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WASHINGTON PUBLIC POWER SUPPLY SYSTEM

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June 1, 1990

Mr. William L. Fitch
Executive Secretary
Energy Facility Site Evaluation Council
Mail Stop PY-11
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SUBJECT: TRANSMITTAL OF OPERATIONAL ECOLOGICAL MONITORING PROGRAM NUCLEAR PLANT 2 ANNUAL REPORT

Dear Mr. Fitch:

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

M K Richmond for J C Bell

J. C. Bell, Manager
Health and Sciences

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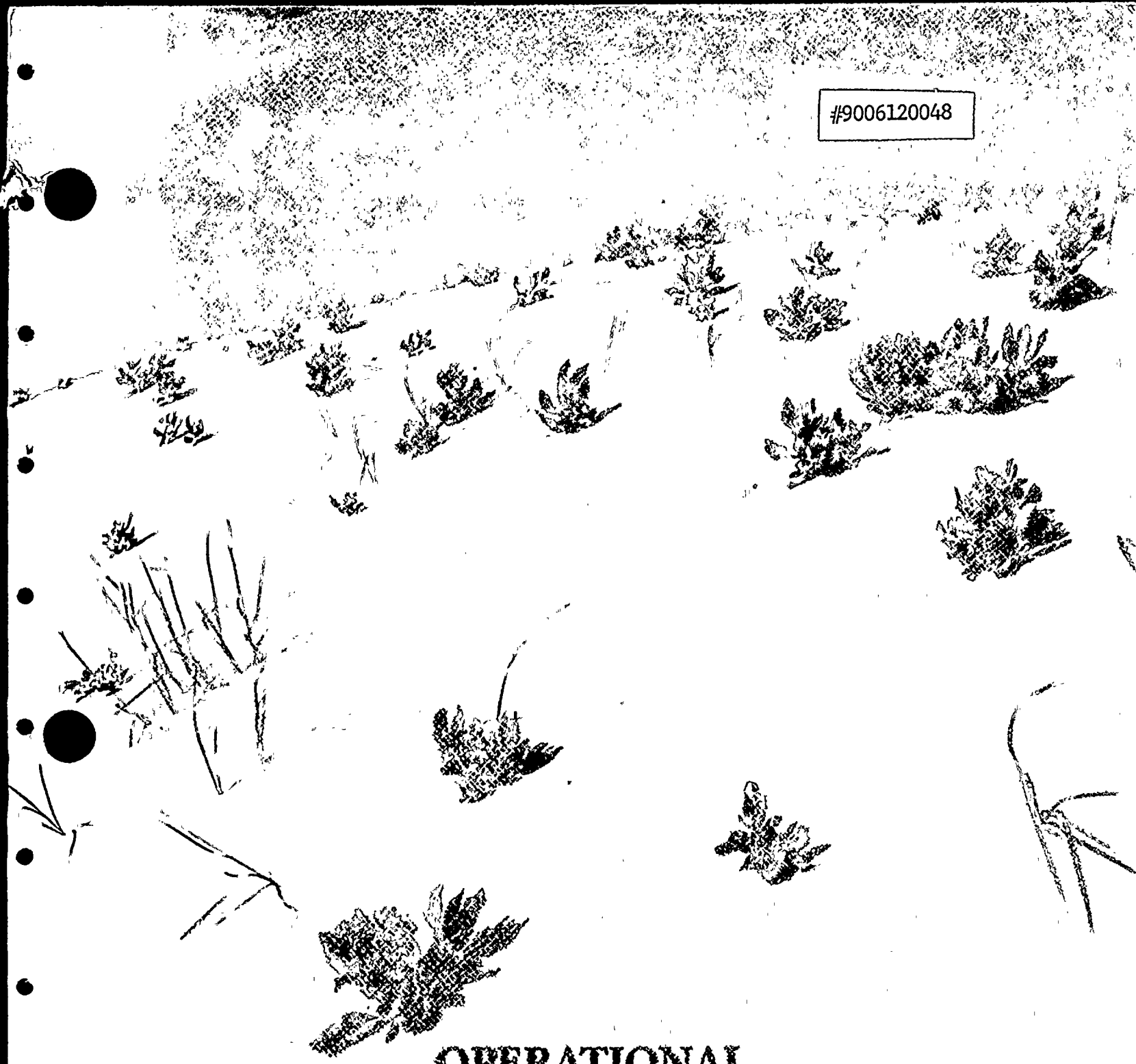

OPERATIONAL ECOLOGICAL MONITORING PROGRAM FOR NUCLEAR PLANT 2

WASHINGTON PUBLIC POWER SUPPLY SYSTEM

1989 Annual Report

Prepared by Environmental Sciences Department

TABLE OF CONTENTS

Section	Page
EXECUTIVE SUMMARY	i
ACKNOWLEDGEMENTS	ii
TABLES	iii
FIGURES	v
1.0 INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.2 THE SITE	1-2
1.3 BIBLIOGRAPHY	1-4
2.0 NOTABLE ENVIRONMENTAL OBSERVATIONS	2-1
2.1 INTRODUCTION	2-1
2.2 METHODS	2-1
2.3 RESULTS	2-1
3.0 FISH BIOASSAYS	3-1
3.1 INTRODUCTION	3-1
4.0 WATER QUALITY	4-1
4.1 INTRODUCTION	4-1
4.2 MATERIALS AND METHODS	4-1
4.2.1 SAMPLE COLLECTION	4-2
4.2.2 FIELD EQUIPMENT & MEASUREMENTS	4-2
4.2.3 LABORATORY MEASUREMENTS	4-3

TABLE OF CONTENTS

(Continued)

Section		Page
4.3	RESULTS	4-3
4.3.1	TEMPERATURE	4-3
4.3.2	DISSOLVED OXYGEN (DO)	4-3
4.3.3	pH AND ALKALINITY	4-4
4.3.4	CONDUCTIVITY	4-5
4.3.5	TOTAL RESIDUAL CHLORINE (TRC)	4-5
4.3.6	METALS	4-5
4.3.7	HARDNESS	4-7
4.3.8	OIL AND GREASE	4-7
4.3.9	AMMONIA-NITROGEN AND NITRATE-NITROGEN	4-8
4.3.10	TOTAL PHOSPHORUS AND ORTHOPHOSPHORUS	4-8
4.3.11	SULFATE	4-8
4.3.12	TOTAL DISSOLVED SOLIDS, TOTAL SUSPENDED SOLIDS AND TURBIDITY	4-9
4.3.13	QUARTERLY DRINKING WELL MEASUREMENTS	4-9
4.4	DISCUSSION	4-10
4.5	BIBLIOGRAPHY	4-10
5.0	COOLING TOWER DRIFT STUDIES	5-1
5.1	INTRODUCTION	5-1
5.2	MATERIALS AND METHODS	5-1
5.2.1	HERBACEOUS CANOPY COVER	5-1
5.2.2	HERBACEOUS PHYTOMASS	5-2
5.2.3	SHRUB CANOPY COVER	5-2
5.2.4	SHRUB DENSITY	5-3
5.2.5	SOIL CHEMISTRY	5-3
5.2.6	VEGETATION CHEMISTRY	5-4

TABLE OF CONTENTS
(Continued)

Section		Page
5.3	RESULTS AND DISCUSSION	5-4
5.3.1	HERBACEOUS COVER	5-4
5.3.2	HERBACEOUS PHYTOMASS	5-5
5.3.3	SHRUB COVER AND DENSITY	5-6
5.3.4	SOIL CHEMISTRY	5-6
5.3.5	VEGETATION CHEMISTRY	5-7
5.4	SUMMARY AND CONCLUSIONS	5-7
5.5	COOLING TOWER DRIFT MODEL VALIDATION STUDY	5-8
5.5.1	INTRODUCTION	5-8
5.5.2	MATERIALS AND METHODS	5-8
5.5.3	SAMPLE PREPARATION AND COLLECTION	5-9
5.5.4	SAMPLE MEASUREMENT AND ANALYSIS	5-9
5.6	BIBLIOGRAPHY	5-9
6.0	INTAKE STRUCTURE FOULING SURVEYS	6-1
6.1	INTRODUCTION	6-1
7.0	CORBICULA CLAM SURVEYS	7-1
7.1	INTRODUCTION	7-1
7.2	METHODS AND MATERIALS	7-1
7.3	RESULTS AND DISCUSSION	7-1
8.0	AERIAL PHOTOGRAPHY	8-1
8.1	INTRODUCTION	8-1
8.2	MATERIALS AND METHODS	8-1
8.3	RESULTS AND DISCUSSION	8-3
8.4	BIBLIOGRAPHY	8-4

EXECUTIVE SUMMARY

During 1989 there were no unusual events which resulted in significant environmental impacts from the operation of WNP-2.

