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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

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April 29, 1994
GO2-94-096

Mr. Jason J. Zeller, Manager
Energy Facility Site Evaluation Council
P.O. Box 43172
Olympia, WA 98501-3172

Dear Mr. Zeller:

Subject: **SUPPLY SYSTEM NUCLEAR PLANT NO. 2**
ECOLOGICAL MONITORING PROGRAM ANNUAL REPORT FOR 1993

Reference: EFSEC Resolution No. 266 dated May 10, 1993

Enclosed, please find five (5) copies of the subject report which is submitted per the referenced Council resolution. If you have questions concerning this submittal please contact W.A. Kiel at SCAN 546-4490.

Sincerely,

J.V. Parrish (Mail Drop 1023)
Assistant Managing Director, Operations

Enclosure

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

NUCLEAR PLANT NUMBER 2

OPERATIONAL ECOLOGICAL MONITORING PROGRAM

1993 ANNUAL REPORT

APRIL 1994

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EXECUTIVE SUMMARY

The Ecological Monitoring Program is comprised of several elements which are intended to determine the effects of the operation of the Supply System's Nuclear Plant No. 2 on the environment. These program elements include: chemistry of receiving water for plant effluents; bioassay tests on selected specimens; vegetation cover and density in selected plots; soil chemistry at established sampling locations; and aerial infrared photography of the surrounding plant communities. The results of the 1993 monitoring efforts may be summarized as follows:

- Flow-through and static bioassays were completed with all tests meeting the survival rate criterion of 80 percent in 100 percent effluent.

- Plant cooling water discharges had no discernible effect on Columbia River water quality.

- Total herbaceous cover and phytomass increased relative to 1992 measurements. Changes in vegetation cover and density appeared to be related to an increase in growing season precipitation and temperature.

- Soil analyte concentrations were generally within the ranges observed in previous years.

- Infrared photography revealed no spatially significant vegetation health differences relative to 1992.

ACKNOWLEDGEMENTS

This annual report, prepared by Washington Public Power Supply System, describes the soil and vegetation studies, aquatic bioassays, and water quality programs for WNP-2.

Project Team

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1.0 INTRODUCTION

1.1 BACKGROUND

The Site Certification Agreement (SCA) for WNP-2 was approved on May 17, 1972, between the State of Washington and the Washington Public Power Supply System. The SCA requires that environmental monitoring be conducted during the preoperational and operational phases of site development and use. The objective of the monitoring program is to provide an environmental measurement history for evaluation by the Supply System and the Washington State Energy Facility Site Evaluation Council (EFSEC) and determine significant effects of plant operation on the environment. Since 1972, several revisions of the SCA have been approved by EFSEC in the form of resolutions (EFSEC Resolution Nos. 193, 194, 214, 239, 266).

Most of the studies, analyses, and reports for the preoperational (1973-1984) environmental program of the SCA were performed by outside laboratories for the Supply System. The aquatic studies were presented in reports by Battelle Pacific Northwest Laboratories for the period of September 1974 through August 1978 (Battelle 1976, 1977, 1978, 1979a, 1979b) and by Beak Consultants, Inc. for the period of August 1978 through March 1980 (Beak 1980). The terrestrial program and reports were done by Battelle from 1974 until 1979 (Rickard 1976, 1977, 1979a, 1979b) and then by Beak from 1980 to 1982 (Beak 1981, 1982a, 1982b).

Since 1983, Supply System laboratories have been responsible for the entire operational environmental monitoring program. Using the data acquired during 1984, the first comprehensive operational environmental annual report was prepared by Supply System scientists (Supply System 1985) and has since continued annually (Supply System 1986, 1987, 1988, 1089, 1990, 1991, 1992). A few studies and report were completed prior to the annual reports, including animal studies (Schleder 1982, 1983, 1984) and terrestrial monitoring (Northstrom et.al. 1984).

This report presents the results of the Ecological Monitoring Program for the period of January through December, 1993.

1.2 THE SITE

The WNP-2 plant site is located 19 km (12 miles) north of Richland, Washington in Benton County (Figure 1-1). 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 1984, a range fire destroyed much of the shrub cover on the Hanford 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 river 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 water surface 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 during a 24-hour period 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 1993, measured at the USGS stream-quality station located at river mile 388.1, near the Vernita Bridge, was 36,100 cfs (cubic feet per second), while average and maximum flows in 1993 were 90,045 and 261,000 cfs, respectively (Figure 1-2).

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 terrestrial sample stations.

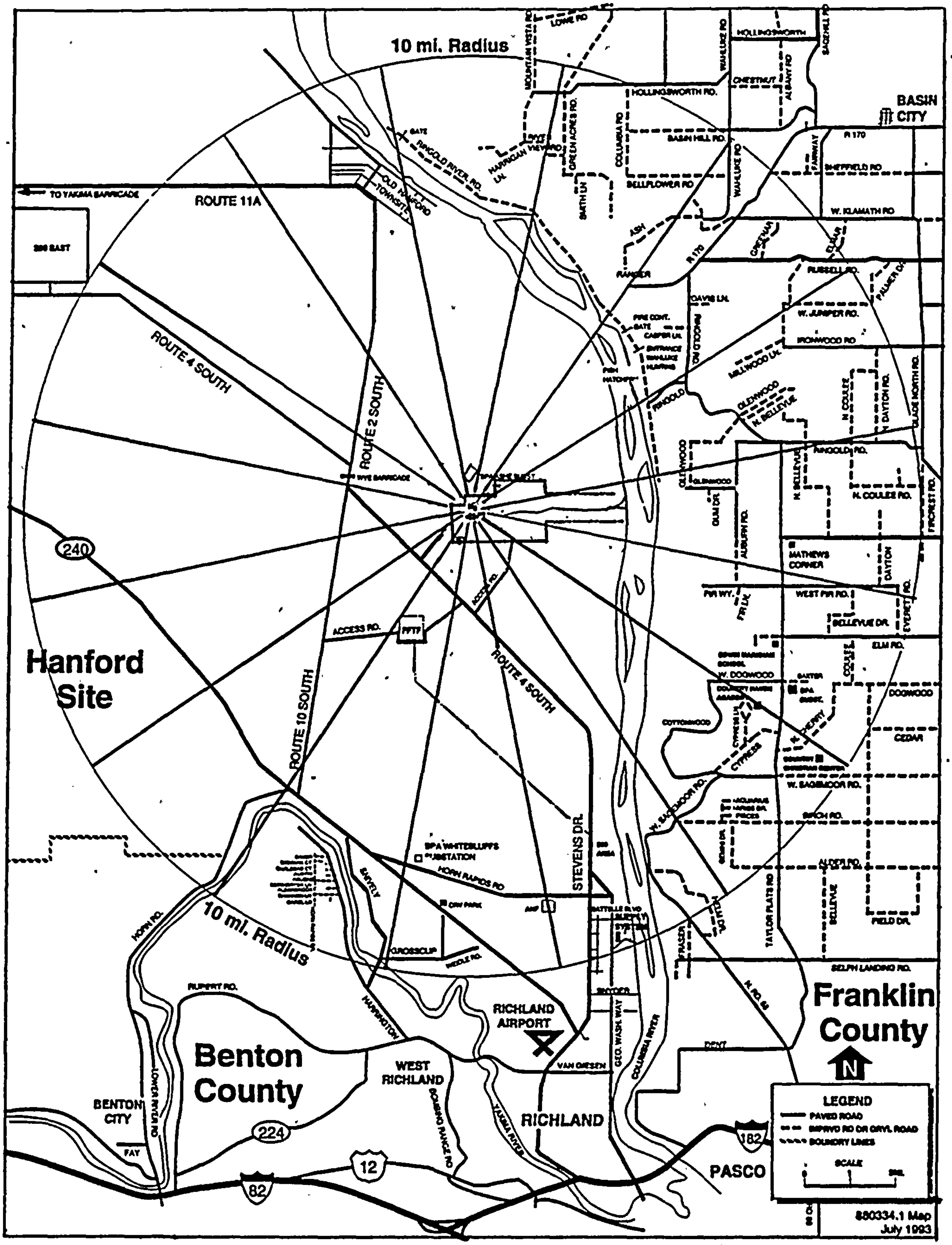


Figure 1-1. WNP-2 Location Map

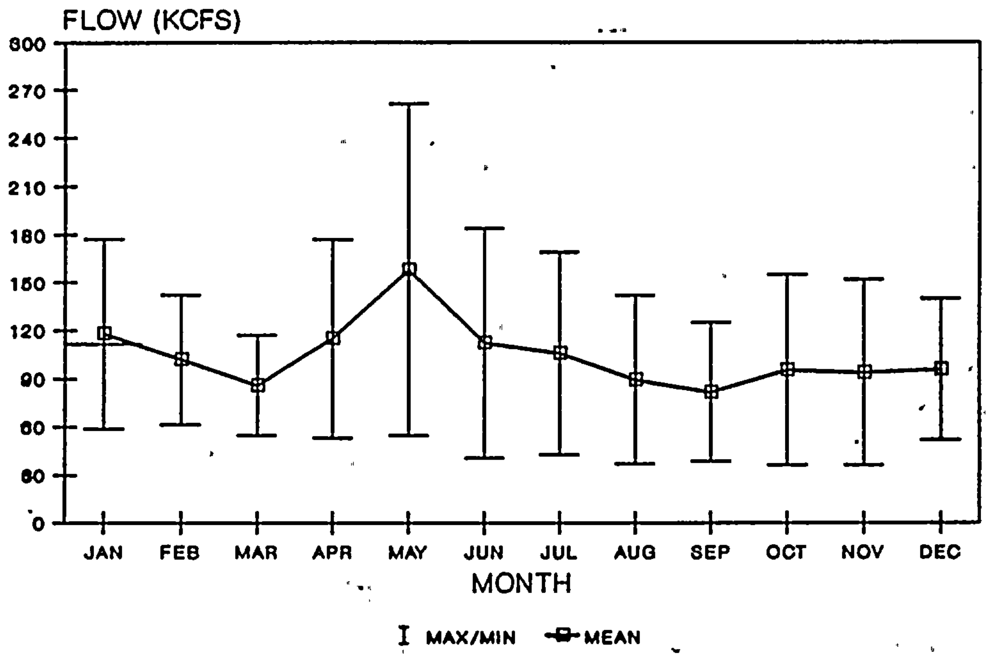


Figure 1-2. Columbia River Monthly Flow for 1993

2.0 AQUATIC BIOSSAYS

2.1 INTRODUCTION

Special condition S4 of the WNP-2 National Pollutant Discharge Elimination System (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. This report includes results of bioassay tests on chinook salmon (Oncorhynchus tshawytscha) and the common water flea (Daphnia pulex).

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 1991) and Quality Assurance Guidelines for Biological Testing (EPA 1978). Sample holding times and analytical methods (Table 2-1) were consistent with EPA guidance (EPA 1983).

2.2.1 Chinook Salmon

Four flow through bioassays of WNP-2 cooling tower effluent were performed March 17-21 (Test 1), March 24-28 (Test 2), November 6-10 (Test 3), and November 14-18 (Test 4), 1993. The flow-through system consisted of six 132-liter capacity glass aquaria with each containing approximately 114 liters of water. The system included three control (100% Columbia River water) and three effluent (100% plant effluent) aquaria selected on a random basis. Flow rates were approximately 1.4 liters/minute/aquaria.

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

High Columbia River dissolved gas levels required the March bioassays to be performed near ambient river temperatures (see discussion section). The temperature conditioning unit was used to cool the effluent to temperatures approximating that of the control water. For the November tests, the temperature conditioning unit was used to maintain the control water and effluent at 12°C (±1°C).

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

Ten fish were distributed to each aquarium, two at a time, in a stratified random manner. Fish were acclimatized in the aquaria with 100% control water for 48 hours prior to plant effluent introduction. The 96-hour test was begun by siphoning down all six aquaria until there was approximately 23 liters of water remaining in each. The test aquaria were then refilled with plant effluent and the control aquaria were refilled with river water.

The aquaria were checked for mortalities twice per day. Temperature, dissolved oxygen, pH, and conductivity were measured in each aquarium and in the control and effluent head boxes at the beginning of the test, daily thereafter, and at test termination. Grab water samples were collected daily from the control and effluent head boxes and each aquarium. The samples were later analyzed for calcium, magnesium, and alkalinity.

Temperature measurements were made with a Fisher NIST-traceable thermometer. The pH measurements were made with an IBM Model EC105-2A portable pH meter. Prior to each use the instrument was calibrated using pH standards 4.0, 7.0, and 10.0. If necessary, the probes were adjusted to within 0.1 units of the standards. Dissolved oxygen measurements were made using a Yellow Springs Instrument (YSI) Model 57 meter. Conductivity measurements were made with a YSI model 33 meter. Calcium and magnesium

measurements were made with a Perkin Elmer Model 40 inductively coupled plasma emission spectrometer.

2.2.2 Daphnia pulex

Two bioassays of WNP-2 cooling tower effluent were performed December 11-15, 1992, (test A) and April 20-24, 1993 (test B). Although test A was performed in 1992, the analytical results and final report were not completed until early 1993. As a result, test A is included in the 1993 reporting period. 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 (EPA, 1991).

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 and 100% dilution water (control) for a 96-hour period. Mortality checks were made two hours after the beginning of the test and daily thereafter.

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

A reference toxicant test using cadmium chloride was performed in conjunction with each test. The cadmium chloride was received from the EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Temperature was measured in control and effluent containers at the start of each test and daily thereafter. Dissolved oxygen, 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. Measurements of pH were made with an Orion Model 701-A meter and Ross Model 8102 electrode. Dissolved oxygen measurements were made using the modified Winkler procedure. Conductivity measurements were made with a YSI Model 33 meter. Calcium and magnesium measurements were made with a Perkin-Elmer Model 40 I.C.P. Emission Spectrometer.

2.3 RESULTS AND DISCUSSION

The tests were successfully completed with respect to a survival rate criterion of 80% or greater. These results are in agreement with previous flow-through and static bioassays performed at WNP-2.

2.3.1 Chinook Salmon

One fish mortality was observed during performance of the four bioassays. This occurred in effluent aquarium T2 at 1430 hours on November 10.

The loading factor varied from approximately 0.9 grams/liter in Test 1 to 1.16 grams/liter in Test 4. Table 2-2 identifies sizes and numbers of control fish utilized in each of the bioassays. Table 2-3 presents the basic water quality parameters and results.

With Columbia River oxygen saturation values at approximately 110% during March, use of the temperature conditioning unit to raise control water temperatures would have created lethal conditions with respect to dissolved gas levels, particularly nitrogen. Effluent temperatures were cooled from approximately 19°C to approximately 8.5°C. Design limitations of the chiller unit prevented a further reduction in effluent temperatures. Use of the water bath table helped to moderate temperatures in both control and effluent aquaria.

During Test 3, activation of a radiation alarm on the circulating cooling water system required cooling tower effluent to be secured at approximately 1145 hours on November 9. This action caused flow to the effluent aquaria to cease at 1320 hours. The problem was linked to welding activity in the vicinity of the radiation alarm. Plant procedures required testing of the circulating water prior to re-establishing cooling tower effluent flow. This task required several hours to complete. During this time period the aquaria, both control and effluent, were maintained in a static test mode. The water bath table housing the aquaria was filled with control water to help maintain the temperature of the aquaria within specified limits. Effluent flow was re-established at 2040 hours. Temperature measurements averaged 11.9°C in both control and effluent aquaria during this period. Dissolved oxygen levels in the effluent aquaria averaged 10.4 mg/L during the 7 hour and 20 minute static mode. The duration of the test was extended to allow a full 96 hours of flow-through testing.

2.3.2 Daphnia pulex

Table 2-4 provides a complete summary of test conditions for Daphnia pulex. Two mortalities were observed in both control and effluent solutions during the performance of Test A. No mortalities were recorded for Test B (Table 2-5).

Following acclimation to test chamber conditions, temperature measurements in the control and effluent containers averaged 20.4°C and 20.2°C, for Tests A and B, respectively. Measurements of physical and chemical parameters for control and effluent solutions at the beginning of each test are presented in Table 2-6.

The results for the reference toxicant cadmium chloride, indicate 24-hour LC_{50} values of 0.24 mg/L (Test A) and 0.32 mg/L (Test B). In addition, a 48-hour LC_{50} value of 0.09 mg/L was recorded for Test B. The LC_{50} was determined using a computer based Trimmed Spearman Karber method.

Table 2-1. 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 2-2. Size and Number of Control Fish Used in WNP-2 Bioassay Tests

		Fork Length (cm)		Weight (g)	
Test	Number	Average	Range	Average	Range
1	30	4.7	3.9-6.0	1.06	0.52-2.30
2	30	5.1	4.7-5.8	1.43	0.92-2.05
3	30	9.8	7.0-13.2	11.6	3.4-28.1
4	30	10.4	8.8-12.3	13.3	7.6-21.1

Table 2-3. Water Quality Parameters and Results for WNP-2 Fish Bioassays

Parameter	Control Aquaria		100% Discharge Aquaria	
Test No.	Average	Range	Average	Range
Temperature (°C)				
1	5.7	5.1-6.3	8.7	7.9-9.3
2	6.2	5.9-6.7	8.9	8.3-9.4
3	11.9	11.5-12.7	12.5	12.0-12.9
4	11.9	11.8-12.1	12.7	12.1-12.9
pH				
1	8.14	7.91-8.33	8.31	8.25-8.37
2	8.27	8.17-8.46	8.21	8.17-8.26
3	7.71	7.61-7.80	8.38	8.19-8.47
4	7.74	7.67-7.85	8.29	8.09-8.40
Dissolved Oxygen (mg/L)				
1	14.2	13.6-14.6	9.8	9.1-11.0
2	13.8	13.5-14.0	9.7	9.2-10.5
3	10.5	10.0-11.0	9.6	9.2-10.0
4	10.6	10.2-11.2	9.4	9.0-10.5
Conductivity (μmhos/cm)				
1	99	97-100	562	447-600
2	101	100-102	564	490-610
3	107	105-110	712	490-850
4	106	105-108	668	410-850
Hardness (mg/L)				
1	68	65-69	381	346-411
2	68	66-68	346	255-398
3	67	64-76	458	282-577
4	67	64-70	442	261-567
Alkalinity (mg/L)				
1	64	62-66	140	126-148
2	47	32-66	115	70-126
3	57	49-59	147	105-171
4	58	57-59	131	101-147

Table 2-4. Test Conditions for <u>Daphnia pulex</u>

1.	Temperature:	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 hrs. Fed daily thereafter
10.	Aeration:	None
11.	Dilution water:	Moderately hard
12.	Test duration:	96 hours
13.	Effect measured:	Mortality

Table 2-5. Mortalities and Percent Survival of Daphnia Pulex in Control and Effluent Solutions

Test	Number of Moralities		Percent Survival	
No.	Control	Effluent	Control	Effluent
A	2	2	90	90
B	0	0	100	100

Table 2-6. Physical and Chemical Characteristics of Control and Effluent Solutions at the Beginning of Each Daphnia Test

Test No.	Sample	Temp. (°C)	pH	D.O. (mg/L)	Cond. (μS/cm)	Hard. (mg/L)	Alk. (mg/L)
A	Control	20.5	7.35	8.0	300	87	58
	Effluent	20.9	8.10	8.4	748	374	171
B	Control	20.9	8.48	8.2	300	79	59
	Effluent	20.3	7.93	8.2	799	366	150

3.0 WATER QUALITY

3.1 INTRODUCTION

EFSEC Resolution No. 266 affected the water quality portion of the monitoring program by the elimination of certain river parameters, expanding the scope of blowdown analysis, and adding water and semiannual sediment sampling from the evaporation/percolation pond located northeast of WNP-2.

3.2 MATERIALS AND METHODS

Columbia River surface water was sampled monthly from January 1993 through December 1993. Samples were collected near river mile 352 from four stations numbered 1, 7, 11, and 8 (Figures 3-1, 3-2). 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 blowdown effects. Station 11, at 91 meters (300 feet) downstream from the discharge, represents the extremity of the mixing zone. 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 blowdown is well mixed in 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, total phosphorus, inorganic phosphate, sulfate, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium. Substations 11M and 11B were analyzed for total copper.

Plant blowdown was sampled monthly during 1993. Samples were collected from the discharge pipe at a sample point located immediately prior to the discharge water entering the Columbia River. Blowdown samples were analyzed for temperature, pH, conductivity, turbidity, total phosphorus, inorganic phosphate, sulfate, oil and grease, total copper, total

iron, total zinc, total nickel, total lead, total cadmium, and total chromium. Organics (VOCs and semi-VOCs) were analyzed on a quarterly basis.

Evaporation/percolation pond water and sediment were sampled monthly and quarterly, and semiannually, respectively. The pond is located approximately 1500 feet northeast of the plant. Monthly water samples were analyzed for pH, conductivity, total iron, total copper, total nickel, total zinc, total lead, total cadmium, total chromium, and oil and grease. In addition, quarterly water samples were analyzed for total dissolved solids and organics (VOCs and semi-VOCs). Semiannual sediment samples were analyzed for the same total metals as the monthly water samples, excluding iron. A summary of water quality parameters, stations and sample frequencies is presented in Table 3-1.

3.2.1 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, sulfate, total phosphorus, inorganic phosphate, 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 Substations 11M and 11B was collected in one-liter polypropylene cubitainers with an all-Teflon pump and Tygon tubing. Water for dissolved oxygen measurements was collected in 300 ml BOD bottles.

Blowdown temperature was determined in-situ. Water for pH, conductivity, turbidity, total phosphorus, inorganic phosphate and total metals analysis was collected in 3.8 liter polypropylene cubitainers. Water for oil and grease and semivolatile organics analysis was collected in one-liter clear and amber glass bottles, respectively. Water for volatile organics analysis was collected in 40 ml glass bottles.

Evaporation/percolation pond water for pH, conductivity and total metals was collected in 3.8 liter polypropylene cubitainers. Water for total dissolved solids analysis was collected in 500 ml plastic bottles. Water for oil and grease and organics (VOCs and semi-VOCs) was collected as described under blowdown sampling. All samples were stored in a cooler until delivered to the EPL for analysis.

Columbia River and blowdown sampling during the annual plant maintenance outage (May through June) consisted of Station 1 (control) samples only.

3.2.2 Analysis Methods

Field 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 for a minimum of one minute.

Total metals, sulfate, conductivity, pH, dissolved oxygen, inorganic phosphate, turbidity, total alkalinity, total hardness, organics (VOCs and semi-VOCs), total phosphorus (July-December), and oil and grease (August-December), were determined by Supply System Environmental Programs personnel. Analysis for total phosphorus (January-June), oil and grease (January-July), and total dissolved solids 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 (EPA, 1983) and Standard Methods approved methods (Table 3-2).

3.3 RESULTS AND DISCUSSION

The river parameters eliminated as a result of the adoption of Resolution No. 266 included total residual chlorine, oil and grease, total dissolved solids, total suspended solids, ammonia nitrogen and nitrate nitrogen. Data acquired for these parameters during the first quarter of 1993, showed no significant differences from historical data and reinforced the decision to

drop them from the monitoring program. Total residual chlorine and oil and grease measurements were below their respective detection limits of <1.0 mg/L for all stations and periods. Total dissolved and suspended solids ranged from 50.0 to 140 mg/L, and <1.0 to 4.0 mg/L, respectively. Ammonia and nitrate nitrogen measurements ranged from <0.01 to 0.06 mg/L, and 0.104 to 0.162 mg/L, respectively.

The evaporation/percolation pond is a separate monitoring system and is not related to the effects of the blowdown on the Columbia River. Pond data is not included with figures depicting river and blowdown results.

Plant blowdown samples could not be collected during January (plant shutdown) and April (blowdown secured).

3.3.1 Temperature

Columbia River surface temperatures varied seasonally with a minimum temperature of 1.0°C at all stations on February 25 and a maximum of 18.3°C at all stations on August 31 (Table 3-3). Blowdown temperatures ranged from 17.6°C in February to 27.3°C in July. Temperatures measured in 1993 are presented graphically in Figure 3-3.

3.3.2 Dissolved Oxygen (DO)

DO measurements for each sample station are presented in Table 3-4. Columbia River DO concentrations ranged from 9.1 mg/L at Stations 1 and 7 in September to 13.8 mg/L at Station 11 in February and Stations 1 and 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 3-4.

3.3.3 pH and Alkalinity

Columbia River pH values ranged from 7.47 at Station 1 in February to 8.49 at Stations 7 and 11 in March. The variation in pH between sample stations is small. The largest difference of 0.43 standard units occurred between Station 8 (pH 8.06) and Stations 7 and 11 (pH 8.49) in March. The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1992). Blowdown pH values ranged from 7.80 in August to 8.19 in July and September. Pond pH values ranged from 7.31 in December to 8.23 in November. Results are listed in Table 3-5. Measurements are presented graphically in Figure 3-5. Columbia River alkalinities ranged from 50.0 to 66.0 mg/L as calcium carbonate (Table 3-6). The alkalinity measurements are presented graphically in Figure 3-6.

3.3.4 Hardness

Hardness ranged from 58.0 to 74.0 mg/L as calcium carbonate (Table 4-7). The hardness measurements are presented graphically in Figure 3-7.

3.3.5 Conductivity

Columbia River conductivity measurements ranged from 123 μS/cm at 25°C at Station 1 in June to 156 μS/cm at 25°C at Stations 1, 7, and 8 in April. Blowdown measurements ranged from 645 μS/cm at 25°C to 1070 μS/cm at 25°C. Pond values ranged from 147 μS/cm at 25°C to 478 μS/cm at 25°C. Conductivity measurements are listed in Table 3-8 and graphically in Figure 3-8.

3.3.6 Turbidity

In the Columbia River, measured turbidities were low and ranged from 0.3 nephelometric turbidity units (NTU) to 2.7 NTU. Blowdown values ranged from 1.8 to 12.6 NTU. River and blowdown results are listed in Table 3-9. Turbidity data is presented graphically in Figure 3-9.

3.3.7 Metals (Total)

Columbia River cadmium concentrations were below the detection limit of 1.4 μg/L for all stations during all periods. Nickel and lead concentrations were below respective detection limits for nearly all periods. A nickel value of 5.2 μg/L was recorded at Station 1 in June. In comparison with the entire year's data as well as with historical data, this result is inconsistent and may represent a contaminated sample. Measurable levels of lead were recorded at Stations 7 and 11 in January, Stations 1 and 7 in March, and Station 1 in May. River copper concentrations ranged from <1.9 μg/L to 3.5 μg/L. Zinc and iron concentrations ranged from <5.0 μg/L to 13.3 μg/L and, 26.4 μg/L to 161.8 μg/L, respectively. Chromium concentrations were generally below the detection limit of 0.3 μg/L. The highest reading of 1.2 μg/L was recorded at Station 1 in May.

Blowdown cadmium concentrations were below the detection limit for all stations and periods. Nickel and lead concentrations were fairly low, ranging from <2.0 μg/L to 8.5 μg/L, and <0.7 μg/L to 2.9 μg/L, respectively. Blowdown copper, zinc and iron concentrations were substantially higher than river concentrations, as would be expected, and ranged from 46.0 μg/L to 155 μg/L, 39.5 μg/L to 98.8 μg/L, and 244 μg/L to 3970 μg/L, respectively. Chromium concentrations ranged from <0.3 μg/L to 9.6 μg/L.

Evaporation/percolation pond water nickel and cadmium concentrations were below their respective detection limits for all periods. Lead concentrations were below detection limits for all periods except March and April. Similar results were obtained from chromium with

the only measurable concentrations being recorded in March, April and November. Copper and zinc concentrations ranged from 2.8 μg/L to 95.9 μg/L and, 28.4 μg/L to 250 μg/L, respectively. Iron concentrations ranged from a low of 45.6 μg/L in September to a high of 1056 μg/L in April. Pond sediment samples produced measurable levels for all of the metal constituents analyzed except cadmium.

Total metal results are listed in Tables 3-10 through 3-16. Columbia River and blowdown total iron measurements are presented graphically in Figure 3-10. Evaporation/percolation pond total metals measurements are presented graphically in Figure 3-11.

3.3.8 Oil and Grease

Blowdown and pond oil and grease values were below the detection limit of 1.0 mg/L for all periods sampled. Oil and grease measurements are summarized in Table 3-17.

3.3.9 Total Phosphorus and Inorganic Phosphate

Columbia River total phosphorus concentrations ranged from <0.01 to 0.07 mgP/L. Blowdown values ranged from 0.6 to 3.7 mgP/L. Columbia River inorganic phosphate concentrations were below 0.1 mg/L for all stations and periods except Station 7 in July. Blowdown inorganic phosphate measurements ranged from 0.8 to 1.2 mgP/L. Total phosphorus and inorganic phosphate measurements are summarized in Tables 3-18 and 3-19, respectively. Total phosphorus measurements are presented graphically in Figure 3-12.

3.3.10 Sulfate

Individual Columbia River sulfate measurements ranged from 8.2 to 12.2 mg/L. Blowdown measurements ranged from 207.0 to 391.0 mg/L. Sulfate measurements are presented in Table 3-20 and graphically in Figure 3-13.

3.3.11 Total Dissolved Solids

The quarterly total dissolved solids (TDS) measurements of the pond ranged from <1.0 mg/L to 94.0 mg/L (Table 3-21).

3.3.12 Organics (VOCs and Semi-VOCs)

Blowdown volatile organic concentrations were below respective detection limits for all compounds during all periods except chloroform in December. A measurement of 5.4 μg/L of chloroform was recorded, which is just slightly above the detection limit of 5.0 μg/L. Semivolatile organic compound concentrations were below respective detection limits for all periods.

Evaporation/percolation pond volatile and semivolatile organic compound concentrations were below respective detection limits for all periods. A list of the volatile and semivolatile organic compounds analyzed for are presented in Tables 3-22 and 3-23, respectively. The evaporation/percolation pond collects runoff from the WNP-2 main site. Some seasonal patterns were observed with concentrations of most metals being highest during spring and early summer. These increases may be due in part to spring thaw conditions and moisture events.

Overall, it appears that, with respect to all the measured parameters sampled under the operating conditions prevailing during 1993, WNP-2 cooling water discharge did not negatively effect Columbia River water quality.

Table 3-1. Summary of Water Quality Parameters, Stations, and Sampling Frequencies, 1993

Parameter	1	7^{++}	11^{++}	11M & $11B^{++}$	8^{++}	Plant Blowdo wn	Pond
Temperature	M	M	M	-	M	M	-
Dissolved Oxygen	M	M	M	-	M	-	-
pH	M	M	M	-	M	M	M
Turbidity	M	M	M	-	M	M	-
Total Alkalinity	M	M	M	-	M	-	-
Filterable Residue (Total Dissolved Solids)	-	-	-	-	-	-	Q
Conductivity	M	M	M	-	M	M	M
Iron (Total)	M	M	M	-	M	M	M
Copper (Total)	M	M	M	M	M	M	M[a]
Nickel (Total)	M	M	M	-	M	M	M[a]
Zinc (Total)	M	M	M	-	M	M	M[a]
Lead (Total)	M	M	M	-	M	M	M[a]
Cadmium (Total)	M	M	M	-	M	M	M[a]
Chromium (Total)	M	M	M	-	M	M	M[a]
Sulfate	M	M	M	-	M	M	-
Orthophosphorus	M	M	M	-	M	M	-
Total Phosphorus	M	M	M	-	M	M	-
Oil and Grease	-	-	-	-		M	M
Hardness	M	M	M	-	M	-	-
Organics (VOCs & Semi-VOCs)	-	-	-	-	-	Q	Q

Symbols Key

Q = Quarterly
M = Monthly
++ Samples collected only if the plant is operating.
a = Semiannual pond sediment samples are analyzed for these parameters.

Table 3-2. Summary of Water Quality Parameters, EPA and Standard Methods Method Numbers

Parameter	EPA Method Number	Standard Methods 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	2340B
Oil and Grease (mg/L)	413.2	
Total Phosphorus (mg/L as P)	365.2	4500-P
Inorganic Phosphate (mg/L as P)	300, 365.2	
Sulfate (mg/L as SO_4)	300, 375.4	
Total Copper (μg/L as Cu)	200.7, 220.1, 220.2	
Total Iron (μg/L as Fe)	200.7, 236.1, 236.2	
Total Nickel (μG/L as Ni)	200.7, 249.1, 249.2	
Total Zinc (μg/L as Zn)	200.7, 289.1, 289.2	
Total Lead (μg/L as pb)	200.7, 239.1, 239.2	
Total Cadmium (μg/L as Cd)	200.7, 213.1, 213.2	
Total Chromium (μg/L as Cr)	200.7, 218.1, 218.2	
Filterable Residue: Total Dissolved Solids (mg/L)	160.1	
Volatile Organics (μg/L)	8240	
Semivolatile Organics (μg/L)	8270	

Table 3-3. Summary of Temperature (°C) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown
01/28/93	2.3	2.3	2.3	2.3	-
02/25/93	1.0	1.0	1.0	1.0	17.6
03/31/93	5.0	5.0	5.0	5.0	19.9
04/28/93	8.5	8.7	8.7	8.6	-
05/27/93	12.2	-	-	-	-
06/14/93	14.8	-	-	-	-
07/29/93	17.9	18.0	18.0	17.9	27.3
08/31/93	18.3	18.3	18.3	18.3	26.4
09/16/93	17.9	17.8	17.8	17.8	26.6
10/29/93	14.3	14.3	14.3	14.3	21.8
11/30/93	8.5	8.5	8.5	8.5	18.3
12/29/93	5.9	5.9	5.9	5.9	17.9

Table 3-4. Summary of Dissolved Oxygen (mg/L) Measurements for 1993

Sample Date	1	7	11	8
01/28/93	13.1	13.0	13.1	13.1
02/25/93	13.5	13.6	13.8	13.6
03/31/93	13.8	13.7	13.6	13.8
04/28/93	12.3	12.2	12.3	12.3
05/27/93	11.7	-	-	-
06/14/93	10.9	-	-	-
07/29/93	9.6	9.5	9.6	9.7
08/31/93	9.7	9.7	9.6	9.7
09/16/93	9.1	9.1	9.2	9.2
10/29/93	9.7	9.7	9.7	9.7
11/29/93	11.1	11.2	11.1	11.1
12/29/93	11.7	11.6	11.4	11.7

Table 3-5. Summary of pH Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/28/93	7.61	7.62	7.63	7.67	-	7.71
02/25/93	7.47	7.49	7.52	7.51	-	7.61
03/31/93	8.17	8.49	8.49	8.06	-	8.06
04/28/93	8.03	7.85	7.96	7.97	-	7.73
05/27/93	7.82	-	-	-	-	8.06
06/14/93	8.20	-	-	-	-	7.84
07/29/93	7.76	7.62	7.62	7.69	8.19	7.73
08/31/93	7.78	7.79	7.71	7.82	7.80	7.51
09/16/93	7.73	7.71	7.74	7.90	8.19	-
10/29/93	7.53	7.54	7.51	7.53	7.87	7.93
11/29/93	7.65	7.67	7.63	7.71	8.02	8.23
12/29/93	7.61	7.63	7.69	7.73	8.07	7.31

Table 3-6. Summary of Alkalinity (mg/L as $CaCO_3$) Measurements for 1993

Sample Date	1	7	11	8
01/28/93	61.0	61.0	61.0	62.0
02/25/93	60.0	59.0	61.0	60.0
03/31/93	64.0	66.0	64.0	66.0
04/28/93	62.5	63.0	65.0	65.0
05/27/93	54.0	-	-	-
06/14/93	50.0	-	-	-
07/29/93	54.0	54.0	54.0	54.0
08/31/93	56.0	57.0	57.0	56.0
09/16/93	57.0	57.0	57.0	58.0
10/29/93	57.0	57.0	57.0	58.0
11/29/93	61.0	61.0	59.0	61.0
12/29/92	63.0	63.0	63.0	63.0

Table 3-7. Summary of Total Hardness (mg/L as $CaCO_3$) Measurements for 1993

Sample Date	1	7	11	8
01/28/93	74.0	73.4	73.9	73.6
02/25/93	71.7	71.7	70.8	72.7
03/31/93	66.3	68.1	68.1	67.8
04/28/93	69.7	69.0	69.0	68.7
05/27/93	62.4	-	-	-
06/14/93	58.0	-	-	-
07/29/93	66.0	63.9	64.9	64.9
08/31/93	64.5	64.1	65.1	63.0
09/16/93	65.1	66.6	66.6	65.3
10/29/93	66.0	66.5	65.3	65.8
11/29/93	69.8	68.3	67.6	67.6
12/29/93	69.9	70.4	70.9	71.1

Table 3-8. Summary of Conductivity (μS/cm) Measurements at 25°C for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/28/93	147	146	148	147	-	171
02/25/93	151	148	150	150	-	147
03/31/93	154	151	151	152	-	188
04/28/93	156	156	155	156	-	293
05/27/93	129	-	-	-	-	183
06/14/93	123	-	-	-	-	196
07/29/93	129	129	131	128	832	281
08/31/93	135	136	136	135	961	195
09/16/93	136	136	135	136	1070	-
10/29/93	136	136	135	136	864	153
11/29/93	143	144	143	142	940	478
12/29/93	148	148	149	148	645	182

Table 3-9. Summary of Turbidity (NTU) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown
01/28/93	0.6	1.0	1.1	1.0	-
02/25/93	2.7	2.5	1.8	2.2	-
03/31/93	0.7	0.7	0.7	0.5	-
04/28/93	0.7	0.7	0.7	0.7	-
05/27/93	2.2	-	-	-	-
06/14/93	1.2	-	-	-	-
07/29/93	1.3	1.4	1.4	1.4	6.1
08/31/93	1.6	1.6	1.6	1.4	5.1
09/16/93	0.5	0.6	0.6	0.5	1.8
10/29/93	0.4	0.4	0.4	0.5	6.2
11/29/93	0.3	0.3	0.4	0.3	7.6
12/29/93	0.6	0.6	0.6	0.6	12.6

Table 3-10. Summary of Copper (μg/L) Measurements for 1993

Sample Date	1	7	11	11M	11B	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	2.7	2.0	2.4	3.4	1.9	3.1	-	6.8	
02/25/93	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	94.1	2.8	
03/31/93	2.5	<1.9	<1.9	<1.9	<1.9	<1.9	155.0	95.9	
04/28/93	<1.9	1.9	<1.9	<1.9	2.2	1.9	-	17.5	
05/27/93	2.2	-	-	-	-	-	-	7.2	
06/14/93	3.1	-	-	-	-	-	-	28.7	139.6
07/29/93	2.1	2.4	2.5	<1.9	<1.9	2.2	120.0	13.4	
08/31/93	2.1	2.5	2.1	<1.9	<1.9	<1.9	98.0	4.3	
09/16/93	3.5	<1.9	<1.9	2.4	<1.9	<1.9	70.0	2.9	
10/29/93	2.0	2.1	<1.9	<1.9	<1.9	<1.9	52.2	13.7	
11/29/93	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	68.0	4.6	
12/29/93	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	46.0	9.6	105.5

