Enclosure B
Terrestrial Ecology Documents

B1. Ecological Monitoring Program for Columbia Generating Station, Summary Report for 1975 to 2002 (ER Ref. EN 2003)

B2. Avian species list, e-mail communication from R.E. Welch to J.P. Chasse, 2009 (ER Ref. EN 2009b)

B3. Rare Plant and Vegetation Survey, Riparian Zone, December 2008 (ER Ref. Link 2008)

B4. Rare Plant and Vegetation Survey, Uplands, July 2009 (ER Ref. Link 2009)

B5. Operational Ecological Monitoring Program – 1987 Annual Report (ER Ref. WPPSS 1988)

B6. CGS Site Area Map (re: Site Audit Needs Request TE-1)

B7. Aerial Photo of CGS Site Area, July 2003 (re: Site Audit Needs Request TE-1)

B8. Procedures (4 each) related to wildlife management

COLUMBIA GENERATING STATION

ENERGY NORTHWEST

1975 to 2002
ECOLOGICAL MONITORING PROGRAM SUMMARY REPORT

ENERGY NORTHWEST
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ECOLOGICAL MONITORING PROGRAM FOR COLUMBIA GENERATING STATION

ENERGY NORTHWEST

SUMMARY REPORT
FOR 1975 TO 2002

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Energy Northwest Environmental Services

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The Energy Facility Site Evaluation Council (EFSEC) established the Ecological Monitoring Program to monitor the environmental effects of cooling tower operation at the Columbia Generating Station. Since its inception in 1975, the program has been modified on several occasions to accommodate technical changes or to delete requirements for completed studies. This report summarizes the results of the program from 1975 to 2002.

The program was designed to determine if cooling tower drift was producing an effect in the surrounding vegetation. In addition to the validation of the original drift deposition model, multiple grassland and shrub sampling sites were established and monitored annually for changes in soil and plant chemistry, phytomass, density, and cover. Aerial photographs were taken to allow examination of the general area for indications of plant stress and changes in vegetation patterns.

Data collected since inception of the monitoring program do not reveal any discernible environmental effect that can be attributed to cooling tower operation. Climatological factors (e.g., precipitation and temperature) and anthropogenic impacts unrelated to Columbia Generating Station operation (e.g., range fires) dominate the productivity of vegetation at the study sites.

SECTION 1 INTRODUCTION

1.0 INTRODUCTION

1.1 Background

Energy Northwest's (formerly Washington Public Power Supply System) Columbia Generating Station (formerly WNP-2) is a 1,154-megawatt nuclear electrical generation facility located approximately 12 miles north of Richland, Washington. Site preparation began in June 1972. Fuel was first loaded in December 1983 and low power testing began in January 1984. The plant was declared commercially operational in December 1984.

The Site Certification Agreement (SCA) for Columbia Generating Station was approved 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 Energy Northwest and the Washington State Energy Facility Site Evaluation Council (EFSEC) and to identify significant impacts of plant operation on the environment. Since 1972, several revisions of the monitoring program have been approved by EFSEC in the form of SCA amendments and EFSEC resolutions.

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

Since the plant began commercial operation in 1984, Energy Northwest scientists have been responsible for the operational environmental monitoring program. Comprehensive operational environmental reports have been prepared annually by Energy Northwest (Supply System 1985 through 2001). A few studies and reports were completed by Energy Northwest personnel prior to the annual reports, including animal studies (Schleder 1982, 1983, 1984) and terrestrial monitoring (Northstrom et al. 1984).

This report provides a summary of the results of the environmental monitoring program from 1975 to 2002. In addition to the continuing programs, also included in this report are the results of studies previously terminated. Detailed results for 2002 are included as Appendix A.

1.2 Site Description

Columbia Generating Station is located approximately 5 km (3.25 miles) west of the Columbia River, on 441 hectares (1,089 acres) of land leased from the U.S. Department of Energy's Hanford Site. The site lies within the boundaries of the Columbia Basin, an extensive area that lies between the Cascade Range and the Blue Mountains in Oregon and Washington.

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, there is insufficient moisture to support arborescent species except along stream banks. In August 1984, a range fire destroyed much of the shrub cover on the Hanford Site and temporarily modified the shrub-steppe associations that were formerly present. Another fire occurred in July 2000, but it affected only one sample site.

The Columbia Basin shrub-steppe region can be divided into nine zonal associations based upon climax vegetation (Daubenmire 1968). Each zone is differentiated by various climatic and edaphic conditions such as temperature, precipitation and soil type. The study area is located in the driest of the nine zones, which is known as the *Artemisia-Agropyron* association. The *Artemisia-Agropyron* association zone typically has four distinct layers of vegetation. The first is a layer of shrubs dominated by *Artemisia tridentata*, *Purshia tridentata*, *Ericameria nauseosa*, and *Chrysothamnus viscidiflorus*. The second is a layer of perennial grasses dominated by *Pseudoroegneria spicata*, *Elymus elymoides*, *Stipa comata*, *Poa secunda*, and *Agropyron dasystachyum*. Next is a layer consisting of herbaceous annual grasses such as *Bromus tectorum*, *Vulpia octoflora* and annual and perennial forbs such as *Astragalus sclerocarpus*, *Brodiaea douglasii*, *Descurainia pinnata*, and *Phlox longifolia*. The final layer consists of a crustose layer of lichens and mosses.

1.3 Meteorology

The climatology of the site is greatly influenced by the presence of the Cascade Mountain Range to the west. This mountain range causes a rain shadow effect, making conditions on the site semi-arid. The wind pattern in the area is also significantly affected by the Cascade Mountains as they serve as a source of cold air drainage. Temperatures on the Hanford Site are moderated by the presence of the Cascade and Rocky Mountain ranges to the west and east, respectively, and mountain ranges in southern Canada. These mountains serve to protect the area from the more severe winter storms and cold polar air masses moving southward across Canada (Hoitink et al. 2002).

The average annual precipitation at the Pacific Northwest National Laboratory (PNNL) Hanford Meteorological Station (HMS) is 6.79 inches (17.2 cm). During the study years of 1975 to 2002, the wettest calendar year was 1995, with a total annual precipitation of 12.31 inches (31.27 cm). The driest year was 1976, with a total precipitation of 2.99 inches (7.6 cm). The growing season for the vegetation on the site is from October through April, which is the time of greatest precipitation. The wettest growing season since the plant became operational was in 1996-97, when the total precipitation was 10.03 inches (25.5 cm). The driest growing season during plant operation was in 1993-94, when 2.41 inches (6.1 cm) of precipitation fell. The average precipitation for the October through April period is 4.98 inches (12.6 cm).

The annual average temperature on the site is 53.4°F (11.9°C). Between 1975 and 2002, the year with the highest annual average temperature was 1992 with an average temperature of 56.4°F (13.6°C) while the year with the lowest annual average was 1985 at 49.6°F (9.8°C). The warmest growing season average temperature during the 1975-2002 period was 45.7°F (7.6°C) in 1991-92. The coolest was 37.1°F (2.8°C) in 1978-79. The average temperature during the October to April growing season is 41.7°F (5.4°C).

The prevailing winds on the site are from the south and from the northwest. During the period of 1982-2001, winds were from the south 11.5% of the time and from the northwest 10.7% of the time. Wind speed from the south tended to be slightly higher, being in the 4 to 7 miles per hour range 5.3% of the time and in the 8 to 18 miles per hour range 4.0% of the time. Winds from the northwest were in the 4 to 7 miles per hour range 3.8% of the time, in the 8 to 18 miles per hour range 3.7% of the time and in the 1 to 3 miles per hour range 2.6% of the time. The joint frequency distribution for the Pacific Northwest National Laboratory tower located near the Columbia Generating Station is shown in Table 1-2 and graphically in Figure 1-1.

1.4 Monitoring Program Overview

Terrestrial monitoring studies at Columbia Generating Station were designed to identify any impact of cooling tower operations on the surrounding plant communities, as well as any edaphic impact. Elements of the monitoring program included the following:

- herbaceous cover (1975-2002)
- shrub cover and density (1980-1992)
- herbaceous phytomass (1975-2002)
- soil chemistry (1980-2002)
- vegetation chemistry (1980-1992)
- aerial photography (1988-2000)
- cooling tower drift deposition study (1989-1990)

Most of the monitoring activities were conducted at fifteen (15) sites located within a 5-mile (8-km) radius of the plant. Table 1-1 lists the sites and their approximate distances from Columbia Generating Station. The location of each site is illustrated in Figure 1-2.

Table 1-1. Terrestrial Sampling Sites and Locations

Grassland Sites			Shrub Sites		
Site	Distance (miles)	Direction	Site	Distance (miles)	Direction
G01	1.0	NNW	S01	1.5	WSW
G02	0.6	W	S02	4.1	N
G03	0.3	S	S03	2.4	E
G04	4.1	SE	S04	5.3	NNW
G05	4.5	NW	S05	4.3	SE
G06	4.8	S	S06	4.6	ESE
G07	1.5	SSW	S07	6.1	NNE
G08	1.5	W			

Soil and vegetation sampling was originally conducted at nine permanent sites, four grassland sites (G01-G04) and five shrub sites (S01-S05). Four grassland (G05-G08) and two shrub (S06-S07) sites were added in 1989 in accordance with EFSEC Resolution No. 239. The original locations for the terrestrial monitoring studies sampling sites were determined from the cooling tower deposition model constructed by Battelle Pacific Northwest Laboratories (Droppo et al. 1976). The six stations added in 1989 were a result of a review that revealed errors in the model.

All vegetation studies were conducted at the peak of the cheatgrass growth cycle known as the purple stage (Kemmedson and Smith 1964).

Study methodologies and principal results for each component of the terrestrial monitoring program are described in the sections that follow.

Table 1-2. Joint Frequency Distribution of Wind near Columbia Generating Station

Begin: January 1982 **End: December 2001** **Total Hours: 171,616**

DIRECTION

MPH	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL %
CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9
1-3	2.5	2.1	1.9	1.3	1.1	1.1	1.4	1.8	2.2	1.9	1.7	1.4	1.6	1.8	2.6	2.8	0.0	29.0
4-7	3.4	2.4	2.1	1.2	0.7	0.9	1.9	4.3	5.3	3.0	1.7	1.2	1.3	1.9	3.8	4.5	0.0	39.4
8-18	1.5	0.9	0.6	0.2	0.1	0.2	0.8	2.2	4.0	4.2	2.6	1.3	1.4	2.5	3.7	1.8	0.0	28.1
19-24	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.2	0.1	0.1	0.5	0.0	0.0	2.1
25-31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.5
>32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TOTAL %	7.5	5.4	4.5	2.7	1.9	2.2	4.1	8.3	11.6	9.7	6.7	4.2	4.4	6.2	10.7	9.1	0.9	100.0

Measurements taken from the 10-meter PNNL tower located approximately 0.5 mile west of Columbia Generating Station.

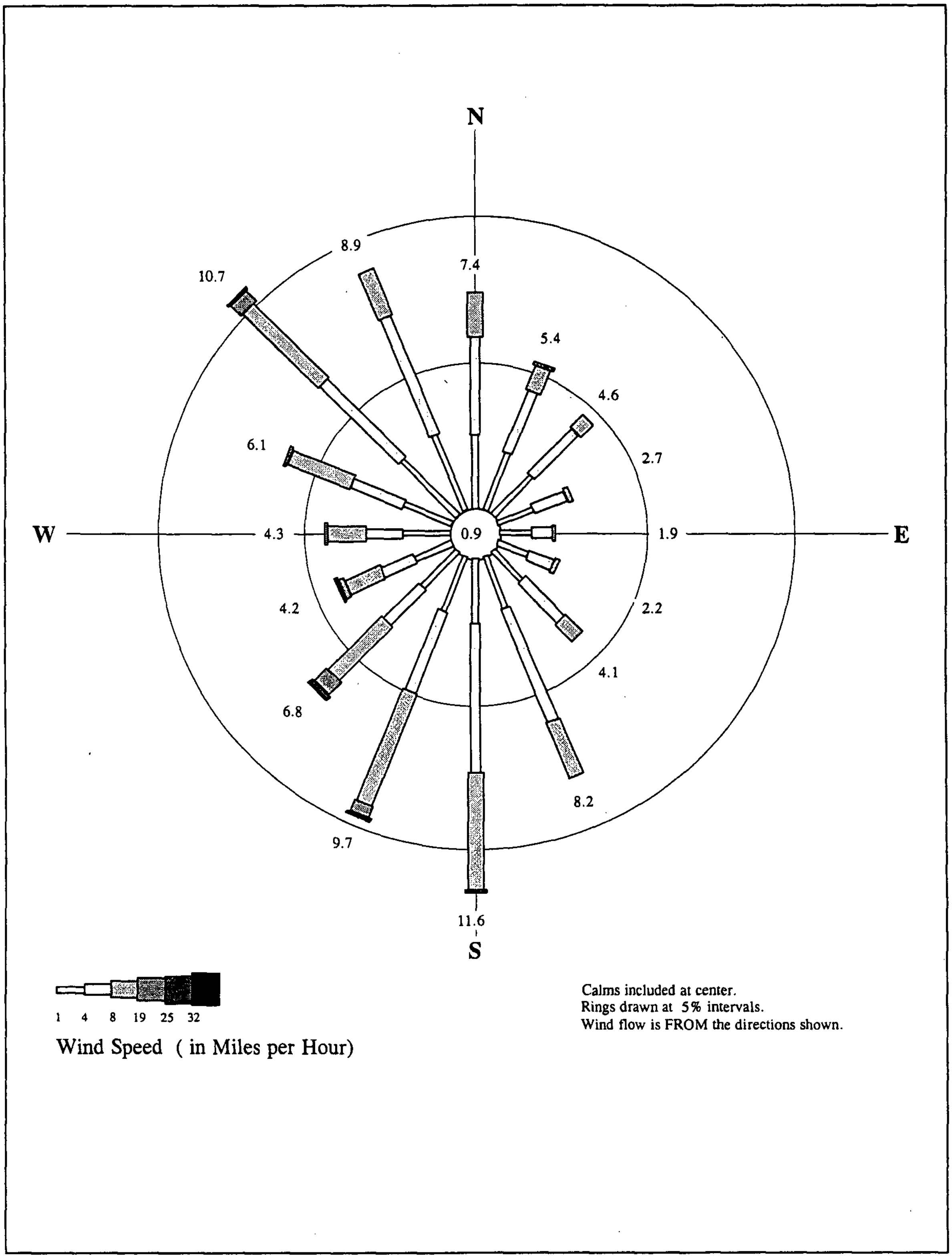
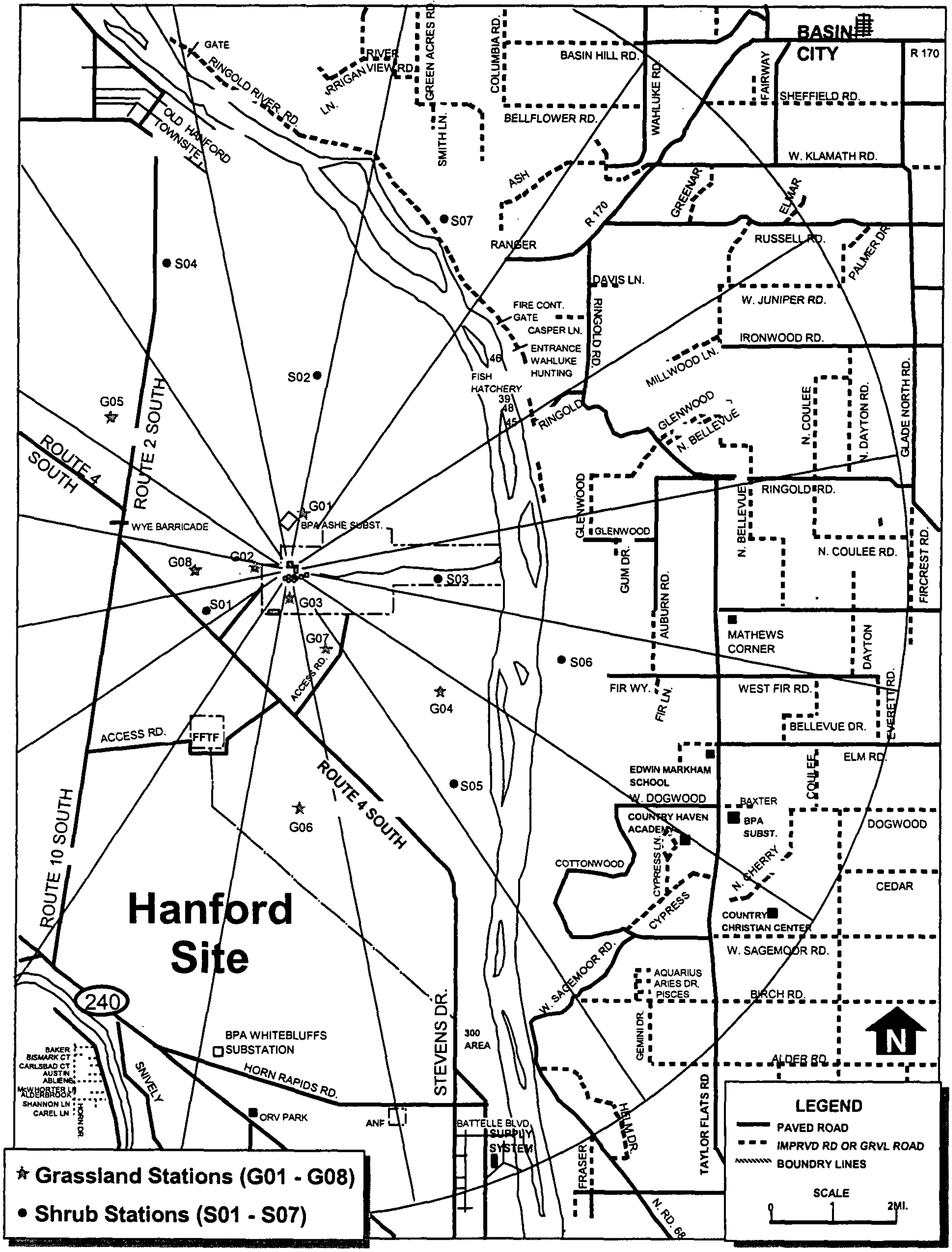


Figure 1-1. 33-Foot Level Wind Rose for Columbia Generating Station 1982 to 2001



880334.19 Map
July 1993

Figure 1-2. Soil and Vegetation Sampling Location Map

SECTION 2 HERBACEOUS COVER

2.0 HERBACEOUS COVER

Herbaceous cover is a measure of the ground canopy that can be assigned to grasses and forbs. It is a relative measure of the vigor and vitality of the plant community.

2.1 Methods and Materials

At each of the sites, fifty microplots (20 cm x 50 cm) were placed at 1-meter intervals on alternate sides of a 50 meter by 10 meter herbaceous transect (Figure 2-1). Canopy cover for each species occurring within a microplot was estimated using Daubenmire's (1968) cover classes. Data were recorded on standard data sheets. 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.

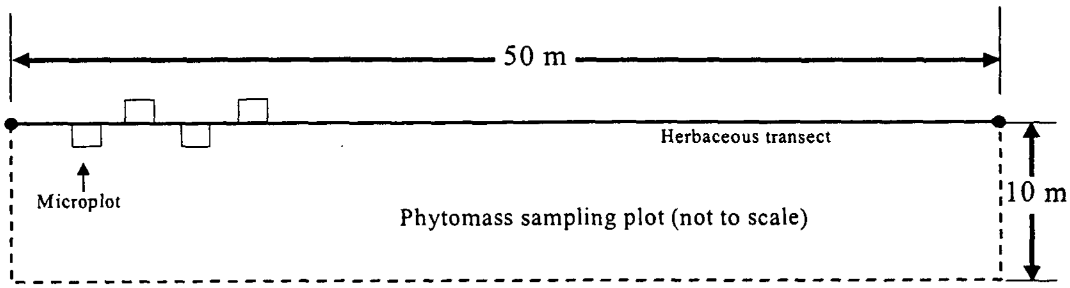


Figure 2-1. Layout of Vegetation and Soil Sampling Plot

2.2 Results and Discussion

Herbaceous cover over the twenty-five year period of the study varies greatly. Average cover for all classes of grasses and forbs range from a high of 146.8% to a low of 2.5%, both of which occurred in the preoperational period of the study. Table 2-1 shows the preoperational herbaceous cover for each herbaceous class and year. Table 2-2 shows the operational herbaceous cover.

Climate appears to have the greatest effect on herbaceous cover. Precipitation during the growing season in 1977 was 1.21 inches, more that 3 inches less than normal for October through April. During that year, cover was the lowest of the study for all classes. Cover for all grass sites during 1977 was 15.5% and at shrub sites, 9.4%. Average cover percentages also declined sharply from the previous year in 1994, which corresponds to the second driest growing season observed during the study years. Figure 2-2 shows the correlation of precipitation during the growing season to the percent cover at the shrub (S) sites and the grass (G) sites. Figures 2-4 through 2-7 diagram the effect of precipitation on each vegetation class.

Temperatures during the growing season are also a factor on the herbaceous cover, although the effects of low temperatures may be mitigated by the amount of snow cover present. During 1978-79 and again in 1984-85, lower than normal average temperature resulted in decreased cover. Cover for all classes during those years was 51.8% and 48.9% respectively. The other two periods where the temperature was two degrees Fahrenheit lower or more than normal, 1985-86 and 1992-93, were periods when there was a substantial cover of snow on the ground. During these periods, cover increased from the preceding year. Figure 2-3 shows the relationship between percent cover and average temperature during the growing season. Figures 2-8 through 2-11 show the relationship of temperature to cover for each vegetation class.

Grass site G03 had the highest total average cover for all herbaceous classes during the preoperational period with an average of 84.1%. The highest preoperational shrub site was S03 with a total average cover of 62.1%. During the operational period, grass site G07 had the highest average at 82.0% and S07 was the highest shrub site at 81.6%. Of those sites sampled during both the operational and preoperational periods (Sites S01-S05 and G01-G04), G01 was the highest with an average of 77.5% and S03 was the highest shrub site with a 67.2% average.

The highest total average cover of annual grasses during the preoperational period was 67.4% at G03. Site S01 was the highest of the shrub sites with an average of 45.0%. Site G07 was the highest site during the operational period at 51.2% while S05 was the highest shrub site with a 41.9%. Site G03 was the highest during the operational period of those sites sampled during both periods with an average cover of 44.7%.

Perennial grass had the highest total average cover during the preoperational period at site G04 while the highest shrub site was S03. The average cover at these sites was 29.0% and 12.7% respectively. During the operational period, G04 remained the site with the highest average at 36.9% cover. The cover at S06 was the highest for shrub sites at 34.1%. The cover at S02 during the operational period was 22.6%, the highest of the shrub sites sampled during both periods.

The site with the highest total average cover of annual forbs during the preoperational period was G01 at 18.2%, while S05 was the highest shrub site with an average of 15.9%. S07 had the highest average cover of annual forbs during the operational period at 22.5% and G03 had the highest grass site average of 17.3%. Of the shrub sites sampled during both preoperational and operational periods, S03 had the highest average at 13.8%.

During the preoperational period, S04 had the highest total average cover for perennial forbs with an average of 5.3%. G04 was the highest grass site with an average of 3.1%. The highest site during the operational period was G06 with an average of 8.9% and the highest shrub site was S02 with an 8.6% average. G03, at 3.0% cover, was the highest grass site of those sampled during both periods.

Bromus tectorum was the dominant annual grass during all years. From 1984 to 1999, it had an average cover of 31.9% for all sites. The highest annual average during this period for *Bromus tectorum* was 52.4% in 1996 and the low was 8.4% in 1988. The dominant perennial grass for the 1984 to 1999 period was *Poa secunda* with an average cover of 13.5%. The highest annual average for *Poa secunda* was in 1989 with a 29.3% cover. The lowest annual average was in 1994 with a 5.1% average cover.

The dominant annual forb was *Holosteum umbellatum* with an average cover of 3.04%. It had a low annual average cover of 0.2% in 1988 and it highest annual average was in 1984 with an average cover of 6.5%. *Draba verna* was also common and had an average cover of 2.7% and ranged from 0.5% in 1988 to 7.6% in 1986. The occurrence of perennial forbs at any of the sites is sparse. No one species of perennial forb dominated the cover at most of the sites.

Table 2-1. Preoperational Herbaceous Cover (%) by Class

CLASS: Annual Grasses

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	49.9	50.7	1.4	51.0	25.0	50.4	74.8	51.5	53.8	41.5	45.0
S02	35.3	40.9	0.7	67.0	29.0	51.8	54.6	25.8	37.6	32.8	37.5
S03	43.8	34.3	1.9	51.0	9.0	24.3	66.5	36.6	33.7	39.4	34.0
S04	-	-	-	-	-	56.2	49.8	32.7	36.8	36.3	42.4
S05	-	-	-	-	-	56.4	76.2	20.0	31.9	36.5	44.2
Mean S01-5	43.0	42.0	1.3	56.3	21.0	47.8	64.4	33.3	38.7	37.3	38.5
G01	43.9	71.2	5.2	68.0	31.0	64.3	77.4	42.2	49.5	60.9	51.4
G02	43.0	51.6	1.5	42.0	10.0	77.8	84.0	45.5	39.6	71.3	46.6
G03	-	-	-	-	-	73.8	88.4	51.0	62.8	60.9	67.4
G04	-	-	-	-	-	12.3	48.9	22.9	17.6	9.6	22.3
Mean G01-4	43.5	61.4	3.3	55.0	20.5	57.1	74.7	40.4	42.3	50.7	44.9
Mean G01-4 and S01-5	43.2	49.7	2.1	55.8	20.8	51.9	69.0	36.5	40.3	43.2	41.3

CLASS: Perennial Grasses

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	0.6	0.4	0.4	3.0	1.0	1.0	0.1	0.4	2.2	1.9	1.1
S02	2.0	10.5	11.3	18.0	18.0	7.2	4.7	6.4	7.7	8.8	9.5
S03	4.5	10.3	8.3	11.0	11.0	23.3	14.3	17.9	14.5	11.6	12.7
S04	-	-	-	-	-	10.9	5.8	4.3	6.4	8.6	7.2
S05	-	-	-	-	-	0.1	0.0	0.8	1.3	0.4	0.5
Mean S01-5	2.4	7.1	6.6	10.7	10.0	8.5	5.0	6.0	6.4	6.2	6.9
G01	3.7	4.4	3.3	8.0	7.0	28.3	19.6	11.2	2.1	1.2	8.9
G02	5.5	3.1	2.9	7.0	5.0	64.0	25.9	11.6	15.8	4.5	14.5
G03	-	-	-	-	-	0.1	0.0	0.1	0.0		0.1
G04	-	-	-	-	-	26.6	36.7	31.3	25.5	25.0	29.0
Mean G01-4	4.6	3.8	3.1	7.5	6.0	29.8	20.6	13.6	10.8	10.2	11.0
Mean G01-4 and S01-5	3.3	5.7	5.2	9.4	8.4	17.9	11.9	9.3	8.4	7.7	8.7

Table 2-1. Preoperational Herbaceous Cover (%) by Class (cont.)

CLASS: Annual Forbs

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	14.6	5.5	0.3	38.0	2.0	7.6	5.3	4.6	8.2	12.4	9.9
S02	11.7	5.3	0.5	10.0	4.0	4.2	3.5	4.2	7.9	8.1	5.9
S03	11.7	7.2	0.9	33.0	10.0	22.5	18.2	7.5	12.6	11.1	13.5
S04	-	-	-	-	-	3.4	1.2	1.6	3.5	4.0	2.7
S05	-	-	-	-	-	14.1	12.5	17.3	22.4	13.4	15.9
Mean S01-5	12.7	6.0	0.6	27.0	5.3	10.4	8.1	7.0	10.9	9.8	9.8
G01	29.5	11.9	2.4	23.0	43.0	7.3	15.9	9.7	18.7	20.7	18.2
G02	13.0	8.5	9.4	25.0	33.0	5.0	11.9	4.6	8.9	9.7	12.9
G03	-	-	-	-	-	28.7	17.5	4.6	8.7	19.5	15.8
G04	-	-	-	-	-	4.9	5.9	4.1	6.7	8.0	5.9
Mean G01-4	21.3	10.2	5.9	24.0	38.0	11.5	12.8	5.8	10.7	14.4	15.5
Mean G01-4 and S01-5	16.1	7.7	2.7	25.8	18.4	10.9	10.2	6.5	10.8	11.9	12.1

CLASS: Perennial Forbs

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	4.3	0.00	0.6	8.0	11.0	2.2	0.0	0.2	0.7	0.3	2.7
S02	0.9	0.5	0.6	0.0	0.0	2.2	3.2	4.3	3.1	4.0	1.9
S03	1.8	0.2	1.4	5.0	3.0	4.7	0.7	0.7	1.1	0.8	1.9
S04	-	-	-	-	-	4.6	4.9	6.2	4.4	6.6	5.3
S05	-	-	-	-	-	1.8	0.5	1.0	2.0	0.7	1.2
Mean S01-5	2.3	0.2	0.9	4.3	4.7	3.1	1.9	2.5	2.2	2.5	2.5
G01	1.5	0.00	0.1	2.0	0.0	0.4	0.2	0.3	0.7	0.7	0.6
G02	2.1	0.2	6.3	3.0	7.0	0.0	0.0	0.0	0.1	0.2	1.9
G03	-	-	-	-	-	0.0	0.0	1.3	2.1	1.1	0.9
G04	-	-	-	-	-	4.6	1.9	3.8	4.0	1.3	3.1
Mean G01-4	1.8	0.1	3.2	2.5	3.5	1.3	0.5	1.4	1.7	0.8	1.7
Mean G01-4 and S01-5	2.1	0.2	1.8	3.6	4.2	2.3	1.3	2.0	2.0	1.7	2.1

Table 2-1. Preoperational Herbaceous Cover (%) by Class (cont.)

CLASS: All

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	69.4	56.6	2.5	100.0	39.0	61.2	80.2	56.7	64.9	56.0	58.7
S02	49.9	57.2	13.1	95.0	51.0	65.4	66.0	40.7	56.3	53.7	54.8
S03	61.8	52.0	12.5	100.0	33.0	74.8	99.7	62.7	61.7	62.8	62.1
S04	-	-	-	-	-	75.1	61.7	44.8	51.0	55.4	57.6
S05	-	-	-	-	-	72.4	89.2	39.1	57.4	51.0	61.8
Mean S01-5	60.4	55.3	9.4	98.3	41.0	69.8	79.4	48.8	58.2	55.8	57.6
G01	78.6	87.5	10.9	101.0	81.0	100.3	113.1	63.4	71.0	83.4	79.0
G02	63.6	63.4	20.0	77.0	55.0	146.8	121.8	61.7	64.2	85.7	75.9
G03						102.6	105.9	57.0	73.5	81.4	84.1
G04						48.4	93.4	62.1	53.7	43.8	60.3
Mean G01-4	71.1	75.5	15.5	89.0	68.0	99.5	108.6	61.1	65.6	73.6	72.8
Mean G01-4 and S01-5	64.7	63.3	11.8	94.6	51.8	83.0	92.3	54.2	61.5	63.7	64.1

Table 2-2. Operational Herbaceous Cover (%) by Class

CLASS: Annual Grass

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
S01	2.1	17.5	28.9	13.8	21.9	36.8	40.3	30.3	27.7	23.3	31.8	58.0	40.5	49.4	45.6	53.6	57.0	47.9	34.8
S02	2.2	2.0	10.0	5.1	12.5	16.8	15.3	30.2	34.7	11.0	9.3	24.4	19.0	14.4	8.9	16.3	20.5	10.1	14.6
S03	14.6	7.2	7.8	8.1	12.5	17.5	40.1	42.6	53.5	28.4	25.8	52.6	53.2	46.7	37.2	46.7	57.7	48.7	33.4
S04	5.0	11.5	19.1	13.8	10.3	32.4	38.6	56.0	58.3	21.2	36.2	54.4	51.1	38.1	36.2	47.9	43.7	34.7	33.8
S05	27.1	13.1	33.4	10.2	32.9	53.4	45.2	51.6	48.2	35.5	46.8	69.3	58.4	46.8	56.7	55.7	69.1	61.0	45.2
Average S01-S05	10.2	10.2	19.8	10.2	18.0	31.4	35.9	42.1	44.5	23.9	30.0	51.7	44.4	39.1	36.9	44.0	49.6	40.4	32.3
S06					15.0	12.9	17.9	23.9	23.7	5.4	4.0	16.0	16.8	21.1	12.9	28.7	38.6	21.1	18.4
S07					47.7	5.5	5.9	15.2	58.0	9.7	1.1	50.8	63.7	78.4	70.4	83.2	83.3	80.4	46.6
Average All S	10.2	10.2	19.8	10.2	21.8	25.0	29.0	35.7	43.4	19.2	22.1	46.5	43.2	42.1	38.2	47.4	52.8	43.4	31.1
G01	8.0	9.4	23.9	23.0	22.5	18.6	26.2	48.7	46.9	47.5	78.7	81.7	77.3	81.4	72.9	69.4	73.2	67.2	48.7
G02	8.1	4.7	9.5	10.1	13.2	7.8	20.8	64.3	68.7	61.9	70.6	82.6	74.5	75.7	62.9	76.6	79.0	67.6	47.7
G03	18.3	13.3	51.7	16.8	65.9	61.6	65.5	53.2	43.4	27.5	55.5	72.4	47.7	39.1	39.5	56.7	63.3	34.8	45.9
G04	7.3	7.4	4.7	4.8	3.1	13.7	18.9	34.2	29.2	9.1	4.8	22.1	19.7	29.8	21.5	23.1	28.9	11.2	16.3
Average G01-G04	10.4	8.7	22.4	13.7	26.2	25.4	32.8	50.1	47.0	36.5	52.4	64.7	54.8	56.5	49.2	56.4	61.1	45.2	39.6
G05					22.4	23.8	37.0	46.0	38.4	6.4	11.1	24.2	33.1	29.1	29.6	29.8	40.8	17.8	27.8
G06					35.1	35.5	37.3	41.8	28.9	17.2	27.7	40.2	24.4	31.9	23.8	32.6	69.7	33.3	34.2
G07					38.1	36.6	48.3	66.2	68.9	42.4	53.7	67.3	52.4	48.4	41.7	50.1	83.0	67.9	54.6
G08					12.1	19.8	38.3	55.2	59.6	51.2	60.2	71.1	70.5	69.3	49.8	48.4	44.3	37.6	49.1
Average All G	10.4	8.7	22.4	13.6	26.5	27.1	36.5	51.2	48.0	32.9	45.3	57.7	49.9	50.6	42.7	48.3	60.2	42.2	37.5
Average S and G	10.3	9.5	21.0	11.7	24.3	26.2	33.0	44.0	45.9	26.5	34.5	52.4	46.8	46.6	40.6	47.9	56.8	42.7	34.5
Average S01-5, G01-4	10.3	9.5	21.0	11.7	21.6	28.7	34.5	45.7	45.6	29.5	39.9	57.5	49.0	46.8	42.3	49.5	54.7	42.5	35.6

CLASS: Perennial Grass

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
S01	1.1	2.2	3.6	1.8	8.3	3.3	7.6	3.3	7.2	2.7	17.6	10.5	4.3	7.7	4.9	13.8	10.7	19.2	7.2
S02	4.7	10.8	21.9	8.4	29.6	12.9	32.1	15.7	22.1	17.0	38.8	36.4	26.2	35.7	27.1	36.9	33.9	33.3	24.6
S03	17.9	17.3	42.7	12.0	64.0	18.4	26.4	11.4	16.3	5.7	30.0	12.2	7.2	14.2	20.1	12.3	9.0	17.7	19.7
S04	2.4	9.9	19.6	9.4	13.0	12.7	14.5	5.4	12.9	3.8	8.6	14.6	3.7	11.2	10.7	16.5	20.6	26.7	12.0
S05	1.9	1.3	2.3	3.4	1.3	0.1	2.3	2.4	4.0	2.2	2.3	3.7	2.7	3.0	2.3	3.4	3.0	3.3	2.5
Average S01-S05	5.6	8.3	18.0	7.0	23.2	9.5	16.6	7.6	12.5	6.2	19.5	15.5	8.8	14.3	13.0	16.5	15.4	20.0	13.2
S06					30.4	18.4	38.4	31.3	46.1	11.2	54.6	53.5	24.4	34.6	31.8	39.2	33.3	44.1	35.1
S07					37.5	17.6	60.6	33.8	23.2	9.6	12.7	14.2	3.8	5.7	10.4	5.5	2.8	8.9	17.6
Average All S	5.6	8.3	18.0	7.0	26.3	11.9	26.0	14.7	18.8	7.4	23.5	20.7	10.3	16.0	15.3	18.2	16.2	21.9	15.9

Table 2-2. Operational Herbaceous Cover (%) by Class (cont.)

CLASS: Perennial Grass (cont.)

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
G01	9.2	19.9	32.5	17.9	60.4	18.7	41.8	25.6	48.3	5.5	10.2	13.1	1.1	3.3	5.9	15.8	17.0	16.9	20.1
G02	18.0	38.7	58.8	21.7	59.6	0.0	50.6	20.0	23.4	4.3	18.0	11.6	0.2	7.1	8.6	13.1	13.3	24.4	21.7
G03	0.0	0.0	0.0	0.1	0.1	0.0	1.4	0.0	2.0	0.6	4.0	3.6	0.7	1.9	1.4	2.3	1.6	4.1	1.3
G04	13.9	26.0	46.0	30.2	49.6	30.0	38.7	32.2	46.1	34.3	64.9	41.9	32.1	36.8	30.6	39.0	44.2	48.0	38.0
Average G01-G04	10.3	21.1	34.3	17.5	42.4	12.2	33.1	19.5	29.9	11.2	24.3	17.5	8.5	12.2	11.6	17.5	19.0	23.3	20.3
G05					36.8	11.9	23.6	18.6	31.4	9.6	47.5	37.2	17.0	32.1	23.2	25.0	18.4	16.9	24.9
G06					16.2	10.7	12.8	10.2	15.4	16.7	4.4	14.9	22.8	19.9	23.5	16.9	8.5	10.0	14.5
G07					32.1	9.3	18.9	5.7	12.3	2.2	16.8	9.6	3.9	13.0	9.7	12.7	11.3	17.2	12.4
G08					49.0	12.1	22.9	8.8	16.4	7.2	22.9	10.4	3.3	8.0	7.9	27.0	28.3	24.5	17.7
Average All G	10.3	21.1	34.3	17.5	37.9	11.6	26.3	15.2	24.4	10.0	23.6	17.8	10.1	15.2	13.8	18.9	17.8	20.2	19.2
Average S and G	7.7	14.0	25.2	11.6	32.5	11.7	26.2	15.0	21.8	8.8	23.5	19.1	10.2	15.6	14.5	18.6	17.0	21.0	17.4
Average S01-5, G01-4	7.7	14.0	25.2	11.6	31.7	10.7	23.9	12.9	20.2	8.4	21.6	16.4	8.7	13.4	12.4	17.0	17.0	21.5	16.3

CLASS: Annual Forb

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
S01	0.7	25.4	12.6	6.1	12.5	8.0	36.3	13.6	13.0	8.1	31.5	6.4	7.6	13.0	7.0	13.8	6.1	8.0	12.7
S02	1.4	16.7	8.5	5.3	7.0	2.6	15.1	5.7	8.7	2.7	7.7	4.9	3.9	7.8	1.5	6.2	3.1	1.6	6.1
S03	9.4	38.1	10.8	3.6	13.1	8.2	16.8	12.0	12.9	7.4	26.3	4.5	13.1	21.3	10.1	11.9	8.0	6.7	13.0
S04	2.3	10.3	6.6	3.1	6.5	4.6	37.3	16.5	14.8	3.3	49.6	7.5	8.1	7.9	8.1	11.8	6.1	8.0	11.8
S05	4.8	16.7	11.4	4.0	11.1	8.9	21.6	13.6	13.3	7.7	14.7	6.4	3.7	17.8	9.1	13.6	5.2	8.1	10.6
Average S01-S05	3.7	21.4	10.0	4.4	10.0	6.4	25.4	12.2	12.5	5.8	25.9	5.9	7.3	13.5	7.1	11.4	5.7	6.5	10.8
S06					0.9	0.1	4.6	4.7	2.2	0.2	14.3	2.1	2.0	4.2	0.2	0.8	0.6	1.3	2.7
S07					5.2	0.0	0.7	23.1	9.9	2.9	102.1	72.5	10.3	13.7	7.4	5.7	2.3	5.4	18.6
Average All S	3.7	21.4	10.0	4.4	8.0	4.6	18.9	12.7	10.7	4.6	35.2	14.9	7.0	12.2	6.2	9.1	4.5	5.6	10.7
G01	18.2	27.7	10.3	6.3	12.9	7.8	0.3	13.3	13.5	4.1	23.8	7.6	10.2	9.8	8.3	6.2	4.4	8.2	10.7
G02	8.2	34.2	11.3	16.2	5.9	2.4	4.2	8.2	6.0	1.9	27.2	7.7	11.0	16.9	5.3	7.1	6.0	6.7	10.3
G03	7.6	25.5	14.0	7.6	42.2	15.7	13.4	15.1	22.6	18.2	23.5	5.5	14.2	21.5	13.7	10.8	7.4	26.3	16.9
G04	3.1	8.7	3.3	1.8	2.9	3.4	1.9	7.3	10.2	2.5	9.2	8.5	5.8	13.6	7.9	12.1	2.6	5.1	6.1
Average G01-G04	9.2	24.0	9.7	8.0	16.0	7.3	4.9	10.9	13.1	6.7	20.9	7.3	10.3	15.4	8.8	9.0	5.1	11.6	11.0
G05					8.9	2.8	5.9	8.6	10.9	2.2	26.3	10.3	4.8	10.4	5.8	9.0	3.5	6.4	8.3
G06					13.6	6.9	6.9	10.2	16.5	6.7	3.8	4.9	5.4	9.4	9.3	12.5	3.2	6.9	8.3
G07					13.1	9.0	34.7	16.7	13.5	11.4	30.9	6.3	11.6	18.8	8.9	21.2	11.2	20.8	16.3
G08					14.0	7.0	19.8	17.4	9.0	2.3	20.7	5.1	8.1	13.0	5.9	10.4	18.5	9.2	11.4
Average All G	9.2	24.0	9.7	8.0	14.2	6.8	10.9	12.1	12.8	6.1	20.6	7.0	8.9	14.1	8.1	11.2	7.1	11.2	11.2
Average S and G	6.2	22.6	9.9	6.0	11.3	5.8	14.6	12.4	11.8	5.4	27.4	10.7	8.0	13.2	7.2	10.2	5.9	8.6	10.9
Average S01-5, G01-4	6.2	22.6	9.9	6.0	12.7	6.8	16.3	11.7	12.8	6.2	23.7	6.5	8.6	14.4	7.9	10.4	5.4	8.7	10.9

Table 2-2. Operational Herbaceous Cover (%) by Class (cont.)

CLASS: Perennial Forb

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
S01	0.0	1.2	5.0	11.6	4.5	0.4	4.5	9.2	13.7	2.3	2.3	0.4	4.4	5.1	0.6	1.2	0.6	0.1	3.7
S02	1.4	5.4	6.0	15.8	14.5	9.6	6.4	10.7	12.7	7.2	0.5	6.8	7.9	11.0	13.5	11.0	7.8	10.8	8.8
S03	1.2	2.3	2.0	2.1	4.4	1.8	2.0	2.3	2.6	3.6	9.4	0.4	1.9	1.5	0.6	0.4	1.2	1.0	2.2
S04	3.0	9.2	10.4	4.9	8.2	3.9	2.4	4.3	8.7	4.5	3.7	6.4	7.5	12.0	5.9	4.8	3.6	7.5	6.1
S05	0.3	1.3	1.8	3.3	0.6	0.1	0.4	1.1	7.4	7.5	8.8	8.2	8.6	1.8	0.4	1.9	1.4	1.1	3.1
Average S01-S05	1.2	3.8	5.0	7.5	6.4	3.1	3.1	5.5	9.0	5.0	4.9	4.4	6.0	6.2	4.2	3.8	2.9	4.1	4.8
S06					0.1	0.0	0.0	0.7	0.1	1.3	4.3	0.0	0.1	1.00	0.2	0.4	0.3	0.0	0.6
S07					0.0	0.0	0.0	0.0	0.1	6.5	6.5	0.0	1.4	0.0	0.3	0.0	0.0	0.0	1.0
Average All S	1.2	3.8	5.0	7.5	4.6	2.2	2.2	4.0	6.5	4.7	5.0	3.2	4.5	4.6	3.0	2.8	2.1	2.9	3.9
G01	0.8	1.8	0.9	0.2	3.9	0.0	0.0	0.1	1.5	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.5
G02	0.1	2.0	1.9	2.0	1.1	0.1	0.1	0.3	0.0	0.1	0.7	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.5
G03	2.4	0.1	0.2	0.0	0.1	0.1	0.6	0.3	0.8	11.3	0.5	1.8	3.4	20.0	4.5	6.5	1.0	0.6	3.0
G04	0.9	2.6	1.6	4.4	3.0	1.2	0.9	0.8	2.2	0.6	0.7	0.3	0.5	1.5	0.4	0.2	1.0	1.2	1.3
Average G01-G04	1.0	1.6	1.1	1.7	2.0	0.3	0.4	0.4	1.1	3.0	0.5	0.5	1.0	5.4	1.2	1.7	0.5	0.4	1.3
G05					6.5	4.0	3.4	2.0	5.9	5.3	7.2	5.7	6.4	7.7	1.0	1.0	1.5	0.5	4.1
G06					10.4	8.6	12.2	12.6	8.9	11.1	1.5	0.3	10.0	9.5	12.6	11.2	6.2	10.3	8.9
G07					12.9	0.1	0.1	1.4	1.6	0.8	4.3	0.2	1.6	6.0	1.7	3.2	1.0	0.1	2.5
G08					10.6	0.2	1.7	3.9	4.5	2.8	2.9	0.1	0.3	1.5	0.2	0.5	1.1	0.4	2.2
Average All G	1.0	1.6	1.1	1.7	6.0	1.8	2.4	2.6	3.1	4.0	2.2	1.0	2.7	5.8	2.5	2.8	1.5	1.6	2.5
Average S and G	1.1	2.8	3.3	4.9	5.4	2.0	2.3	3.3	4.7	4.3	3.5	2.0	3.6	5.2	2.8	2.8	1.8	2.2	3.2
Average S01-5, G01-4	1.1	2.8	3.3	4.9	4.5	1.9	1.9	3.2	5.5	4.1	2.9	2.7	3.8	5.9	2.9	2.9	1.8	2.5	3.2

CLASS: All Forb and Grass

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
S01	3.9	46.2	50.1	33.2	47.1	48.5	88.6	56.3	61.5	36.3	83.1	75.3	56.7	75.0	58.0	82.2	74.4	75.1	58.4
S02	9.6	34.7	46.4	34.5	63.5	41.8	68.7	62.3	78.2	37.8	56.2	72.4	56.9	68.8	50.8	70.3	65.2	55.7	54.1
S03	43.0	64.9	63.3	25.8	93.9	45.8	85.1	68.2	85.2	45.1	91.5	69.6	75.4	83.6	67.9	71.3	75.9	74.1	68.3
S04	12.7	40.7	55.6	31.2	37.9	53.6	92.7	82.1	94.6	32.8	98.1	82.8	70.3	69.1	60.7	80.9	73.9	76.8	63.7
S05	33.9	32.3	48.9	20.8	45.8	662.4	69.4	68.6	72.9	52.8	72.5	87.6	73.4	69.3	68.5	74.5	78.6	73.4	94.7
Average S01-S05	20.6	43.8	52.8	29.1	57.6	50.4	80.9	67.5	78.5	41.0	80.3	77.5	66.5	73.1	61.5	75.8	73.6	71.0	61.2
S06					46.3	31.4	60.8	60.6	72.0	18.0	77.2	71.6	43.3	60.9	45.0	69.0	72.8	66.5	56.8
S07					90.3	23.0	67.2	72.1	91.0	28.6	122.3	137.4	79.1	97.7	88.5	94.3	88.4	94.6	83.9
Average All S	20.6	43.8	52.8	29.1	60.7	43.8	76.1	67.1	79.3	35.9	85.8	85.2	65.0	74.9	62.7	77.5	75.6	73.7	61.6

Table 2-2. Operational Herbaceous Cover (%) by Class (cont.)

CLASS: All Forb and Grass (cont.)