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

Significant interstation differences could not be detected among any of the water quality parameters measured for nearly all sampling periods. All measurements taken, with the exception of the pH values recorded at all stations (including the control) during April, were within the water quality standards for class A waters both above and below the mixing zone. It appears that during 1989, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

There were no fish bioassays performed during 1989 at WNP-2. The spring 1990 test was cancelled when the concentration of the circulating (cooling) water was reduced by approximately 50% due to plant condenser leakage problems. The first "flow through" bioassay is scheduled for fall 1990.

Total herbaceous cover at fifteen sampling stations averaged 73.5% in 1989 representing a 126% increase over 1988. A corresponding increase in herbaceous phytomass was measured at all stations. Soil and vegetation analyte concentrations were generally lower than or similar to measurements made in previous years. Changes in vegetation cover and density recorded in 1989 appear to be climatically induced and no signs of adverse impacts from the operation of WNP-2 cooling towers are evident.

Five aerial flightlines covering the areas of suspected high cooling tower drift deposition were photographed with color infrared film during May, 1989. None of the photographs revealed areas of vegetation stress and growth patterns remained consistent on all flightlines.

ACKNOWLEDGEMENTS

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

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List of Tables

Number	Title	Page
1-1	Summary of Historical and Long-term Environmental Monitoring Programs for WNP-2	1-7
4-1	Summary of Water Quality Parameters, Stations, and Sampling Frequencies, 1989	4-12
4-2	Summary of Water Quality Parameters and EPA Method Number	4-13
4-3	Summary of Temperature Measurements for 1989	4-14
4-4	Summary of Dissolved Oxygen Measurements for 1989	4-15
4-5	Summary of pH Measurements for 1989	4-16
4-6	Summary of pH, Alkalinity and Hardness Measurements for 1989	4-17
4-7	Summary of Conductivity Measurements for 1989	4-18
4-8	Summary of Turbidity and Total Residual Chlorine Measurements for 1989	4-19
4-9	Summary of Copper Measurements for 1989	4-20
4-10	Summary of Nickel and Zinc Measurements for 1989	4-21
4-11	Summary of Iron and Lead Measurements for 1989	4-22
4-12	Summary of Cadmium and Chromium Measurements for 1989	4-23
4-13	Summary of Oil and Grease, and Ammonia Measurements for 1989	4-24
4-14	Summary of Nitrate and Total Phosphorus Measurements for 1989	4-25
4-15	Summary of Orthophosphate and Sulfate Measurements for 1989	4-26
4-16	Summary of Total Dissolved and Total Suspended Solids Measurements for 1989	4-27
4-17	Quarterly Drinking Well Monitoring Measurements from January - December 1989	4-28
5-1	Vascular Plants Observed During 1989 Field Work	5-11
5-2	Vascular Plants Observed During 1975-1989 Field Work	5-14
5-3	Herbaceous Cover for Fifteen Sampling Stations-1989	5-18
5-4	Mean Herbaceous Cover for 1975 Through 1989	5-19
5-5	Mean Frequency Values (%) by Species for Each Sampling Station - 1989	5-20

List of Tables
(Continued)

Number	Title	Page
5-6	Mean Terrestrial Phytomass for 1989	5-21
5-7	Comparison of Herbaceous Phytomass for 1975 Through 1989	5-22
5-8	Summary of Shrub Density for 1989	5-23
5-9	Summary of Shrub Cover (%) at Five Stations for 1989	5-24
5-10	Summary of Soil Chemistry for 1989	5-25
5-11	Summary of Vegetation Chemistry for 1989	5-26

List of Figures

Number	Title	Page
1-1	WNP-2 Gross Thermal Production for 1989	1-8
1-2	WNP-2 Days Per Month Discharging and Mean Monthly Discharge	1-9
1-3	WNP-2 Location Map	1-10
1-4	Columbia River Mean Monthly Flow for 1989	1-11
2-1	WNP-2 Property Boundary	2-2
4-1	Location of Sampling Stations in the Columbia River	4-29
4-2	Sampling Station Locations for Water Chemistry	4-30
4-3	Columbia River Temperature Measurements at Six Stations During 1989	4-31
4-4	Columbia River Dissolved Oxygen Measurements at Four Stations During 1989	4-32
4-5	Columbia River pH Measurements at Six Stations During 1989	4-33
4-6	Columbia River Total Alkalinity Measurements at Four Stations During 1989	4-34
4-7	Columbia River Conductivity Measurements at Six Stations During 1989	4-35
4-8	Columbia River Total Copper Measurements at Six Stations During 1989	4-36
4-9	Columbia River Total Zinc Measurements at Four Stations During 1989	4-37
4-10	Columbia River Total Iron Measurements at Four Stations During 1989	4-38
4-11	Columbia River Total Lead Measurements at Four Stations During 1989	4-39
4-12	Columbia River Total Hardness Measurements at Four Stations During 1989	4-40
4-13	Columbia River Nitrate - Nitrogen Measurements at Four Stations During 1989	4-41
4-14	Columbia River Total Sulfate Measurements at Four Stations During 1989	4-42
4-15	Columbia River Total Dissolved Solids Measurements at Four Stations During 1989	4-43
4-16	Columbia River Total Suspended Solids Measurements at Four Stations During 1989	4-44

List of Figures
(Continued)

Number	Title	Page
4-17	Columbia River Turbidity Measurements at Four Stations During 1989	4-45
5-1	Soil and Vegetation Sampling Location Map	5-27
5-2	Layout of Vegetation and Soil Sampling Plots	5-28
5-3	Mean Herbaceous Cover for 1975 Through 1979	5-29
5-4	Mean Herbaceous Cover for 1980 Through 1984	5-30
5-5	Mean Herbaceous Cover for 1985 Through 1989	5-31
5-6	Mean (%) Herbaceous Cover for 1975 Through 1989	5-32
5-7	Mean Herbaceous Cover, Total Precipitation, and Mean Temperature From 1982 Through 1989	5-33
5-8	Mean Herbaceous Phytomass for May 1989	5-34
5-9	Mean Herbaceous Phytomass at Grassland and Shrub Stations for 1975 Through 1989	5-35
5-10	Mean Herbaceous Cover and Phytomass for Station G01 for 1980 Through 1989	5-36
5-11	Mean Herbaceous Cover and Phytomass for Station G02 for 1980 Through 1989	5-37
5-12	Mean Herbaceous Cover and Phytomass for Station G03 for 1980 Through 1989	5-38
5-13	Mean Herbaceous Cover and Phytomass for Station G04 for 1980 Through 1989	5-39
5-14	Mean Herbaceous Cover and Phytomass for Station G05 for 1980 Through 1989	5-40
5-15	Mean Herbaceous Cover and Phytomass for Station G06 for 1980 Through 1989	5-41
5-16	Mean Herbaceous Cover and Phytomass for Station G07 for 1980 Through 1989	5-42
5-17	Mean Herbaceous Cover and Phytomass for Station G08 for 1980 Through 1989	5-43
5-18	Mean Herbaceous Cover and Phytomass for Station S01 for 1980 Through 1989	5-44

List of Figures
(Continued)