Table 3-11. Summary of Nickel (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	<2.0	<2.0	<2.0	<2.0	-	<2.0	
02/25/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
03/31/93	<2.0	<2.0	<2.0	<2.0	8.5	<2.0	
04/28/93	<2.0	<2.0	<2.0	<2.0	-	<2.0	
05/27/93	<2.0	-	-	-	-	<2.0	
06/14/93	5.2	-	-	-	-	<2.0	6.5
07/29/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
08/31/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
09/16/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
10/29/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
11/29/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
12/29/93	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	21.9

Table 3-12. Summary of Zinc (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	6.7	<5.0	<5.0	5.6	-	63.3	
02/25/93	6.0	6.1	8.1	6.4	65.9	47.0	
03/31/93	<5.0	<5.0	<5.0	<5.0	98.8	93.7	
04/28/93	5.2	<5.0	<5.0	5.6	-	250.0	
05/27/93	7.9	-	-	-	-	75.6	
06/14/93	7.2	-	-	-	-	215.0	404.0
07/29/93	10.4	<5.0	5.0	5.3	83.8	135.0	
08/31/93	<5.0	<5.0	<5.0	<5.0	57.2	77.4	
09/16/93	13.3	7.0	6.2	9.3	49.8	83.6	
10/29/93	11.5	10.3	13.1	8.9	55.4	46.2	
11/29/93	<5.0	6.8	5.1	7.0	82.3	28.4	
12/29/93	<5.0	<5.0	<5.0	<5.0	39.5	38.0	385.2

Table 3-13. Summary of Iron (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/28/93	50.8	43.1	49.4	48.2	-	133.4
02/25/93	34.9	29.8	27.3	31.6	244.0	76.0
03/31/93	35.1	34.7	28.9	22.3	3970.0	175.0
04/28/93	30.9	29.8	32.1	34.2	-	1056.0
05/27/93	121.9	-	-	-	-	58.8
06/14/93	40.5	-	-	-	-	171.4
07/29/93	77.9	74.2	83.9	72.4	409.6	275.7
08/31/93	161.8	75.5	73.7	65.3	411.0	52.4
09/16/93	55.9	57.8	53.7	127.0	595.0	45.6
10/29/93	96.6	83.3	78.8	74.7	854.0	461.3
11/29/93	35.5	36.5	35.3	32.8	926.0	54.2
12/29/93	61.3	26.4	31.9	29.4	1060.0	152.0

Table 3-14. Summary of Lead (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	<0.7	0.9	0.8	<0.7	-	<0.7	
02/25/93	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	
03/31/93	1.6	0.7	<0.7	<0.7	<0.7	3.8	
04/28/93	<0.7	<0.7	<0.7	<0.7	-	1.1	
05/27/93	0.7	-	-	-	-	<0.7	
06/14/93	<0.7	-	-	-	-	<0.7	14.0
07/29/93	<0.7	<0.7	<0.7	<0.7	2.9	<0.7	
08/31/93	<0.7	<0.7	<0.7	<0.7	0.8	<0.7	
09/16/93	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	
10/29/93	<0.7	<0.7	<0.7	<0.7	2.2	<0.7	
11/29/93	<0.7	<0.7	<0.7	<0.7	2.9	<0.7	
12/29/93	<0.7	<0.7	<0.7	<0.7	2.8	<0.7	19.4

Table 3-15. Summary of Cadmium (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	<1.4	<1.4	<1.4	<1.4	-	<1.4	
02/25/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
03/31/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
04/28/93	<1.4	<1.4	<1.4	<1.4	-	<1.4	
05/27/93	<1.4	-	-	-	-	<1.4	
06/14/93	<1.4	-	-	-	-	<1.4	<0.3
07/29/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
08/31/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
09/16/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
10/29/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
11/29/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	
12/29/93	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<0.3

Table 3-16. Summary of Chromium (μg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/28/93	<0.3	<0.3	<0.3	<0.3	-	<0.3	
02/25/93	0.3	<0.3	<0.3	0.3	1.5	<0.3	
03/31/93	0.5	<0.3	0.3	<0.3	9.6	0.3	
04/28/93	0.5	0.4	0.5	0.6	-	<1.1	
05/27/93	1.2	-	-	-	-	<0.3	
06/14/93	<0.3	-	-	-	-	<0.3	2.2
07/29/93	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	
08/31/93	<0.3	<0.3	<0.3	<0.3	1.4	<0.3	
09/16/93	<0.3	<0.3	<0.3	0.7	8.9	<0.3	
10/29/93	<0.3	<0.3	<0.3	<0.3	0.6	<0.3	
11/29/93	0.4	0.8	0.4	0.3	3.2	0.4	
12/29/93	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	24.4

Table 3-17. Summary of Oil and Grease (mg/L) Measurements for 1993

Sample Date	Plant Blowdown	Pond
01/28/93	-	-
02/25/93	-	-
03/31/93	-	-
04/28/93	-	-
05/27/93	-	<1.0
06/14/93	-	<1.0
07/29/93	<1.0	<1.0
08/31/93	<1.0	<1.0
09/16/93	<1.0	<1.0
10/29/93	<1.0	<1.0
11/29/93	<1.0	<1.0
12/29/93	<1.0	<1.0

Table 3-18. Summary of Total Phosphorus (mg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown
01/28/93	<0.01	<0.01	<0.01	<0.01	-
02/25/93	<0.01	<0.01	<0.01	<0.01	-
03/31/93	0.01	0.01	0.07	0.03	-
04/28/93	<0.01	<0.01	<0.01	<0.01	-
05/27/93	<0.01	-	-	-	-
06/14/93	0.01	-	-	-	-
07/29/93	0.01	0.01	0.02	0.03	3.0
08/31/93	<0.01	<0.01	<0.01	<0.01	3.4
09/16/93	0.02	0.02	0.02	0.02	3.1
10/29/93	0.03	0.03	0.03	0.03	2.9
11/29/93	0.03	0.03	0.03	0.03	3.7
12/29/93	0.02	<0.01	<0.01	<0.01	0.6

Table 3-19. Summary of Inorganic Phosphate (mg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown
01/28/93	<0.1	<0.1	<0.1	<0.1	-
02/25/93	<0.1	<0.1	<0.1	<0.1	-
03/31/93	<0.1	<0.1	<0.1	<0.1	-
04/28/93	<0.1	<0.1	<0.1	<0.1	-
05/27/93	<0.1	-	-	-	-
06/14/93	<0.1	-	-	-	-
07/29/93	<0.1	<0.1	<0.1	<0.1	0.9
08/31/93	<0.1	<0.1	<0.1	<0.1	1.2
09/16/93	<0.1	<0.1	<0.1	<0.1	0.9
10/29/93	<0.1	<0.1	<0.1	<0.1	1.0
11/29/93	<0.1	<0.1	<0.1	<0.1	1.0
12/29/93	<0.1	<0.1	<0.1	<0.1	0.8

Table 3-20. Summary of Sulfate (mg/L) Measurements for 1993

Sample Date	1	7	11	8	Plant Blowdown
01/28/93	10.9	10.9	11.0	11.0	-
02/25/93	10.5	10.5	10.5	10.6	-
03/31/93	11.5	11.3	11.4	11.4	-
04/28/93	12.1	12.2	12.1	12.2	-
05/27/93	10.2	-	-	-	-
06/14/93	8.2	-	-	-	-
07/29/93	8.5	8.6	9.3	8.5	248
08/31/93	9.1	9.6	9.5	9.1	391
09/16/93	9.0	9.1	9.1	9.1	389
10/29/93	9.9	10.0	10.1	9.9	316
11/29/93	10.1	10.3	10.2	10.2	358
12/29/93	10.1	10.1	10.2	10.1	207

Table 3-21. Summary of Quarterly Total Dissolved Solids (mg/L) Measurements for 1993

Sample Date	Pond
06/14/93	90.0
09/16/93	<1.0
12/29/93	94.0

Table 3-22. Summary of Volatile Organic Compounds

Chloromethane	Vinyl Chloride
Trichlorofluoromethane	Bromomethane
Freon 113	Chloroethane
1, 1-Dichloroethene	Carbon Disulfide
Acetone	Methylene Chloride
Cis-1,2-Dichloroethene	Trans-1,2-Dichloroethene
1,1-Dichloroethane	Chloroform
1,2-Dichloroethane	2-Butanone
1,1,1-Trichloroethane	Carbon Tetrachloride
Benzene	Trichloroethene
1,2-Dichloropropane	Vinyl Acetate
Bromodichloromethane	2-Chloroethylvinylether
Cis 1,3-Dichloropropene	1,1,2-Trichloroethane
Trans-1,3-Dichloropropene	Bromoform
Dibromochloromethane	4-Methyl-2-Pentanone
Toluene	Tetrachloroethene
2-Hexanone	Chlorobenzene
Ethylbenzene	Total Xylene
Styrene	1,3-Dichlorobenzene
1,4-Dichlorobenzene	1,2-Dichlorobenzene
1,1,2,2-Tetrachloroethane	

Table 3-23. Summary of Semivolatile Organic Compounds

Acids

Phenol
2-Chlorophenol
2-Methylphenol
4-Methylphenol
2-Nitrophenol
2,4-Dimethylphenol
2,4-Dichlorophenol
Benzoic Acid
4-Chloro-3-methylphenol
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2,4-Dinitrophenol
4-Nitrophenol
4,6-Dinitro-2-methylphenol
Pentachlorophenol

Base Neutrals

bis (2-Chloroethyl) ether
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
1,2-Dichlorobenzene
bis (2-chloroisopropyl) ether
n-Nitroso-di-n-propylamine
Hexachloroethane
Nitrobenzene
Isophorone
bis (2-Chloroethoxy)methane
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
2-Methylnaphthalene
Hexachlorocyclopentadiene

Base Neutrals

2-Chloronaphthalene
2-Nitroaniline
Dimethylphthalate
Acenaphthylene
2,6-Dinitrotoluene
3-Nitroaniline
Acenaphthene
Dibenzofuran
2,4-Dinitrotoluene
Diethylphthalate
Fluorene
4-Chlorophenyl-phenylether
4-Nitroaniline
n-Nitrosodiphenylamine
4-Bromophenyl-phenylether
Hexachlorobenzene
Phenanthrene

Anthracene
Di-n-butylphthalate
Fluoranthene
Pyrene
Butylbenzylphthalate
Benzo[a]anthracene
3,3-Dichlorobenzidine
Chyrsene
bis (2-Ethylhexyl)phthalate
Di-n-octylphthalate
Benzo[b]fluoranthene
Benzo[k]fluoranthene
Benzo[a]pyrene
Indeno[1,2,3-cd]pyrene
Dibenz[a,h]anthracene
Benzo[g,h,i]perylene

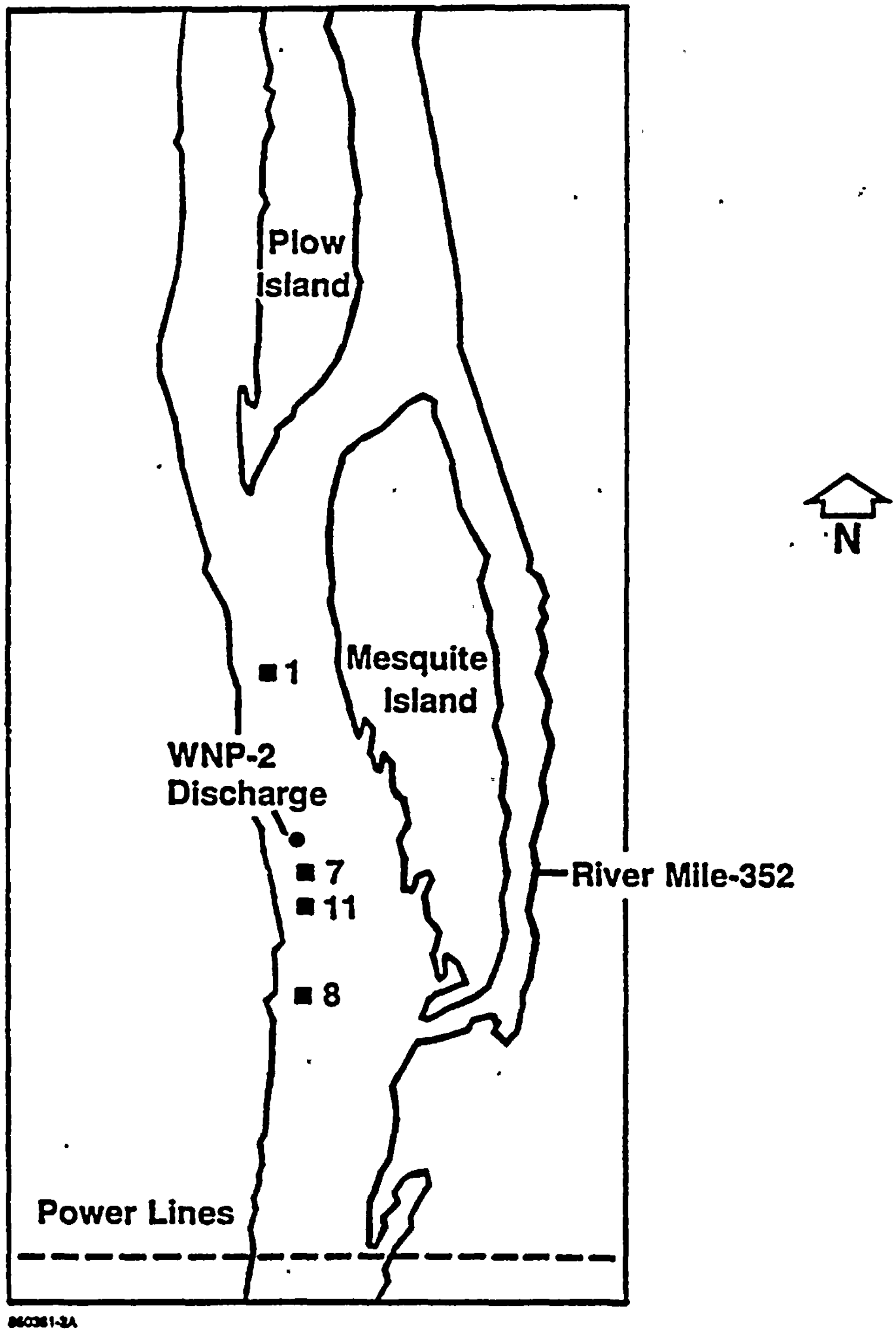


Figure 3-1. Location of Sampling Stations in the Columbia River

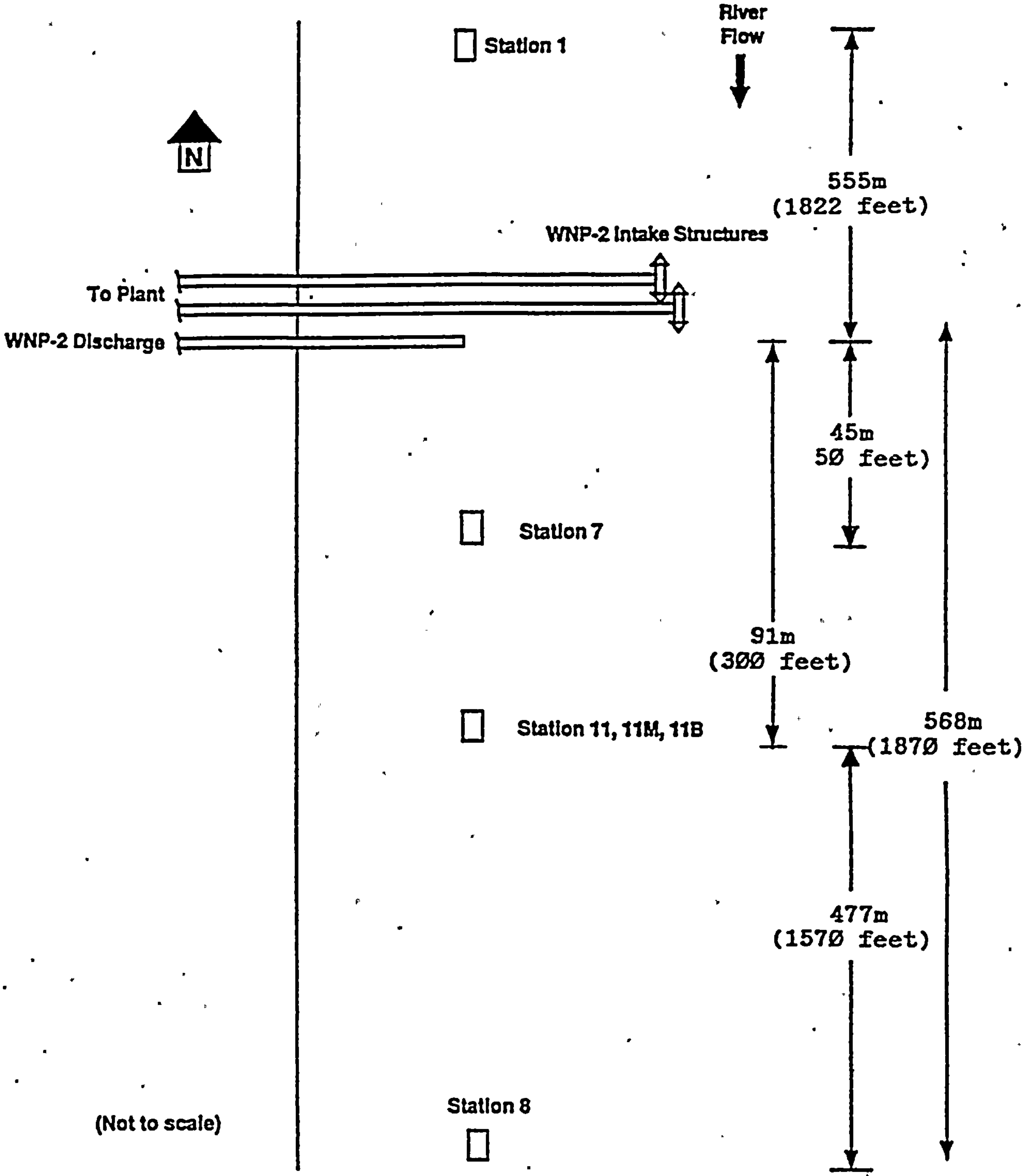


Figure 3-2. Schematic of River Sample Locations for Water Chemistry

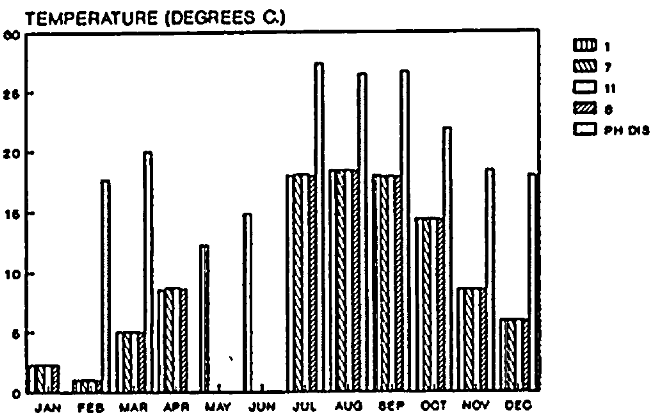


Figure 3-3. Columbia River and WNP-2 Blowdown Temperature Measurements During 1993

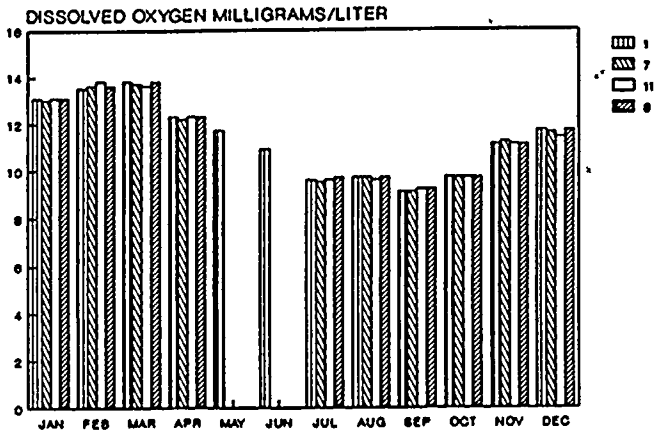


Figure 3-4. Columbia River Dissolved Oxygen Measurements at Four Stations During 1993

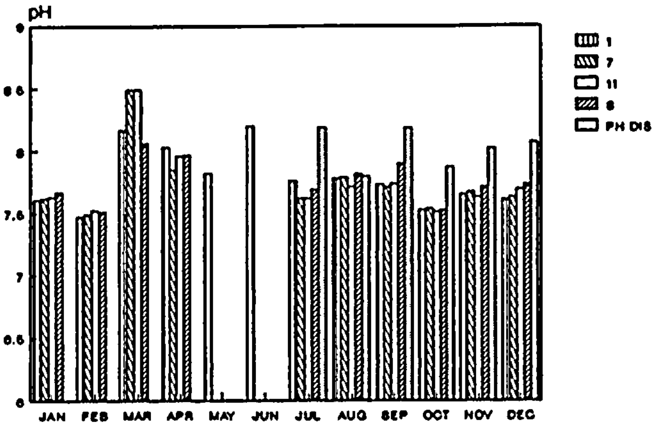


Figure 3-5. Columbia River and WNP-2 Blowdown pH Measurements During 1993

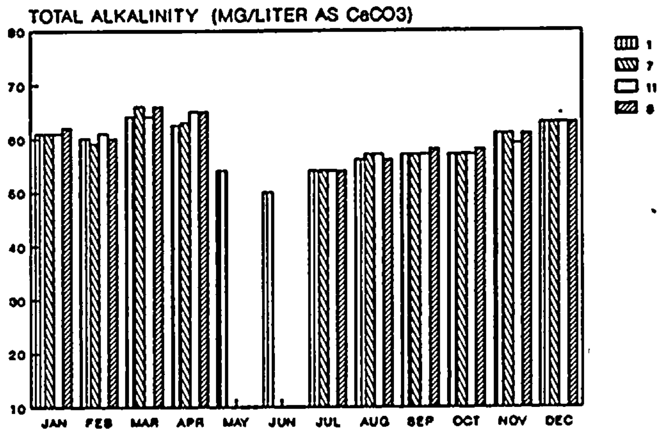


Figure 3-6. Columbia River Total Alkalinity Measurements at Four Stations During 1993

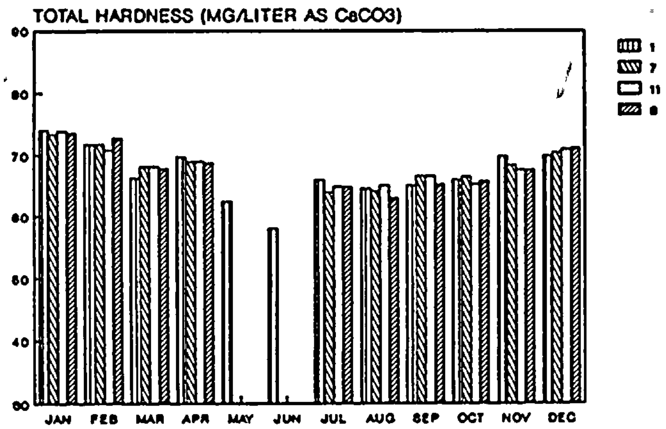


Figure 3-7. Columbia River total Hardness Measurements at Four Stations During 1993

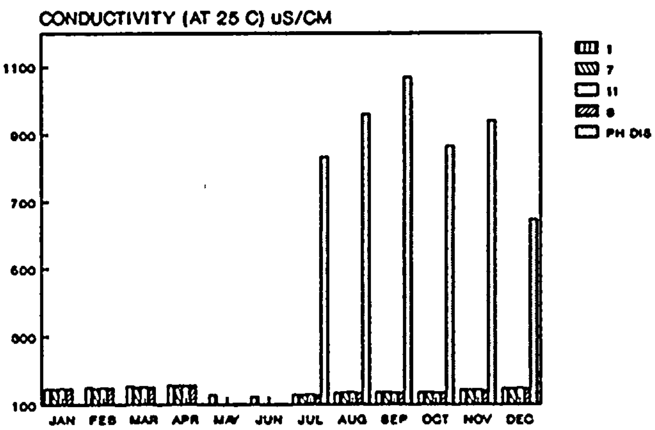


Figure 3-8. Columbia River and WNP-2 Blowdown Conductivity Measurements During 1993

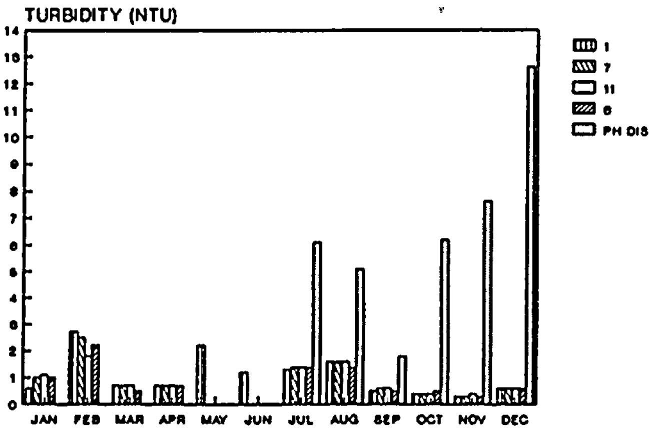


Figure 3-9. Columbia River and WNP-2 Blowdown Turbidity Measurements During 1993

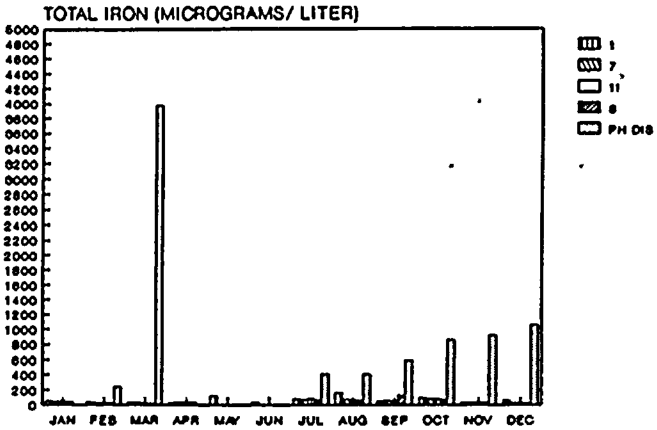


Figure 3-10. Columbia River and WNP-2 Blowdown Total Iron Measurements During 1993

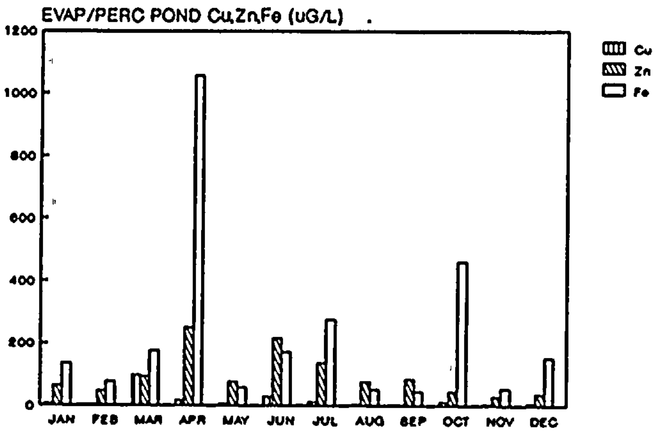


Figure 3-11. Evaporation/Percolation Pond Total Metals Measurements During 1993

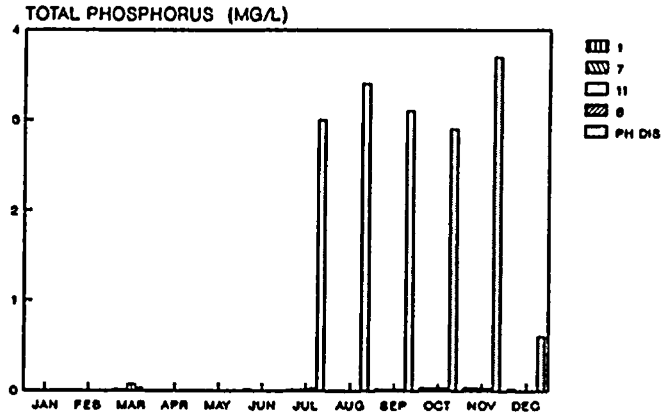


Figure 3-12. Columbia River and WNP-2 Blowdown Total Phosphorus Measurements During 1993

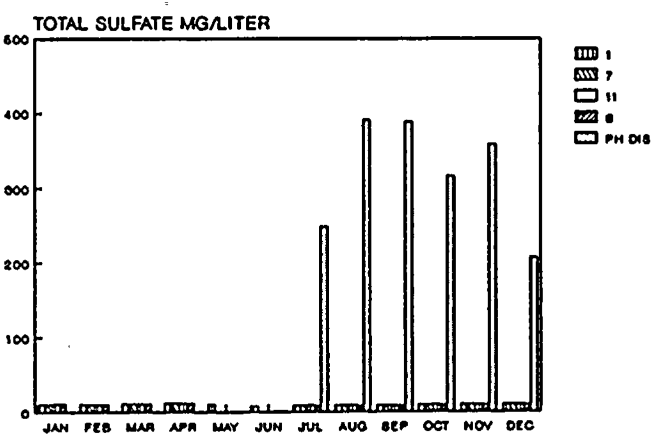


Figure 3-13. Columbia River and WNP-2 Blowdown Total Sulfate Measurements During 1993

4.0 SOIL AND VEGETATION STUDIES

4.1 INTRODUCTION

The soil and vegetation studies were designed to identify any impact of cooling tower operation upon the surrounding plant communities, as well as any edaphic impacts. All vegetation sampling is conducted in May or at the peak of the cheatgrass growth cycle known as the purple stage (Klemmedson 1964). The program includes the measurement of herbaceous canopy cover, herbaceous phytomass, and soil chemistry. Soil chemical parameters measured include pH, carbonate, bicarbonate, sulfate, chloride, sodium, copper, zinc, and conductivity. This study provides operational data for comparison with preoperational data.

Fifteen sampling stations are located within the sampling area. The fifteen stations consist of eight grassland sites (G01-G08) and seven shrub sites (S01-S07). Figure 4-1 shows the location of each station. The orientation of the various components including transects and productivity plots within each community are depicted in Figure 4-2.

4.2 MATERIALS AND METHODS

4.2.1 Herbaceous Canopy Cover

Fifty microplots (20 cm x 50 cm) were placed at 1-m intervals on alternate sides of the herbaceous transect (Figure 4-2). 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.

4.2.2 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 4-2). 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 singularly 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.

4.2.3 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. Nine parameters were analyzed in each sample including pH, bicarbonate, carbonate, conductivity, sulfate, chloride, copper, zinc, and sodium. Samples were analyzed for pH, bicarbonate, carbonate, chloride and conductivity according to Methods of Soil Analysis (1965). Samples were analyzed for sulfate and chloride according to EPA 300.0. Copper, zinc and sodium were analyzed by inductively coupled plasma emission spectroscopy, (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 procedures (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.

4.3 RESULTS AND DISCUSSION

During the 1993 season, 54 plant taxa were observed in the study area. A new species of forb was observed at Station G01. A sample of the plant is currently in the process of being identified. Plant taxa observed in 1993 are presented in Table 4-1. Table 4-2 lists by year the species of vascular plants observed during field activities from 1975-1993. Many of the graphs will depict a preoperational, operational and 1993 status. The preoperational data was collected annually prior to WNP-2 becoming fully operational (1980-1984). Operational data was collected after 1984 but does not include the current year (1993), which is listed separately.

4.3.1 Herbaceous Cover

Herbaceous cover data for 1993 are summarized in Tables 4-3 and 4-4. Figures 4-3 and 4-4 provide a comparison of grassland and shrub sites (annual grasses - AG, perennial grasses - PG, annual forbs - AF, and perennial forbs - PF) respectively, with the data of previous years. Total herbaceous cover averaged 84.08% in 1993 which represents an increase of 14.60% from 1992 (73.38%). As in previous years, the dominant annual grass is Bromus tectorum with 45.79% cover, a 4.35% increase over last year. Poa sandbergii is the dominant perennial grass at thirteen of the stations. Oryzopsis hymenoides averaged 0.04% cover, a 100% increase over last year (0.02%).

Total annual forb cover increased by 5.18% over 1992. Holosteum umbellatum was the dominant species with 4.69% followed by Draba verna (3.19%). Microsteris gracilis (0.76%) increased 100% over last year (0.38%).

Perennial forb cover for 1993 is 4.68%. The perennial forb cover continues to increase as demonstrated by a 42.68% increase over 1992 (3.28%). The dominant species is Oenothera pallida (1.81%) followed by Cymopterus terebinthinus (0.87%). Comandra umbellata (0.09%) increased 350% from 1992 (0.02%).

Species frequency values (%) continue to increase for annual forbs (Table 4-5). The annual forbs with the highest frequency values were Holosteum umbellatum with 100% at stations G06 and S03, and Draba verna with 100% at stations G03 and S03. The greatest diversity of species continues to be observed at station S02 (20). The most significant change in total species per site was observed at station G05. Thirteen species were observed in 1993, a decrease of 5 species from 1992 (18). The most significant increase was at station G03, increasing by 4 species from 1992 (7).

Growing season (October 92 - April 93) precipitation increased 53.79% above the 1991-1992 growing season (12.14 cm versus 18.67 cm). The three growing season months (January, February and March) of 1993 produced 7.98 cm or 40.12% of the total precipitation (19.88 cm) for the calendar year. Mean temperature during the growing season was 4.30°C with the average temperature for the year being 11.01°C.

4.3.2 Herbaceous Phytomass

Mean production of herbaceous phytomass in 1993 was 140.3 g/m^2, a 44.79% increase from the previous year (96.9 g/m^2). At grassland and shrub stations the phytomass production averaged 121.4 g/m^2 and 159.2 g/m^2 respectively. Mean herbaceous phytomass production at grassland stations and at shrub stations for 1975 through 1993 is shown graphically in Figure 4-5 (stations G05, G06, G07, G08, S06 and S07 were not added until 1989) and is summarized in Table 4-6. Table 4-7 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 1993 are presented graphically in Figures 4-6 through 4-9.

4.3.3 Soil Chemistry

The results of the 1993 soil chemical analyses are presented in Table 4-8 and are shown graphically in Figures 4-10 through 4-13.

Most metallic element concentrations were within the ranges observed in previous years. Bicarbonate was similar to that observed in past data. Conductivity was generally within previous ranges at all stations. There is no carbonate present due to the pH level of the samples (< 8.3). There was no significant change in pH at any of the stations. Chloride and sulfate concentrations were within their expected ranges.

No adverse trends or impacts upon soil chemistry or vegetation are apparent from the operation of WNP-2.