Station	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average 1985-2002
G01	36.2	58.7	67.5	47.3	99.6	45.1	68.2	87.7	110.1	57.3	112.7	102.5	88.6	94.5	87.1	91.3	94.7	92.2	80.0
G02	34.3	79.4	81.5	50.0	79.8	10.2	75.7	92.7	98.0	68.1	116.5	101.9	85.7	99.8	76.8	96.7	98.3	98.6	80.2
G03	28.2	38.8	65.8	24.4	108.2	77.3	80.8	68.5	68.8	57.5	83.4	83.2	65.9	82.4	59.0	76.3	73.2	65.8	67.1
G04	25.1	44.6	55.4	41.2	58.5	48.2	60.4	74.4	87.7	46.5	79.6	72.7	58.0	81.6	60.3	74.3	76.7	65.4	61.7
Average G01-G04	10.4	55.4	67.5	40.7	86.5	45.2	71.2	80.8	91.1	57.3	98.0	90.0	74.5	89.5	70.8	84.6	85.7	80.5	71.1
G05					74.4	42.4	69.8	75.2	86.5	23.4	92.0	77.4	61.2	79.2	59.5	64.8	64.0	41.6	65.1
G06					75.3	61.6	69.2	74.8	69.6	51.6	37.3	60.1	62.5	70.5	69.1	73.2	87.5	60.3	65.9
G07					96.1	54.9	102.0	90.2	96.1	56.7	105.5	83.3	69.4	86.0	61.9	87.2	106.4	105.9	85.8
G08					85.6	39.1	82.6	85.2	89.5	63.5	106.6	86.6	82.2	91.7	63.7	86.2	92.1	71.7	80.4
Average All G	31.0	55.4	67.5	40.7	84.7	47.3	76.1	81.1	88.3	53.1	91.7	83.4	71.7	85.7	67.2	81.2	86.6	75.2	70.4
Average S and G	25.2	48.9	59.4	34.2	73.5	45.7	76.1	74.6	84.1	45.1	89.0	84.3	68.6	80.7	65.1	79.5	81.4	74.5	66.1
Average S01-5, G01-4	25.2	48.9	59.4	34.2	70.5	48.1	76.6	73.4	84.1	48.2	88.2	83.1	70.1	80.4	65.4	79.7	79.0	75.2	66.1

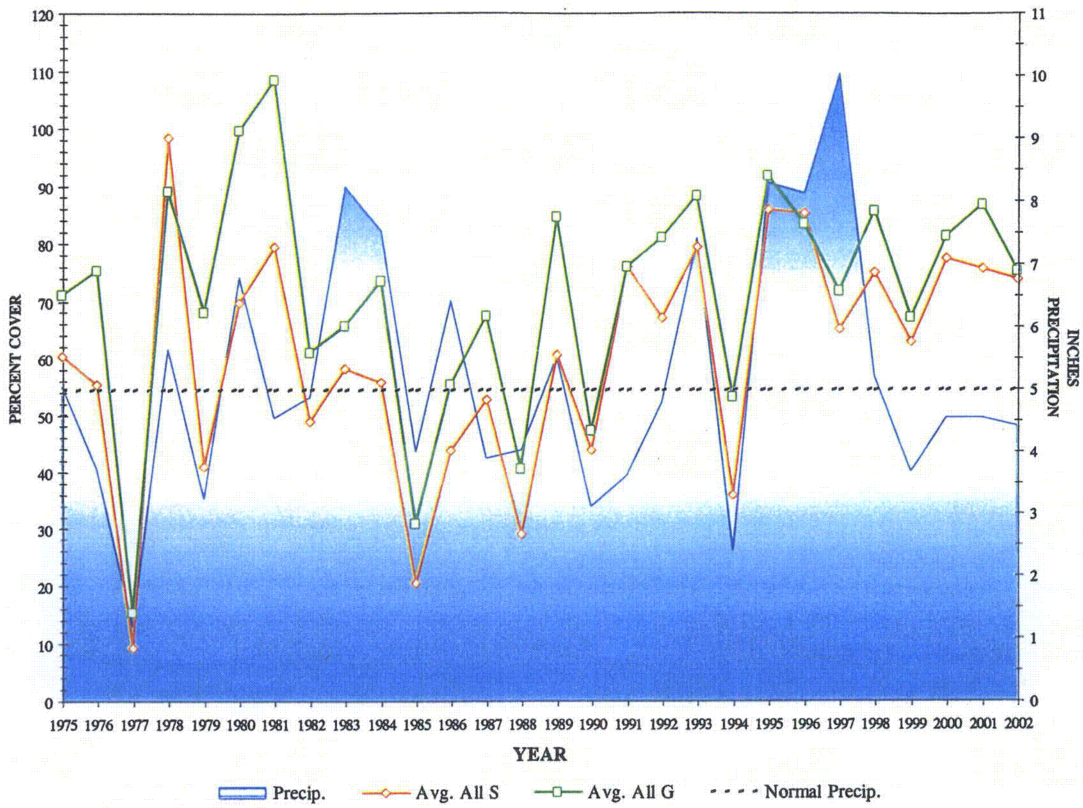


Figure 2-2. Percent Cover vs. Precipitation, 1975-2002

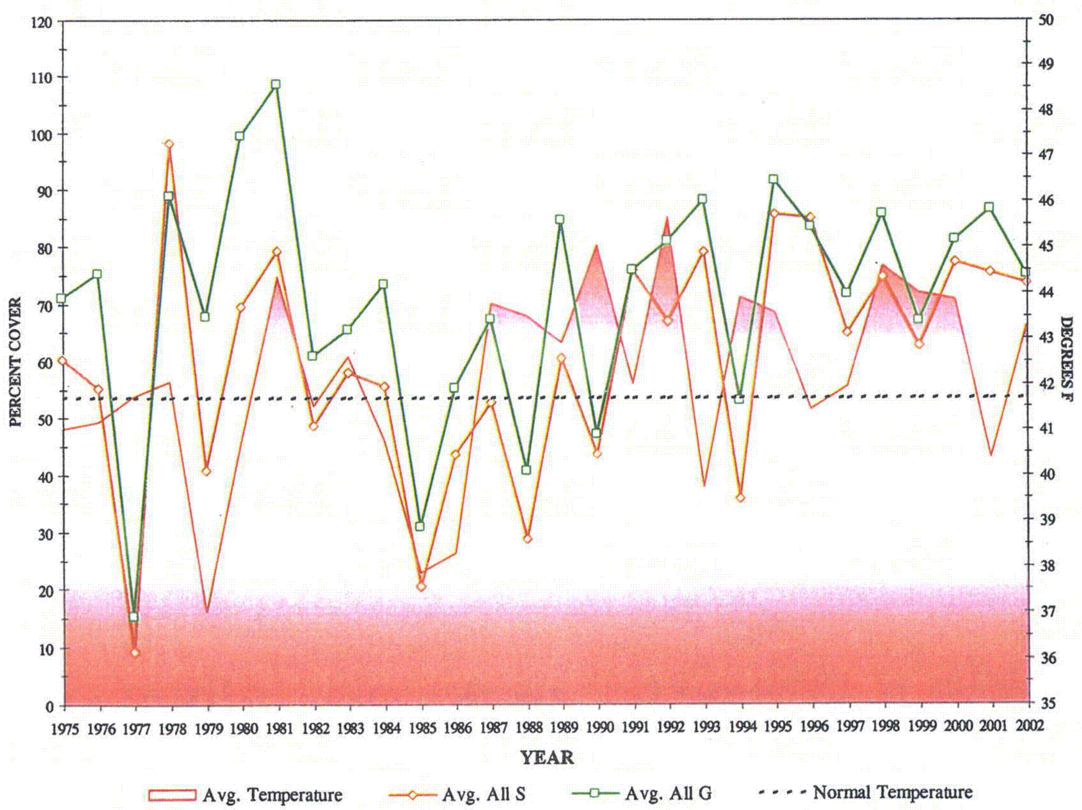


Figure 2-3. Percent Cover vs. Temperature, 1975-2002

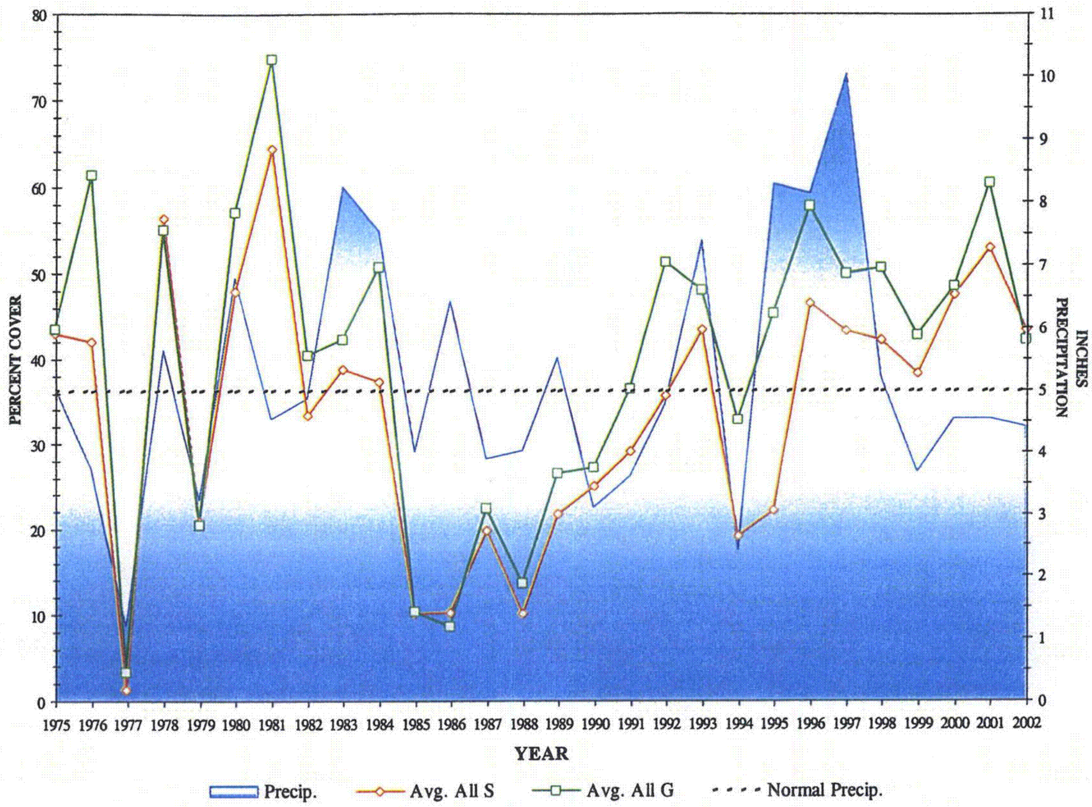


Figure 2-4. Annual Grasses Percent Cover vs. Precipitation, 1975-2002

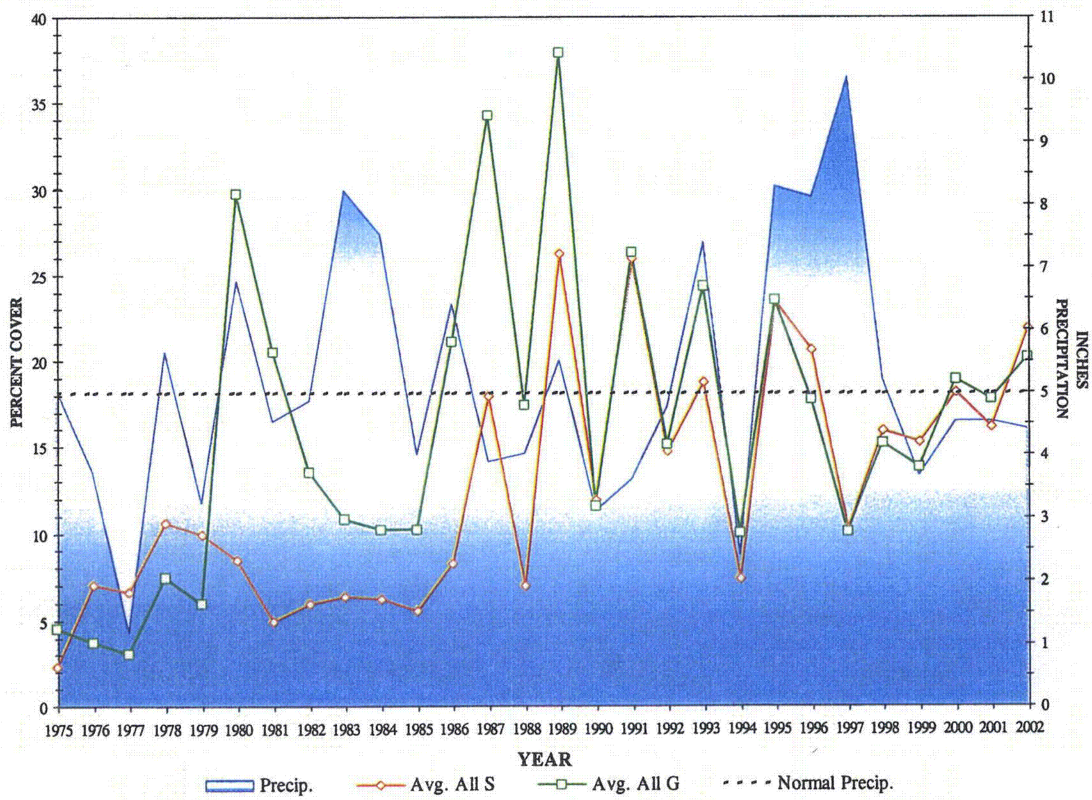


Figure 2-5. Perennial Grasses Percent Cover vs. Precipitation, 1975-2002

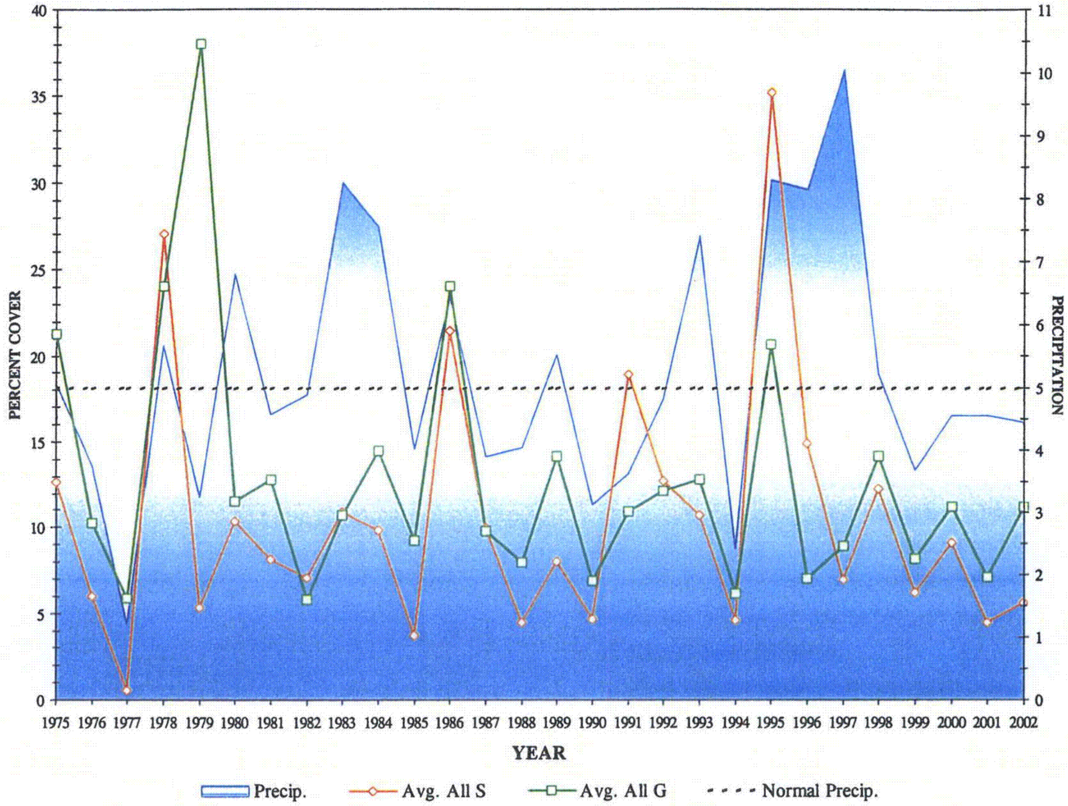


Figure 2-6. Annual Forbs Percent Cover vs. Precipitation, 1975-2002

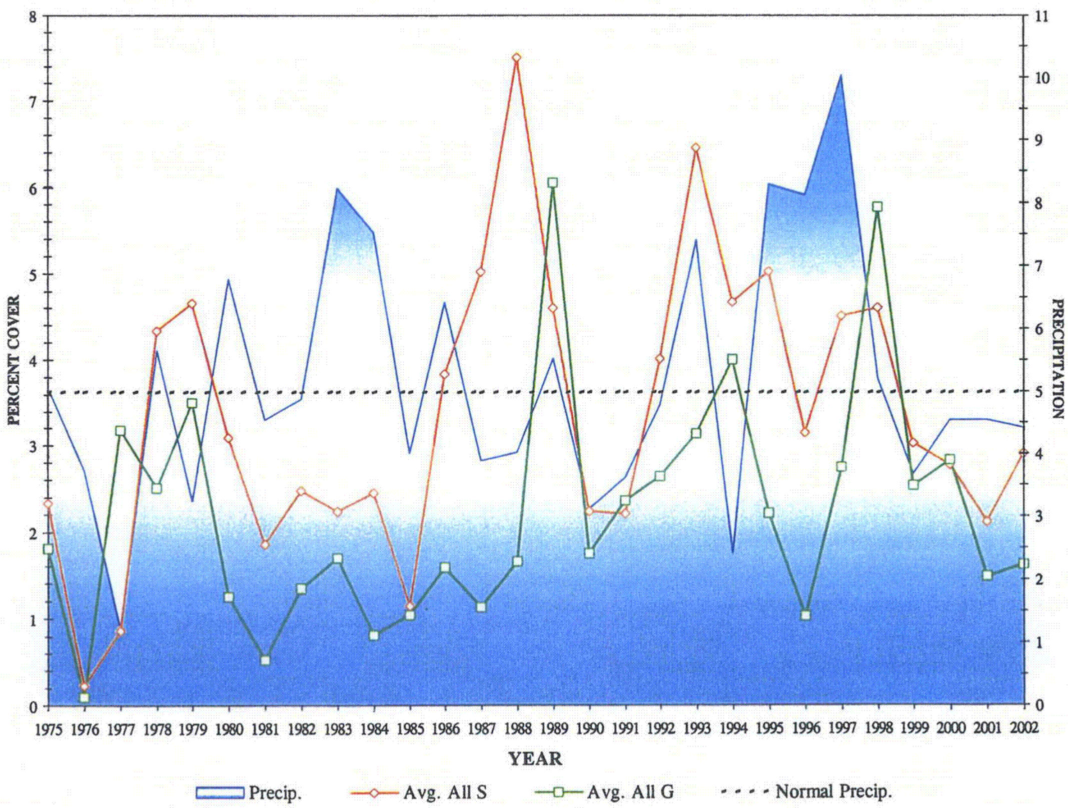


Figure 2-7. Perennial Forbs Percent Cover vs. Precipitation, 1975-2002

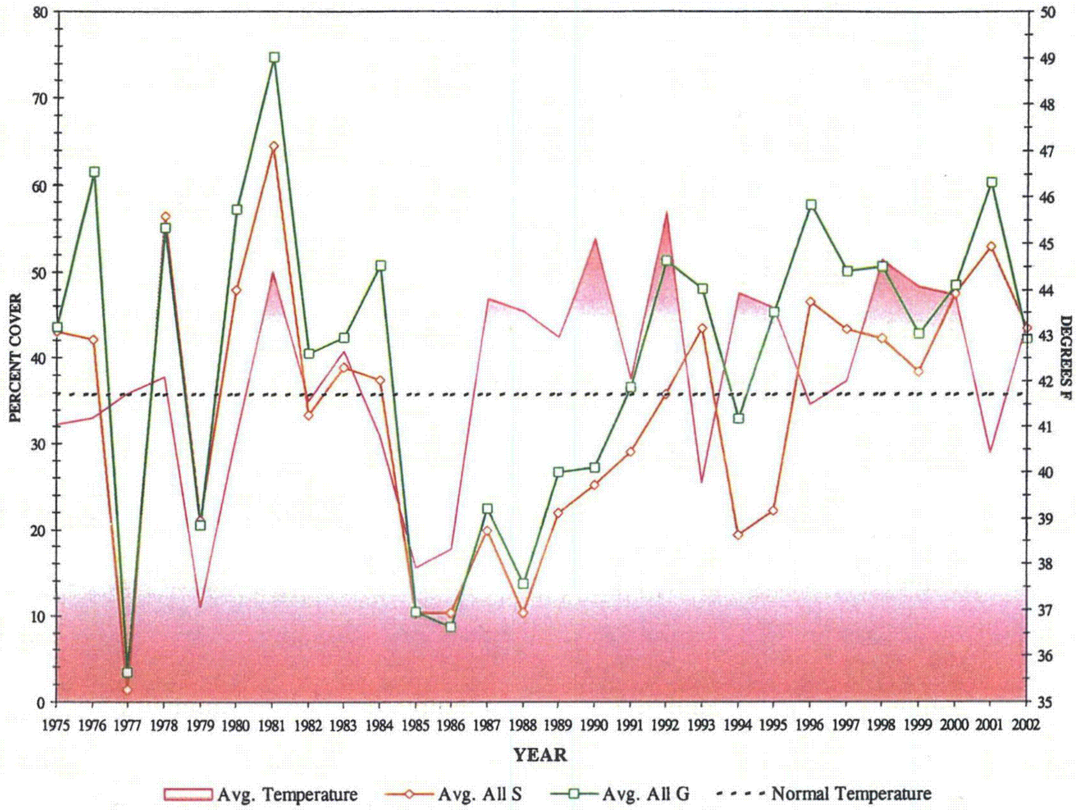


Figure 2-8. Annual Grasses Percent Cover vs. Temperature, 1975-2002

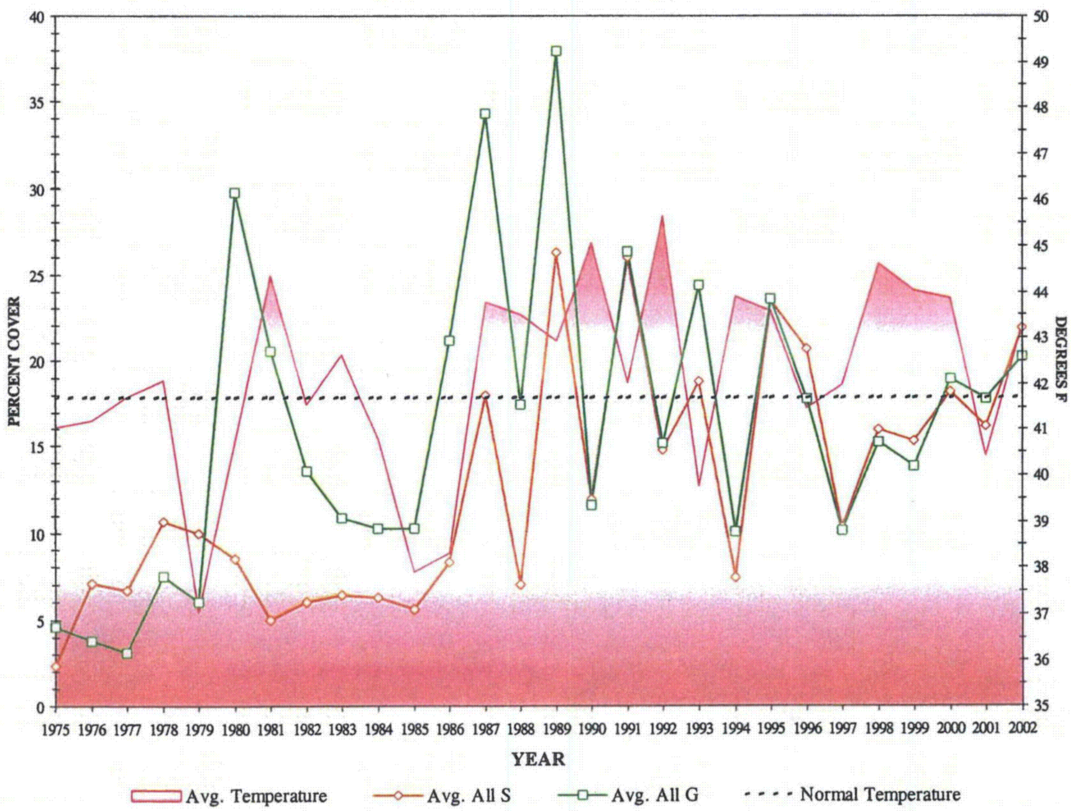


Figure 2-9. Perennial Grasses Percent Cover vs. Temperature, 1975-2002

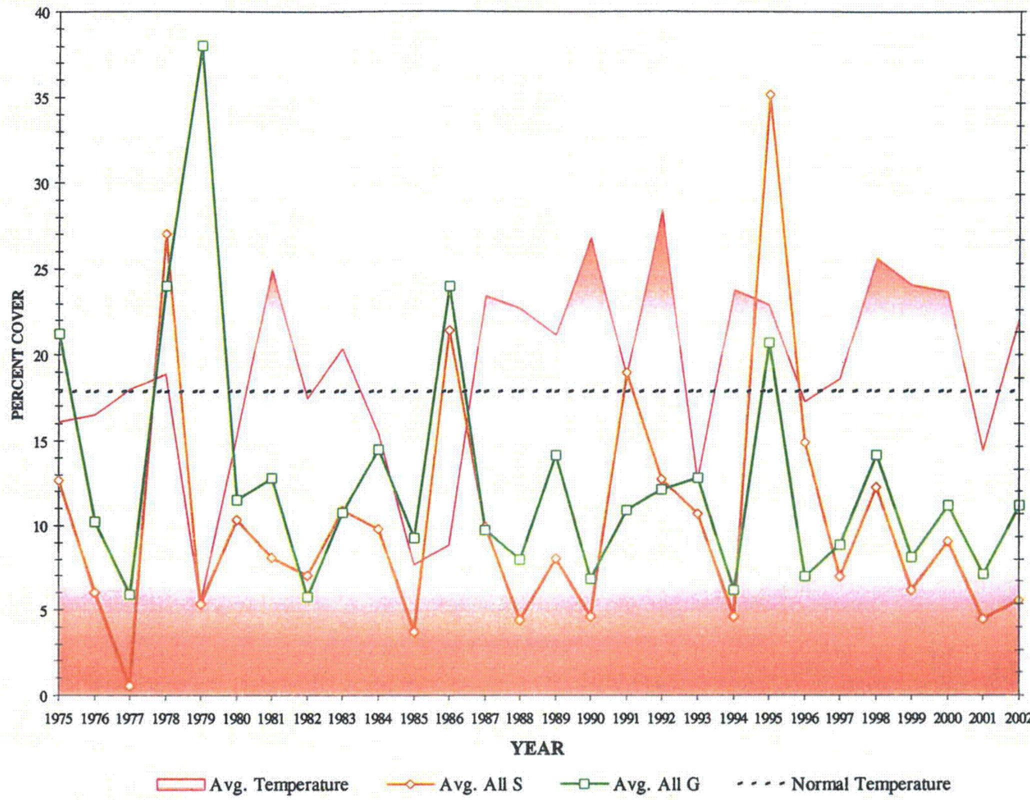


Figure 2-10. Annual Forbs Percent Cover vs. Temperature, 1975-2002

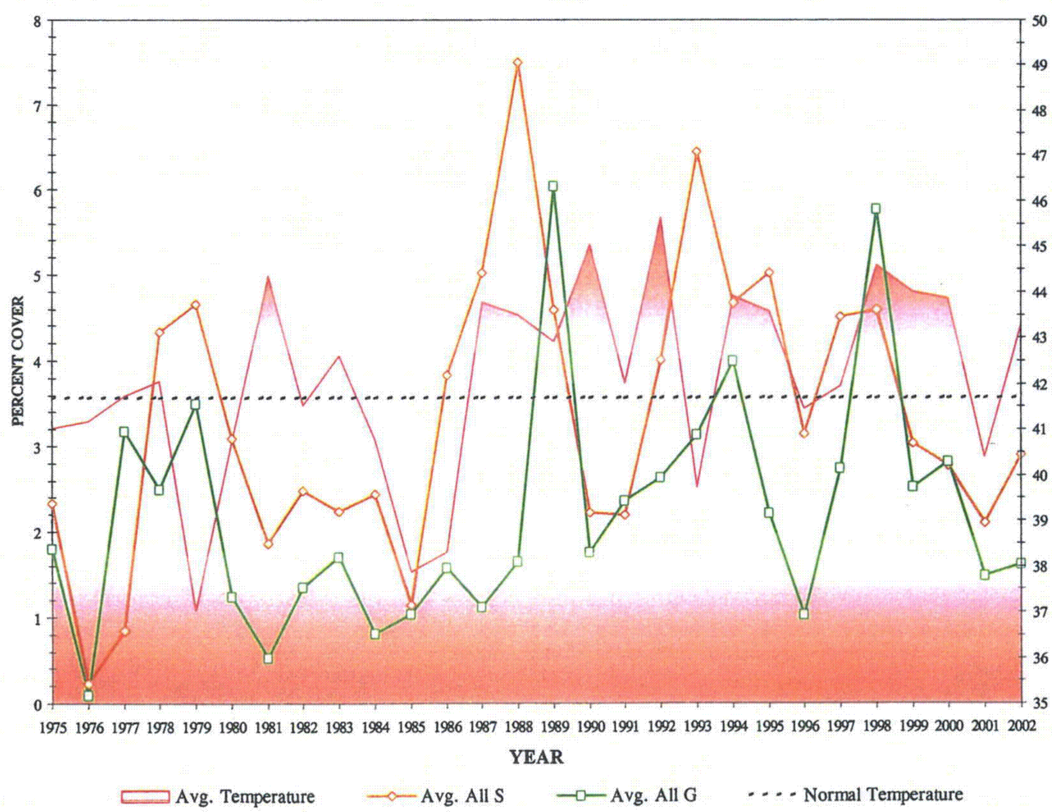


Figure 2-11. Perennial Forbs Percent Cover vs. Temperature, 1975-2002

SECTION 3 SHRUB COVER AND DENSITY

3.0 SHRUB CANOPY COVER AND DENSITY

Measurements of shrub canopy cover are conducted on shrub species in a manner similar to the measurements of herbaceous cover (Section 2). Shrub density is simply based on shrub counts per unit area. These field measurements were included in the terrestrial program until they were terminated in 1992.

3.1 Methods and Materials

Five 50-meter lines were used to measure shrub canopy cover in each of the seven shrub sites (Figure 3-1). Whenever a tape stretched between the end posts crossed a shrub, its species and the distance (cm) at which it intercepted the line were recorded. For each shrub site, intercept distances of each species along all five lines were summed to give a total intercept distance. From this, a shrub canopy cover value in percent was obtained by dividing the total intercept distance by total line length.

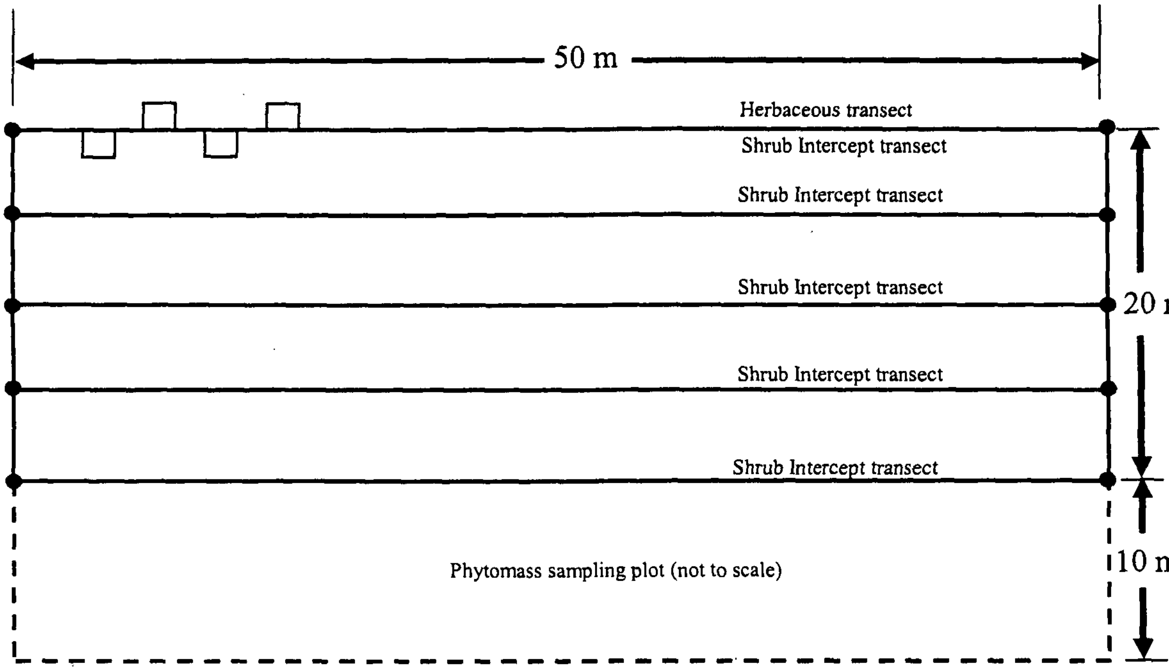


Figure 3-1. Shrub Cover and Density Sampling Transects

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

Shrub density was determined by counting live individual shrubs. These were recorded by species within each of the four strips delineated by shrub intercept transects. The number of shrubs per strip was summed to obtain shrub density by species for the entire 1000 square meter plot. Sampling was done concurrent with cover sampling.

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

3.2 Results and Discussion

In the summer of 1984, a range fire destroyed nearly all shrubs at Sites S01, S02 and S04. Mean shrub cover fell from 12.9% in the spring of 1984 to 5.0% in the spring of 1985. The lowest mean shrub density came in 1991, with 1.4%. Mean shrub cover results for 1975 to 1992 are listed in Table 3-1 and graphically shown in Figure 3-2.

Shrub density also shows the effect of the 1984 fire. Density at sites S01 and S04 fell from 1200 and 2010 shrubs per hectare (shrubs/ha) to zero in 1985. During the same period, shrub density at site S02 declined from 2340 to 110 shrubs/ha. Site S03 was not burned and showed increased density during the study. Site S05 also escaped the 1984 fire but was recovering from a 1981 fire. Table 3-2 lists the shrub density at the fives stations for 1980 to 1992. Figure 3-3 graphically shows the density at each of the shrub sites from 1980 to 1992.

Table 3-1. Mean Shrub Cover (%), 1975-92

1975	13.4	**1984**	12.9
1976	14.4	**1985**	5.0
1977	11.9	**1986**	2.2
1978	25.6	**1987**	1.7
1979	14.0	**1988**	1.8
1980	19.1	**1989**	1.6
1981	15.9	**1990**	1.6
1982	12.5	**1991**	1.4
1983	12.8	**1992**	2.1

Table 3-2. Shrub Density (shrub/hectare) at Five Shrub Sites, 1980-92

Station	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
S01	1080	1016	1060	1310	1200	0	100	90	140	140	130	70	90
S02	2100	1823	1770	2060	2340	110	0	12	20	12	20	20	10
S03	476	376	500	550	540	520	530	640	570	580	570	660	570
S04	2073	1897	1820	1950	2010	0	0	50	100	100	90	60	60
S05	619	568	60	40	100	110	100	90	110	120	160	140	150

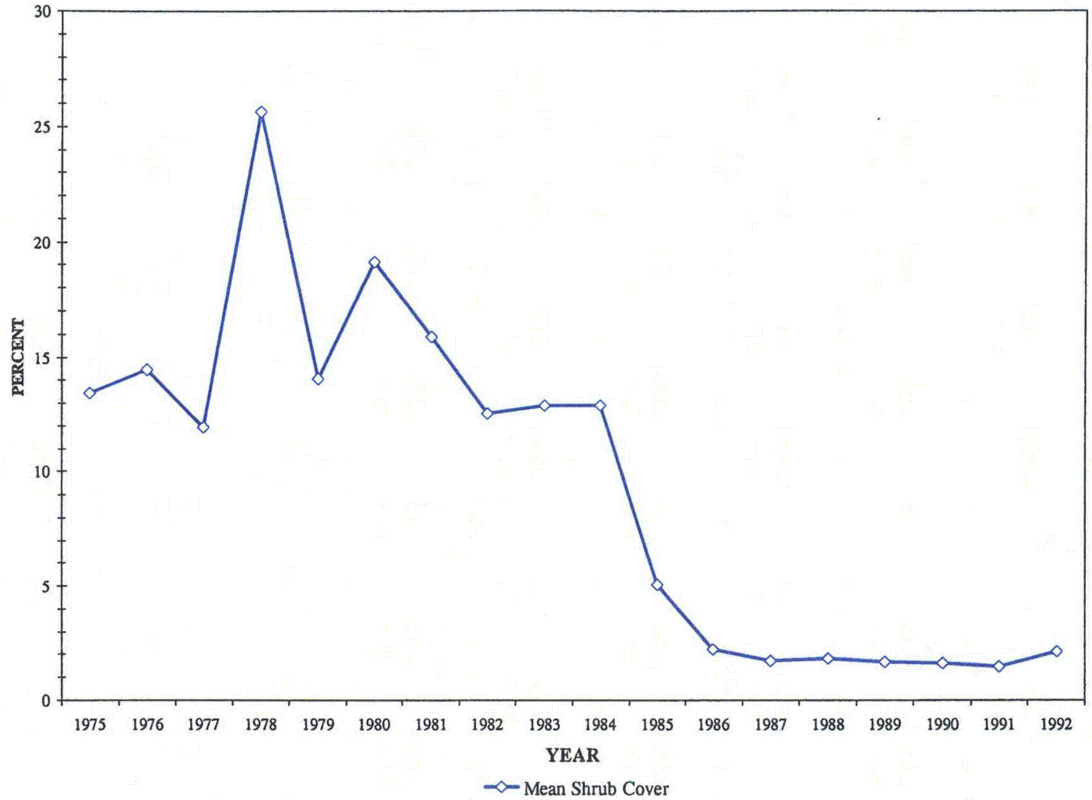


Figure 3-2. Mean Shrub Cover, 1975-1992

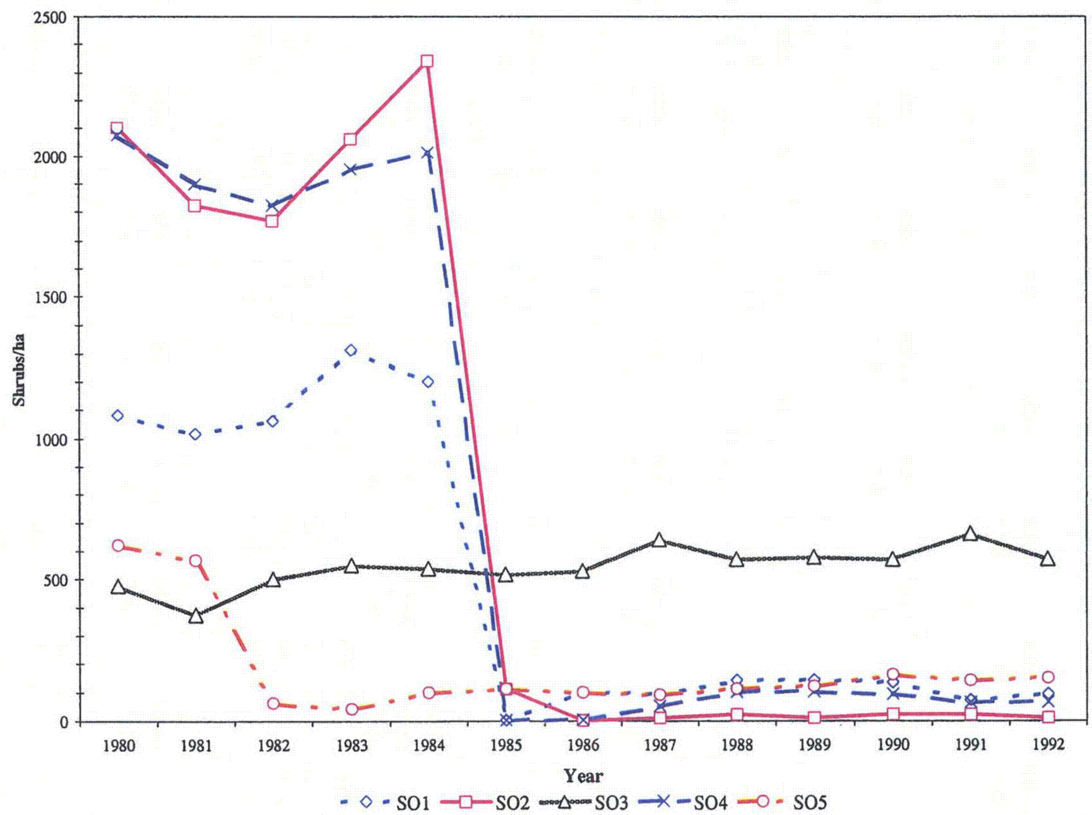


Figure 3-3. Shrub Density at Five Shrub Sites, 1980-1992

SECTION 4 HERBACEOUS PHYTOMASS

4.0 HERBACEOUS PHYTOMASS

Herbaceous phytomass is a measure of the amount of vegetative matter per unit area in the same plant communities for which cover measurements were made (Section 2). The results are compared over the period of the study for trends that may indicate potential impact from cooling tower operation.

4.1 Methods and Materials

Phytomass sampling was conducted concurrently with herbaceous cover sampling. Phytomass sampling plots were randomly located within an area adjacent to the permanent transects or plots (Figure 2-1). At each site, live herbaceous vegetation rooted in five microplots (20 x 50 cm) was clipped to ground level and placed in paper bags. Each bag was stapled shut and labeled with site code, plot number, and date.

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

4.2 Results and Discussion

Herbaceous phytomass, like herbaceous cover, is influenced by the climate during the growing season. As illustrated in Figure 4-1, the 1977 and 1994 periods of low precipitation correspond to low phytomass at both shrub and grass sites. During 1977, the average phytomass at shrub sites was six grams per square meter (gm/m^2) and 16 gm/m^2 at grass sites. In 1994, the average phytomass was 24 gm/m^2 at shrub sites and grass sites averaged 40 gm/m^2.

Other periods of low phytomass relate with periods of low temperatures. In 1979, when the average growing season temperature was 4.6° F below the norm, the average phytomass decreased at shrub sites to 21.7 gm/m^2 from the 138.7 gm/m^2 in 1978. Average phytomass at grass sites was 50.5 gm/m^2, a decrease of 113.5 gm/m^2 from the 1978 average. Low temperatures combined with recovery from the devastating 1984 range fire may have contributed to the low phytomass observed in 1985. The average growing season temperature was 3.8° F below normal seasonal temperatures. Phytomass during 1985 was 21 gm/m^2 at shrub sites and 36.5 gm/m^2 at grass sites. Figure 4-2 shows the relationship between growing season temperature and phytomass.

Preoperational phytomass averaged 105.1 gm/m^2 and ranged from a low of four gm/m^2 at S01 in 1977 to 359 gm/m^2 observed at G01 in 1975. Operational phytomass ranged from one gm/m^2 at S02 in 1985 to 438.5 gm/m^2 at G01 in 1996 and averaged 79.5 gm/m^2. Table 4-1 presents the site and annual comparison of preoperational herbaceous phytomass. Table 4-2 shows the comparison of herbaceous phytomass during the operational period.

Table 4-1. Herbaceous Phytomass (gm/m^2) during the Preoperational Period

SITE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	TOTAL MEAN
S01	126.0	137.0	4.0	173.0	21.0	36.0	180.0	98.0	171.0	104.0	105.0
S02	144.0	98.0	7.0	128.0	28.0	63.0	115.0	24.0	232.0	57.0	89.6
S03	88.0	177.0	7.0	115.0	16.0	43.0	31.0	22.0	54.0	95.0	64.8
S04	-	-	-	-	-	78.0	52.0	39.0	68.0	93.0	66.0
S05	-	-	-	-	-	71.0	81.0	184.0	136.0	43.0	103.0
Mean Shrub Sites	119.3	137.3	6.0	138.7	21.7	58.2	91.8	73.4	132.2	78.4	85.7
G01	359.0	108.0	21.0	166.0	64.0	160.0	200.0	90.0	77.0	94.0	133.9
G02	302.0	258.0	11.0	162.0	37.0	68.0	255.0	60.0	137.0	116.0	140.6
G03	-	-	-	-	-	53.0	261.0	62.0	64.0	133.0	114.6
G04	-	-	-	-	-	79.0	159.0	113.0	82.0	67.0	100.0
Mean Grass Sites	330.5	183.0	16.0	164.0	50.5	90.0	218.8	81.3	90.0	102.5	132.7
Mean All Sites	203.8	155.6	10.0	148.8	33.2	72.3	148.2	76.9	113.4	89.1	105.1

Table 4-2. Herbaceous Phytomass (gm/m^2) during the Operational Period

SITE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	TOTAL MEAN
S01	5.0	34.8	62.4	59.5	53.9	32.8	225.1	49.2	80.2	27.3	76.5	65.6	42.7	49.0	61.2	77.8	60.2	43.8	61.5
S02	1.0	111.8	143.6	73.4	72.8	78.3	58.2	147.5	84.1	13.4	84.6	231.1	43.5	40.7	32.2	72.4	106.4	38.2	79.6
S03	27.0	25.3	48.3	15.2	67.0	28.2	87.6	90.7	91.7	20.5	53.8	110.3	75.2	66.8	48.0	42.6	55.2	51.0	55.8
S04	11.0	176.5	108.0	24.4	39.8	30.9	185.2	80.3	261.4	19.8	244.1	45.5	33.6	79.6	37.2	55.4	94.4	42.0	87.1
S05	61.0	24.3	144.6	18.6	103.7	43.4	111.3	110.8	173.1	60.8	113.9	63.8	39.4	41.1	85.8	86.6	83.0	38.4	79.0
S06	-	-	-	-	72.7	34.0	225.1	101.3	93.5	7.0	73.5	54.2	31.0	41.5	41.8	24.9	78.4	24.2	64.5
S07	-	-	-	-	149.5	6.1	226.0	187.3	330.3	19.1	214.5	281.3	159.9	183.3	181.8	248.0	157.6	144.0	177.8
Mean Shrub Sites	21.0	74.5	101.4	38.2	79.9	36.2	159.8	109.6	159.2	24.0	123.0	121.7	60.8	71.7	69.7	86.8	90.7	54.5	82.6
G01	70.0	50.4	83.1	34.0	174.3	13.6	87.7	142.4	146.0	45.7	208.5	438.5	46.0	100.9	86.8	84.8	128.0	85.2	112.5
G02	27.0	61.5	76.6	14.1	65.7	4.1	97.2	109.4	156.6	48.8	174.5	183.4	48.9	93.9	73.4	90.8	133.8	54.4	84.1
G03	12.0	31.6	133.6	16.0	105.1	64.0	161.6	82.7	70.3	49.2	33.5	78.8	17.5	56.9	69.2	64.4	97.4	46.6	66.2
G04	37.0	35.1	89.9	61.4	49.5	73.2	67.6	60.0	109.8	15.6	65.5	50.2	37.7	46.9	67.6	131.2	77.8	45.4	62.3
G05	-	-	-	-	43.2	36.8	171.8	54.4	75.3	13.2	35.5	49.2	28.2	42.6	43.4	87.4	64.6	11.1	54.1
G06	-	-	-	-	61.0	39.8	101.4	49.4	162.0	60.1	92.4	75.5	51.2	53.9	49.0	130.0	103.8	52.0	77.3
G07	-	-	-	-	113.1	29.1	168.4	101.4	150.7	41.5	107.0	44.1	22.5	75.2	66.2	66.8	138.4	82.6	86.2
G08	-	-	-	-	112.3	10.0	137.3	74.3	100.3	44.1	139.3	316.6	58.8	66.3	50.4	112.6	55.8	47.0	94.7
Mean Grass Sites	36.5	44.7	95.8	31.4	90.5	33.8	124.1	84.3	121.4	39.8	107.0	154.5	38.9	67.1	63.3	96.0	100.0	53.0	76.8
Mean All Sites	27.9	61.3	98.9	35.2	85.6	35.0	140.8	96.1	139.0	32.4	114.5	139.2	49.1	69.2	66.3	91.7	95.7	53.7	79.6

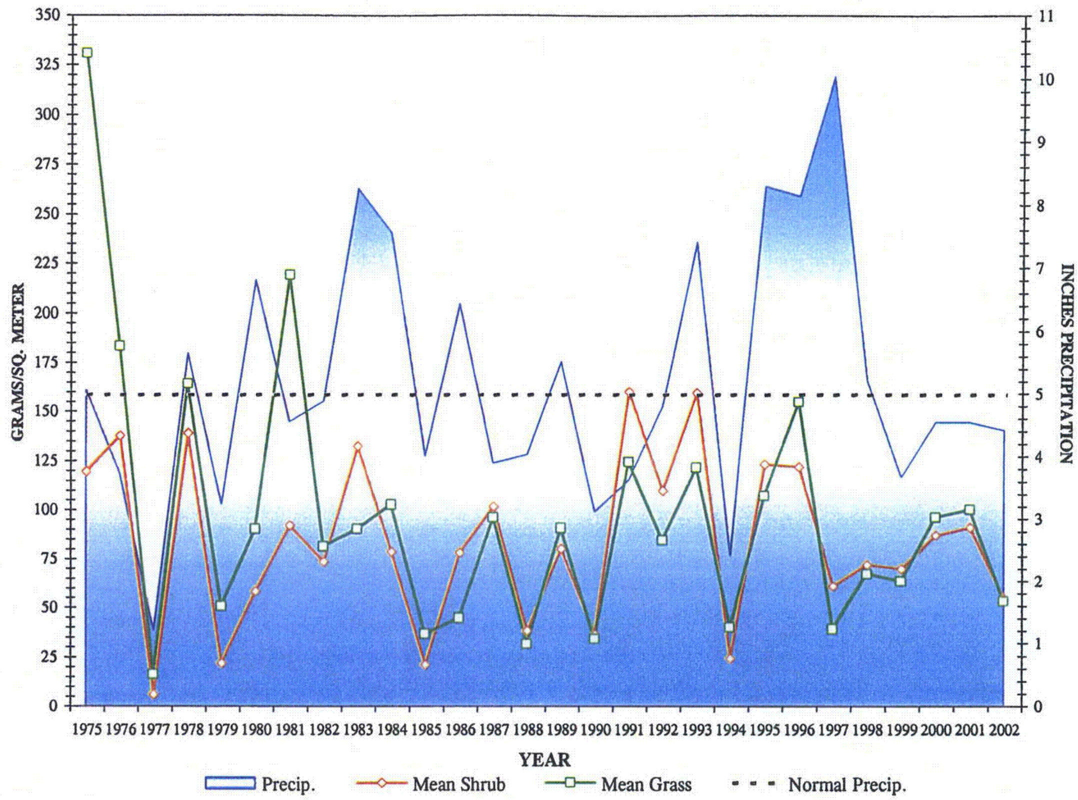


Figure 4-1. Phytomass vs. Precipitation, 1975-2002

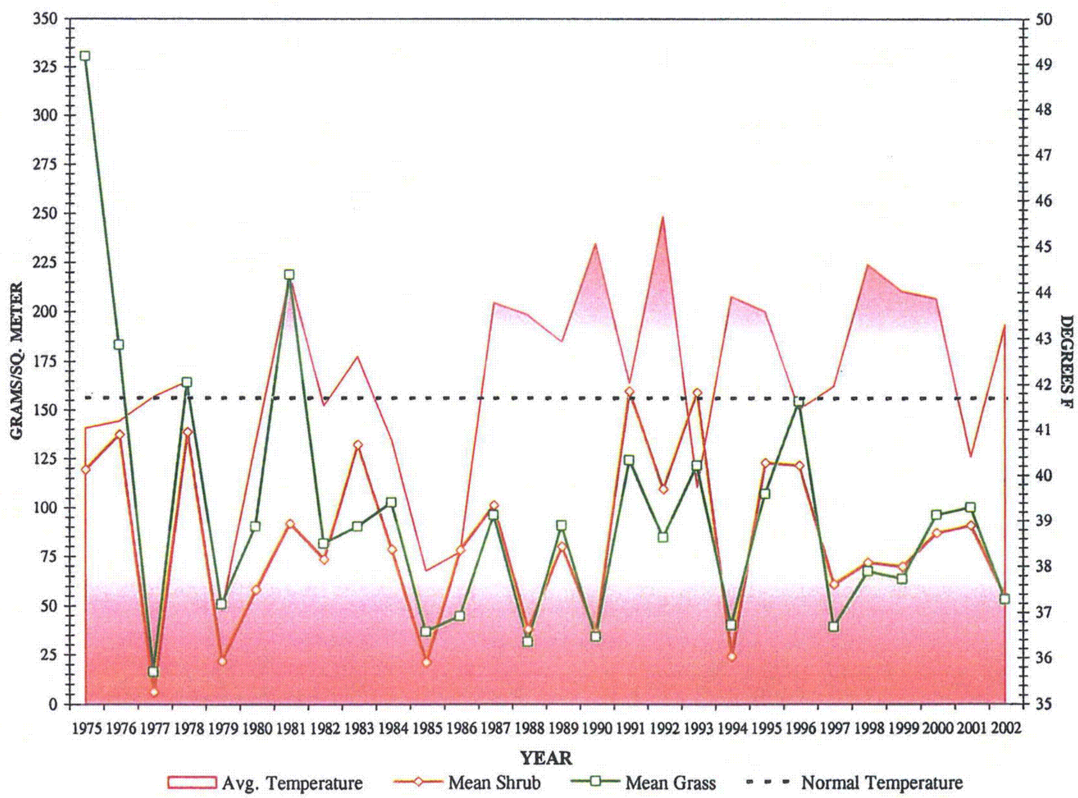


Figure 4-2. Phytomass vs. Temperature, 1975-2002

SECTION 5 SOIL CHEMISTRY

5.0 SOIL CHEMISTRY

The concentration of chemical constituents in the cooling tower drift should be very similar to concentrations in the circulating cooling water. Due to the evaporative process, concentrations of cations, anions, and metals will be elevated as compared to rainwater. The accumulation of one or more chemical constituents in the soil surrounding the plant can be an indicator of a potentially adverse impact.