Number	Title	Page
5-19	Mean Herbaceous Cover and Phytomass for Station S02 for 1980 Through 1989	5-45
5-20	Mean Herbaceous Cover and Phytomass for Station S03 for 1980 Through 1989	5-46
5-21	Mean Herbaceous Cover and Phytomass for Station S04 for 1980 Through 1989	5-47
5-22	Mean Herbaceous Cover and Phytomass for Station S05 for 1980 Through 1989	5-48
5-23	Mean Herbaceous Cover and Phytomass for Station S06 for 1980 Through 1989	5-49
5-24	Mean Herbaceous Cover and Phytomass for Station S07 for 1980 Through 1989	5-50
5-25	Shrub Density at Five Stations for 1984 Through 1989	5-51
5-26	Mean Total Shrub Cover for 1975 Through 1989	5-52
5-27	Shrub Cover and Density for Five Stations for 1989	5-53
5-28	Soil pH for 1980 Through 1983	5-54
5-29	Soil pH for 1984 through 1989	5-55
5-30	Soil Conductivity for 1980 Through 1983	5-56
5-31	Soil Conductivity for 1984 Through 1989	5-57
5-32	Soil Sulfate for 1980 Through 1983	5-58
5-33	Soil Sulfate for 1984 Through 1989	5-59
5-34	Soil Chloride for 1980 Through 1983	5-60
5-35	Soil Chloride for 1984 Through 1989	5-61
5-36	Soil Bicarbonate for 1980 Through 1983	5-62
5-37	Soil Bicarbonate for 1984 Through 1989	5-63
5-38	Soil Copper for 1980 Through 1983	5-64
5-39	Soil Copper for 1984 Through 1989	5-65
5-40	Soil Lead for 1980 Through 1983	5-66
5-41	Soil Lead for 1984 Through 1989	5-67
5-42	Soil Nickel for 1980 Through 1983	5-68
5-43	Soil Nickel for 1984 Through 1989	5-69
5-44	Soil Cadmium for 1980 Through 1983	5-70

List of Figures
(Continued)

Number	Title	Page
5-45	Soil Cadmium for 1984 Through 1989	5-71
5-46	Soil Zinc for 1980 Through 1983	5-72
5-47	Soil Zinc for 1984 Through 1989	5-73
5-48	Soil Chromium for 1980 Through 1983	5-74
5-49	Soil Chromium for 1984 Through 1989	5-75
5-50	Soil Sodium for 1980 Through 1983	5-76
5-51	Soil Sodium for 1984 Through 1989	5-77
5-52	Soil Potassium for 1980 Through 1983	5-78
5-53	Soil Potassium for 1984 Through 1989	5-79
5-54	Soil Calcium for 1980 Through 1983	5-80
5-55	Soil Calcium for 1984 Through 1989	5-81
5-56	Soil Magnesium for 1980 Through 1983	5-82
5-57	Soil Magnesium for 1984 Through 1989	5-83
5-58	Copper Concentration (ug/g) in *Sisymbrium altissimum* by Station for 1984 Through 1989	5-84
5-59	Copper Concentration (ug/g) in *Poa sandbergii* by Station for 1984 Through 1989	5-85
5-60	Copper Concentration (ug/g) in *Artemisia tridentata* by Station for 1984 Through 1989	5-86
5-61	Copper Concentration (ug/g) in *Purshia tridentata* by Station for 1984 Through 1989	5-87
5-62	Copper Concentration (ug/g) in *Phlox longifolia* by Station for 1984 Through 1989	5-88
5-63	Copper Concentration (ug/g) in *Bromus tectorum* by Station for 1984 Through 1989	5-89
5-64	Total Vegetation Copper for May 1989	5-90
5-65	Chloride Concentration (%) in *Poa sandbergii* by Station for 1984 Through 1989	5-91
5-66	Chloride Concentration (%) in *Sisymbrium altissimum* by Station for 1984 Through 1989	5-92
5-67	Chloride Concentration (%) in *Artemisia tridentata* by Station for 1984 Through 1989	5-93

List of Figures
(Continued)

Number	Title	Page
5-68	Chloride Concentration (%) in *Purshia tridentata* by Station for 1984 Through 1989	5-94
5-69	Chloride Concentration (%) in *Bromus tectorum* by Station for 1984 Through 1989	5-95
5-70	Chloride Concentration (%) in *Phlox longifolia* by Station for 1984 Through 1989	5-96
5-71	Total Vegetation Chloride for May 1989	5-97
5-72	Total Vegetation Sulfate for May 1989	5-98
5-73	Sulfate Concentrations (%) in *Poa sandbergii* by Station for 1984 Through 1989	5-99
5-74	Sulfate Concentration (%) in *Bromus tectorum* by Station for 1984 Through 1989	5-100
5-75	Sulfate Concentration (%) in *Artemisia tridentata* by Station for 1984 Through 1989	5-101
5-76	Sulfate Concentration (%) in *Purshia tridentata* by Station for 1984 Through 1989	5-102
5-77	Sulfate Concentration in *Phlox longifolia* by Station for 1984 Through 1989	5-103
5-78	Sulfate Concentrations (%) in *Sisymbrium altissimum* by Station for 1984 Through 1989	5-104
5-79	Location Map of Cooling Tower Drift Monitoring Sites	5-105
5-80	Cooling Tower Drift Collection Vessel	5-106
8-1	Aerial Photography Flightlines	8-5

1.0 INTRODUCTION

1.1 BACKGROUND

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

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

The Supply System in 1974 retained Battelle Pacific Northwest Laboratories (BNW) to conduct the preoperational aquatic monitoring for WNP-2. The results of aquatic studies performed from September 1974 through August 1978 are presented in various reports (Battelle 1976, 1977, 1978, 1979a and 1979b). From August 1978 through March 1980 the aquatic studies were performed by Beak Consultants, Inc. (Beak 1980). In 1982 the Supply System analyzed the 1974-1980 aquatic data and presented the results and a recommended operational monitoring program to EFSEC (Mudge et. al., 1982). The operational program was accepted with minor modifications and initiated in March 1983. Because of

operational conditions, the plant did not consistently discharge liquid effluents until the fall of 1984. Figures 1-1 and 1-2 present summaries of electrical generation and monthly discharges for 1989.

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

During their regular meeting of September 14, 1987 the Energy Facility Site Evaluation Council approved Resolution No. 239 which adopted a long-term environmental Monitoring Program for WNP-2. This decision was based upon the council's examination of the document titled Review of the Environmental Monitoring Program for WNP-2 with Recommendations for Design of Continuing Studies (Davis and Northstrom, 1987). A summary of the monitoring program conducted through September 1987, and the long term program adopted in EFSEC Resolution No. 239 is presented in Table 1-1.

This report presents the results of the Ecological Monitoring Program (EMP) for the period January 1989 through December 1989.

1.2 THE SITE

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

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

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

The flow of the Columbia River at WNP-2 is controlled by releases from Priest Rapids Dam. The minimum flow, measured at the USGS stream-quality station located at river mile 388.1 near the Vernita bridge, was 37,200 cfs, while average and maximum flows in 1989 were 101,599 cfs and 293,000 cfs, respectively (Figure 1-4).

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

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

Specific Programs	Historical Program	Proposed Program
	Asiatic clam - inspections in response to an NRC information bulletin.	These inspections will continue based upon our technical response to Inspection and Enforcement Bulletin 81-03.
Water Quality Program	Samples are collected at 4 stations; an upstream control, nearfield just downstream of discharge, just past the end of the mixing zone, and 1800 feet downstream of the discharge.	Continue with slight modifications to the location of the nearfield and downstream station. Add vertical samples to the station at the edge of the mixing zone and increase sampling for copper, the best tracer of the discharge which we have identified.
Terrestrial Annimal Program	Deer and Rabbits - Six plots were reduced to three as the result of fire.	Terminated 1987
	Birds - Spring and fall surveys are conducted.	Terminated 1987
Terrestrial Soil and Vegetation	Vegetation and soil samples are collected each spring at four glassland and 5 shrubland sites.	Continue with the addition of six new sites. Discontinue fluoride and mercury measurements.
	Aerial Photography - Currently not performed.	Initiate annual program to assess changes in vegetation.
	Terrestrial Bioassays - None conducted.	Conduct bioassays on selected plant species utilizing soil exposed to cooling tower drift. Initially conduct the bioassays annually.
Cooling Tower Drift	Indirect drift information from vegetation and soil chemistry data.	Develop a program to directly monitor the pattern and chemistry of the cooling tower drift.
Aquatic Biology Program	Periphyton - Collected quarterly or twice quarterly from 16 artificial sampler stations in the Columbia River.	Terminated 1987
	Benthic Macrofauna - Collected quarterly from 8 artificial sampler stations in the Columbia River.	Terminated 1987

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

Specific Programs	Historical Program	Proposed Program
Aquatic Biology Program (Cont)	Fish - Four static bioassays were required by EFSEC. Additional bioassays have been performed to support changes in chemistry of the circulating water.	Conduct flow through bioassays.
	Drift studies in the discharge plume.	Regulatory commitment has been completed. No further studies are proposed.
	Entrainment studies in the intake water pumphouse.	Regulatory commitment has been completed. No further studies are proposed.
	Impingement studies.	Regulatory commitment has been completed. No further studies are proposed; however, incidental observations will be made when maintenance inspections of the intakes are conducted.