Table 4-1. Vascular Plants Observed During 1993

	Common Name
APIACEAE	Parsley Family
Cymopterus terebinthinus (Hook.) T.&G. var. terebinthinus	Turpentine cymopterus
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 leucophaea (Dougl.) Pays.	
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
CARYOPHYLLACEAE	Pink Family
Arenaria franklinii Dougl. var. franklinii	Franklin's sandwort
Holosteum umbellatum L.	Jagged chickweed

Table 4-1. (Continued)

	Common Name
CHENOPODIACEAE	Chenopod Family
Chenodium leptophyllum (MOQ.) Wats.	Slimleaf goosefoot
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
GERANIACEAE	
Erodium cicutarium (L.) L'Her	Alfifaria, filaree, storks-bill
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.	White-stemmed mentzelia
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach	White-stemmed globe-mallow
ONAGRACEAE	Evening-primrose Family
Oenothera pallida Lindl. var. *pallida*	White-stemmed evening-primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat

Table 4-1. (Continued)

	Common Name
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
Leptodactylon pungens (Torr.) Nutt.	Granite 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 4-1. (Continued)

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

Table 4-2. Vascular Plants Observed During 1975-1993 Field Work

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Annual Grasses																			
Bromus tectorum	X	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	X
Festuca sp.		X		X															
Perennial Grasses																			
Agropyron cristatum							X	X	X	X	X	X	X	X	X	X	X	X	X
Agropyron dasystachyum			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	X
Koeleria cristata				X		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	X
Poa sandbergii							X	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	X
Stipa comata		X		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	X
Amsinckia lycopsoides	X	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	X
Cryptantha pterocarya		X		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	X
Descurainia pinnata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 4-2. (Cont'd)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Draba verna	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Epilobium paniculatum	X	X	X	X	X														
Erodium circutarium																			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	X
Lagophylla ramosissima						X													
Layia glandulosa			X		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	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	X
Phacelia sp.		X																	
Plantago patagonica	X	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	X
Sisymbrium altissimum	X	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	X
Perennial Forbs																			
Achillea millefolium	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 4-2. (Cont'd

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Antennaria dimorpha						X	X	X	X	X	X	X	X	X	X	X	X	X	
Arenaria franklinii var. franklinii						X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aster canescens																			X
(Machaeranthera canescens)		X			X				X	X	X	X	X	X	X	X	X	X	X
Astragalus lyallii			X																X
Astragalus purshii	X	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	X
Astragalus sp.				X															
Balsamorhiza careyana	X	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	X
Brodiaea howellii				X															
Calochortus macrocarpus	X				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	X
Crepis atrabarba		X	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	X
Delphinium sp.				X					X	X	X	X	X	X	X	X	X	X	
Erigeron divergens								X											
Fritillaria pudica									X	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	X

Table 4-2. (Cont'd

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Penstemon acuminatus							X	X	X	X	X	X	X	X	X	X	X	X	X
Penstemon sp.						X													
Phlox longifolia	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Psoralea lanceolata	X	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	X
Sphaeralcea munroana								X	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	X
Chrysothamnus nauseosus	X	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	X
Eriogonum niveum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grayia spinosa															X		X	X	X
Leptodactylon pungens									X	X									X
Opuntia polyacantha	X			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	X
Ribes aureum											X	X	X	X	X	X	X	X	X

Table 4-3. Herbaceous Cover for Fifteen Sampling Stations - 1993

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07	AVG. G01-S07	AVG. G01-G04	AVG. S01-S05	AVG. G01-4, S01-5
Annual Grasses																			
Bromus tectorum	46.90	68.65	43.40	29.20	38.20	28.45	68.85	59.60	27.70	34.65	53.45	57.95	48.20	23.65	57.95	45.79	47.04	44.39	45.71
Festuca octoflora	0.00	0.00	0.00	0.00	0.15	0.45	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.06	0.00	0.06	0.03
Total Annual Grass Cover	46.90	68.65	43.40	29.20	38.35	28.90	68.85	59.60	27.70	34.65	53.45	58.25	48.20	23.65	57.95	45.85	47.04	44.45	45.74
Perennial Grasses																			
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	0.00	0.00	1.70	0.00	0.00	0.26	0.00	0.79	0.40
Oryzopsis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.13	0.07
Poa sandbergii	48.25	23.35	2.00	26.40	31.40	4.70	12.25	14.55	7.15	16.49	16.25	12.85	0.00	43.45	23.15	11.17	25.00	10.55	17.77
Stipa comata	0.00	0.00	0.00	19.70	0.00	10.70	0.00	1.80	0.00	2.75	0.00	0.00	2.30	2.65	0.00	2.66	4.93	1.01	2.97
Total Perennial Grass Cover	48.25	23.35	2.00	46.10	31.40	15.40	12.25	16.35	7.15	22.14	16.25	12.85	4.00	46.10	23.15	21.78	29.93	12.48	21.20
Annual Forbs																			
Amsinckia lycopsoides	0.05	0.00	2.35	0.00	0.50	0.00	1.65	0.00	3.40	0.65	0.00	0.00	1.50	0.00	2.10	0.81	0.60	1.11	0.86
Brodiaea douglasii	0.00	0.00	0.15	0.10	0.00	0.00	0.05	0.20	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.01	0.04
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cryptantha circumscissa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.01	0.00	0.02	0.01
Descurainia pinnata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.55	0.06	0.00	0.04	0.02
Draba verna	5.10	4.45	11.75	4.45	3.40	1.90	3.00	2.05	2.65	0.95	3.00	2.80	2.25	0.05	0.05	3.19	6.44	2.33	4.38
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
Franseria acanthicarpa	0.00	0.00	1.05	0.00	0.00	0.20	0.10	0.00	0.00	0.25	0.05	0.05	0.10	0.00	0.00	0.12	0.26	0.09	0.18
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	6.65	0.70	3.40	3.15	6.50	11.10	8.25	6.52	4.40	5.95	4.25	4.85	4.65	0.00	0.00	4.69	3.48	4.82	4.15
Layia glandulosa	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
Mentzelia albicaulis	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
Microsteris gracilis	0.05	0.25	3.00	0.05	0.25	1.65	0.30	0.10	1.65	0.10	0.95	1.15	1.85	0.00	0.00	0.76	0.84	1.14	0.99
Phacelia linearis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.25	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.11	0.06
Plantago patagonica	1.60	0.35	0.00	2.40	0.00	0.00	0.00	0.05	0.00	0.05	4.55	0.00	0.50	0.00	1.30	0.72	1.09	1.02	1.05
Salsola kali	0.00	0.05	0.05	0.00	0.25	1.35	0.00	0.00	0.00	0.25	0.00	0.75	0.05	0.00	0.00	0.18	0.03	0.21	0.12
Sisymbrium altissimum	0.00	0.15	0.85	0.05	0.00	0.25	0.10	0.10	0.50	0.20	0.10	4.95	2.25	2.00	5.85	1.16	0.26	1.60	0.93
Total Annual Forb Cover	13.45	5.95	22.60	10.20	10.90	16.45	13.45	9.02	12.95	8.70	12.90	14.80	13.25	2.15	9.85	11.77	13.05	12.52	12.79
Perennial Forbs																			
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.13	0.07
Aster canescens	0.00	0.00	0.00	0.30	0.00	0.30	0.40	0.00	2.70	0.30	0.00	0.00	0.00	0.00	0.00	0.27	0.08	0.60	0.34
Astragalus purshii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.09	0.00	0.21	0.11
Balsamorhiza careyana	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.00	7.25	0.30	0.00	0.00	0.61	0.00	1.51	0.76
Comandra umbellata	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	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	2.25	0.00	0.00	0.00	0.00	0.15	0.00	0.45	0.23
Cymopterus terebinthinus	1.35	0.00	0.00	0.00	0.00	4.85	0.30	0.00	0.00	6.45	0.00	0.00	0.00	0.00	0.05	0.87	0.34	1.29	0.81
Eriogonum niveum	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.45	0.00	0.00	0.48	0.00	1.29	0.65
Oenothera pallida	0.00	0.00	0.75	1.50	2.00	1.75	0.45	4.15	10.65	5.25	0.00	0.00	0.65	0.00	0.00	1.81	0.56	3.31	1.94
Phlox longifolia	0.00	0.00	0.00	0.35	1.70	0.00	0.10	0.35	0.35	0.10	0.35	0.00	0.00	0.05	0.00	0.22	0.09	0.16	0.12
Rumex venosus	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	0.00	0.01	0.00	0.01
Tragopogon dubius	0.05	0.00	0.00	0.00	0.00	0.05	0.30	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.05	0.01	0.06	0.04
Total Perennial Forb Cover	1.45	0.00	0.75	2.15	5.85	8.85	1.55	4.50	13.70	12.70	2.60	8.65	7.40	0.05	0.05	4.68	1.09	9.01	5.06
Total Herbaceous Cover	110.05	97.95	68.75	87.65	86.50	69.60	96.10	89.47	61.50	78.19	85.20	94.55	72.85	71.95	91.00	84.09	91.10	78.46	84.78

Table 4-4. Mean Herbaceous Cover for 1975 through 1993

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 4-4. Mean Herbaceous Cover for 1975 through 1993 (continued)

CLASS	YEAR	S01	S02	S03	S04	S05	S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
AG	1983	53.80	37.60	33.65	36.75	31.85	38.73			38.73	49.50	39.55	62.75	17.55	42.35					42.34	40.33	40.33
PG	1983	2.15	7.70	14.45	6.40	1.29	6.40			6.40	2.10	15.75	0.00	25.50	10.84					10.84	8.37	8.37
AF	1983	8.20	7.85	12.55	3.45	22.35	10.88			10.88	18.70	8.85	8.65	6.65	10.71					10.71	10.81	10.81
PF	1983	0.70	3.10	1.05	4.40	1.95	2.24			2.24	0.65	0.05	2.10	4.00	1.70					1.70	2.00	2.00
ALL	1983	64.85	56.25	61.70	51.00	57.44	58.25			58.25	70.95	64.20	73.50	53.70	65.59					65.59	61.51	61.51
AG	1984	41.50	32.75	39.35	36.30	36.50	37.28			37.28	60.85	71.30	60.85	9.60	50.65					50.65	43.22	43.22
PG	1984	1.85	8.80	11.55	8.55	0.40	6.23			6.23	1.20	4.45		25.00	10.22					10.22	6.87	7.73
AF	1984	12.35	8.10	11.10	4.00	13.40	9.79			9.79	20.65	9.70	19.45	7.95	14.44					14.44	11.86	11.86
PF	1984	0.30	4.00	0.75	6.55	0.65	2.45			2.45	0.70	0.20	1.10	1.25	0.81					0.81	1.72	1.72
ALL	1984	56.00	53.65	62.75	55.40	50.95	55.75			55.75	83.40	85.65	81.40	43.80	73.56					73.56	63.67	63.67
AG	1985	2.10	2.15	14.60	4.95	27.05	10.17			10.17	8.00	8.10	18.30	7.25	10.41					10.41	10.28	10.28
PG	1985	1.05	4.70	17.85	2.40	1.85	5.57			5.57	9.20	17.95	0.00	13.90	10.26					10.26	7.66	7.66
AF	1985	0.70	1.35	9.40	2.30	4.75	3.70			3.70	18.20	8.15	7.55	3.05	9.24					9.24	6.16	6.16
PF	1985	0.00	1.35	1.15	3.00	0.25	1.15			1.15	0.80	0.10	2.35	0.90	1.04					1.04	1.10	1.10
ALL	1985	3.85	9.55	43.00	12.65	33.90	20.59			20.59	36.20	34.30	28.20	25.10	30.95					30.95	25.19	25.19
AG	1986	17.45	1.95	7.20	11.45	13.05	10.22			10.22	9.40	4.65	13.25	7.35	8.66					8.66	9.53	9.53
PG	1986	2.20	10.75	17.25	9.85	1.30	8.27			8.27	19.85	38.65	0.00	26.00	21.13					21.13	13.98	13.98
AF	1986	25.40	16.65	38.10	10.25	16.70	21.42			21.42	27.65	34.15	25.45	8.70	23.99					23.99	22.56	22.56
PF	1986	1.15	5.35	2.30	9.15	1.25	3.84			3.84	1.80	1.95	0.05	2.55	1.59					1.59	2.84	2.84
ALL	1986	46.20	34.70	64.85	40.70	32.30	43.75			43.75	58.70	79.40	38.75	44.60	55.36					55.36	48.91	48.91
AG	1987	28.90	9.95	7.80	19.05	33.40	19.82			19.82	23.85	9.45	51.65	4.65	22.40					22.40	20.97	20.97
PG	1987	3.60	21.90	42.65	19.55	2.30	18.00			18.00	32.45	58.79	0.05	45.95	34.31					34.31	25.25	25.25
AF	1987	12.56	8.50	10.80	6.55	11.40	9.96			9.96	10.30	11.32	14.00	3.25	9.72					9.72	9.85	9.85
PF	1987	5.00	6.00	2.00	10.40	1.75	5.03			5.03	0.90	1.90	0.15	1.55	1.13					1.13	3.29	3.29
ALL	1987	50.06	46.35	63.25	55.55	48.85	52.81			52.81	67.50	81.46	65.85	55.40	67.55					67.55	59.36	59.36
AG	1988	13.80	5.05	8.10	13.80	10.15	10.18	10.40	12.24	10.51	22.95	10.10	16.75	4.80	13.65	11.95	19.20	15.85	10.40	14.00	12.32	11.72
PG	1988	1.75	8.40	11.95	9.40	3.35	6.97	16.85	17.50	9.89	17.85	21.70	0.05	30.20	17.45	9.50	12.05	10.45	14.30	14.51	12.34	11.63
AF	1988	6.08	5.25	3.60	3.10	4.00	4.41	0.00	0.35	3.20	6.30	16.15	7.55	1.80	7.95	1.20	1.45	12.35	6.12	6.61	5.16	5.98
PF	1988	11.55	15.75	2.10	4.85	3.25	7.50	0.10	0.00	5.37	0.20	2.00	0.00	4.40	1.65	15.25	8.70	2:45	4.34	4.34	4.79	4.90
ALL	1988	33.18	34.45	25.75	31.15	20.75	29.06	27.35	30.09	28.96	47.30	49.95	24.35	41.20	40.70	37.90	41.40	41.10	32.52	39.47	34.60	34.23
AG	1989	21.85	12.50	12.45	10.25	32.90	17.99	15.00	47.65	21.80	22.50	13.20	65.85	3.05	26.15	22.35	35.10	38.05	12.05	26.52	24 05	21.62
PG	1989	8.30	29.55	64.00	13.00	1.25	23.22	30.35	37.50	26.28	60.40	59.60	0.05	49.55	42.40	36.75	16.20	32.05	48.95	37.94	32.54	31.74
AF	1989	12.50	6.95	13.05	6.45	11.10	10.01	0.85	5.15	8.01	12.85	5.90	42.20	2.85	15.95	8.85	13.55	13.05	13.95	14.15	11.48	12.65
PF	1989	4.45	14.50	4.40	8.20	0.55	6.42	0.10	0.00	4.60	3.85	1.10	0.05	3.00	2.00	6.45	10.40	12.90	10.60	6.04	5.23	4.46
ALL	1989	47.10	63.50	93.90	37.90	45.80	57.64	46.30	90.30	60.69	99.60	79.80	108.15	58.45	86.50	74.40	75.25	96.05	85.55	84.66	73.31	70 47
AG	1990	36.80	16.80	17.50	32.40	53.35	31.37	12.90	5.45	25.03	18.60	7.75	61.55	13.65	25.39	23.80	35.45	36.55	19.75	27.01	26.06	28.71
PG	1990	3.30	12.85	18.35	12.70	0.05	9.45	18.40	17.55	11.89	18.70	0.00	0.00	30.00	12.18	11.90	10.70	9.30	12.10	11.59	11.73	10.66
AF	1990	7.95	2.60	8.15	4.55	8.90	6.43	0.10	0.00	4.61	7.75	2.35	15.70	3.35	7.290.	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	41.70	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
AG	1993	27.70	34.65	53.45	58.25	48.20	44.45	23.65	57.95	43.41	46.90	68.65	43.40	29.20	47.04	38.35	28.90	68.85	59.60	47.98	45.85	45.74
PG	1993	7.15	22.14	16.25	12.85	4.00	12.48	46.10	23.15	18.81	48.25	23.35	2.00	46.10	29.93	31.40	15.40	12.25	16.35	24.39	21.78	21.2
AF	1993	12.95	8.70	12.90	14.80	13.25	12.52	2.15	9.85	10.66	13.45	5.95	22.60	10.20	13.05	10.90	16.45	13.45	9.02	12.75	11.77	12.79
PF	1993	13.70	12.70	2.690	8.65	7.40	9.01	0.05	0.05	6.45	1.45	0.00	0.75	2.15	1.09	5.85	8.85	1.55	4.50	3.14	4.68	5.05
ALL	1993	58.10	77.49	85.20	94.55	71.35	77.34	71.95	88.90	78.22	110.00	97.95	66.25	87.55	90.44	86.00	69.60	94.40	89.27	87.63	84.08	83.89

Table 4-5. Mean Frequency Values (%) by Species for Each Sampling Station - 1993

	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	92	100	100	100	96	100
Festuca octoflora					6	8						12			
Perennial Grasses															
Agropyron spicatum										12			2		
Oryzopis hymenoides										6					
Poa sandbergii	98	100	4	88	86	18	56	54	28	44	90	36		78	86
Stipa comata				66		28		6		14			6	10	
Annual Forbs															
Amsinckia lycopsoides	2		26		10		46		30	6			30		16
Chenopodium Leptophyllum															
Cryptantha circumscissa									2			2			
Cryptantha pterocarya															
Descurainia pinnata												8		4	12
Draba verna	96	98	100	98	86	56	90	72	96	28	100	72	60	2	2
Erodium cicutarium													2		
Franseria acanthacarpa			42			8	4			10	2	2	4		
Gilia sinuata															
Holosteum umbellatum	90	8	96	68	92	100	96	96	96	60	100	74	90		
Layia glandulosa													2		
Mentzelia albicaulis															
Microsteris gracilis	2	10	70	2	10	66	12	4	46	4	28	26	34		
Phacelia linearis									12	10					
Plantago patagonica	56	14		46				2		2	93		10		12
Salsola kali		2	2		10	54				10		20	2		
Sisymbrium altissimum		6	24	2		10	4	4	10	8	4	60	30	14	52
Tragopogon dubius	2					2	2					2			
Perennial Forbs															
Achillea millefolium										4		2			
Aster canescens				2		2	6		20	2					
Astragalus purshii															
Astragalus sclerocarpus						4						4			
Balsamorhiza careyana					4	4						18	2		
Brodiaea douglasii			6	4			2	8		2					
Comandra umbellata					8										
Crepis atrabarba											6				
Cymopterus terebinthinus	6					20	2			18					2
Eriogonum niveum					2								36		
Oenothera pallida			10	12	12	20	8	30	50	34			6		
Phlox longifolia				4	2		4	4	4	4	4			2	
Rumex venosus	2														
Total Species per Site	10	8	11	12	13	16	14	11	12	20	10	15	16	7	8

Table 4-6. Mean Terrestrial Phytomass for 1993

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/10	G01	6-1	21.4	213.6	05/10	G02	6-1	9.6	95.6	05/05	G03	6-1	3.9	38.7
05/10	G01	7-2	9.1	91.1	05/10	G02	7-2	12.4	123.9	05/05	G03	7-2	6.5	64.9
05/10	G01	26-4	11.8	118.0	05/10	G02	26-4	9.7	97.2	05/05	G03	26-4	8.8	87.5
05/10	G01	31-6	13.7	137.0	05/10	G02	31-6	20.7	207.0	05/05	G03	31-6	7.7	76.5
05/10	G01	45-8	17.1	170.5	05/10	G02	45-8	25.9	259.3	05/05	G03	45-8	8.4	84.0
		AVG	14.6	146.0			AVG	15.7	156.6			AVG	7.0	70.3
		STD	4.3	42.5			STD	6.5	65.4			STD	1.8	17.6

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/11	G04	6-1	8.1	80.6	05/12	G05	6-1	6.6	65.8	05/07	G06	6-1	7.3	72.9
05/11	G04	7-2	6.4	64.1	05/12	G05	7-2	2.5	24.9	05/07	G06	7-2	25.7	257.1
05/11	G04	26-4	6.8	67.9	05/12	G05	26-4	10.4	103.6	05/07	G06	26-4	23.1	231.3
05/11	G04	31-6	12.8	128.1	05/12	G05	31-6	6.7	67.4	05/07	G06	31-6	6.1	61.0
05/11	G04	45-8	20.8	208.3	05/12	G05	45-8	11.5	114.8	05/07	G06	45-8	18.8	187.9
		AVG	11.0	109.8			AVG	7.5	75.3			AVG	16.2	162.0
		STD	5.4	54.3			STD	3.2	31.8			STD	8.1	80.8

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	G07	6-1	11.6	116.0	05/11	G08	6-1	8.0	80.3	05/11	S01	6-1	4.1	40.8
05/12	G07	7-2	15.6	155.6	05/11	G08	7-2	8.4	84.2	05/11	S01	7-2	7.1	71.4
05/12	G07	26-4	7.2	71.5	05/11	G08	26-4	6.9	69.3	05/11	S01	26-4	5.4	53.7
05/12	G07	31-6	7.6	76.4	05/11	G08	31-6	11.4	113.6	05/11	S01	31-6	12.3	123.0
05/12	G07	45-8	33.4	334.1	05/11	G08	45-8	15.4	153.9	05/11	S01	45-8	11.2	112.0
		AVG	15.1	150.7			AVG	10.0	100.3			AVG	8.0	80.2
		STD	9.7	96.6			STD	3.1	30.6			STD	3.2	32.2

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	6-1	7.5	74.5	05/11	S03	6-1	7.6	76.0	05/12	S04	6-1	23.7	237.1
05/14	S02	7-2	2.3	22.8	05/11	S03	7-2	4.0	39.6	05/12	S04	7-2	30.4	303.5
05/14	S02	26-4	5.0	49.8	05/11	S03	26-4	9.1	91.4	05/12	S04	26-4	49.6	495.5
05/14	S02	31-6	18.3	183.4	05/11	S03	31-6	11.9	119.3	05/12	S04	31-6	22.9	228.9
05/14	S02	45-8	9.0	89.8	05/11	S03	45-8	13.2	132.0	05/12	S04	45-8	4.2	42.1
		AVG	8.4	84.1			AVG	9.2	91.7			AVG	26.1	261.4
		STD	5.5	54.6			STD	3.3	32.7			STD	14.6	145.8

DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER	DATE	SITE	PLOT	WT.(g)	WT./SQ. METER
05/14	S05	6-1	23.9	238.5	05/17	S06	6-1	1.3	12.6	05/17	S07	6-1	50.3	502.7
05/14	S05	7-2	19.2	192.0	05/17	S06	7-2	5.4	53.9	05/17	S07	7-2	29.7	297.1
05/14	S05	26-4	20.3	203.3	05/17	S06	26-4	16.2	162.0	05/17	S07	26-4	46.8	467.9
05/14	S05	31-6	15.9	158.8	05/17	S06	31-6	15.3	152.5	05/17	S07	31-6	27.5	274.8
05/14	S05	45-8	7.3	73.0	05/17	S06	45-8	8.7	86.6	05/17	S07	45-8	10.9	109.2
		AVG	17.3	173.1			AVG	9.4	93.5			AVG	33.0	330.3
		STD	5.6	56.2			STD	5.7	57.2			STD	14.3	142.6

Phytomass Summary

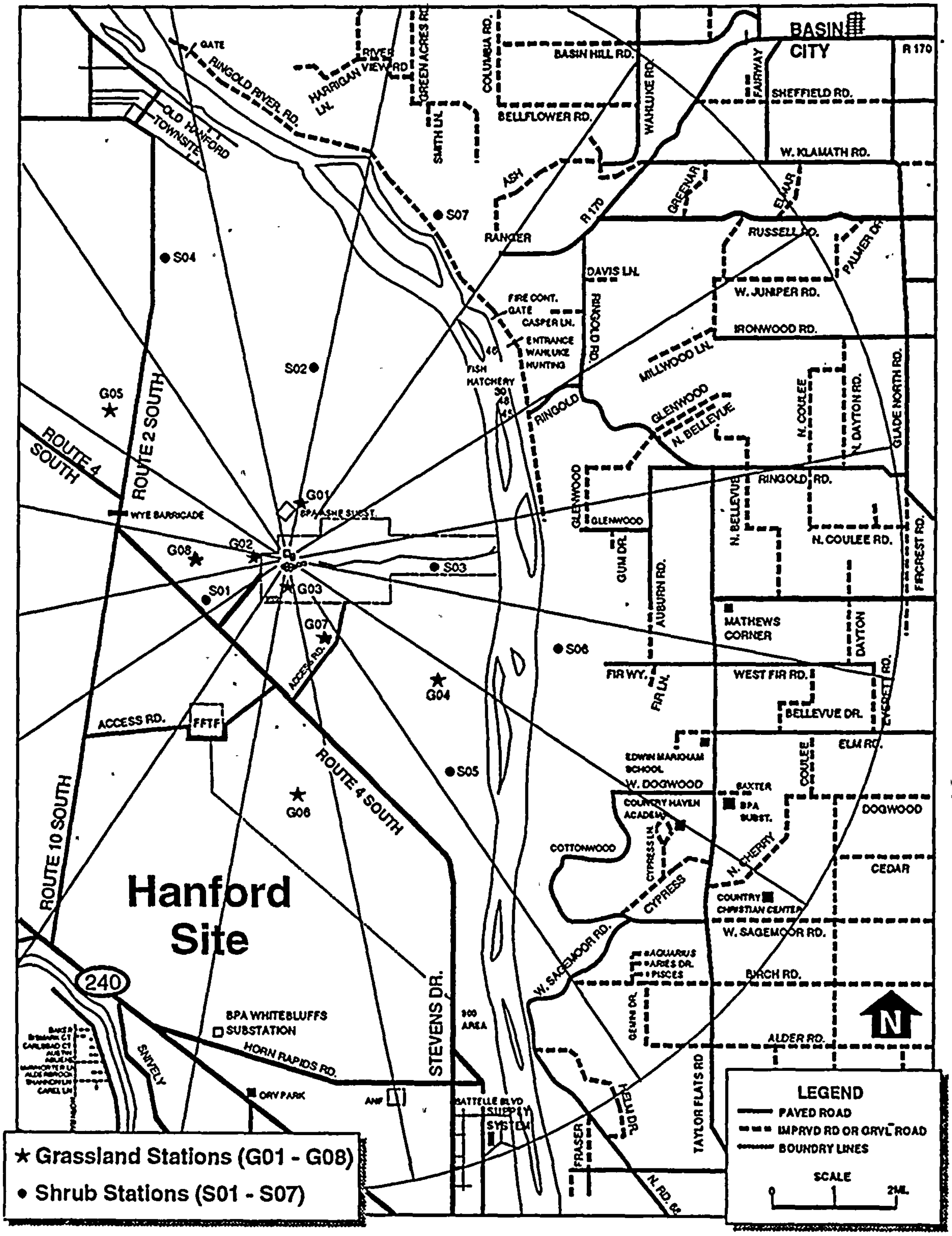
MEAN G01-G08 121.4 Grams/sq. meter
MEAN S01-S07 159.2 Grams/sq. meter

Table 4-7. Comparison of Herbaceous Phytomass (g/m^2) for 1975 through 1993

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
G01	359	108	21	166	64	160	200	90	77	94	70	50	83	34	174.3	13.6	87.7	142.4	146.0
G02	302	258	11	162	37	68	255	60	137	116	27	61	77	14	65.7	4.1	97.2	109.4	156.6
G03	-	-	-	-	-	53	261	62	64	133	12	32	134	16	105.1	64.0	161.6	82.7	70.3
G04	-	-	-	-	-	79	159	113	82	67	37	35	90	61	49.5	73.2	67.6	60.0	109.8
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43.2	36.8	171.8	54.4	75.3
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61.0	39.8	101.4	49.4	162.0
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113.1	29.1	168.4	101.4	150.7
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	112.3	10.0	137.3	74.3	100.3
S01	126	137	4	173	21	36	180	98	171	104	5	35	62	59	53.9	32.8	225.1	49.2	80.2
S02	144	98	7	128	28	63	115	24	232	57	1	112	144	73	72.8	78.3	58.2	147.5	84.1
S03	88	177	7	115	16	43	31	22	54	95	27	25	48	15	67.0	28.2	87.6	90.7	91.7
S04	-	-	-	-	-	78	52	39	68	93	11	176	108	24	39.8	30.9	185.2	80.3	261.4
S05	-	-	-	-	-	71	81	184	136	43	61	42	145	19	103.7	43.4	111.3	110.3	173.1
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72.7	34.0	225.1	101.3	93.5
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	149.5	6.1	226.0	187.3	330.3

Table 4-8. Summary of Soil Chemistry for 1993

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
pH (1:2 soil-water)	7.11	6.91	6.80	6.69	6.88	7.14	6.91	7.11	6.82	7.53	7.13	7.17	7.01	7.19	7.84
Conductivity (1:2 soil-water) microsiemens/cm	26.50	24.50	45.00	13.50	18.50	19.00	30.00	13.50	23.00	21.50	20.00	19.00	30.50	31.50	89.00
Sulfate ug/gm	5.16	3.09	3.99	2.10	2.20	2.04	2.33	1.60	1.30	1.38	1.10	1.28	1.96	1.35	1.59
Chloride ug/gm	4.00	3.00	9.00	2.00	4.00	2.00	4.00	2.00	9.00	12.00	9.00	5.00	1.00	9.00	12.00
Copper ug/gm	12.00	10.00	10.00	8.00	9.00	9.00	11.00	7.00	7.00	6.00	8.00	8.00	8.00	7.00	15.00
Zinc ug/gm	55.00	52.00	50.00	46.00	40.00	41.00	50.00	36.00	37.00	25.00	44.00	40.00	40.00	38.00	56.00
Sodium %	0.0345	0.0340	0.0265	0.0295	0.0225	0.0250	0.0300	0.0250	0.0260	0.0205	0.0380	0.0395	0.0285	0.0200	0.0335
Bicarbonate (meq/HC03/gm)	0.0020	0.0026	0.0030	0.0014	0.0018	0.0018	0.0028	0.0014	0.0022	0.0026	0.0026	0.0018	0.0028	0.0034	0.0136



880334.19 Map
July 1993

Figure 4-1. Soil and Vegetation Sampling Location Map

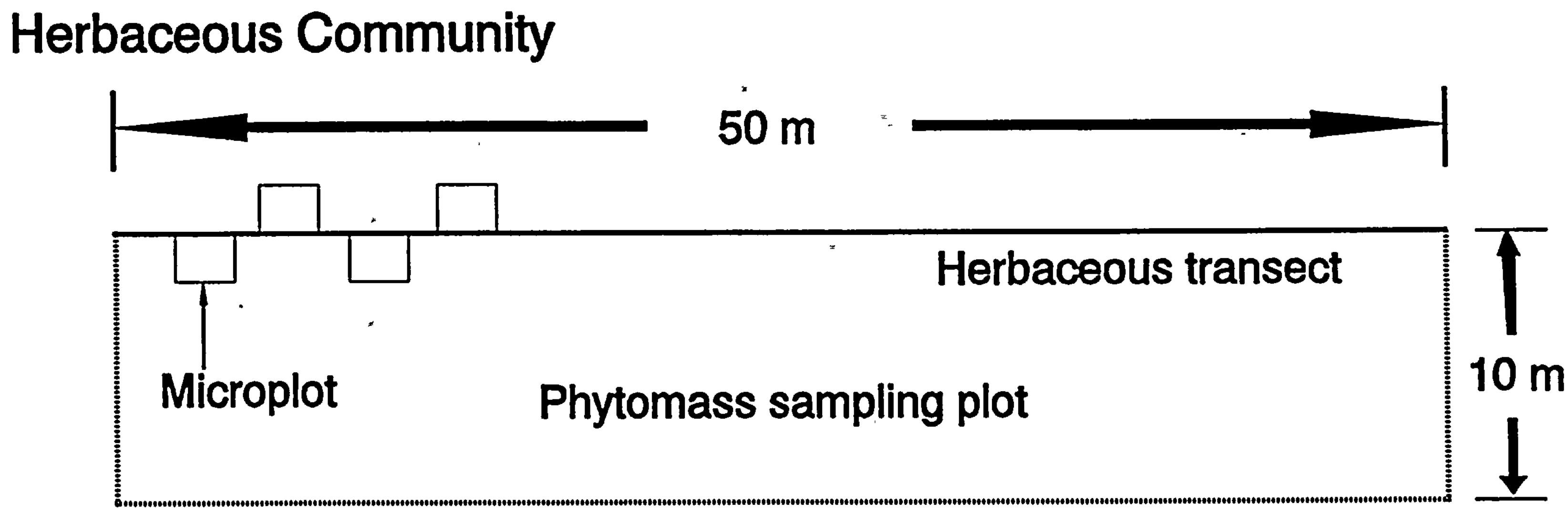


Figure 4-2. Layout of Vegetation and Soil Sampling Plots

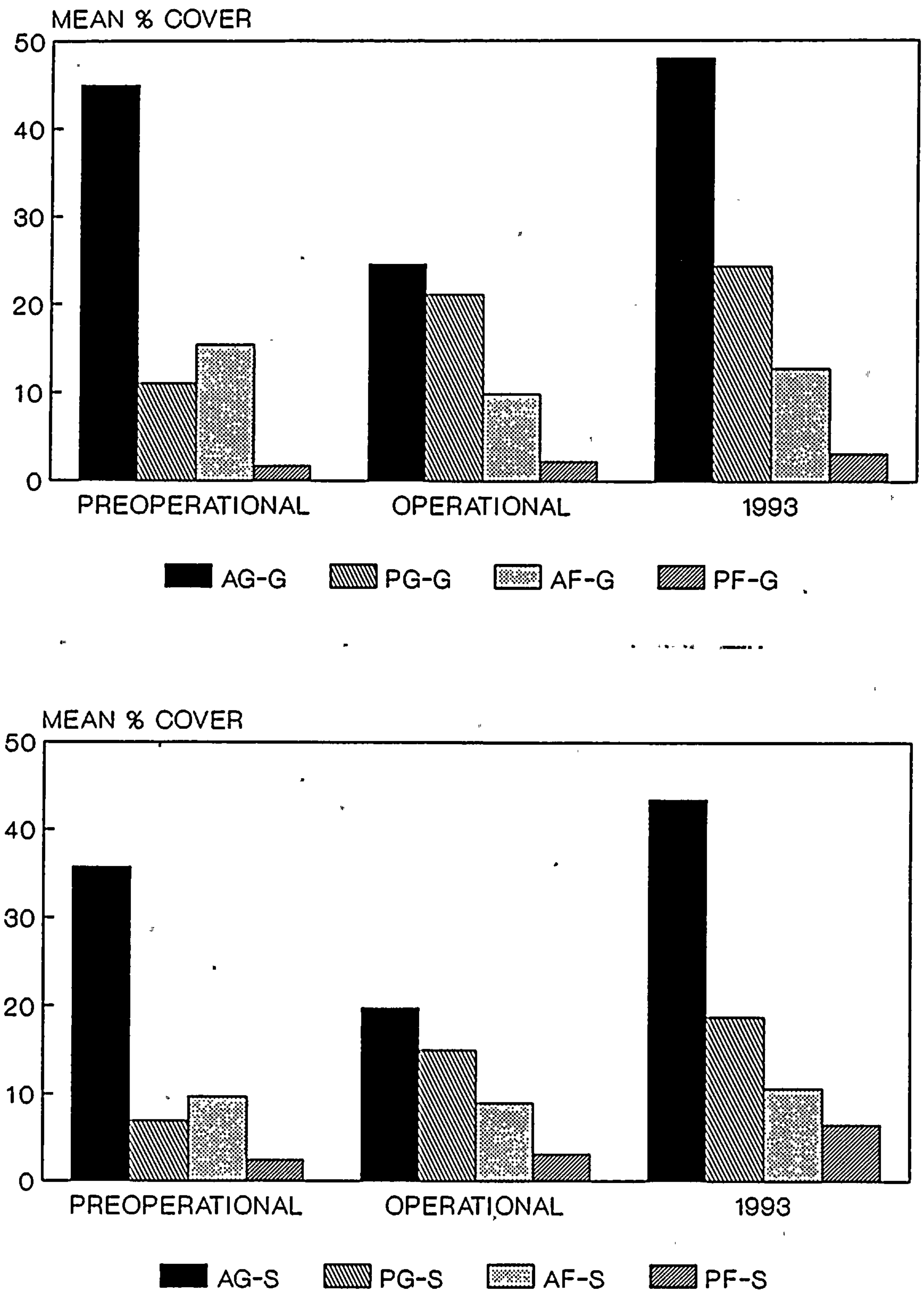


Figure 4-3. Mean Herbaceous Cover for 1975 through 1993

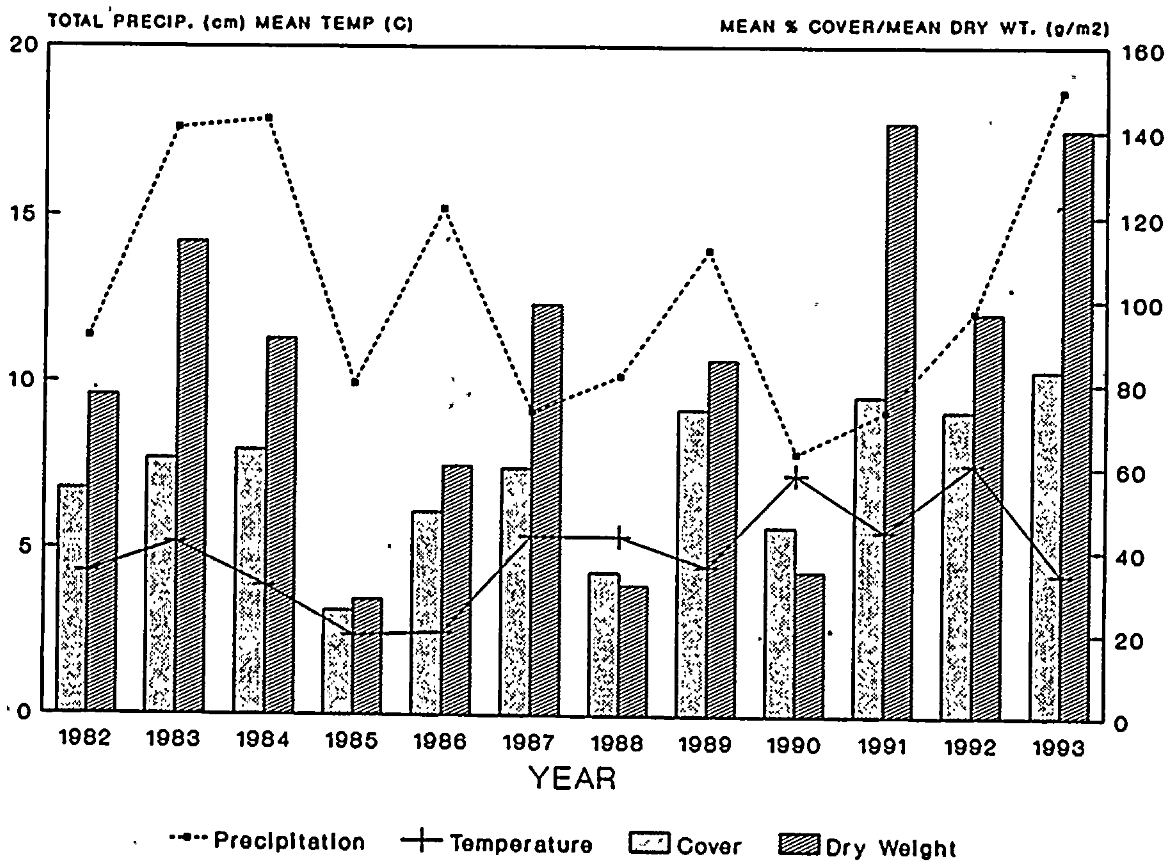
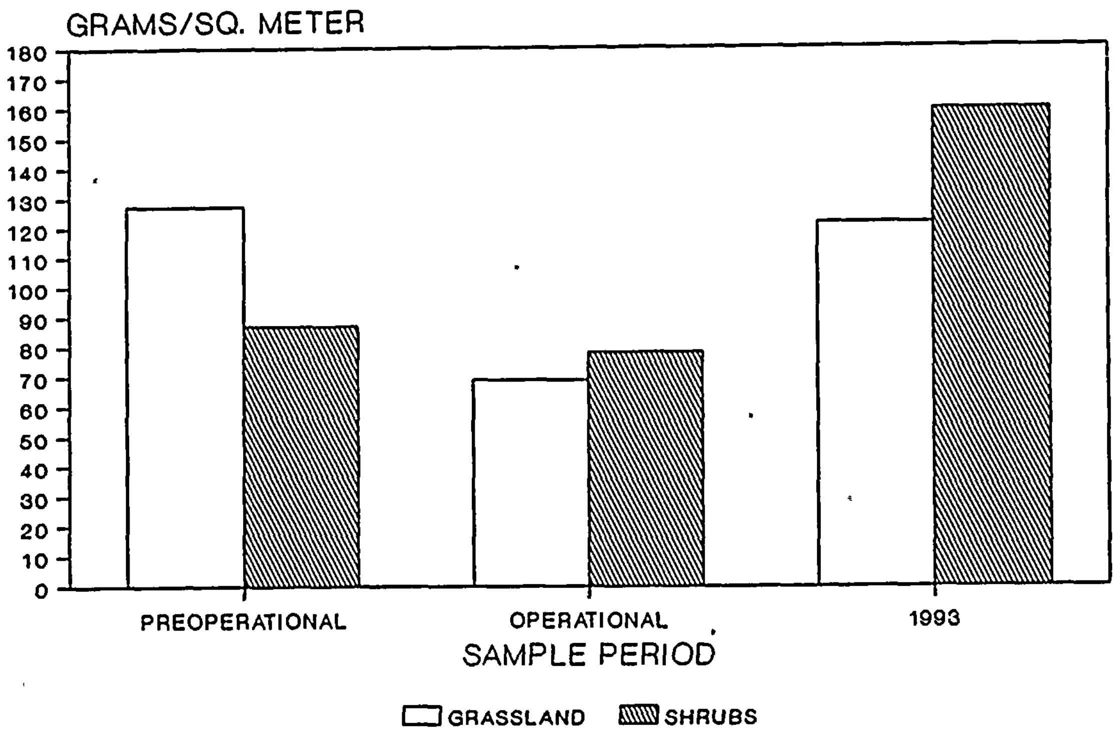