5.1 Methods and Materials

At each of the grassland and shrub sites, soil samples were collected at two locations from the top 15 cm of soil with a clean stainless steel trowel. The soil sample locations were randomly selected and taken from the phytomass sampling plot. The samples were placed in 250-ml sterile plastic cups with lids, labeled and refrigerated at 4°C. Each sample was analyzed for pH, bicarbonate alkalinity, carbonate alkalinity, conductivity, sulfate, chloride, copper, zinc and sodium. Aliquots of soil for trace metal analyses were microwave digested according to Gilman (1989). Preservation times and conditions followed Environmental Protection Agency procedures (EPA 1991).

Laboratory quality control comprised 10%-20% of the sample analysis load for soil chemistry. Routine quality control samples included internal laboratory check standards, reagent blanks, and prepared EPA or National Institute of Standards and Technology (NIST) controls.

5.2 Results and Discussion

Soil chemistry analyses results are presented in Tables 5-1 and 5-2. Comparison of the preoperational and operational results for sulfate and chloride is difficult due to several factors. The methods used for determining the amount of sulfate and chloride in soil have changed and been refined such that there is less error introduced into determining the quantity of the element present. Also, the number of sites increased from a total of nine shrub and grass sites during the preoperational phase to fifteen in 1989.

The pH in soil ranged from a low of 6.22 standard units (STU) at site S03 in 1995, to a high of 8.79 STU at Site S02 in 1983. During the preoperational phase, the site with the highest average pH was S02 with 8.07 STU. The site with the lowest pH during the preoperational phase was S04, with an average of 6.92 STU. The average pH for the five shrub sites was 7.34 STU and for the four grass sites, the average pH was 7.44 STU. During the operational phase, site S07 had the highest average pH at 7.62 STU. The site with the highest single pH reading during the operational phase was S07 with a pH of 8.50 in 1995. The shrub sites averaged a pH of 7.10 during the operational phase of the program, while the grass sites averaged 6.87 STU. Soil pH results from 1980 to 2002 are shown graphically in Figure 5-1.

The conductivity of soil ranged from a low of 8.5 microsiemen per centimeter (μS/cm) at site S03 in 1981 to a high of 345 μS/cm at S07 in 2002. The site with the highest average conductivity during the preoperational phase was G02, with an average of 49.1 μS/cm. Site S04 had the lowest preoperational average conductivity at 28.3 μS/cm. Site S07 had the highest average conductivity during the operational phase at 115.4 μS/cm. The lowest average conductivity was at G06, with an average of 33.1 μS/cm. The average conductivity at shrub sites during the preoperational phase was 33.7 μS/cm and averaged 55.8 μS/cm during the operational phase. Grass sites averaged 42.6 μS/cm during the preoperational phase and 48.7 μS/cm during the operational phase. In 2002, eleven of the fifteen sites showed a marked increase over previous years. Only sites S03, G01, G02 and G08 had a conductivity result that was not the highest result for that site. The high conductivity readings may be the result of the leaching of ash deposited during the large range fire that occurred in the summer of 2000. Figure 5-2 graphically shows the soil conductivity from 1980 to 2002.

Sulfate in soil ranged from less than detectable at several stations to 188.5 micrograms per gram (μg/gm) at S05 in 1980. The site with the highest preoperational average was S05, with an average sulfate concentration of 50 μg/gm. Site S04, with an average of 10.7 μg/gm, had the lowest preoperational concentration. During the operational phase of the program, the site with the highest average sulfate concentration was 10.3 μg/gm at G03. The lowest average sulfate concentration for the operational period was at 3.4 μg/gm at G05. The average sulfate concentration at shrub sites was 23.5 μg/gm during the preoperational phase and 3.7 μg/gm during the operational phase. Grass sites averaged 18.2 μg/gm during the preoperational phase and 4.8 μg/gm during operation. Sulfate results from 1980 to 2002 are graphically shown in Figure 5-3.

The chloride in soil results ranged from below detection level to 26.4 μg/gm in 1991 at site G07. Site G01 had the highest average preoperational concentration at 9.2 μg/gm. The lowest preoperational average was 6 μg/gm at G03. Site S07 had the highest operational average of 4.3 μg/gm and site G08 had the lowest operational average at 1.8 μg/gm. Shrub sites averaged 7 μg/gm during the preoperational phase and grass sites average 7.3 μg/gm. During the operational phase, both shrub and grass sites averaged 3 μg/gm. Chloride results for 1980 to 2002 are illustrated in Figure 5-4.

Copper in soil ranged from a low of 0.2 μg/gm at sites S03 through S06 in 2001 to a high of 19.9 μg/gm in 1992 at S07. Grass site G02 had the highest preoperational average concentration at 12.5 μg/gm. Site S02 had the lowest preoperational average at 8.9 μg/gm. Grass sites overall averaged 11.4 μg/gm during the preoperational phase. Shrub sites during the preoperational phase averaged 10.3 μg/gm. During the operational phase, site S07 had the highest average copper concentration at 12.8 μg/gm and site G05 had the lowest operational average at 7.5 μg/gm. Overall, shrub sites averaged 9.2 μg/gm of copper annually during the operational phase and grass sites averaged 8.9 μg/gm. A general decline in copper in soil has been noted. This trend has also been shown to be occurring in the plant's circulating water. In 1994, copper in the circulating water averaged 75.9 μg/l. By the end of 2001, copper in the circulating water was averaging 16.2 μg/l. The copper in soil results from 1980 to 2002 is graphically shown in Figure 5-5.

The results for zinc in soil ranged from 15.2 μg/gm at S02 in 1995 to 82.5 μg/gm at S05 in 1980. The highest preoperational average was at 55.9 μg/gm at G02. The low preoperational average during the preoperational phase was at 29.9 μg/gm at S02. Grass sites averaged 51.6 μg/gm during the preoperational phase and shrub sites averaged 46.2 μg/gm. During the operational phase, site S07 had the highest average zinc concentration at 52.1 μg/gm. Site S02 had the lowest average at 27.2 μg/gm. Grass sites averaged 43.3 μg/gm overall during the operational phase. Shrub sites averaged 42.3 μg/gm annually during the operational phase.

The mean concentrations of zinc at grass and shrub sites from 1980 to 2002 are graphically shown in Figure 5-6.

Sodium in soil ranged from a low of 0.001 percent by weight (%wt) at site S05 in 1999 to a high of 0.170 %wt in 1980, also at S05. Site G02 had the highest preoperational average concentration of sodium at 0.059 %wt. The lowest preoperational average was at site S02 with an average of 0.042 %wt. Overall, grass sites averaged 0.055 %wt during the preoperational phase and shrub sites average 0.049 %wt. Site S02 had the lowest average concentration during the operational phase with an average of 0.022 %wt. The site with the highest average during the operational phase was G02, at 0.042 %wt. Grass sites averaged 0.034 %wt during the operational phase and shrub sites averaged 0.030 %wt. Figure 5-7 graphically shows the sodium results at grass and shrub sites from 1980 to 2002.

Bicarbonate in soil results ranged from a low of 0.002 milliequivalents (meq) bicarbonate per gram (meq/HCO^3/gm) at several sites during the preoperational phase and at site S04 in 1997 and 2000, to a high of 0.0200 meq/HCO^3/gm at site G07 in 2001. The sites with the lowest preoperational average were S04, S05, G02, and G04, with an average of 0.0004 meq/HCO^3/gm. The highest preoperational average was 0.0011 meq/HCO^3/gm at site S02. Overall, grass sites averaged 0.0006 meq/HCO^3/gm during the preoperational phase and shrub sites averaged 0.0007 meq/HCO^3/gm. During the operational phase, grass sites averaged 0.0021 meq/HCO^3/gm and shrub sites averaged 0.0027 meq/HCO^3/gm. The site with the highest average concentration during the operational phase was S07 with an average of 0.0070. Site G06 had the lowest average, averaging 0.0011 meq/HCO^3/gm during the operational phase. Shrubs sites averaged 0.0027 meq/HCO^3/gm during the operational phase and grass sites averaged 0.0021 meq/HCO^3/gm. Bicarbonate results for 1980 to 2002 are shown in Figure 5-8.

The soil chemistry data from 1980 to 2002 for each element were grouped by site type and as upwind or downwind of the plant. The upwind sites, as determined by the long-term meteorological data were G02, G05, G08, S01, and S03. The mean and standard deviation for each year and site type was calculated and the data compared. Results between upwind and downwind sites showed a good overlap of the standard deviations and no statistical difference over the years. These results are presented graphically in Figures 5-9 through 5-24.

Table 5-1. Preoperational Soil Chemistry Results

pH (STU)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	6.90	7.10	7.50	7.00	6.82	7.17
S02	7.70	8.10	7.70	8.79	8.04	7.83
S03	6.90	7.50	7.80	7.40	7.30	7.40
S04	6.80	7.30	7.45	6.61	6.43	7.18
S05	7.20	7.60	7.30	7.37	6.95	7.37
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	7.30	7.70	7.40	7.35	7.47	7.47
G02	7.40	7.60	7.70	7.50	7.30	7.57
G03	7.20	7.30	7.60	7.31	7.36	7.37
G04	7.30	7.30	7.80	7.69	7.20	7.47
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	7.10	7.52	7.55	7.43	7.11	7.39
Mean G	7.30	7.48	7.63	7.46	7.33	7.47
Mean All	7.19	7.50	7.58	7.45	7.21	7.42

Conductivity (µS/cm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	19.0	10.0	67.0	27.0	22.0	29.0
S02	29.0	11.0	-	45.0	40.0	31.3
S03	32.0	8.5	92.0	44.0	26.0	40.5
S04	17.0	8.6	66.0	25.0	25.0	28.3
S05	15.4	9.4	117.0	24.0	30.0	39.2
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	22.0	26.0	104.0	45.0	25.0	44.4
G02	17.5	23.0	140.0	34.0	31.0	49.1
G03	35.0	8.9	110.5	30.0	34.0	43.7
G04	21.0	12.0	73.0	32.0	29.0	33.4
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	22.5	9.5	85.5	33.0	28.6	33.7
Mean G	23.9	17.5	106.9	35.3	29.8	42.6
Mean All	23.1	13.0	96.2	33.9	29.1	37.8

Table 5-1. Preoperational Soil Chemistry Results (cont.)

Sulfate (µg/gm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	29.00	12.00	14.00	2.50	1.00	18.33
S02	68.00	6.00	16.50	2.50	1.50	30.17
S03	56.00	22.00	40.00	7.50	5.50	39.33
S04	16.00	9.50	20.00	7.40	<1.00	15.17
S05	188.50	13.00	36.00	7.40	5.00	79.17
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	64.00	<5.00	21.00	3.00	3.00	42.50
G02	39.00	<5.00	16.00	3.00	3.00	27.50
G03	60.00	26.00	16.00	7.50	7.00	34.00
G04	52.00	9.50	20.00	5.00	4.25	27.17
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	71.50	12.50	25.30	5.46	3.25	36.43
Mean G	53.75	17.75	18.25	4.63	4.31	32.35
Mean All	63.61	14.00	22.17	5.09	3.78	34.80

Chloride (µg/gm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	17.00	6.00	<5.00	2.00	5.80	11.50
S02	12.00	7.00	7.00	2.10	7.50	8.67
S03	17.00	8.00	<5.00	2.60	6.20	12.50
S04	7.30	<5	14.00	2.70	4.60	10.65
S05	12.00	8.00	8.00	2.80	8.60	9.33
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	17.00	13.00	<5.00	7.50	6.00	15.00
G02	12.00	11.00	6.00	1.80	7.00	9.67
G03	12.00	7.00	<5.00	2.50	6.20	9.50
G04	12.00	8.00	<5.00	2.30	6.10	10.00
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	13.06	7.25	9.67	2.44	6.54	10.28
Mean G	13.25	9.75	6.00	3.53	6.33	10.89
Mean All	13.14	8.50	8.75	2.92	6.44	10.54

Table 5-1. Preoperational Soil Chemistry Results (cont.)

Copper (µg/gm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	12.0	10.0	10.0	10.3	10.0	10.7
S02	11.0	8.0	7.7	9.6	8.0	8.9
S03	13.0	11.0	9.2	11.0	9.5	11.1
S04	11.0	10.0	11.0	10.6	10.9	10.7
S05	13.0	10.0	9.8	10.8	9.5	10.9
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	12.0	12.0	12.0	13.5	10.4	12.0
G02	15.0	13.0	11.0	12.5	11.1	13.0
G03	12.0	10.0	9.7	10.8	9.5	10.6
G04	11.5	8.6	9.8	14.4	8.7	10.0
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	12.0	9.8	9.5	10.5	9.6	10.4
Mean G	12.6	10.9	10.6	12.8	9.9	11.4
Mean All	12.3	10.3	10.0	11.5	9.7	10.9

Zinc (µg/gm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	56.0	41.5	51.3	58.0	42.8	49.6
S02	38.0	26.5	28.6	31.0	25.6	31.0
S03	64.5	46.3	47.1	54.0	41.6	52.6
S04	54.0	54.7	48.3	47.0	41.0	52.3
S05	82.5	39.9	50.3	43.0	42.7	57.6
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	60.3	48.9	49.4	60.0	42.9	52.9
G02	73.5	46.7	56.3	58.0	45.1	58.8
G03	57.0	37.3	47.1	50.0	41.0	47.1
G04	59.7	50.3	50.5	59.0	39.5	53.5
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	59.0	41.8	45.1	46.6	38.7	48.6
Mean G	62.6	45.8	50.8	56.8	42.1	53.1
Mean All	60.6	43.6	47.7	51.1	40.2	50.6

Table 5-1. Preoperational Soil Chemistry Results (cont.)

Sodium (wt%)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	0.123	0.019	0.026	0.021	0.032	0.056
S02	0.060	0.039	0.071	0.015	0.026	0.057
S03	0.130	0.022	0.017	0.017	0.044	0.056
S04	0.150	0.019	0.073	0.021	0.034	0.081
S05	0.170	0.016	0.036	0.012	0.032	0.074
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	0.043	0.039	0.108	0.022	0.033	0.063
G02	0.113	0.035	0.102	0.015	0.031	0.083
G03	0.163	0.040	0.052	0.017	0.033	0.085
G04	0.129	0.014	0.066	0.018	0.031	0.070
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	0.127	0.023	0.045	0.017	0.034	0.065
Mean G	0.112	0.032	0.082	0.018	0.032	0.075
Mean All	0.120	0.027	0.061	0.018	0.033	0.069

Bicarbonate (meq/HCO^3/gm)

Site	1980	1981	1982	1983	1984	Pre-op Mean
S01	0.0002	0.0011	0.0008	0.0009	0.0009	0.0007
S02	0.0004	0.0021	0.0019	0.0006	0.0006	0.0015
S03	0.0007	0.0010	0.0009	0.0005	0.0006	0.0009
S04	0.0003	0.0009	0.0002	0.0003	0.0003	0.0005
S05	0.0002	0.0006	0.0002	0.0004	0.0004	0.0003
S06	-	-	-	-	-	-
S07	-	-	-	-	-	-
G01	0.0002	0.0014	0.0009	0.0009	0.0009	0.0008
G02	0.0002	0.0014	0.0002	0.0002	0.0002	0.0006
G03	0.0002	0.0012	0.0004	0.0004	0.0004	0.0006
G04	0.0002	0.0009	0.0003	0.0003	0.0003	0.0005
G05	-	-	-	-	-	-
G06	-	-	-	-	-	-
G07	-	-	-	-	-	-
G08	-	-	-	-	-	-
Mean S	0.0004	0.0011	0.0008	0.0005	0.0006	0.0008
Mean G	0.0002	0.0012	0.0005	0.0004	0.0005	0.0006
Mean All	0.0003	0.0012	0.0006	0.0005	0.0005	0.0007

Table 5-2. Operational Soil Chemistry Results

pH (STU)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	7.12	6.81	6.55	6.86	6.23	7.19	6.81	6.93	6.82	6.84	7.14	6.89	7.16	7.03	6.46	7.08	7.30	6.49	6.87
S02	7.83	7.94	6.91	7.20	7.17	7.65	6.82	7.35	7.53	7.22	7.62	7.66	7.63	7.56	6.69	7.95	7.37	7.23	7.41
S03	7.26	7.29	6.69	6.77	6.68	6.78	6.46	6.96	7.13	6.72	6.22	6.85	6.71	6.90	6.47	6.72	7.04	6.66	6.79
S04	7.44	7.22	6.41	6.75	6.75	6.93	6.77	6.84	7.17	6.84	7.16	7.12	6.72	6.79	6.23	7.07	7.14	6.43	6.88
S05	6.86	7.02	6.80	6.99	6.55	7.00	6.68	6.73	7.01	6.79	7.03	7.16	7.23	7.05	6.48	7.07	6.87	6.91	6.90
S06	-	-	-	-	6.87	7.13	6.82	6.98	7.19	7.47	7.91	7.73	7.75	7.86	7.26	7.95	7.92	7.30	7.44
S07	-	-	-	-	7.36	7.20	6.73	7.64	7.84	7.34	8.50	7.81	7.97	7.99	8.21	7.29	7.42	7.33	7.62
G01	6.83	7.17	6.84	6.92	6.60	6.86	6.71	6.87	7.11	6.87	6.91	7.15	7.06	6.64	6.81	6.98	6.91	6.71	6.89
G02	6.73	7.18	6.81	6.99	6.24	6.92	6.58	6.82	6.91	6.65	7.21	7.15	6.94	6.78	6.89	6.88	7.18	6.84	6.87
G03	7.12	6.97	6.86	6.71	6.50	6.95	7.02	7.14	6.80	7.05	7.13	7.20	7.26	6.99	6.75	7.18	7.18	6.74	6.97
G04	7.32	7.01	6.61	6.78	6.27	6.94	6.60	6.75	6.69	6.48	6.84	7.05	6.83	6.76	6.34	6.90	6.82	6.66	6.76
G05	-	-	-	-	6.83	6.77	6.65	6.77	6.88	6.83	6.94	6.94	6.71	7.48	6.44	7.57	6.98	6.96	6.91
G06	-	-	-	-	6.35	7.02	6.65	6.83	7.14	6.71	6.85	7.04	6.75	6.75	6.56	7.09	6.70	6.56	6.79
G07	-	-	-	-	6.54	7.12	6.77	6.83	6.91	6.82	7.08	7.07	6.75	7.16	6.58	6.97	6.88	6.80	6.88
G08	-	-	-	-	7.04	7.07	6.68	6.85	7.11	6.62	7.11	7.11	6.60	7.05	6.76	6.46	7.10	6.80	6.88
Mean S	7.30	7.26	6.67	6.91	6.80	7.13	6.73	7.06	7.24	7.03	7.37	7.32	7.31	7.31	6.83	7.30	7.29	6.90	7.10
Mean G	7.00	7.08	6.78	6.85	6.55	6.96	6.71	6.86	6.94	6.75	7.01	7.09	6.86	6.95	6.64	7.00	6.96	6.76	6.87
Mean All	7.17	7.18	6.72	6.89	6.67	7.04	6.72	6.95	7.08	6.88	7.18	7.20	7.07	7.12	6.73	7.15	7.13	6.83	6.98

Conductivity (µS/cm)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	56.6	21.0	46.0	23.2	24.6	27.8	49.6	24.0	23.0	60.5	33.7	43.0	17.9	33.2	28.0	39.0	-	150.0	41.2
S02	42.5	26.1	36.5	61.4	23.4	32.2	14.6	74.5	21.5	28.0	19.1	46.0	43.2	51.1	23.1	58.0	-	270.0	51.2
S03	118.3	13.7	42.2	43.8	21.4	39.4	48.3	23.0	20.0	29.0	131.0	44.0	17.5	29.0	24.2	88.5	-	91.5	48.5
S04	38.6	24.2	29.6	49.9	52.6	29.9	21.2	25.5	19.0	50.5	18.6	52.0	25.6	28.0	17.7	49.5	-	113.5	38.0
S05	25.9	13.6	55.0	40.5	15.8	21.9	28.0	29.5	30.5	63.0	23.9	41.0	32.7	26.1	37.2	56.5	-	95.0	37.4
S06	-	-	-	-	32.2	55.2	25.8	28.5	31.5	71.0	43.7	112.5	39.7	95.2	74.6	155.0	-	245.0	77.7
S07	-	-	-	-	43.8	65.8	44.4	63.0	89.0	79.0	212.0	142.0	71.6	83.6	100.9	160.0	-	345.0	115.4
G01	69.9	37.8	52.3	35.3	21.2	46.3	43.5	24.5	26.5	51.5	29.9	38.5	22.9	35.5	43.2	122.0	-	98.5	47.0
G02	97.2	28.1	42.2	46.6	18.0	54.6	39.5	65.0	24.5	47.5	36.3	40.5	25.1	37.9	48.5	106.0	-	99.0	50.4
G03	98.0	25.8	50.6	125.6	19.6	96.8	63.5	77.0	45.0	109.0	71.8	82.0	32.6	42.9	77.0	108.0	-	195.0	77.7
G04	15.3	50.8	24.8	21.2	16.2	28.8	20.6	18.0	13.5	35.0	15.4	28.0	18.3	29.8	23.3	48.0	-	54.5	27.1
G05	-	-	-	-	28.4	14.4	13.6	26.5	18.5	33.0	19.2	68.0	17.9	48.8	29.4	87.0	-	300.0	54.2
G06	-	-	-	-	12.8	19.0	42.2	24.0	19.0	73.5	16.6	21.0	22.5	27.6	18.2	50.0	-	84.0	33.1
G07	-	-	-	-	19.2	53.2	28.7	38.0	30.0	63.0	61.1	47.5	29.4	39.9	35.6	125.0	-	220.0	60.8
G08	-	-	-	-	25.6	38.0	20.7	24.0	13.5	25.5	28.1	30.0	12.0	32.4	44.1	122.0	-	98.5	36.7
Mean S	56.4	19.7	41.9	43.8	30.5	38.9	33.1	38.3	33.5	54.4	68.9	68.6	35.5	49.5	43.7	86.6	-	187.1	55.8
Mean G	70.1	35.6	42.5	57.2	20.1	43.9	34.0	37.1	23.8	54.8	34.8	44.4	22.6	36.9	39.9	90.6	-	144.5	48.7
Mean All	62.5	26.8	42.1	49.7	25.0	41.6	33.6	37.7	28.3	54.6	50.7	55.7	28.6	42.7	41.7	88.6	-	165.8	52.1

Table 5-2. Operational Soil Chemistry Results (cont.)

Sulfate (μg/gm)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	1.48	2.84	2.64	1.44	1.82	6.78	3.20	10.28	1.30	1.73	1.15	1.82	1.05	0.45	1.68	< 0.1	5.95	19.50	3.83
S02	1.68	2.80	9.90	3.72	0.99	6.80	3.28	9.66	1.38	0.99	0.33	0.63	2.29	0.75	0.85	0.18	2.00	19.50	3.76
S03	0.44	2.16	2.18	3.82	1.35	6.88	2.49	10.32	1.10	0.98	2.01	0.90	1.00	2.18	1.31	0.21	4.85	18.00	3.45
S04	3.08	2.84	2.18	4.06	7.97	12.95	3.22	10.20	1.28	1.40	0.32	0.77	1.69	1.06	1.32	< 0.1	9.10	2.90	3.90
S05	0.88	0.88	3.34	4.26	0.58	6.78	3.10	10.18	1.96	1.65	0.37	0.77	1.67	2.35	2.29	< 0.1	3.20	20.00	3.78
S06	-	-	-	-	0.84	6.81	3.08	9.81	1.35	1.78	0.39	0.94	0.83	1.28	2.26	0.38	2.48	16.15	3.46
S07	-	-	-	-	0.75	6.62	3.28	9.01	1.59	1.53	5.85	1.67	1.31	2.52	4.27	< 0.1	6.90	2.80	3.70
G01	3.38	4.88	2.82	0.40	1.21	6.62	3.00	10.01	5.16	2.43	1.01	1.06	1.04	1.00	1.50	0.20	3.10	22.00	3.93
G02	2.80	3.04	3.72	3.54	0.75	6.87	3.11	9.59	3.09	1.59	0.94	0.90	0.85	0.76	2.77	0.39	10.50	26.00	4.51
G03	30.26	5.44	0.64	18.56	2.31	14.29	2.44	10.13	3.99	8.52	6.43	4.45	5.94	0.72	26.67	0.35	9.80	34.50	10.30
G04	0.44	7.96	1.28	0.84	0.51	7.07	3.08	10.37	2.10	1.69	1.34	0.67	1.22	0.54	1.46	0.35	4.75	20.50	3.68
G05	-	-	-	-	1.15	6.80	2.42	10.13	2.20	1.40	0.86	0.72	1.38	1.07	1.38	< 0.1	1.57	13.45	3.43
G06	-	-	-	-	0.45	6.77	3.06	9.98	2.04	1.36	0.63	0.74	1.86	1.97	1.60	< 0.1	2.55	11.70	3.44
G07	-	-	-	-	0.68	5.77	3.20	9.85	2.33	2.61	0.83	1.47	2.25	0.88	2.27	0.20	2.75	23.00	4.15
G08	-	-	-	-	0.67	6.78	3.38	10.09	1.60	1.22	0.85	0.63	0.97	0.49	2.22	0.19	4.45	21.00	3.90
Mean S	1.51	2.30	4.05	3.46	2.04	7.66	3.09	9.92	1.42	1.44	1.49	1.07	1.41	1.51	2.00	0.25	4.93	14.12	3.70
Mean G	9.22	5.33	2.12	5.84	0.97	7.62	2.96	10.02	2.81	2.60	1.61	1.33	1.94	0.93	4.98	0.28	4.93	21.52	4.81
Mean All	4.94	3.65	3.19	4.52	1.47	7.64	3.02	9.97	2.16	2.06	1.55	1.21	1.69	1.20	3.59	0.27	4.93	18.07	4.28

Chloride (μg/gm)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	3.04	4.56	7.92	0.96	0.72	1.44	12.00	4.00	9.00	1.04	0.28	0.50	0.35	0.52	0.31	0.19	0.39	0.94	2.67
S02	2.56	5.76	7.04	1.44	0.56	1.28	6.00	1.00	12.00	2.11	0.20	0.13	0.38	1.36	0.22	0.71	0.89	1.01	2.48
S03	2.32	4.80	6.64	1.84	0.78	1.04	18.40	6.00	9.00	0.80	0.53	0.30	0.38	1.47	0.25	0.57	0.50	0.85	3.14
S04	2.88	5.92	14.64	2.40	1.57	0.96	12.40	5.00	5.00	2.06	0.21	0.42	0.43	2.01	0.19	0.27	1.76	2.45	3.36
S05	2.40	4.56	9.52	1.28	0.32	0.32	17.60	2.00	1.00	1.11	0.14	0.29	0.50	0.50	0.51	0.41	0.36	0.78	2.42
S06	-	-	-	-	0.41	0.64	11.60	5.00	9.00	0.89	0.21	0.33	0.46	3.78	0.53	1.32	0.31	1.19	2.55
S07	-	-	-	-	1.08	0.88	21.20	5.00	12.00	1.00	2.51	2.41	0.91	2.80	5.47	1.95	1.89	1.35	4.32
G01	6.95	4.80	13.60	1.20	0.71	1.12	16.00	3.00	4.00	0.46	0.21	0.14	0.66	2.14	0.98	1.26	0.66	1.95	3.32
G02	4.62	4.48	11.68	1.44	0.25	0.56	17.60	4.00	3.00	0.64	0.33	0.22	0.62	0.62	1.01	0.91	0.60	0.93	2.97
G03	4.40	5.92	13.28	2.48	0.62	1.76	13.20	4.00	9.00	2.71	0.61	1.79	1.35	3.15	2.43	1.85	0.76	2.35	3.98
G04	1.60	4.56	16.64	0.48	0.47	0.24	15.20	10.00	2.00	0.59	0.16	0.16	0.33	0.45	0.49	0.39	0.30	1.00	3.06
G05	-	-	-	-	0.56	1.04	20.00	3.00	4.00	1.08	0.22	0.04	0.35	0.71	0.29	0.27	1.54	0.85	2.42
G06	-	-	-	-	0.26	0.80	18.80	7.00	2.00	1.15	0.16	0.17	0.39	1.80	0.24	0.17	0.47	0.64	2.43
G07	-	-	-	-	0.42	1.12	26.40	<1.00	4.00	1.14	0.21	0.63	0.63	0.74	0.57	0.57	3.73	1.85	3.23
G08	-	-	-	-	0.32	0.48	13.20	4.00	2.00	0.55	0.25	0.29	0.32	0.71	0.70	0.89	0.71	1.29	1.84
Mean S	2.64	5.12	9.15	1.58	0.78	0.94	14.17	5.00	8.14	1.29	0.58	0.62	0.49	1.78	1.07	0.77	0.87	1.22	2.96
Mean G	4.39	4.94	13.80	1.40	0.45	0.89	17.55	4.38	3.75	1.04	0.27	0.43	0.58	1.29	0.84	0.79	1.09	1.36	2.96
Mean All	3.42	5.04	11.22	1.50	0.60	0.91	15.97	4.50	5.80	1.16	0.41	0.52	0.54	1.52	0.95	0.78	0.99	1.29	2.96

Table 5-2. Operational Soil Chemistry Results (cont.)

Copper (µg/gm)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	11.3	14.5	17.3	10.6	8.7	7.6	15.8	12.5	7.0	8.0	9.9	5.1	9.3	8.7	6.6	7.1	0.5	6.6	9.3
S02	10.4	14.3	13.7	9.5	6.0	6.8	7.8	10.0	6.0	4.0	3.1	4.9	8.6	9.2	6.5	6.7	3.2	6.4	7.6
S03	11.6	12.9	15.0	12.3	7.5	8.8	10.4	14.6	8.0	6.0	10.0	6.0	10.2	9.8	6.9	8.6	0.2	6.9	9.2
S04	12.0	17.1	13.1	14.0	7.0	7.9	10.7	9.9	8.0	8.0	9.0	6.2	10.0	9.0	6.5	8.0	0.2	6.6	9.1
S05	10.9	10.7	12.0	9.7	6.3	7.2	12.1	9.1	8.0	8.0	7.8	6.3	8.9	8.1	6.5	8.3	0.2	6.7	8.2
S06	-	-	-	-	7.3	9.5	17.9	11.0	7.0	10.0	8.7	4.7	9.0	10.3	7.4	7.9	0.2	10.5	8.7
S07	-	-	-	-	11.6	13.1	16.6	19.9	15.0	14.0	13.1	9.1	13.9	14.1	12.5	12.5	5.8	8.4	12.8
G01	14.6	14.3	13.2	12.0	8.2	11.1	13.7	11.4	12.0	11.0	8.9	8.1	12.1	10.8	8.2	10.3	4.3	6.8	10.6
G02	12.1	16.9	12.7	12.9	8.3	9.2	11.4	10.1	10.0	9.0	10.9	7.9	11.7	10.9	8.0	8.9	2.6	7.8	10.1
G03	12.6	10.6	11.6	11.1	7.2	9.6	11.8	12.0	10.0	10.0	9.0	8.0	10.5	9.9	6.9	8.4	2.1	6.4	9.3
G04	10.9	13.9	10.4	10.0	6.5	6.9	9.3	8.9	8.0	6.0	8.1	6.3	10.5	7.9	6.5	7.0	0.2	6.4	8.0
G05	-	-	-	-	7.7	7.4	8.5	11.4	9.0	8.0	7.8	3.8	9.5	9.3	7.9	6.5	1.0	7.6	7.5
G06	-	-	-	-	7.4	8.2	10.4	11.2	9.0	6.0	8.1	6.6	11.4	10.0	6.4	6.7	0.2	6.4	7.7
G07	-	-	-	-	7.2	8.5	9.8	16.8	11.0	7.0	12.7	6.5	10.7	9.7	6.9	6.9	1.4	7.1	8.7
G08	-	-	-	-	7.5	8.1	12.4	9.6	7.0	7.0	12.8	5.5	8.9	9.6	7.9	7.6	2.2	7.6	8.1
Mean S	11.2	13.9	14.2	11.2	7.8	8.7	13.0	12.4	8.4	8.3	8.8	6.0	10.0	9.9	7.6	8.4	1.4	7.4	9.2
Mean G	12.6	13.9	12.0	11.5	7.5	8.6	10.9	11.4	9.5	8.0	9.8	6.6	10.7	9.8	7.3	7.8	1.7	7.0	8.9
Mean All	11.8	13.9	13.2	11.3	7.6	8.7	11.9	11.9	9.0	8.1	9.3	6.3	10.3	9.8	7.4	8.1	1.6	7.2	9.0

Zinc (µg/gm)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	52.7	50.5	51.0	47.8	39.7	33.5	78.7	51.6	37.0	38.0	33.5	37.5	47.7	42.2	44.9	40.0	51.0	31.0	44.9
S02	35.5	37.5	31.4	28.1	21.0	21.6	27.8	32.3	25.0	16.0	15.2	36.6	28.3	27.2	28.6	24.5	32.0	21.0	27.2
S03	57.1	56.4	60.6	47.0	36.0	37.9	52.4	49.0	44.0	32.0	53.9	45.9	51.6	42.0	44.7	44.5	54.5	33.0	46.8
S04	51.0	56.6	44.4	48.5	29.8	31.9	45.6	42.3	40.0	32.0	43.4	59.5	43.1	38.9	41.4	46.0	50.5	30.0	43.1
S05	52.1	56.2	47.0	44.5	30.5	30.4	51.4	45.4	40.0	39.0	42.6	59.7	45.8	35.3	41.5	36.5	49.5	27.0	43.0
S06	-	-	-	-	34.1	38.6	62.6	44.5	38.0	42.0	41.3	28.5	39.7	41.4	36.1	36.5	40.0	54.0	41.2
S07	-	-	-	-	43.4	47.3	61.2	57.5	56.0	55.0	59.2	50.7	50.7	54.0	55.9	56.0	53.0	29.5	52.1
G01	62.6	54.0	50.3	48.7	38.1	40.6	54.8	49.7	55.0	48.0	46.7	47.5	56.4	49.2	51.2	49.5	59.5	34.0	49.8
G02	55.3	51.2	50.6	50.6	36.9	37.9	68.0	49.0	52.0	48.0	53.7	42.9	53.1	50.4	49.6	41.5	57.0	33.5	49.0
G03	54.3	44.0	43.4	47.2	35.4	37.3	50.6	49.3	50.0	41.0	46.4	49.0	51.6	41.0	43.1	38.0	55.5	32.5	45.0
G04	51.3	51.6	43.1	45.3	31.8	29.3	43.5	37.6	46.0	30.0	46.4	36.0	49.6	37.1	40.8	37.5	51.5	30.0	41.0
G05	-	-	-	-	30.4	26.5	33.8	46.6	40.0	31.0	38.3	40.4	39.6	33.3	40.2	32.0	43.5	26.5	35.9
G06	-	-	-	-	32.0	30.0	46.2	45.2	41.0	30.0	43.1	28.1	51.0	41.3	42.3	36.0	53.5	27.5	39.1
G07	-	-	-	-	35.0	38.4	47.4	50.5	50.0	38.0	47.6	40.8	53.1	45.5	48.8	49.5	55.5	33.0	45.2
G08	-	-	-	-	32.8	31.6	44.0	40.8	36.0	33.0	42.8	33.1	45.4	40.5	42.9	41.5	39.5	31.5	38.2
Mean S	49.7	51.4	46.9	43.2	33.5	34.5	54.2	46.1	40.0	36.3	41.3	45.5	43.8	40.1	41.9	40.6	47.2	32.2	42.3
Mean G	55.9	50.2	46.9	48.0	34.1	34.0	48.5	46.1	46.3	37.4	45.6	39.7	50.0	42.3	44.9	40.7	51.9	31.1	43.3
Mean All	52.4	50.9	46.9	45.3	33.8	34.2	51.2	46.1	43.3	36.9	43.6	42.4	47.1	41.3	43.5	40.6	49.7	31.6	42.8

Table 5-2. Operational Soil Chemistry Results (cont.)

Sodium (wt%)

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	0.023	0.017	0.065	0.054	0.010	0.028	0.037	0.035	0.026	0.032	0.049	0.051	0.061	0.039	0.010	0.010	0.028	0.009	0.032
S02	0.019	0.008	0.046	0.030	0.010	0.021	0.020	0.025	0.021	0.015	0.032	0.037	0.039	0.027	0.011	0.010	0.018	0.010	0.022
S03	0.019	0.018	0.084	0.089	0.010	0.033	0.027	0.033	0.038	0.029	0.057	0.057	0.060	0.026	0.010	0.012	0.025	0.008	0.035
S04	0.020	0.017	0.064	0.067	0.010	0.031	0.026	0.032	0.040	0.031	0.051	0.059	0.057	0.026	0.011	0.012	0.026	0.009	0.033
S05	0.017	0.017	0.080	0.081	0.010	0.033	0.029	0.030	0.029	0.042	0.051	0.063	0.056	0.025	0.001	0.010	0.027	0.010	0.034
S06	-	-	-	-	0.010	0.032	0.027	0.026	0.020	0.031	0.042	0.038	0.043	0.022	0.008	0.012	0.016	0.009	0.024
S07	-	-	-	-	0.010	0.042	0.036	0.033	0.034	0.034	0.056	0.068	0.055	0.026	0.009	0.013	0.011	0.004	0.031
G01	0.030	0.018	0.092	0.110	0.010	0.037	0.028	0.027	0.035	0.043	0.047	0.055	0.062	0.045	0.012	0.008	0.030	0.007	0.039
G02	0.029	0.020	0.096	0.150	0.010	0.038	0.031	0.026	0.034	0.043	0.053	0.058	0.063	0.043	0.011	0.011	0.031	0.009	0.042
G03	0.019	0.013	0.068	0.108	0.010	0.033	0.026	0.027	0.027	0.035	0.046	0.059	0.059	0.040	0.010	0.007	0.032	0.009	0.035
G04	0.017	0.013	0.054	0.111	0.010	0.029	0.025	0.026	0.030	0.028	0.053	0.053	0.064	0.040	0.009	0.008	0.041	0.011	0.035
G05	-	-	-	-	0.010	0.026	0.024	0.033	0.023	0.030	0.043	0.045	0.047	0.036	0.011	0.009	0.029	0.011	0.027
G06	-	-	-	-	0.010	0.031	0.026	0.032	0.025	0.029	0.054	0.054	0.067	0.044	0.010	0.010	0.029	0.011	0.031
G07	-	-	-	-	0.010	0.035	0.025	0.028	0.030	0.034	0.056	0.057	0.062	0.041	0.011	0.009	0.027	0.009	0.031
G08	-	-	-	-	0.010	0.027	0.030	0.027	0.025	0.030	0.047	0.045	0.046	0.036	0.011	0.010	0.019	0.008	0.026
Mean S	0.020	0.015	0.068	0.064	0.010	0.031	0.029	0.031	0.030	0.031	0.048	0.053	0.053	0.027	0.009	0.011	0.021	0.008	0.030
Mean G	0.024	0.016	0.078	0.120	0.010	0.032	0.027	0.028	0.029	0.034	0.050	0.053	0.059	0.041	0.011	0.009	0.030	0.009	0.034
Mean All	0.021	0.016	0.072	0.089	0.010	0.032	0.028	0.029	0.029	0.032	0.049	0.053	0.056	0.034	0.010	0.010	0.026	0.009	0.032

Bicarbonate (meq/HCO^3/gm

Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Operational Mean
S01	0.0020	0.0007	0.0015	0.0009	0.0012	0.0010	0.0022	0.0048	0.0022	0.0022	0.0010	0.0008	0.0006	0.0021	0.0013	0.0003	0.0052	0.0011	0.0017
S02	0.0030	0.0024	0.0019	0.0035	0.0027	0.0013	0.0013	0.0044	0.0026	0.0020	0.0010	0.0026	0.0011	0.0038	0.0018	0.0009	0.0091	0.0029	0.0027
S03	0.0012	0.0010	0.0018	0.0022	0.0014	0.0014	0.0028	0.0026	0.0026	0.0016	0.0006	0.0012	0.0005	0.0017	0.0010	0.0004	0.0054	0.0012	0.0017
S04	0.0012	0.0006	0.0010	0.0016	0.0023	0.0009	0.0017	0.0022	0.0018	0.0030	0.0008	0.0018	0.0002	0.0017	0.0005	0.0002	0.0046	0.0011	0.0015
S05	0.0017	0.0006	0.0025	0.0025	0.0007	0.0009	0.0015	0.0026	0.0028	0.0034	0.0007	0.0013	0.0008	0.0017	0.0012	0.0003	0.0033	0.0011	0.0016
S06	-	-	-	-	0.0020	0.0023	0.0027	0.0030	0.0034	0.0054	0.0030	0.0055	0.0019	0.0091	0.0040	0.0031	0.0047	0.0061	0.0040
S07	-	-	-	-	0.0060	0.0027	0.0042	0.0092	0.0136	0.0056	0.0054	0.0090	0.0044	0.0112	0.0095	0.0013	0.0086	0.0076	0.0070
G01	0.0015	0.0021	0.0019	0.0014	0.0018	0.0015	0.0022	0.0026	0.0020	0.0036	0.0011	0.0013	0.0009	0.0018	0.0018	0.0003	0.0039	0.0012	0.0018
G02	0.0027	0.0025	0.0018	0.0023	0.0011	0.0020	0.0039	0.0050	0.0026	0.0028	0.0010	0.0013	0.0013	0.0021	0.0020	0.0005	0.0047	0.0015	0.0023
G03	0.0032	0.0015	0.0015	0.0018	0.0012	0.0014	0.0038	0.0052	0.0030	0.0044	0.0018	0.0020	0.0016	0.0027	0.0017	0.0005	0.0048	0.0013	0.0024
G04	0.0011	0.0014	0.0010	0.0009	0.0005	0.0009	0.0016	0.0020	0.0014	0.0016	0.0005	0.0012	0.0008	0.0013	0.0010	0.0002	0.0035	0.0008	0.0012
G05	-	-	-	-	0.0025	0.0006	0.0010	0.0028	0.0018	0.0026	0.0007	0.0020	0.0006	0.0051	0.0018	0.0005	0.0079	0.0020	0.0023
G06	-	-	-	-	0.0008	0.0008	0.0012	0.0024	0.0018	0.0018	0.0005	0.0007	0.0004	0.0018	0.0008	0.0003	0.0019	0.0008	0.0011
G07	-	-	-	-	0.0011	0.0017	0.0019	0.0040	0.0028	0.0034	0.0014	0.0130	0.0006	0.0024	0.0015	0.0015	0.0200	0.0015	0.0041
G08	-	-	-	-	0.0032	0.0015	0.0016	0.0022	0.0014	0.0016	0.0009	0.0009	0.0003	0.0018	0.0023	0.0006	0.0040	0.0013	0.0017
Mean S	0.0018	0.0011	0.0017	0.0021	0.0023	0.0015	0.0023	0.0041	0.0041	0.0033	0.0018	0.0032	0.0014	0.0045	0.0028	0.0009	0.0058	0.0030	0.0027
Mean G	0.0021	0.0019	0.0016	0.0016	0.0015	0.0013	0.0022	0.0033	0.0021	0.0027	0.0010	0.0028	0.0008	0.0024	0.0016	0.0006	0.0063	0.0013	0.0021
Mean All	0.0020	0.0014	0.0017	0.0019	0.0019	0.0014	0.0022	0.0037	0.0031	0.0030	0.0014	0.0030	0.0011	0.0034	0.0021	0.0007	0.0061	0.0021	0.0024