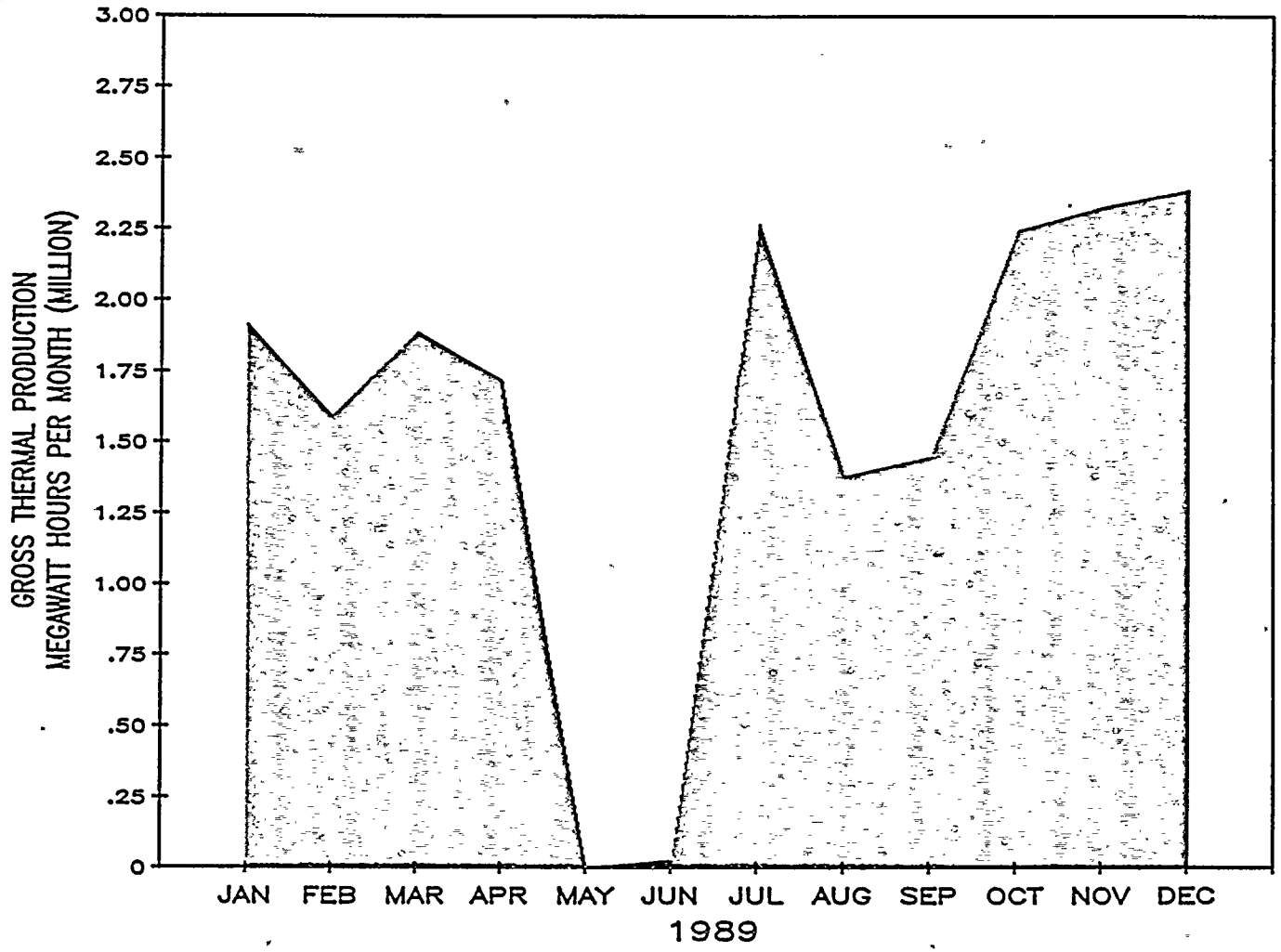

Figure 1-1 WNP-2 Gross Thermal Production for 1989

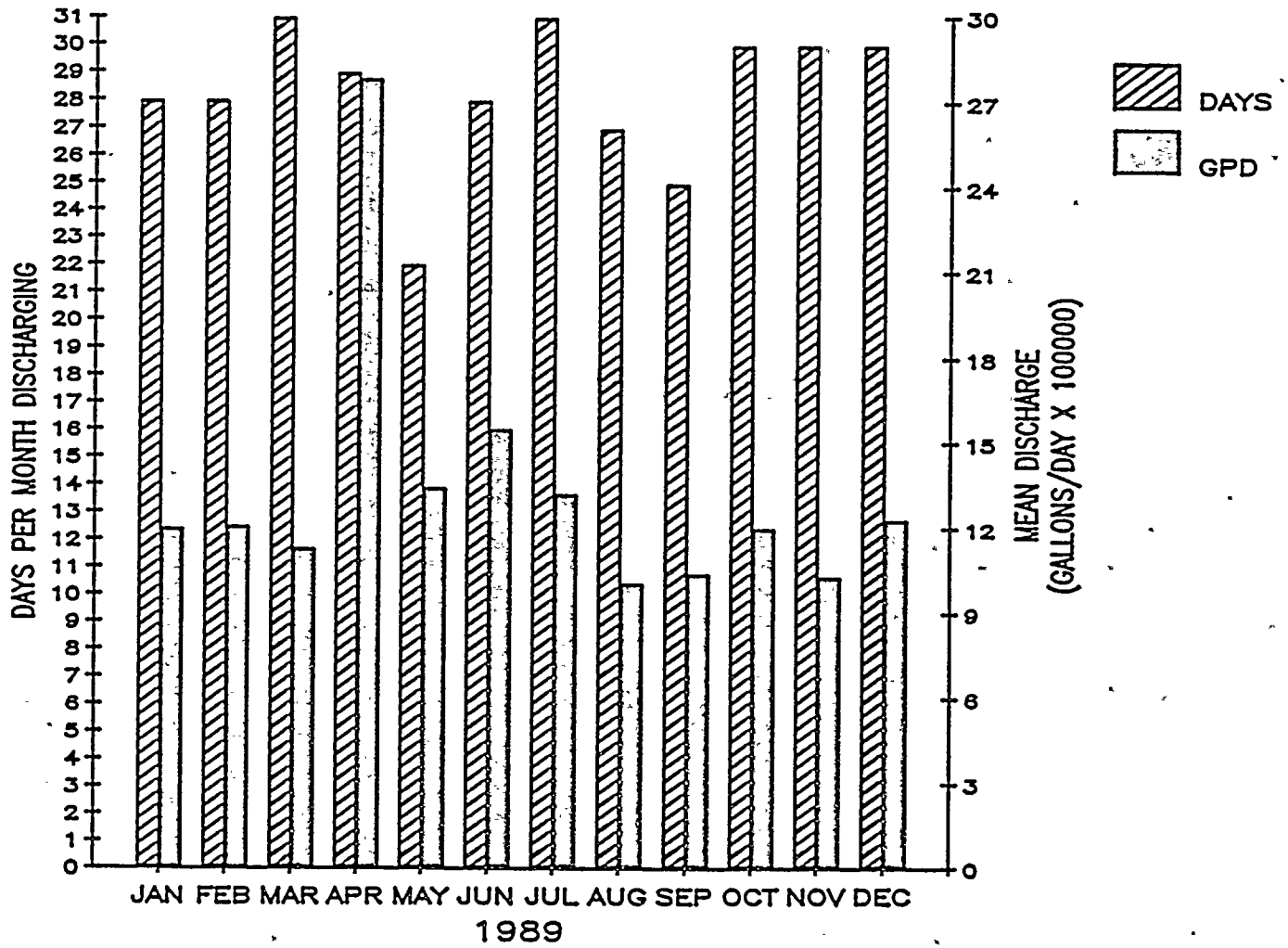

Figure 1-2 WNP-2 Days Per Month Discharging and Mean Monthly Discharge

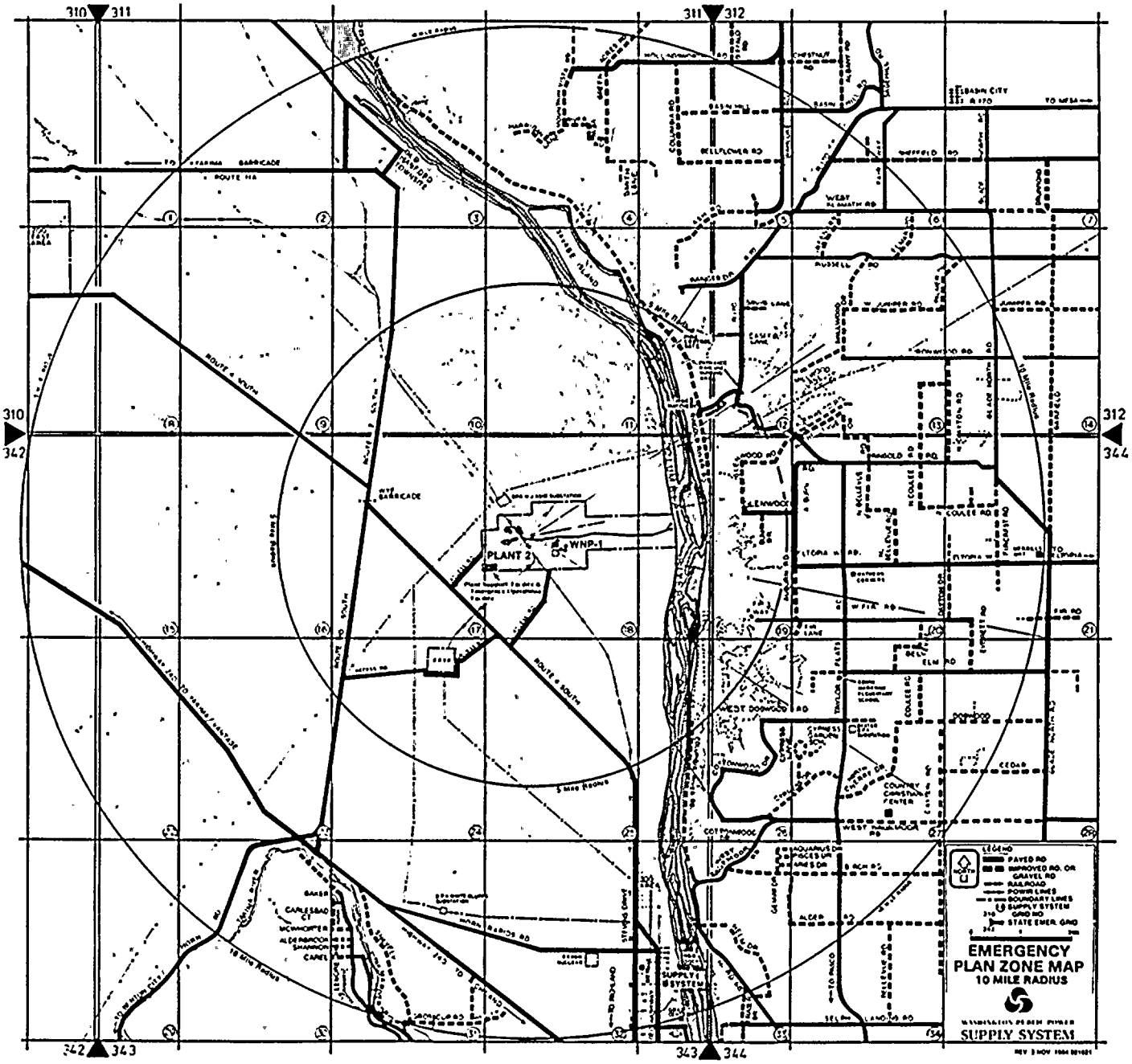

Figure 1-3 WNP-2 Location Map

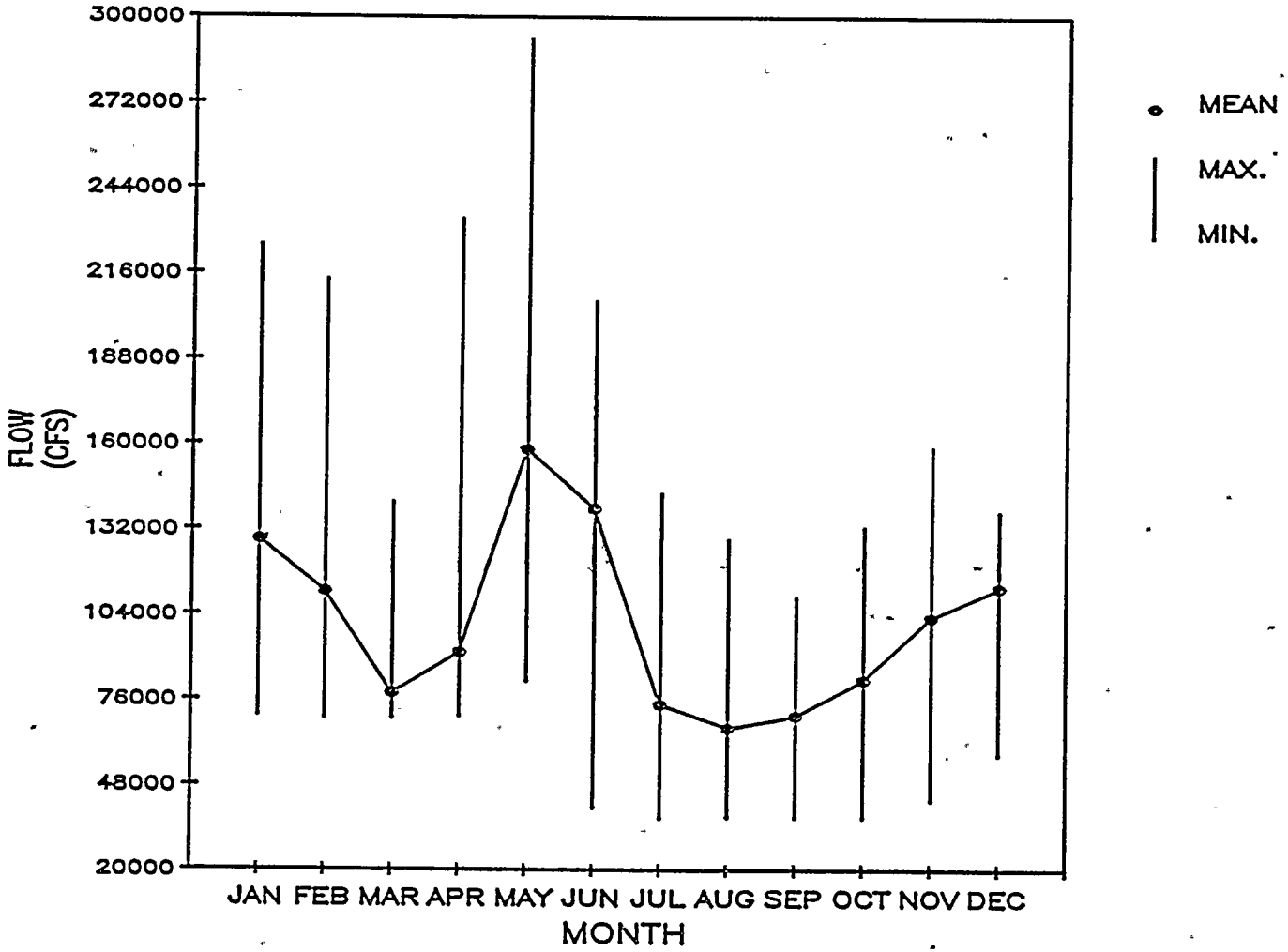

Figure 1-4 Columbia River Mean Monthly Flow for 1989

2.0 NOTABLE ENVIRONMENTAL OBSERVATIONS

2.1 INTRODUCTION

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

2.2 METHODS

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

2.3 RESULTS

There were no unusual or notable events which resulted in significant environmental impacts from the operation of WNP-2. Notable avian observations included, sightings of *Aquila chrysaetos* (Golden Eagle) and *Pelecanus erythrorhynchos* (American White Pelican).