Figure 4-4. Mean Herbaceous Cover, Mean Dry Weight (g/m^2), Total Precipitation, and Mean Temperature from 1982 through 1993



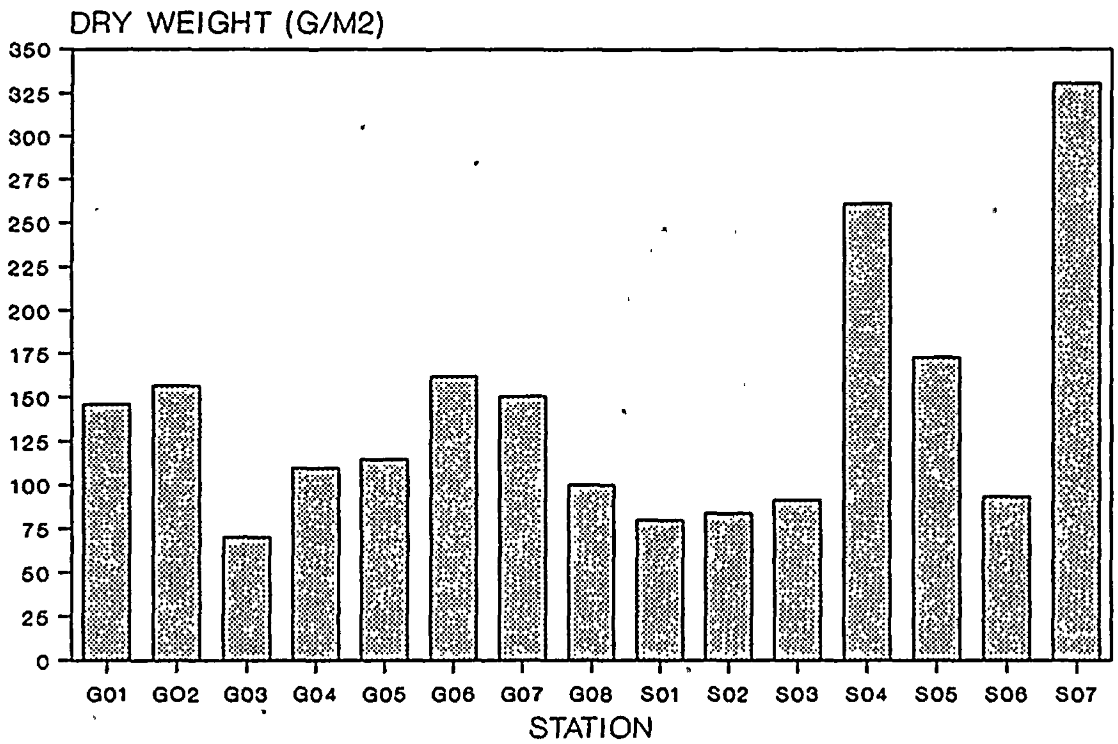


Figure 4-5. Mean Herbaceous Phytomass at Grassland and Shrub Stations for 1975 through 1993

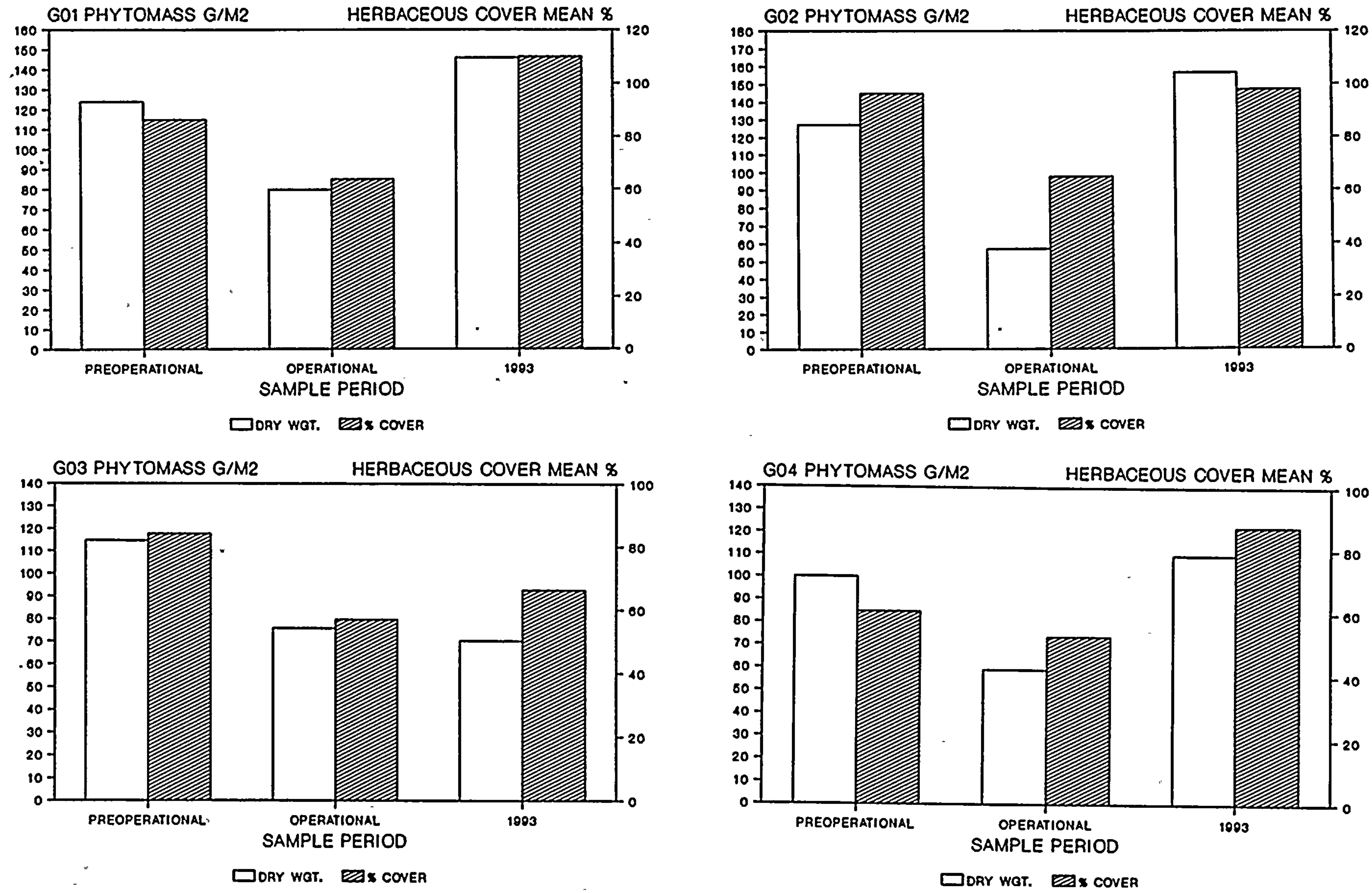


Figure 4-6. Mean Herbaceous Cover and Phytomass
for Stations GO1 to GO4 for 1980 through 1993

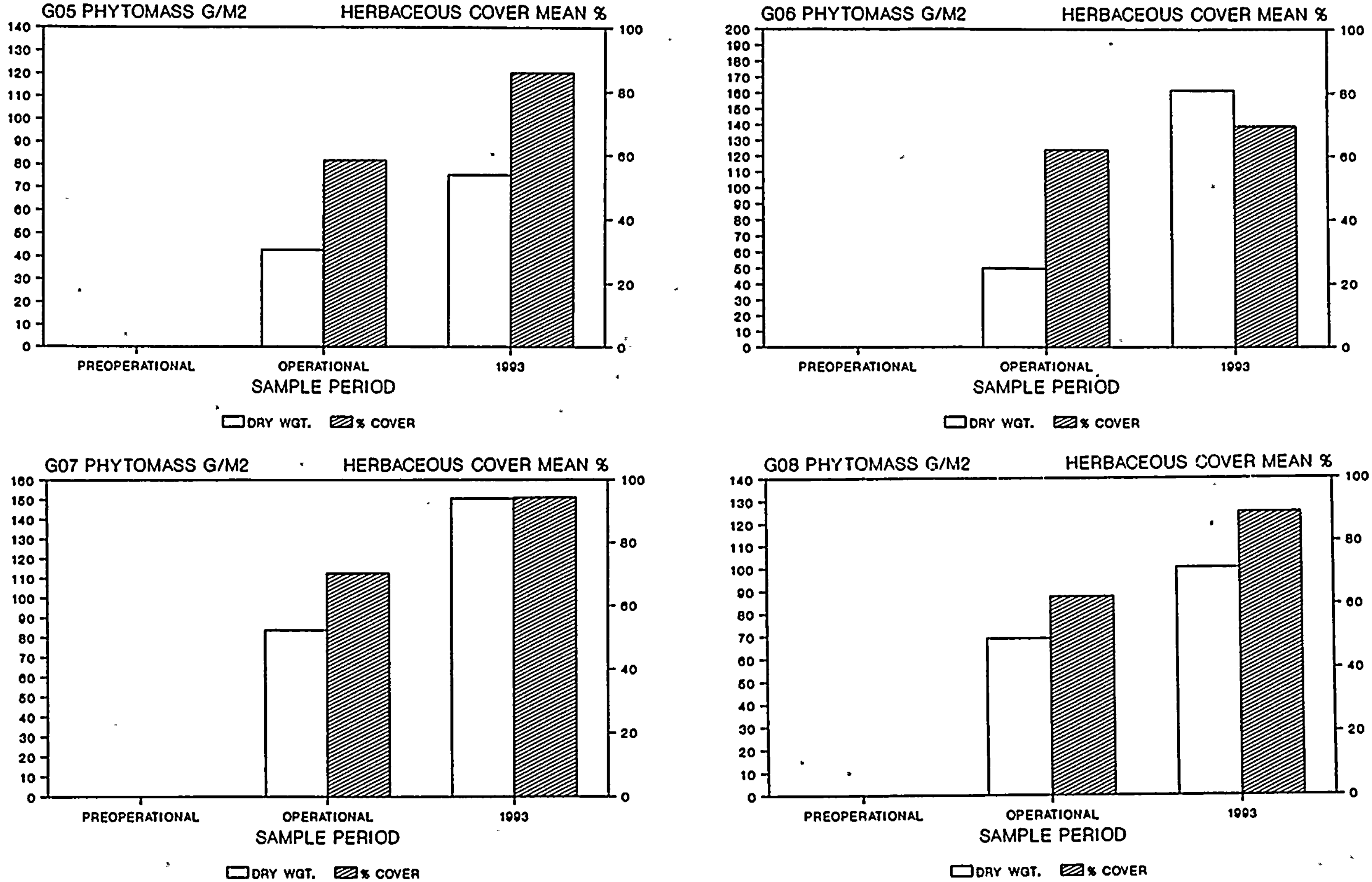


Figure 4-7. Mean Herbaceous Cover and Phytomass for Stations GO5 to GO8 for 1980 through 1993

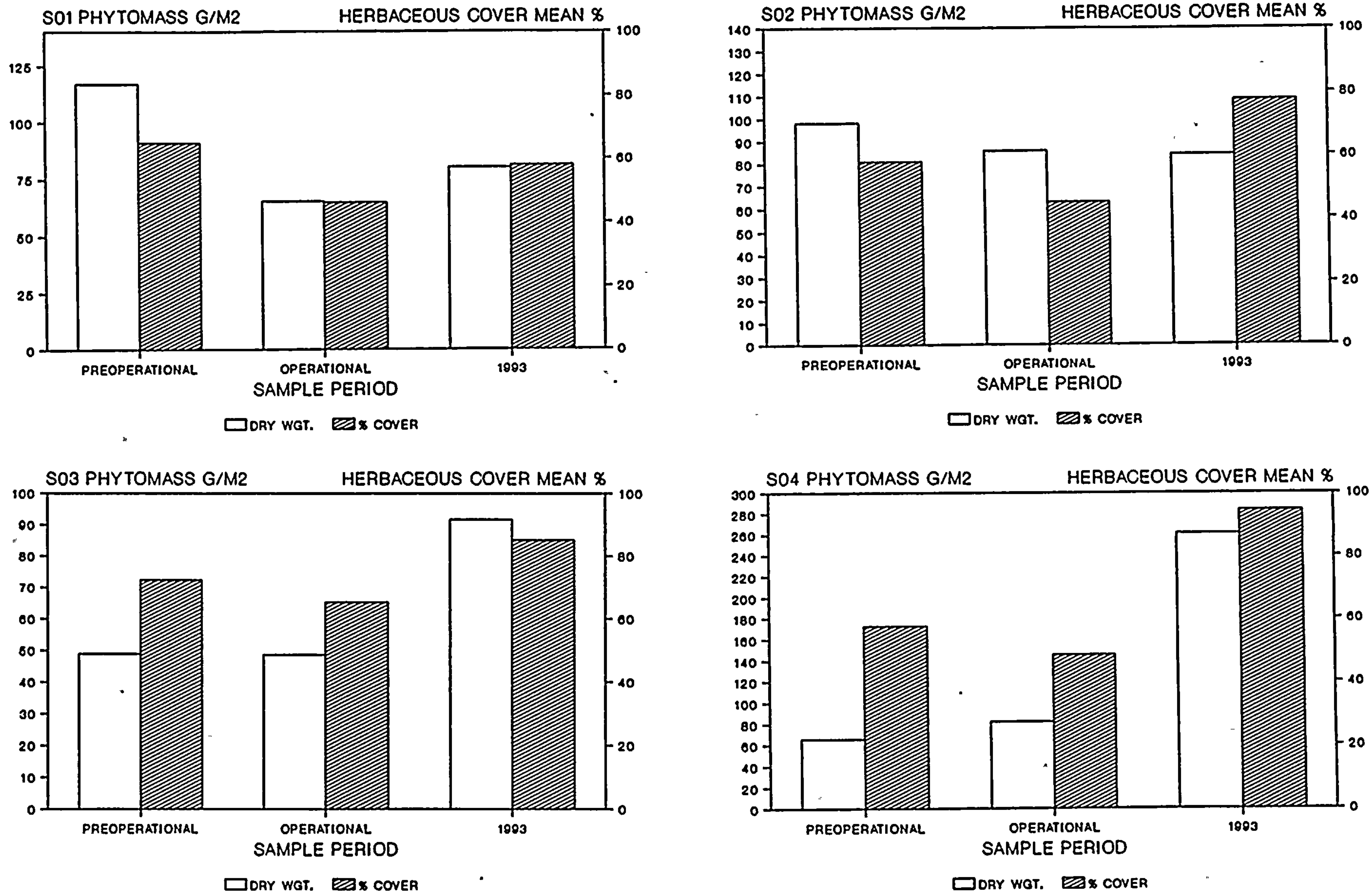


Figure 4-8. Mean Herbaceous Cover and Phytomass for Stations SO1 to SO4 for 1980 through 1993

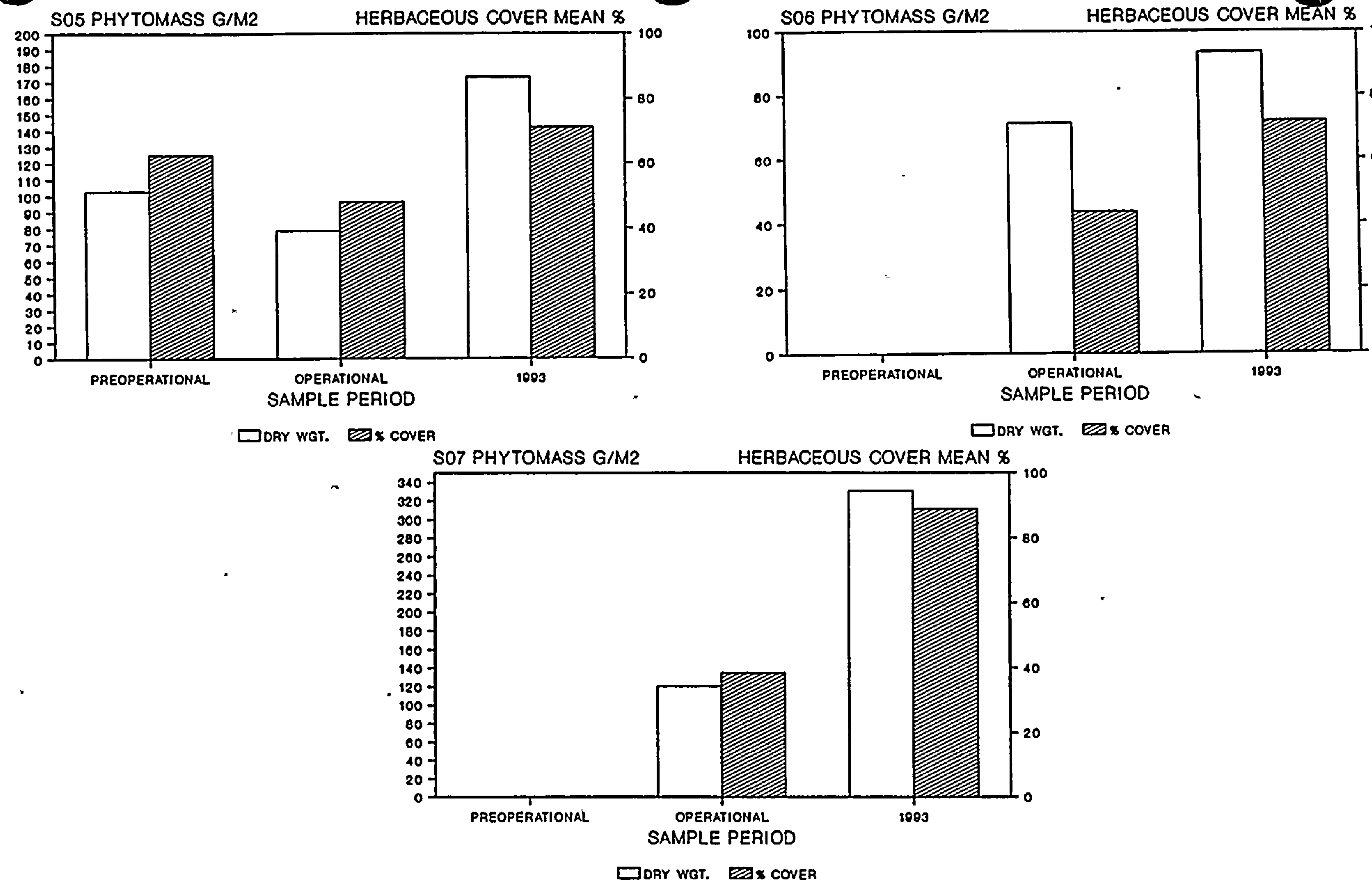
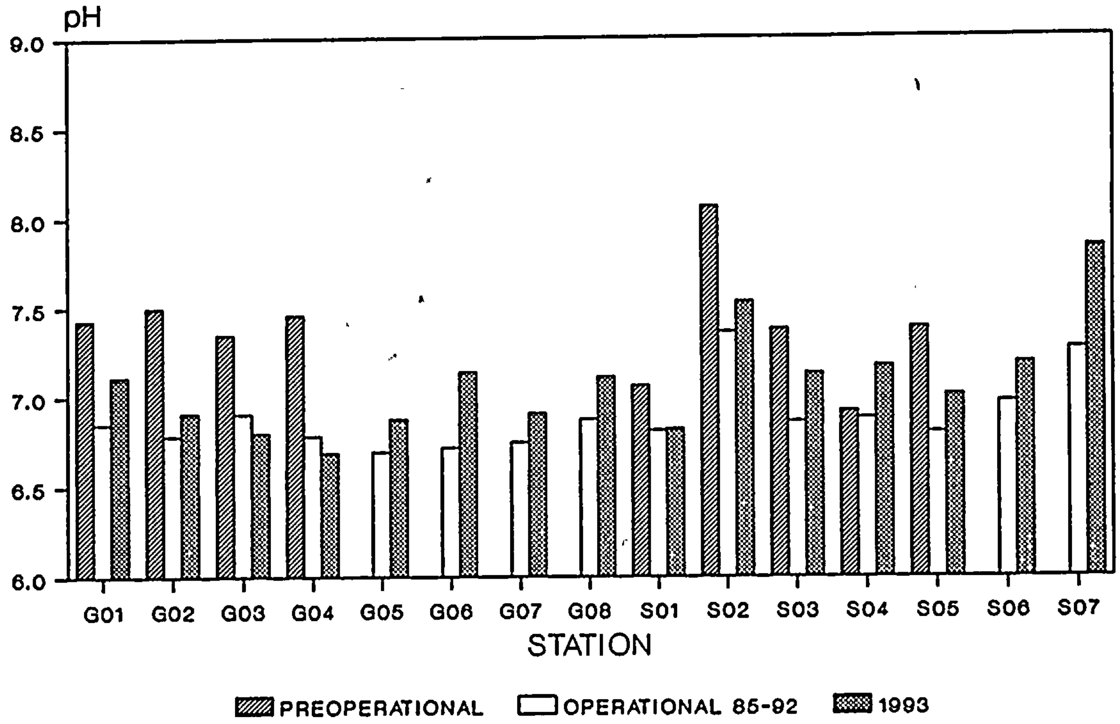


Figure 4-9. Mean Herbaceous Cover, and Phytomass for Stations SO5 for 1980 through 1992 and Stations SO6 and SO7 for 1989 through 1993



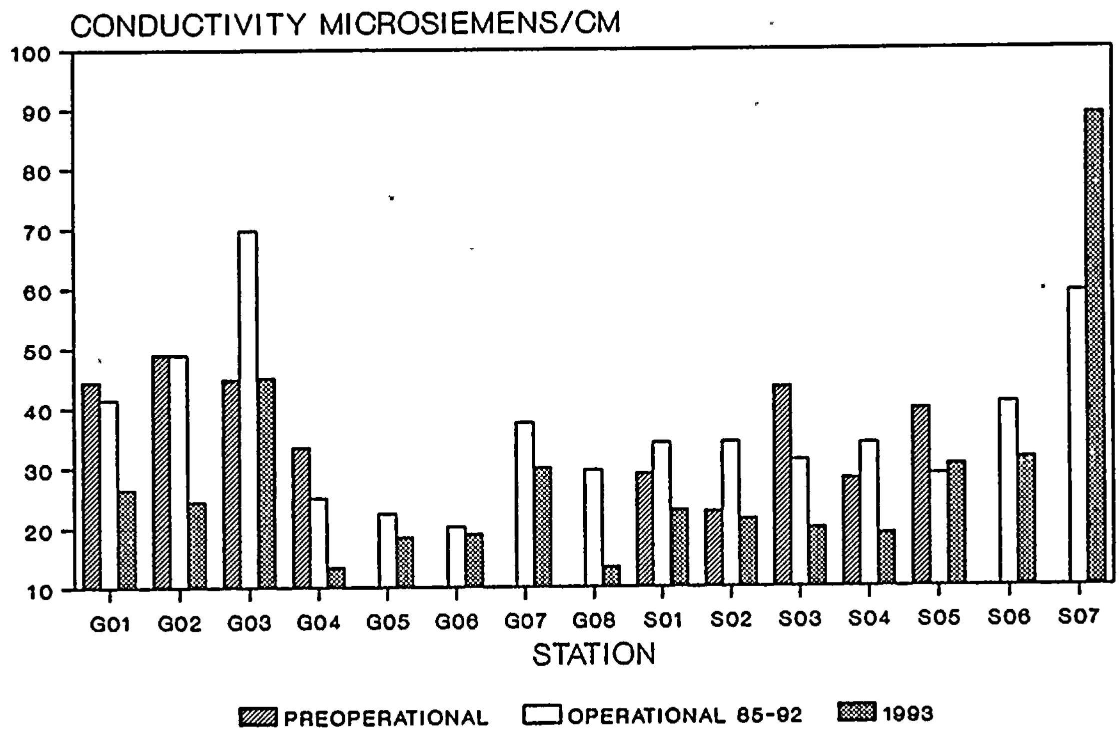


Figure 4-10. Soil pH and Conductivity for 1980 through 1993

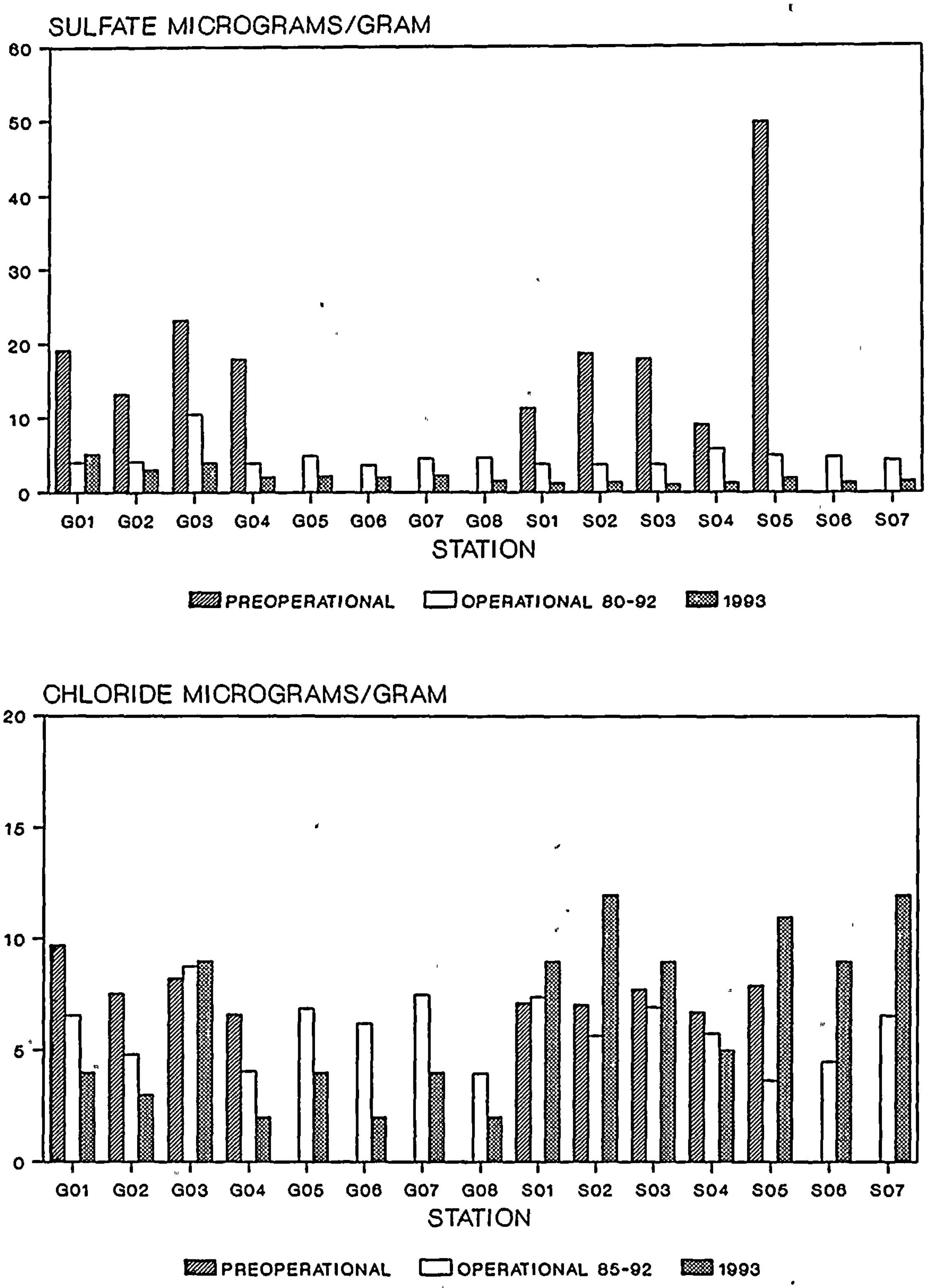
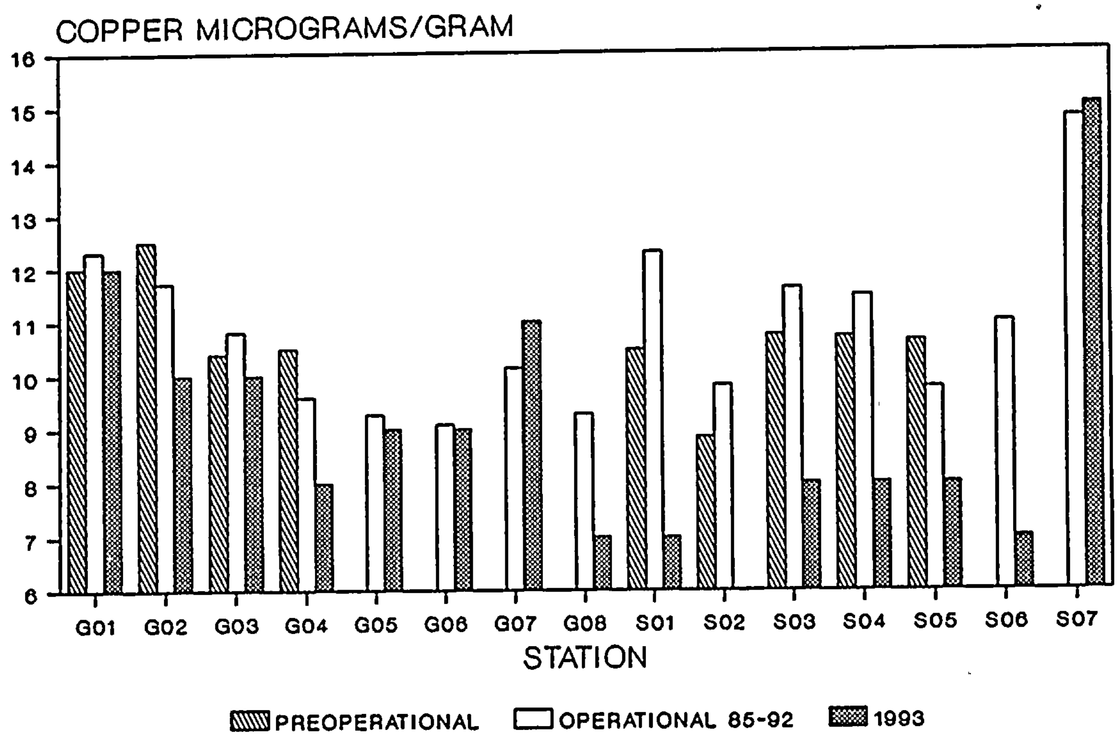


Figure 4-11. Soil Sulfate and Chloride for 1980 through 1993



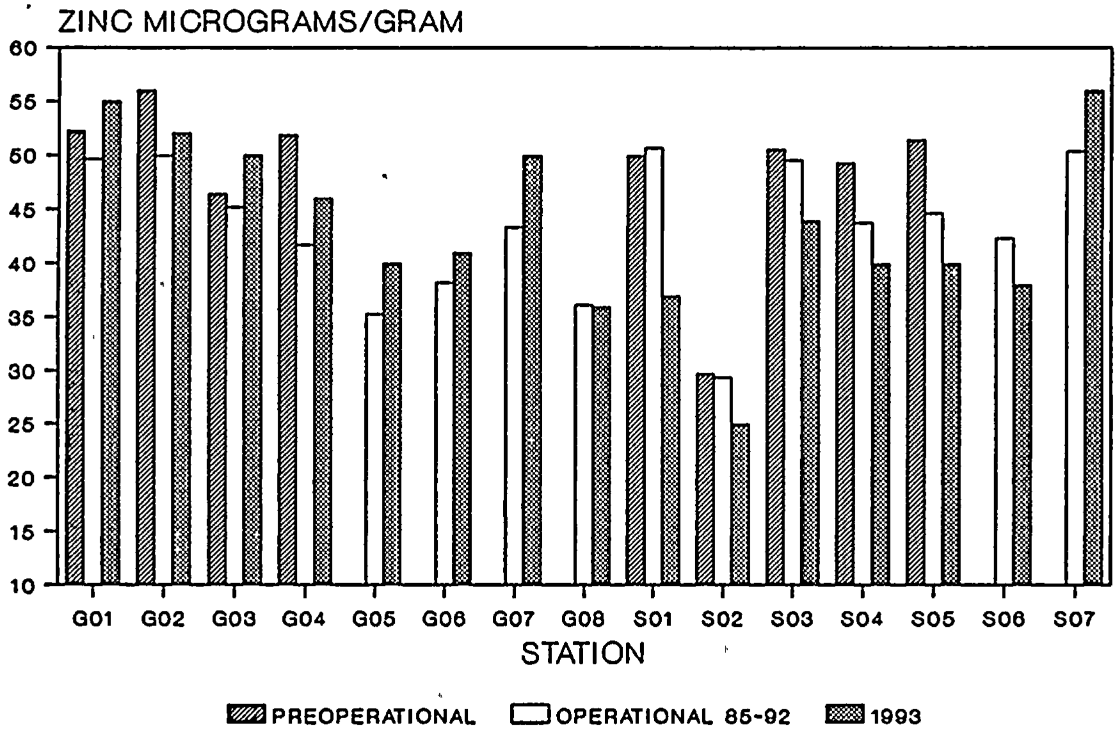
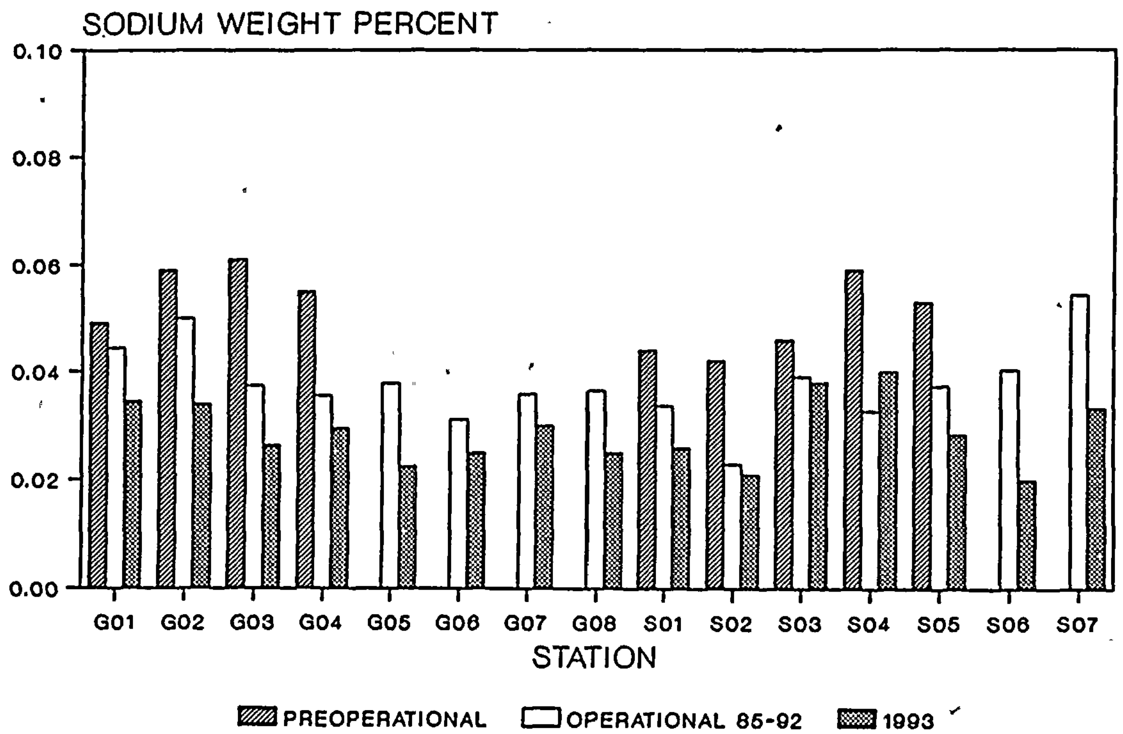


Figure 4-12. Soil Copper and Zinc for 1980 through 1993



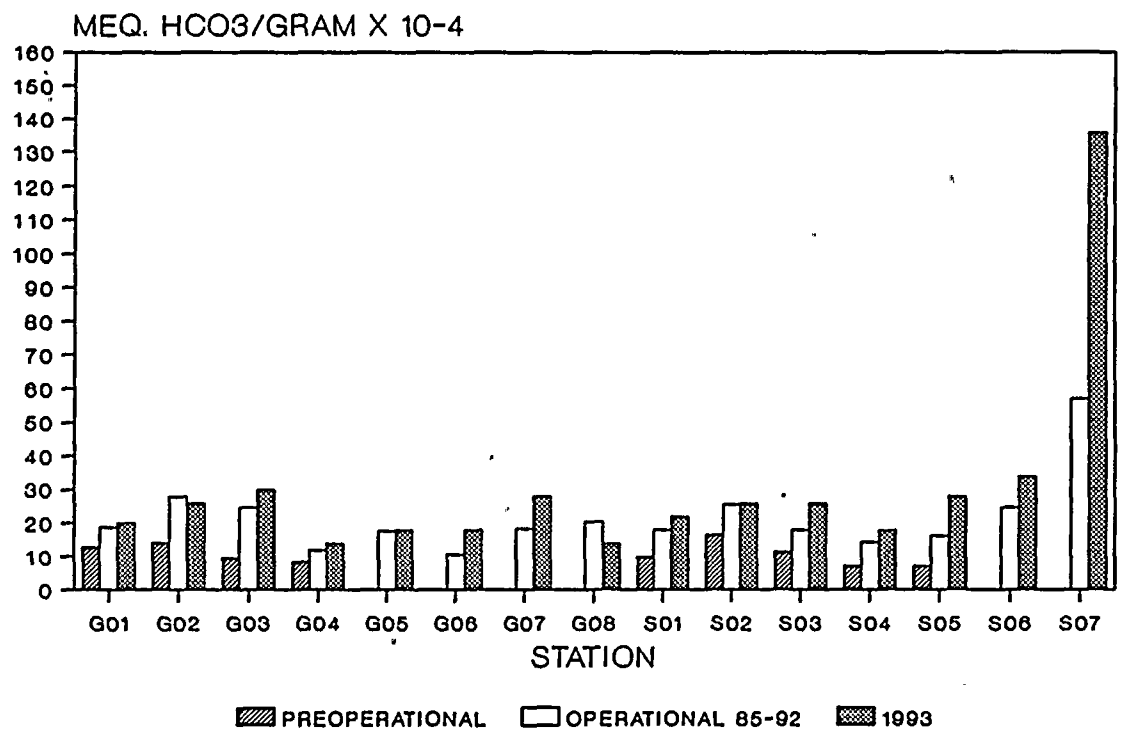


Figure 4-13. Soil Sodium and Bicarbonate for 1980 through 1993

5.0 AERIAL PHOTOGRAPHY PROGRAM

5.1 INTRODUCTION

In compliance with the Washington State Energy Facility Site evaluation Council (EFSEC) Resolution No. 239, 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.