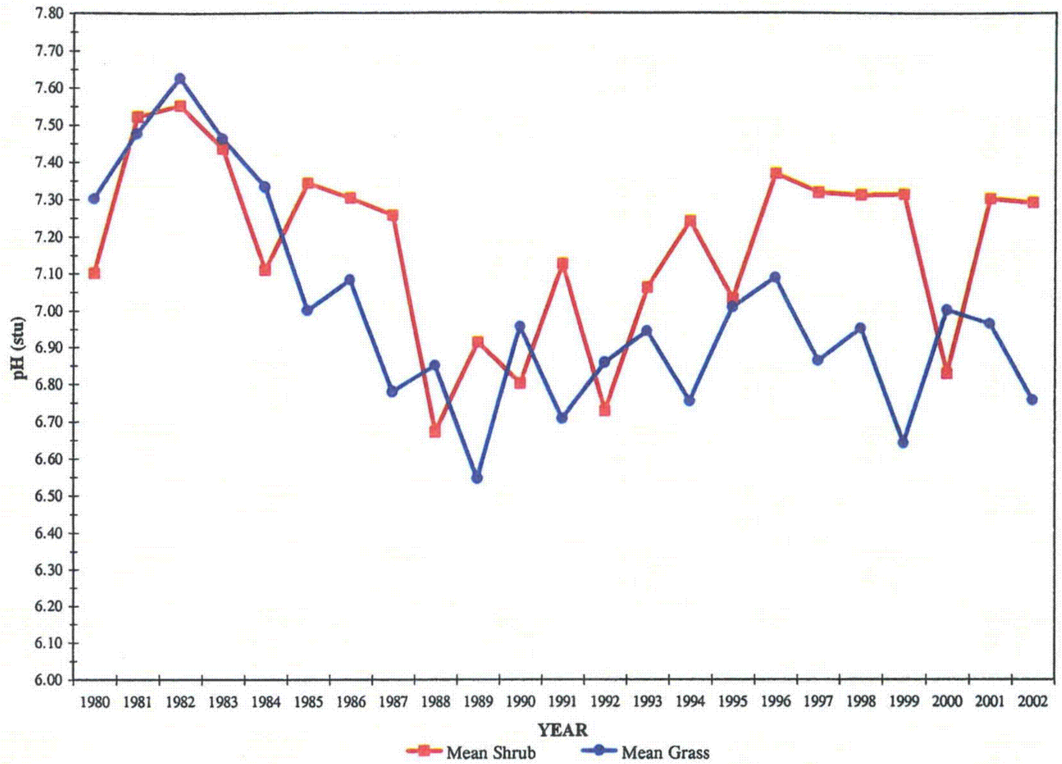


Figure 5-1. Mean pH in Soil, 1980-2002

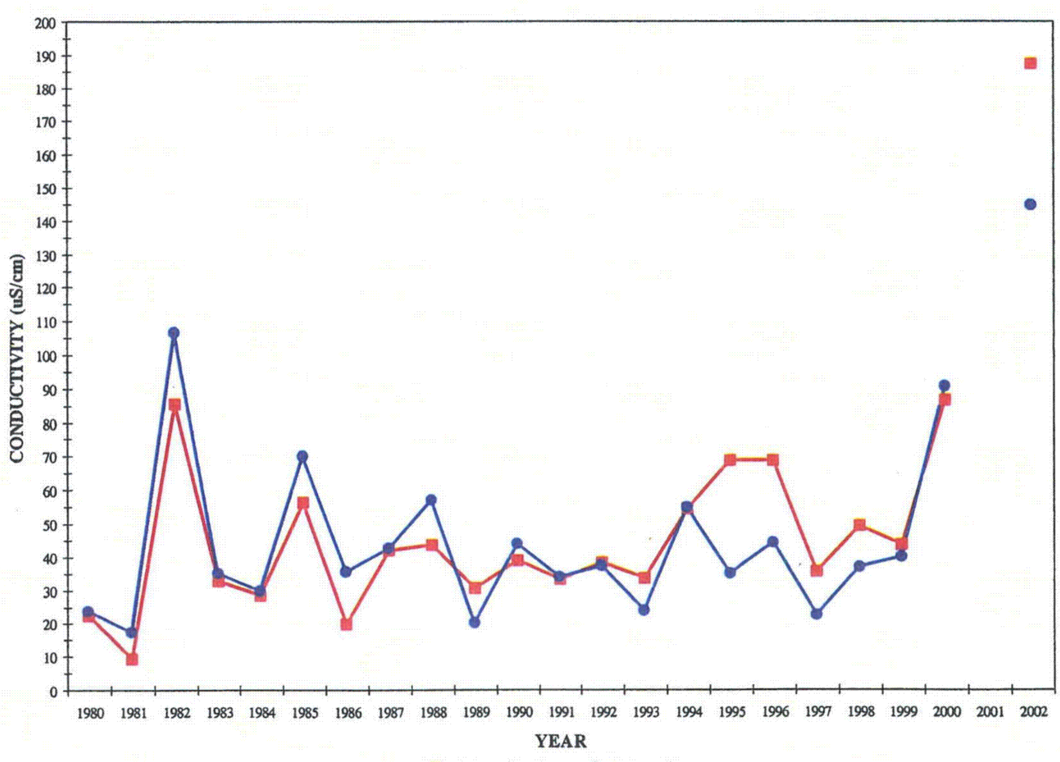


Figure 5-2. Mean Conductivity in Soil, 1980-2002

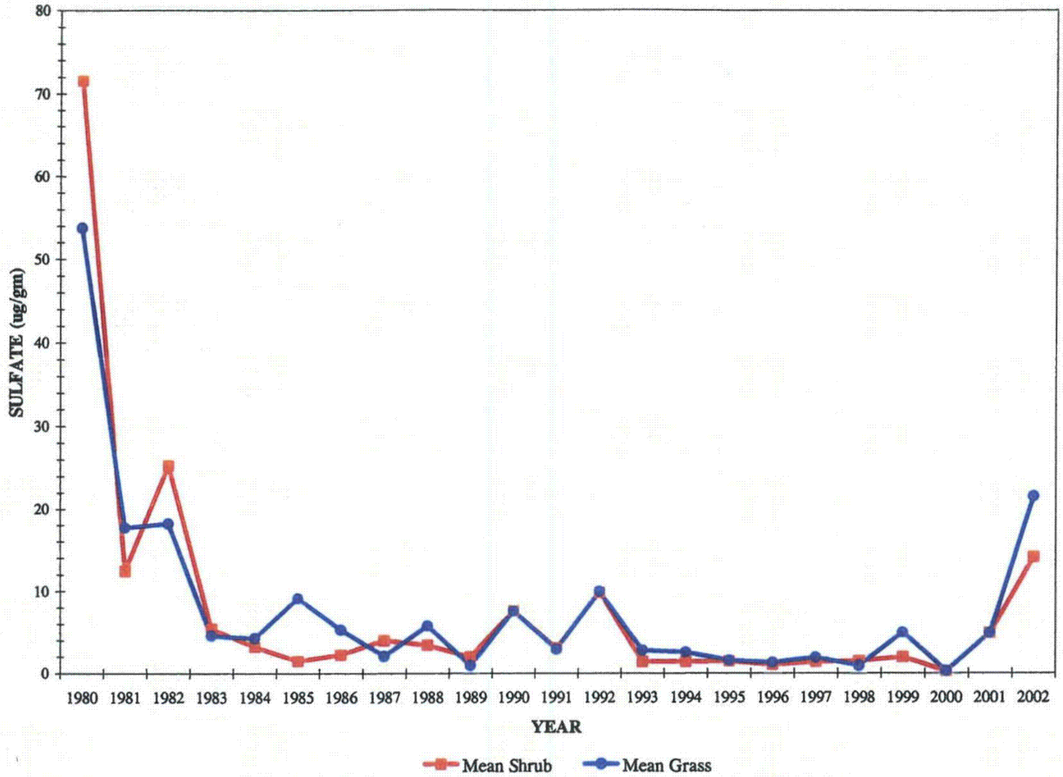


Figure 5-3. Mean Sulfate in Soil, 1980-2002

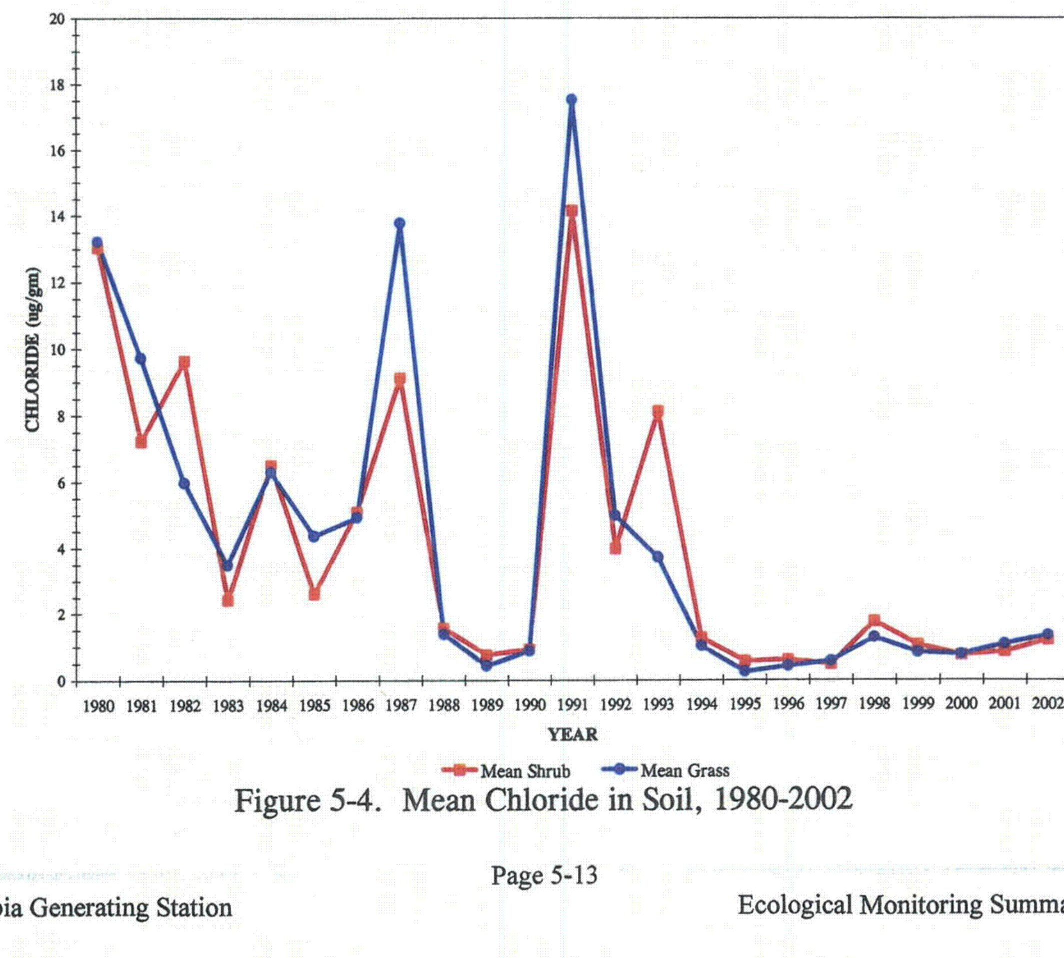


Figure 5-4. Mean Chloride in Soil, 1980-2002

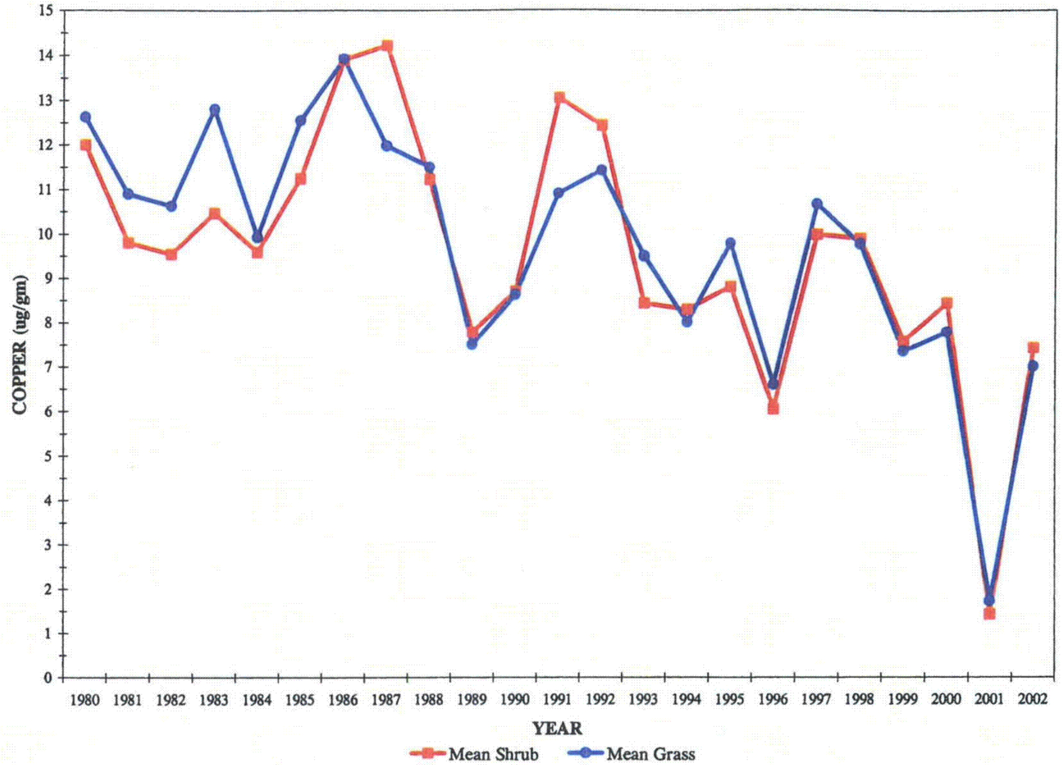


Figure 5-5. Mean Copper in Soil, 1980-2002

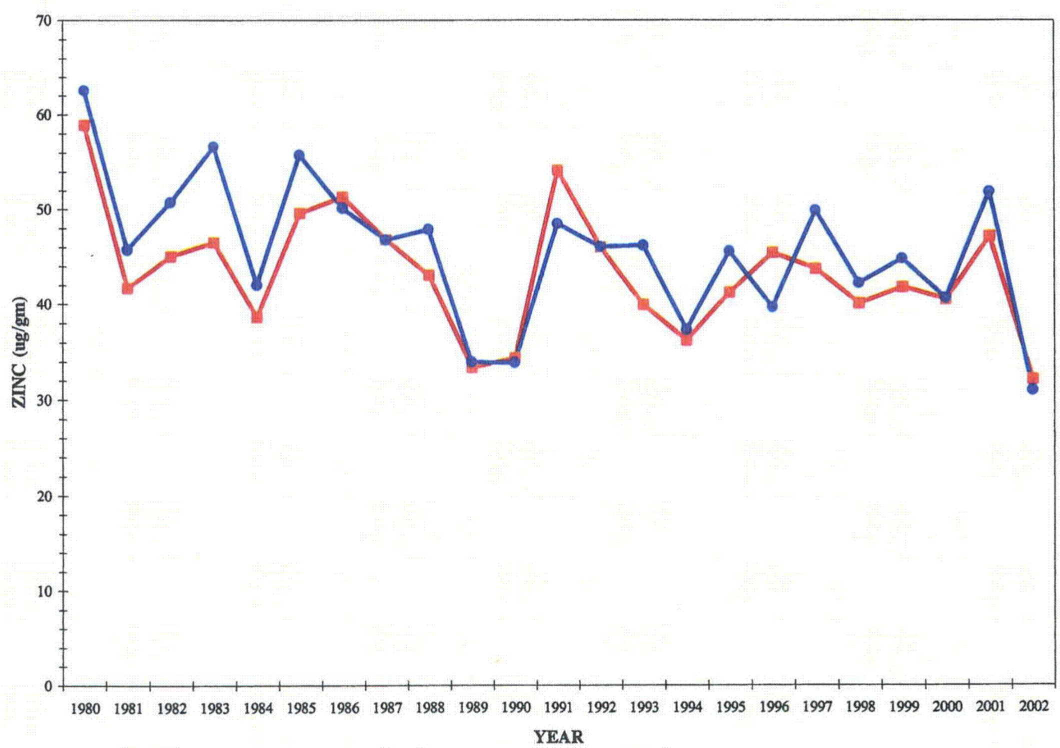


Figure 5-6. Mean Zinc in Soil, 1980-2002

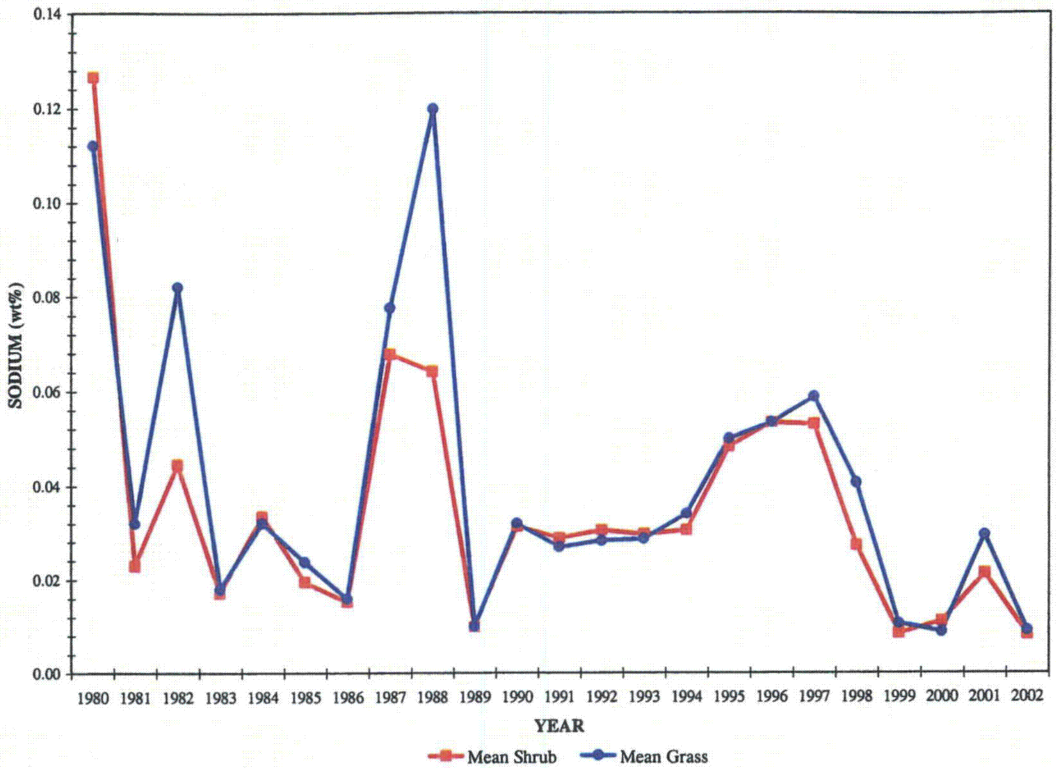


Figure 5-7. Mean Sodium in Soil, 1980-2002

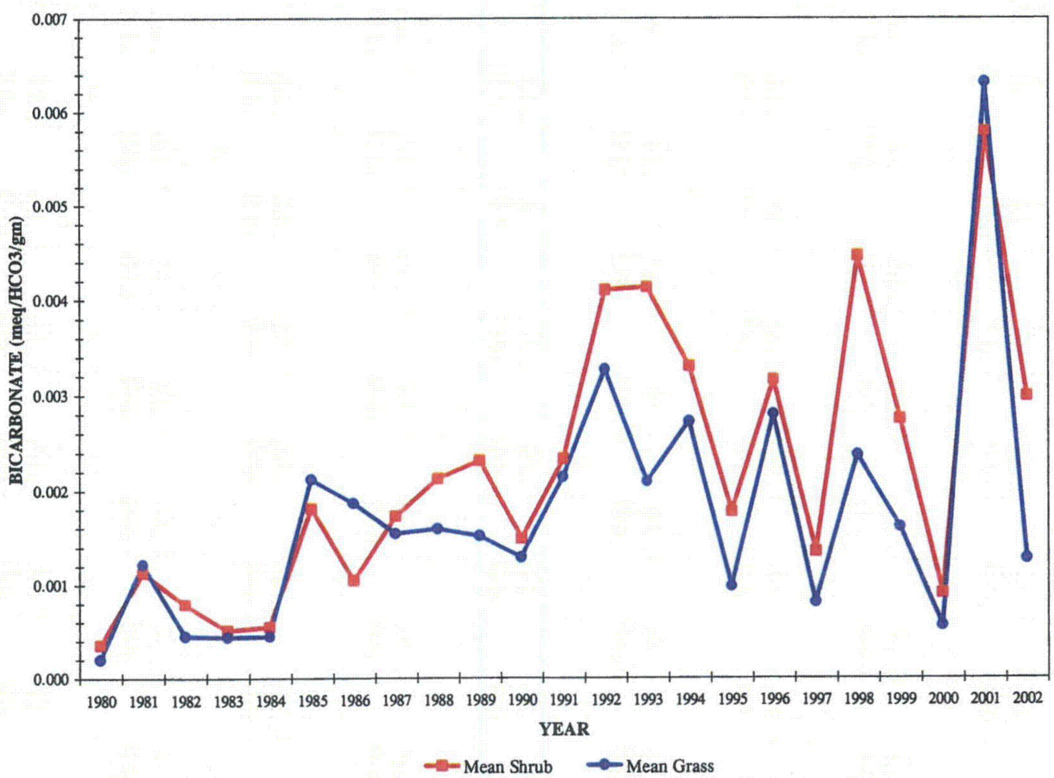


Figure 5-8. Mean Bicarbonate in Soil, 1980-2002

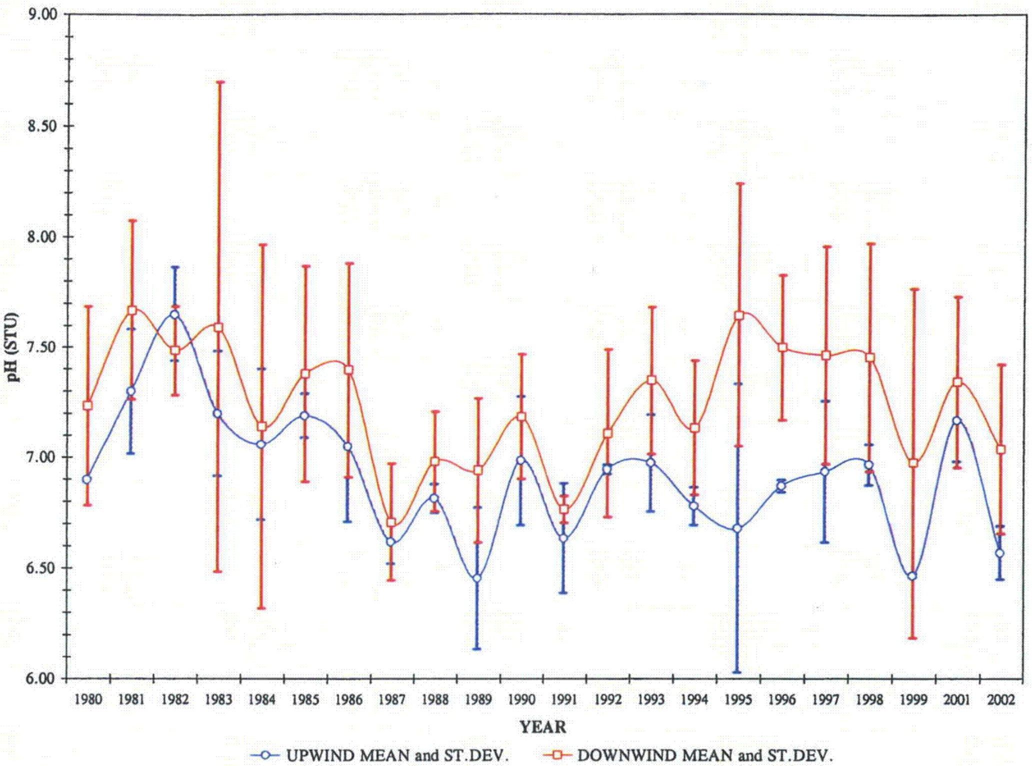


Figure 5-9. Upwind vs. Downwind pH in Soil at Shrub Sites

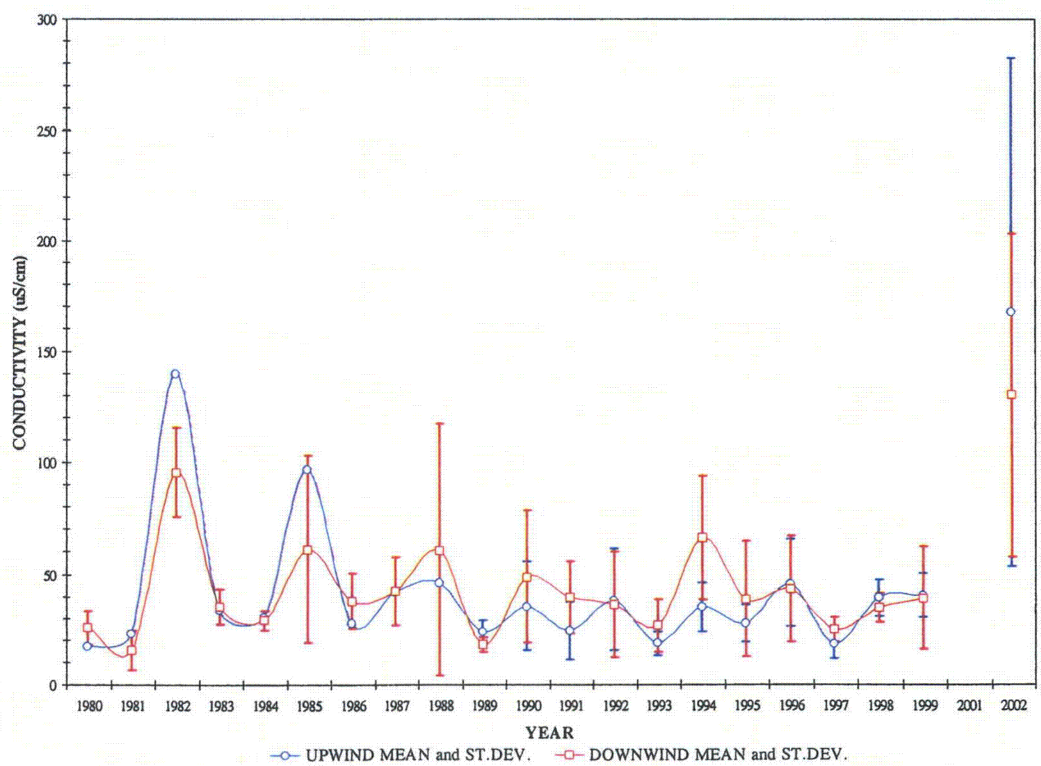


Figure 5-10. Upwind vs. Downwind pH in Soil at Grass Sites

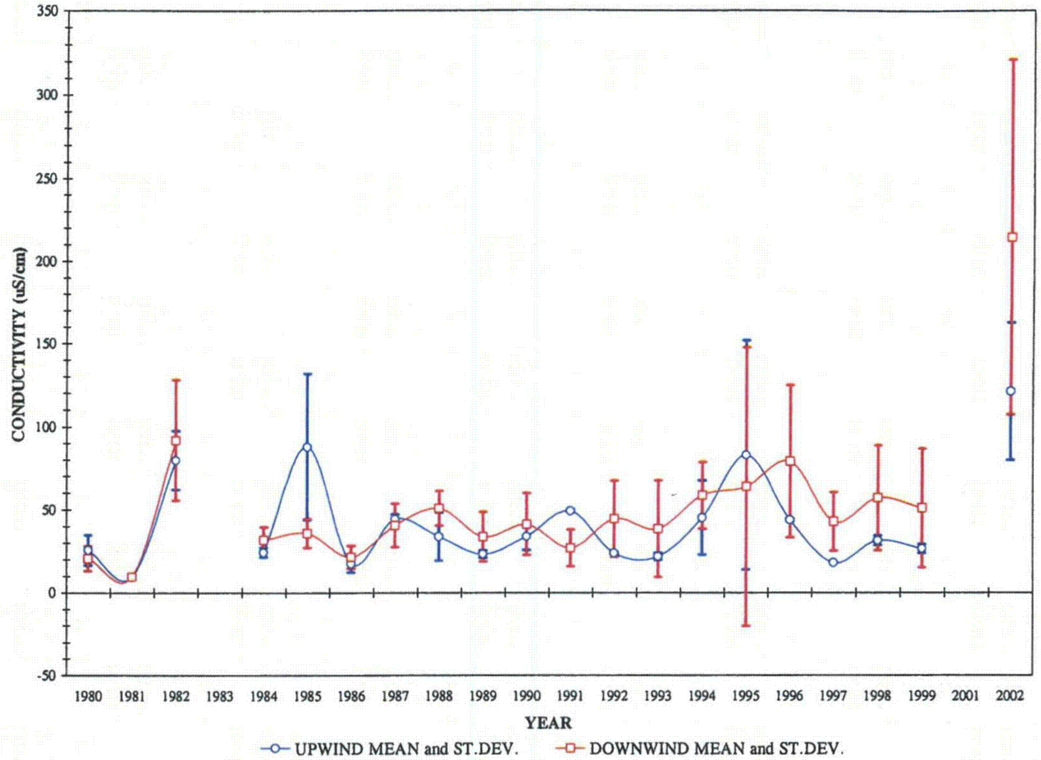


Figure 5-11. Upwind vs. Downwind Conductivity in Soil at Shrub Sites

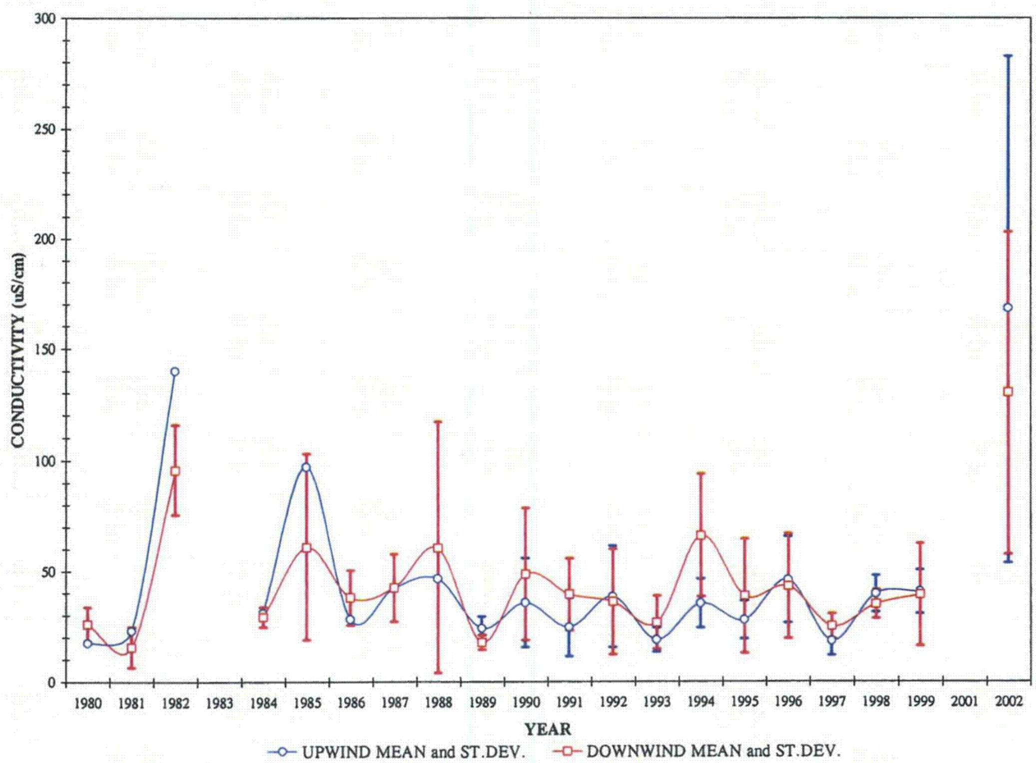


Figure 5-12. Upwind vs. Downwind Conductivity in Soil at Grass Sites

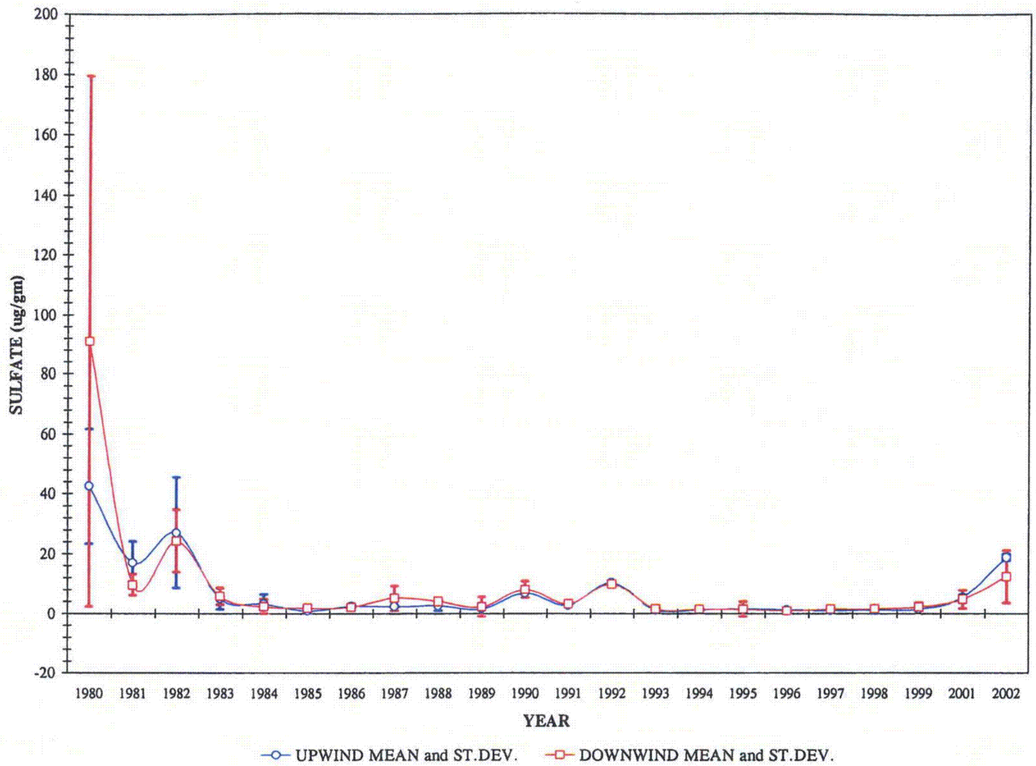


Figure 5-13. Upwind vs. Downwind Sulfate in Soil at Shrub Sites

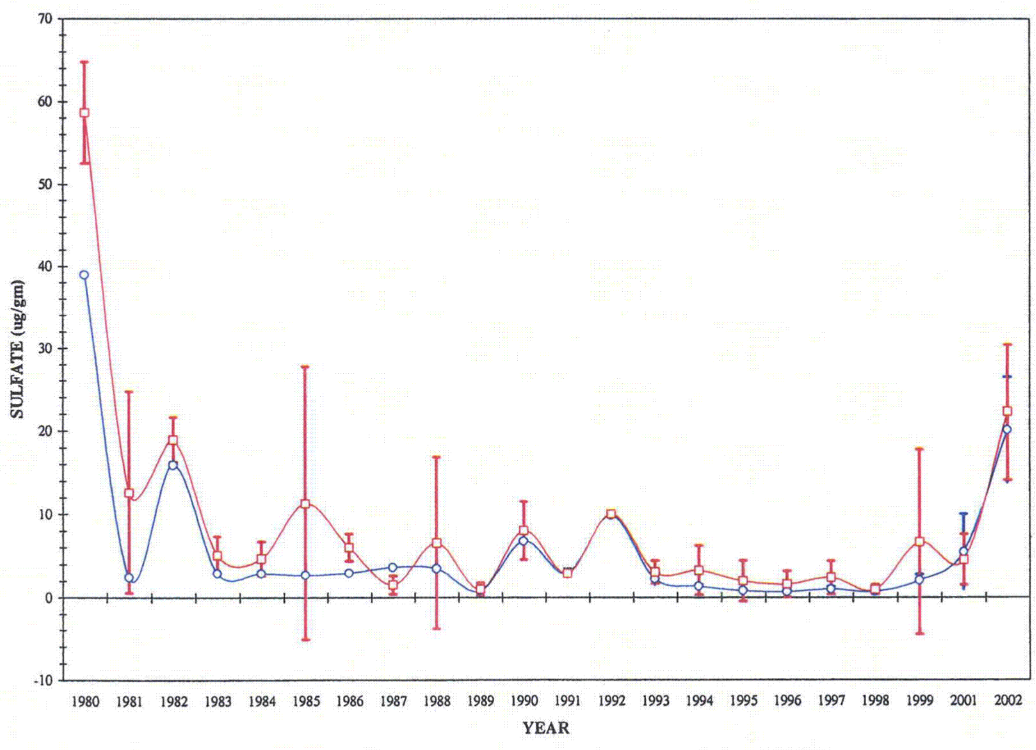


Figure 5-14. Upwind vs. Downwind Sulfate in Soil at Grass Sites

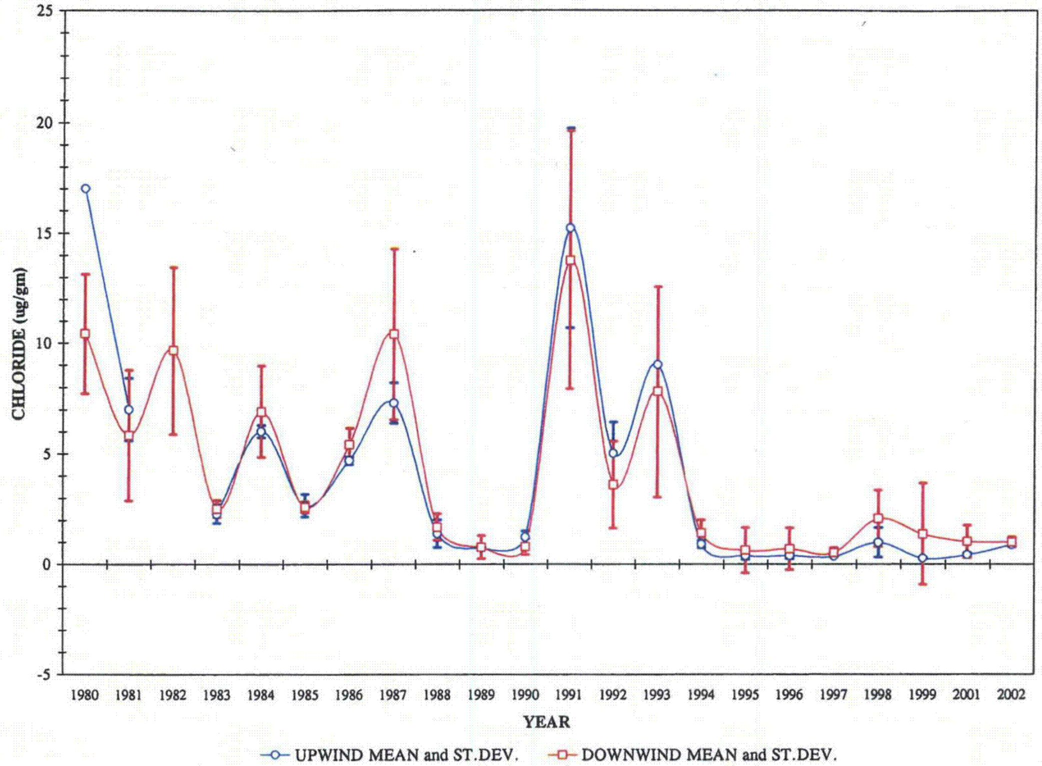


Figure 5-15. Upwind vs. Downwind Chloride in Soil at Shrub Sites

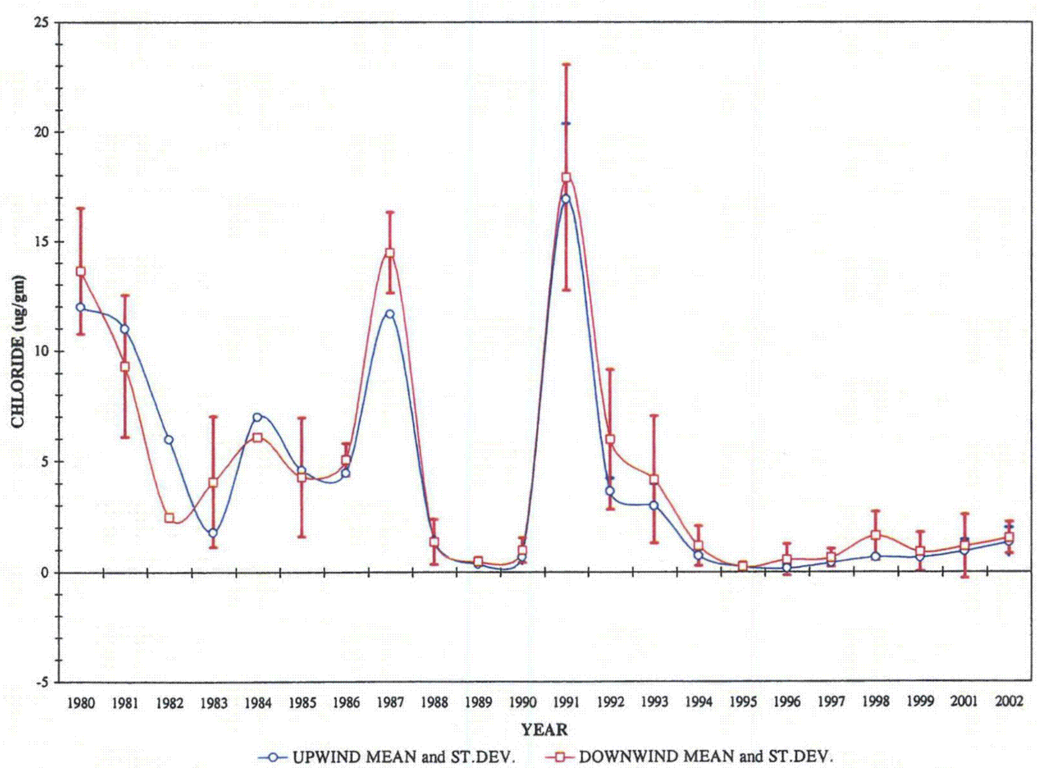


Figure 5-16. Upwind vs. Downwind Chloride in Soil at Grass Sites

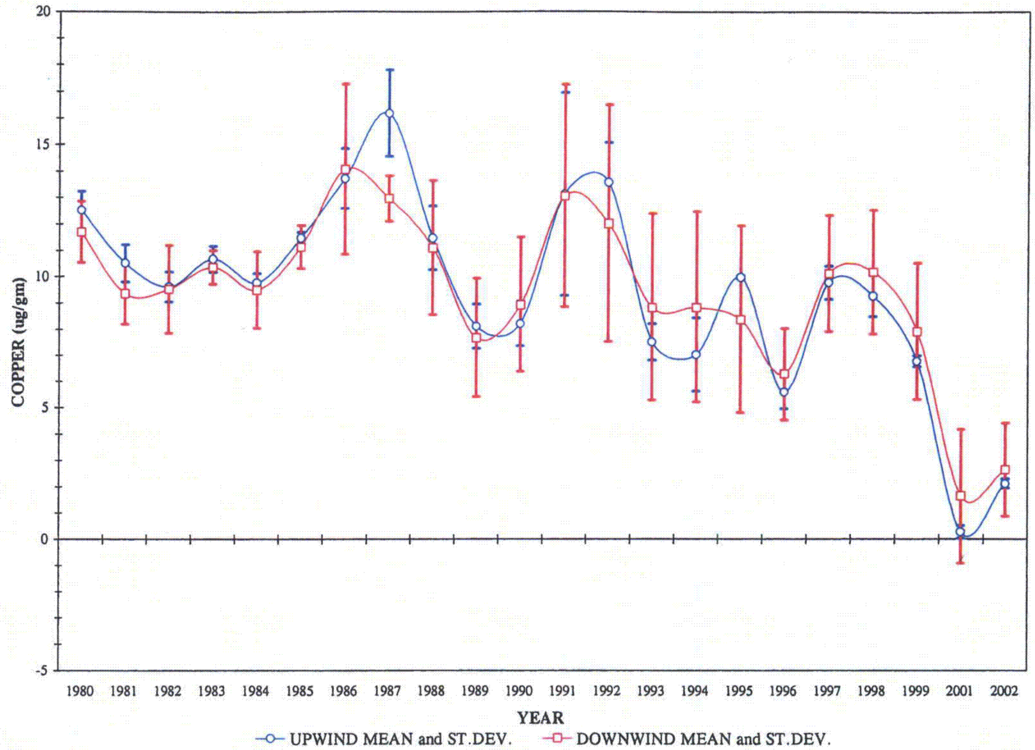


Figure 5-17. Upwind vs. Downwind Copper in Soil at Shrub Sites

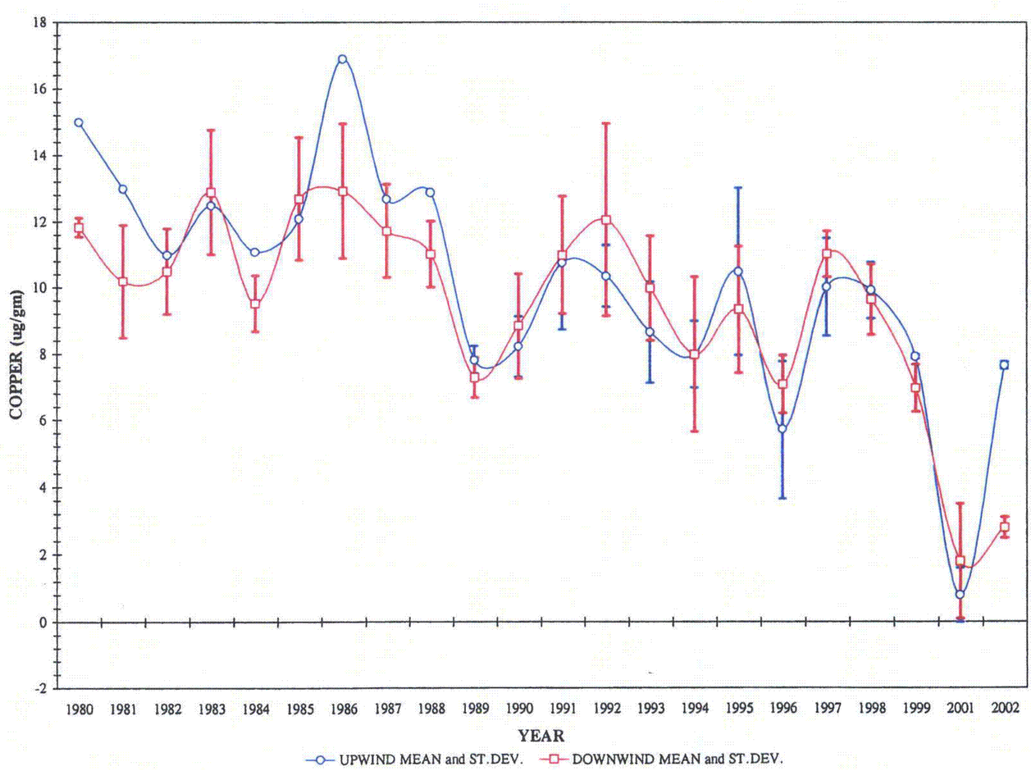


Figure 5-18. Upwind vs. Downwind Copper in Soil at Grass Sites

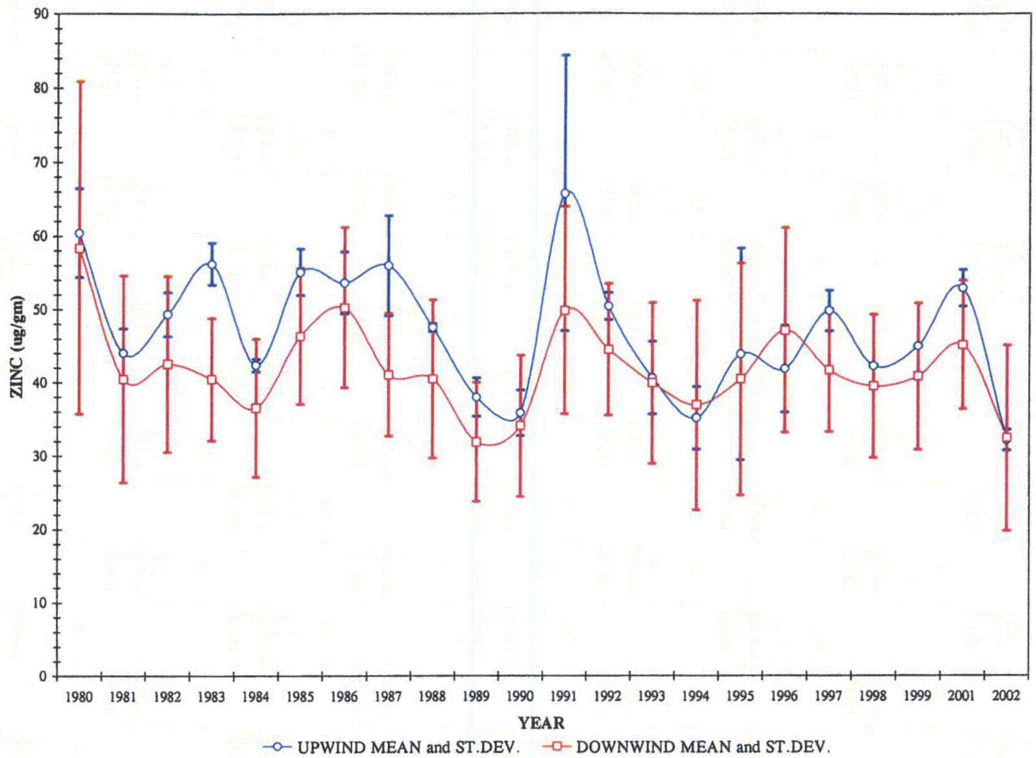


Figure 5-19. Upwind vs. Downwind Zinc in Soil at Shrub Sites

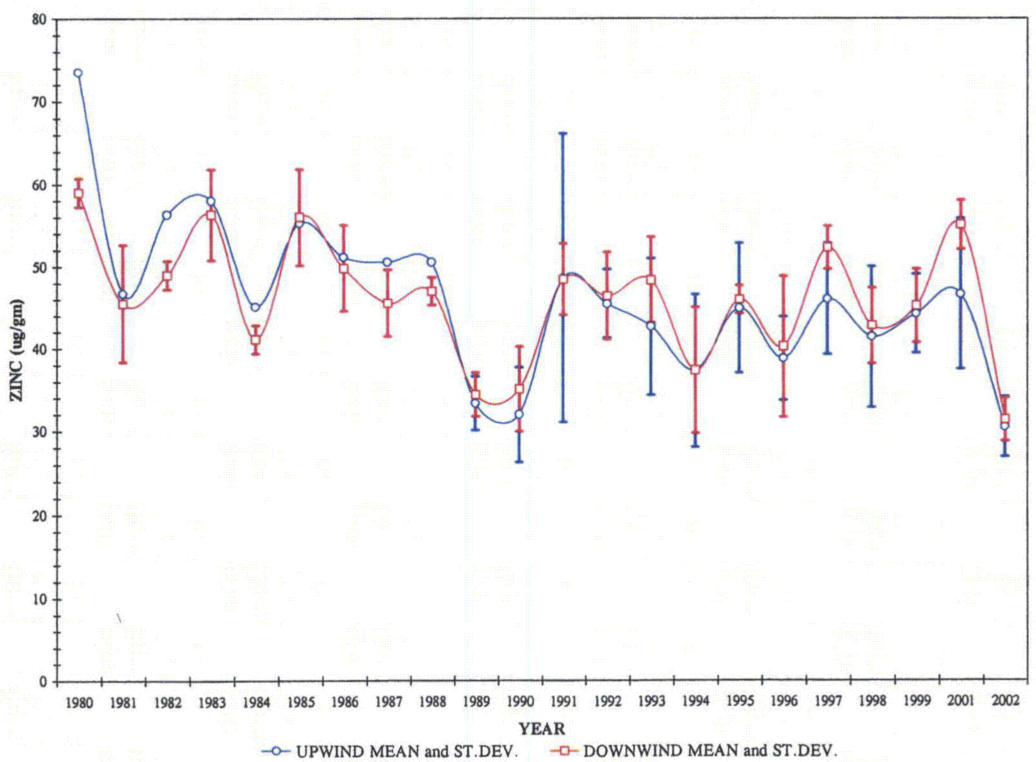


Figure 5-20. Upwind vs. Downwind Zinc in Soil at Grass Sites

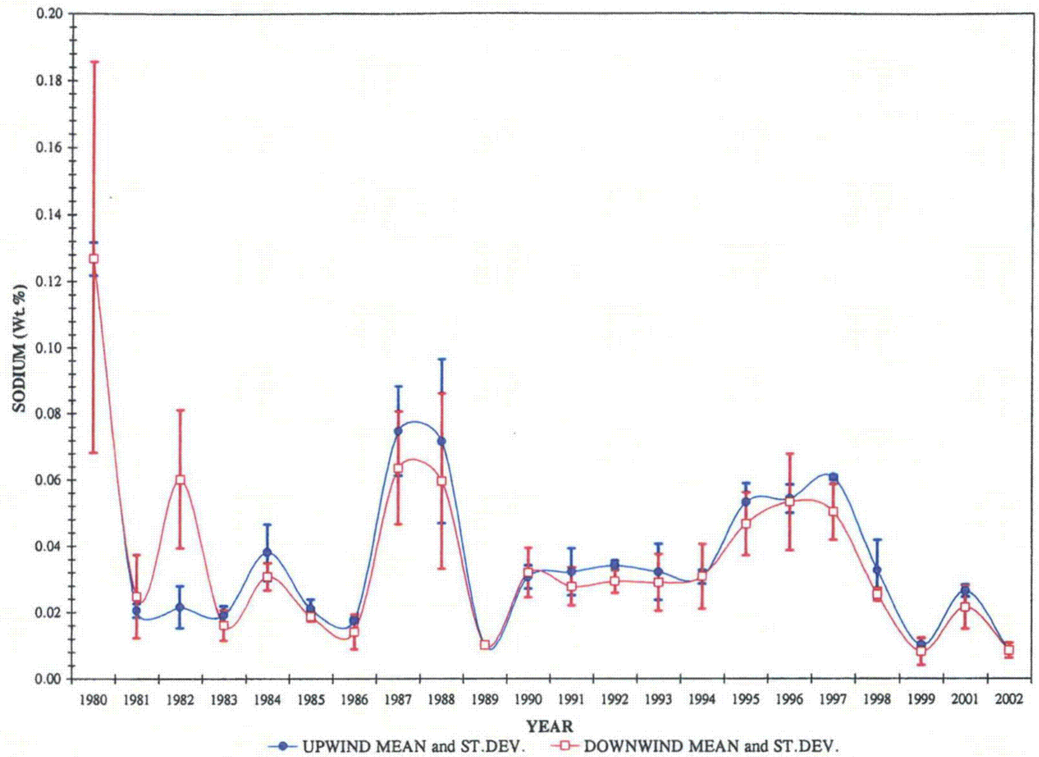


Figure 5-21. Upwind vs. Downwind Sodium in Soil at Shrub Sites

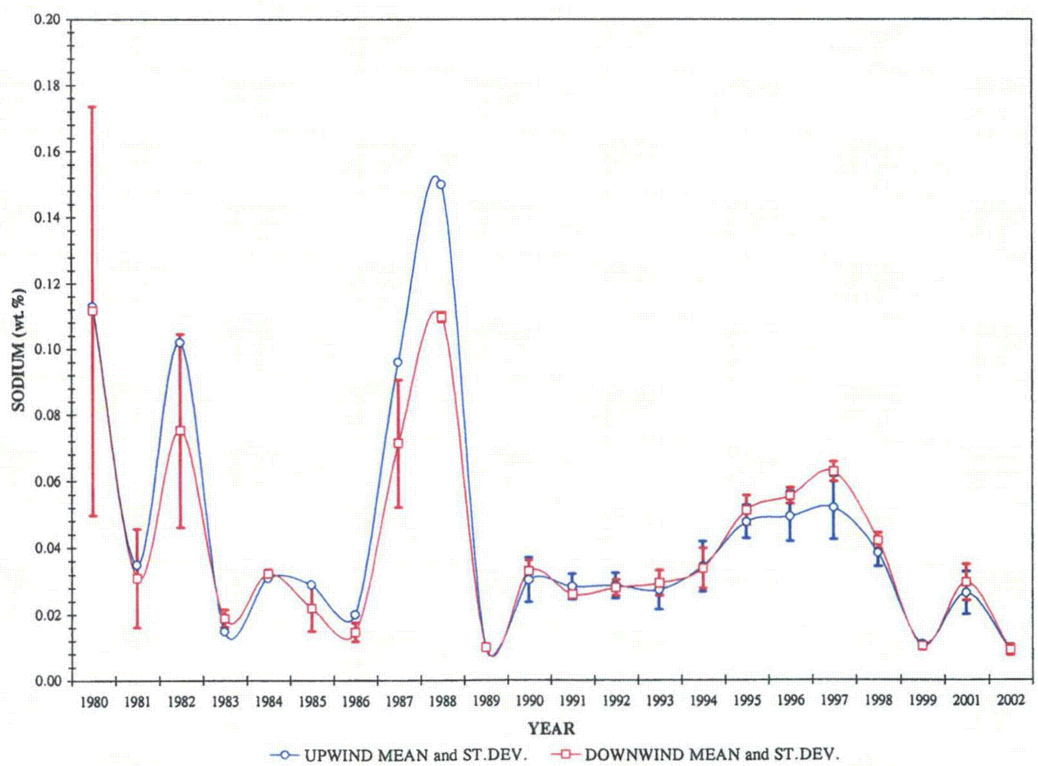


Figure 5-22. Upwind vs. Downwind Sodium in Soil at Grass Sites

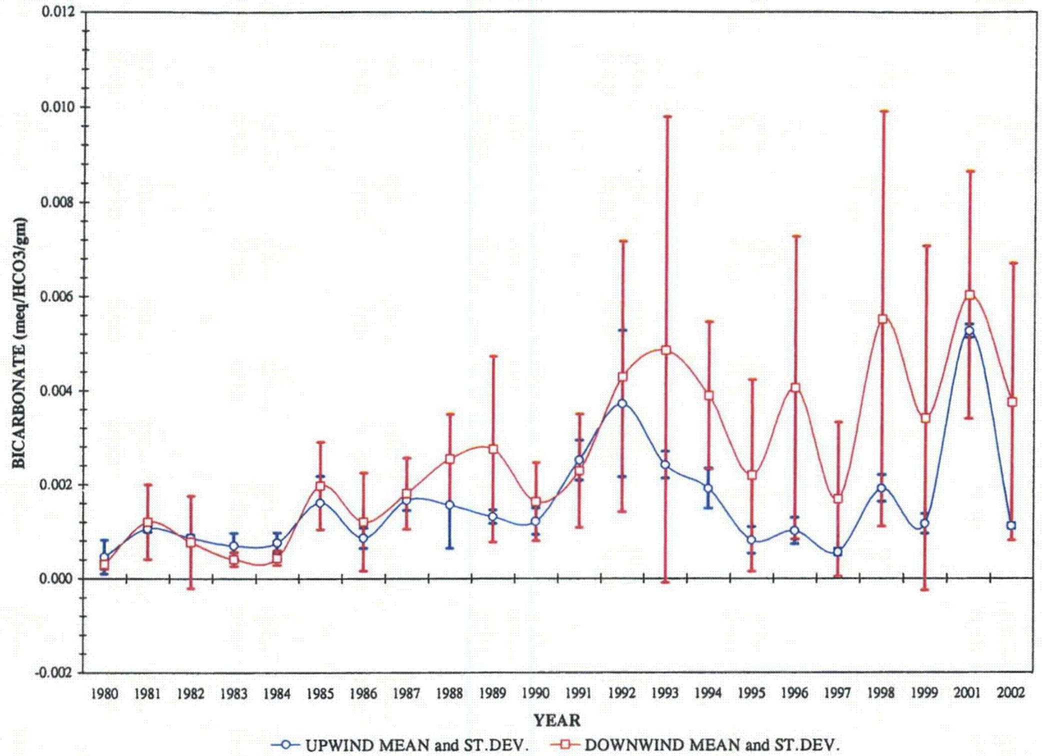


Figure 5-23. Upwind vs. Downwind Bicarbonate in Soil at Shrub Sites

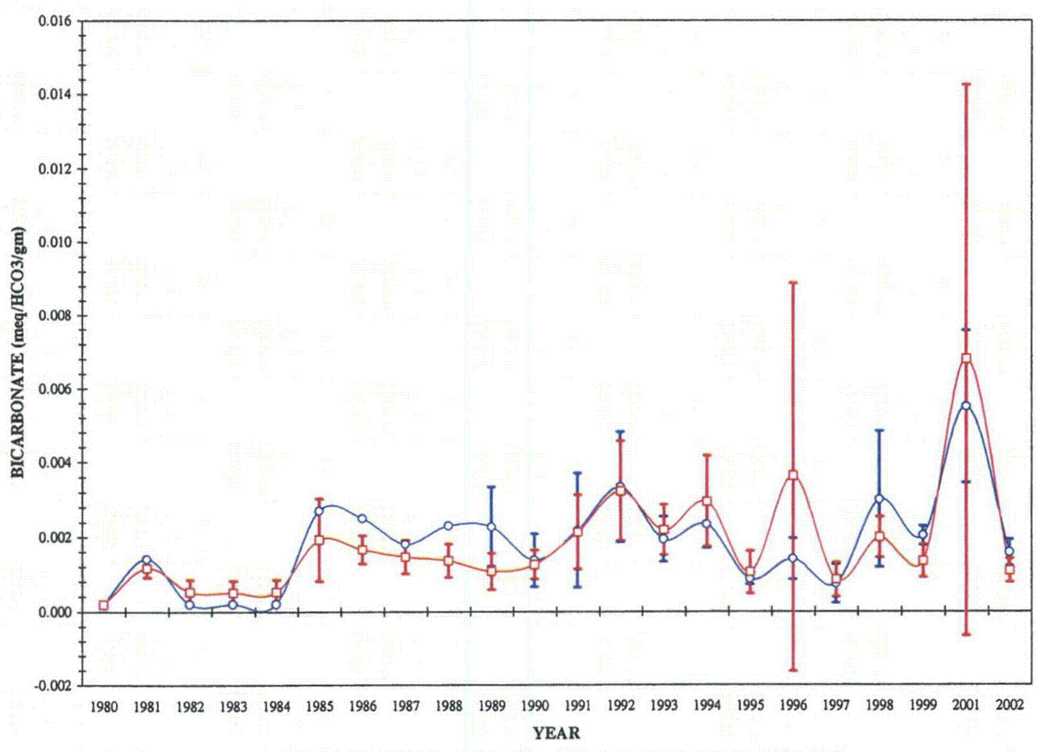


Figure 5-24. Upwind vs. Downwind Bicarbonate in Soil at Grass Sites

SECTION 6 VEGETATION CHEMISTRY

6.0 VEGETATION CHEMISTRY

Studies of vegetation chemistry were conducted in parallel with soil chemistry studies until 1992. Vegetation was collected and analyzed for copper, extractable chloride and sulfate. The studies were discontinued because no impacts were observed and because the soil results would provide a primary indicator of an incipient trend.

6.1 Methods and Materials

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

In the laboratory, the clipped plant tissue was oven dried to a constant weight, ground in a Wiley mill and digested according to Gilman (1989). Sulfate was analyzed by nephalometry and chloride by mercuric chloride titration according to EPA methods (1991). Copper was analyzed by graphite furnace or ICP according to EPA methods (1991).

6.2 Results and Discussion

The results for the analyses of copper, extractable chloride and extractable sulfate in vegetation samples are shown in Tables 6-1 through 6-18. Figures 6-1 through 6-18 graphically present the results of each analyte in each species.

Results for copper in vegetation were generally consistent between the preoperational and operational periods for all species. *Artemisia tridentata* had the highest average concentration for both periods, with 8.6 μg/gm during the preoperational period and 7.1 μg/gm during the operational period. *Poa secunda* had the lowest average concentrations during the preoperational and operational periods, with 3.6 μg/gm and 3.4 μg/gm respectively.

Extractable chloride results were also consistent in four of the six species. The preoperational period averages in *Bromus tectorum, Phlox longifolia, Poa secunda and Purshia tridentata* ranged from 0.08% in *Purshia tridentata* to 0.15% in *Bromus tectorum* and operational averages ranged from a low of 0.10% in *Phlox longifolia* and *Purshia tridentata* to 0.19% in *Poa secunda*. *Sisymbrium altissimum* and *Artemisia tridentata* had higher concentrations during both periods than the other species and showed the largest increase between the preoperational and operational periods. *Sisymbrium altissimum* averaged 0.25% during the preoperational period and 0.45% during the operational period and *Artemisia tridentata* averaged 0.30% and 0.55% respectively during those periods.

Extractable sulfate declined in all species between the preoperational period and the operational period. This observation is contrary to what would be expected from cooling tower operation as the water has a higher level of sulfate in it due to the addition of sulfuric acid for pH control. Results during the preoperational period ranged from 0.034% in *Poa secunda* to 0.395% in *Sisymbrium altissimum*. During the operational period, averages ranged from 0.013% in *Purshia tridentata* to 0.215% in *Sisymbrium altissimum*.

Table 6-1. Copper (µg/gm) in *Poa secunda* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	3.4	3.4	3.5	3.2	3.6	3.4	4.4	2.5	5.4	4.3	0.8	2.8	4.0	3.6	3.5
G02	3.0	3.0	3.5	4.4	4.2	3.6	3.9	8.3	2.6	3.5	1.0	3.0	4.0	3.4	3.7
G03	3.2	3.2	4.0	5.8	6.9	4.6	7.0	4.9	4.7	-	1.0	4.2	4.0	3.4	4.2
G04	3.2	3.2	-	4.6	8.9	5.0	3.8	7.8	3.6	4.4	0.9	2.8	2.0	0.0	3.2
G05	-	-	-	-	-	-	-	-	-	-	0.9	2.2	8.0	0.0	2.8
G06	-	-	-	-	-	-	-	-	-	-	0.9	2.6	2.0	3.2	2.2
G07	-	-	-	-	-	-	-	-	-	-	0.9	4.4	4.0	3.4	3.2
G08	-	-	-	-	-	-	-	-	-	-	1.0	2.6	2.0	3.2	2.2
S01	3.6	3.6	3.3	3.6	2.5	3.3	5.5	3.4	2.1	4.3	0.7	2.6	2.0	3.6	3.0
S02	2.6	2.6	2.3	3.4	4.3	3.0	3.4	9.1	1.8	-	0.8	2.8	4.0	3.6	3.6
S03	3.3	3.3	3.4	3.4	3.2	3.3	3.3	4.0	2.5	3.9	0.7	3.2	8.0	5.8	3.9
S04	3.7	3.7	2.8	3.8	3.4	3.5	6.2	5.1	2.8	-	1.1	3.6	2.0	5.8	3.8
S05	3.0	3.0	3.8	3.4	3.5	3.3	3.8	5.4	3.9	4.0	1.2	3.6	2.0	5.8	3.7
S06	-	-	-	-	-	-	-	-	-	-	0.9	3.8	2.0	8.4	3.8
S07	-	-	-	-	-	-	-	-	-	-	-	3.2	2.0	-	2.6
Mean Grass	3.2	3.2	3.7	4.5	5.9	4.1	4.8	5.9	4.1	4.0	0.9	3.1	3.8	2.5	3.3
Mean Shrub	3.2	3.2	3.1	3.5	3.4	3.3	4.4	5.4	2.6	4.0	0.9	3.3	3.1	5.5	3.6

Table 6-2. Copper (µg/gm) in *Bromus tectorum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	4.0	3.5	4.5	3.4	6.2	4.3	7.2	4.1	6.9	6.0	1.0	4.8	14.0	3.6	5.9
G02	4.0	3.7	5.0	3.6	5.9	4.4	4.8	4.7	4.7	5.8	1.5	5.0	10.0	3.6	5.0
G03	4.4	3.9	3.8	4.0	7.1	4.6	9.7	14.6	6.6	4.8	1.4	6.6	4.0	3.6	6.4
G04	5.5	4.2	-	4.5	6.0	5.1	5.0	10.1	5.2	4.8	1.2	4.0	4.0	0.0	4.3
G05	-	-	-	-	-	-	-	-	-	-	1.2	4.8	4.0	0.0	2.5
G06	-	-	-	-	-	-	-	-	-	-	1.2	4.2	4.0	3.6	3.2
G07	-	-	-	-	-	-	-	-	-	-	1.1	5.2	4.0	3.4	3.4
G08	-	-	-	-	-	-	-	-	-	-	1.0	4.8	2.0	3.2	2.8
S01	4.9	4.2	4.8	3.5	4.3	4.3	5.0	6.8	5.4	5.0	1.1	4.0	2.0	3.8	4.1
S02	3.9	2.6	2.8	3.0	4.1	3.3	5.5	4.5	4.0	5.4	0.9	4.2	4.0	3.6	4.0
S03	3.5	4.3	5.0	4.3	4.1	4.2	5.4	5.5	4.8	5.1	1.2	5.0	6.0	6.0	4.9
S04	4.0	4.0	6.8	4.0	3.4	4.4	9.5	6.2	5.1	5.8	1.3	4.8	4.0	6.0	5.3
S05	5.0	4.4	4.5	4.4	3.8	4.4	4.3	6.3	6.3	4.4	1.0	4.6	4.0	8.6	4.9
S06	-	-	-	-	-	-	-	-	-	-	1.0	6.4	6.0	8.8	5.6
S07	-	-	-	-	-	-	-	-	-	-	1.2	6.0	4.0	8.4	4.9
Mean Grass	4.5	3.8	4.4	3.9	6.3	4.6	6.7	8.4	5.8	5.4	1.2	4.9	5.8	2.6	4.6
Mean Shrub	4.3	3.9	4.7	3.8	3.9	4.1	5.9	5.9	5.1	5.1	1.1	5.0	4.3	6.5	4.7

Table 6-3. Copper (μg/gm) in *Sisymbrium altissimum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	4.0	3.0	5.4	3.8	2.8	3.8	5.1	5.2	4.9	6.8	1.1	6.6	4.0	3.8	4.7
G02	5.0	3.3	5.0	3.4	7.3	4.8	4.8	4.1	6.1	6.0	0.9	3.6	4.0	3.6	4.1
G03	5.6	2.0	4.1	3.4	6.7	4.4	5.6	7.9	3.5	4.6	1.1	3.6	4.0	0.0	3.8
G04	7.5	2.8	-	-	6.7	5.7	4.2	16.0	4.5	-	1.1	3.4	4.0	0.0	4.7
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	4.0
G08	-	-	-	-	-	-	-	-	-	-	0.9	3.4	2.0	4.0	2.6
S01	-	-	-	-	-	-	4.3	3.1	6.1	4.4	1.3	3.2	2.0	3.8	3.5
S02	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	3.8
S03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S04	-	-	3.8	-	-	3.8	7.6	6.3	5.2	5.1	0.9	3.4	4.0	5.8	4.8
S05	-	-	-	-	-	-	-	-	-	-	-	3.2	-	-	3.2
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	5.5	2.8	4.8	3.5	5.9	4.5	4.9	8.3	4.7	5.8	1.0	4.1	3.7	2.3	4.1
Mean Shrub	-	-	3.8	-	-	3.8	6.0	4.7	5.6	4.7	1.1	3.3	3.0	4.5	4.1

Table 6-4. Copper (μg/gm) in *Phlox longifolia* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	4.0	3.0	4.3	3.8	7.0	4.4	4.7	4.9	4.8	6.2	1.0	4.2	4.0	3.6	4.2
G02	3.5	4.0	4.3	3.4	4.0	3.8	4.9	4.5	2.8	4.5	3.2	3.6	4.0	3.6	3.9
G03	5.0	2.0	5.0	4.8	6.8	4.7	5.5	-	-	4.9	-	4.4	4.0	-	4.7
G04	5.5	2.6	2.7	5.1	7.8	4.7	3.3	6.4	5.1	4.2	1.1	4.0	4.0	0.0	3.5
G05	-	-	-	-	-	-	-	-	-	-	-	2.6	-	-	2.6
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	4.0
G08	-	-	-	-	-	-	-	-	-	-	1.0	4.0	2.0	4.0	2.8
S01	-	-	-	-	-	-	5.2	8.3	4.0	4.9	1.2	3.4	4.0	3.8	4.3
S02	-	4.0	4.5	5.2	5.5	4.8	4.8	3.1	3.6	3.8	0.8	4.0	-	3.8	3.4
S03	-	3.6	4.8	4.0	4.9	4.3	4.3	12.0	4.0	4.7	1.2	4.2	4.0	5.8	5.0
S04	-	3.5	4.8	-	4.4	4.2	8.1	7.4	6.2	4.5	1.2	3.6	2.0	5.8	4.8
S05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	4.5	2.9	4.1	4.3	6.4	4.4	4.6	5.3	4.2	4.9	1.6	3.8	3.7	2.8	3.8
Mean Shrub	-	3.7	4.7	4.6	4.9	4.5	5.6	7.7	4.4	4.4	1.1	3.8	3.3	4.8	4.4

Table 6-5. Copper (µg/gm) in *Purshia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	8.5	6.4	6.5	1.1	4.6	-	-	5.4
G04	-	-	-	3.4	-	3.4	-	-	-	4.9	-	4.4	-	-	4.7
G05	-	-	-	-	-	-	-	-	-	-	3.2	3.6	4.0	-	3.6
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S01	6.0	4.6	3.8	4.4	4.2	4.6	-	-	-	-	-	-	-	-	-
S02	-	-	-	-	4.7	4.7	3.7	4.7	4.0	5.8	0.9	3.8	4.0	-	3.8
S03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S05	4.5	4.8	4.2	8.7	4.3	5.3	5.2	4.0	5.4	4.2	1.3	5.0	4.0	9.0	4.7
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	-	-	-	3.4	-	3.4	-	8.5	6.4	5.7	2.2	4.2	4.0	-	4.7
Mean Shrub	5.3	4.7	4.0	6.6	4.4	4.9	4.4	4.4	4.7	5.0	1.1	4.4	4.0	9.0	4.3

Table 6-6. Copper (µg/gm) in *Artemisia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G05	-	-	-	-	-	-	-	-	-	-	2.8	7.2	8.0	0.0	4.5
G06	-	-	-	-	-	-	-	-	-	-	2.0	10.0	8.4	-	6.8
G07	-	-	-	-	-	-	-	-	-	-	2.0	8.2	-	4.0	4.7
G08	-	-	-	-	-	-	-	-	-	-	-	9.2	-	-	9.2
S01	8.5	9.5	-	8.6	6.9	8.4	-	-	-	-	-	-	-	-	-
S02	-	-	-	-	-	-	-	-	-	5.4	-	8.2	2.0	-	5.2
S03	9.3	9.0	9.5	7.3	10.3	9.1	11.0	6.8	10.0	11.0	2.4	10.2	8.0	6.0	8.2
S04	9.5	7.4	10.1	8.5	10.9	9.3	-	-	-	25.5	-	9.0	-	0.0	11.5
S05	7.4	7.6	9.6	6.3	6.8	7.5	9.0	6.4	9.2	16.6	2.3	9.2	8.0	6.2	8.4
S06	-	-	-	-	-	-	-	-	-	-	1.8	8.0	4.0	9.0	5.7
S07	-	-	-	-	-	-	-	-	-	-	1.7	6.2	8.0	8.8	6.2
Mean Grass	-	-	-	-	-	-	-	-	-	-	2.3	8.7	8.2	2.0	5.6
Mean Shrub	8.7	8.4	9.7	7.7	8.7	8.6	10.0	6.6	9.6	14.6	2.0	8.5	6.0	6.0	7.7

Table 6-7. Extractable Chloride (%) in *Poa secunda* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	0.11	0.08	0.20	0.21	0.20	0.16	0.32	0.13	0.27	0.27	0.20	0.21	0.15	0.10	0.21
G02	0.08	0.11	0.11	0.24	0.10	0.13	0.20	0.47	0.15	0.25	0.16	0.21	0.26	0.07	0.22
G03	0.09	0.10	0.08	0.28	0.18	0.15	0.20	0.33	0.34	-	0.09	0.29	0.28	0.11	0.23
G04	0.04	0.07	-	0.24	0.14	0.12	0.21	0.15	0.17	-	0.25	0.32	0.19	0.11	0.20
G05	-	-	-	-	-	-	-	-	-	-	0.17	0.25	0.12	0.09	0.16
G06	-	-	-	-	-	-	-	-	-	-	0.26	0.22	0.20	0.08	0.19
G07	-	-	-	-	-	-	-	-	-	-	0.22	0.24	0.20	0.11	0.19
G08	-	-	-	-	-	-	-	-	-	-	0.15	0.28	0.18	0.10	0.18
S01	0.11	0.05	0.12	0.29	0.15	0.14	0.18	0.14	0.14	0.19	0.15	0.25	0.09	0.03	0.15
S02	0.09	0.09	0.13	0.21	0.18	0.14	0.25	0.14	0.11	-	0.20	0.25	0.22	0.11	0.18
S03	0.08	0.09	0.08	0.23	0.17	0.13	0.18	0.17	0.17	0.27	0.20	0.30	0.11	0.12	0.19
S04	0.11	0.08	0.09	0.20	0.15	0.13	0.20	0.14	0.26	-	0.21	0.32	0.15	0.10	0.20
S05	0.07	0.08	0.11	0.24	0.17	0.13	0.24	0.19	0.27	0.22	0.16	0.32	0.07	0.09	0.20
S06	-	-	-	-	-	-	-	-	-	-	0.11	0.16	0.19	0.09	0.14
S07	-	-	-	-	-	-	-	-	-	-	-	0.17	0.16	-	0.17
Mean Grass	0.08	0.09	0.13	0.24	0.16	0.14	0.23	0.27	0.23	0.26	0.19	0.25	0.20	0.10	0.20
Mean Shrub	0.09	0.08	0.10	0.23	0.16	0.13	0.21	0.16	0.19	0.23	0.17	0.25	0.14	0.09	0.18