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

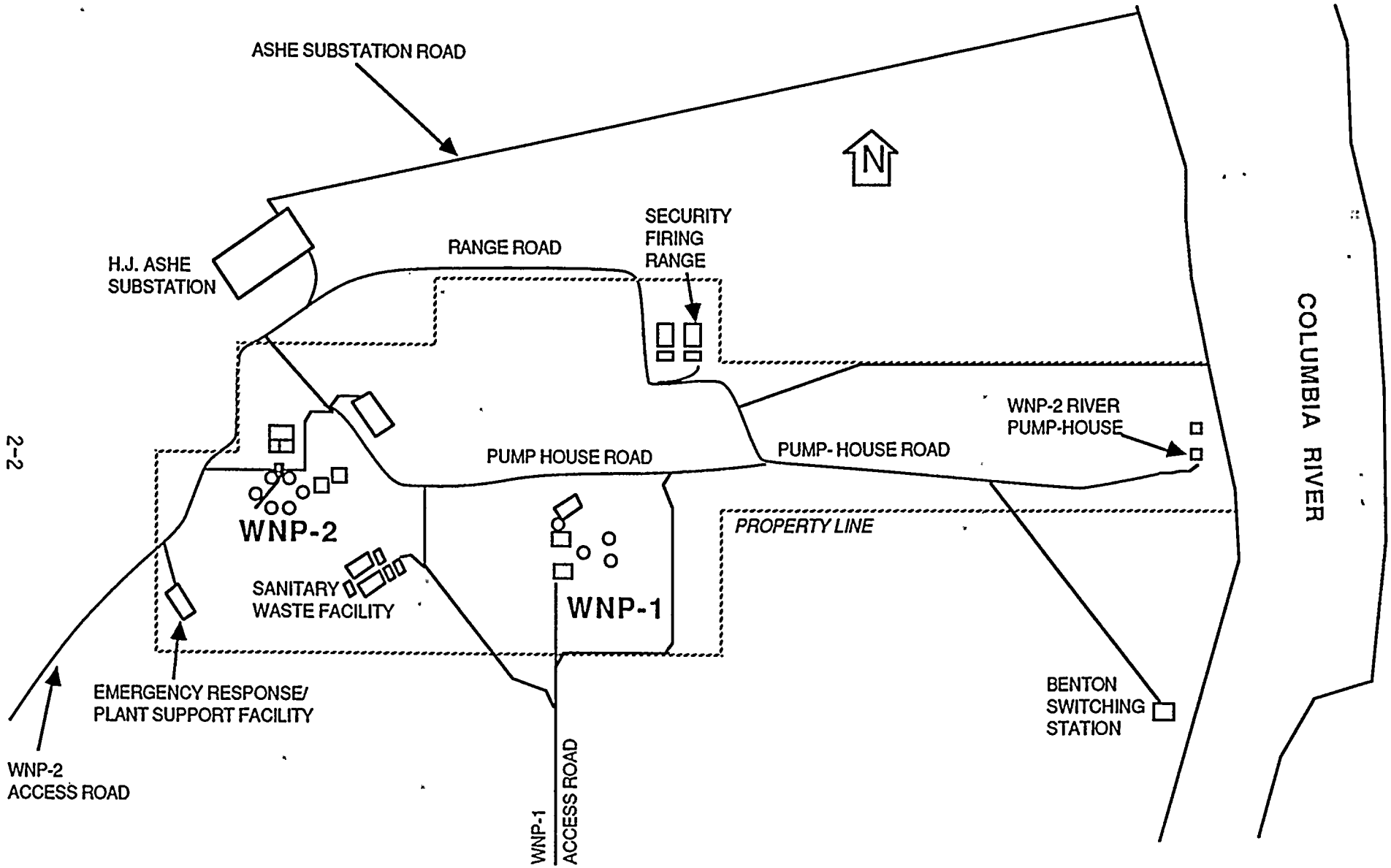

Figure 2-1 WNP-2 Property Boundary

871032.4
FEB 1988

3.0 FISH BIOASSAYS

3.1 INTRODUCTION

There were no plant effluent characterization bioassays performed during 1989 (see 1988 Annual Report for a description of this type of test).

Completion of the flow-through system, including chiller and temperature conditioning unit, was delayed until mid-January 1990 due to problems associated with the manufacturing and delivery of system components. Preliminary testing was performed in February, with the first bioassay scheduled for late March, 1990. The Washington Department of Fisheries Permit (granted February 6, 1989) was extended to April 1, 1990 to allow acquisition of chinook smolts from the Ringold Hatchery.

Development of a minor problem with WNP-2's condensers (January 1990) forced plant operations to reduce the concentration of the circulating water from 12 cycles (normal operating level) to 5 cycles. In addition, a gradual reduction in power of from approximately 100 percent to near 80 percent was scheduled to be performed prior to the annual maintenance outage (April, 1990).

From these events, it was determined that an appropriate assessment of the effect of WNP-2's effluent on Columbia River salmonids could not be performed during the spring test. The first flow-through bioassay has been rescheduled for Fall, 1990.

4.0 WATER QUALITY

4.1 INTRODUCTION

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

4.2 MATERIALS AND METHODS

Columbia River surface water was sampled monthly January 1989 through December 1989. Samples were collected near River Mile 352 from four stations numbered 1, 7, 11, and 8 (Figure 4-1, 4-2). Station 1 is upstream of the WNP-2 intake and discharge and represents a control. Station 7 is in the center of the mixing zone approximately 45 meters (150 feet) downstream of the discharge and provides a measure of near-field discharge effects. Station 11, at 91 meters (300 feet) downstream from the discharge, represents the extremity of the mixing zone allowed by WNP-2's National Pollutant Discharge Elimination System (NPDES) permit. Sub-stations 11M and 11B sample water from middle and bottom depths, respectively. Station 8 is approximately 568 meters (1870 feet) downstream from the discharge and represents a location where the discharge is well mixed in the Columbia River.

The samples were analyzed for temperature, dissolved oxygen (DO), pH, conductivity, turbidity, total alkalinity, total hardness, filterable residue (total dissolved solids), nonfilterable residue (total suspended solids), ammonia-nitrogen, nitrate-nitrogen, total phosphorus, orthophosphorus, sulfate, oil and grease, total residual chlorine, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium. A summary of water quality parameters, stations and sample frequencies is presented in Table 4-1.

4.2.1 Sample Collection

Columbia River samples were collected by boat approximately 300 feet from the Benton County shore. Temperature, conductivity, dissolved oxygen, and pH were determined in-situ with portable instruments. Water for total metal, conductivity, sulfate, total phosphorus, orthophosphorus, ammonia-nitrogen, nitrate-nitrogen, turbidity, total alkalinity and total hardness analyses was collected in one-liter polypropylene cubitainers and kept on ice until delivered to the Supply System's Environmental Programs Laboratory (EPL). Water for total copper analysis from Stations 11M and 11B were collected in 125 ml nalgene bottles with an All-Teflon pump and Tygon tubing. In the laboratory the metals samples were acidified to 0.5% with concentrated nitric acid. Determinations for filterable residue, non-filterable residue, and total residual chlorine were made on water samples collected in 3.8-liter polypropylene cubitainers and kept on ice until delivered to the Supply System's Radiological Services Laboratory (RSL). Water for oil and grease analysis was skimmed from the surface into solvent rinsed borosilicate glass bottles. After collection, samples were placed on ice and transported to the RSL for analysis.

4.2.2 Field Equipment and Measurements

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

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

Conductivity measurements were made with an IBM Model EC105-1A meter and YSI model 33 and 34 meters. Prior to each sample date, measurements of conductivity standards were performed.

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

4.2.3 Laboratory Measurements

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

4.3 RESULTS

4.3.1 Temperature

Columbia River temperatures varied seasonally with a minimum temperature of 2.2°C at Stations 1, 7, 11 and 8 on February 23rd and a maximum of 19.5°C at Stations 11M and 11B on July 27 (Table 4-3). River temperatures measured in 1989 are presented graphically in Figure 4-3.

4.3.2 Dissolved Oxygen (DO)

The mean and range of DO measurements for each sample station are presented in Table 4-4. Columbia River DO concentrations ranged from

9.0 mg/l at Stations 7, 11 and 8 in October to 13.0 mg/l at Station 7 in April. The mean DO concentrations ranged from 10.8 mg/l at Station 8 to 10.9 mg/l at Stations 1, 7, and 11. The largest interstation difference in DO occurred between Station 1 (12.2 mg/l) and Station 7 (13.0 mg/l) in April.

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

4.3.3 pH and Alkalinity

Columbia River mean pH values ranged from 7.82 at Station 7 to 7.90 at Station 11M (Table 4-5). pH varied with a measured minimum of 7.23 at Station 7 in December to a maximum of 8.60 at Station 1 in April. The variation in pH between sample stations is small. The largest difference of 0.33 standard units occurred between Station 1 (pH 7.88) and Station 7 (pH 7.55) in October.