5.2 MATERIALS AND METHODS

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

The interpretation of the flightline data was performed by Phillip Jackson of the Geosciences Department at Oregon State University.

Five flightlines (Figure 5-1) 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 (#1 and 2), 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 (#3, 4, and 5) each 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 (477 m) 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 subsequent years.

The photographs were taken on May 17, 1993 with Kodak Aerochrome 2443 color infrared film in a Hasselblad ELM 70 mm camera by Photography Plus, Inc. of Umatilla, Oregon. A Planar lens with an 80 mm focal length was used with a Number 12 Wratten filter attached. The scale is 1:6,000 in a 70 mm x 70 mm format. The relatively large scale of approximately 1:6,000 was chosen as being large enough to differentiate the types of shrubs in the areas surrounding WNP-2. The 70 mm 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 for this mission 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 (relative to the cooling tower) sites, and compare the 1993 film to the 1992 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 5-2). This map was constructed from field notes, global position surveys, and the United States Geological Survey (USGS) Wooded Island Quadrangle.

5.3 RESULTS AND DISCUSSION

The film quality was judged to be acceptable. The color balance and contrast were sufficient for interpretation of plant health and vigor, but only marginally. The problem of contrast arises not entirely from processing or camera exposure but rather from the time of photo acquisition. The overflight occurred nearly a month later in the season than in 1992; in this semi-arid environment, photosynthetic activity (PSA) decreases rapidly from late spring to summer. As PSA decreases, so does CIR reflectance. Weak leaf reflectance recorded against a bright sand background reduces photo contrast. Even though spring 1993 was probably cooler and wetter than normal, the strong PSA of range vegetation diminishes rapidly as the dry season approaches.

Based on the flightline map supplied by Photography Plus, the 1993 aerial coverage of each flightline appears to be marginally within acceptable limits. A camera problem on Flightline 3 resulted in three restarts on this line; there were numerous light leaks and exposure changes. The flightline was eventually photographed with little loss of coverage; however, these difficulties created substantial orientation problems for the interpreter.

5.3.1 Flightline #1

Beginning at Route 4 South and proceeding northwest, Flightline 1 was slightly east of last year's alignment, resulting in some loss of coverage at monitoring Site A. Site A was chosen for its distinctive vegetation patterns, its upwind location, and its accessibility to ground investigation. No visual indication of recent human-induced disturbance (as was observed in 1992) was noted near the beginning of the flightline. As in 1992, the greatest PSA at Site A was observed in the dune troughs and on the lee side (east face) of dunes.

Overall PSA appears weaker than that observed in the 1992 photography. The later date of photo acquisition may account for the apparent reduction in observable plant vigor.

Adjacent to the administrative buildings landscaped lawn areas appear to exhibit strong PSA. Within the fenced compound numerous colonies of disturbance plant species occupy soil and gravel piles. These disturbed areas were noted on the 1992 photos and have changed very little.

Strong linear PSA patterns are observed to the lee side of roadways, railways, and trails. Such microtopographic features tend to reduce evaporation and create favorable, relatively humid, locations for some plant species.

5.3.2 Flightline #2

In 1992, dead tumbleweed plants (Salsola kali) were observed concentrated along the sides of the fences, railway tracks, and other barrier features. The 1993 photos show anomalous patterns of dead vegetation near the sewage lagoons and to the west of the transformer station. On CIR photos, these patterns somewhat resemble burned areas. These distinctive patterns of dead vegetation were later field checked, and it was found that tumbleweed was intentionally piled in these locations.

Patterns of bitterbrush (Pursha) appear similar to those observed in 1992. The near circular, shrubby appearance of the plant is easily identified, especially from its low PSA reflectance. Northwest of South Power Plant Loop Road an area of moderate PSA was observed. It is comparable in aerial size and PSA vigor to the grass cover identified at that location in 1992. Strong individual plant PSA is noted southeast of Site GO 3 and under the powerlines to the west. Bunchgrass plants are apparently responsible for this observation (crested wheatgrass).

5.3.3 Flightline #3

Many photographic problems were encountered on this flightline. The entire flightline is recorded, but in numerous pieces. The first two frames of Flightline 3 are unusable due to light leaks. Two frames past the divided highway, the film stops then starts again with

darker contrast. This is followed by a frame of the plane's interior. The film then starts once again at the divided highway. Seven frames to the east of the substation, the film record is once again interrupted then begins slightly south of the flightline with darker contrast to the film. Four frames from this restart, light leaks are apparent, which severely affect interpretation of the last six frames before EOF at the river.

The PSA of vegetation closely resembles that observed on 1992 photography. Dense PSA on east dune faces and along roadsides is observed.

Water level in the Columbia River is slightly higher than in 1992 judging by the area of exposed gravel. Riparian vegetation does not exhibit as bright CIR reflectance as in 1992, but that may be attributed to the film contrast and the light leaks that rendered the last frames generally unusable.

5.3.4 Flightline #4

Flightline 4 starts at the divided highway and proceeds east. Contrast is acceptable but slightly over-exposed. Riparian vegetation again shows slightly weaker PSA, but over-exposure may be a factor.

Phlox appears to be blooming in some areas, but these white spots, readily observed in 1992 photographs are not as prevalent in 1993. Perhaps the later date of photo acquisition missed the primary flowering period.

5.3.5 Flightline #5

Flightline 5 starts at the divided highway and powerline crossing and proceeds east to the river. The contrast is good and there are no interruptions or light leaks.

In 1993, vegetation along the east side of the road paralleling the river and the riparian vegetation along the river both exhibit strong PSA once again.

5.3.6 Scanning and Digital Conversion

The overall patterns of spectral plant response were similar when comparing photo scenes from 1992 and 1993. Changes in specific statistical reflectance signatures are noted, however, and may be the result of inherent natural environmental features or photo acquisition and processing differences. The comparison shows differences in magnitude related to exposure and emulsion densities between photographs. It was possible to compare the mean statistical reflectance values for known plant communities in upwind and downwind locations. These signatures are illustrated in Figure 5-3. The highest CIR reflectance, is tumble mustard (Sisymbrium altissimum). Tumble mustard at Site A exhibits slightly higher reflectance than at Site D, but both signatures were statistically similar through red, green, and blue separations. This reflectance pattern is also observed on 1992 photography. The very generalized "Range" classification, illustrates a signature composed of many plant and background edaphic characteristics. These signatures provide only an indication that the plant communities at Site A appear to exhibit slightly higher overall PSA than at Site D. A key to this comparison is found in the green and blue spectral differences. Range at Site A has higher overall blue reflectance, indicating that white sand background, i.e., more exposed sand, provides higher reflectance in this spectral region. Site D likely has less exposed sand and perhaps higher densities of low PSA plants, such as sagebrush or bitterbrush.

Figure 5-4 illustrates spectral signatures produced by the Normalized Difference Vegetation Index (NDVI). This statistical technique allows for a focused look at the relative PSA of selected plant species near Site B. The relative "greenness" of plants can be observed from the CIR reflectance values. Russian thistle (Salsola kali) appears green; it reflects CIR highly. Most grasses (Poaceae) have a weaker CIR reflectance at this time of year, followed by average range vegetation, and finally, sagebrush (Artemisia tridentata).

The signatures generated from features at Site B were the product of a minimum distance to means algorithm. This algorithm assigns image pixels to the closest image class and thus clusters digital reflectance values into discrete classes based on values from all three spectral bands. Table 5-1 records the comparison of minimum and maximum values for three spectral signatures extracted from digital images. One key to successful multi-spectral classification is clear separation between the signatures of different land cover conditions. A clear separation of signatures is not found. The scale of this photography, the variable density of the vegetation, and variations in substrate reflectance across each scene, all tend to produce overlapping spectral signatures. For example, the signatures of "Range" and "Grasses" have a 77% overlap of the digital number values in the near infrared spectral band. In the near infrared spectral band the maximum separation appears to be between the signatures of "Sagebrush" and "Grasses." Even these signatures have a 50 percent overlap in the near infrared spectral band. The data recorded in Table 5-1 illustrates that we do not record a clear separate signature for each distinctive vegetation association, but it is possible to distinguish forbs from shrubs.

Photosynthetic reflectance characteristics for range plants and plant associations have been compared temporarily, from 1992 to 1993, and spatially, from downwind to upwind sites. Out interpretation shows no spatially significant vegetative health differences relative to PSA. That is comparable plant associations in downwind sites appear to have similar reflectance properties as plant associations in up wind sites. Natural vegetation associations have been greatly disturbed in the recent past by human activity throughout this vicinity and these effects on plant type and distribution appear to be more controlling of PSA than precipitate from cooling towers.

Noticeable differences in overall PSA are observed in 1993 photography. Weaker PSA in most sampling stations is likely attributable to a later photo acquisition date, rather than to cooling tower precipitate.

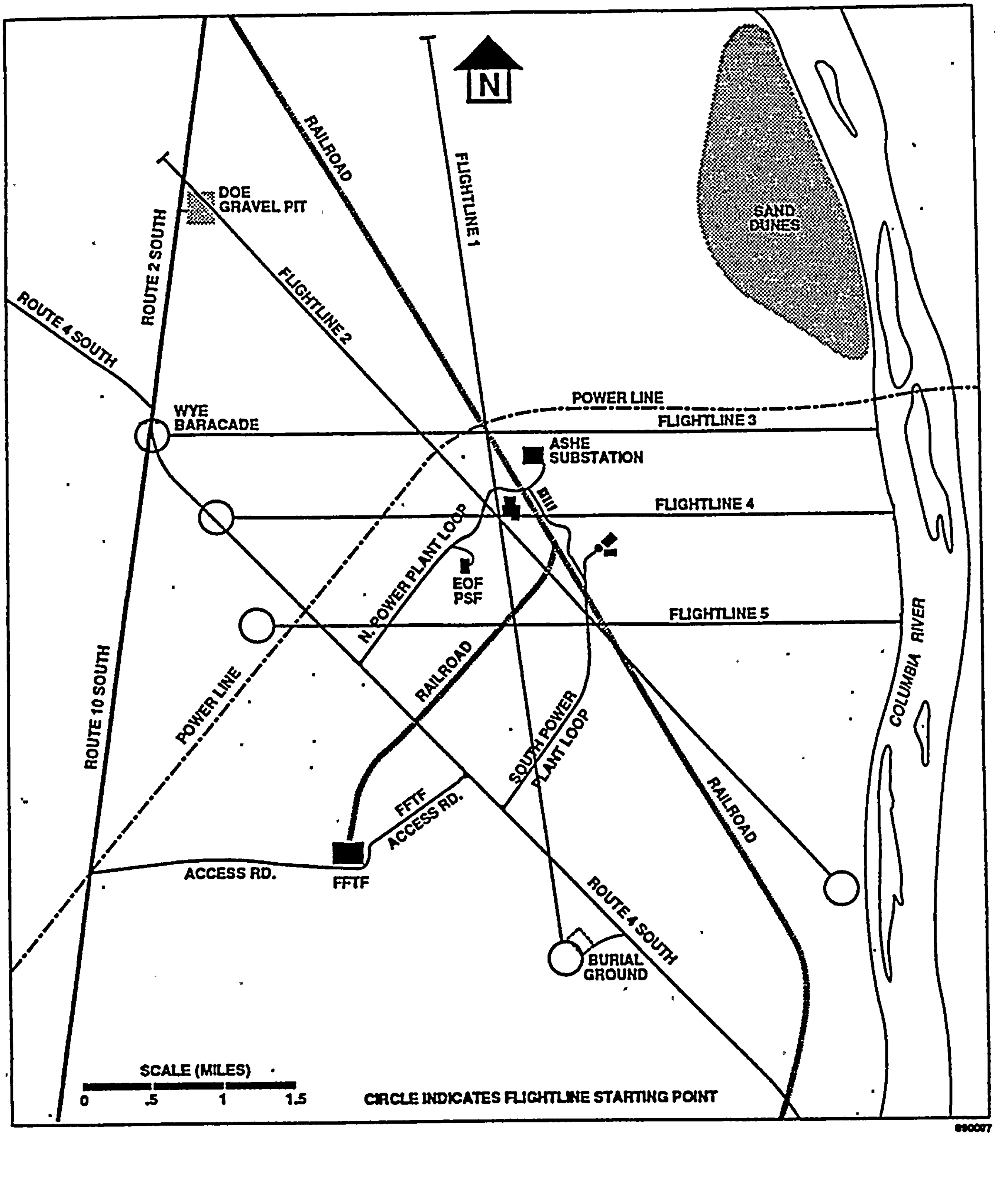
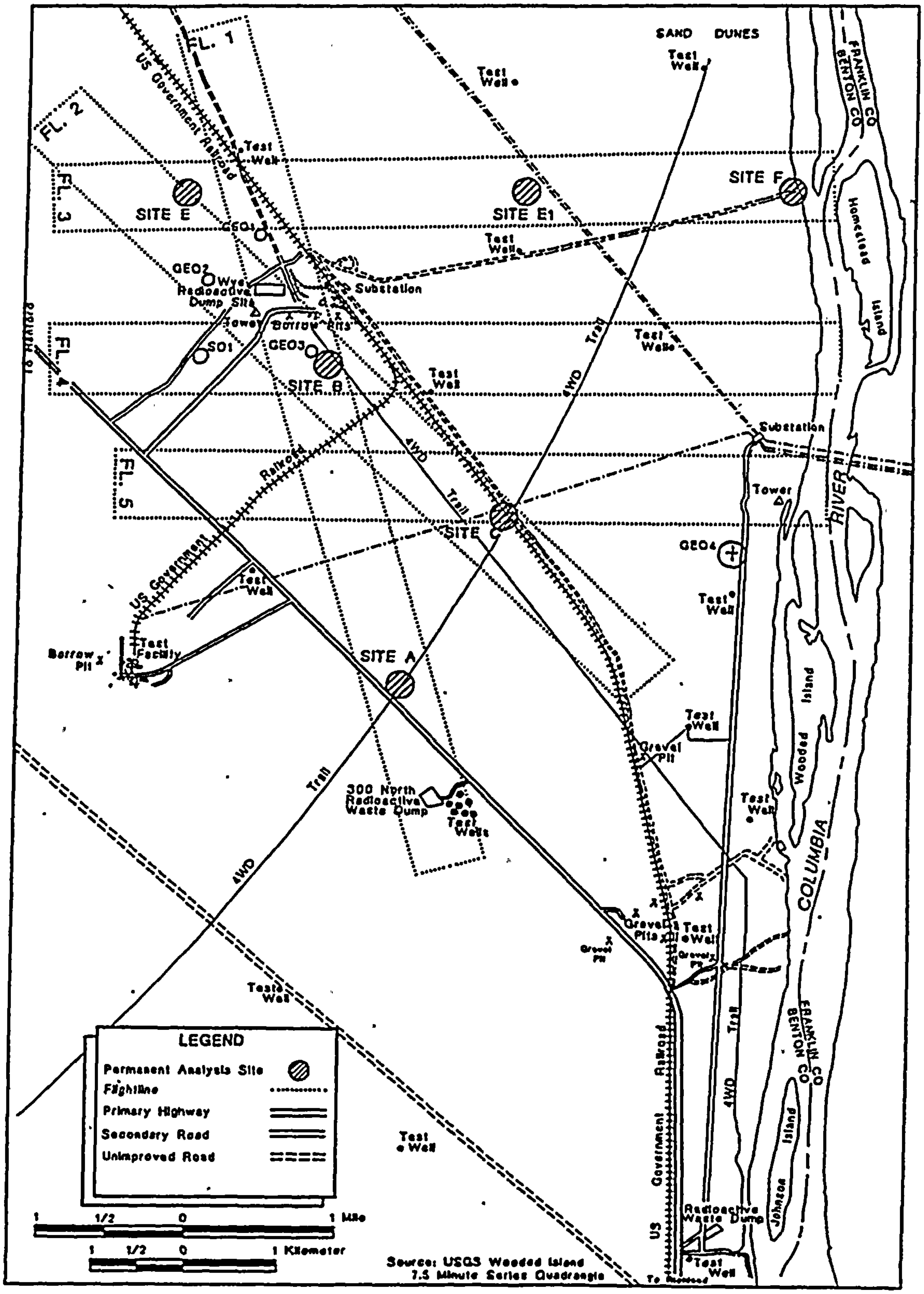


Figure 5-1. Aerial Photography Flightlines



Vegetation Plots and Flightlines
Figure 5-2. Location of Digitized Test Sites

Table 5-1. Signature Comparison

	Near IR		Spectral Bands Red		Green	
Signature	Min	Max	Min	Max	Min	Max
Grasses	73	255	71	255	80	221
Range	20	252	13	194	20	175
Sagebrush	23	190	20	164	28	174

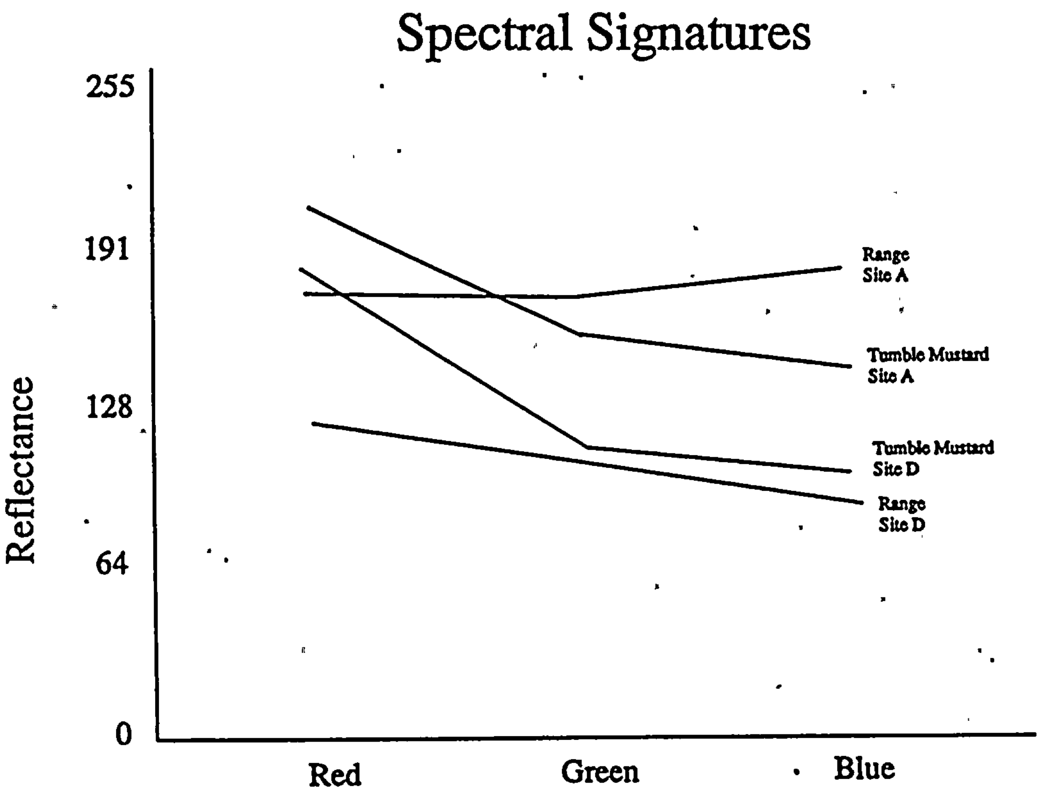


Figure 5-3. Comparison of Statistical Reflectance Signatures

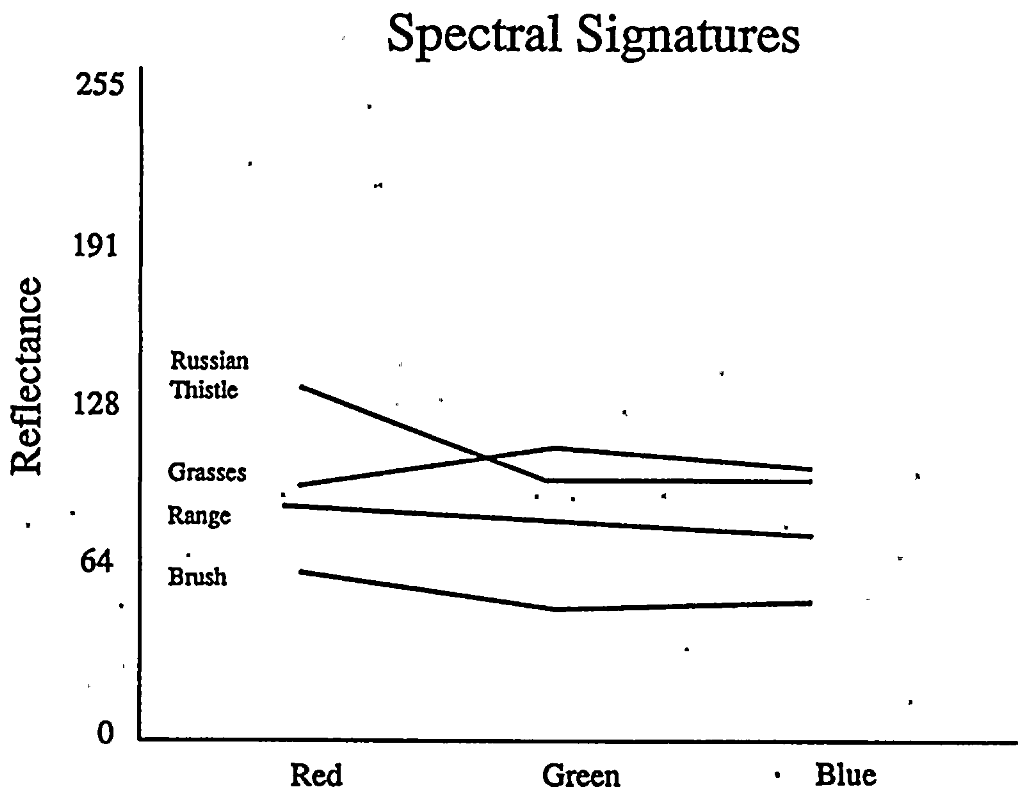


Figure 5-4. Spectral Signatures Produced by the Normalized Difference Vegetation Index (NDVI)

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

Operational Ecological Monitoring Program For Nuclear Plant 2

1994 Annual Report

Prepared by Environmental Sciences Department

WASHINGTON PUBLIC POWER
SUPPLY SYSTEM

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EXECUTIVE SUMMARY

The Ecological Monitoring Program is comprised of several elements which are intended to determine the effects of the operation of the Supply System's Nuclear Plant No. 2 on the environment. These program elements include: plant effluent and Columbia River water quality; bioassay tests on selected aquatic species; vegetation cover and phytomass in selected plots; soil chemistry at established sampling locations; and aerial infrared photography of the surrounding plant communities. The results of the 1994 monitoring efforts may be summarized as follows:

- Flow-through and static bioassays were completed with all tests meeting the survival rate criterion of 80 percent in 100 percent effluent.

- Plant cooling water discharges had no discernible effect on Columbia River water quality.

- Temperature during the growing season was similar to 1993. Precipitation during this period was significantly less than the recorded values for 1993. The decrease in vegetation cover and phytomass appear to be directly related to the decrease in precipitation

- Infrared aerial photography revealed no spatially significant vegetation health differences relative to photosynthetic activity (PSA).

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This report, prepared by Washington Public Power Supply System, decribes the soil and vegetation studies, aquatic bioassays, and water quality programs for WNP-2.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Site Certification Agreement (SCA) for WNP-2 was approved on May 17, 1972, by the State of Washington and the Washington Public Power Supply System (Supply System). The SCA requires that environmental monitoring be conducted during the preoperational and operational phases of site development and use. The objective of the monitoring program is to provide an environmental measurement history for evaluation by the Supply System and the Washington State Energy Facility Site Evaluation Council (EFSEC) and to identify significant effects of plant operation on the environment. Since 1972, several revisions of the monitoring program have been approved by EFSEC in the form of SCA attachments and EFSEC resolutions Nos. 193, 194, 214, 239, 266.

Most of the studies, analyses, and reports for the preoperational (1973-1984) environmental program of the SCA were performed by outside laboratories for the Supply System. The aquatic studies were in reports by Battelle Pacific Northwest Laboratories for the period of September 1974 through August 1978 (Battelle 1976, 1977, 1978, 1979a, 1979b) and by Beak Consultants, Inc. for the period of August 1978 through March 1980 (Beak 1980). The terrestrial program was performed and reports were prepared by Battelle from 1974 until 1979 (Rickard 1976, 1977, 1979a, 1979b) and then by Beak from 1980 to 1982 (Beak 1981, 1982a, 1982b).

Since 1983, Supply System scientists have been responsible for the entire operational environmental monitoring program. Using the data acquired during 1984, the first comprehensive operational environmental annual report was prepared by Supply System scientists (Supply System 1985) and has since continued annually (Supply System 1986 through 1993). A few studies and reports were completed by Supply System personnel prior to the annual reports, including animal studies (Schleder 1982, 1983, 1984) and terrestrial monitoring (Northstrom 1984).

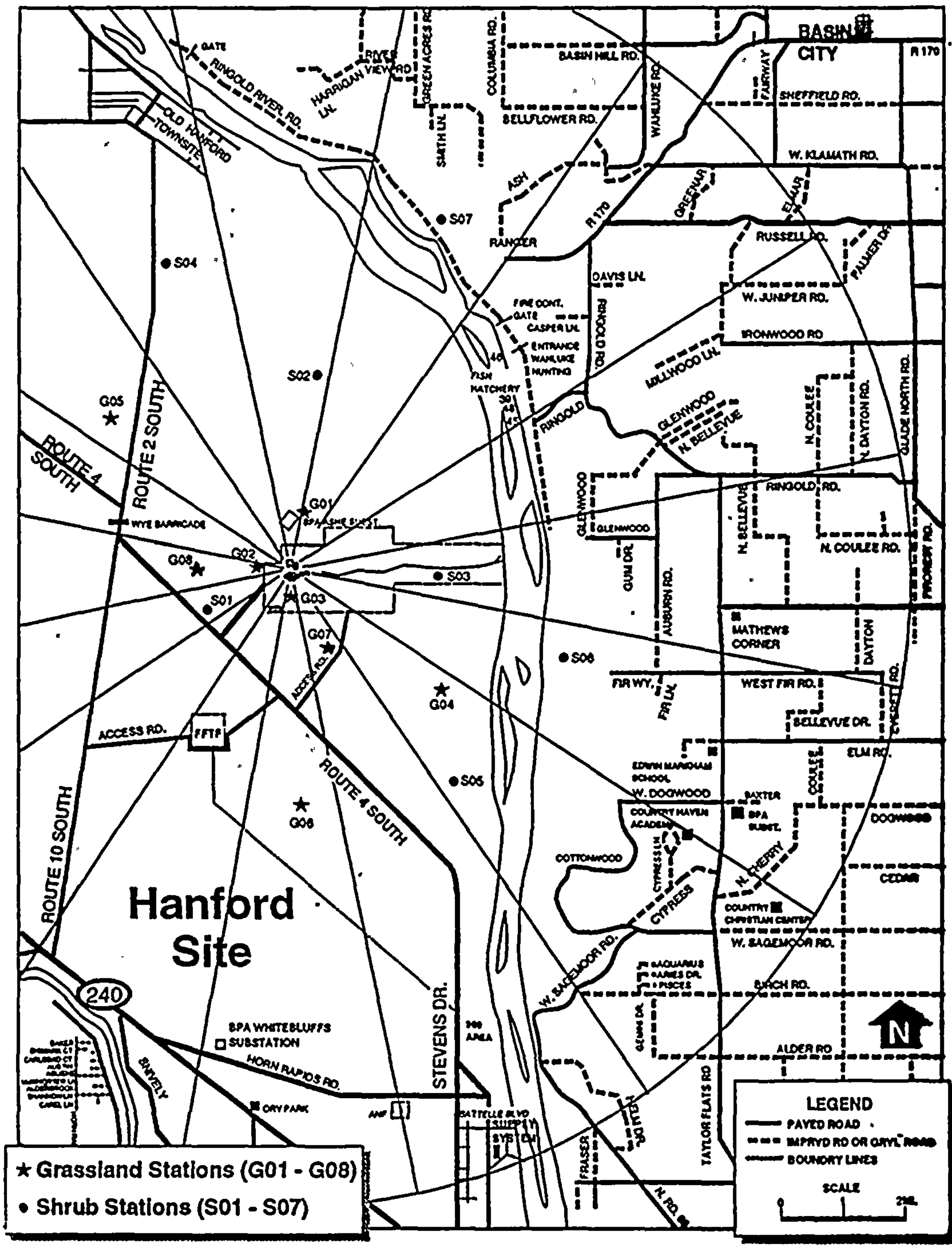
This report presents the results of the Ecological Monitoring Program for the period of January through December 1994.

1.2 THE SITE

The Supply System leases the WNP-2 site (441 hectares or 1089 acres) from the U. S. Department of Energy. WNP-2 lies within the boundaries of the Columbia Basin between the Cascade Range in Washington and Blue Mountains in Oregon and comprises approximately two-thirds of the area lying east of the Cascades. Approximately 5 km (3.25 miles) to the east, the site is bounded by the Columbia River. The plant communities within the region are described as shrub-steppe communities consisting of various layers of perennial grasses overlaid by a discontinuous layer of shrubs. In general, moisture relations do not support arborescent species, except along streambanks. In August 1984, a range fire destroyed much of the shrub cover on

the Hanford site and temporarily modified the shrub-steppe associations which were formerly present.

Figure 1-1. WNP-2 Location Map



July 1993

2.0 AQUATIC BIOASSAYS

2.1 INTRODUCTION

Special condition S4 of the WNP-2 National Pollutant Discharge Elimination System 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 criterion. This section includes results of bioassay tests performed on chinook salmon (*Oncorhynchus tshawytscha)* and the common water flea (*Daphnia pulex).*

2.2 MATERIALS AND METHODS

The bioassays followed the guidance set forth in EPA Publications *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (EPA 1991) and *Quality Assurance Guidelines for Biological Testing* (EPA 1978). Sample holding times and analytical methods (Table 2-1) were consistent with EPA guidance (EPA 1983).

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

Parameter	EPA Method Number
Temperature (°C)	170.1
Conductivity (μS/cm) at 25°C	120.1
Dissolved Oxygen (mg/L)	360.1, 360.2
pH	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

2.2.1 *Oncorhynchus tshawytscha*

Two flow-through bioassays of WNP-2 cooling tower effluent were performed October 27-31 (Test A) and November 10-14 (Test B), 1994. The flow-through system consisted of six 132-liter capacity glass aquaria with each containing 114 liters of water. The system included three control (100% Columbia River water) and three effluent (100% plant effluent) aquaria selected on a random basis. Flow rates were approximately 1.4 liters/minute/aquaria.

Effluent used for the tests was diverted from the discharge pipe and pumped to the test facility.

Control water was untreated Columbia River water pumped from the makeup pumphouse directly to the test facility. A temperature conditioning unit was used to maintain the control water and effluent at 12°C (±1°C).

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

Ten fish were distributed to each aquarium, two at a time, in a stratified random manner. Fish were acclimatized in the aquaria with 100% control water for 48 hours prior to plant effluent introduction. The 96-hour test was begun by siphoning down all six aquaria until there was approximately 23 liters of water remaining in each. The test aquaria were then refilled with plant effluent and the control aquaria were refilled with river water.

The aquaria were checked for mortalities twice per day. Temperature, dissolved oxygen, pH, and conductivity were measured in each aquarium and in the control and effluent head boxes at the beginning of the test, daily thereafter, and at test termination. Grab water samples were collected daily from the control and effluent head boxes and each aquarium. The samples were later analyzed for calcium, magnesium and alkalinity.

Temperature measurements were made with a Fisher NIST-traceable thermometer. The pH measurements were made with an IBM Model EC105-2A portable pH meter. Dissolved oxygen measurements were made using a Yellow Springs Instrument (YSI) Model 57 meter. Conductivity measurements were made with a YSI Model 33 meter. Calcium and magnesium measurements were made with a Perkin Elmer Model 40 inductively coupled plasma emission spectrometer.

2.2.2 *Daphnia pulex*

Two static bioassays of WNP-2 cooling tower effluent were performed April 6-9, (Test A) and April 19-23 (Test B), 1994. Effluent used for the tests 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 (EPA 1991).

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 and 100% dilution water (control) for a 96-hour period. Mortality checks were made two hours after the beginning of the test and daily thereafter. The *Daphnia pulex* used in the tests are from a stock culture obtained from the EPA Regional Laboratory, Manchester, Washington, in July 1991. The WNP–2 Environmental Laboratory maintains a breeding population of this organism.

A reference toxicant test using cadmium chloride was performed in conjunction with Test B. The

cadmium chloride was received from the EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

Temperature was measured in control and effluent containers at the start of each test and daily thereafter. Dissolved oxygen, 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. Measurements of pH were made with an Orion Model 701-A meter and Ross Model 8102 electrode. Dissolved oxygen measurements were made using the modified Winkler procedure. Conductivity measurements were made with a YSI Model 33 meter. Calcium and magnesium measurements were made using a Perkin Elmer Model 40 inductively coupled plasma emission spectrometer.

2.3 RESULTS AND DISCUSSION

The tests were successfully completed with respect to the survival rate criterion of 80% or greater. These results are in agreement with previous flow-through and static bioassays performed at WNP-2.

2.3.1 *Oncorhynchus tshawytscha*

A complete summary of the test conditions for the *Oncorhynchus tshawytscha* bioassay is provided in Table 2-2.

Table 2-2. Test Conditions for *Oncorhynchus tshawytscha*

Temperature	12°± 1°C
Photoperiod	16h light/24h
Size of test vessel	132 liter aquaria
Volume of test solution	114 liters
Flow rate	1.4 liters/minute/aquaria
No. fish/test vessel	10
No. of replicate test vessels/ concentration	3
Total no. fish/ conc.	30
Feeding regime	Not fed during 96 hour test
Aeration	None
Control water	Columbia River
Test duration	96 hours
Effect measured	Mortality

No fish mortalities were observed during performance of the two bioassays.

Information regarding length, weight, and loading factor of control fish used in the bioassays is presented in Table 2-3. Table 2-4 provides a summary of physical and chemical data for the two bioassays.

Table 2-3. Size and Number of *Oncorhynchus tshawytscha* Juveniles Used in WNP-2 Bioassay Tests

Date/Test		Length (cm)			Weight (g)			Loading Factor
		No.	Mean	Range	No.	Mean	Range	(g/liter)
10/31/94	Test A	30	9.1	7.3-11.9	30	9.1	4.6-19.8	0.8
11/14/94	Test B	30	9.8	8.0-12.1	30	11.4	6.0-21.0	1.0

Table 2-4. Physical and Chemical Data for WNP-2 *Oncorhynchus tshawytscha* Juvenile Bioassays

	Test A				Test B			
	Control		Effluent		Control		Effluent	
Parameter	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Temperature	12.3	11.9-12.7	12.6	12.1-12.8	12.4	12.0-12.7	12.8	12.5-12.9
pH	7.56	7.49-7.69	8.11	8.01-8.19	7.54	7.49-7.61	8.16	8.06-8.25
DO (mg/L)	9.1	8.1-9.8	8.2	7.5-8.7	9.7	9.3-10.0	8.6	8.3-9.0
Conductivity (μS/cm)	104	100-110	761	600-850	101	100-103	706	425-800
Hardness (mg/L as $CaCO_3$)	58	56-61	441	369-488	57	56-59	423	280-473
Alkalinity (mg/L as $CaCO_3$)	54	53-55)	108	87-141	50	30-55	108	95-121
Plant Effluent (gpm)	-----	-----	1800	—	-----	-----	1500	--------

2.3.2 <u>Daphnia pulex</u>

A complete summary of the test conditions for *Daphnia pulex* is provided in Table 2-5. During the performance of the two bioassays no mortalities were observed.

Table 2-5. Test Conditions for *Daphnia pulex*

Temperature	20°±2°C
Photoperiod	16 h light/24h
Size of test vessel	30 mL beaker
Volume of test solution	25 mL
Age of test animals	1-24 h (neonates)
No. organisms/test vessel	5
No. of replicate test vessels/conc.	4
Total no. organisms/conc.	20
Feeding regime	Not fed first 48 hrs. Fed daily therafter
Aeration	None
Dilution water:	Moderately hard
Test duration:	96 hours
Effect measured:	Mortality

Following acclimation to test chamber conditons, temperature measurements for Tests A and B in the control and effluent containers averaged 20.6°C and 20.5°C, respectively. Measurements of physical and chemical parameters for control and effluent solutions at the beginning of each test are presented in the following table (2-6).

Table 2-6. Physical and Chemical Characteristics of Control and Effluent Solutions at the Beginning of Each Daphnia Test

Test No.	Sample	Temp. (°C)	pH	D.O. (mg/L)	Cond. (µS/cm)	Hardness (mg/L)	Alkalinity (mg/L)
A	Control	20.8	8.76	8.5	300	74	60
	Effluent	20.7	7.91	8.4	679	315	97
B	Control	20.5	8.82	8.6	293	96	58
	Effluent	20.5	7.46	8.7	650	358	103

The results for the reference toxicant, cadmium chloride, indicate LC_{50} values of 0.34 mg/L (24h) and 0.02 mg/L (48h). The LC_{50} was determined using a computer based Trimmed Spearman Karber method.

3.0 WATER QUALITY

3.1 INTRODUCTION

The water quality sampling stations are located near the west bank of the Columbia River at river mile 352. Sampling was limited to the main channel on the Benton County side. Near the site, the river averages 370 meters (1200 feet) wide with a water surface 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 during a 24-hour period and from day to day in response to release patterns at the Priest Rapids Dam (river mile 397). The maximum, minimum and mean flow rates measured at the USGS stream-quality station located at river mile 388.1 (near the Vernita Bridge) can be seen in Table 3-1.