Table 6-8. Extractable Chloride (%) in *Bromus tectorum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	0.12	0.10	0.13	0.29	0.13	0.15	0.38	0.28	0.23	0.28	0.22	0.29	0.21	0.13	0.25
G02	0.12	0.15	0.15	0.22	0.24	0.18	0.23	0.16	0.18	0.30	0.06	0.24	0.23	0.14	0.19
G03	0.09	0.07	0.04	0.34	0.28	0.16	0.36	0.15	0.39	0.26	0.27	0.29	0.07	0.04	0.23
G04	0.04	0.04	-	0.22	0.16	0.12	0.17	0.15	0.07	0.17	0.22	0.14	0.11	0.10	0.14
G05	-	-	-	-	-	-	-	-	-	-	0.15	0.18	0.08	0.03	0.11
G06	-	-	-	-	-	-	-	-	-	-	0.14	0.26	0.15	0.11	0.17
G07	-	-	-	-	-	-	-	-	-	-	0.25	0.24	0.17	0.08	0.19
G08	-	-	-	-	-	-	-	-	-	-	0.17	0.12	0.14	0.09	0.13
S01	0.09	0.14	0.13	0.27	0.16	0.16	0.16	0.10	0.15	0.27	0.21	0.21	0.22	0.09	0.18
S02	0.04	0.06	0.08	0.16	0.09	0.09	0.23	0.12	0.11	0.17	0.10	0.19	0.13	0.08	0.14
S03	0.07	0.14	0.14	0.26	0.18	0.16	0.22	0.17	0.10	0.14	0.12	0.19	0.42	0.08	0.18
S04	0.21	0.17	0.03	0.29	0.15	0.17	0.55	0.40	0.13	0.23	0.31	0.18	0.17	0.17	0.27
S05	0.10	0.11	0.13	0.11	0.22	0.13	0.10	0.15	0.15	0.21	0.22	0.16	0.11	0.10	0.15
S06	-	-	-	-	-	-	-	-	-	-	0.11	0.10	0.19	0.11	0.13
S07	-	-	-	-	-	-	-	-	-	-	0.18	0.20	0.28	0.11	0.19
Mean Grass	0.09	0.09	0.11	0.27	0.20	0.15	0.29	0.19	0.22	0.25	0.19	0.22	0.15	0.09	0.19
Mean Shrub	0.10	0.12	0.10	0.22	0.16	0.14	0.25	0.19	0.13	0.20	0.18	0.18	0.22	0.11	0.18

Table 6-9. Extractable Chloride (%) in *Sisymbrium altissimum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	0.28	0.14	0.19	0.40	0.32	0.27	0.63	0.75	0.28	0.54	0.58	0.57	0.31	0.17	0.48
G02	0.18	0.10	0.26	0.37	0.50	0.28	0.50	0.49	0.41	0.90	0.34	0.78	0.39	0.20	0.88
G03	0.36	0.09	0.15	0.24	0.40	0.25	0.54	0.45	0.56	0.64	0.78	0.62	0.28	0.20	0.51
G04	0.30	0.08	-	-	0.29	0.22	0.49	0.51	0.38	0.49	0.26	0.43	0.30	0.13	0.37
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	0.28	-	0.28
G08	-	-	-	-	-	-	-	-	-	-	0.01	0.04	0.73	0.14	0.23
S01	-	-	-	-	-	-	0.56	0.31	0.67	0.50	0.59	0.68	0.18	0.12	0.45
S02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S04	-	-	0.08	-	-	0.08	0.80	0.53	1.13	0.57	0.41	0.38	0.15	0.36	0.54
S05	-	-	-	-	-	-	-	-	-	-	-	0.34	-	-	0.34
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	0.28	0.10	0.20	0.34	0.38	0.26	0.54	0.55	0.41	0.64	0.39	0.49	0.38	0.17	0.44
Mean Shrub	-	-	0.08	-	-	0.08	0.68	0.42	0.90	0.54	0.50	0.47	0.17	0.24	0.49

Table 6-10. Extractable Chloride (%) in *Phlox longifolia* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	0.08	0.11	0.10	0.11	0.16	0.11	0.13	0.16	0.09	0.12	0.09	0.12	0.12	0.08	0.11
G02	0.08	0.05	0.06	0.09	0.17	0.09	0.13	0.14	0.07	0.14	0.07	0.07	0.12	0.06	0.10
G03	0.04	0.05	0.10	0.12	0.14	0.09	0.10	-	-	0.16	-	0.08	0.28	-	0.16
G04	0.07	0.06	0.08	0.14	0.13	0.10	0.12	0.14	0.10	0.10	0.08	0.06	0.30	0.06	0.12
G05	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	0.09
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	0.05	0.09	-	0.07
G08	-	-	-	-	-	-	-	-	-	-	0.09	0.08	0.09	0.04	0.08
S01	-	-	-	-	-	-	0.13	0.19	0.09	0.09	0.07	0.08	0.10	0.06	0.10
S02	-	0.06	0.09	0.20	0.14	0.12	0.10	0.13	0.08	0.10	0.08	0.09	-	0.07	0.09
S03	-	0.07	0.05	0.06	0.17	0.09	0.11	0.16	0.06	0.09	0.06	0.10	0.05	0.07	0.09
S04	-	0.13	0.08	-	0.15	0.12	0.14	0.11	0.08	0.13	0.09	0.07	0.04	0.07	0.09
S05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	0.07	0.07	0.09	0.12	0.15	0.10	0.12	0.15	0.09	0.13	0.08	0.08	0.17	0.06	0.11
Mean Shrub	-	0.09	0.07	0.13	0.15	0.11	0.12	0.15	0.08	0.10	0.08	0.09	0.06	0.07	0.09

Table 6-11. Extractable Chloride (%) in *Purshia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	0.17	0.09	0.12	0.22	0.17	-	0.03	0.13
G04	-	-	-	0.16	-	0.16	-	-	-	0.11	-	0.11	-	-	0.11
G05	-	-	-	-	-	-	-	-	-	-	0.09	0.14	0.05	0.04	0.08
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S01	0.04	0.01	0.04	0.15	0.07	0.06	-	-	-	-	-	-	-	-	-
S02	0.09	0.02	0.03	0.12	0.12	0.08	0.09	0.19	0.04	0.12	0.04	0.10	0.06	0.03	0.08
S03	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	0.06
S04	-	-	-	0.16	-	0.16	-	-	-	-	-	-	-	-	-
S05	0.03	0.02	0.02	0.13	0.10	0.06	0.10	0.09	0.07	0.14	0.06	0.18	0.05	0.05	0.09
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	-	-	-	0.16	-	0.16	-	0.17	0.09	0.12	0.16	0.14	0.05	0.04	0.11
Mean Shrub	0.05	0.02	0.03	0.14	0.10	0.07	0.10	0.14	0.06	0.13	0.05	0.14	0.06	0.04	0.09

Table 6-12. Extractable Chloride (%) in *Artemisia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G05	-	-	-	-	-	-	-	-	-	-	0.47	0.92	0.48	0.28	0.54
G06	-	-	-	-	-	-	-	-	-	-	0.49	0.90	0.60	0.19	0.55
G07	-	-	-	-	-	-	-	-	-	-	0.03	0.67	-	0.19	0.30
G08	-	-	-	-	-	-	-	-	-	-	-	0.63	-	-	0.63
S01	0.39	0.27	-	0.54	0.35	0.39	-	-	-	-	-	-	-	-	-
S02	-	-	-	-	-	-	-	-	-	0.75	-	0.95	0.30	-	0.67
S03	0.25	0.31	0.18	0.28	0.30	0.26	0.82	0.85	0.61	0.50	0.56	0.78	0.35	0.24	0.59
S04	0.22	0.17	0.15	0.55	0.40	0.30	-	-	-	-	-	0.91	-	-	1.15
S05	0.22	0.14	0.24	0.47	0.26	0.27	0.53	0.85	0.48	0.84	0.50	0.89	0.40	0.22	0.59
S06	-	-	-	-	-	-	-	-	-	-	0.57	0.73	0.41	0.28	0.50
S07	-	-	-	-	-	-	-	-	-	-	0.36	0.59	0.66	0.20	0.45
Mean Grass	-	-	-	-	-	-	-	-	-	-	0.33	0.78	0.54	0.22	0.49
Mean Shrub	0.27	0.22	0.19	0.46	0.33	0.30	0.68	0.85	0.55	0.70	0.50	0.81	0.42	0.24	0.58

Table 6-13. Extractable Sulfate (%) in *Poa secunda* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	0.020	0.020	0.045	0.028	0.011	0.000	0.023	0.019	0.004	0.020	0.012	0.012	0.013
G02	-	-	0.022	0.067	0.032	0.040	0.010	0.170	0.026	0.019	0.004	0.019	0.012	0.012	0.034
G03	-	-	0.028	0.019	0.033	0.027	0.077	0.000	0.023	-	0.005	0.023	0.044	0.011	0.026
G04	-	-	0.035	0.032	0.096	0.054	0.024	0.000	0.023	-	0.005	0.020	0.012	0.012	0.014
G05	-	-	-	-	-	-	-	-	-	-	0.003	0.019	0.036	0.014	0.018
G06	-	-	-	-	-	-	-	-	-	-	0.008	0.018	0.012	0.012	0.013
G07	-	-	-	-	-	-	-	-	-	-	0.004	0.018	0.015	0.011	0.012
G08	-	-	-	-	-	-	-	-	-	-	0.003	0.000	0.012	0.012	0.007
S01	0.036	-	0.022	0.024	0.026	0.027	0.019	0.000	0.023	0.018	0.005	0.019	0.011	0.012	0.013
S02	-	0.034	0.044	0.028	0.026	0.033	0.000	0.037	0.024	-	0.003	0.019	0.014	0.012	0.016
S03	-	-	0.019	0.036	0.018	0.024	0.025	0.026	0.021	0.020	0.004	0.026	0.012	0.011	0.018
S04	-	-	0.023	0.030	0.045	0.033	0.029	0.000	0.027	-	0.144	0.019	0.014	0.014	0.035
S05	0.047	-	0.045	0.028	0.038	0.040	0.027	0.000	0.028	0.018	0.003	0.019	0.014	0.011	0.015
S06	-	-	-	-	-	-	-	-	-	-	0.004	0.024	0.062	0.010	0.025
S07	-	-	-	-	-	-	-	-	-	-	-	0.018	0.061	-	0.040
Mean Grass	-	-	0.026	0.035	0.052	0.037	0.031	0.043	0.024	0.019	0.005	0.017	0.019	0.012	0.018
Mean Shrub	0.042	0.034	0.031	0.029	0.031	0.032	0.020	0.013	0.025	0.019	0.027	0.021	0.027	0.012	0.021

Table 6-14. Extractable Sulfate (%) in *Bromus tectorum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	0.119	0.051	0.085	0.090	0.068	0.028	0.018	0.006	0.041	0.049	0.013	0.039
G02	0.081	-	0.025	0.013	0.044	0.041	0.022	0.294	0.023	0.019	0.005	0.029	0.037	0.012	0.055
G03	-	-	-	0.006	0.052	0.029	0.177	0.026	0.093	0.019	0.004	0.036	0.045	0.012	0.052
G04	-	-	0.012	0.038	0.032	0.027	0.048	0.078	0.023	0.020	0.003	0.021	0.047	0.011	0.031
G05	-	-	-	-	-	-	-	-	-	-	0.007	0.018	0.042	0.011	0.020
G06	-	-	-	-	--	-	-	-	-	-	0.003	0.018	0.044	0.012	0.019
G07	-	-	-	-	-	-	-	-	-	-	0.005	0.023	0.032	0.012	0.018
G08	-	-	-	-	-	-	-	-	-	-	0.003	0.022	0.037	0.014	0.019
S01	-	-	-	0.106	0.032	0.069	0.062	0.019	0.026	0.018	0.004	0.020	0.032	0.012	0.024
S02	-	-	-	0.056	0.026	0.041	0.101	0.176	0.022	0.022	0.004	0.019	0.012	0.014	0.046
S03	-	-	0.031	0.022	0.028	0.027	0.020	0.094	0.023	0.019	0.006	0.027	0.015	0.012	0.027
S04	-	0.088	0.019	0.031	0.034	0.043	0.160	0.000	0.025	0.021	0.003	0.017	0.021	0.011	0.032
S05	-	-	-	0.076	0.043	0.060	0.000	0.079	0.023	0.017	0.003	0.030	0.012	0.010	0.022
S06	-	-	-	-	-	-	-	-	-	-	0.006	0.025	0.036	0.011	0.020
S07	-	-	-	-	-	-	-	-	-	-	0.009	0.029	0.062	0.010	0.028
Mean Grass	0.081	-	0.019	0.044	0.045	0.043	0.084	0.117	0.042	0.019	0.005	0.026	0.042	0.012	0.036
Mean Shrub	-	0.088	0.025	0.058	0.033	0.046	0.069	0.074	0.024	0.019	0.005	0.024	0.027	0.011	0.029

Table 6-15. Extractable Sulfate (%) in *Sisymbrium altissimum* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	0.040	0.150	0.580	0.640	0.073	0.297	0.527	0.596	0.162	0.115	0.141	0.084	0.013	0.043	0.210
G02	0.350	0.470	0.410	0.640	0.097	0.393	0.490	0.793	0.148	0.103	0.079	0.073	0.013	0.011	0.214
G03	0.470	0.480	1.050	0.680	0.065	0.549	0.593	0.822	0.532	0.115	0.225	0.125	0.221	0.060	0.337
G04	0.450	0.230	-	-	0.049	0.243	0.343	0.524	0.231	0.086	0.079	0.055	0.175	0.069	0.195
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	0.161	-	0.161
G08	-	-	-	-	-	-	-	-	-	-	0.139	0.097	0.153	0.040	0.107
S01	-	-	-	-	-	-	0.454	0.564	0.198	0.121	0.083	0.063	0.104	0.039	0.203
S02	-	-	-	-	-	-	-	-	-	-	-	-	-	0.000	0.000
S03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S04	-	-	0.590	-	-	0.590	0.602	0.671	0.267	0.086	0.129	0.049	0.075	0.038	0.240
S05	-	-	-	-	-	-	-	-	-	-	-	0.047	-	-	0.047
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	0.328	0.333	0.680	0.653	0.071	0.385	0.488	0.684	0.268	0.105	0.133	0.087	0.123	0.045	0.223
Mean Shrub	-	-	0.590	-	-	0.590	0.528	0.618	0.233	0.104	0.106	0.053	0.090	0.026	0.199

Table 6-16. Extractable Sulfate (%) in *Phlox longifolia* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	0.034	0.075	0.040	0.050	0.017	0.000	0.025	0.117	0.004	0.023	0.015	0.012	0.027
G02	-	0.150	0.023	0.043	0.032	0.062	0.062	0.000	0.026	0.018	0.008	0.018	0.029	0.011	0.022
G03	-	-	0.056	0.042	0.030	0.043	0.059	-	-	0.020	-	-	0.012	-	0.030
G04	0.027	-	0.024	0.027	0.034	0.028	0.000	0.000	0.023	0.018	0.005	-	0.012	0.011	0.010
G05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	0.015	-	0.015
G08	-	-	-	-	-	-	-	-	-	-	0.003	0.025	0.018	0.011	0.014
S01	-	-	-	-	-	-	0.031	0.096	0.023	0.018	0.003	0.021	0.015	0.011	0.027
S02	-	-	0.027	0.072	0.049	0.049	0.060	0.018	0.025	0.018	0.005	0.018	-	0.012	0.022
S03	-	-	0.026	0.019	0.024	0.023	0.028	0.026	0.023	0.020	0.005	0.026	0.016	0.011	0.019
S04	-	-	0.038	-	0.019	0.029	0.195	0.036	0.023	0.020	0.005	0.018	0.012	0.012	0.040
S05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	0.027	0.150	0.034	0.047	0.034	0.046	0.035	0.000	0.025	0.043	0.005	0.022	0.017	0.011	0.020
Mean Shrub	-	-	0.030	0.046	0.031	0.034	0.079	0.044	0.024	0.019	0.005	0.021	0.014	0.012	0.027

Table 6-17. Extractable Sulfate (%) in *Purshia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	0.000	0.021	0.021	0.005	0.041	-	0.012	0.017
G04	-	-	-	0.098	-	0.098	-	-	-	0.021	-	0.015	-	-	0.018
G05	-	-	-	-	-	-	-	-	-	-	0.004	0.023	0.021	0.012	0.015
G06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S01	-	-	0.011	0.019	0.019	0.016	-	-	-	-	-	-	-	-	-
S02	-	0.229	0.019	0.056	0.061	0.091	0.013	0.000	0.013	0.021	0.004	0.019	0.017	0.012	0.012
S03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S04	-	-	-	0.034	-	0.034	-	-	-	-	-	-	-	-	-
S05	-	-	-	0.008	0.028	0.018	0.000	0.000	0.015	0.018	0.004	0.018	0.013	0.013	0.010
S06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Grass	-	-	-	0.098	-	0.098	-	0.000	0.021	0.021	0.005	0.026	0.021	0.012	0.016
Mean Shrub	-	0.229	0.015	0.029	0.036	0.048	0.007	0.000	0.014	0.020	0.004	0.019	0.015	0.013	0.011

Table 6-18. Extractable Sulfate (%) in *Artemisia tridentata* 1980 to 1992

Site	1980	1981	1982	1983	1984	Pre-Op Mean	1985	1986	1987	1988	1989	1990	1991	1992	Operational Mean
G01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G05	-	-	-	-	-	-	-	-	-	-	0.003	0.020	0.012	0.011	0.012
G06	-	-	-	-	-	-	-	-	-	-	0.004	0.018	0.039	0.011	0.018
G07	-	-	-	-	-	-	-	-	-	-	0.004	0.016	-	0.012	0.011
G08	-	-	-	-	-	-	-	-	-	-		0.020	-	-	0.020
S01	0.070	0.065	-	0.047	0.070	0.063	-	-	-	-	-	-	-	-	-
S02	-	-	-	-	0.120	0.120	-	-	-	0.018	-	0.024	0.017	-	0.020
S03	0.323	-	0.040	0.024	-	0.129	0.021	0.000	0.025	0.024	0.001	0.021	0.016	0.012	0.015
S04	0.045	-	0.020	0.051	-	0.039	-	-	-	0.022	-	0.020	-	-	0.021
S05	-	0.075	0.020	0.021	0.100	0.054	0.021	0.050	0.023	0.024	0.002	0.021	0.012	0.011	0.021
S06	-	-	-	-	-	-	-	-	-	-	0.004	0.037	0.062	0.010	0.028
S07	-	-	-	-	-	-	-	-	-	-	0.001	0.018	0.054	0.010	0.021
Mean Grass	-	-	-	-	-	-	-	-	-	-	0.004	0.019	0.026	0.011	0.014
Mean Shrub	0.146	0.070	0.027	0.036	0.097	0.073	0.021	0.025	0.024	0.022	0.002	0.024	0.032	0.011	0.020