The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1988). Measurements for all stations during April were slightly outside this range. pH measurements, presented graphically in Figure 4-5, generally agree with historical data for the Columbia River (Silker 1964).

The alkalinity of a water is a measure of its capacity to neutralize acids and is generally due to the presence of carbonates, bicarbonates, phosphates, silicates, borates, and hydroxides. Columbia River alkalinities ranged from 43.0 to 62.5 mg/l as calcium carbonate (Table 4-6). The greatest interstation differences occurred in December between Station 1 (50.0 mg/l) and Station 8 (59.0 mg/l). The alkalinity measurements are presented graphically in Figure 4-6.

4.3.4 Conductivity

Conductivity is a measure of the ionic content of a solution. Columbia River conductivity measurements ranged from 110.4 uS/cm at 25°C at Station 1 in June to 176.1 uS/cm at 25°C at Station 11B in February (Table 4-7). Station mean conductivities ranged from 141.5 uS/cm at 25°C at Station 1 to 148.8 uS/cm at 25°C at Stations 11M and 11B. The conductivity results are very comparable to those reported in earlier studies of the Columbia River (Silker 1964). The measurements are presented graphically in Figure 4-7.

4.3.5 Total Residual Chlorine (TRC)

Total residual chlorine (TRC) measurements for 1989 were less than the measured detection limit of 50 ug/l (Table 4-8).

TRC measurements were made using the Amperometric Titration Method. This method has a detection limit of 50 ug/l.

4.3.6 Metals

Total Copper

Columbia River mean total copper values ranged from 1.3 ug/l at Station 8 to 1.6 ug/l at Stations 1 and 11M (Table 4-9). Individual copper measurements ranged from 0.8 ug/l to 2.9 ug/l. The largest interstation difference in copper (2.1 ug/l) occurred between Station 11M (2.9 ug/l) and Station 8 (0.8 ug/l) in February. Our copper results show good agreement with earlier studies. In 1962, Silker (1964) analyzed 27 Columbia River samples collected upstream of WNP-2 and reported a mean copper concentration of 4.3 ug/l. Neutron activation analysis of Columbia River water was done in 1968-1969 by

Cushing and Rancitelli (1972). They reported a mean copper concentration of 1.4 ug/l. Florence and Batley (1977) state that total copper concentrations in the range of 0.3 - 3.0 ug/l are found in many unpolluted fresh-water rivers throughout the world. The Hanford reach of the Columbia River would generally be in that category.

Total Zinc

Mean total zinc measurements ranged from 6.4 ug/l at Stations 11 and 8 to 6.9 ug/l at Station 7 (Table 4-10). Individual zinc measurements ranged from 2.1 ug/l at Station 8 to 15.0 ug/l at Station 11. The greatest interstation difference (2.7 ug/l) occurred between Station 7 (6.7 ug/l) and Station 11 (4.0 ug/l) in September.

Total Iron

Columbia River mean iron concentrations ranged from 52.6 ug/l at Station 11 to 59.2 ug/l at Station 1 (Table 4-11). The greatest interstation difference in concentration of 31 ug/l occurred between Station 1 (21.0 ug/l) and Station 8 (52.0 ug/l) in October.

Total Nickel

Mean total nickel concentrations ranged from 0.6 ug/l to 0.7 ug/l (Table 4-10). Nickel concentrations showed little variation through time or between sample locations.

Total Lead

Mean total lead concentrations ranged from 1.0 ug/l at Station 8 to 1.4 ug/l at Station 1 (Table 4-11). The greatest interstation difference (1.8 ug/l) occurred between Station 8 (1.5 ug/l) and Station 1 (3.3 ug/l) in January.

Total Cadmium

Mean cadmium concentrations were fairly low and ranged from 0.1 ug/l at Station 7 to 0.2 ug/l at Stations 1, 11 and 8 (Table 4-12). Several individual measurements were below the minimum detection limit of 0.1 ug/l. No significant interstation differences were evident.

Total Chromium

Mean chromium concentrations ranged from 0.1 ug/l at Stations 7, 11, and 8 to 0.2 ug/l at Station 1. The 1.8 ug/l reported for Station 1 during July is uncharacteristic and probably represents a contaminated sample rather than an actual Columbia River chromium measurement.

Total copper, total zinc, total iron, and total lead measurements are presented graphically in Figures 4-8, 4-9, 4-10 and 4-11, respectively.

4.3.7 Hardness

Hardness indicates the quantity of divalent metallic cations present in the system, principally calcium and magnesium ions. Hardness ranged from 51.6 to 87.8 mg/l as calcium carbonate (Table 4-6). Mean hardness values ranged from 65.9 mg/l at Station 1 to 68.7 mg/l at Station 11. The hardness measurements are presented graphically in Figure 4-12.

4.3.8 Oil and Grease

Oil and grease values were below the detection limit of 0.5 mg/l for all stations and periods. Oil and grease measurements are summarized in Table 4-13.

4.3.9 Ammonia-Nitrogen and Nitrate-Nitrogen

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

Ammonia concentrations ranged from <0.01 to 0.07 mg-N/l (Table 4-13). Nitrate concentrations ranged from <0.01 to 0.30 mg-N/l. The nitrate measurements are summarized in Table 4-14. The nitrate measurements are presented graphically in Figure 4-13.

4.3.10 Total Phosphorus and Orthophosphorus

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

Measured total phosphorus concentrations ranged from <0.1 to 0.13 mg-P/l. Orthophosphorus concentrations ranged from <0.01 to 0.03 mg-P/l (Table 4-15).

4.3.11 Sulfate

Mean sulfate concentrations ranged from 10.9 mg/l at Station 1 to 11.9 mg/l at Stations 7 and 11 (Table 4-15). Individual sulfate measurements ranged from 7.5 to 20.6 mg/l. Generally, sulfate concentrations between stations were similar with the largest difference of 3.1 mg/l occurring in October between Stations 1 and 7. Sulfuric acid is added at WNP-2 to control circulating water pH and a by-product is sulfate. Based on the river measurements, WNP-2 discharges are not appreciably altering river sulfate concentrations. Total sulfate measurements are presented graphically in Figure 4-14.

4.3.12 Total Dissolved Solids, Total Suspended Solids and Turbidity

Total dissolved solids or total filterable residue, TDS, is defined as that portion of the total residue that passes through a glass fiber filter and remains after ignition at 180°C for one hour. Total dissolved solids do not necessarily represent only the dissolved constituents but may also include colloidal materials and some small particulates. The mean TDS measured in the Columbia River varied from 80.5 mg/l at Station 7 to 83.4 mg/l at Station 1 (Table 4-16). There were no consistent differences in TDS concentrations between stations or through time.

Total suspended solids (TSS) or total nonfilterable residue is the material retained on a standard glass fiber filter after filtration of a well-mixed sample. TSS concentrations were generally low and varied from <0.5 to 9.4 mg/l (Table 4-16). Mean TSS concentrations ranged from 2.2 mg/l at Station 11 to 3.7 mg/l at Station 1.

Turbidity is a measure of the suspended matter that interferes with the passage of light through water. In the Columbia River, measured turbidities were low and ranged from 0.60 nephelometric turbidity units (NTU) to 2.20 NTU (Table 4-8). Total dissolved solids, total suspended solids and turbidity data are presented graphically in Figures 4-15, 4-16, and 4-17.

4.3.13 Quarterly Drinking Well Measurements

The results of the 1989 quarterly drinking well water analyses for pH, alkalinity, nitrate-nitrogen, total phosphorus and orthophosphorus are presented in Table 4-17. pH values ranged from 7.81 to 8.52 which are similar to river pH measurements (Table 4-5). The other parameters are comparable to river measurements and have the following value ranges: alkalinity, 37.1-39.0 mg/l; nitrate-nitrogen, 0.02 - 0.19 mg/l. Total-phosphorus and orthophosphorus were below detection limits for all periods.

4.4 DISCUSSION

On nearly all sampling periods, significant interstation differences could not be detected for any of the measured parameters.

Results for Stations 11M & 11B were consistant with surface measurements and generally indicate that the discharge plume is well mixed and uniform in its vertical dispersion as it exits the mixing zone.

Overall, it appears that, with respect to all the measured parameters sampled under the operating conditions prevailing during 1989, WNP-2 cooling water discharge had little effect upon Columbia River water quality.