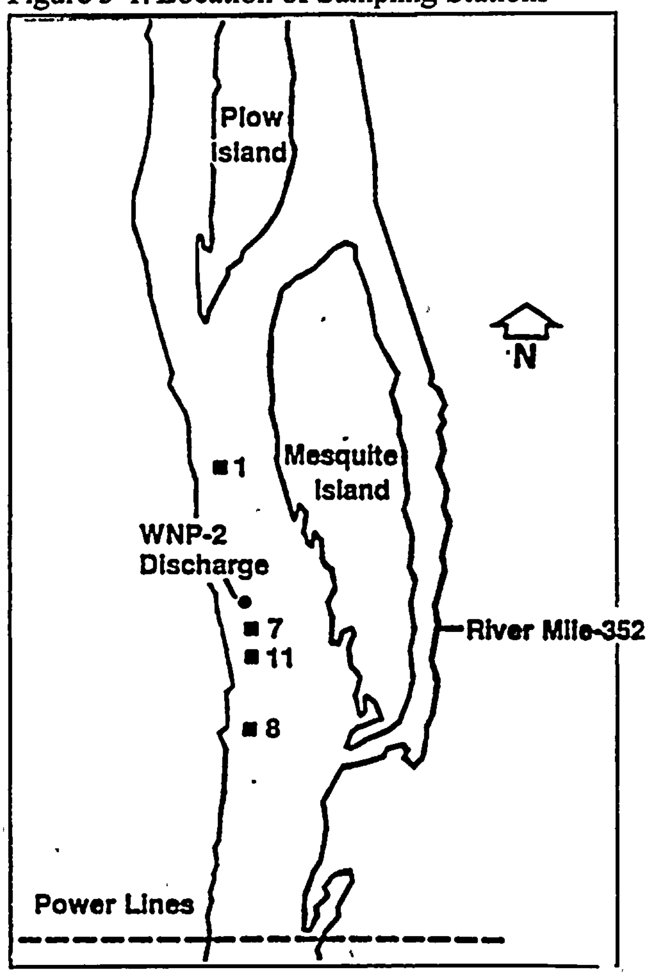
Table 3-1. Columbia River Monthly Flow Rates for 1994

	Flow (cfs)		
Month	Mean	Maximum	Minimum
January	87950	124000	51900
February	112600	144000	77600
March	87290	120000	63200
April	90020	128000	55200
May	121400	153000	92100
June	151400	180000	126000
July	106800	142000	68300
August	77770	96400	40700
September	60050	84100	41600
October	70790	87500	49500
November	82650	109000	66400
December	91450	128000	60600

3.2 MATERIALS AND METHODS

Columbia River surface water samples were collected monthly from January through December 1994. Samples were collected near river mile 352 from four stations numbered 1, 7, 11, and 8 (Figures 3-1 and 3-2). 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 blowdown effects. Station 11, 91 meters (300 feet) downstream from the discharge, represents the extremity of the mixing zone. At substations 11M and 11B water samples are taken from middle and bottom depths, respectively. Station 8 is approximately 568 meters (1870 feet) downstream from the discharge and represents a location where the blowdown is well mixed in 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, total phosphorus, inorganic phosphate, sulfate, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium. The samples from substations (11M and 11B) were analyzed for total copper only.

Figure 3-1. Location of Sampling Stations



Plant blowdown was sampled monthly during 1994. Samples were collected from the discharge pipe at a sample point located in the makeup pumphouse. Blowdown samples were analyzed for temperature, pH, conductivity, turbidity, total phosphorus, inorganic phosphate, sulfate, oil and grease, total copper, total iron, total zinc, total nickel, total lead, total cadmium, and total chromium. Volatile organic compounds (VOCs) and semi-volatile organic compounds (semi-VOCs) were analyzed on a quarterly basis.

An evaporation/percolation pond (storm drain pond) is located approximately 1500 feet northeast of the plant. The pond is a collection point for water from various locations within the controlled area. Water and sediment were sampled monthly and semiannually, respectively. Monthly water samples were analyzed for pH, conductivity, total iron, total copper, total nickel, total zinc, total lead, total cadmium, total chromium, and oil and grease. In addition, quarterly water samples were analyzed for total dissolved solids and VOCs and semi-VOCs. Semiannual sediment samples were analyzed for the same total metals as the monthly water samples, except iron. A summary of this information is presented in Table 3-2.

Table 3-2. Summary of Water Quality Parameters, Stations, and Sampling Frequencies, 1994

Parameter	1	7**	11**	11M &11B**	8**	Plant** Blowdown	Pond
Temperature	M	M	M	—	M	M	—
Dissolved Oxygen	M	M	M	—	M	—	—
pH	M	M	M	—	M	M	M
Turbidity	M	M	M	—	M	M	—
Total Alkalinity	M	M	M	—	M	—	—
Filterable Residue (TDS)	—	—	M	—	—	—	Q
Conductivity	M	M	M	—	M	M	M
Iron (Total)	M	M	M	—	M	M	M
Copper (Total)	M	M	M	M	M	M	M
Nickel (Total)	M	M	M	—	M	M	M
Zinc (Total)	M	M	M	—	M	M	M
Lead (Total)	M	M	M	—	M	M	M
Cadmium (Total)	M	M	M	—	M	M	M
Chromium (Total)	M	M	M	—	M	M	M
Sulfate	M	M	M	—	M	M	—
Orthophosphate as P	M	M	M	—	M	M	—
Total Phosphorus	M	M	M	—	M	M	—
Oil and Grease	—	—	—	—	—	M	M
Hardness	M	M	M	—	M	—	—
Organics (VOCs and semi-VOCs)	—	—	—	—	—	Q	Q

Symbols Key

Q= Quarterly
M= Monthly
**= Samples collected only if the plant is operating

3.2.1 Sample Collection

Columbia River samples were collected by boat, approximately 100 meters from the Benton County shore. Temperature was determined in-situ. Water for total metals, conductivity, pH, sulfate, total phosphorus, inorganic phosphate, 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 and Analytical Support Laboratory. Water for total copper

analysis from substations 11M and 11B was collected in one-liter polypropylene cubitainers with an all-Teflon pump and Tygon tubing. Water for dissolved oxygen measurements was collected in 300 mL (Biological Oxygen Demand) BOD bottles.

Blowdown temperature was determined in-situ. Water for pH, conductivity, turbidity, total phophorus, inorganic phosphate and total metals analyses was collected in 3.8 liter polypropylene cubitainers. Water for oil and grease,VOCs and semi-VOCs analysis was collected in one-liter clear and amber glass bottles, respectively. Water for volatile organics analysis was collected in 40-mL glass bottles.

Evaporation/percolation pond water for pH, conductivity and total metals was collected in 3.8 liter polypropylene cubitainers. Water for total dissolved solids analyses was collected in 500 mL plastic bottles. Water for oil and grease, VOCs and semi-VOCs was collected as described under blowdown sampling. All samples were stored in a cooler until delivered to the laboratory for analyses.

Water quality samples collected during the annual plant maintenance outage (May through June) consisted of station 1 (control) samples only.

3.2.2 Analysis Methods

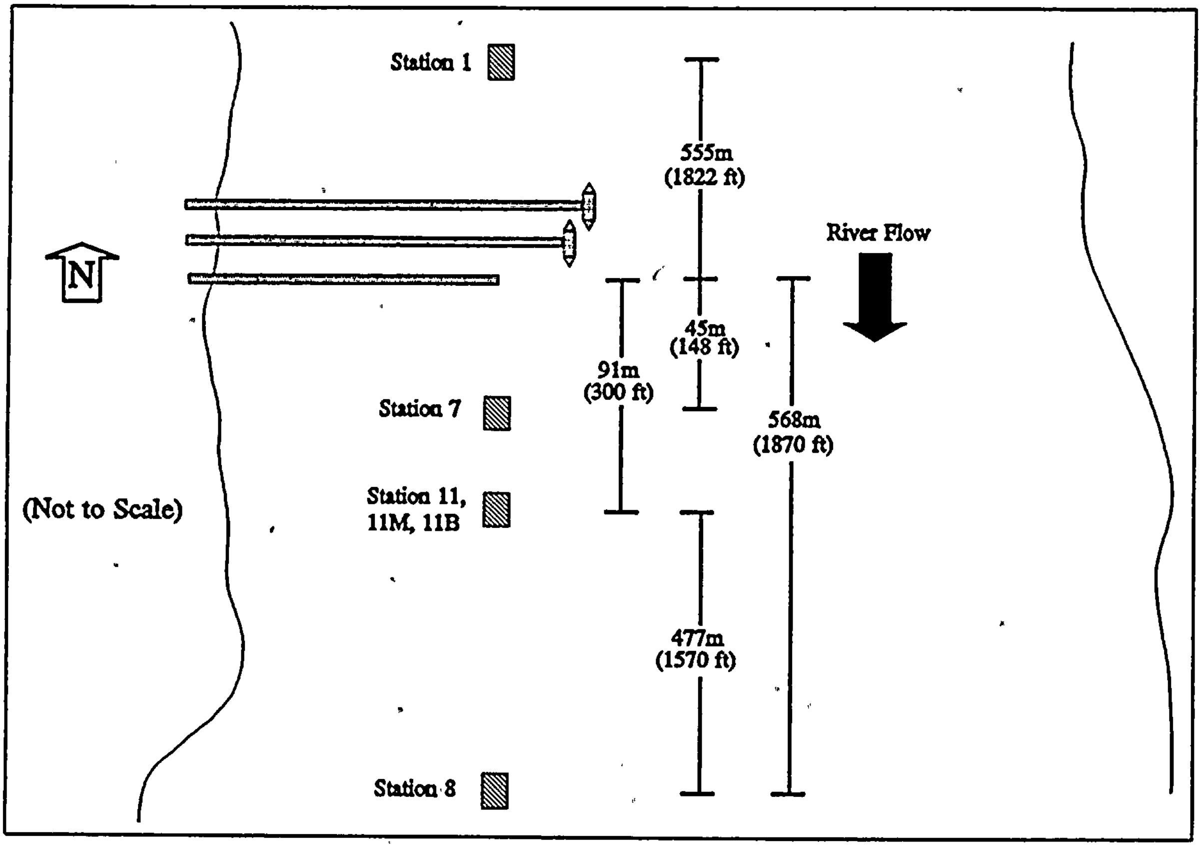
Field temperature measurements were made using a Fisher NIST-traceable thermometer. Temperature was recorded to within 0.1°C after the probe had been allowed to equilibrate for a minimum of one minute.

Total metals, sulfate, conductivity, pH, dissolved oxygen, inorganic phosphate, turbidity, total alkalinity, total hardness, VOCs and semi-VOCs, total phosphorus, and oil and grease, were determined by Supply System laboratory personnel. Analysis for total dissolved solids were performed by an offsite laboratory. Sample holding times followed those recommended by the U.S. Environmental Protection Agency (EPA 1983). Table 3-3 lists the approved EPA and Standard Methods used.

Table 3-3. Summary of Water Quality Parameters, EPA and Standard Methods Numbers

Parameter	EPA Method Number	Standard Methods Number
Water Temperature (°C)	170.1	
Turbidity (NTU)	180.1	
Conductivity (μS/cm) at 25°C	120.1	
Dissolved Oxygen (mg/L) Probe	360.1	
Dissolved Oxygen (mg/L) Modified Winkler	360.2	
pH	150.1	
Total Alkalinity (mg/L as $CaCO_3$)	310.1	
Total Hardness (mg/L as $CaCO_3$)	130.2, 6010	2340-B
Oil and Grease (mg/L)	413.2	
Total Phosphorus (mg/L as P)	365.2	4500-P
Inorganic Phosphate (mg/L as P)	300, 365.2	
Sulfate (mg/L as SO_4)	300, 375.4	
Total Copper (μg/L as Cu)	200.7, 220.1, 220.2	
Total Iron (μg/L as Fe)	200.7, 236.1, 236.2	
Total Nickel (μg/L asNi)	200.7, 249.1, 249.2	
Total Zinc (μg/L as Zn)	200.7, 289.1, 289.2	
Total Lead (μg/L as Pb)	200.7, 239.1, 239.2	
Total Cadmium (μg/L as Cd)	200.7, 213.1, 213.2	
Total Chromium (μg/L as Cr)	200.7, 218.1, 218.2	
Filterable Residue: TDS (mg/L)	160.1	
Volatile Organics (μg/L)	8240	
Semivolatile Organics (μg/L)	8270	

Figure 3-2. Schematic of River Sample Locations for Water Quality



3.3 RESULTS AND DISCUSSION

The evaporation/percolation pond is a separate monitoring system and is not related to the effects of the blowdown on the Columbia River.

3.3.1 Temperature

Columbia River surface temperatures varied seasonally with a minimum temperature of 3.2°C at all stations on February 17 and a maximum of 19.5°C at all stations on August 18 (Table 3-4). Blowdown temperatures ranged from 14.7°C in April to 26.3°C in September.

Table 3-4. Summary of Temperature (°C) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/27/94	4.4	4.4	4.5	4.4	21.2
02/17/94	3.2	3.2	3.2	3.2	20.2
03/31/94	5.9	6.0	6.0	6.0	22.4
04/28/94	9.5	9.4	9.4	9.5	14.7
05/25/94	12.9	--	--	--	--
06/15/94	13.8	--	--	--	--
07/26/94	19.3	19.3	19.3	19.3	22.3
08/18/94	19.5	19.5	19.5	19.5	22.0
09/27/94	19.0	19.0	19.0	19.0	26.3
10/27/94	15.0	15.0	15.0	15.0	25.5
11/29/94	9.5	9.5	9.5	9.5	20.3
12/19/94	7.4	7.3	7.3	7.3	21.3

3.3.2 Dissolved Oxygen (DO)

DO measurements for each sample station are presented in Table 3-5. Columbia River DO concentrations ranged from 9.3 mg/L at stations 1 and 11 in August and all stations in September to 14.6 mg/L at station 7 in March.

Table 3-5. Summary of Dissolved Oxygen (mg/L) Measurements

Sample Date	1	7	11	8
01/27/94	12.4	12.5	12.7	12.6
02/17/94	12.8	13.0	12.8	12.8
03/31/94	14.5	14.6	14.4	14.5
04/28/94	12.9	12.9	12.7	12.9
05/25/94	12.2	--	--	--
06/15/94	11.0	--	--	--
07/26/94	9.5	9.6	9.6	9.5
08/18/94	9.3	9.4	9.3	9.4
09/27/94	9.3	9.3	9.3	9.3
10/27/94	9.7	9.6	9.7	9.7
11/29/94	11.0	11.0	11.0	11.1
12/19/94	12.2	12.2	12.3	11.9

DO concentrations were inversely related to river temperaure 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.

3.3.3 pH and Alkalinity

Columbia River pH values ranged from 7.31 at station 8 in October to 7.98 at station 8 in March. The largest difference of 0.29 standard units occurred between station 7 (pH 7.69) and station 8 (pH 7.98) in March. The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1992). Blowdown pH values ranged from 7.56 in January to 8.26 in August. Pond pH values ranged from 7.41 in October to 8.19 in February. Columbia River alkalinities ranged from 52 to 65 mg/L as calcium carbonate. Results for pH and alkalinity are listed in Tables 3-6 and 3-7.

Table 3-6. Summary of pH Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/27/94	7.67	7.62	7.69	7.65	7.56	7.79
02/17/94	7.63	7.67	7.68	7.73	8.20	8.19
03/31/94	7.74	7.69	7.80	7.98	8.03	7.76
04/28/94	7.96	7.86	7.92	7.87	7.69	8.01
05/25/94	7.90	--	--	--	--	7.76
06/15/94	7.78	--	--	--	--	7.72
07/26/94	7.45	7.57	7.50	7.67	7.63	7.89
08/18/94	7.50	7.60	7.52	7.56	8.26	7.46
09/27/94	7.53	7.56	7.48	7.63	8.08	8.02
10/27/94	7.33	7.35	7.32	7.31	7.95	7.41
11/29/94	7.53	7.61	7.69	7.53	7.81	7.75
12/19/94	7.66	7.54	7.60	7.59	8.22	8.01

Table 3-7. Summary of Alkalinity Measurements

Sample Date	1	7	11	8
01/27/94	62	62	62	63
02/17/94	63	64	64	64
03/31/94	64	63	65	65
04/28/94	59	59	60	60
05/25/94	57	--	--	--
06/15/94	53	--	--	--
07/26/94	54	54	56	54
08/18/94	52	53	53	53
09/27/94	55	54	54	55
10/27/94	54	53	53	54
11/29/94	55	54	56	55
12/19/94	59	59	59	60

3.3.4 Hardness

Hardness ranged from 58 to 88 mg/L as calcium carbonate. This data is presented in Table 3-8.

Table 3-8. Summary of Total Hardness Measurements

Sample Date	1	7	11	8
01/27/94	72	72	73	73
02/17/94	76	76	77	77
03/31/94	73	74	74	74
04/28/94	88	83	82	82
05/25/94	79	--	--	--
06/15/94	58	--	--	--
07/26/94	59	58	58	58
08/18/94	59	61	61	61
09/27/94	65	67	68	67
10/27/94	65	66	66	66
11/29/94	65	68	67	66
12/19/94	69	71	71	71

3.3.5 Conductivity

Columbia River conductivity measurements ranged from 127 μS/cm at 25°C at station 1 in June to 153 μS/cm at 25°C at station 11 in February. Blowdown measurements ranged from 193 μS/cm at 25°C to 1460 μS/cm at 25°C. Storm drain pond values ranged from 157 to 463 μS/cm at 25°C. Conductivity measurements are listed in Table 3-9.

Table 3-9. Summary of Conductivity Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/27/94	149	150	149	149	687	273
02/17/94	152	152	153	152	635	463
03/31/94	150	150	150	150	517	164
04/28/94	139	140	140	141	556	327
05/25/94	137	--	--	--	--	167
06/15/94	127	--	--	--	--	157
07/26/94	131	132	131	131	193	318
08/18/94	132	130	131	130	977	176
09/27/94	136	135	136	136	1460	424
10/27/94	131	132	132	134	1200	334
11/29/94	135	137	139	137	987	377
12/19/94	147	147	147	148	964	257

3.3.6 Turbidity

In the Columbia River, measured turbidities were low and ranged from 0.6 nephelometric turbidity units (NTU) to 2.8 NTU. Blowdown values ranged from 3.2 to 19.5 NTU. Blowdown results are listed in Table 3-10.

Table 3-10. Summary of Turbidity Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/27/94	0.8	0.8	0.7	0.7	13.0
02/17/94	0.6	0.8	0.8	0.7	5.0
03/31/94	1.7	1.5	1.8	1.4	3.2
04/28/94	2.1	2.2	2.1	2.1	19.5
05/25/94	2.8	--	--	--	--
06/15/94	1.1	--	--	--	--
07/26/94	1.3	1.1	1.1	1.3	5.3
08/18/94	1.6	1.6	1.7	1.7	5.3
09/27/94	1.1	1.2	1.2	1.1	9.8
10/27/94	1.0	1.1	1.1	1.0	7.6
11/29/94	0.9	0.9	0.9	0.9	18.0
12/19/94	1.1	0.7	0.8	0.7	4.6

3.3.7 Metals (Total)

Columbia River cadmium, nickel, and lead concentrations were below the respective method detection limits (1.4, 2.0, 0.7 $\mu g/L$) at all stations during all periods. River copper concentrations ranged from <1.9 $\mu g/L$ to 2.5 $\mu g/L$. Zinc concentrations ranged from <5.0 $\mu g/L$ to 25$\mu g/L$ and iron concentrations ranged from 22 $\mu g/L$ to 86 $\mu g/L$. Chromium concentrations were generally below the detection limit of 0.3 $\mu g/L$. The highest chromium reading of 1.0 $\mu g/L$ was recorded at all stations in July.

Blowdown cadmium concentrations were below the detection limit for all stations and periods. Nickel and lead concentrations were fairly low, ranging from <2.0 $\mu g/L$ to 6.9 $\mu g/L$ and < 0.7 $\mu g/L$ to 3.6 $\mu g/L$, respectively. Blowdown copper, zinc and iron concentrations were substantially higher than river concentrations and ranged from 34 $\mu g/L$ to 187 $\mu g/L$, 25 $\mu g/L$ to 106 $\mu g/L$, and 120 $\mu g/L$ to 1300 $\mu g/L$, respectively. Chromium concentrations ranged from <0.3 $\mu g/L$ to 2.3 $\mu g/L$.

Evaporation/percolation pond water cadmium and nickel concentrations were below their respective detection limits for all periods. Lead concentrations ranged from <0.7 $\mu g/L$ to 2.1 $\mu g/L$. Chromium concentrations ranged from <0.3 $\mu g/L$ to 9.8 $\mu g/L$. Copper and zinc concentrations ranged from <1.9 $\mu g/L$ to 27 $\mu g/L$ and zinc concentrations ranged from 7.4 $\mu g/L$ to 410 $\mu g/L$. Iron concentrations ranged from a low of 11 $\mu g/L$ in April to a high of 570 $\mu g/L$ in October. Storm drain pond sediment samples produced measurable levels for all of the metal constituents analyzed.

Total metal results are listed in Tables 3-11 through 3-17.

Table 3-11. Summary of Copper ($\mu g/L$) Measurements

Sample Date	1	7	11	11M	11B	8	Plant Blowdown	Pond	Pond Sediment ($\mu g/g$)
01/27/94	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	34	<1.9	–
02/17/94	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	47	2.5	–
03/31/94	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	41	2.1	–
04/28/94	<1.9	<1.9	2.3	<1.9	<1.9	<1.9	76	2.1	–
05/25/94	1.9	–	–	–	–	–	–	3.6	–
06/15/94	<1.9	–	–	–	–	–	–	2.5	751
07/26/94	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	187	2.2	–
08/18/94	2.5	<1.9	<1.9	<1.9	<1.9	<1.9	128	4.4	–
09/27/94	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	64	<1.9	–
10/27/94	<1.9	2.2	<1.9	<1.9	<1.9	<1.9	72	27	–
11/29/94	<1.9	4.9	<1.9	<1.9	<1.9	<1.9	62	19	–
12/19/94	2.4	2.0	<1.9	<1.9	2.0	<1.9	48	4.8	223

Table 3-12. Summary of Nickel ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment ($\mu g/g$)
01/27/94	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
02/17/94	<2.0	<2.0	<2.0	<2.0	6.9	<2.0	—
03/31/94	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
04/28/94	<2.0	<2.0	<2.0	<2.0	3.5	<2.0	—
05/25/94	<2.0	—	—	—	—	<2.0	—
06/15/94	<2.0	—	—	—	—	<2.0	179
07/26/94	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
08/18/94	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
09/27/94	<2.0	<2.0	<2.0	<2.0	6.3	<2.0	—
10/27/94	<2.0	<2.0	<2.0	<2.0	2.3	<2.0	—
11/29/94	<2.0	<2.0	<2.0	<2.0	4.2	<2.0	—
12/19/94	<2.0	<2.0	<2.0	<2.0	3.3	<2.0	55

Table 3-13. Summary of Zinc ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment ($\mu g/g$)
01/27/94	5.1	5.9	5.2	5.6	28	7.4	–
02/17/94	6.2	<5.0	<5.0	5.0	52	15	–
03/31/94	6.1	<5.0	<5.0	<5.0	25	22	–
04/28/94	7.4	6.1	6.2	5.4	53	47	–
05/25/94	8.2	–	–	–	–	86	–
06/15/94	6.3	–	–	–	–	86	6800
07/26/94	23	16	13	25	106	66	–
08/18/94	<5.0	5.7	5.7	5.6	81	103	–
09/27/94	7.0	<5.0	<5.0	<5.0	43	19	–
10/27/94	<5.0	<5.0	5.3	5.3	58	410	–
11/29/94	8.4	7.4	10	10	62	280	–
12/19/94	6.0	6.2	5.9	<5.0	70	71	1410

Table 3-14. Summary of Iron ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/27/94	33	30	25	42	240	12
02/17/94	41	39	33	31	120	24
03/31/94	33	27	32	28	240	93
04/28/94	86	61	83	61	920	11
05/25/94	52	–	–	–	–	38
06/15/94	53	–	–	–	–	32
07/26/94	74	48	58	69	230	21
08/18/94	79	72	70	71	228	157
09/27/94	61	71	62	59	540	22
10/27/94	84	61	52	59	735	570
11/29/94	38	47	42	40	1300	160
12/19/94	23	31	25	22	404	113

Table 3-15. Summary of Lead ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment ($\mu g/g$)
01/27/94	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	–
02/17/94	<0.7	<0.7	<0.7	<0.7	1.8	<0.7	–
03/31/94	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	–
04/28/94	<0.7	<0.7	<0.7	<0.7	1.2	<0.7	–
05/25/94	<0.7	–	–	–	–	<0.7	–
06/15/94	<0.7	–	–	–	–	<0.7	115
07/26/94	<0.7	<0.7	<0.7	<0.7	1.2	0.7	–
08/18/94	<0.7	<0.7	<0.7	<0.7	0.9	<0.7	–
09/27/94	<0.7	<0.7	<0.7	<0.7	1.3	<0.7	–
10/27/94	<0.7	<0.7	<0.7	<0.7	3.6	2.1	–
11/29/94	<0.7	<0.7	<0.7	<0.7	2.3	1.0	–
12/19/94	<0.7	<0.7	<0.7	<0.7	2.9	0.8	32

Table 3-16. Summary of Cadmium (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/27/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
02/17/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
03/31/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
04/28/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
05/25/94	<1.4	--	--	--	--	<1.4	--
06/15/94	<1.4	--	--	--	--	<1.4	73
07/26/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
08/18/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
09/27/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
10/27/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
11/29/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
12/19/94	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	15

Table 3-17. Summary of Chromium (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/27/94	<0.3	<0.3	<0.3	<0.3	1.3	<0.3	--
02/17/94	<0.3	<0.3	<0.3	<0.3	2.0	<0.3	--
03/31/94	<0.3	<0.3	<0.3	<0.3	0.8	0.4	--
04/28/94	<0.3	<0.3	<0.3	<0.3	0.9	<0.3	--
05/25/94	<0.3	--	--	--	--	<0.3	--
06/15/94	0.7	--	--	--	--	1.0	49
07/26/94	1.0	1.0	1.0	1.0	1.6	1.0	--
08/18/94	<0.3	<0.3	<0.3	<0.3	1.8	<0.3	--
09/27/94	<0.3	<0.3	<0.3	<0.3	<0.3	0.6	--
10/27/94	<0.3	<0.3	<0.3	<0.3	2.3	0.8	--
11/29/94	<0.3	<0.3	<0.3	<0.3	1.6	9.8	--
12/19/94	<0.3	<0.3	<0.3	<0.3	0.6	<0.3	68

3.3.8 Oil and Grease

Blowdown and pond oil and grease values were below the detection limit of 1.0 mg/L for all periods sampled except October, in which 1.4 mg/L was recorded from the plant blowdown. Oil and grease measurements are summarized in the following table.

Table 3-18. Summary of Oil and Grease (mg/L) Measurements

Sample Date	Plant Blowdown	Pond
01/27/94	<1.0	<1.0
02/17/94	<1.0	<1.0
03/31/94	<1.0	<1.0
04/28/94	<1.0	<1.0
05/25/94	--	<1.0
06/15/94	--	<1.0
07/26/94	<1.0	<1.0
08/18/94	<1.0	<1.0
09/27/95	<1.0	<1.0
10/27/94	1.4	<1.0
11/29/94	<1.0	<1.0
12/19/95	<1.0	<1.0

3.3.9 Total Phosphorus and Inorganic Phosphate

Columbia River total phosphorus concentrations ranged from <0.01 to 0.03 mg/L as P. Blowdown values ranged from 1.05 to 3.85 mg/L as P. Columbia River inorganic phosphate concentrations were at or below 0.1 mg/L for all stations and periods. Blowdown inorganic phosphate measurements ranged from 0.7 to 1.3 mg/L as P. Total phosphorus and inorganic phosphate measurements are summarized in the following tables (3-19 and 3-20).

Table 3-19. Summary of Total Phosphorus (mg/L as P) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/27/94	0.01	<0.01	<0.01	<0.01	1.05
02/17/94	0.01	<0.01	0.01	<0.01	3.66
03/31/94	0.02	0.01	0.02	0.02	2.71
04/28/94	0.02	0.02	0.02	0.02	3.85
05/25/94	0.02	—	—	—	—
06/15/94	<0.01	—	—	—	—
07/26/94	0.02	0.02	0.02	0.01	2.78
08/18/94	0.01	0.01	0.02	0.01	2.73
09/27/94	0.02	0.02	0.02	0.02	2.60
10/27/94	0.01	0.02	0.02	0.02	3.60
11/29/94	0.02	0.03	0.03	0.02	3.42
12/19/94	0.01	0.01	0.01	0.01	3.20

Table 3-20. Summary of Inorganic Phosphate (mg/L as P) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/27/94	<0.1	<0.1	<0.1	<0.1	0.7
02/17/94	<0.1	<0.1	<0.1	<0.1	1.2
03/31/94	<0.1	<0.1	<0.1	<0.1	0.7
04/28/94	<0.1	0.1	<0.1	<0.1	1.3
05/25/94	0.1	—	—	—	—
06/15/94	<0.1	—	—	—	—
07/26/94	<0.1	0.1	<0.1	<0.1	1.1
08/18/94	<0.1	0.1	<0.1	<0.1	0.9
09/27/94	<0.1	<0.1	<0.1	<0.1	1.0
10/27/94	<0.1	0.1	<0.1	<0.1	1.1
11/29/94	0.1	0.1	0.1	<0.1	1.3
12/19/94	<0.1	0.1	<0.1	<0.1	0.9

3.3.10 Sulfate

Individual Columbia River sulfate measurements ranged from 8.5 to 11.5 mg/L. Blowdown measurements ranged from 11.3 to 670 mg/L. The results are presented in Table 3-21.

Table 3-21. Summary of Sulfate (mg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/27/94	10.7	10.7	11.2	10.7	269
02/17/94	11.3	11.4	11.5	11.4	346
03/31/94	11.1	11.1	11.4	11.2	126
04/28/94	10.5	10.6	10.6	10.6	151
05/25/94	10.1	—	—	—	—
06/15/94	8.5	—	—	—	—
07/26/94	8.6	8.6	8.5	8.5	11.3
08/18/94	8.7	8.8	9.2	8.7	389
09/27/94	9.7	9.7	9.8	9.6	670
10/27/94	9.4	9.4	9.8	9.6	538
11/29/94	9.3	10.9	10.8	9.7	438
12/19/94	9.8	9.9	9.9	10.4	346

3.3.11 Total Dissolved Solids

The quarterly total dissolved solids (TDS) measurements of the pond ranged from 52 mg/L to 250 mg/L. This data is presented in Table 3-22.

Table 3-22. Summary of Quarterly Total Dissolved Solid (mg/L) Measurements

Sample Date	Conc.
03/31/94	52
06/15/94	110
09/27/94	250
12/19/94	96

3.3.12 VOCs and Semi-VOCs

Blowdown volatile and semivolatile concentrations were below their respective detection limits for all compounds during all periods.

Evaporation/percolation pond semivolatile organic compound concentrations were below their respective detection limits for all periods. Volatile organic concentrations were below their respective detection limits for all compounds during all periods, except acetone in March and chloroform in September. Measurements of 42 $\mu g/L$ of acetone and 15 $\mu g/L$ of chloroform were recorded. Limits of detection for acetone and chloroform are 20 $\mu g/L$ and 5 $\mu g/L$, respectively. A list of the volatile and semivolatile organic compounds analyzed are presented in Tables 3-22 and 3-23, respectively.

Table 3-23. Summary of Volatile Organic Compounds

Chloromethane	Vinyl chloride	trans-1,3-Dichloropropene
Trichlorofluoromethane	Bromomethane	Dibromochloromethane
Freon 113	Chloroethane	Toluene
1,1-Dichloroethene	Carbon disulfide	2-Hexanone
Acetone	Methylene chloride	Ethylbenzene
cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Styrene
1,1-Dichloroethane	Chloroform	1,4-Dichlorobenzene
1,2-Dichloroethane	2-Butanone	1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane	Carbon tetrachloride	Bromoform
Benzene	Trichloroethene	4-Methyl-2-pentanone
1,2-Dichloropropane	Vinyl acetate	Tetrachloroethene
Bromodichloromethane	2-Chloroethylvinylether	Chlorobenzene
cis 1,3-Dichloropropene	1,1,2-Trichloroethane	Total Xylenes
1,3-Dichlorobenzene	1,2-Dichlorobenzene	

Table 3-24. Summary of Semivolatile Organic Compounds

Acids	Base Neutrals	
Phenol	2-Chloronaphthalene	2,4-Dinitrotoluene
2-Chlorophenol	2-Nitroaniline	Diethylphthalate
2-Methylphenol	Dimethylphthalate	Fluorene
4-Methylphenol	Acenaphthalene	4-Chlorophenyl-phenylether
2-Nitrophenol	2,6-Dinitrotoluene	4-Nitroaniline
2,4-Dimethylphenol	3-Nitroaniline	n-Nitrosodiphenylamine
2,4-Dichlorophenol	Acenaphthene	4-Bromophenyl-phenylether
Benzoic Acid	Dibenzofuran	Hexachlorobenzene
4-Chloro-3-methylphenol	Phenanthrene	bis (2-Chloroethyl)ether
2,4,6-Trichlorophenol	1,3-Dichlorobenzene	Anthracene
2,4,5-Trichlorophenol	1,4-Dichlorobenzene	Di-n-butylphthalate
2,4-Dinitrophenol	Benzyl Alcohol	Fluoranthene
4-Nitrophenol	1,2-Dichlorobenzene	Pyrene
4,6-Dinitro-2-methylphenol	bis (2-chloroisopropyl) ether	Butylbenzylphthalate
Pentachlorophenol	n-Nitroso-di-n-propylamine	Benzo[a]anthracene

Table 3-24. Summary of Semivolatile Organic Compounds (Continued)

Base Neutrals

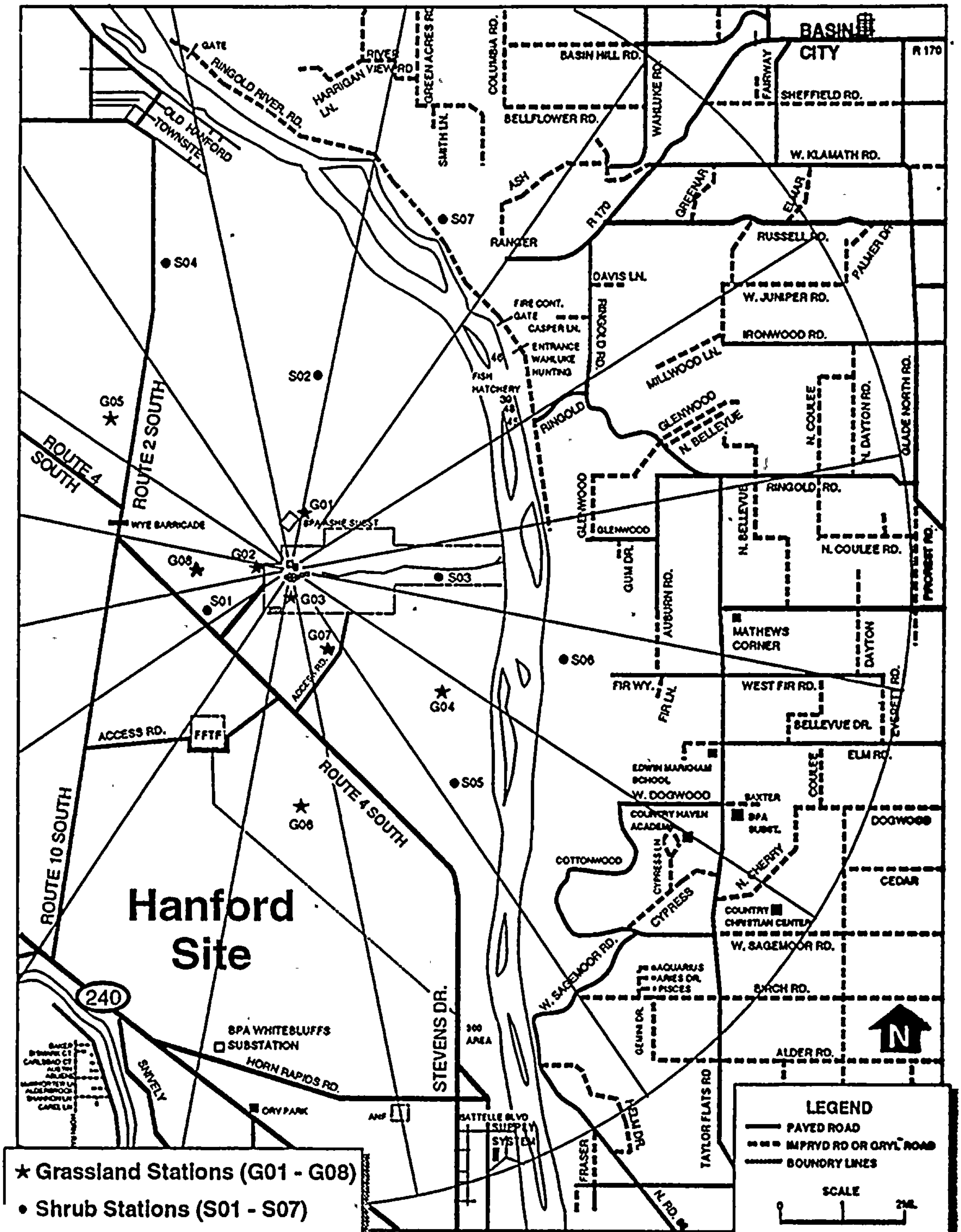
Hexachloroethane	Nitrobenzene
Isophorone	bis (2-Chloroethoxy)methane
1,2,4-Trichlorobenzene	Naphthalene
4-Chloroaniline	Dibenzo[a,h]anthracene
Benzo[g,h,i]perylene	Hexachlorobutadiene
2-Methylnaphthalene	Hexachlorocyclopentadiene
Benzo[b]fluoranthene	3,3-Dichlorobenzidine
Benzo[k]fluoranthene	Chrysene
Benzo[a]pyrene	bis (2-Ethylhexyl)phthalate
Indeno[1,2,3-cd]pyrene	

4.0 SOIL AND VEGETATION STUDIES

4.1 INTRODUCTION

The objective of the soil and vegetation studies is to identify any significant effects or impacts of plant cooling tower operation upon the plant communities surrounding WNP-2. Vegetation and soil sampling is conducted at the peak of the cheatgrass growth cycle known as the purple stage (Klemmedson 1964). Cheatgrass *(Bromus tectorum)* is the predominant species within all fifteen of the sampling plots with a mean frequency >98% and cover often approaching 50%. Cheatgrass fruits turn purple shortly after reaching viability and then brown when mature. The purple stage of development correlates well with the peak productivity of many associated species and serves as a marker for initiation of annual sampling and comparison of phytomass productivity between years. The program includes the measurement of herbaceous canopy cover, herbaceous phytomass and soil chemistry. Soil chemical parameters measured include pH, carbonate, bicarbonate, sulfate, chloride, sodium, copper, zinc and conductivity. Fifteen sampling stations are located within a five mile radius of the plant. The stations consist of eight grassland (G01-G08) and seven shrub sites (S01-S07). The location of each station is illustrated in Figure 4-1.

