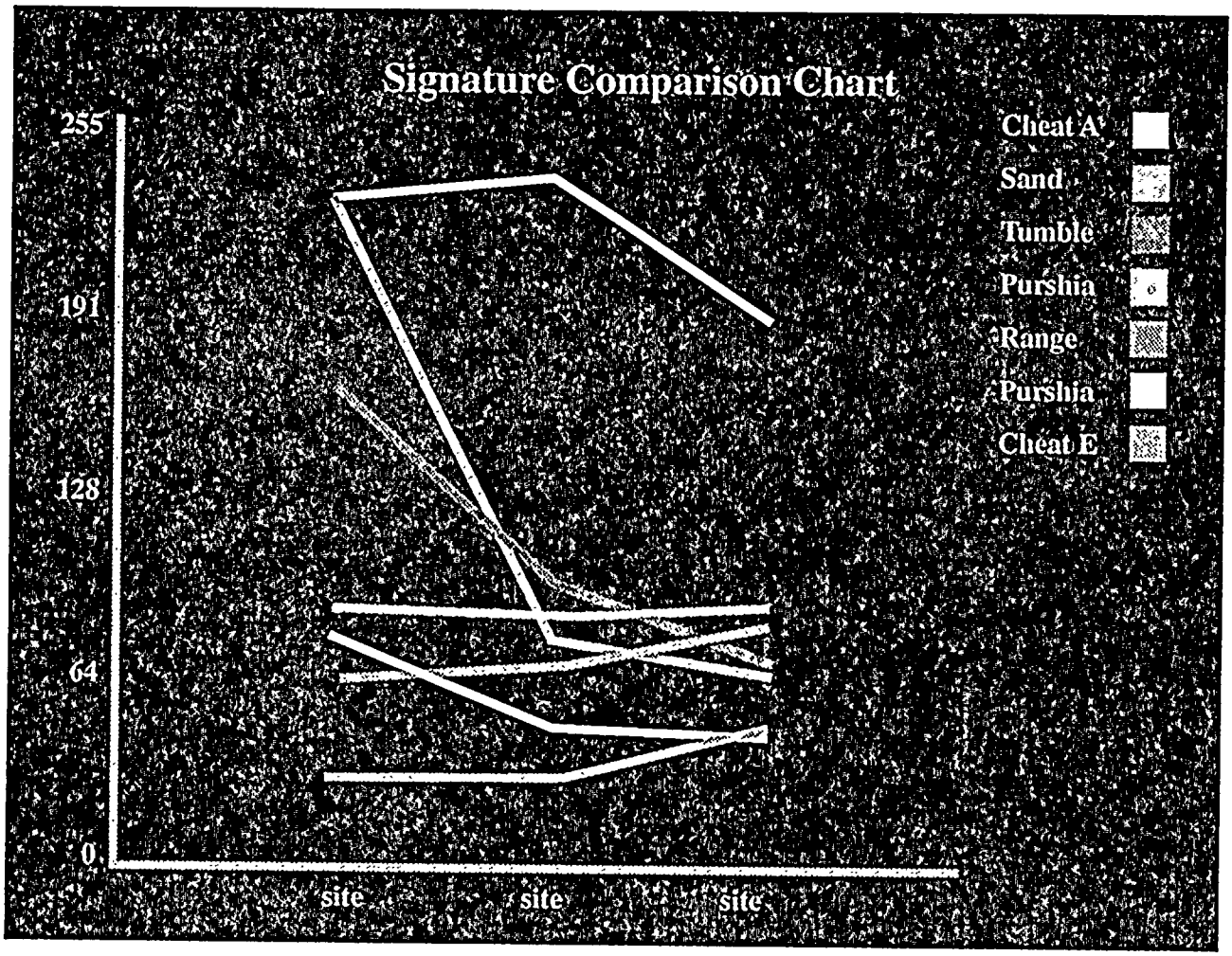


Figure 7-4. Composite spectral signatures for sand and four vegetation types identified at sites A, B, C, and E. These signatures statistically characterize vegetation and background according to average reflectance values across three spectral bands. Y axis values refer to reflectance; X axis values refer to red, green and blue. 1) sand, high value reflectance in all three bands; 2) tumble mustard, very high red reflectance; 3,4) cheat grass from Sites A and E, parallel in character but slightly different in reflectance values from site to site; 5) general range vegetation, mixture of common vegetation types; 6,7) Purshia tridentata from sites B and C, parallel in character but slightly different in reflectance values from site to site.

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