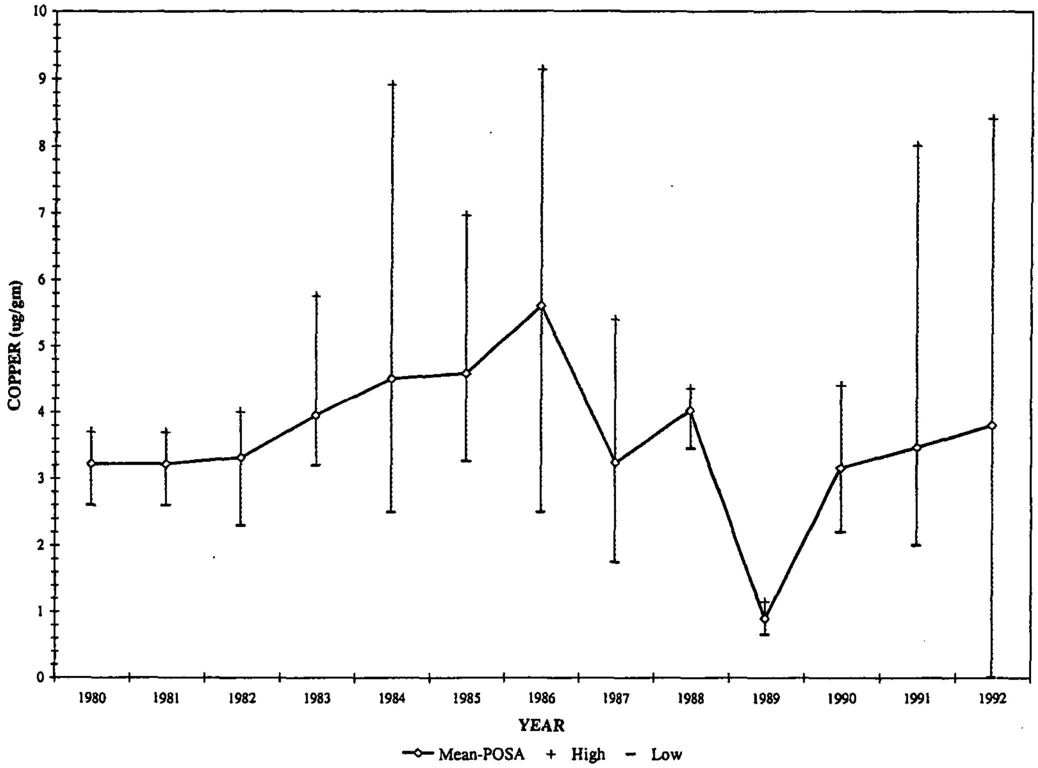


Figure 6-1. Copper in *Poa secunda*, 1980-1992

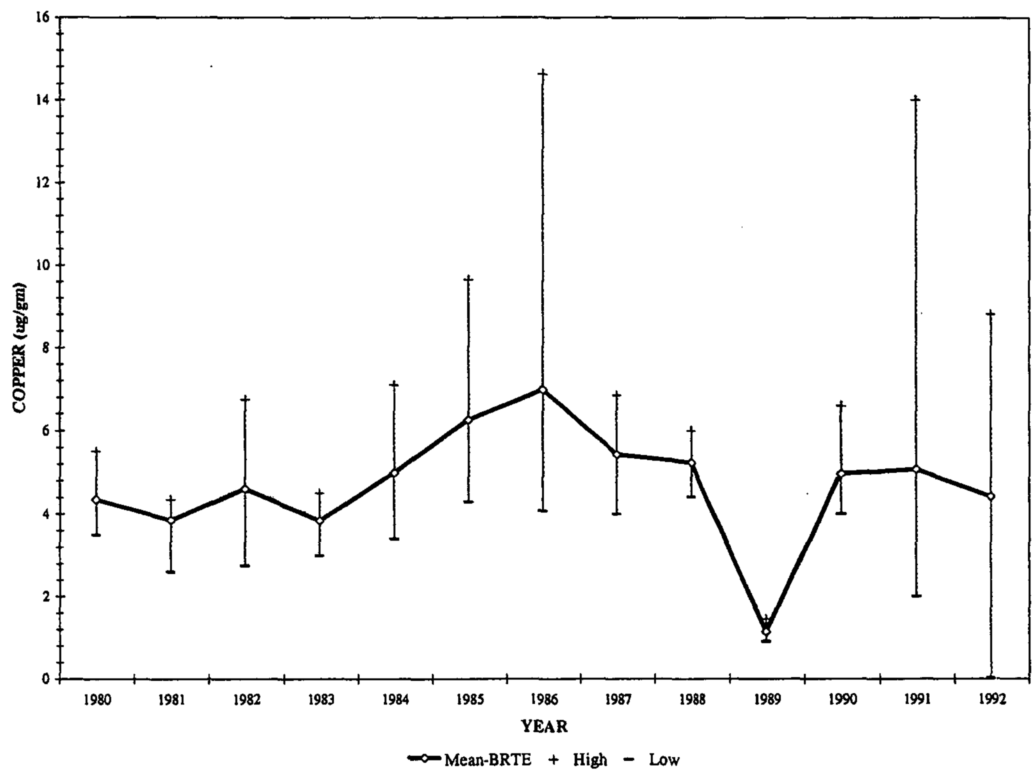


Figure 6-2. Copper in *Bromus tectorum*, 1980-1992

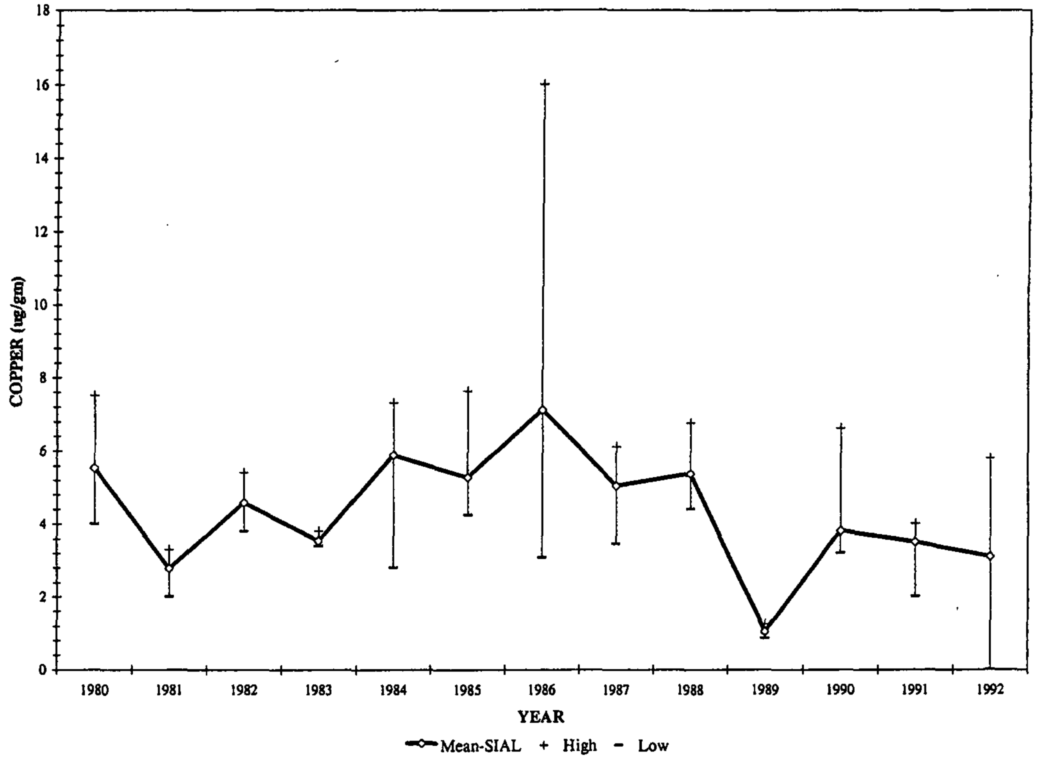


Figure 6-3. Copper in *Sisymbrium altissimum*, 1980-1992

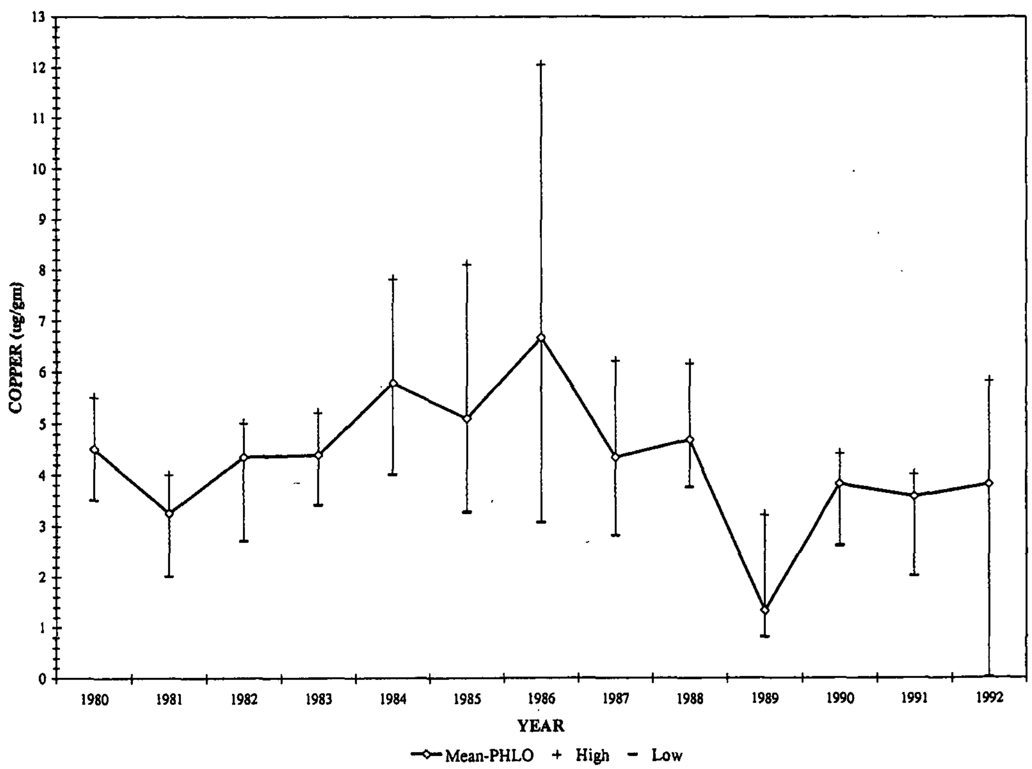


Figure 6-4. Copper in *Phlox longifolia*, 1980-1992

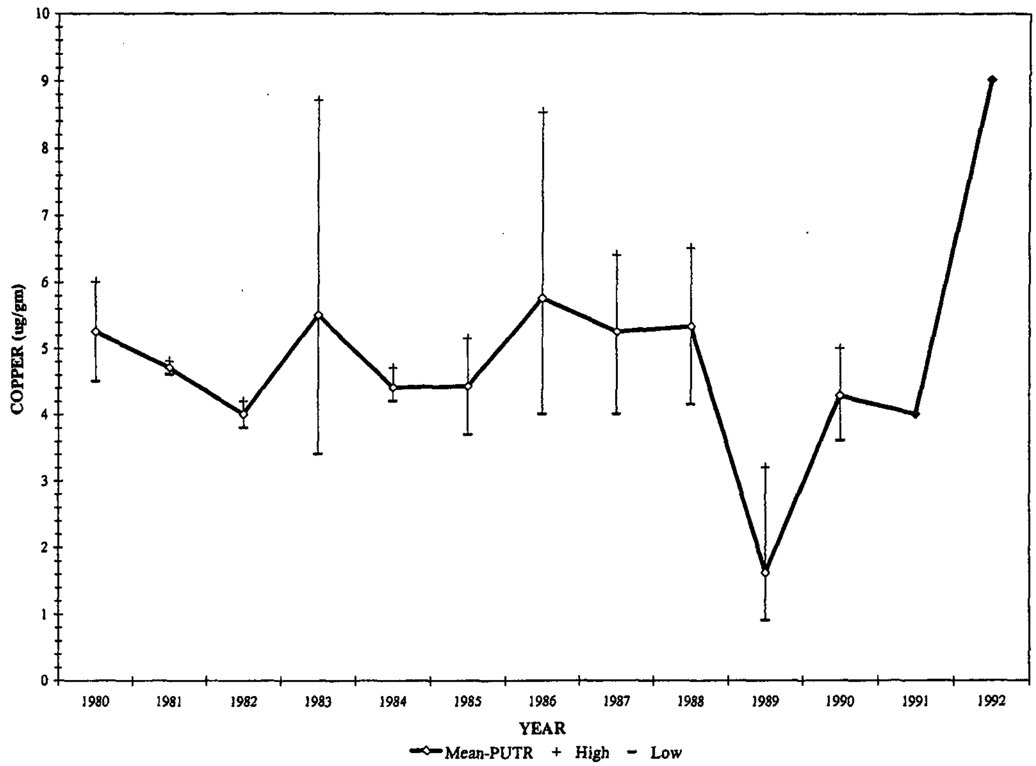


Figure 6-5. Copper in *Purshia tridentata,* 1980-1992

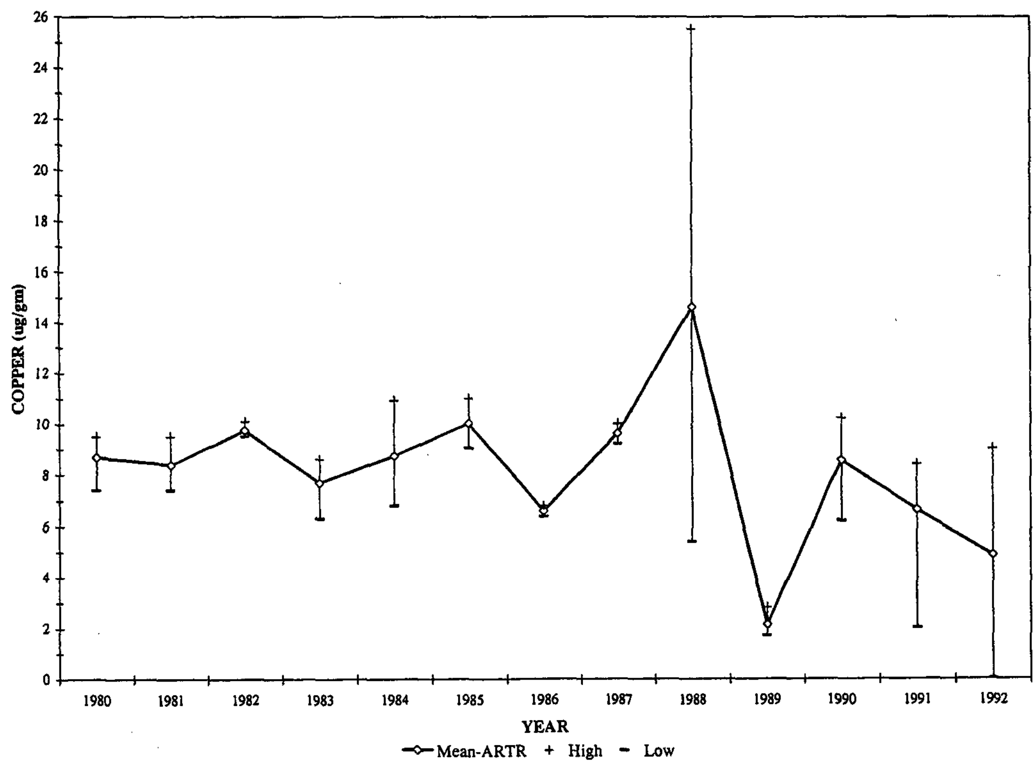


Figure 6-6. Copper in *Artemisia tridentata*, 1980-1992

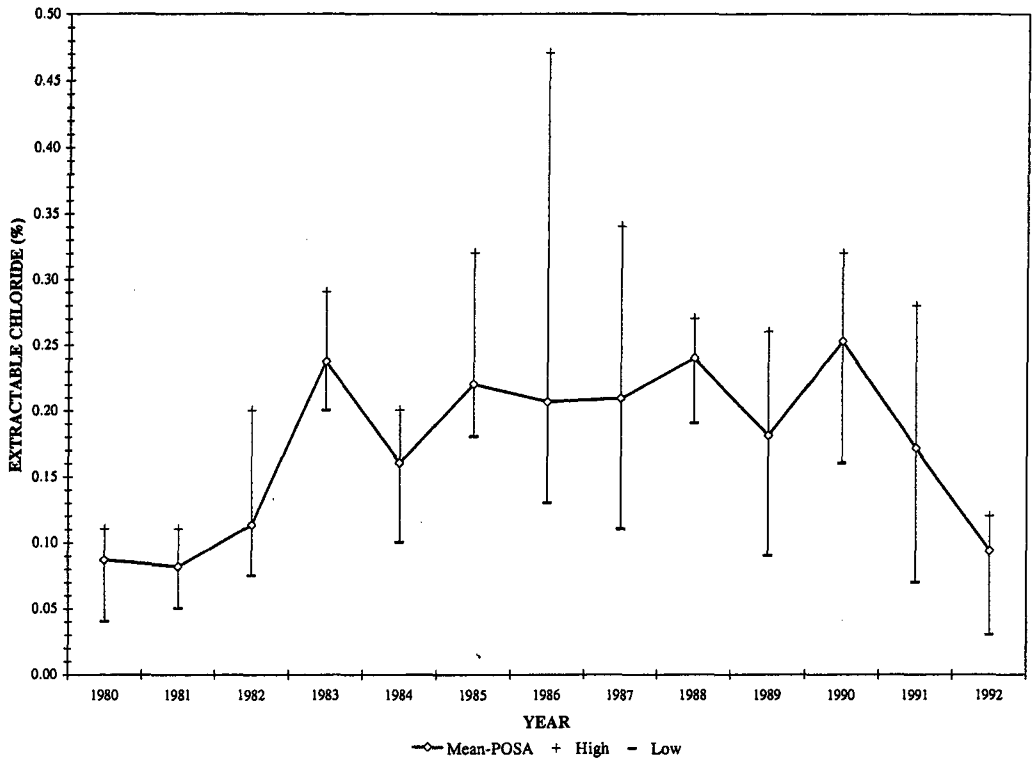


Figure 6-7. Extractable Chloride in *Poa secunda*, 1980-1992

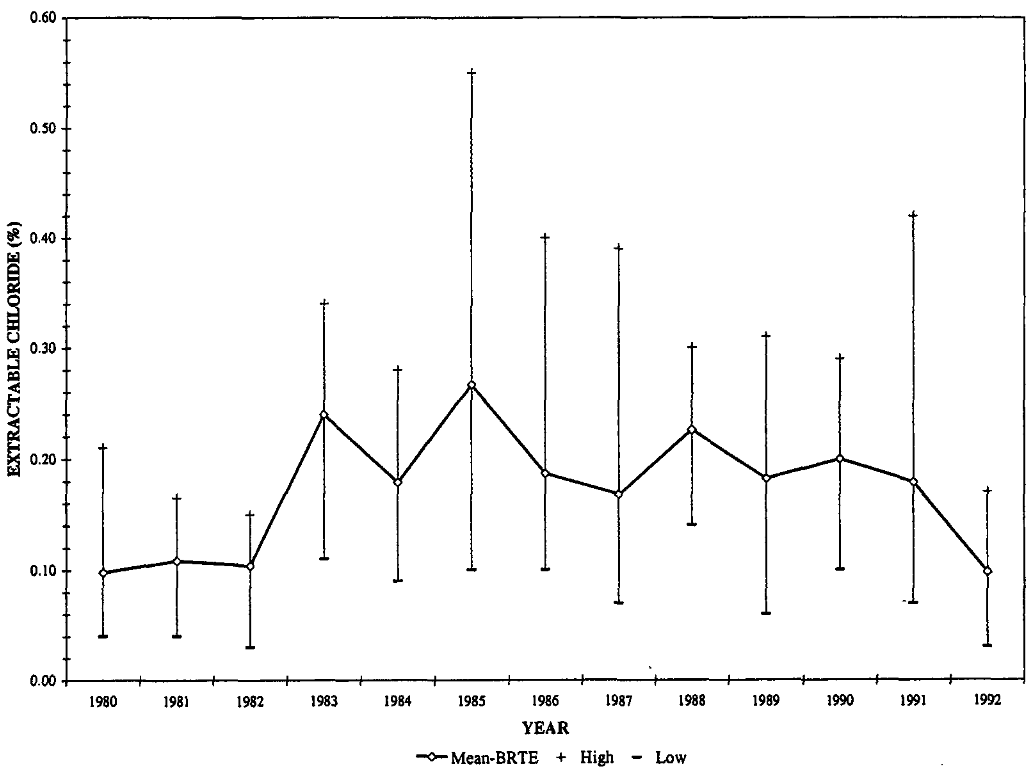


Figure 6-8. Extractable Chloride in *Bromus tectorum*, 1980-1992

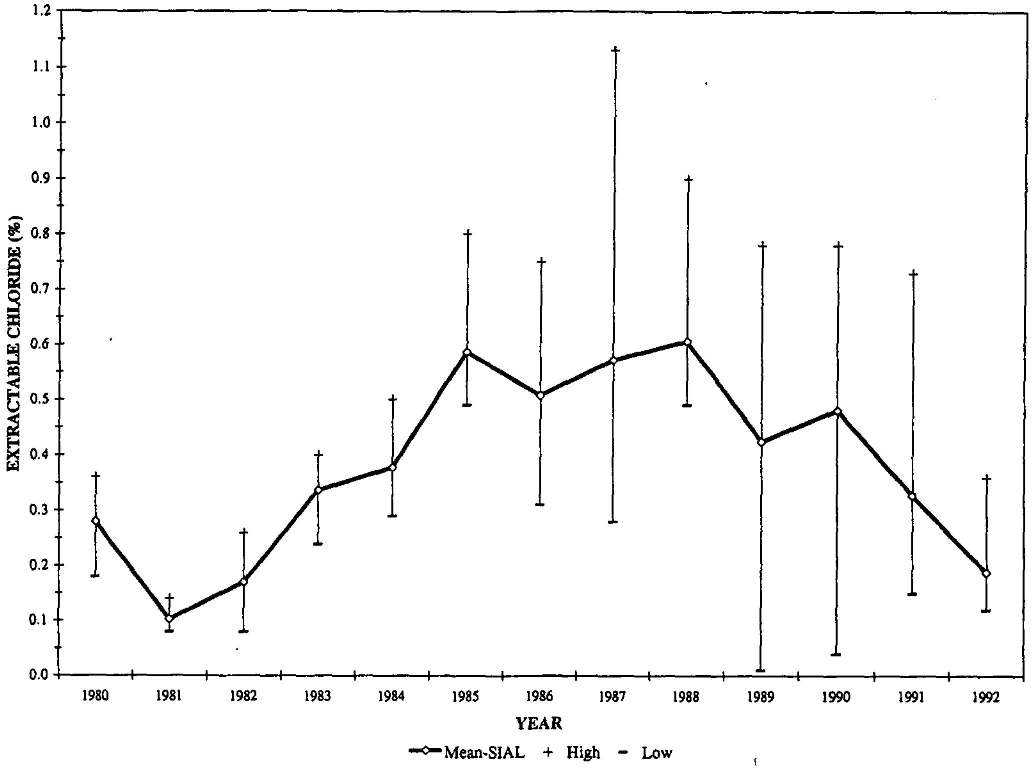


Figure 6-9. Extractable Chloride in *Sisymbrium altissimum*, 1980-1992

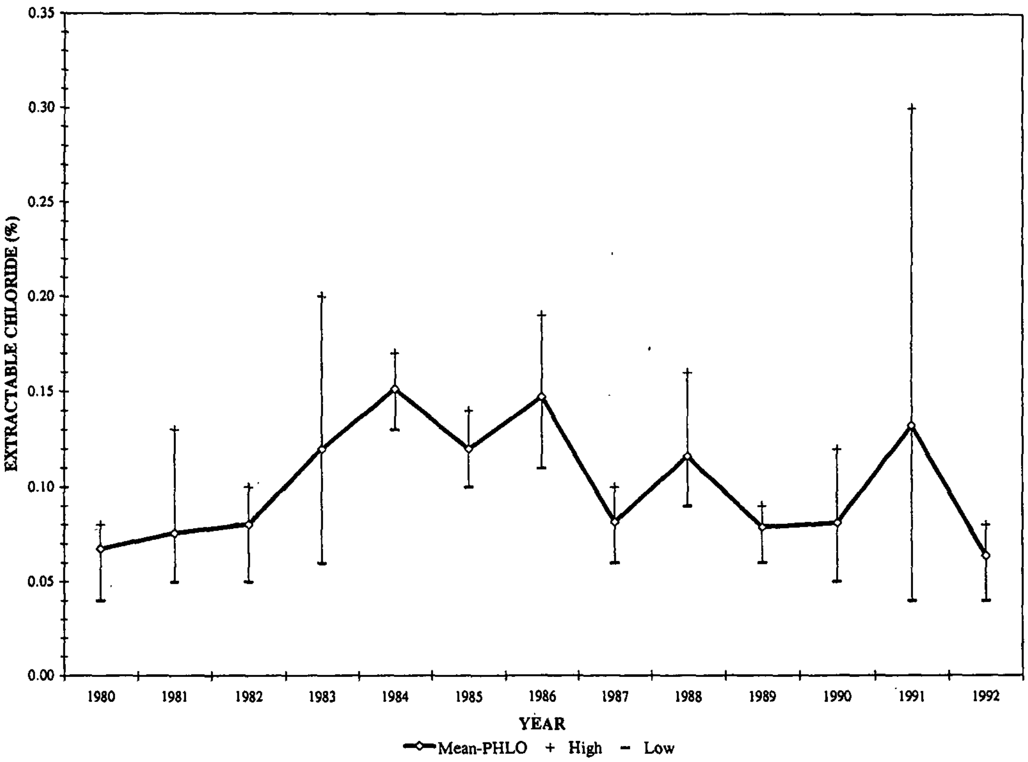


Figure 6-10. Extractable Chloride in *Phlox longifolia*, 1980-1992

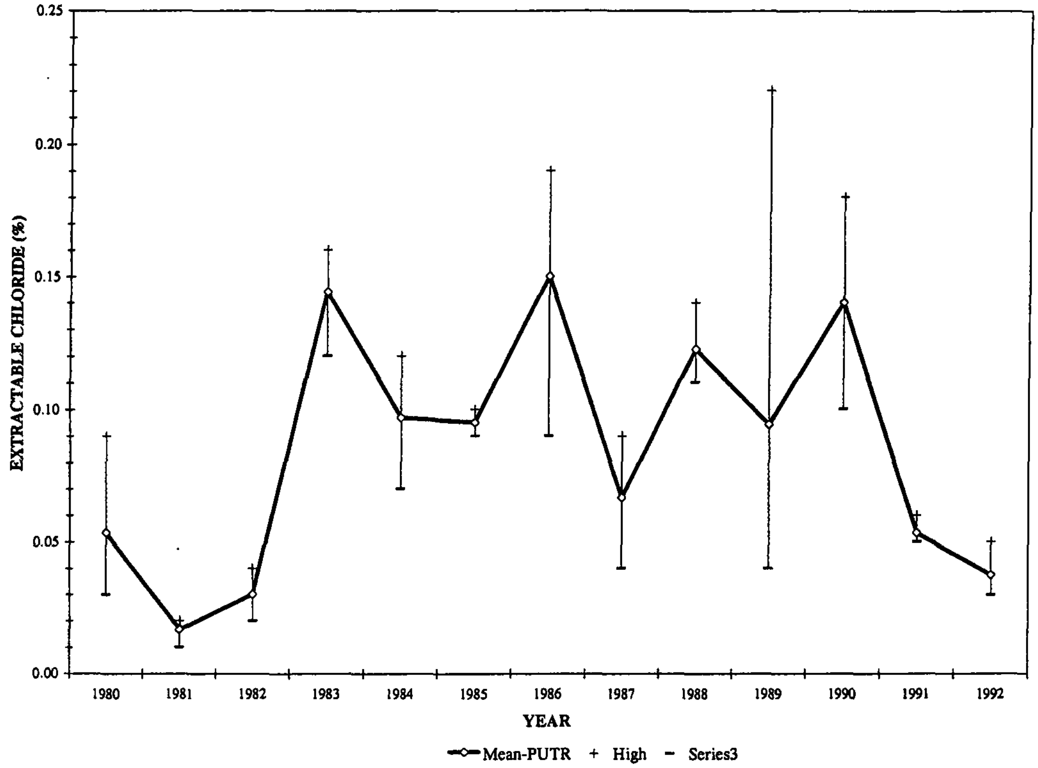


Figure 6-11. Extractable Chloride in *Purshia tridentata*, 1980-1992

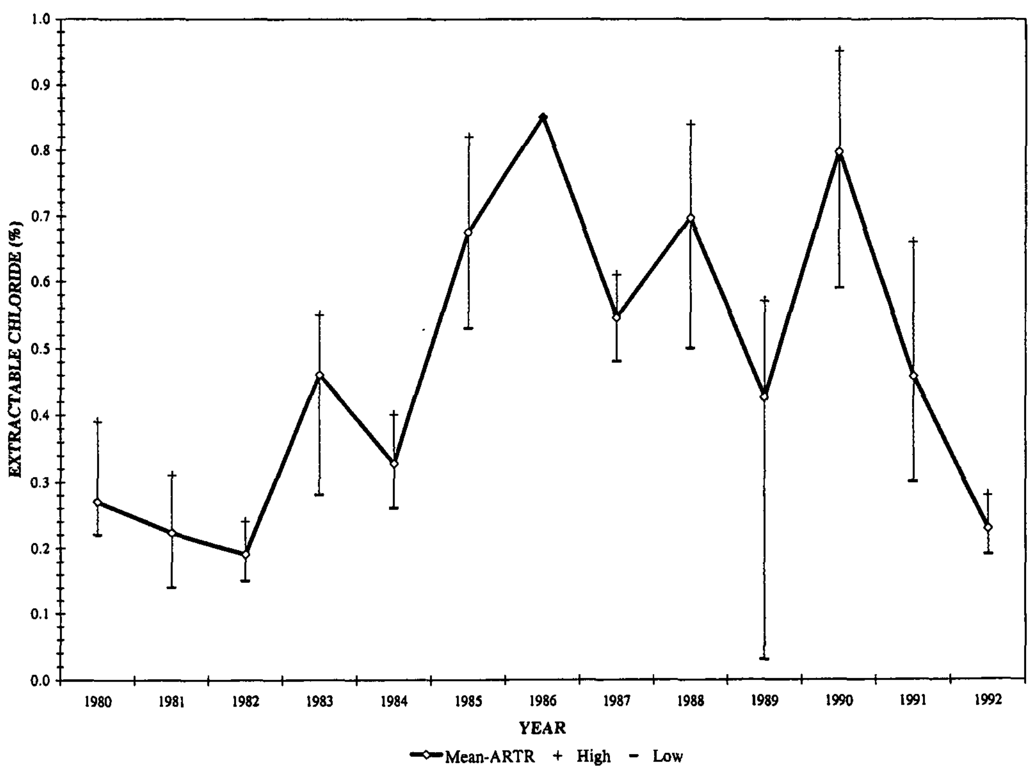


Figure 6-12. Extractable Chloride in *Artemisia tridentata*, 1980-1992

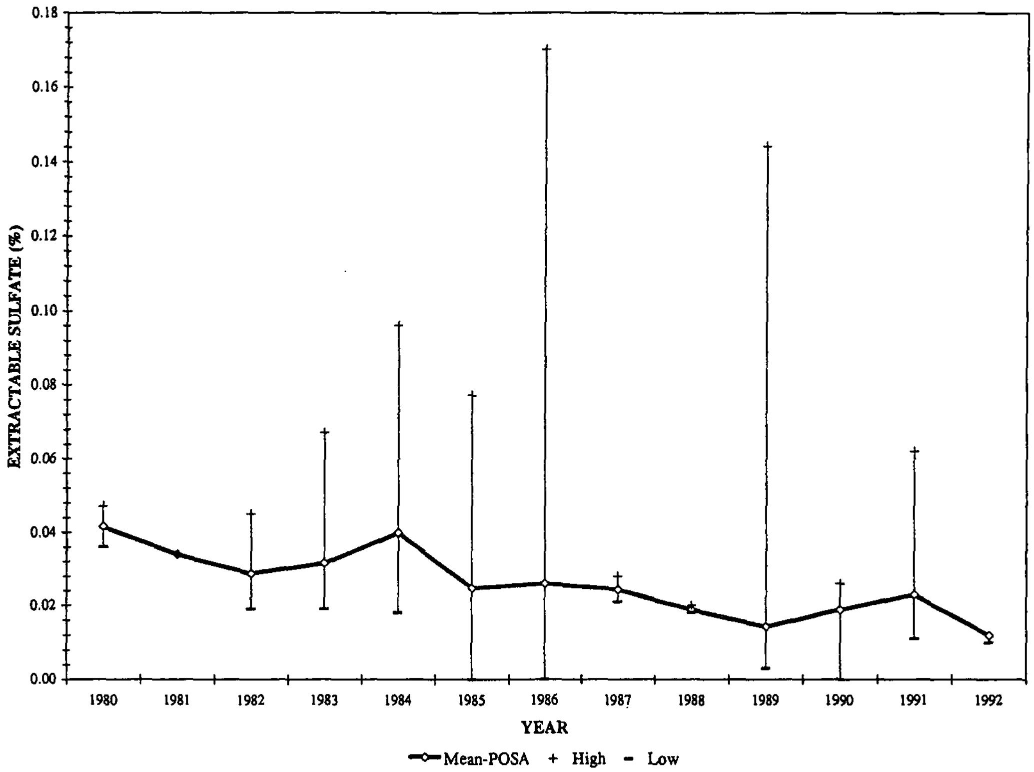


Figure 6-13. Extractable Sulfate in *Poa secunda*, 1980-1992

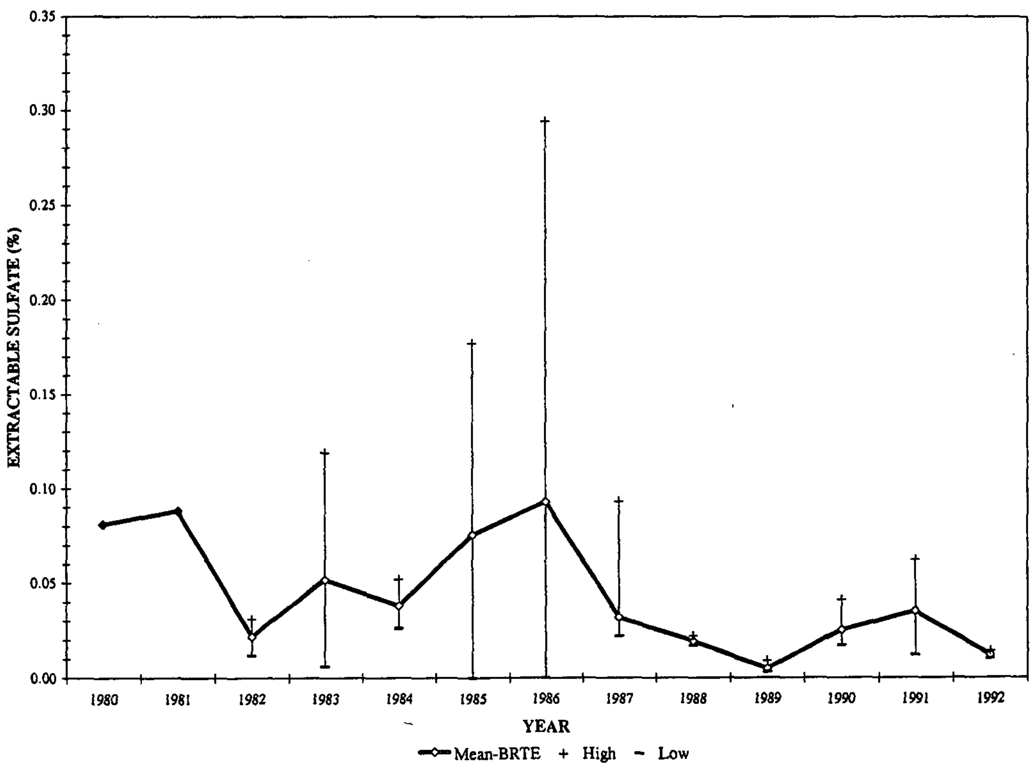


Figure 6-14. Extractable Sulfate in *Bromus tectorum*, 1980-1992

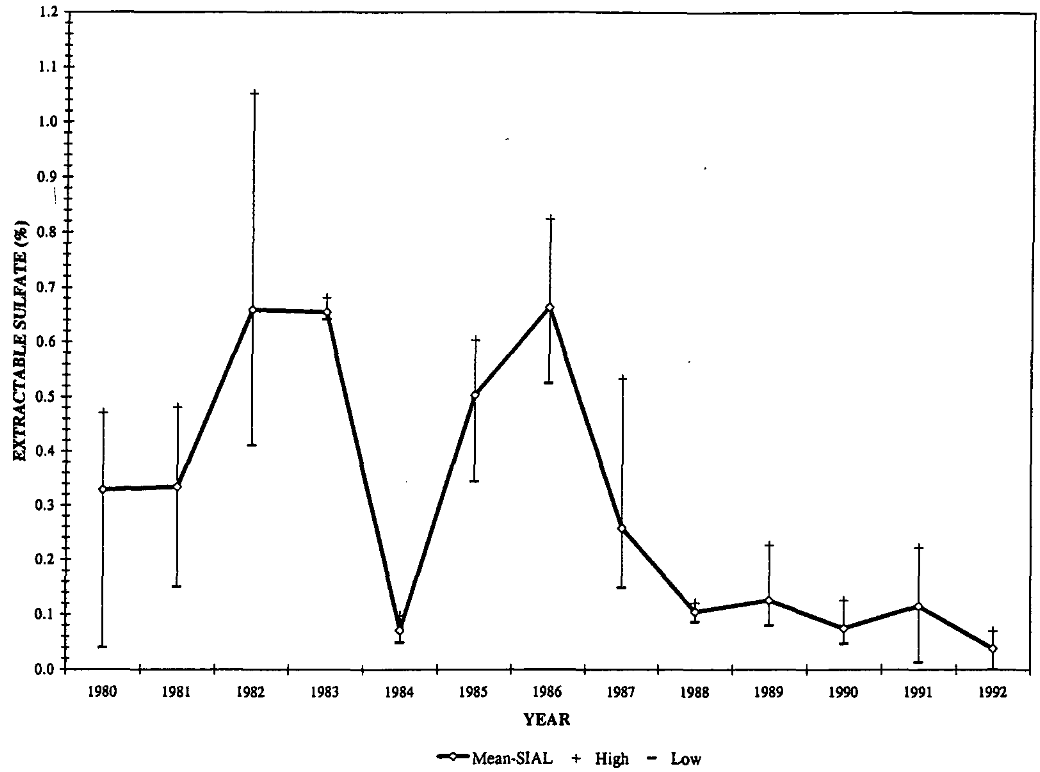


Figure 6-15. Extractable Sulfate in *Sisymbrium altissimum*, 1980-1992

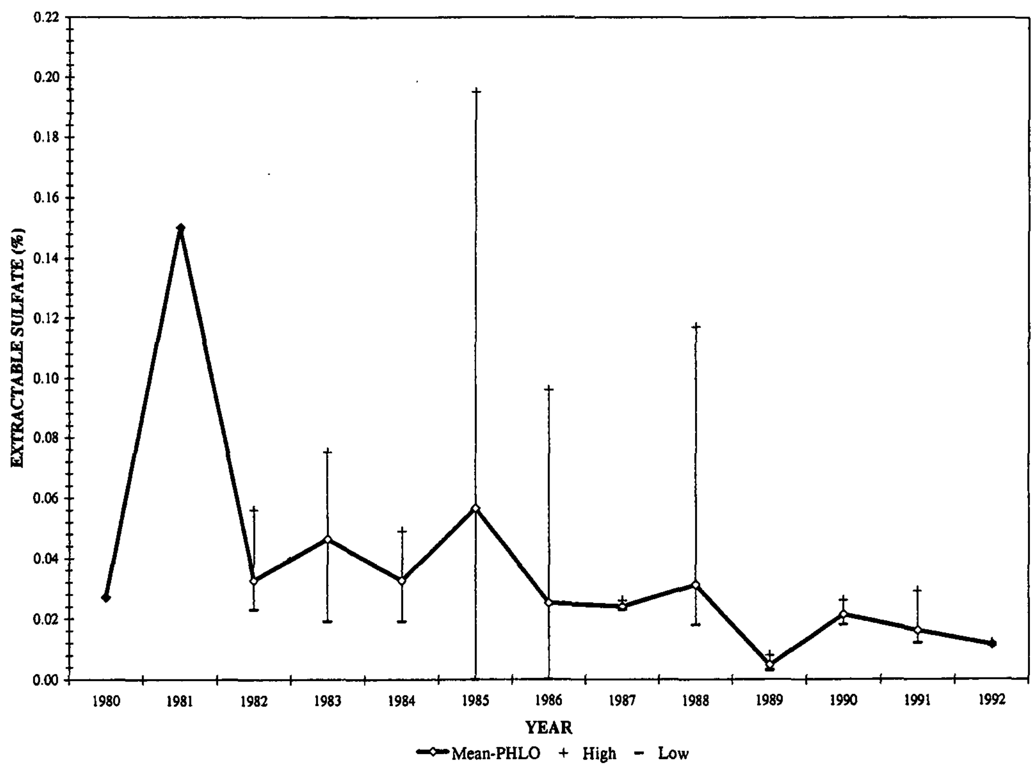


Figure 6-16. Extractable Sulfate in *Phlox longifolia*, 1980-1992

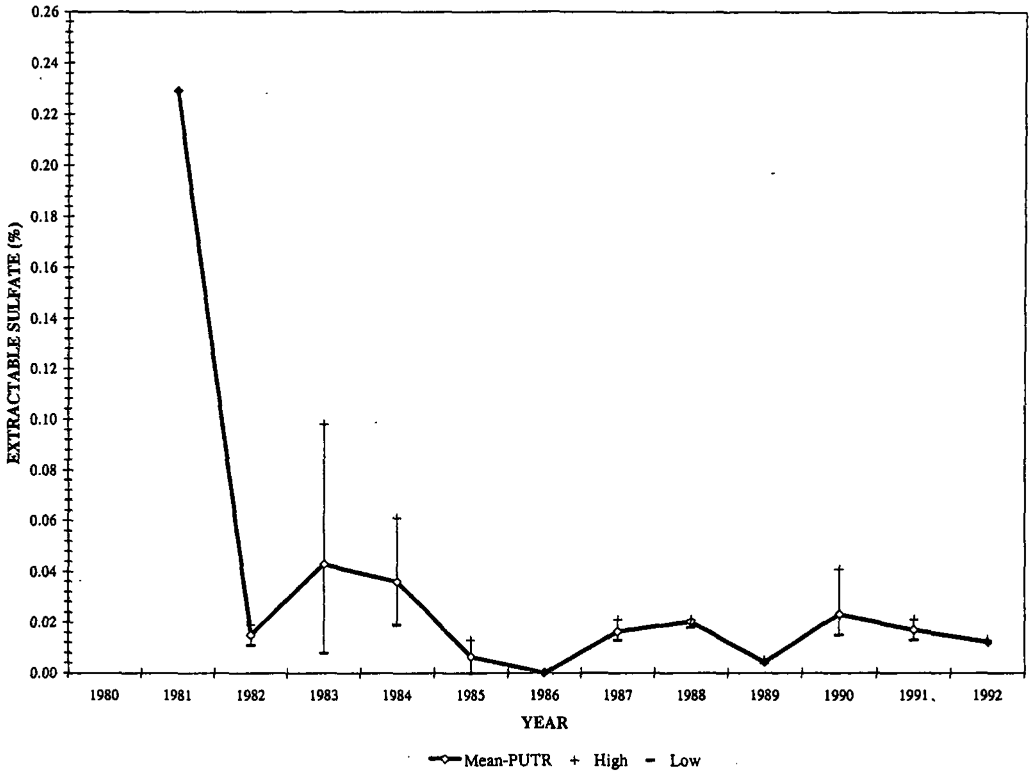


Figure 6-17. Extractable Sulfate in *Purshia tridentata*, 1980-1992

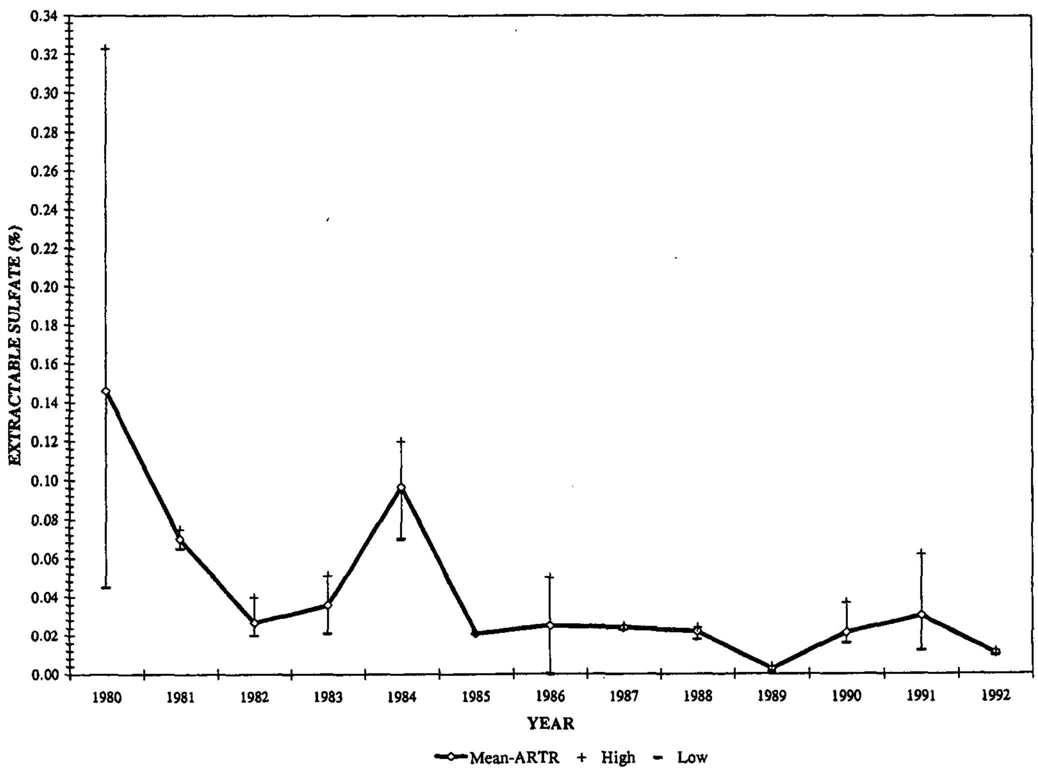


Figure 6-18. Extractable Sulfate in *Artemisia tridentata*, 1980-1992

SECTION 7 AERIAL PHOTOGRAPHY

7.0 AERIAL PHOTOGRAPHY PROGRAM

The aerial photography program was initiated in June of 1988 to monitor the vegetation surrounding Columbia Generating Station 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 vegetation stress before it becomes visible to the human eye. In addition to examination for stress, the photographs were compared with those taken in previous years to look for changes in vegetation patterns and evidence of cumulative damage.

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. Dr. Philip Jackson of the Geosciences Department at Oregon State University performed interpretation of the flightline data.

7.1 Methods and Materials

Five flightlines (Figure 7-1) were planned to cover the areas of greatest anticipated cooling tower drift deposition according to the drift model constructed by Battelle Pacific Northwest Laboratories (Droppo et al., 1976). A sixth high level flightline was added in 1997. Two flightlines (medium 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 prediction 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 flightlines were flown at an altitude of 1,550 feet (477 m) above mean sea level, resulting in a photo scale approximating 1:6000. The high level flightline (only for 1994 and 1997) was flown at an altitude of 5100 feet (1550 m) above mean sea level, with a resulting photo scale of approximately 1:19,000. The flightline coordinates were stored in the long-range navigation (LORAN) system in the photo contractor's airplane. This allowed similar lines to be photographed in subsequent years. The suggestion for a higher altitude flightline at a smaller photo scale resulted from the observation that photo scenes were not accurately repeated from year to year. In this particular study area, strong southwest winds in excess of 30 mph at the flight levels used are common in early summer. Winds of this velocity affect the flightline bearing and, thus, the photo track of the light aircraft used for photo missions. If monitoring sites are to be compared from one flight season to the next, a smaller scale must be used to provide a margin for spatial error. Such a trade-off results in reduced ground detail, but increases the probability of capturing a particular site with photo coverage.

Interpretation and comparison of the color infrared films was conducted visually and with digital image enhancement and analysis equipment. The 70-mm positive transparency film was visually evaluated on a light table, with a 30X magnification stereo viewer. Monitoring sites were digitally scanned with an Eikonix Digital Scanner, and subsequently analyzed with the aid of Idrisi Digital Classification and Signature Comparison software. Factors that affected the accuracy of year-to-year comparisons of vegetation patterns, and plant health and vigor included loss of photo coverage due to flightline misalignment; extreme differences in film contrast; and dissimilar dates of overflight coverage. Year-to-year climatic variability also affected vegetation photo observations as well. Within the Columbia Basin, natural vegetation ground coverage and plant vigor is highly related to soil moisture levels.

Wet years favor enhanced ground coverage by grasses and forbs with generally strong photosynthetic vigor; in dry years, greater expanses of active sand dunes, and sandy soils with weakly photosynthetic and dormant vegetation are more likely to be observed. Precipitation in months preceding overflights was both above and below monthly precipitation norms for the observation years. In 1994, the precipitation total for the growing season of October through April was 2.41 inches, 2 inches below normal. In 1997, precipitation totaled 10.03 inches for the growing season. Thus the vegetation in the flightlines has been observed after the extremes in precipitation.

The photography overflights discussed here, were made annually in the months of April, May, or June from 1988 to 1994, then triennially beginning in 1997. Kodak Aerochrome 2443 Color Infrared positive transparency film was used in a Hassleblad ELM 70-mm camera with a Planar 80mm focal length lens and a No. 12 Wratten haze filter attached. The 70-mm positive transparency film was chosen over the larger nine by nine inch prints for ease of handling and storage for over 300 photo scenes per overflight.

7.2 Results and Discussion

Aerial photos of selected ground sites were scanned using the Eikonix Digital scanner. Each frame was scanned with a red, blue, and green filter to extract multispectral information.

Using the near infrared and red reflectance information, a Normalized Difference Vegetation Index (NDVI) image was created. Actively photosynthetic vegetation strongly reflects near infrared light and absorbs red light. Higher NDVI values indicate greater photosynthetic activity and a greater mass of photosynthetic vegetation. These normalized images allow comparisons both spatially (upwind to downwind sites) and temporally (year to year). This method of interpretation was used on the 1988-1991 results when Dr. Jackson did a reevaluation of those photographs in 1999 and to the photographs taken in 2000.

7.2.1 1988-1991 Results

The overflights were performed on June 14, 1988; May 13, 1989; June 18, 1990; and May 15, 1991. The interpretation by Oregon State University staff of these four years of photographs was performed in July 1999 and confirmed the results in the 1988 to 1991 annual reports (Supply System 1988-1991). Three sites (A, B and E) were evaluated from both 1988 and 1991. Average NDVI output values were evaluated for each of five land cover/vegetation types: dead vegetation, barren areas, weak grasses, healthy grasses and shrubs. The actual average NDVI values were quite comparable for the land cover/vegetation types for all three sites for both 1988 and 1991. NDVI values within a given year showed nearly equal histograms for all three sites. Histogram shape differed only slightly between 1988 and 1991, with the 1991 sites showing a greater NDVI variance between shrubs and dead vegetation. A general histogram shift was also noted, with lower values occurring in 1991. In each case, the specific order of NDVI values were retained, with dead vegetation producing the lowest values, while shrubs maintained the highest values. The lone exception was Site B in 1991, which had some shrubs that fell into the dead vegetation category.

7.2.2 1992 Results

The 1992 overflights were taken on April 23 and were compared with the photos taken in 1991. Overall, vegetative patterns appeared to be unchanged from the 1991 overflights. However, no clear distinctions could be made due to the poor quality of the 1991 photographs. Comparisons of the upwind and downwind sites revealed no significant differences in the vegetative cover characteristics and no significant vegetative health differences existed.

7.2.3 1993 Results

The 1993 overflights took place on May 17. Photosynthetic reflectance characteristics for range plants and plant associations were compared temporally, from 1992 to 1993, and spatially, from downwind to upwind sites. The interpretation showed no spatially significant vegetative health differences relative to photosynthetic activity (PSA). That is, comparable plant associations in downwind sites appeared to have similar reflectance properties as plant associations in upwind sites. Noticeable differences in overall PSA were observed between 1992 and 1993, but is likely attributable to a later photo acquisition date rather than cooling tower precipitate.

7.2.4 1994 Results

The aerial photographs for 1994 were taken on May 5. The area surrounding the plant had already encountered its peak PSA values for the year and the values were declining. Contrast of the film was poor and made interpretation difficult. Upon visual inspection, the overall pattern of spectral reflectance seemed considerably different between 1993 and 1994. There was a generally lower range of reflectance values for photosynthesizing vegetation, which was influenced by two factors, one of which was somewhat mitigated by digital image processing. The first factor was that there was an overall shift in photosynthetic values. The second factor was an overall trend downward from the green to blue spectral bands recorded on film due to underexposure. A comparison of the blue band reflectance values shows a 6% decrease in overall light intensity in 1994 from those in 1993. A 6% correction factor added to the 1994 blue light intensity makes the overall reflectance patterns between the red and blue bands similar to that observed in 1993. Red band intensity remained fairly constant from 1993 to 1994. The spatial comparison between sites in 1994 revealed no changes that could be attributed to cooling tower drift.

7.2.5 1997 Results

The overflight for 1997 was conducted on April 25. The photosynthetic reflectance characteristics for range plants and plant associations were compared temporally from 1993 and 1994 to 1997. It was noted that there were differences in the spectral reflectance between the 1994 photographs and the 1997 photographs. These were attributed to the poor contrast noted in the 1994 film and to the later acquisition time in 1994. Overall, no spatially significant vegetation health differences relative to PSA were noted.

7.2.6 2000 Results

The 2000 overflight was conducted on April 10. The photographs were examined digitally and the NDVI used to evaluate the health of the vegetation at two sites. The NDVI evaluation for the two sites peak nearly at the same reflectance values and indicates an abundance of actively growing range grasses. Spatially, no significant vegetation health differences relative to PSA were noted.

7.3 Conclusion

Comparisons of the 1988-2000 aerial photographs show little differences in vegetative patterns. Within years, no significant differences between sites located upwind and downwind of the plant could be determined. Differences noted in the PSA between years are more likely the result of variations in precipitation, as well as the quality of the film and date of photo acquisition. Overall, no vegetative changes attributable to cooling tower drift could be detected on the photographs.