Figure 4-1. Soil and Vegetation Sampling Location Map



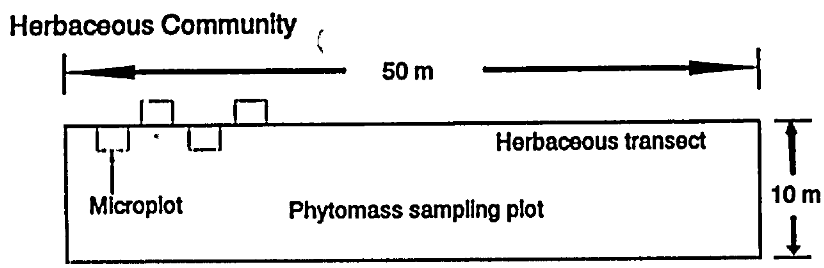
880334.19 Map
July 1993

4.2 MATERIALS AND METHODS

4.2.1 Herbaceous Canopy Cover

At each of the fifteen stations fifty microplots (20 cm x 50 cm) were placed at 1-meter intervals on alternate sides of the herbaceous transect (fig. 4-2). 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. To assure the quality of the sampling, three randomly selected microplots were sampled twice. The entire transect was resampled if cover estimates for any major species (>50% frequency) differed by more than one cover class.

Figure 4-2. Layout of Vegetation and Soil Sampling Plots



4.2.2 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 4-2). At each station, all live herbaceous vegetation rooted in the designated microplot (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 initials.

Sampling 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 singularly 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.

4.2.3 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 soil samples are randomly selected and taken from the phytomas sampling plot. The samples were placed in 250 ml sterile plastic cups with lids, labeled and refrigerated at 4°C. Nine parameters were analyzed in each sample, including pH, bicarbonate, carbonate, conductivity, sulfate, chloride, copper, zinc, and sodium. Aliquots of soil for trace metal analysis were microwave digested according to Gilman (1989). Preservation times and conditions, when applicable, followed EPA procedures (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.

4.3 RESULTS AND DISCUSSION

During the 1994 season, 64 plant taxa were observed in the study areas. Table 4-1 lists the vascular plants observed during 1994 field studies.

Table 4-1. Vascular Plants Observed During 1994

Scientific Name	Common Name
APIACEAE	Pasley Family
Cymopterus terebinthinus (Hook.) T.&G. *terebinthinus*	Turpentine cymopterus
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 leucophaea (Dougl.) Pays	NA
Cryptantha pterocarya (Torr.) Greene	Winged cryptantha
BRASSICAEAE	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 polycantha Haw.	Starvation cactus

Table 4-1. Vascular Plants Observed During 1994 (Continued)

Scientific Name	Common Name
CARYOPHYLLACEAE	Pink Family
Arenaria franklinii Dougl. var *franklinii*	Franklin's sandwort
Holosteum umbellatum L.	Jagged chickweed
CHENOPODIACEAE	Chenopod Family
Chenopodium leptophyllum (MOQ.) Wats.	Slimleaf goosefoot
Grayia spinosa (Hook.) MOQ	
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
GERANIACEAE	Geranium Family
Erodium cicutarium (L.) L'Her	Filaree, storks-bill
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	Blasing-star Family
Mentzelia albicaulis Dougl. Ex Hook.	White-stemmed mentzelia
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach Ex Gray	White-stemmed globe-mallow
ONAGRACEAE	Evening-primrose Family
Oenothera pallida Lindl. var. *pallida*	White-stemmed evening-primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat

Table 4-1. Vascular Plants Observed During 1994 (Continued)

Scientific Name	Common Name
POACEAE	Grass Family
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron dasystachyum (Hook.) 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
Oryzopsos 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
Leptodactylon pungens (Torr.) Nutt.	Granite gilia
Microsteris gracilis (Hook.) Greene var. *humilior* (Hook.) Cronq.	Pink microsteris
Phlox longifolia Nutt.	Long-leaf phlox
POLYGONACEAE	Buckwheat Family
Eriogonuum 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
SANTALACEAE	Sandalwood Family
Comandra umbellata (L.) Nutt.	Bastard toad-flax
SAXIFRAGACEAE	Saxifrage Family
Ribes aureum Pursh	Golden current
SCROPHULARIACEAE	Figwort Family
Penstemon acuminatus Dougl.	Sand-dune penstemon

Table 4-1. Vascular Plants Observed During 1994 (Continued)

Scientific Name	Common Name
VALERIANACEAE	Valerian Family
Plectritis macrocera T&G	Longhorn plectritis

4.3.1 Herbaceous Cover

Total herbaceous cover averaged 45.05% in 1994 which represents a decrease of 46% from 1993 (84.09). Each of the fifteen stations showed a decrease in total herbaceous cover. Total annual forb cover was 5.42%, a decrease of 53.95%. Total annual grass cover was 26.5%, 42.2% less than the previous year. *Bromus tectorum* continues to be the dominant annual grass with an average cover of 25.45%, a decrease of 42.23%. The total perennial forb cover was 4.32%, with a 7.69% decrease. In contrast to 1993, the dominant perennial forb was *Cymopterus terebinthinus*. Total perennial grass cover was 8.82%, a decrease of 59.5%. The dominant perennial grass as in previous years was *Poa sandbergii* with an average cover of 5.13%.

Frequency values (%) decreased at each of the fifteen stations. This is to be expected with the observed decrease in herbaceous cover. *Bromus tectorum*, which received frequency values of 100% at twelve of the fifteen stations in 1993, had 100% frequency values at only nine of the stations for 1994. The most significant decrease in frequency values was seen in annual forbs. In 1993 four species received frequency values of 100% at three different stations. This year, the frequency values at all of the stations for the annual forbs were less than 92%. The most significant change in total species per site was observed at stations GO3, SO1, and SO4. Each station had an increase of four species per site. Table 4-3 shows mean frequency values (%) by species for each sampling station.

Table 4-2. Herbaceous Cover for Fifteen Sampling Station - 1994

	G01	G02	G03	G04	G05	G06	G07	G08	S01
Annual Grasses									
Bromus tectorum	47.50	61.85	27.50	9.05	6.25	16.70	42.40	51.20	23.30
Festuca octoflora	0.00	0.00	0.00	0.00	0.10	0.50	0.00	0.00	0.00
Total Annual Grass Cover	47.50	61.85	27.50	9.05	6.35	17.20	42.40	51.20	23.30
Perennial Grasses									
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oryzopis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poa sandbergii	5.50	4.30	0.60	9.55	9.55	1.25	2.20	5.95	2.65
Stipa comata	0.00	0.00	0.00	24.75	0.00	15.40	0.00	1.25	0.00
Total Perennial Grass Cover	5.50	4.30	0.60	34.30	9.55	16.65	2.20	7.20	2.65
Annual Forbs									
Amsinckia lycopsoides	0.05	0.00	5.50	0.00	0.15	0.05	4.90	0.05	1.30
Brodiaea douglasii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Chenopodium leptophyllum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cryptantha circumscissa	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.30
Descurainia pinnata	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Draba verna	0.55	0.50	2.05	0.70	0.35	1.60	2.20	0.70	1.50
Erodium cicutarium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frasera acanthacarpa	0.00	0.00	5.35	0.00	0.00	0.00	0.50	0.00	0.60
Gilia minutiflora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holosteum umbellatum	0.70	0.25	0.40	0.35	0.00	2.50	0.80	0.10	0.70
Layia glandulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mentzelia albicaulis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Microsteris gracilis	0.05	0.10	3.30	0.00	0.30	1.35	0.40	0.75	2.15
Phacelia linearis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Plantago patagonica	1.60	0.30	0.00	1.30	0.00	0.00	0.00	0.25	0.00
Salsola kali	0.30	0.15	0.80	0.15	1.15	0.85	1.00	0.00	0.80
Sisymbrium altissimum	0.85	0.60	0.65	0.00	0.15	0.20	1.55	0.35	0.70
Total Annual Forb Cover	4.10	1.90	18.15	2.50	2.20	6.65	11.35	2.25	8.10
Perennial Forbs									
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aster canescens	0.00	0.00	10.70	0.00	0.00	0.10	0.60	0.00	1.75
Astragalus purshii	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	1.30	0.00	0.00	0.00
Balsamorhiza careyana	0.00	0.00	0.00	0.00	2.00	0.30	0.00	0.00	0.00
Comandra umbellata	0.00	0.00	0.00	0.00	0.70	0.00	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
Cymopterus terebinthinus	0.00	0.00	0.00	0.00	0.00	9.25	0.05	0.00	0.00
Eriogonum niveum	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.05
Oenothera pallida	0.00	0.00	0.20	0.20	0.85	0.15	0.00	0.00	0.05
Phlox longifolia	0.10	0.05	0.25	0.40	0.35	0.00	0.10	2.80	0.40
Rumex venosus	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Tragopogon dubius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Perennial Forb Cover	0.15	0.05	11.25	0.60	5.30	11.10	0.75	2.80	2.25
Total Herbaceous Cover	57.25	68.10	57.50	46.45	23.40	51.60	56.70	63.45	36.30

	S02	S03	S04	S05	S06	S07	AVG. G01-S07	AVG. G01-G04	AVG. S01-S05
Annual Grasses									
Bromus tectorum	11.00	28.40	21.10	35.50	5.35	9.70	26.45	36.48	23.86
Festuca octoflora	0.00	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.02
Total Annual Grass Cover	11.00	28.40	21.20	35.50	5.35	9.70	26.50	36.48	23.88
Perennial Grasses									
Agropyron spicatum	0.15	0.00	0.00	0.30	0.00	0.00	0.03	0.00	0.09
Oryzopis hymenoides	2.85	0.00	0.00	0.00	1.25	0.00	0.27	0.00	0.57
Poa sandbergii	6.50	5.70	3.75	0.00	9.90	9.55	5.13	4.99	3.72
Stipa comata	7.45	0.00	0.00	1.85	0.05	0.00	3.38	6.19	1.86
Total Perennial Grass Cover	16.95	5.70	3.75	2.15	11.20	9.55	8.82	11.18	6.24
Annual Forbs									
Amsinckia lycopsoides	0.00	0.00	0.00	1.95	0.00	0.00	0.93	1.39	0.65
Brodiaea douglasii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chenopodium leptophyllum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cryptantha circumscissa	0.25	0.00	0.05	0.15	0.00	0.00	0.06	0.00	0.15
Descurainia pinnata	0.00	0.00	0.15	0.00	0.00	0.05	0.02	0.03	0.03
Draba verna	0.05	1.10	0.15	1.75	0.00	0.00	0.88	0.95	0.91
Erodium cicutarium	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01
Frasera acanthacarpa	1.30	0.05	0.15	0.40	0.00	0.00	0.56	1.34	0.50
Gilia minutiflora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holosteum umbellatum	0.00	1.15	0.10	0.60	0.00	0.00	0.51	0.43	0.51
Layia glandulosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mentzelia albicaulis	0.05	0.00	0.10	0.00	0.00	0.00	0.01	0.00	0.03
Microsteris gracilis	0.10	0.65	0.15	1.10	0.00	0.00	0.69	0.86	0.83
Phacelia linearis	0.10	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
Plantago patagonica	0.00	3.80	0.00	0.95	0.00	2.15	0.69	0.80	0.95
Salsola kali	0.80	0.10	1.30	0.20	0.00	0.00	0.51	0.35	0.64
Sisymbrium altissimum	0.05	0.55	1.15	0.50	0.15	0.70	0.54	0.53	0.59
Total Annual Forb Cover	2.70	7.40	3.30	7.65	0.15	2.90	5.42	6.66	5.83
Perennial Forbs									
Achillea millefolium	0.05	0.00	0.10	0.00	1.30	0.00	0.10	0.00	0.03
Aster canescens	0.05	0.00	0.05	0.00	0.00	0.00	0.88	2.68	0.37
Astragalus purshii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
Balsamorhiza careyana	0.00	0.00	3.45	0.75	0.00	0.00	0.43	0.00	0.84
Comandra umbellata	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Crepis atrabarba	0.00	2.40	0.00	0.00	0.00	0.00	0.16	0.00	0.48
Cymopterus terebinthinus	6.95	0.00	0.00	0.00	0.00	6.45	1.51	0.00	1.39
Eriogonum niveum	0.00	0.00	0.00	6.75	0.00	0.00	0.55	0.00	1.36
Oenothera pallida	0.05	0.00	0.35	0.00	0.00	0.00	0.12	0.10	0.09
Phlox longifolia	0.05	1.20	0.55	0.00	0.00	0.00	0.42	0.20	0.44
Rumex venosus	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00
Tragopogon dubius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Perennial Forb Cover	7.15	3.60	4.50	7.50	1.30	6.45	4.32	3.01	5.00
Total Herbaceous Cover	37.80	45.10	32.75	52.80	18.00	28.60	45.05	57.33	40.95

Table 4-3. Mean Frequency Values (%) by Species for Each Sampling Station

	GO1	GO2	GO3	GO4	GO5	GO6	GO7	GO8	SO1	SO2	SO3	SO4	SO5	SO6	SO7
Annual Grasses															
Bromus tectorum	100	100	100	98	88	98	100	100	100	74	100	96	100	86	100
Festuca octoflora					4	10						4			
Perennial Grasses															
Agropyron spicatum										6			2		
Oryzopis hymenoides										10				10	
Poa sandbergii	60	38	4	88	82	10	28	50	36	44	82	36		72	92
Stipa comata				82		36		2		42			6	6	
Annual Forbs															
Amsinckia lycopsoides	2		38		6	2	68	2	32				38		
Chenopodium leptophyllum															
Cryptantha circumscissa					4	4			10			2	6	4	
Cryptantha pterocarya									6						
Descurainia pinnata			4									6			2
Draba verna	22	20	22	28	14	64	68	28	60	2	44	6	60		
Erodium cicutarium													2		
Franseria acanthacarpa			64				20		24	22	2	6	16		
Gilia sinuata															
Holosteum umbellatum	28	10	16	14		90	32	4	38		46	4	34		
Layia glandulosa															
Mentzelia albicaulis							2			2		4			
Microsteris gracilis	2	4	82		12	54	16	30	56	4	26	6	44		
Phacelia linearis									2	4					
Plantago pategonica	44	12		42				10			82		18		
Salsola kali	12	6	32	6	36	34	30		32	22	4	32	8		
Sisymbrium altissimum	24	24	26		6	8	22	14	28	2	22	46	20	6	8
Tragopogon dubius												2			
Perennial Forbs															
Achillea millifolium										2		4		4	
Aster canescens			82			4	24		50	2		2			
Astragalus purshii															
Astragalus sclerocarpus						4						10			
Balsamorhiza careyana					4	2						14	2		
Brodiaea douglasii							8	2							
Comandra umbellata					8										
Crepis atrabarba											6				
Cymopterus terebinthinus							2			16					
Eriogonum niveum					8				2				36		
Oenothera pallida			8	8	14	6			2	2		4	40		
Phlox longifolia	4	2	10	6	4		4	32	6	2	38	22			
Rumex venosus	2		4												
Total Species per Site	11	9	14	9	14	15	14	11	16	17	11	19	16	7	4

Table 4-4. Mean Herbaceous Cover for 1975 through 1994

CLASS	YEAR	S01	S02	S03	S04	S05	X 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	97.60	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
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

Table 4-4. Mean Herbaceous Cover for 1975 through 1994 (continued)

CLASS	YEAR	S01	S02	S03	S04	S05	X S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
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	0.09	0.35	3.20	6.30	16.15	7.55	1.80	7.95	1.20	1.45	12.35	6.12	6.61	5.16	5.98
PF	1988	11.55	15.75	2.10	4.85	3.25	7.50	0.10	0.00	5.37	0.20	2.00	0.00	4.40	1.65	15.25	8.70	2.45	4.34	4.34	4.79	4.90
ALL	1988	33.18	34.45	25.75	31.15	20.75	29.06	27.35	30.09	28.96	47.30	49.95	24.35	41.20	40.70	37.90	41.40	41.10	32.52	39.47	34.60	34.23
AG	1989	21.85	12.50	12.45	10.25	32.90	17.99	15.00	47.65	21.80	22.50	13.20	65.85	3.05	26.15	22.35	35.10	38.05	12.05	26.52	24.05	21.62
PG	1989	8.30	29.55	64.00	13.00	1.25	23.22	30.35	37.50	26.28	60.40	59.60	0.05	49.55	42.40	36.75	16.20	32.05	48.95	37.94	32.54	31.74
AF	1989	12.50	6.95	13.05	6.45	11.10	10.01	0.85	5.15	8.01	12.85	5.90	42.20	2.85	15.95	8.85	13.55	13.05	13.95	14.15	11.48	12.65
PF	1989	4.45	14.50	4.40	8.20	0.55	6.42	0.10	0.00	4.60	3.85	1.10	0.05	3.00	2.00	6.45	10.40	12.90	10.60	6.04	5.23	4.46
ALL	1989	47.10	63.50	93.90	37.90	45.80	57.64	46.30	90.30	60.69	99.60	79.80	108.15	58.45	86.50	74.40	75.25	96.05	85.55	84.66	73.31	70.47
AG	1990	36.80	16.80	17.50	32.40	53.35	31.37	12.90	5.45	25.03	18.60	7.75	61.55	13.65	25.39	23.80	35.45	36.55	19.75	27.01	26.06	28.71
PG	1990	3.30	12.85	18.35	12.70	0.05	9.45	18.40	17.55	11.89	18.70	0.00	0.00	30.00	12.18	11.90	10.70	9.30	12.10	11.59	11.73	10.66
AF	1990	7.95	2.60	8.15	4.55	8.90	6.43	0.10	0.00	4.61	7.75	2.35	15.70	3.35	7.290.3	2.75	6.90	8.95	7.00	6.84	5.80	6.81
PF	1990	0.40	9.55	1.75	3.90	0.05	3.313	0.00	0.00	2.24	0.00	0.05	0.05	1.20	3	3.95	8.55	0.05	0.20	1.76	1.98	1.88
ALL	1990	48.45	41.80	45.30	53.55	62.35	50.29	31.40	23.00	43.69	45.05	10.15	77.30	48.20	45.18	42.40	61.60	53.85	39.05	47.20	45.56	48.02
AG	1991	40.25	15.25	40.05	38.55	48.15	35.85	17.85	5.90	25.14	26.15	20.80	65.55	18.90	32.85	36.95	37.25	48.30	38.25	36.52	33.81	34.52
PG	1991	7.60	32.05	26.35	14.45	2.30	11.14	38.40	60.60	25.96	41.75	50.55	1.35	38.70	29.09	23.55	12.80	0.00	22.85	23.94	26.14	11.12
AF	1991	36.25	15.00	16.75	37.30	21.60	24.29	4.85	7.30	19.86	0.25	4.20	13.35	1.85	4.92	4.75	6.30	35.13	16.65	10.31	14.77	16.26
PF	1991	4.45	6.35	1.95	2.35	0.30	3.08	0.30	0.00	2.24	0.00	0.10	0.60	0.90	0.25	3.35	12.20	0.05	1.70	2.29	2.25	1.88
ALL	1991	88.55	63.65	85.10	89.65	72.35	74.36	61.40	73.80	76.36	61.15	75.65	80.25	60.35	66.11	68.60	68.55	83.48	79.45	72.19	76.97	63.78
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	10.693
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	.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
AG	1993	27.70	34.65	53.45	58.25	48.20	44.45	23.65	57.95	43.41	46.90	68.65	43.40	29.20	47.04	38.35	28.90	68.85	59.60	47.98	45.85	45.74
PG	1993	7.15	22.14	16.25	12.85	4.00	12.48	46.10	23.15	18.81	48.25	23.35	2.00	46.10	29.93	31.40	15.40	12.25	16.35	24.39	21.78	21.2
AF	1993	12.95	8.70	12.90	14.80	13.25	12.52	2.15	9.85	10.66	13.45	5.95	22.60	10.20	13.05	10.90	16.45	13.45	9.02	12.75	11.77	12.79
PF	1993	13.70	12.70	2.690	8.65	7.40	9.01	0.05	0.05	6.45	1.45	0.00	0.75	2.15	1.09	5.85	8.85	1.55	4.50	3.14	4.68	5.05
ALL	1993	58.10	77.49	85.20	94.55	71.35	77.34	71.95	88.90	78.22	110.00	97.95	66.25	87.55	90.44	86.00	69.60	94.40	89.27	87.63	84.08	83.89
AG	1994	23.30	11.00	28.40	21.20	35.50	23.88	5.35	9.70	19.21	47.50	61.85	27.50	9.05	36.48	6.35	16.70	42.40	51.20	32.88	26.50	30.18
PG	1994	2.65	16.95	5.70	3.75	2.15	6.24	11.20	9.55	7.42	5.50	4.30	0.60	34.30	11.18	9.55	16.65	2.20	7.20	10.04	8.82	8.71
AF	1994	8.10	2.70	7.40	3.30	7.65	5.83	0.15	2.90	4.60	4.10	1.90	18.15	2.50	6.66	2.20	6.65	11.35	2.25	6.14	5.42	6.25
PF	1994	2.25	7.15	3.60	4.50	7.50	5.00	1.30	6.45	4.68	0.15	0.05	11.25	0.60	3.01	5.30	11.10	0.75	2.80	4.00	4.32	4.01
ALL	1994	36.30	37.80	45.10	32.75	52.80	40.95	18.00	28.60	35.91	57.25	68.10	57.50	46.45	57.33	23.40	51.60	56.70	63.45	53.06	45.05	49.14

Fig. 4-3. Mean Herbaceous Cover for 1975 through 1994

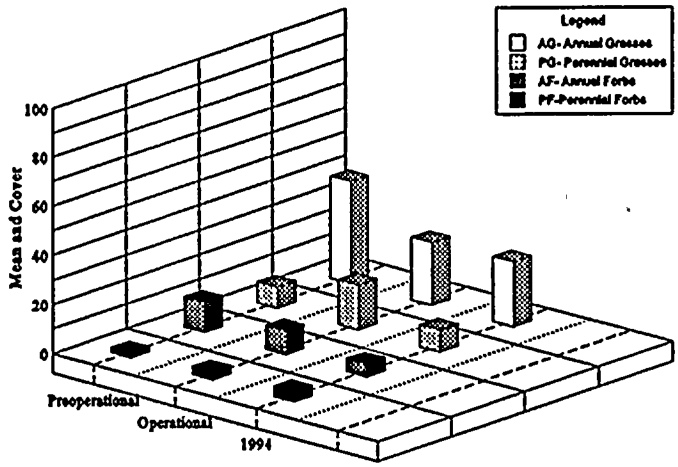


Figure 4-3 shows a comparison of the current data with previous data. Growing season (October 93 - April 94) precipitation (3.73cm) decreased 80% from the previous season (18.67 cm). The mean temperature during the growing season was 6.61°C compared with 4.30°C for 1993. A comparison of mean cover and precipitation for 1982 through 1994 can be seen in figure 4-4.

4.3.2 Herbaceous Phytomass

The decrease (77.6%) in herbaceous phytomass is in direct correlation to the decrease in herbaceous cover. At grassland and shrub stations, the phytomass production averaged 39.8g/m² and 24.0g/m² respectively. Mean herbaceous phytomass production at grassland and shrub stations is shown graphically in Figure 4-5 and summarized in Table 4-6.

Fig. 4-4. Mean Herbaceous Cover and Total Precipitation

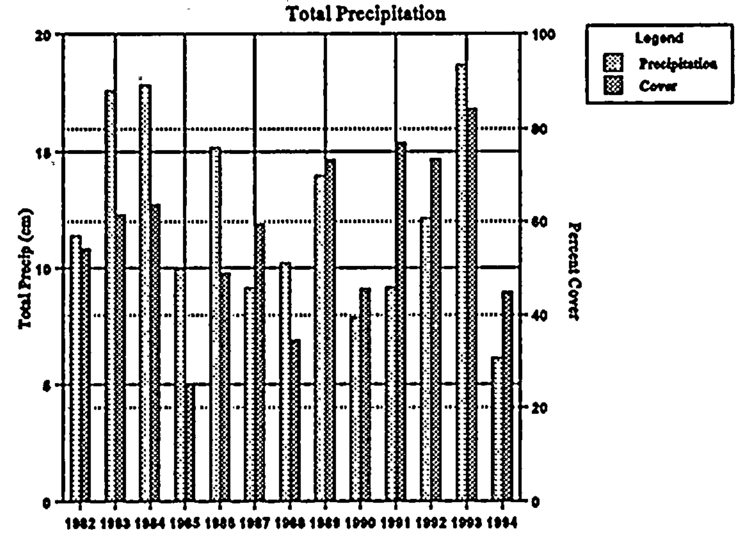


Table 4-5. .Mean Terrestrial Phytomass for 1994

DATE	SITE	PLOT	WT.(g)	WT./m²
05/11	GO1	7-4	0.6	5.9
05/11	GO1	14-3	3.9	38.6
05/11	GO1	17-2	6.1	60.7
05/11	GO1	27-3	5.7	56.6
05/11	GO1	41-6	6.7	66.5
		AVG	4.6	45.7
		STD	2.2	22.0

DATE	SITE	PLOT	WT.(g)	WT./m²
05/11	GO2	7-4	4.4	43.8
05/11	GO2	14-3	6.2	62.2
05/11	GO2	17-2	6.0	60.0
05/11	GO2	27-3	4.1	41.3
05/11	GO2	41-6	3.7	36.8
		AVG	4.9	48.8
		STD	1.0	10.3

DATE	SITE	PLOT	WT.(g)	WT./m²
05/03	GO3	7-9	4.6	45.9
05/03	GO3	14-3	7.6	76.3
05/03	GO3	17-2	6.4	64.1
05/03	GO3	27-4	4.0	39.6
05/03	GO3	41-6	2.0	19.9
		AVG	4.9	49.2
		STD	2.0	19.6

DATE	SITE	PLOT	WT(g)	WT./m²
05/06	GO4	7-9	1.7	16.9
05/06	GO4	14-3	1.1	11.4
05/06	GO4	17-2	1.0	10.0
05/06	GO4	27-4	3.7	36.6
05/06	GO4	41-6	0.3	2.9
		AVG	1.6	15.6
		STD	1.1	11.4

DATE	SITE	PLOT	WT.(g)	WT./m²
05/04	GO5	7-9	0.8	8.3
05/04	GO5	14-6	0.3	2.9
05/04	GO5	17-2	0.4	3.8
05/04	GO5	26-2	1.3	13.4
05/04	GO5	41-3	3.8	37.7
		AVG	1.3	13.2
		STD	1.3	12.8

DATE	SITE	PLOT	WT.(g)	WT./m²
05/05	GO6	7-9	10.8	108.4
05/05	GO6	14-3	14.3	143
05/05	GO6	17-2	3.8	38.0
05/05	GO6		0.0	
05/05	GO6	41-6	1.1	11.0
		AVG	7.5	60.1
		STD	5.3	56.1

DATE	SITE	PLOT	TE.(g)	WT./m²
05/05	GO7	7-9	1.6	16.3
05/05	GO7	14-3	2.8	27.9
05/05	GO7	17-2	5.1	50.9
05/05	GO7	27-4	4.6	46.1
05/05	GO7	41-6	6.6	66.4
		AVG	4.2	41.5
		STD	1.8	17.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/11	GO8	7-4	2.1	21.4
05/11	GO8	14-3	1.7	17.3
05/11	GO8	17-2	12.6	126.4
05/11	GO8	27-3	2.3	22.8
05/11	GO8	41-6	3.2	32.4
		AVG	4.4	44.1
		STD	4.1	41.5

DATE	SITE	PLOT	WT.(g)	WT./m²
05/04	SO1	9-7	4.4	43.6
05/04	SO1	14-6	2.8	27.7
05/04	SO1	17-2	2.3	23.2
05/04	SO1	26-2	2.1	21.0
05/04	SO1	41-3	2.1	20.8
		AVG	2.7	27.3
		STD	0.9	8.5

DATE	SITE	PLOT	WT.(g)	WT./m²
05/11	SO2	7-4	0.7	6.8
05/11	SO2	14-3	2.1	20.7
05/11	SO2	17-2	1.6	16.2
05/11	SO2	27-3	1.8	18.0
05/11	SO2	41-6	0.5	5.1
		AVG	1.3	13.4
		STD	0.6	6.2

DATE	SITE	PLOT	WT.(g)	WT./m²
05/06	SO3	7-4	1.4	14.3
05/06	SO3	14-3	1.6	15.5
05/06	SO3	17-2	3.7	36.8
05/06	SO3	27-3	3.0	30.0
05/06	SO3	41-6	0.6	6.1
		AVG	2.1	20.5
		STD	1.1	11.2

DATE	SITE	PLOT	WT.(g)	WT./m²
05/05	SO4	7-9	4.4	44.2
05/05	SO4	14-3	0.2	1.5
05/05	SO4	17-2	0.6	6.0
05/05	SO5	27-4	4.6	45.5
05/05	SO4	41-6	0.2	1.8
		AVG	2.0	19.8
		STD	2.1	20.5

DATE	SITE	PLOT	WT.(g)	WT./m²
05/03	SO5	7-9	4.4	43.5
05/03	SO5	14-3	7.7	76.7
05/03	SO5	17-2	7.4	73.9
05/03	SO5	27-4	7.2	72.1
05/03	SO5	41-6	3.8	37.6
		AVG	6.1	60.8
		STD	1.7	16.7

DATE	SITE	PLOT	WT.(g)	WT./m²
05/10	SO6	7-4	0.1	1.4
05/10	SO6	14-3	0.5	5.1
05/10	SO6	17-2	2.1	21.2
05/10	SO6	27-3	0.3	2.6
05/10	SO6	41-6	0.5	4.5
		AVG	0.7	7.0
		STD	0.7	7.2

DATE	SITE	PLOT	WT.(g)	WT./m²
05/10	SO7	6-1	1.1	11.2
05/10	SO7	7-2	0.8	7.7
05/10	SO7	26-4	2.9	29.0
05/10	SO7	31-6	3.1	31.2
05/10	SO7	45-8	1.6	16.4
		AVG	1.9	19.1
		STD	0.9	9.4

Phytomass Summary

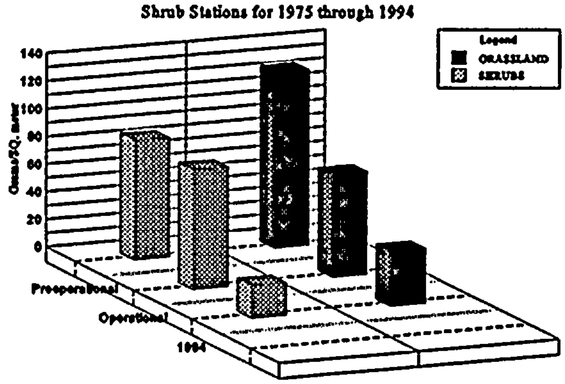
MEAN GO1-GO8	39.8 Grams/sq. meter
MEAN SO1-SO7	24.0 Grams/sq. meter

Table 4-6 presents mean phytomass values for each station in each year since 1975. This data can also be seen graphically in Figures 4-6 through 4-9.

Table 4-6. Comparison of Herbaceous Phytomass (g/m²) for 1975 through 1994

YEAR	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
1975	359	302	–	–	–	–	–	–	126	144	88	–	–	–	–
1976	108	258	–	–	–	–	–	–	137	98	177	–	–	–	–
1977	21	11	–	–	–	–	–	–	4	7	7	–	–	–	–
1978	166	162	–	–	–	–	–	–	173	128	115	–	–	–	–
1979	64	37	–	–	–	–	–	–	21	28	16	–	–	–	–
1980	160	68	53	79	–	–	–	–	36	63	43	78	71	–	–
1981	200	255	261	159	–	–	–	–	180	115	31	52	81	–	–
1982	90	60	62	113	–	–	–	–	98	24	22	39	184	–	–
1983	77	137	64	82	–	–	–	–	171	232	54	68	136	–	–
1984	94	116	133	67	–	–	–	–	104	57	95	93	43	–	–
1985	70	27	12	37	–	–	–	–	5	1	27	11	61	–	–
1986	50	61	32	35	–	–	–	–	35	112	25	176	42	–	–
1987	83	77	134	90	–	–	–	–	62	144	48	108	145	–	–
1988	34	14	16	61	–	–	–	–	59	73	15	24	19	–	–
1989	174.3	65.7	105.1	49.5	43.2	61.0	113.1	112.3	53.9	72.8	67.0	39.8	103.7	72.7	149.5
1990	13.6	4.1	64	73.2	36.8	39.8	29.1	10.8	32.8	78.3	28.2	30.9	43.4	34.0	6.1
1991	87.7	97.2	161.6	67.6	171.8	101.4	168.4	137.3	225.1	58.2	87.6	185.2	111.3	225.1	226.0
1992	142.4	109.4	82.7	60	54.4	49.4	101.4	74.3	49.2	147.5	90.7	80.3	110.3	101.3	187.3
1993	146	156.6	70.3	109.8	75.3	162.0	150.7	100.3	80.2	84.1	91.7	261.4	173.1	93.5	330.3
1994	45.7	48.8	49.2	15.6	13.2	60.1	41.5	44.1	27.3	13.4	20.5	19.8	60.8	7.0	19.1

Fig. 4-5. Phytomass at Grassland and Shrub Stations for 1975 through 1994



The following figures provide a visual comparison of preoperational, operational and current herbaceous cover for the individual stations.