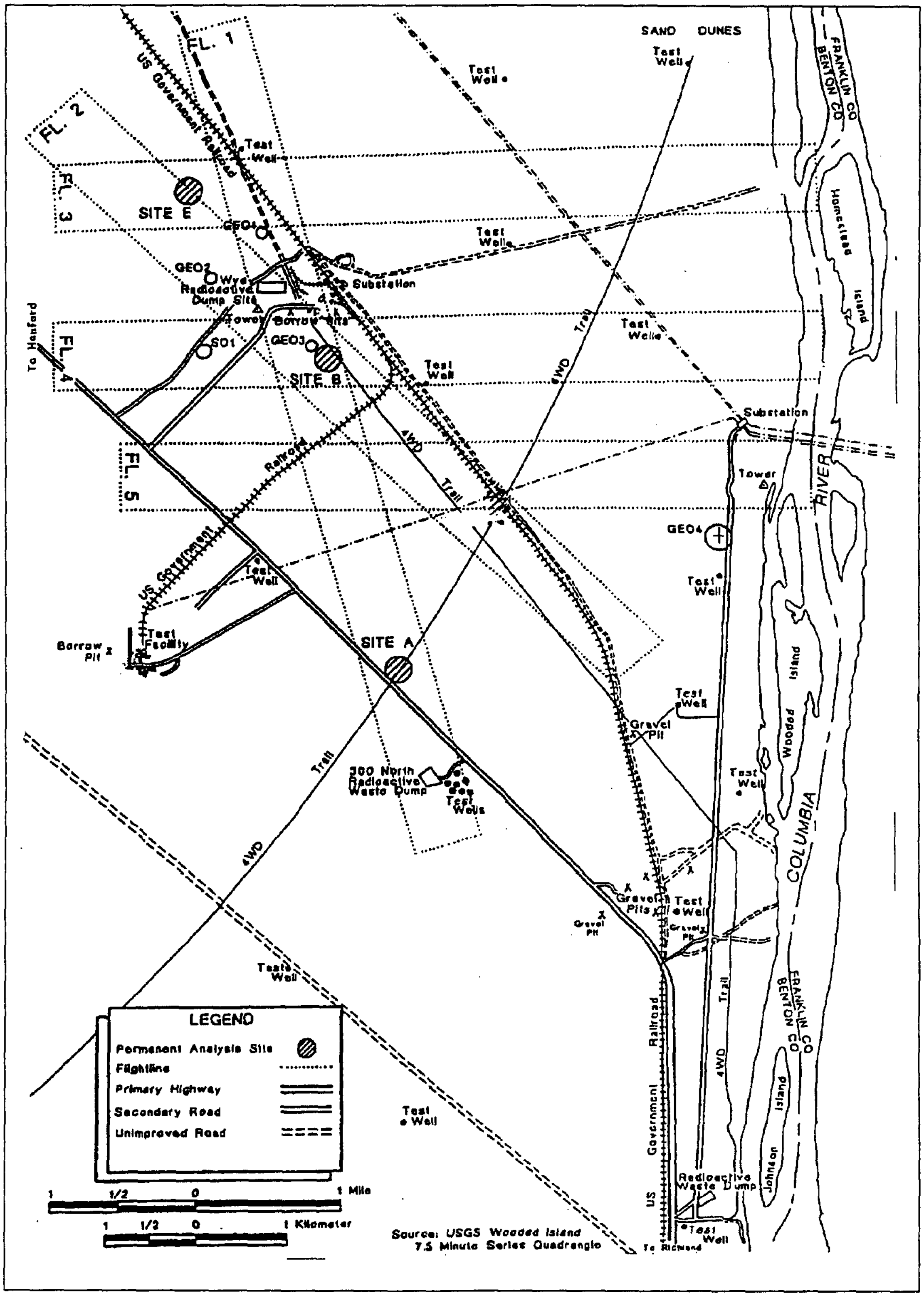


Figure 7-1. Aerial Photography Flightlines

SECTION 8 COOLING TOWER DRIFT DEPOSITION STUDY

8.0 COOLING TOWER DRIFT DEPOSITION STUDY

This study was conducted between 1989 and 1990 to measure the levels and the rate of airborne salt deposition originating from the Columbia Generating Station cooling tower condensate plume. The year-long study was designed to verify the predicted areas of maximum and minimum deposition as modeled by a Battelle Pacific Northwest Laboratories study (Droppo et al, 1976).

The condensate plume is the result of the Columbia Generating Station heat rejection system. This system consists of a steam condenser, six mechanical draft cooling towers, and the interconnecting piping. The operation of the cooling tower fans results in the emission of droplets of circulating cooling water to the atmosphere. The drift droplets are produced mechanically inside the towers and contain similar concentrations of chemicals as the circulating water. The presence of these chemicals in the drift may have an effect upon the environment.

Data gathered for this study involved surface deposition measurements. These measurements were used to determine bulk mineral mass deposition. Sample collection was based upon criteria set forth in the American Standard Test method (ASTM) D1739-70 for the collection and analysis of dust fall.

8.1 Sample Locations

The sample locations were laid out in such a manner as to transect the areas of greatest deposition as predicted in the Battelle model. Sixteen sites were initially included in the study and their locations are shown in Figure 8-1. The sixteen sites included one located at the center of the six cooling towers and one located at the old Hanford townsite that was used as the control. Figures 8-2 and 8-3 graphically represent the deposition patterns from the model as published by Battelle. The directions and approximate distances from the center of the cooling towers are listed in Table 8-1.

Table 8-1. Cooling Tower Drift Study Sample Site Locations

Sample Site #	Distance (miles)	Direction (0° North)	Sample Site #	Distance (miles)	Direction (0° North)
1	3.1	165°	9	0.4	294°
2	2.6	167.5°	10	0.9	306°
3	2.1	170°	11	1.3	312°
4	1.6	172.5°	12	1.8	314°
5	1.2	175°	13	2.4	315°
6	0.7	180°	14	2.8	314°
7	0.2	205°	15	3.4	312°
8	0	-	16*	7	287°

*Control Site

As can be seen in the deposition model, the predicted areas of maximum drift deposition were to the northwest and south-southeast direction from the plant. The sampling sites were chosen to lie along a northwest radial transect and an approximately south-southeast radial transect.

8.2 Methods and Materials

The sample collection vessel consisted of an open topped linear polyethylene cylinder with vertical sides and a flat bottom. The cylinder was six inches in diameter and eighteen inches high. A support stand positioned the cylinder such that its bottom was eighteen inches above grade. The top of the container was three feet above grade which deviates from the ASTM recommended minimum and maximum heights of eight and fifty feet. This was to more closely monitor drift deposition at the typical height of local vegetation. Positioned above the cylinder was a metal bird ring to prevent interference from birds. A screen covered the cylinder to prevent sample contamination from bird droppings and insects. A pair of samplers was placed at each of the sampling locations. Figure 8-4 shows the configuration of the sampler.

Samples were collected every 30 days when possible. The cylinders were thoroughly washed and rinsed in the laboratory, filled with four liters of deionized water and covered. They were then transported out to the sampling sites and placed in the stands. During the summer months, the water level in the samplers was checked periodically and additional deionized water added to maintain an adequate level. Initially, isopropyl alcohol was added as antifreeze during the winter months, but was discontinued due to its ineffectiveness and to eliminate a potential source of contamination. After 30 days, the samplers were covered and exchanged for clean samplers and transported back to the laboratory. Any evidence of contamination, such as insects or bird droppings was noted and recorded. The total volume of water was measured; a 500-milliliter aliquot taken for analysis and the remaining sample was discarded.

The sample aliquots were analyzed for calcium, magnesium, sodium, sulfate and chloride. The analytical techniques utilized ion chromatography for sulfate and chloride. A Dionex Series 4000I ion chromatograph equipped with an AS4A anion separation column was used. Calcium, magnesium and sodium were analyzed by inductively coupled plasma (ICP) atomic emission techniques using a Perkin-Elmer P40 Model ICP.

The average ion masses for each of the analytes were summed to give a monthly bulk deposition for each of the 16 sampling sites. The 12 monthly depositions for each site were then totaled to give a yearly bulk deposition in milligrams. Based on the surface area of the sampler, the mass was converted to pounds per acre per year. The deposition rates were corrected for background by subtracting the control site deposition rate from the rate of each sample site.

8.3 Results and Discussion

Based on the predicted drift patterns, the greatest deposition was expected to occur adjacent to the cooling towers and to decrease as a function of distance from the towers. This was verified by the sampling program, showing a maximum deposition rate of 52 lbs/acre/year at 0.2 mile south of the towers (Site 7), decreasing to a deposition rate not significantly higher than background at a distance of 3 miles.

The model also predicted deposition rates would increase during the winter months due to higher humidity and lower temperatures that would permit the larger diameter drift droplets to intersect the ground surface. In the winter, the drift falls as wet deposition in more highly concentrated areas while in the summer, drift is more widely dispersed because droplet size is reduced by evaporation. This prediction was verified by the study. As an example, drift accumulated at Site 7 during the months of November, December and January accounted for almost 70 percent of the total drift mass deposited during the twelve-month sampling period. Site 8, located in the center of the towers, had drift deposition during the same three-month period that accounted for almost 60 percent of the total mass accumulated.

For areas of maximum deposition, the model predicted that maximum salt deposition would be directly proportional to the wind direction frequency. From this, and the site-specific wind frequency percentages from 1984-90, one would expect the maximum areas of deposition to be found to the north and southeast of the plant, correlating with the maximum wind direction frequencies of 10.9 percent from the south and 10.6 percent from the northwest. This was in direct contradiction to the isopleths in the model showing the predicted areas of deposition. The isopleths (Figures 8-2 and 8-3) show areas of maximum deposition in a northwesterly and nearly southwesterly direction. The Battelle reports states that, "the maximum wind direction frequency at Columbia Generating Station was 9 percent from the south. The measurement elevation was seven meters (23 feet). At an elevation of 122 meters (400 feet) at the Hanford Meteorological Station, the maximum direction frequency was 20 percent from the northwest." Further investigation confirmed that the isopleths, as originally presented, had been inadvertently rotated a full 180° and, therefore, incorrectly predicted the locations of maximum deposition. Field data from the transformer yard drift study further substantiated this. At the transformer yard, 0.25 miles to the north of the cooling towers, samplers experienced an average rate of 112 lbs/acre for the nine-month period that coincided with the original sample collection. This rate is more than twice the maximum twelve-month rate determined by the samplers placed along the two radial transects.

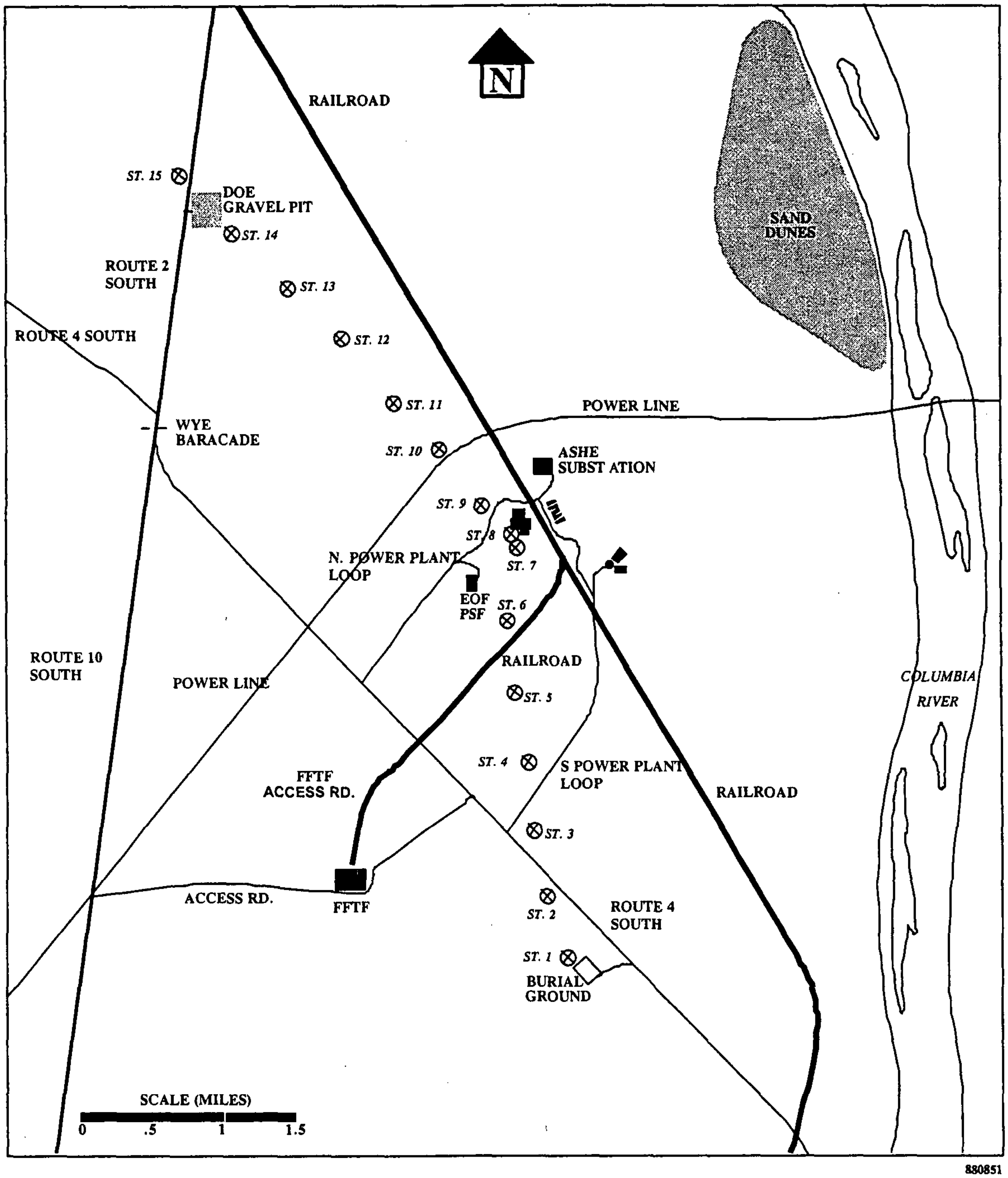
Since the samplers were not placed along transects in line with the directions of maximum deposition, it was difficult to verify the predicted extent of the drift plume, or the distance at which the cooling tower drift deposition is no longer distinguishable from background drift. The isopleths from the model predict that at approximately 0.5 miles from the towers, drift deposition would diminish to a rate of 1 lbs/acre/year. The sampling from that approximate distance determined rates of 8 to 22 lbs/acre/year, significantly higher than that predicted by the model. This indicates that appreciable amounts of drift may be deposited beyond the 0.5-mile radius at higher rates than predicted.

The maximum rates predicted by the model were 400 lbs/acre/year and 300 lbs/acre/year at 0.25 miles from the towers. These estimates are high as compared to the highest rate of deposition determined by the field sampling which was 112 lbs/acre for a nine month period, in the transformer yard 0.25 miles to the north of the towers. The efficiency factor for the drift collectors used was not determined and thus made it difficult to compare the predicted absolute rate with the experimentally determined relative rate of deposition. However, if an efficiency rate of 100 percent is assumed, the measured rates are still within the same order of magnitude as those that were predicted. Sources of error, which may have biased the experimental results, include the fact that only five constituents were analyzed to determine the amount of drift deposited. The plant cooling water system was also operating at reduced cycles of concentration from mid-January 1990 through the end of sampling period because of a condenser tube leak. Consequently, the circulating water dissolved solids concentrations were about half the normal concentration. Drift deposition rates by site is listed in Table 8-2 and shown graphically in Figures 8-5 and 8-6.

Table 8-2. Drift Deposition Rates (Gross and Background Corrected)

Site	lbs/acre-year	Corrected for Background (lbs/acre-year)
1	11	3
2	9	1
3	10	2
4	14	6
5	12	4
6	17	9
7	60	52
8	2998	2990
9	16	8
10	11	3
11	9	1
12	9	1
13	8	0
14	8	0
15	8	0
16	8	*

*Control Site



⊗ SAMPLE LOCATIONS WITH REPLICATE SAMPLES
ST. 16 CONTROL SAMPLE LOCATION AT OLD HANFORD TOWNSITE

Figure 8-1. Cooling Tower Drift Study Sample Sites

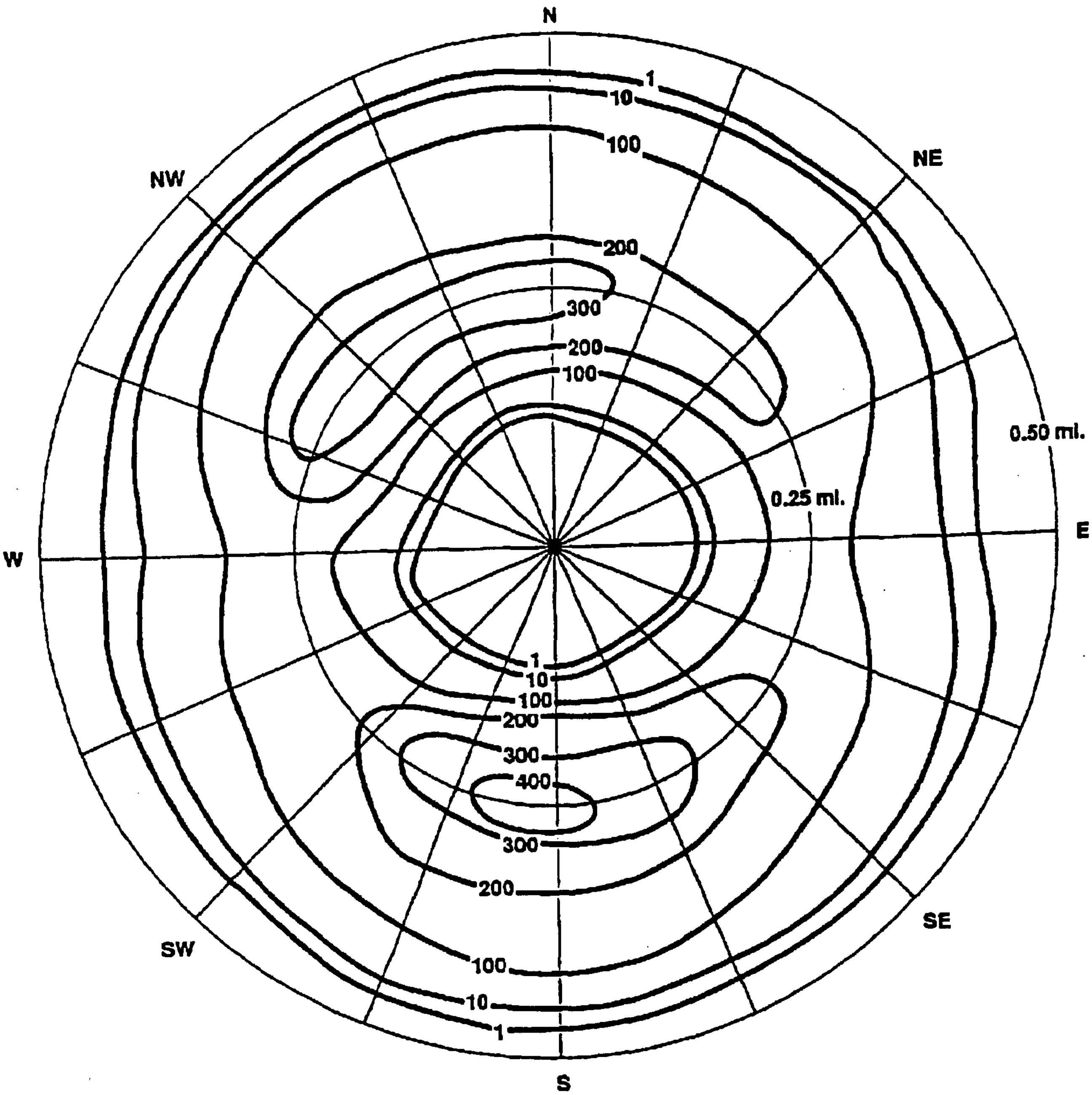


Figure 8-2. Predicted Salt Deposition Patterns out to 0.5 Mile (lbs/acre/yr)

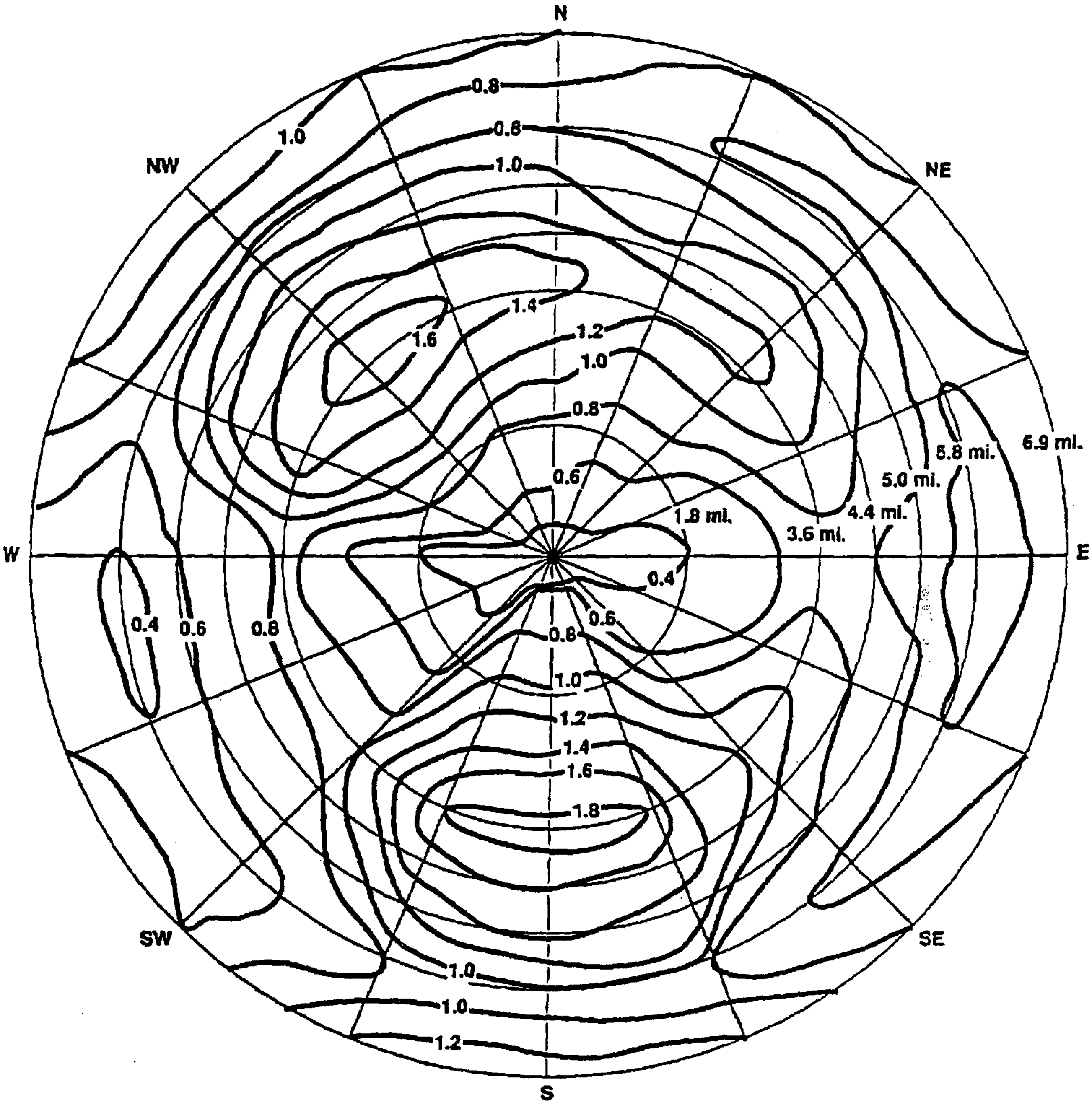


Figure 8-3. Predicted Salt Deposition Patterns out to 6.9 Miles (lbs/acre/yr)

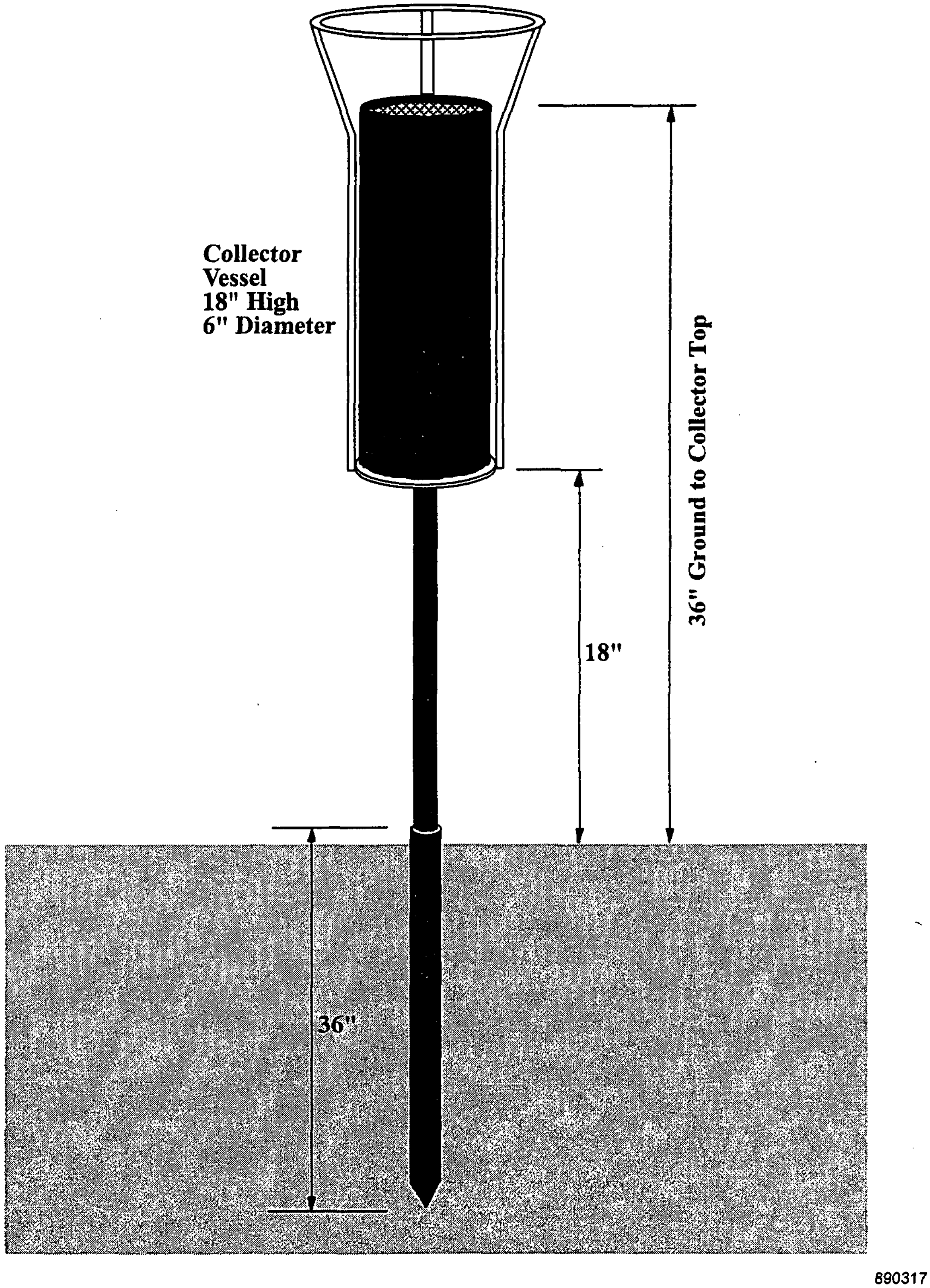


Figure 8-4. Cooling Tower Drift Sampler

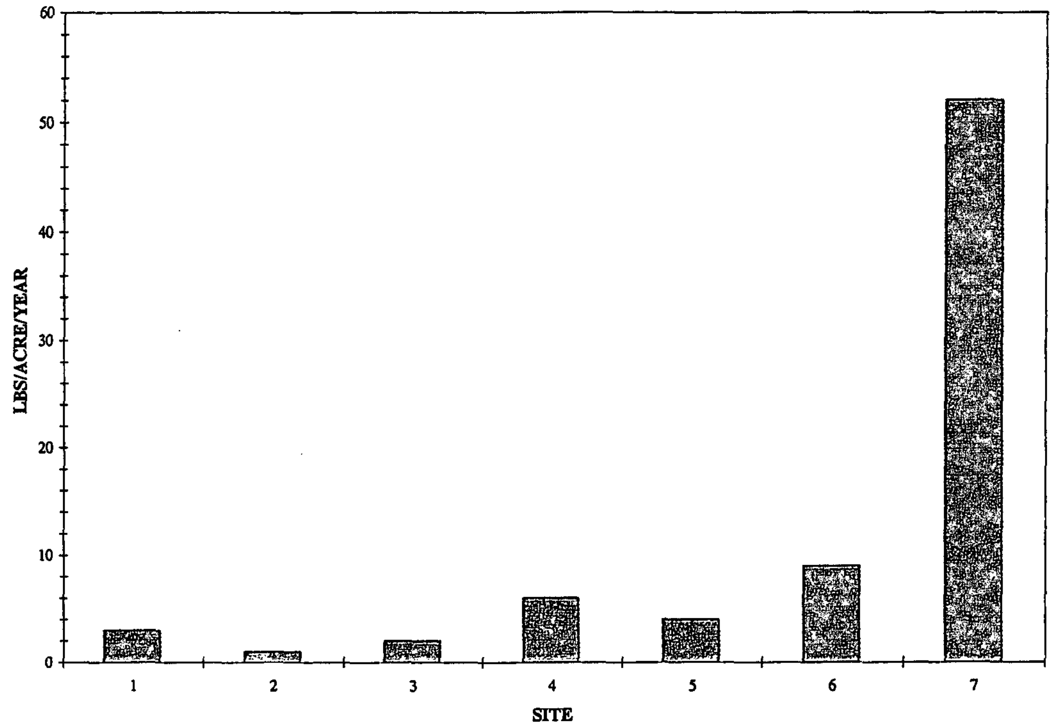


Figure 8-5. Deposition Rate at South Sites

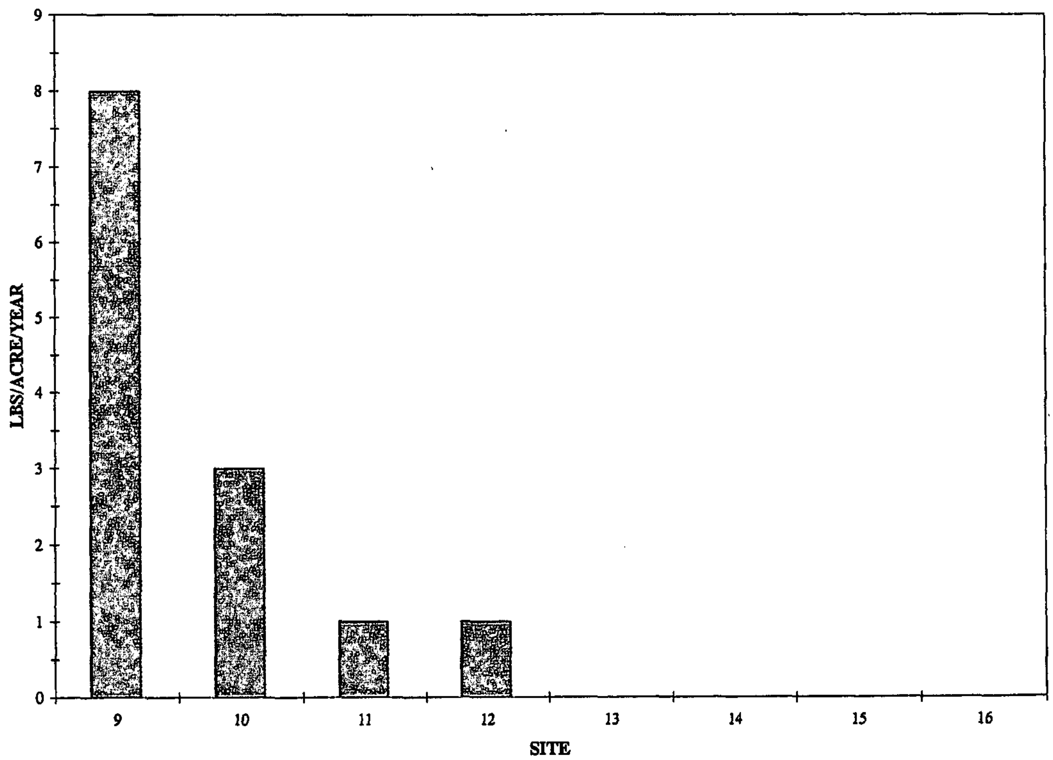


Figure 8-6. Deposition Rate at Northwest Sites

SECTION 9 SUMMARY

9.0 SUMMARY

Analysis of the results from monitoring programs summarized in this report reveals no impact that can be attributed to the operation of Columbia Generating Station. Studies of soil and vegetation chemistry, shrub and vegetation cover, and phytomass suggest that fire and weather have substantially more influence on the surrounding environment than drift from plant cooling towers. This conclusion is corroborated through the aerial photography portion of the monitoring program. Overall, the Ecological Monitoring Program has determined that cooling tower operation has not affected the surrounding plant communities since Columbia Generating Station became operational in 1984.

The analysis of herbaceous cover and phytomass show no measurable direct or secondary effects from cooling tower drift. When the results are plotted against the amount of precipitation or temperature during the growing season (October through April), climate can be seen to have a much greater impact on the environment surrounding the station.

Shrub density and cover were most influenced by the 1984 range fire. Shrub cover declined in 1985 and was showing the beginning of recovery when the study ended in 1992. Shrub density also declined greatly at sites S01, S02 and S04 after the fire. Site S05 had burned in 1981 and was recovering from that fire. There were no effects on shrub density or cover that could be attributed to cooling tower drift.

Herbaceous phytomass results are also related to the climate during the growing season. Periods of low phytomass have occurred during years with low precipitation and below average temperatures. There were no observable trends apparent in the herbaceous phytomass that can be attributed to cooling tower drift.

Soil chemistry was generally consistent between the preoperational and operational periods and annually between sites. The operational period average pH showed a decrease of 0.44 STU from the preoperational period, but displays a general upward trend toward preoperational norms. Sulfate also shows a decrease between the preoperational and operational periods however, results from 1983 and 1984 are closer to those observed during the operational period. The operational average bicarbonate result for all sites increased from the preoperational result, but the individual results for the sites were generally within the ranges seen during the preoperational period. Overall, there is no apparent impact to the soil chemistry from the cooling tower drift.

Copper and extractable chloride results were the most consistent in the vegetation chemistry between the preoperational and operational periods. All species showed a decline in extractable sulfates when compared with the preoperational period, but were generally consistent between sites on an annual basis. There was no apparent effect from cooling tower drift on vegetation chemistry.

The chemical analyses of soil and vegetation performed for the Ecological Monitoring Program revealed no measurable direct or secondary effects caused by the plant's cooling tower drift. The decrease in sulfate in soil and vegetation is contrary to what would be expected from cooling tower operation as the water has a higher level of sulfate in it due to the addition of sulfuric acid for pH control. Other chemical analyses generally remained consistent throughout the studies.

Comparisons of the 1988-2000 aerial photographs show little differences in vegetative patterns. Within years, no significant differences between sites located upwind and downwind of the plant could be discerned. Differences noted in the photosynthetic activity between years are more likely the result of variations in precipitation and temperature, as well as the quality of the film and date of photo acquisition. Overall, no vegetative changes attributable to cooling tower drift could be detected on the photographs.

A year-long cooling tower drift collection study determined that the maximum rate of deposition was less than predicted but within the same order of magnitude. The study confirmed that the greatest deposition occurred adjacent to the cooling towers and decreased as a function of distance from the towers.

SECTION 10 REFERENCES

10.0 REFERENCES

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SECTION 11 ERRATA

11.0 ERRATA

The following errors were noted in the 2000-2001 Operational Ecological Monitoring Program Annual Report. The corrected pages are included.

Page 27, Table 2 "Herbaceous Cover for Fifteen Sampling Sites (%) Observed in 2000". The total annual grass cover mean for sites G01 through S07 should be 47.9% instead of 48.9%.

Page 29, Table 4 "Mean Frequency Values (%) by Species at Each Sampling Site for 2000". Total species per site for G01 should be 7 instead of 6; G07 should be 15 instead of 14; S04 should be 12 instead of 11; S07 should be 8 instead of 7.

Table 11-1. Herbaceous Cover (%) for Fifteen Sampling Sites Observed in 2000 (Corrected)

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07	MEAN G01-S07
Annual Grasses																
Bromus tectorum	69.40	76.55	56.70	23.05	29.65	32.45	50.10	48.35	53.55	16.30	46.70	47.90	55.65	28.70	83.15	47.88
Festuca octoflora	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Total Annual Grass Cover	69.40	76.55	56.70	23.05	29.80	32.60	50.10	48.35	53.55	16.30	46.70	47.90	55.65	28.70	83.15	47.90
Perennial Grasses																
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.20	0.00	0.00	3.00	0.00	0.00	0.88
Oryzopsis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	0.00	0.00	1.70	0.00	0.23
Poa sandbergii	15.75	13.05	2.25	14.20	25.00	2.15	12.65	24.95	13.75	22.20	12.30	15.70	0.35	37.45	5.45	14.48
Stipa comata	0.00	0.00	0.00	24.80	0.00	14.75	0.00	2.00	0.00	2.75	0.00	0.75	0.00	0.00	0.00	3.00
Total Perennial Grass Cover	15.75	13.05	2.25	39.00	25.00	16.90	12.65	26.95	13.75	36.85	12.30	16.45	3.35	39.15	5.45	18.59
Annual Forbs																
Amsinckia lycopsoides	0.10	0.00	2.90	0.20	2.05	0.05	3.00	0.00	1.95	0.10	0.10	0.00	0.95	0.05	0.10	0.77
Cryptantha circumscissa	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	0.00	0.00
Descurainia pinnata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Draba verna	2.85	2.65	3.20	5.20	3.65	4.70	6.40	3.70	3.90	1.65	2.95	5.20	3.50	0.30	0.20	3.34
Franseria acanthicarpa	0.00	0.00	0.10	0.05	0.00	0.00	0.50	0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.05
Gilia sinuata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01
Holosteum umbellatum	2.35	3.50	3.25	6.00	3.10	5.25	8.50	6.15	6.15	3.15	3.95	4.40	6.80	0.25	4.25	4.47
Mentzelia albicaulis	0.00	0.00	0.10	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Microsteris gracilis	0.00	0.55	1.20	0.00	0.05	2.50	0.45	0.05	1.25	0.45	0.70	0.20	1.85	0.00	0.00	0.62
Phacelia linearis	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.04
Plantago patagonica	0.00	0.05	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.05	3.55	0.00	0.25	0.00	0.10	0.29
Salsola kali	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sisymbrium altissimum	0.45	0.35	0.05	0.20	0.10	0.00	1.15	0.45	0.50	0.25	0.60	1.55	0.15	0.15	0.30	0.42
Tragopogon dubius	0.40	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.70	0.10
Total Annual Forb Cover	6.15	7.10	10.80	12.05	9.00	12.50	21.20	10.40	13.75	6.15	11.85	11.80	13.60	0.80	5.65	10.19
Perennial Forbs																
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Aster canescens	0.00	0.00	6.50	0.05	0.00	0.00	1.45	0.00	0.35	2.95	0.00	1.55	0.30	0.35	0.00	0.90
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.02
Balsamorhiza careyana	0.00	0.00	0.00	0.00	0.65	0.30	0.00	0.00	0.00	0.00	0.00	2.90	1.25	0.00	0.00	0.34
Comandra umbellata	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Crepis atrabarba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.02
Cymopterus terebinthinus	0.00	0.00	0.00	0.00	0.00	10.25	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	1.22
Oenothera pallida	0.00	0.00	0.00	0.10	0.00	0.65	0.00	0.00	0.75	0.00	0.00	0.00	0.30	0.00	0.00	0.12
Phlox longifolia	0.00	0.00	0.00	0.05	0.00	0.00	0.45	0.40	0.05	0.00	0.05	0.00	0.00	0.00	0.00	0.07
Rumex venosus	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total Perennial Forb Cover	0.00	0.00	6.50	0.20	1.00	11.20	3.20	0.50	1.15	10.95	0.40	4.75	1.85	0.35	0.00	2.80
Total Herbaceous Cover	91.30	96.70	76.25	74.30	64.80	73.20	87.15	86.20	82.20	70.25	71.25	80.90	74.45	69.00	94.25	79.48

Table 11-2. Mean Frequency Values (%) by Species at Each Sampling Site for 2000 (Corrected)

	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	76	100	96	100	96	100
Festuca octoflora					6	6									
Perennial Grasses															
Agropyron spicatum										26			14		
Oryzopsis hymenoides										2				10	
Poa sandbergii	94	100	12	90	80	26	54	74	58	52	90	54	4	78	50
Stipa comata				78		44		12		6		2			
Annual Forbs															
Amsinckia lycopsoides	4		32	8	14	2	50		30	4	4		18	2	4
Cryptantha circumscissa										2					
Descurainia pinnata														2	
Draba verna	94	96	98	98	96	98	96	98	96	36	98	98	80	12	8
Franseria acanthicarpa			4	2			20	2				4			
Gilia sinuata													4		
Holosteum umbellatum	84	100	100	100	94	100	100	96	96	56	98	96	92	10	80
Mentzelia albicaulis			4				6								
Microsteris gracilis		12	18		2	60	8	2	20	8	18	8	24		
Phacelia linearis				2	2					18					
Plantago patagonica		2		14						2	82		10		4
Salsola kali							2								
Sisymbrium altissimum	8	4	2	8	4		8	18	10	10	24	42	6	6	12
Tragopogon dubius	6						2					4			8
Perennial Forbs															
Achillea millefolium							2								
Aster canescens			48	2			18		4	22		14	2	4	
Astragalus sclerocarpus												2			
Balsamorhiza careyana					6	2						20	2		
Comandra umbellata					4										
Crepis atrabarba											4				
Cymopterus terebinthinus						24				18					
Oenothera pallida				4		6			2				2		
Phlox longifolia				2			8	6	2		2				
Rumex venosus							2	4							
Total Species per Site	7	7	10	13	11	11	15	10	10	15	10	12	13	9	8

APPENDIX A 2002 TERRESTRIAL RESULTS

A. 2002 TERRESTRIAL MONITORING PROGRAM

Sampling of soil and vegetation for 2002 was done from May 13 to May 23. The samples for 2002 were collected beginning on May 2 and completing on May 10. During the 2002 season, 62 plant taxa were observed in the study areas. Plants observed during 2002 are presented in Table A-1.

A.1 Herbaceous Cover

Total herbaceous cover averaged 74.5% in 2002, compared to the 2001 average of 86.6%. *Bromus tectorum* continues to be the dominant annual grass with an average cover of 42.4% in 2002. The average cover for *Bromus tectorum* during 2001 was 56.8%. *Vulpia octoflora* continued to have a negligible contribution to the total annual grass cover. The total perennial grass cover in 2002 was 21%, compared to the 17% cover in 2001 . The dominant perennial grass was *Poa secunda*, which increased from an average cover of 13.1% in 2001 to 17.6% in 2002. Total cover for annual forbs was 5.9% in 2001 and 8.6% in 2002. Perennial forb cover for 2001 was 1.8% in 2001 and 2.2% in 2002. Total cover in 2002 for each site is shown in Table A-2.

Bromus tectorum, Poa secunda, Draba verna and *Holosteum umbellatum* were present in all 15 of the sample sites during 2002. The percent frequency in 2002 for *Bromus tectorum* increased at site G04 decreased at sites G02, G05, G07, S01, S02, S04 and S06 compared to the 2001 values. During 2002 *Poa secunda* percent frequency increased at twelve sites and decreased at two sites when compared to 2001. Only S05 remained the same between the 2001 and 2002. *Draba verna* frequency increased at nine sites during 2002. *Holosteum umbellatum* increased over the previous year at all sites except G03, G07, and S02.

Twenty-nine species were observed within the plots during 2002, the same amount as observed in 2000. The number of species observed during 2002 decreased at eight of the sample sites and increased at four sites when compared to 2001 data. The greatest decrease occurred at G07, which had eleven species observed in 2001 and seven species in 2002. Site S02 increased by two species. Table A-3 shows the mean frequency (%) values by species for each sample site.

A.2 Herbaceous Phytomass

During 2002, grassland and shrub site herbaceous phytomass production averaged 53 g/m^2 and 54.5 g/m^2 respectively. This is a decrease of 47 g/m^2 from 2001 at the grassland sites and of 36.5 g/m^2 at the shrub sites. The mean herbaceous phytomass in 2002 decreased at all of the sites by an average of 44% from 2001. The largest decrease in 2002 occurred at site G05 where it decreased from 65 g/m^2 to 11 g/m^2, a decrease of 83%. Phytomass at S03 decreased 8%, from 56 g/m^2 in 2001 to 51 g/m^2 in 2000. As with herbaceous cover, herbaceous phytomass shows a relationship with the amount of precipitation and the mean temperature in a growing season. Mean herbaceous phytomass measurement at grassland and shrub sites is summarized in Table A-4.

A.3 Soil Chemistry

Copper concentrations in the 2002 samples at all sites were at levels seen in previous years. Sulfate was higher than seen in prior operational years, but is within levels observed during the preoperational phase of the program. The data was checked and no problems were found with the chemical analyses. The data from 1985 to 2002 for each soil chemistry parameter was grouped by site type and as upwind or downwind of the plant. The upwind sites, as determined by the long-term meteorological data were G02, G05, G08, S01, and S03. The mean and standard deviation for each year and site type was calculated and the data compared. Results between upwind and downwind sites showed no statistical difference over the years. The difference noted for sulfate is most likely due to variations caused by weather or other environmental factors rather than caused by cooling tower operation. Soil chemistry results are presented in Table A-5.

A.4 Conclusions

The analysis of the herbaceous cover, phytomass, and soil chemistry shows no measurable direct or secondary effects from the operation of the cooling towers. The concentration of soil sulfate measured in 2002 are within the range observed in the preoperational phase of the program. Other factors, such as climate or range fires, appear to have had a much greater impact on the vegetation in the study area to date.

Table A-1. Vascular Plants Observed During 2002

Scientific Name	**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
Machaeranthera canescens *(Pursh) Gray* (former *Aster canescens*)	Hoary aster
Balsamorhiza careyana Gray	Carey's balsamroot
Ericameria nauseosa (Pallas ex Pursh) (former *Chrysothamnus nauseosus*)	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
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
BRASSICACEAE	Mustard Family
Descurainia pinnata (Walt.) Britt.	Western tansymustard
Draba verna L.	Spring draba
Erysimum asperum (Nutt.) DC.	Prairie rocket
Sisymbrium altissimum L.	Tumblemustard
CACTACEAE	Cactus Family
Opuntia polyacantha Haw.	Starvation cactus

Table A-1. Vascular Plants Observed During 2002 (cont.)

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.	Hopsage
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	Blazing-star Family
Mentzelia albicaulis Dougl. Ex Hook.	White-stemmed mentzelia
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach Ex Gray	White-stemmed globe-mallow

Scientific Name	Common Name
ONAGRACEAE	Evening-primrose Family
Oenothera pallida Lindl. var. *pallida*	White-stemmed evening primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat
POACEAE	Grass Family
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron dasystachyum (Hook.) Scribn.	Thick-spiked wheatgrass
Pseudoroegneria spicata (Pursh) A. Löve (former *Agropyron spicatum*)	Bluebunch wheatgrass
Bromus tectorum L.	Cheatgrass
Vulpia octoflora (Walt.) Rydb. (former *Festuca octoflora*).	Six-weeks fescue
Koeleria cristata Pers.	Prairie junegrass
Oryzopsis hymenoides (R&S) Ricker	Indian ricegrass
Poa secunda J.Presl (former *Poa sandbergii*)	Sandberg's bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush squirreltail
Hesperostipa comata (Trin. & Rupr.) (former *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
Eriogonum niveum Dougl.	Snow buckwheat
Rumex venosus Pursh.	Wild begonia

Table A-1. Vascular Plants Observed During 2002 (cont.)

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

Table A-2. Herbaceous Cover (%) for Fifteen Sampling Sites Observed in 2002

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07	MEAN G01-S07
Annual Grasses																
Bromus tectorum	67.15	67.55	34.80	11.20	17.80	27.65	67.85	37.60	47.85	10.05	48.70	34.65	60.95	21.10	80.35	42.35
Vulpia octoflora						5.60										5.60
Total Annual Grass Cover	67.15	67.55	34.80	11.20	17.80	33.25	67.85	37.60	47.85	10.05	48.70	34.65	60.95	21.10	80.35	42.72
Perennial Grasses																
Hesperostipa comata				23.45		3.60		5.20		10.05		0.30				8.52
Oryzopsis hymenoides										2.90				0.70		1.80
Poa secunda	16.90	24.40	4.10	24.50	16.90	6.35	17.15	18.55	19.20	18.45	17.65	26.35	0.60	43.40	8.85	17.56
Pseudoroegneria spicata								0.75		1.85			2.70			1.77
Total Perennial Grass Cover	16.90	24.40	4.10	47.95	16.90	9.95	17.15	24.50	19.20	33.25	17.65	26.65	3.30	44.10	8.85	20.99
Annual Forbs																
Amsinckia lycopsoides	0.10		16.45	0.50	0.85		4.75	0.85	0.75	0.05			1.05	0.05	0.30	2.34
Descurainia pinnata								0.05							0.10	0.08
Draba verna	4.10	2.25	3.90	2.20	2.20	2.85	0.80	2.65	2.25	0.25	1.95	1.75	2.25	0.95	1.00	2.09
Erodium cicutarium				0.05		0.05							0.30	0.05		0.11
Franseria acanthacarpa			0.05									0.10				0.08
Holosteum umbellatum	3.95	4.25	5.90	2.20	3.20	3.95	15.25	5.30	4.80	0.90	2.85	4.75	3.75	0.25	3.90	4.35
Mentzelia albicaulis										0.30			0.30			0.30
Microsteris gracilis		0.05							0.05				0.40			0.17
Phacelia linearis					0.05					0.05						0.05
Plantago patagonica		0.05		0.15							1.45		0.05		0.05	0.35
Plectritis macrocera											0.05					0.05
Sisymbrium altissimum		0.05			0.10			0.35	0.10		0.40	1.40			0.05	0.35
Tragopogon dubius	0.05							0.05				0.05			0.15	0.08
Total Annual Forb Cover	8.15	6.65	26.30	5.10	6.40	6.85	20.80	9.20	7.95	1.55	6.70	8.00	8.10	1.30	5.40	8.56
Perennial Forbs																
Astragalus sclerocarpus												0.30				0.30
Balsamorhiza careyana					0.05	1.00						4.95	1.05			1.76
Comandra umbellata					0.05						0.05					0.05
Crepis atrabarba											0.35					0.35
Cymopterus terebinthinus						8.30	0.05			8.20						5.52
Machaeranthera canescens			0.30	0.05						2.55		1.90				1.20
Oenothera pallida			0.30	0.50	0.05	0.60		0.15	0.05	0.05						0.24
Phlox longifolia				0.60	0.30	0.25	0.05	0.10			0.60	0.30				0.31
Psoralea lanceolata						0.10										0.10
Rumex venosus								0.15								0.15
Total Perennial Forb Cover	0.00	0.00	0.60	1.15	0.45	10.25	0.10	0.40	0.05	10.80	1.00	7.45	1.05	0.00	0.00	2.22
Total Herbaceous Cover	92.20	98.60	65.80	65.40	41.55	60.30	105.90	71.70	75.05	55.65	74.05	76.75	73.40	66.50	94.60	74.50

Table A-3. Mean Frequency Values (%) by Species at Each Sampling Site for 2002

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
Annual Grasses															
Bromus tectorum	100	98	100	100	88	100	96	100	94	44	100	90	100	98	100
Vulpia octoflora						4									
Perennial Grasses															
Hesperostipa comata				88		20		18		26		2			
Oryzopsis hymenoides										10				8	
Poa secunda	94	100	18	96	90	34	72	76	76	48	86	80	4	86	60
Pseudoroegneria spicata								2		6			12		
Annual Forbs															
Amsinckia lycopsoides	4		54	10	14		26	4	20	2			22	2	12
Descurainia pinnata								2							4
Draba verna	88	80	96	88	88	94	30	96	70	10	68	70	80	28	40
Erodium cicutarium				2		2							12	2	
Franseria acanthacarpa			2									4			
Holosteum umbellatum	98	100	96	88	88	98	80	86	92	36	94	90	90	10	66
Mentzelia albicaulis										2			2		
Microsteris gracilis		2							2				6		
Phacelia linearis					2					2					
Plantago patagonica		2		6							28		2		2
Plectritis macrocera											2				
Sisymbrium altissimum		2			4			8	4		6	18			2
Tragopogon dubius	2							2				2			6
Perennial Forbs															
Astragalus sclerocarpus												2			
Balsamorhiza careyana					2	4						16	4		
Comandra umbellata					2						2				
Crepis atrabarba											4				
Cymopterus terebinthinus						26	2			18					
Machaeranthera canescens			12	2						16		8			
Oenothera pallida			2	10	2	4		6	2	2					
Phlox longifolia				4	2	6	2	4			14	2			
Psoralea lanceolata						4									
Rumex venosus								4							
2002 Total Species per Site	6	7	8	11	11	12	7	13	8	13	10	12	11	7	9

Table A-4. Herbaceous Phytomass for 2002

DATE	SITE	PLOT	WT. (g)	WT./m²
5/22/02	G01	12-3	6.8	68
5/22/02	G01	19-7	14.0	140
5/22/02	G01	2-7	3.0	30
5/22/02	G01	36-9	11.0	110
5/22/02	G01	41-9	7.8	78
		AVG	8.5	85.2
		STD	3.7	37.5

DATE	SITE	PLOT	WT. (g)	WT./m²
5/23/02	G02	12-3	5.8	58
5/23/02	G02	19-7	4.8	48
5/23/02	G02	2-7	5.4	54
5/23/02	G02	36-9	5.7	57
5/23/02	G02	41-9	5.5	55
		AVG	5.4	54.4
		STD	0.3	3.5

DATE	SITE	PLOT	WT. (g)	WT./m²
5/22/02	G03	12-3	3.0	30
5/22/02	G03	19-7	5.2	52
5/22/02	G03	2-7	9.9	99
5/22/02	G03	36-9	3.2	32
5/22/02	G03	41-9	2.0	20
		AVG	4.7	46.6
		STD	2.8	28.2

DATE	SITE	PLOT	WT. (g)	WT./m²
5/23/02	G04	12-3	3.2	32
5/23/02	G04	19-7	5.6	56
5/23/02	G04	2-7	6.8	68
5/23/02	G04	36-9	3.9	39
5/23/02	G04	41-9	3.2	32
		AVG	4.5	45.4
		STD	1.4	14.3

DATE	SITE	PLOT	WT. (g)	WT./m²
5/20/02	G05	12-3	1.3	13
5/20/02	G05	19-7	0.5	4.6
5/20/02	G05	2-7	1.7	17
5/20/02	G05	36-9	1.1	11
5/20/02	G05	41-9	1.0	9.8
		AVG	1.1	11.1
		STD	0.4	4.1

DATE	SITE	PLOT	WT. (g)	WT./m²
5/20/02	G06	12-3	4.0	40
5/20/02	G06	19-7	7.8	78
5/20/02	G06	2-7	3.1	31
5/20/02	G06	36-9	6.1	61
5/20/02	G06	41-9	5.0	50
		AVG	5.2	52
		STD	1.6	16.4

DATE	SITE	PLOT	WT. (g)	WT./m²
5/23/02	G07	12-3	4.3	43
5/23/02	G07	19-7	7.6	76
5/23/02	G07	2-7	5.4	54
5/23/02	G07	36-9	13	130
5/23/02	G07	41-9	11	110
		AVG	8.3	82.6
		STD	3.3	32.9

DATE	SITE	PLOT	WT. (g)	WT./m²
5/22/02	G08	12-3	4.4	44
5/22/02	G08	19-7	5.8	58
5/22/02	G08	2-7	4.9	49
5/22/02	G08	36-9	7.1	71
5/22/02	G08	41-9	1.3	13
		AVG	4.7	47
		STD	1.9	19.3

DATE	SITE	PLOT	WT. (g)	WT./m²
5/23/02	S01	12-3	3.3	33
5/23/02	S01	19-7	2.7	27
5/23/02	S01	2-7	8.6	86
5/23/02	S01	36-9	3.6	36
5/23/02	S01	41-9	3.7	37
		AVG	4.4	43.8
		STD	2.1	21.4

DATE	SITE	PLOT	WT. (g)	WT./m²
5/21/02	S02	12-3	3.1	31
5/21/02	S02	19-7	4.6	46
5/21/02	S02	2-7	1.7	17
5/21/02	S02	36-9	3.2	32
5/21/02	S02	41-9	6.5	65
		AVG	3.8	38.2
		STD	1.6	16.2

DATE	SITE	PLOT	WT. (g)	WT./m²
5/23/02	S03	12-3	4.6	46
5/23/02	S03	19-7	4.0	40
5/23/02	S03	2-7	9.4	94
5/23/02	S03	36-9	2.7	27
5/23/02	S03	41-9	4.8	48
		AVG	5.1	51
		STD	2.3	22.7

DATE	SITE	PLOT	WT. (g)	WT./m²
5/20/02	S04	12-3	2.6	26
5/20/02	S04	19-7	11	110
5/20/02	S04	2-7	2.1	21
5/20/02	S04	36-9	3.7	37
5/20/02	S04	41-9	1.6	16
		AVG	4.2	42
		STD	3.5	34.7

DATE	SITE	PLOT	WT. (g)	WT./m²
5/21/02	S05	12-3	8.6	86
5/21/02	S05	19-7	2.3	23
5/21/02	S05	2-7	3.7	37
5/21/02	S05	36-9	2.6	26
5/21/02	S05	41-9	2	20
		AVG	3.8	38.4
		STD	2.4	24.5

DATE	SITE	PLOT	WT. (g)	WT./m²
5/13/02	S06	12-3	2.4	24
5/13/02	S06	19-7	2.5	25
5/13/02	S06	2-7	2.8	28
5/13/02	S06	36-9	2.1	21
5/13/02	S06	41-9	2.3	23
		AVG	2.4	24.2
		STD	0.2	2.3

DATE	SITE	PLOT	WT. (g)	WT./m²
5/13/02	S07	12-3	11	110
5/13/02	S07	19-7	17	170
5/13/02	S07	2-7	18	180
5/13/02	S07	36-9	13	130
5/13/02	S07	41-9	13	130
		AVG	14.4	144
		STD	2.7	26.5

Phytomass Summary

Mean G01-G08 53 g/m²

Mean S01-S07 54.5 g/m²

Table A-5. Summary of Soil Chemistry for 2002

Station/ Parameter	pH	Conductivity (μS/cm)	Sulfate (μg/g)	Chloride (μg/g)	Copper (μg/g)	Zinc (μg/g)	Sodium (μg/g)	Bicarbonate* (meq/HCO_3/g)
G01	6.71	98.5	22	1.95	6.8	34	0.0069	0.0012
G02	6.84	99	26	0.93	7.8	33.5	0.0091	0.0015
G03	6.74	195	34.5	2.35	6.4	32.5	0.0087	0.0013
G04	6.66	54.5	20.5	1.00	6.4	30	0.0108	0.0008
G05	6.96	300	13.5	0.85	7.6	26.5	0.0109	0.0020
G06	6.56	84	11.7	0.64	6.4	27.5	0.0105	0.0008
G07	6.80	220	23	1.85	7.1	33	0.0088	0.0015
G08	6.80	105	21	1.29	7.6	31.5	0.0077	0.0013
S01	6.49	150	19.5	0.94	6.6	31	0.0087	0.0011
S02	7.23	270	19.5	1.01	6.4	21	0.0098	0.0029
S03	6.66	91.5	18	0.85	6.9	33	0.0080	0.0012
S04	6.43	113.5	2.9	2.45	6.6	30	0.0085	0.0011
S05	6.91	95	20	0.78	6.7	27	0.0099	0.0011
S06	7.30	245	16.2	1.19	10.5	54	0.0091	0.0061
S07	7.33	345	2.8	1.35	8.4	29.5	0.0045	0.0076

* All alkalinity was measured as bicarbonate.

Encl. B2

Chasse, James P.

From: Welch, Richard E.
Sent: Tuesday, August 18, 2009 10:01 AM
To: Chasse, James P.
Cc: Northstrom, Terry E.; Schleder, Lana S.
Subject: Avian Species List
Attachments: CGS Avian Species List (Aug09).xls

Jim,

Per your request, Lana Schleder and I searched our collective memory to compile the attached list of birds we have observed in the vicinity of the CGS site over the last 20 years or so. As you know, our operational phase environmental monitoring program did not include proceduralized bird surveys after spring 1987, so our list of sightings comes from observations that are incidental to our other field work. It should be noted that most of the waterfowl and shorebirds included on the list have been sighted along the Columbia River and at the Sanitary Waste Treatment Facility, where the lagoons provide resting/feeding opportunities and limited breeding habitat for a few species.

Rick Welch
Environmental Services
509-377-8324

Birds Sighted on the CGS Site

Common Name	Scientific Name
Passerines	
horned lark	*Eremophila alpestris*
western meadowlark	*Sturnella neglecta*
loggerhead shrike	*Lanius ludovicianus*
black-billed magpie	*Pica pica*
brewer's blackbird	*Euphagus cyanocephalus*
red-winged blackbird	*Agelaius phoeniceus*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
common raven	*Corvus corax*
barn swallow	*Hirundo rustica*
bank swallow	*Riparia riparia*
cliff swallow	*Hirundo pyrrhonota*
white-crowned sparrow	*Zonotrichia leucophrys*
lark sparrow	*Chondestes grammacus*
savannah sparrow	*Passerculus sandwichensis*
house sparrow	*Passer domesticus*
sage sparrow	*Amphispiza belli*
dark-eyed junco	*Junco hyemalis*
eastern kingbird	*Tyrannus tyrannus*
western kingbird	*Tyrannus verticalis*
say's phoebe	*Sayornis saya*
American robin	*Turdus migratorius*
house finch	*Carpodacus mexicanus*
Eurasian starling	*Sturnus vulgaris*
northern flicker	*Colaptes auratus*
common nighthawk	*Chordeiles minor*
Bullock's oriole	*Icterus bullockii*
golden-crowned kinglet	*Regulus satrapa*
brown-headed cowbird	*Molothrus ater*
western tanager	*Piranga ludoviciana*
American crow	*Corvus brachyrhynchos*
mountain chickadee	*Poecile gambeli*
house wren	*Troglodytes aedon*
Raptors	
sharp-shinned hawk	*Accipter striatus*
ferruginous hawk	*Buteo regalis*
Swainson's hawk	*Buteo swainsoni*
red-tailed hawk	*Buteo jamaicensis*
rough-legged hawk	*Buteo lagopus*
bald eagle	*Haliaeetus leucocephalus*
golden eagle	*Aquila chrysaetos*
American kestrel	*Falco sparverius*
northern harrier	*Circus cyaneus*
prairie falcon	*Falco mexicanus*
turkey vulture	*Cathartes aura*
barn owl	*Tyto alba*
great horned owl	*Bubo virginianus*
western screech-owl	*Megascops kennicottii*
burrowing owl	*Athene cunicularia*
osprey	*Pandion haliaetus*

Compiled Aug '09
by RE Welch and LS Schleder

Birds Sighted on the CGS Site

Waterbirds	
great blue heron	*Ardea herodias*
long-billed curlew	*Numenius americanus*
sandhill crane	*Grus canadensis*
common loon	*Gavia immer*
california gull	*Larus californicus*
killdeer	*Charadrius vociferus*
belted kingfisher	*Ceryle alcyon*
great egret	*Ardea alba*
pied-billed grebe	*Podilymbus podiceps*
eared grebe	*Podiceps nigricollis*
western grebe	*Aechmophorus occidentalis*
American white pelican	*Pelecanus erythrorhynchos*
double-crested cormorant	*Phalacrocorax auritus*
green heron	*Butorides virescens*
black-crowned night heron	*Nycticorax nycticorax*
American coot	*Fulica americana*
black-necked stilt	*Himantopus mexicanus*
American avocet	*Recurvirostra americana*
spotted sandpiper	*Actitis macularia*
Wilson's phalarope	*Phalaropus tricolor*
Caspian tern	*Hydroprogne caspia*
Forster's tern	*Sterna forsteri*
lesser yellowlegs	*Tringa flavipes*
Waterfowl	
redhead	*Aythya americana*
mallard	*Anas platyrhynchos*
snow goose	*Chen caerulescens*
canada goose	*Branta canadensis*
tundra swan	*Cygnus columbianus*
American wigeon	*Anas americana*
blue-winged teal	*Anas discors*
cinnamon teal	*Anas cyanoptera*
northern shoveler	*Anas clypeata*
northern pintail	*Anas acuta*
green-winged teal	*Anas carolinensis*
canvasback	*Aythya valisineria*
gadwall	*Anas strepera*
ring-necked duck	*Aythya collaris*
lesser scaup	*Aythya affinis*
bufflehead	*Bucephala albeola*
common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
ruddy duck	*Oxyura jamaicensis*
common merganser	*Mergus merganser*
Upland Gamebirds	
california quail	*Callipepla californica*
ringnecked pheasant	*Phasianus colchicus*
chukar	*Alectoris chukar*
gray partridge	*Perdix perdix*
Doves	
morning dove	*Zenaida macroura*
rock dove	*Columba livia*

Compiled Aug '09
by RE Welch and LS Schleder

Rare Plant and Vegetation Survey of the Columbia River Riparian Zone at the Columbia Generating Station, Richland, WA

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Environmental Solutions
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Introduction

The purpose of this work was to document the vascular plants found in the riparian zone along the Columbia River on property leased by Energy Northwest from the U.S. Department of Energy. Energy Northwest leases approximately 2060 acres on the Hanford Site for the operating Columbia Generating Station and two terminated nuclear power plant projects. The contiguous parcels are a generally rectangular area that is roughly 1.7 km (north-south) by 6.2 km (east-west). The eastern boundary is the Columbia River west shoreline at river mile 352 where the lease area width (north-south) is about 870 meters. Emphasis for a vegetation survey was placed on the riparian zone because this area is most likely to have plant species that are relatively rare.

Methods

The project area (Figure 1) was surveyed on May 29*, June 24*, July 8, and October 7, 2008. The length of the survey is approximately 2.1 km. The survey occurred in the riparian zone that was up to about 90 m from the river's edge depending on the elevation of the river and proximity to the steep riverbank. This included most of the area to the west of the river shoreline, but not all the way to the edge of the upper soil zone or toe of the stabilized sand dunes that form the riverbank. The entire area was surveyed to find all vascular plant species. The survey was done by walking and meandering along the shoreline midway between the shoreline and the toe of the stabilized dunes, and, lastly, along the upper edge of the area nearer the toe of the stabilized dunes. A few areas were densely covered by tumbleweed making it difficult to enter and view the ground.

Most plants were identified in the field; some plants were placed in plastic bags for later identification in the laboratory. Identification was done using Hitchcock and Cronquist (1973) and applying current naming conventions (USDA NRCS, 2008).

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* Assisted by T.E. Northstrom, PhD, Environmental Services Supervisor, Energy Northwest

Figure 1. Survey area along the Columbia River. The road to Energy Northwest's river pumphouse is in the center of the figure. The length of the survey is approximately 2.1 km.

Rare Plant Surveys

Plants of concern (rare and watch list) that may occur on the property are listed in Table 1 and were taken from the Washington Natural Heritage webpage lists for Benton County (http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/bent.html), Franklin County (http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/franklin.html), and from the Washington State Watch List (http://www1.dnr.wa.gov/nhp/refdesk/lists/watch.html). Table 1 does not contain all species possibly occurring in the two counties, but does list those that may occur near the Columbia River and adjacent dry lands.

Table 1. Potential rare and watch list plants that may occur within the survey area.

Scientific Name	**Common Name**	**State Status**	**Federal Status**	**Historic Record**
Ammannia robusta	Grand Redstem	T		
Artemisia lindleyana	Columbia River wormwood	W		
Astragalus misellus var. pauper	Pauper Milk-vetch	S		H
Astragalus sclerocarpus	Woodypod milkvetch	W		
Astragalus succumbens	Columbia milkvetch	W		
Calyptridium roseum	Rosy Pussypaws	T		
Camissonia minor	Small flower Evening primrose	S		
Camissonia pygmaea	Dwarf Evening-primrose	S		
Centunculus minimus	Chaffweed	R1		
Chaenactis douglasii var. glandulosa	Douglas' dustymaiden	W		
Chrysothamnus nauseosus ssp. nanus	Rubber rabbitbrush	W		
Cryptantha leucophaea	Gray Cryptantha	S	SC	
Cryptantha scoparia	Miner's Candle	S		
Cryptantha spiculifera	Snake River Cryptantha	S		
Cuscuta denticulata	Desert Dodder	T		
Cyperus bipartitus	Shining flatsedge	W		
Erigeron piperianus	Piper's Daisy	S		
Gilia leptomeria	Great Basin Gilia	T		
Hierochloe odorata	Common Northern Sweet Grass	R1		H
Hypericum majus	Canadian St. John's-wort	S		
Lipocarpha aristulata	Awned Halfchaff Sedge	T		
Mimulus suksdorfii	Suksdorf's Monkey flower	S		
Nicotiana attenuata	Coyote Tobacco	S		H
Oenothera caespitosa ssp. caespitosa	Cespitose Evening-primrose	S		H
Rorippa columbiae	Persistentsepal Yellowcress	E	SC	
Rotala ramosior	Lowland Toothcup	T		
Spiranthes diluvialis	Ute Ladies' Tresses	E	LT	

Description of Table 1 Codes:

Historic Record:

H indicates most recent sighting in the county is before 1977.

State Status:
State Status of plant species is determined by the Washington Natural Heritage Program. Factors considered include abundance, occurrence patterns, vulnerability, threats, existing protection, and taxonomic distinctness. Categories include:

E = Endangered. In danger of becoming extinct or extirpated from Washington.
T = Threatened. Likely to become endangered in Washington.
S = Sensitive. Vulnerable or declining and could become endangered or threatened in the state.
R1 = Review group 1. Of potential concern but needs more field work to assign another rank.
W = Watch status is assigned to each vascular plant taxon that is more abundant and/or less threatened in Washington than previously assumed. Although the Washington Natural Heritage Program does not focus on these taxa, some information about them is still gathered and stored in our information system.

Federal Status:
Federal Status under the U.S. Endangered Species Act (USESA) as published in the Federal Register:

LT = Listed Threatened. Likely to become endangered.
SC = Species of Concern. An unofficial status; the species appears to be in jeopardy, but insufficient information to support listing.

Plant Survey Results

The sensitive species, *Rotala ramosior, Cyperus bipartitus,* and *Artemisia lindleyana* were found in the survey area (Table 2). *Rotala ramosior* is a state listed threatened species and *C. bipartitus* is on the state watch list along with *A. lindleyana* (Table 1). *Rotala ramosior* and *C. bipartitus* were found together in fine soils near the water's edge at low flow. They were observed in the October 7 survey near the south end of the survey area (Figure 1) well outside the Energy Northwest lease area. *Artemisia lindleyana* was found closer to the water throughout the survey.

A total of 84 vascular plant species (Table 2) were identified during the survey. Of these, 26 of the plant species are non-native, accounting for 31% of the total.

Table 2. Plants of the Columbia River riparian zone at the Columbia Generating Station. "Code" is the letter plant code as shown on the USDA PLANTS database. "Alien" species that are not native to the area are indicated with an "A."

Code	**Scientific Name**	**Common name/ Synonym**	**Family**	**Alien**
ACMI2	*Achillea millefolium* L.	common yarrow	Asteraceae	
ACRE3	*Acroptilon repens* (L.) DC.	Hardheads; Russian knapweed	Asteraceae	A
AGSC5	*Agrostis scabra* Willd	rough bentgrass	Poaceae	
ALSC	*Allium schoenoprasum* L.	wild chives	Liliaceae	
APCA	*Apocynum cannabinum* L.	Indianhemp	Apocynaceae	
ARCAS5	*Artemisia campestris* L. ssp. *Borealis* (Pall.) H.M. Hall & Clem. var. *scouleriana* (Hook.) Cronquist	field sagewort	Asteraceae	
ARLI2	*Artemisia lindleyana* Besser	Columbia River wormwood	Asteraceae	
ARLU	*Artemisia ludoviciana* Nutt.	white sagebrush	Asteraceae	
ASSP	*Asclepias speciosa* Torr.	showy milkweed	Asclepiadaceae	
ASOF	*Asparagus officinalis* L.	garden asparagus	Liliaceae	A
BRTE	*Bromus tectorum* L.	cheatgrass	Poaceae	A
CADO2	*Carex douglasii* Boott	Douglas' sedge	Cyperaceae	
CEDI3	*Centaurea diffusa* Lam.	diffuse knapweed	Asteraceae	A
CESTM	*Centaurea stoebe* L. ssp. *micranthos* (Gugler) Hayek	spotted knapweed	Asteraceae	A
CHGL13	*Chamaesyce glyptosperma* (Engelm.)	Small ribseed sandmat	Euphorbiaceae	
CHSES	*Chamaesyce serpyllifolia* (Pers.) Small ssp. *serpyllifolia*	thymeleaf sandmat	Euphorbiaceae	
CIIN	*Cichorium intybus* L.	chicory	Asteraceae	A
CIAR4	*Cirsium arvense* (L.) Scop.	Canada thistle	Asteraceae	A
CIUN	*Cirsium undulatum* (Nutt.) Spreng.	wavyleaf thistle	Asteraceae	
COAR4	*Convolvulus arvensis* L.	field bindweed	Convolvulaceae	A
COTIA	*Coreopsis tinctoria* Nutt. var. *atkinsoniana* (Douglas ex Lindl.) H.M. Parker ex E.B. Sm.	Atkinson's tickseed	Asteraceae	
CYDA	*Cynodon dactylon* (L.) Pers.	Bermudagrass	Poaceae	A
CYBI6	*Cyperus bipartitus* Torr.	slender flatsedge	Cyperaceae	
CYER2	*Cyperus erythrorhizos* Muhl.	redroot flatsedge	Cyperaceae	
CYSQ	*Cyperus squarrosus* L.	bearded flatsedge	Cyperaceae	
DRVE2	*Draba verna* L.	spring draba	Brassicaceae	A
ELAC	*Eleocharis acicularis* (L.) Roem. & Schult.	needle spikerush	Cyperaceae	
ELOV	*Eleocharis ovata* (Roth) Roem. & Schult.	ovate spikerush	Cyperaceae	

Code	**Scientific Name**	**Common name/ Synonym**	**Family**	**Alien**
ELPA3	*Eleocharis palustris* (L.) Roem. & Schult.	common spikerush	Cyperaceae	
EQHY	*Equisetum hyemale* L.	scouringrush horsetail	Equisetaceae	
ERNA10	*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird	rubber rabbitbrush	Asteraceae	
ERCO12	*Eriogonum compositum* Douglas ex Benth.	Northern buckwheat	Polygonaceae	
ERNI2	*Eriogonum niveum* Douglas ex Benth.	snow buckwheat	Polygonaceae	
ERCI6	*Erodium cicutarium* (L.) L'Hér. ex Aiton	redstem stork's bill	Geraniaceae	A
EUOC4	*Euthamia occidentalis* Nutt.	western goldentop	Asteraceae	
GAAR	*Gaillardia aristata* Pursh	common gaillardia	Asteraceae	
GNPA	*Gnaphalium palustre* Nutt.	western marsh cudweed	Asteraceae	
GRNE	*Gratiola neglecta* Torr.	clammy hedgehyssop	Scrophulariaceae	
GRCO	*Grindelia columbiana* (Piper) Rydb.	Columbia River gumweed	Asteraceae	
HEAU	*Helenium autumnale* L.	common sneezeweed	Asteraceae	
HYPE	*Hypericum perforatum* L.	common St. Johnswort	Clusiaceae	A
JUAC	*Juncus acuminatus* Michx.	tapertip rush	Juncaceae	
JUTE	*Juncus tenuis* Willd.	poverty rush	Juncaceae	
JUSC2	*Juniperus scopulorum* Sarg.	Rocky Mountain juniper	Cupressaceae	
LOGR	*Lomatium grayi* (J.M. Coult. & Rose) J.M. Coult. & Rose	Gray's biscuitroot	Apiaceae	
LOUNU	*Lotus unifoliolatus* (Hook.) Benth. var. *unifoliolatus*	American bird's-foot trefoil	Fabaceae	
LUPU	*Lupinus pusillus* Pursh	rusty lupine	Fabaceae	
LUSE4	*Lupinus sericeus* Pursh	silky lupine	Fabaceae	
LYAM	*Lycopus americanus* Muhl. ex W. Bartram	American water horehound	Lamiaceae	
MACA2	*Machaeranthera canescens* (Pursh) A. Gray	hoary tansyaster	Asteraceae	
MEOF	*Melilotus officinalis* (L.) Lam.	yellow sweetclover (white flower)	Fabaceae	A
MEAR4	*Mentha arvensis* L.	wild mint	Lamiaceae	
MOAL	*Morus alba* L.	white mulberry	Moraceae	A
MYSP2	*Myriophyllum spicatum* L.	Eurasian watermilfoil	Haloragaceae	A
OEVIS	*Oenothera villosa* Thunb. ssp. *strigosa* (Rydb.) W. Dietr. & P.H. Raven	hairy evening primrose	Onagraceae	
OPPO	*Opuntia polyacantha* Haw.	plains pricklypear	Cactaceae	
PASM	*Pascopyrum smithii* (Rydb.) A. Löve	western wheatgrass	Poaceae	
PHAR3	*Phalaris arundinacea* L.	reed canarygrass	Poaceae	A

Code	**Scientific Name**	**Common name/ Synonym**	**Family**	**Alien**
PLLA	*Plantago lanceolata* L.	narrowleaf plantain	Plantaginaceae	A
POBU	*Poa bulbosa* L.	bulbous bluegrass	Poaceae	A
POCO	*Poa compressa*	Canadian bluegrass	Poaceae	A
POSE	*Poa secunda* J. Presl	Sandberg bluegrass	Poaceae	
	Polygonum sp.	knotweed	Polygonaceae	
POBAT	*Populus balsamifera* L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook) Brayshaw	black cottonwood	Salicaceae	
RIAU	*Ribes aureum* Pursh	golden currant	Grossulariaceae	
ROIS2	*Rorippa islandica* (Oeder) Borbas	Northern marsh yellowcress	Brassicaceae	
ROWO	*Rosa woodsii* Lindl..	Woods' rose	Rosaceae	
RORA	*Rotala ramosior* (L.) Koehne	lowland rotala	Lythraceae	
RUCR	*Rumex crispus* L.	curly dock	Polygonaceae	A
RUSA	*Rumex salicifolius* Weinm.	willow dock	Polygonaceae	
SAEX	*Salix exigua* Nutt.	narrowleaf willow	Salicaceae	
SATR12	*Salsola tragus* L.	prickly Russian thistle	Chenopodiaceae	A
SCTA2	*Schoenoplectus tabernaemontani* (C.C. Gmel.) Palla	softstem bulrush	Cyperaceae	
SEPUP2	*Setaria pumila* (Poir.) Roem. & Schult. ssp. *pumila*	yellow foxtail	Poaceae	A
SIAL2	*Sisymbrium altissimum* L.	tall tumblemustard	Brassicaceae	A
SPCR	*Sporobolus cryptandrus* (Torr.) A. Gray	sand dropseed	Poaceae	
SYCAC	*Symphyotrichum campestre* (Nutt.) G.L. Nesom var. *campestre*	western meadow aster	Asteraceae	
TRDU	*Tragopogon dubius* Scop.	yellow salsify	Asteraceae	A
ULPU	*Ulmus pumila* L.	Siberian elm	Ulmaceae	A
VETH	*Verbascum thapsus* L.	common mullein	Scrophulariaceae	A
VEBR	*Verbena bracteata* Cav. ex Lag. & Rodr.	bigbract verbena	Verbenaceae	
VIAM	*Vicia americana* Muhl. ex Willd.	American vetch	Fabaceae	
XAST	*Xanthium strumarium* L.	rough cocklebur	Asteraceae	

Noxious Weeds

Observed plants that are categorized as noxious weeds are listed in Table 3. Species that are listed as B Designates have prevention of new infestations as the primary goal for Benton County. Class B species are already abundant and control is decided at the local level. Containment of these weeds is the primary goal so that they do not spread into uninfested regions. The Class C status allows a county to enforce control if it is beneficial to that county.

Table 3. Noxious weeds found in the study area. Classes are defined by the Washington State Noxious Weed Control Board (www.nwcb.wa.gov).

Species	**Common name**	**Class**
Acroptilon repens	Hardheads; Russian knapweed	B
Centaurea diffusa	diffuse knapweed	B
Centaurea stoebe	spotted knapweed	B Designate
Cirsium arvense	Canada thistle	C
Convolvulus arvensis	field bindweed	C
Hypericum perforatum	common St. Johnswort	C
Myriophyllum spicatum	Eurasian watermilfoil	B Designate
Phalaris arundinacea	reed canarygrass	C

References

Hitchcock, C.L. and Cronquist, A., 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA, 730 pp.

USDA NRCS, 2008. The PLANTS Database (http://plants.usda.gov), National Plant Data Center, Baton Rouge, LA.

Rare Plant and Vegetation Survey of the Uplands at the Columbia Generating Station, Richland, WA

Steven O. Link, Ph. D.
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Introduction

The purpose of this work was to document all the vascular plants found in the dry upland zone on the property of the Columbia Generating Station. Plants are grouped into native, invasive alien, Federal threatened and endangered, Washington State rare plants, and Washington State noxious weeds. Plant associations were defined to prepare a plant association map of the area. This work complements a 2008 survey of the riparian zone at the Columbia Generating Station (Link 2008).

The site area is located in the shrub-steppe of the south-central Columbia Basin along the Columbia River. The soils are sands to gravels in stabilized dune formations. Much of the site has been disturbed and the vegetation in the disturbed areas is now largely dominated by *Bromus tectorum* and other invasive species. Throughout the site area the vegetative cover is composed of annual grasses, perennial bunchgrasses, forbs, and shrubs.

Methods

The project area (Figure 1) was surveyed on April 23 and 27, May 4 and 22, and June 9, 2009. The area was surveyed to find all vascular plant species. The survey was done by walking and driving along tracks (Figure 1).

A few tracks were not recorded and occurred south of the road on the way to and near the river plus in and around the industrial area with the mothballed infrastructure. A Garmin Etrex Vista HCx was used to record waypoints and tracks. Waypoints were recorded for federally and state recognized species. Pictures were taken of some plants and a number of locations during the survey. These pictures were used to define some plant associations. Waypoints and track location data are recorded in a separate appendix.

Plants were identified in the field and in the laboratory. Some plants were placed in plastic bags for later identification in the laboratory. Identification was done using Hitchcock and Cronquist (1973) and applying current naming conventions (USDA NRCS, 2008). Plant associations were defined after Daubenmire (1970) and NatureServe (2009).

Figure 1. Survey area in the uplands at the Columbian Generating Station, Richland, WA. The road to the river is in the center of the figure. Tracks and waypoints are the dark lines and white points.

Rare Plant Surveys

Plants of concern (rare and watch list) that may occur on the property are listed in Table 1 and were taken from the Washington Natural Heritage Webpage for Benton County list http://www1.dnr.wa.gov/nhp/refdesk/lists/plantsxco/bent.html) and from the Washington State Watch List (http://www1.dnr.wa.gov/nhp/refdesk/lists/watch.html).

Table 1. Potential rare and watch list plants that may occur within the survey area.

Scientific Name	Common Name	State Status	Federal Status	Historic Record
Aliciella leptomeria	Great Basin gilia	T		
Allium robinsonii	Robinson's onion	W		
Astragalus misellus var. pauper	Pauper Milk-vetch	S		H
Astragalus sclerocarpus	Woodypod milkvetch	W		
Astragalus succumbens	Columbia milkvetch	W		
Calyptridium roseum	Rosy Pussypaws	T		
Camissonia minor	Small flower Evening primrose	S		
Camissonia pygmaea	Dwarf Evening-primrose	S		
Cistanthe rosea	rosy pussypaws	T		
Cryptantha leucophaea	Gray Cryptantha	S	SC	
Cryptantha scoparia	Miner's Candle	S		
Cryptantha spiculifera	Snake River Cryptantha	S		
Cuscuta denticulata	Desert Dodder	T		
Erigeron piperianus	Piper's Daisy	S		
Mimulus suksdorfii	Suksdorf's Monkey flower	S		
Oenothera caespitosa ssp. caespitosa	Cespitose Evening-primrose	S		H

Description of Codes

Historic Record:

H indicates most recent sighting in the county is before 1977.

State Status

State Status of plant species is determined by the Washington Natural Heritage Program. Factors considered include abundance, occurrence patterns, vulnerability, threats, existing protection, and taxonomic distinctness. Values include:

E = Endangered. In danger of becoming extinct or extirpated from Washington.
T = Threatened. Likely to become Endangered in Washington.
S = Sensitive. Vulnerable or declining and could become Endangered or Threatened in the state.
R1 = Review group 1. Of potential concern but needs more field-work to assign another rank.
W = Watch status is assigned to each vascular plant taxon that is more abundant and/or less threatened in Washington than previously assumed. Although the Washington Natural Heritage Program does not focus on these taxa, some information about them is still gathered and stored in our information system.

Federal Status
Federal Status under the U.S. Endangered Species Act (USESA) as published in the Federal Register:

LT = Listed Threatened. Likely to become endangered
SC = Species of Concern. An unofficial status, the species appears to be in jeopardy, but insufficient information to support listing.

Results

There were no federally listed species in the survey area. The Washington State listed species found in the surveys were *Astragalus sclerocarpus* and *Erigeron piperianus* (Figures 2 and 3).

Astragalus sclerocarpus is on the state watch list and *E. piperianus* is a state sensitive species (Table 1). Both species were only found in a few locations. *Astragalus sclerocarpus* was found on open sand. A population was found on top of a stabilized dune or constructed sand hill. There were several individuals in the population. Only two plants of *E. piperianus* were observed. They were in a flat area with a sand and gravel surface. GPS locations for these species are noted in the appendix.

A total of 66 vascular plant species (Table 2) were identified during the survey. Of these, 18 of the plant species are non-native, accounting for 27% of the total.

Figure 2. *Astragalus sclerocarpus.*

Figure 3. *Erigeron piperianus.*

Table 2. Plants of the upland zone at the Columbia Generating Station. "Code" is the letter plant code as shown on the USDA PLANTS database. "Alien" species that are not native to the area are indicated with an "A".

Code	Scientific Name	Common name/ Synonym	Family	Alien
ACMI2	*Achillea millefolium* L.	common yarrow	Asteraceae	
ACHY	*Achnatherum hymenoides* (Roem. & Schult.) Barkworth	Indian ricegrass	Poaceae	
AGCR	*Agropyron cristatum* (L.) Gaertn.	crested wheatgrass	Poaceae	A
AMAC2	*Ambrosia acanthicarpa* Hook.	flatspine bur ragweed	Asteraceae	
AMLY	*Amsinckia lycopsoides* Lehm.	tarweed fiddleneck	Boraginaceae	
ASSP	*Asclepias speciosa* Torr.	showy milkweed	Asclepiadaceae	
ASOF	*Asparagus officinalis* L.	garden asparagus	Liliaceae	A
ARPUL	*Aristida purpurea* Nutt. var. *longiseta* (Steud.) Vasey.	Fendler threeawn	Poaceae	
ARDR4	*Artemisia dracunculus* L.	tarragon	Asteraceae	
ARTRT	*Artemisia tridentata* Nutt. ssp. *tridentata*	basin big sagebrush	Asteraceae	
ASCA12	*Astragalus caricinus* (M.E. Jones) Barneby	buckwheat milkvetch	Fabaceae	
ASSC6	*Astragalus sclerocarpus* A. Gray	woodypod milkvetch	Fabaceae	
BACA3	*Balsamorhiza careyana* A. Gray	Carey's balsamroot	Asteraceae	
BRTE	*Bromus tectorum* L.	cheatgrass	Poaceae	A
CEDI3	*Centaurea diffusa* Lam.	diffuse knapweed	Asteraceae	A
CESO3	*Centaurea solstitialis L.*	yellow star-thistle	Asteraceae	A
CEST8	*Centaurea stoebe L.*	spotted knapweed	Asteraceae	A
CHJU	*Chondrilla juncea* L.	rush skeletonweed	Asteraceae	A
CLPE	*Claytonia perfoliata* Donn ex Willd.	Miner's lettuce	Portulacaceae	
COUM	*Comandra umbellata* (L.) Nutt.	bastard toadflax	Santalaceae	
CRAT	*Crepis atribarba* A. Heller	slender hawksbeard	Asteraceae	
CRPT	*Cryptantha pterocarya* (Torr.) Greene	wingnut cryptantha	Boraginaceae	
DAOR2	*Dalea ornata* (Douglas ex Hook.) Eaton & J. Wright	Blue Mountain prairie clover	Fabaceae	
DENU2	*Delphinium nuttallianum* Pritz. ex Walp.	twolobe larkspur	Ranunculaceae	
DEPI	*Descurainia pinnata* (Walter) Britton	western tansymustard	Brassicaceae	
DRVE2	*Draba verna* L.	spring draba	Brassicaceae	A
ELEL5	*Elymus elymoides* (Raf.) Swezey	squirreltail	Poaceae	
ELLAL	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould ssp. *lanceolatus*	thickspike wheatgrass	Poaceae	
ERNA10	*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird	rubber rabbitbrush	Asteraceae	
ERPI3	*Erigeron piperianus* Cronquist	Piper's fleabane	Asteraceae	
ERPU2	*Erigeron pumilus* Nutt.	shaggy fleabane	Asteraceae	
ERNI2	*Eriogonum niveum* Douglas ex Benth.	snow buckwheat	Polygonaceae	
ERCI6	*Erodium cicutarium* (L.) L'Hér. ex Aiton	redstem stork's bill	Geraniaceae	A

Code	**Scientific Name**	**Common name/ Synonym**	**Family**	**Alien**
EROC3	*Erysimum occidentale* (S. Watson) B.L. Rob.	pale wallflower	Brassicaceae	
GISI	*Gilia sinuata* Douglas ex Benth.	rosy gilia	Polemoniaceae	
HECO26	*Hesperostipa comata* (Trin. & Rupr.) Barkworth	needle and thread	Poaceae	
HOUM	*Holosteum umbellatum* L.	jagged chickweed	Caryophyllaceae	A
LAGL5	*Layia glandulosa* (Hook.) Hook. & Arn.	whitedaisy tidytips	Asteraceae	
LELA2	*Lepidium latifolium* L.	broadleaved pepperweed	Brassicaceae	A
LIDA	*Linaria dalmatica* (L.) Mill.	Dalmatian toadflax	Scrophulariaceae	A
LOMA3	*Lomatium macrocarpum* (Nutt. ex Torr. & A. Gray) J.M. Coult. & Rose	bigseed biscuitroot	Apiaceae	
LUSE4	*Lupinus sericeus* Pursh	silky lupine	Fabaceae	
MACA2	*Machaeranthera canescens* (Pursh) A. Gray	hoary tansyaster	Asteraceae	
MEOF	*Melilotus officinalis* (L.) Lam.	yellow sweetclover	Fabaceae	A
MIGRH	*Microsteris gracilis* var. *humilior*	slender phlox	Polemoniaceae	
OEPA	*Oenothera pallida* Lindl.	pale evening primrose	Onagraceae	
OPPO	*Opuntia polyacantha* Haw.	plains pricklypear	Cactaceae	
PEAC	*Penstemon acuminatus* Douglas ex Lindl.	sharpleaf penstemon	Scrophulariaceae	
PHHA	*Phacelia hastata* Douglas ex Lehm.	silverleaf phacelia	Hydrophyllaceae	
PHLI	*Phacelia linearis* (Pursh) Holz.	threadleaf phacelia	Hydrophyllaceae	
PHLO2	*Phlox longifolia* Nutt.	longleaf phlox	Polemoniaceae	
PLPA2	*Plantago patagonica* Jacq.	woolly plantain	Plantaginaceae	
POBU	*Poa bulbosa* L.	bulbous bluegrass	Poaceae	A
POSE	*Poa secunda* J. Presl	Sandberg bluegrass	Poaceae	
POMI	*Polemonium micranthum* Benth.	annual polemonium	Polemoniaceae	
PSLA3	*Psoralidium lanceolatum (*Pursh) Rydb.	lemon scurfpea	Fabaceae	
PTTET	*Pteryxia terebinthina* (Hook.) J.M. Coult. & Rose var. *terebinthina*	turpentine wavewing	Apiaceae	
PUTR2	*Purshia tridentata* (Pursh) DC.	antelope bitterbrush	Rosaceae	
RUVE2	*Rumex venosus* Pursh	veiny dock	Polygonaceae	
SATR12	*Salsola tragus* L.	prickly Russian thistle	Chenopodiaceae	A
SIAL2	*Sisymbrium altissimum* L.	tall tumblemustard	Brassicaceae	A
SPCR	*Sporobolus cryptandrus* (Torr.) A. Gray	sand dropseed	Poaceae	
TRDU	*Tragopogon dubius* Scop.	yellow salsify	Asteraceae	A
TRGRG2	*Triteleia grandiflora* Lindl. var. *grandiflora*	largeflower triteleia	Liliaceae	
VUBR	*Vulpia bromoides* (L.) Gray	brome fescue	Poaceae	A
VUOC	*Vulpia octoflora*	Sixweeks fescue	Poaceae	

Noxious Weeds

Species that are listed as B-designates have prevention of new infestations as the primary goal for Benton County. Class B species are already abundant and control is decided at the local level. Containment of these weeds is the primary goal so that they do not spread into un-infested regions. The Class C status allows a county to enforce control if it is beneficial to that county. *Centaurea diffusa* was found scattered throughout the survey area, but were more common near roads and other disturbances. *Chondrilla juncea* was also found throughout the survey area and was common in patches. These patches were apparently not related to human disturbances making this species a high risk for degrading the condition of relatively undisturbed areas. *Linaria dalmatica* was most common near roads and other disturbances and appears to be moving into undisturbed areas. *Lepidium latifolium* was only in a small swale near a parking lot. These few plants may easily be controlled.

Table 3. Noxious weeds found in the study area. Classes are defined by the Washington State Noxious Weed Control Board (www.nwcb.wa.gov).

Species	Common name	Class
Centaurea diffusa	diffuse knapweed	B
Centaurea solstitialis	yellow star-thistle	B
Centaurea stoebe	spotted knapweed	B
Chondrilla juncea	rush skeletonweed	B
Lepidium latifolium	broadleaved pepperweed	B
Linaria dalmatica	Dalmatian toadflax	B

Plant Associations

Plant associations (Table 4) are typical of those in sandy soils in the Columbia Basin. In Table 4 relative cover is a value that indicates how abundant a particular association or habitat is in the entire surveyed area. Much of the area has experienced varying degrees of disturbance that creates the *Bromus tectorum* semi-natural herbaceous alliance. This type is common throughout the area. Areas dominated by *A. cristatum* are common where revegetation occurred after construction activities. These areas are found near power lines, roads, the water lines from the river, borrow pits, and other revegetated disturbances. A plant association dominated by *A. cristatum* is not recognized (NatureServe 2009). Areas with *A. cristatum* are associated with other native bunchgrasses. The three *Artemisia tridentata* ssp. *tridentata* communities (Figs. 4 and 5) occupy relatively small areas because the *Artemisia tridentata* ssp. *tridentata* is killed after fires and is slow to recover. Areas dominated by *Ericameria nauseosa* are small and grade into *Artemisia tridentata* ssp. *tridentata* areas. The *Eriogonum niveum/ Poa secunda* association is common (Figs. 5 and 7) and grades into areas with *Artemisia tridentata* ssp. *tridentata* and *Hesperostipa comata.* The *Eriogonum niveum* community is almost a monoculture and is found in one area. The *Hesperostipa comata/ Poa secunda* type occurs in patches throughout the area. Dune ridges have unique plant associations usually dominated by *Eriogonum niveum, Hesperostipa comata,* and other forbs (Figs. 6 and 8). These plant associations are all found in varying amounts throughout the upland portion of the property. The riparian habitat is near the Columbia River and exists up to edge of the sand dune faces, but with fewer riparian species with distance from the water line.

Table 4. Plant associations and habitats after Daubenmire (1970) and NatureServe (2009) with relative landscape level cover (1 = low, 4 = high).

Primary associate	Secondary associate	Relative cover
Agropyron cristatum		2
Artemisia tridentata ssp. *tridentata*	*Hesperostipa comata*	2
Artemisia tridentata ssp. *tridentata*	*Poa secunda*	2
Artemisia tridentata ssp. *tridentata*	*Ericameria nauseosa*	2
Bromus tectorum Semi-natural Herbaceous Alliance		4
Ericameria nauseosa		2
Eriogonum niveum	*Poa secunda*	3
Eriogonum niveum		1
Hesperostipa comata	*Poa secunda*	3
Riparian		1
Dune ridges		3

Figure 4. *Artemisia tridentata/Ericameria nauseosa* association with *Eriogonum niveum.*

Figure. 5. A mix of *Artemisia tridentata* (dark shrubs) and *Eriogonum niveum* (low gray sub-shrubs) community types.

Figure 6. Dune ridge with *Hesperostipa comata*, some shrubs, and forbs including *Astragalus sclerocarpus*.

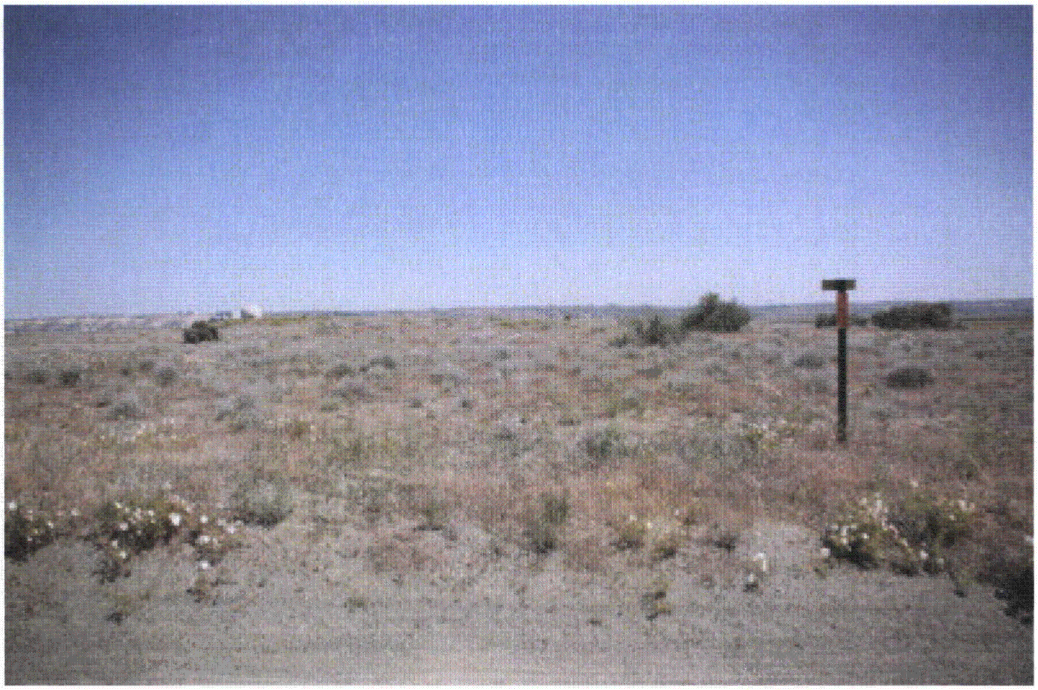

Figure 7. *Eriogonum niveum* community types with inclusions of *P. tridentata* and *O. pallida*.

Figure. 8. Dune ridge with *Eriogonum niveum* association with other forbs. The yellow flowered forb is *Pteryxia terebinthina* and the white flowered forb is *Oenothera pallida.*

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Appendix

Separate Excel file with GPS data.