Fig. 4-6. Mean Herbaceous Cover and Phytomass for Station GO1

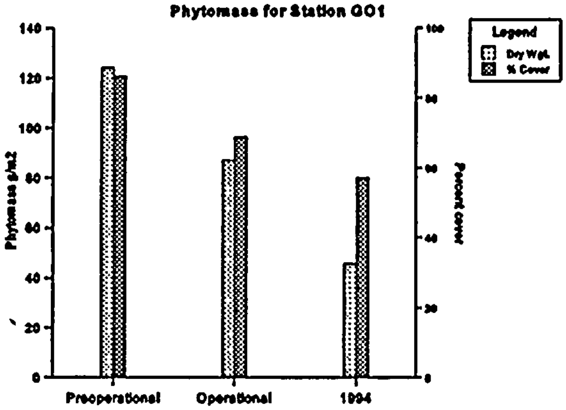


Fig.4-7. Mean Herbaceous Cover and Phytomass for Station GO2

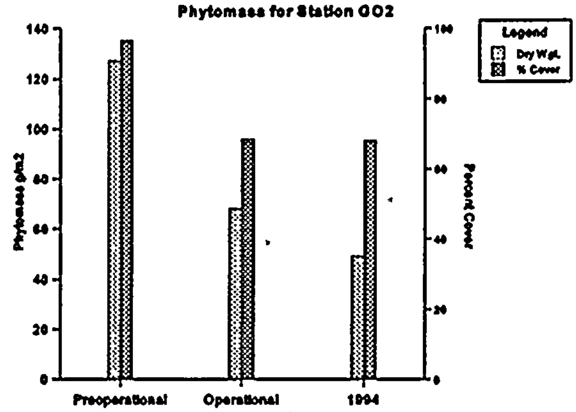


Fig. 4-8. Mean Herbaceous Cover and Phytomass for Station GO3

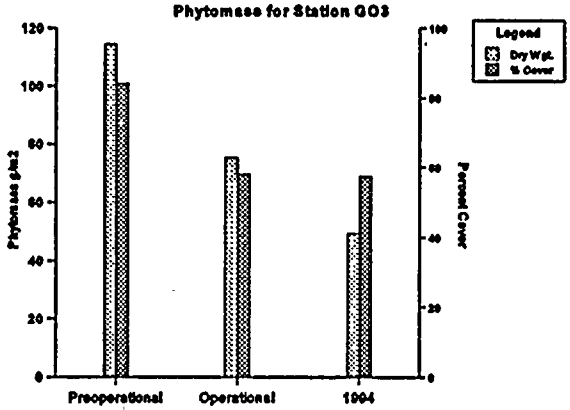


Fig. 4-9. Mean Herbaceous Cover and Phytomass for Station GO4

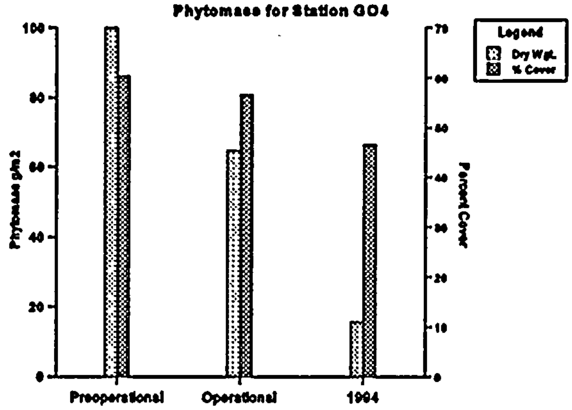


Fig. 4-10. Mean Herbaceous Cover and Phytomass for Station GO5

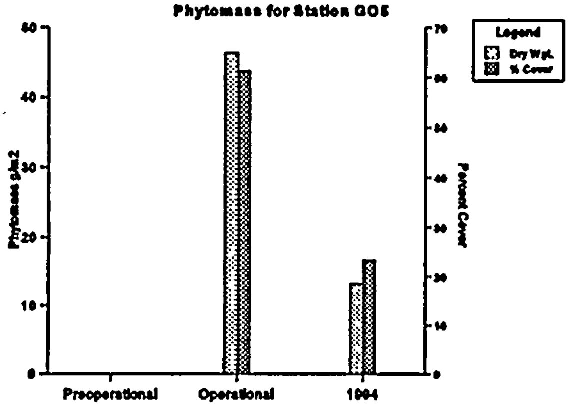


Fig. 4-11. Mean Herbaceous Cover and Phytomass for Station GO6

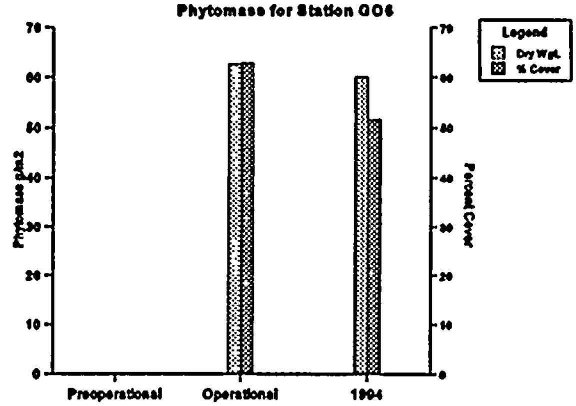


Fig. 4-12. Mean Herbaceous Cover and Phytomass for Station GO7

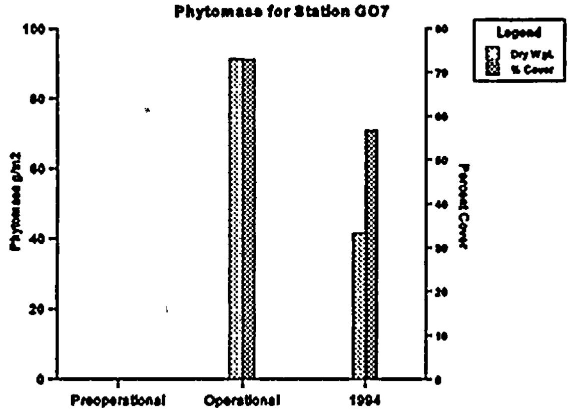


Fig. 4-13. Mean Herbaceous Cover and Phytomass for Station GO8

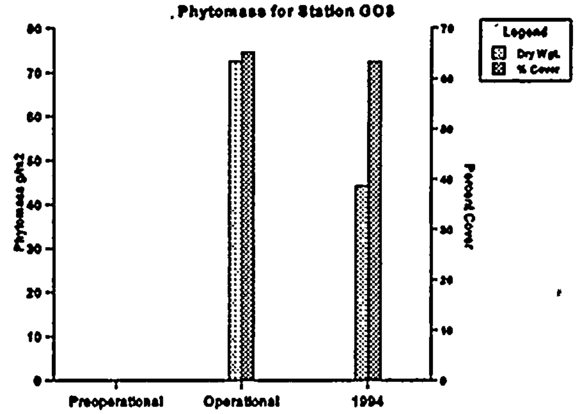


Fig. 4-13. Mean Herbaceous Cover and Phytomass for Station SO1

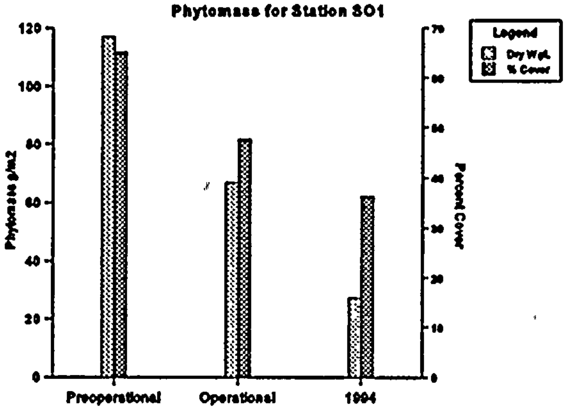


Fig. 4-15. Mean Herbaceous Cover and Phytomass for Station SO2

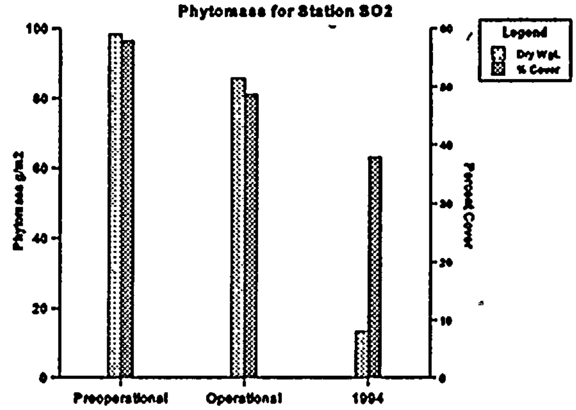


Fig. 4-16. Mean Herbaceous Cover and Phytomass for Station SO3

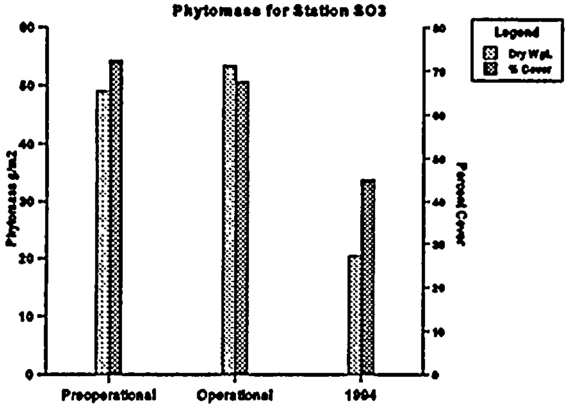
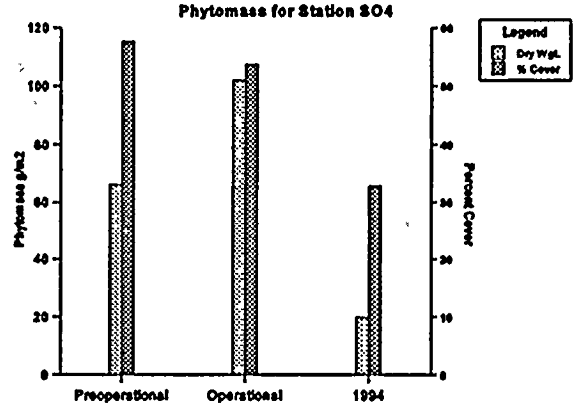


Fig. 4-17. Mean Herbaceous Cover and Phytomass for Station SO4



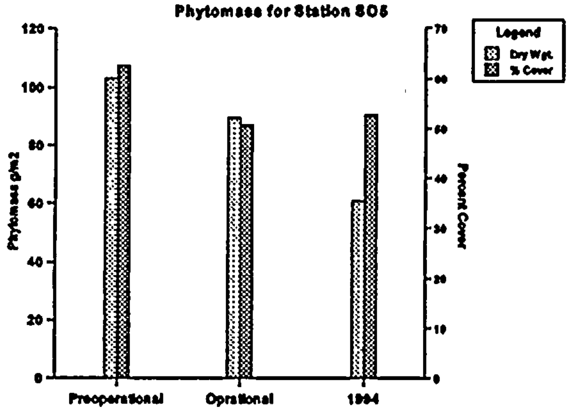


Fig. 4-18. Mean Herbaceous Cover and Phytomass for Station SO5

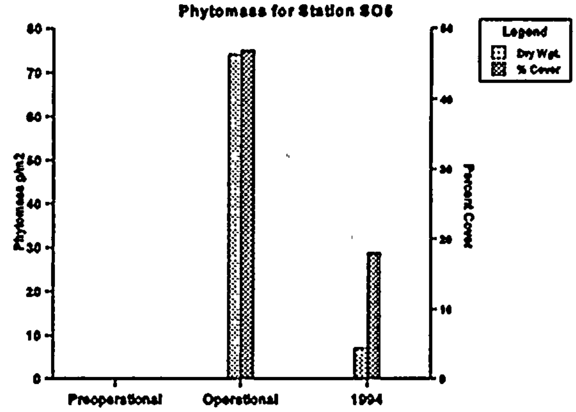


Fig. 4-19. Mean Herbaceous Cover and Phytomass for Station SO6

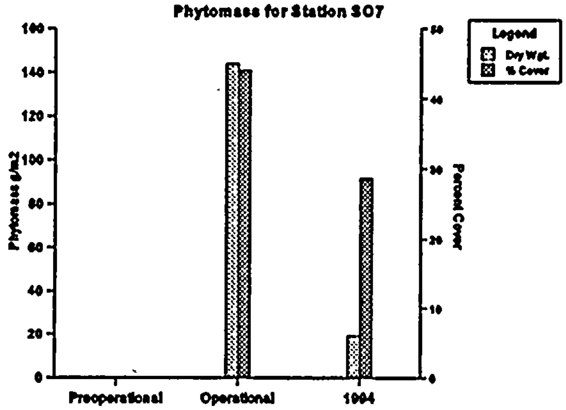


Fig. 4-20. Mean Herbaceous Cover and Phytomass for Station SO7

4.3.3 Soil Chemistry

In comparison to previous years data, there has been no significant change in soil chemistry for the fifteen sampling stations. Conductivity values are slightly higher than last years reported values, however, in comparison to long term data, the values are within the expected ranges. The following table (4-8) is a summation of soil chemistry for 1994.

Table 4-8 Summary of Soil Chemistry for 1994

	pH	Conductivity μS/cm	Sulfate μg/gm	Chloride μg/gm	Copper μg/gm	Zinc μg/gm	Sodium μg/gm	Bicarbonate (meq/HCO_3/gm)
GO1	6.87	51.50	2.43	0.46	11.0	48	0.0430	0.0036
GO2	6.65	47.50	1.59	0.64	9.0	48	0.0430	0.0028
GO3	7.05	109	8.52	2.71	10.0	41	0.0350	0.0044
GO4	6.48	35.0	1.69	0.59	6.0	30	0.0280	0.0016
GO5	6.83	33	1.4	1.08	8.0	31	0.0300	0.0026
GO6	6.71	73.50	1.36	1.15	6.0	30	0.0290	0.0018
GO7	6.82	63	2.61	1.14	7.0	38	0.0340	0.0034
GO8	6.62	25.5	1.22	0.55	7.0	33	0.0300	0.0016
SO1	6.84	60.5	1.73	1.04	8.0	38	0.0320	0.0022
SO2	7.22	28	0.99	2.11	4.0	16	0.0150	0.0020
SO3	6.72	29	0.98	0.80	6.0	32	0.0290	0.0016
SO4	6.84	50.5	1.40	2.06	8.0	32	0.0310	0.0030
SO5	6.79	63	1.65	1.11	8.0	39	0.0420	0.0034
SO6	7.47	71	1.78	0.89	10.0	42	0.0310	0.0054
SO7	7.34	79	1.53	1.00	14.0	55	0.0340	0.0056

Figures 4-21 to 4-28 are a summarization of each of the soil chemistry parameters for preoperational, operational and 1994 periods at each of the stations.

Fig. 4-21. Soil pH for 1985 through 1994

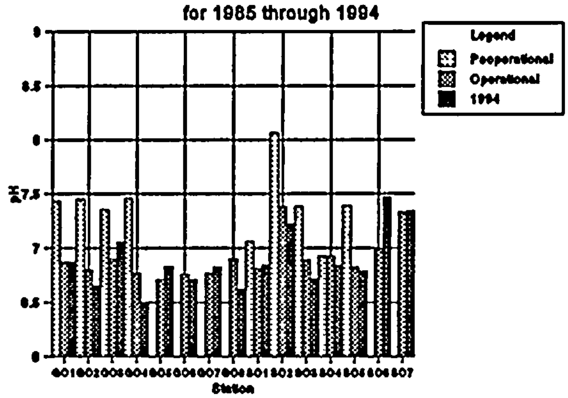


Fig. 4-22. Soil Conductivity for 1985 through 1994

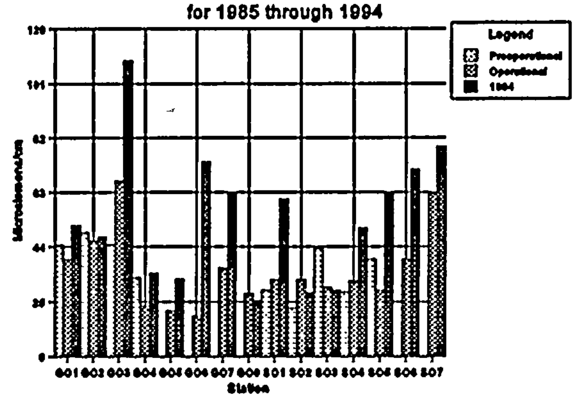


Fig. 4-23. Soil Sulfate for 1980 through 1994

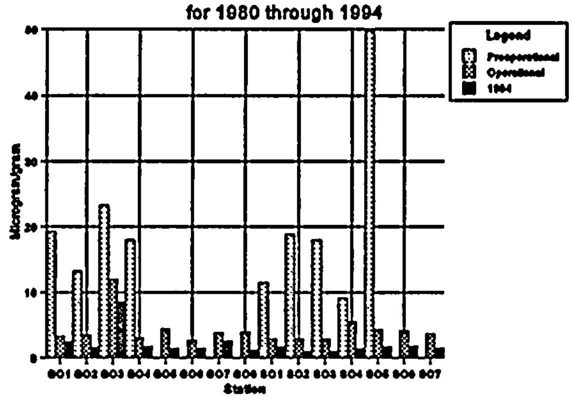


Fig. 4-24. Soil Chloride for 1985 through 1994

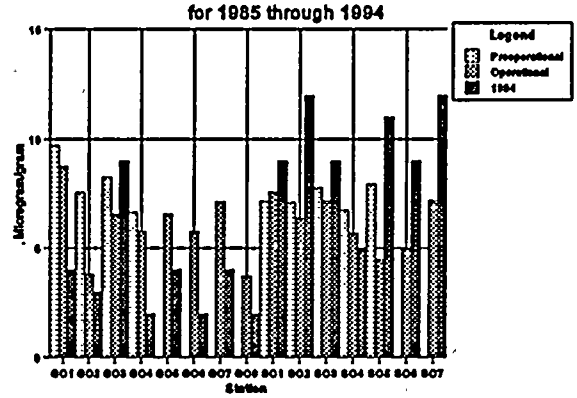


Fig. 4-25. Soil Copper for 1985 through 1994

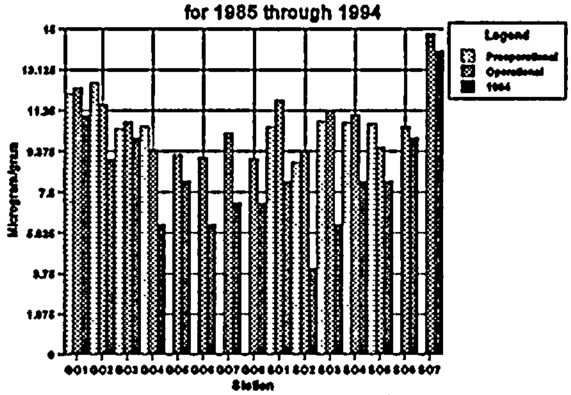


Fig. 4-26. Soil Zinc for 1985 through 1994

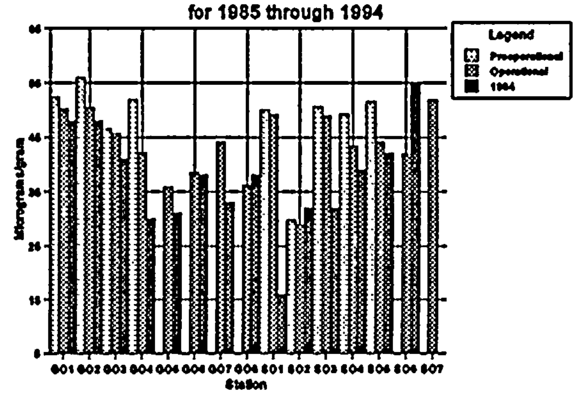


Fig. 4-27. Soil sodium for 1985 through 1994

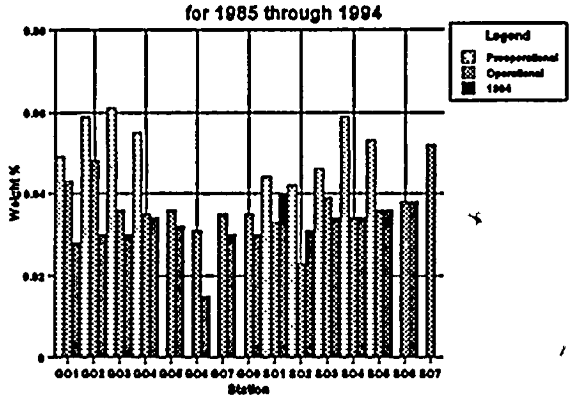
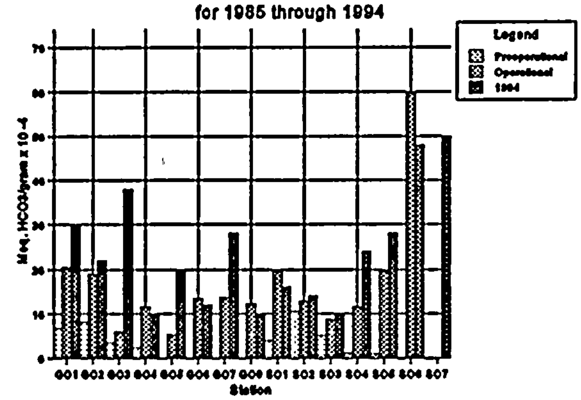


Fig. 4-28. Soil Bicarbonate for 1985 through 1994



5.0 AERIAL PHOTOGRAPHY

5.1 INTRODUCTION

In compliance with the Washington State Energy Facility Site Evaluation Council (EFSEC) Resolution No. 239, the aerial photography program began in June 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.

5.2 MATERIALS AND METHODS

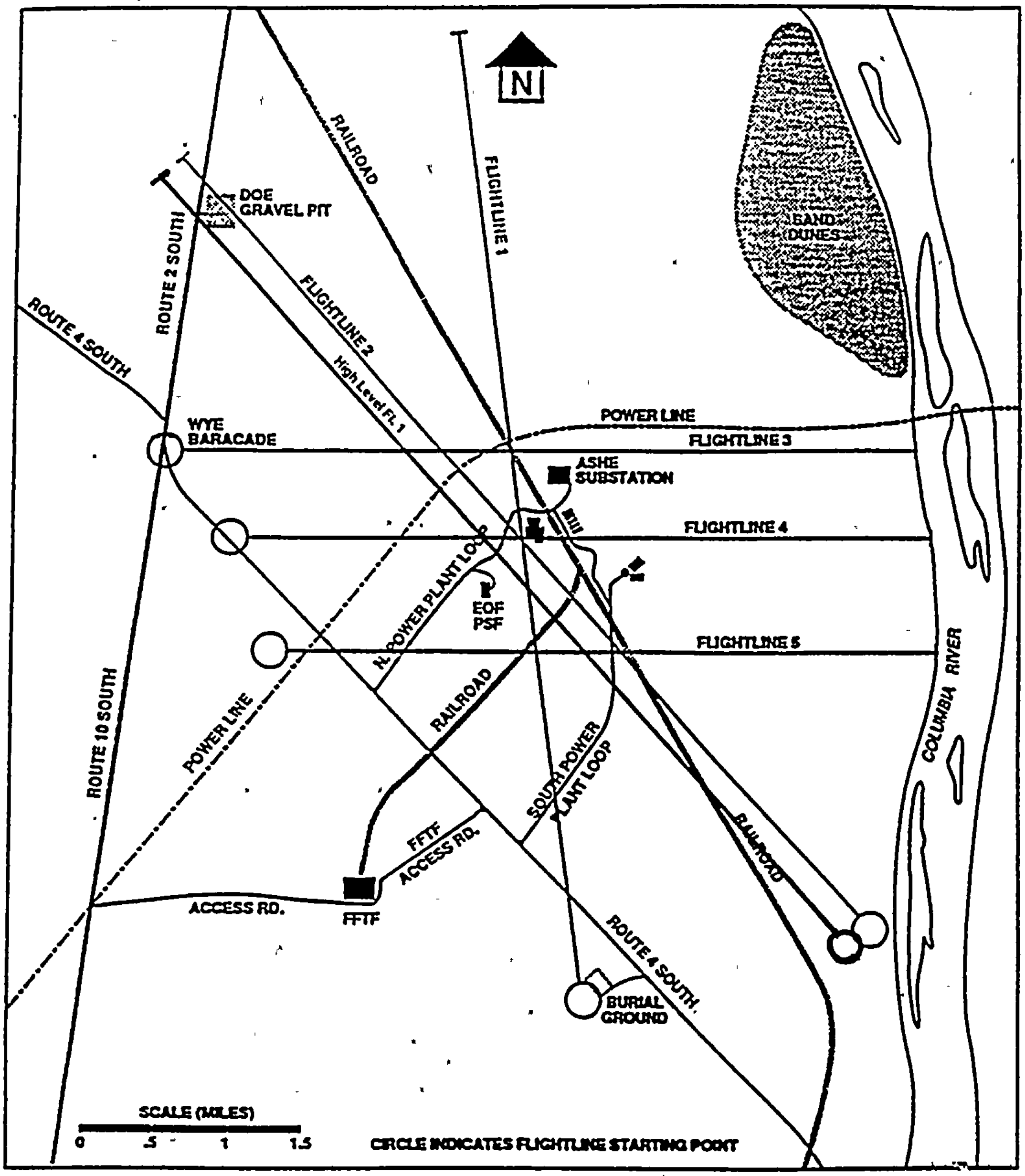
This program was developed using guidelines published in NUREG/CR-1231 (Shipley 1980), which outlines the basic requirements for an aerial monitoring program and suggests types of film, photograph scales, frequency of photograph acquisition and size of prints.

The interpretation of flightline data was performed by Philip Jackson and staff of the Geosciences Department at Oregon State University.

Five flightlines (Figure 5-1) were originally planned to cover the areas of greatest deposition, according to the drift model constructed by Battelle Pacific Northwest Laboratories (Droppo 1976). A sixth high-level flightline was added in 1994. Three flightlines (high elevation #1 and 2), 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 (# 3, 4, and 5) each approximately 5 miles (8.1 km) in length, run in an east-west direction and were placed to cross gradients of deposition. The five original flightlines were flown at an altitude of 1,550 feet (477 m) above mean sea level. The high level flightline was flown at an altitude of approximately 3100 feet (954 m) above mean sea level. The flightline coordinates are stored in the long-range navigation (LORAN) system in the contractor's airplane. This allows the same lines to be photographed in subsequent years.

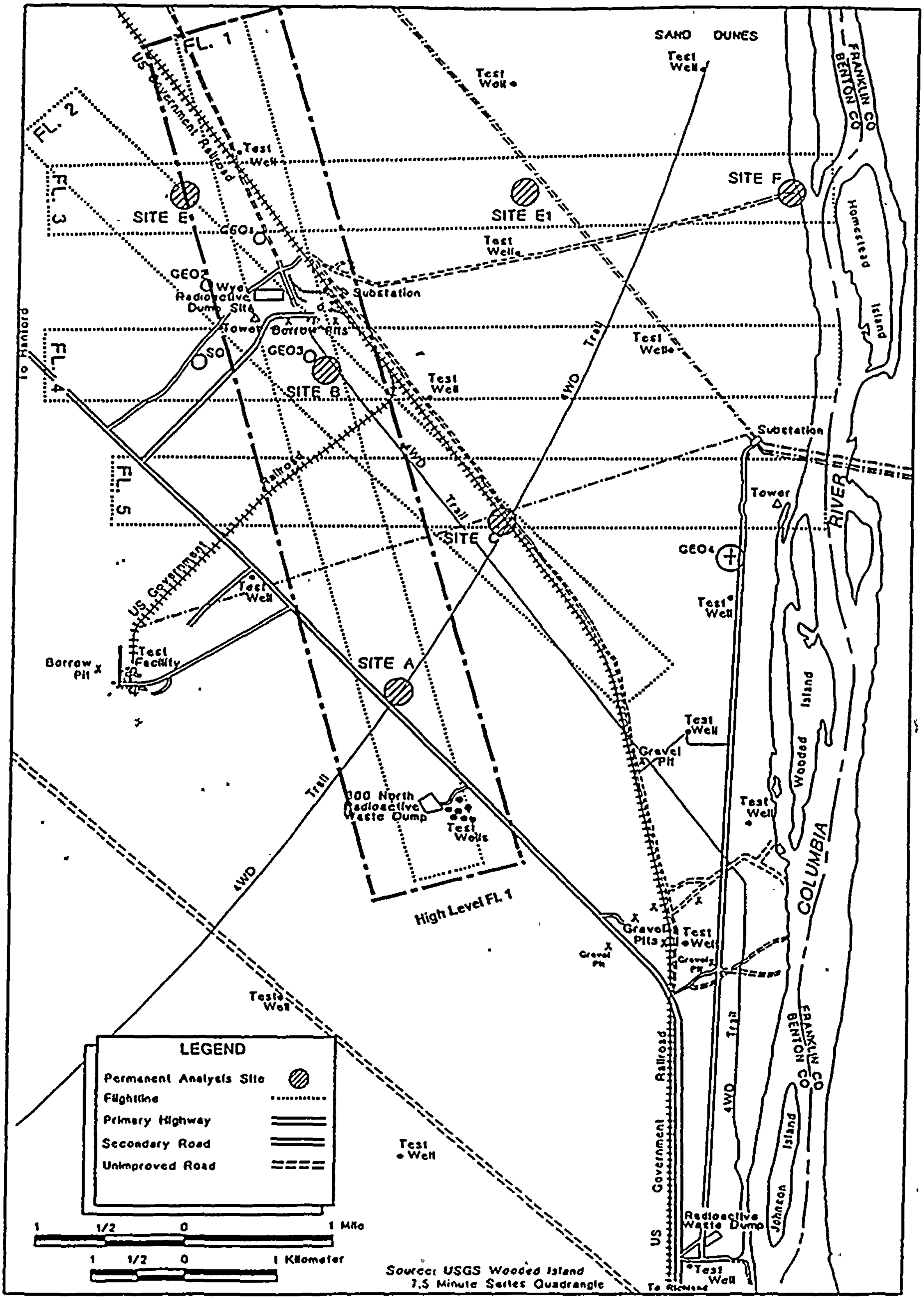
The photographs were taken by Photography Plus, Inc. of Umatilla, Oregon on May 5, 1994 with Kodak Aerochrome 2443 color infrared film in a Hasselblad ELM 70 mm camera. A planar lens with an 80-mm focal length was used with a Number 12 Wratten filter attached. The scale is 1:6,000 in a 70-mm x 70-mm format. The relatively large scale of approximatley 1:6000 was chosen as being large enough to differentiate the types of shrubs in the areas surrounding WNP-2. The 70-mm size was chosen over the larger nine inch format for ease of handling and the storage of nearly 300 photographs.

Figure 5-1. Aerial Photography Flightlines



The photos for this study 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 (relative to the cooling tower) sites, and compare the 1994 film to the 1993 film. Selected scenes were converted to digital format and computer enhanced for further analysis. A map of vegetation plots and flightlines shows the location of digitized sites (Figure 5-2). This map was contructed from field notes, global position surveys, and the United States Geological Survey (USGS) Wooded Island Quadrangle.

Figure 5-2. Vegetation Plots and Flightline Locations of Digitized Test Sites



5.3 RESULTS AND DISCUSSION

The quality of the CIR film was degraded by underexposure and its effectiveness was reduced by weak photosynthetic activity (PSA) in the surrounding vegetation. By May 5th , when the photographs were taken, the semi-arid environment around the plant had already encountered its peak PSA values for the year and the values were declining. CIR reflectance decreases as PSA decreases. The poor contrast of the film made it more difficult to interpret. Interpretation required the comparison of a location near the plant where little disturbance has occurred over previous years. Spectral brightness readings were taken in two locations to determine if the difference in reflectance between the last two film years is due to film exposure differences.

5.3.1 Flightline #1

The first flightline began over the 300 North Radioactive Waste Dump. It followed a northwesterly course very comparable to the 1993 overflight. In general, the 1994 overflight of the area exhibits less PSA than the 1993 overflight. Two factors may account for the majority of the difference. The first factor is the underexposure of the 1994 film. The darker appearance of the film masks out some of the weak reflectance areas of PSA . The second factor was the reduced level of moisture in 1994 compared to 1993.

5.3.2 Flightline #2

Flightline 2 starts northwest of the plant and followed in a southeasterly direction. The 1994 flightline 2 was flown west of 1993 flightline 2. This difference in the location of the flightline led to considerably different areas being covered by the flightline north of the plant. The 1993 and 1994 flightlines had some overlap in areas south of the plant. Only slight PSA is visible along the first portion of flightline 2. The area southeast of South Power Plant Loop Road exhibited considerably less PSA in 1994 than it did in 1993. Because of the flightline misalignment, dissimilar areas were covered. The coverage of 1994 took in sandy areas and areas of range which were not covered in previous years. These sandy range areas exhibited less PSA than that observed in 1993. The area along the southwest side of the plant displayed stronger PSA in 1993, but, in 1994 greater overall ground coverage by range plants was observed.

5.3.3 Flightline #3

Flightline 3 is located north of the plant and runs in a west-east direction. The 1994 overflight was flown further north than the 1993 overflight. Only slight PSA is visible in both the 1993 and the 1994 flightline 3, but more PSA is visible in the 1993 overflight. The apparent visible decrease in PSA between the overflights is most likely caused by the underexposure of the 1994 film and the decrease in precipitation for the year.

5.3.4 Flightline #4

Flightline 4 begins just south of the plant and runs in a west to east direction. The 1994 flightline was flown to the south of the 1993 flightline. Only slight amounts of PSA were visible along the

flightline. Far less PSA was visible along the southern portion of the plant in 1994 than was visible in 1993. Ground disturbance and vegetation clearing, was observed in 1993 and apparently completed by the time of the 1994 overflight. An area of strong PSA was visible on the 1994 film just west of the disturbed area. The PSA in this area is stronger than the PSA which was visible in the 1993 overflight. The apparent increase in PSA intensity is likely caused by the underexposure of the 1994 film. The underexposure helped to mask out some of the undrelying white sand making the PSA appear to be more intense.

5.3.5 Flightline #5

Flightline 5 was flown north of its 1993 position, but it contained a small area of overlap. An area of disturbed range is visible in 1994. The disturbed area showed stronger PSA than the surrrounding range.

5.3.6 High Elevation Flightline 1

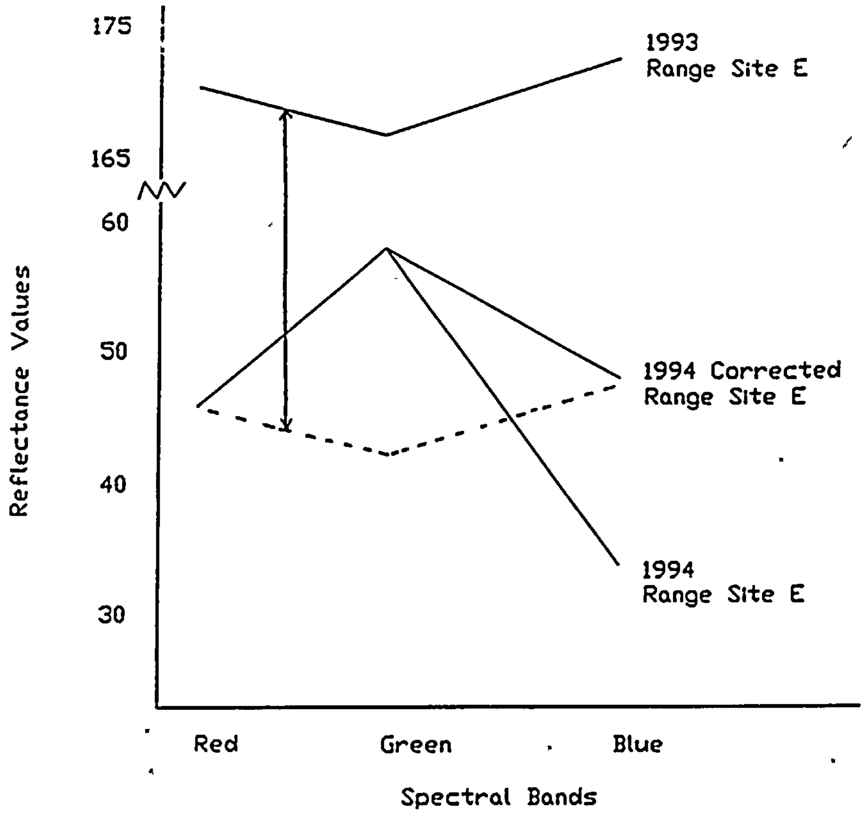
The high elevation flightline was added in 1994 to acquire better coverage of large scale patterns visible on the landscape. The high level overflight parallels low elevation flightline 1, but it is at roughly twice the scale (1:40,000). The high level overflight provides complete coverage of the plant area. Broad coverage comparison shows strong contrasts in the vegetation patterns north and south of the plant site. The range area displayed moderate PSA which was concentrated south of the plant. The area northwest of the plant is dominated by a large dune field which exhibits almost no PSA. North of the plant site, extensive areas of barren sand and rock are visible, with vegetation largely limited to interdune troughs. To the south of the plant site, on relatively flat undissected terrain, greater vegetation density is observed. In each broadly defined disturbance site the opportunity exists for vegetation to flourish, particularly annual species.

5.3.7 Scanning and Digital Conversion

Upon visual inspection, the overall pattern of spectral reflectance seems considerably different between 1993 and 1994. However, this interpretation is not entirely correct. The generally lower range of reflectance values for photosynthesizing vegetation is influenced by two factors one of which can be somewhat mitigated by digital image processing. An overall documented shift in photosynthetic values is identifiable in Figures 5-3 and 5-5. The second factor is an overall downward trend from the green to blue spectral bands recorded on film. A comparison of the blue band reflectance values at a known measured area for 1993 and 1994 show on average a six percent decrease in overall light intensity for 1994. This reduction in the measured light intensity is directly related to the underexposure of the 1994 film. When a six percent correction value is added to the 1994 blue light intensity, overall reflectance patterns between the red and blue bands are similar to that observed in 1993 (Figure 5-3). The intensity of the red bands remained relatively constant between 1993 and 1994.

The green band cannot be corrected in the same way the blue band was corrected. The underexposure gave the film a slight greenish tinge. The greenish tinge was amplified by the green filter used on the digital scanner. This amplification made the reflectance of the green band appear to be elevated in comparison to the red and blue band patterns.

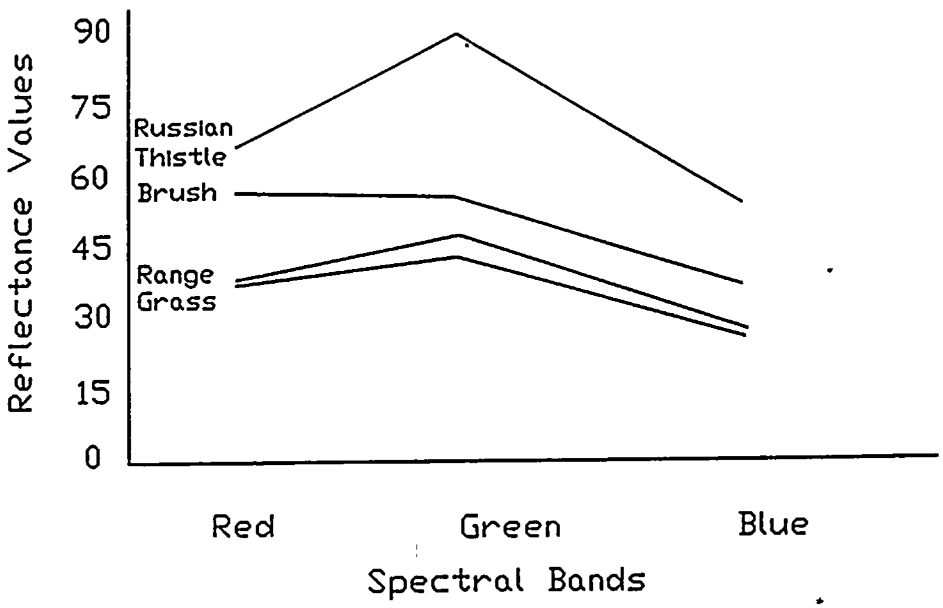
Figure 5-3. Comparison of 1993 and 1994 Spectral Signatures



The dashed line represents the expected Spectral Signature for 1994

It was possible to compare the mean statistical reflectance values for known plant communities in upwind and downwind locations. These signatures are illustrated in figure 5-4. Three general categories, range, shrub and grass were chosen for comparison. When the spectral patterns for Site A and Site E were compared for the grass category, little difference was visible in the overall spectral pattern observed at each site. Since the overall patterns for the two locations were similar, the difference in average intensity between the two locations is likely due to background reflectance rather than any actual difference in the plant communities.

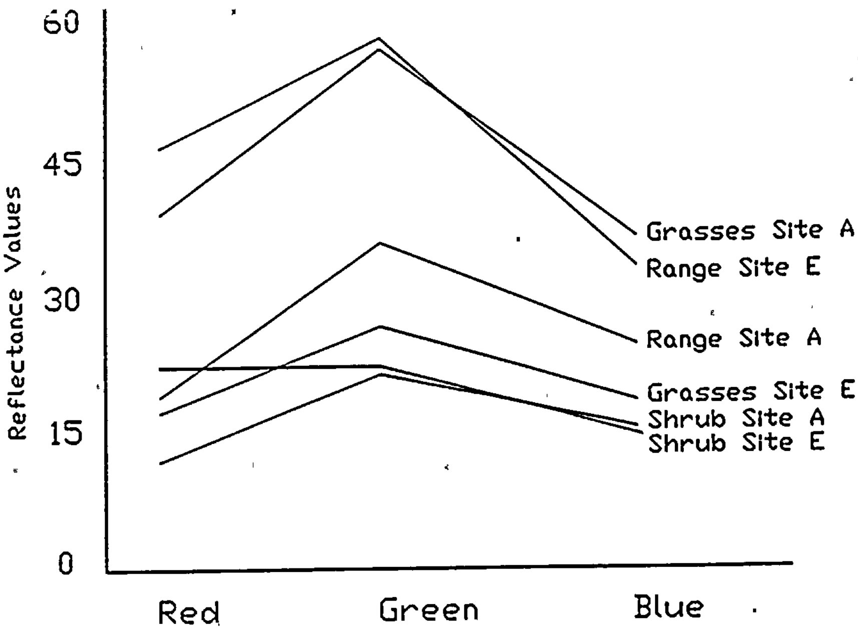
Figure 5-4. Comparison of Spectral Reflectance Values at Sites A and E



The range category is made up of areas of grasses and shrubs, and bare ground. The general spectral trend for the range areas is similar. The major difference between the upwind (site A) and downwind (site E) sites occurs in the blue band. The downwind site displays a greater downward shift between the green and blue bands than the upwind location. The blue band primarily records the spectral intensity of the underlying sandy soils. The presence of small amounts of tumble mustard is observed scattered throughout Site E. Tumble mustard, which has a very high reflectance value, raises the intensity of the spectral averages. This accounts for site E displaying more intense spectral signatures in the range vegetation category than Site A.

Figure 5-5 compares the relative reflectance of different vegetation types at the same site. The vegetation classes were observed at Site B just upwind form the plant. In comparing PSA levels, Russian thistle (*Salsola kali*), exhibited the most PSA closely followed by sagebrush (*Artemisia tridentata*). The range and grass areas displayed less PSA. This order closely approximates the conditions that would be expected following the optimum spring peak for PSA.

Figure 5-5. Spectral Comparisons of Four Areas in Monitoring Site B



Photosynthetic reflectance characteristics for range plants and plant associations have been compared temporally from 1993 to 1994, and spatially from downwind to upwind sites. Data shows no spatially significant vegetation health differences relative to PSA. That is, comparable plant associations in downwind sites appear to have similar reflectance properties as plant associations in upwind sites. No changes which could be caused by precipitate from cooling towers appears to have occurred prior to the 1994 overflight.

6.0 REFERENCES

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