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Table 4-1. Summary of Water Quality Parameters, Stations, and Sampling Frequencies, 1989

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

Symbols Key

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

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

Parameter	EPA Method Number	ASTM Method Number
Water Temperature (°C)	170.1	
Turbidity, (NTU)	180.1	
Conductivity (umhos/cm) at 25°C	120.1	
Dissolved Oxygen (mg/l) probe	360.1	
Dissolved Oxygen (mg/l) Modified Winkler	360.2	
pH (Standard Unit)	150.1	
Total Alkalinity (mg/l as $CaCO_3$)	310.1	
Total Hardness (mg/l as $CaCO_3$)	130.2, 6010	
Oil and Grease (mg/l)	413.2	
Nitrogen, Ammonia, Total (mg/l as N)	350.3	
Nitrate Nitrogen, Total (mg/l as N)	352.1	D4327-88
Total Phosphorus (mg/l as P)	365.2	
Ortho Phosphorus (mg/l as P)	365.2	D4327-88
Sulfate (mg/l as SO_4)	375.4	D4327-88
Total Copper (ug/l as Cu)	220.1, 220.2, 200.7	
Total Iron (ug/l as Fe)	236.1, 236.2, 200.7	
Total Nickel (ug/l as Ni)	249.1, 249.2	
Total Zinc (ug/l as Zn)	289.1, 289.2, 200.7	
Total Lead (ug/l as P6)	239.1, 239.2	
Total Cadmium (ug/l as Cd)	213.1, 213.2	
Total Chromium (ug/l as Cr)	218.1, 218.2	
Total Residual Chlorine (ug/l)	330.1	
Filterable Residue: Total Dissolved Solids (mg/l)	160.1	
Non-Filterable Residue: Total Suspended Solids (mg/l)	160.2	

Table 4-3. Summary of Temperature Measurements for 1989.

Sample Date	Temperature (Degrees C) 1	7	11	11M	11B	8
01/18/89	3.8	3.8	3.8	4.8	4.9	3.8
02/23/89	2.2	2.2	2.2	2.7	2.8	2.2
03/15/89	3.0	3.0	3.0	3.3	3.4	3.0
04/12/89	7.0	7.0	7.0	7.2	7.2	7.0
05/25/89	11.5	--	--	--	--	--
06/15/89	15.2	--	--	--	--	--
07/27/89	19.2	19.0	19.0	19.5	19.5	19.0
08/29/89	19.0	19.0	19.0	19.0	19.0	19.0
09/19/89	17.8	17.8	17.8	17.6	17.9	17.8
10/30/89	13.6	13.7	13.7	14.0	13.7	13.7
11/15/89	11.6	11.5	11.7	11.7	11.5	11.6
12/14/89	7.5	7.7	7.3	7.3	7.3	7.5
Mean	11.0	10.5	10.5	10.7	10.7	10.5
SD	5.94	6.32	6.34	6.19	6.17	6.33
Maximum	19.2	19.0	19.0	19.5	19.5	19.0
Minimum	2.2	2.2	2.2	2.7	2.8	2.2

Table 4-4. Summary of Dissolved Oxygen Measurements for 1989.

Sample Date	Dissolved Oxygen (mg/l) 1	7	11	8
01/18/89	12.4	12.4	12.4	12.3
02/23/89	12.0	11.9	11.9	11.8
03/15/89	11.6	11.6	11.8	11.6
04/12/89	12.2	13.0	12.6	12.5
05/25/89	11.8	--	--	--
06/15/89	11.1	--	--	--
07/27/89	9.6	9.9	9.8	9.7
08/29/89	9.6	9.8	9.7	9.6
09/19/89	9.1	9.0	9.0	9.0
10/30/89	9.8	10.3	9.8	9.8
11/15/89	10.6	11.0	10.8	10.6
12/14/89	NA	NA	NA	NA
Mean	10.9	10.9	10.9	10.9
SD	1.14	1.26	1.27	1.23
Maximum	12.4	13.0	12.6	12.5
Minimum	9.1	9.0	9.0	9.0

Table 4-5. Summary of pH Measurements for 1989.

Sample Date	pH 1	7	11	11M	11B	8
01/18/89	8.04	7.92	8.01	8.04	8.04	8.04
02/23/89	7.78	7.73	7.81	7.78	7.72	7.84
03/15/89	8.16	8.09	7.99	8.10	8.12	8.12
04/12/89	8.60	8.55	8.58	8.52	8.57	8.52
05/25/89	7.97	--	--	--	--	--
06/15/89	7.52	--	--	--	--	--
07/27/89	8.09	8.03	8.14	8.06	8.05	8.10
08/29/89	8.02	7.98	8.06	8.21	8.05	8.08
09/19/89	7.58	7.63	7.55	7.68	7.64	7.60
10/30/89	7.88	7.55	7.60	7.78	7.61	7.66
11/15/89	7.57	7.46	7.49	7.52	7.59	7.55
12/14/89	7.35	7.23	7.27	7.26	7.35	7.38
Mean	7.88	7.82	7.85	7.90	7.87	7.89
SD	0.33	0.36	0.36	0.35	0.34	0.33
Maximum	8.60	8.55	8.58	8.52	8.57	8.52
Minimum	7.35	7.23	7.27	7.26	7.35	7.38

Table 4-6. Summary of Alkalinity and Hardness Measurements for 1989.

Sample Date	Total Alkalinity (mg/l) 1	7	11	8	Sample Date	Total Hardness (mg/l) 1	7	11	8
01/18/89	60.0	62.5	62.5	62.5	01/18/89	66.0	65.0	66.0	66.0
02/23/89	60.0	60.0	62.0	60.0	02/23/89	77.3	74.7	74.9	74.8
03/15/89	60.0	62.0	62.0	62.0	03/15/89	75.3	76.0	77.4	78.7
04/12/89	60.0	62.0	61.0	61.0	04/12/89	86.3	87.8	85.6	84.6
05/25/89	53.0	--	--	--	05/25/89	59.6	--	--	--
06/15/89	55.0	--	--	--	06/15/89	51.6	--	--	--
07/27/89	50.0	48.0	45.0	43.0	07/27/89	53.7	54.2	55.4	54.4
08/29/89	53.0	56.0	57.0	55.0	08/29/89	64.9	66.7	69.5	64.4
09/19/89	55.0	55.0	56.0	55.0	09/19/89	60.5	62.4	62.5	61.9
10/30/89	59.0	59.0	59.0	60.0	10/30/89	60.8	66.4	65.8	64.3
11/15/89	56.0	56.0	55.0	56.0	11/15/89	63.9	64.9	63.1	65.1
12/14/89	50.0	58.0	58.0	59.0	12/14/89	70.6	67.3	67.2	67.4
Mean	55.9	57.9	57.8	57.4	Mean	65.9	68.5	68.7	68.2
SD	3.71	4.17	4.95	5.45	SD	9.62	8.62	8.15	8.35
Maximum	60.0	62.5	62.5	62.5	Maximum	86.3	87.8	85.6	84.6
Minimum	50.0	48.0	45.0	43.0	Minimum	51.6	54.2	55.4	54.4

Table 4-7. Summary of Conductivity Measurements for 1989.

Conductivity at 25°C (uS/cm)

Sample Date	1	7	11	11M	11B	8
01/18/89	140.0	142.0	148.0	134.3	136.6	147.0
02/23/89	174.1	171.6	171.5	173.8	176.1	170.7
03/15/89	168.4	169.6	171.2	173.1	174.5	170.1
04/12/89	164.7	165.3	165.6	166.3	164.9	164.2
05/25/89	125.0	--	--	--	--	--
06/15/89	110.4	--	--	--	--	--
07/27/89	124.3	123.2	125.4	128.8	128.8	125.4
08/29/89	135.4	136.9	136.1	137.0	139.3	135.9
09/19/89	135.6	140.3	136.3	137.6	142.6	137.2
10/30/89	139.6	142.2	146.0	143.0	139.8	135.6
11/15/89	134.1	134.3	134.0	134.0	139.7	133.4
12/14/89	146.7	145.9	148.3	146.4	146.0	146.3
Mean	141.5	147.1	148.2	147.4	148.8	146.6
SD	18.30	15.78	15.69	16.24	15.86	15.46
Maximum	174.1	171.6	171.5	173.8	176.1	170.7
Minimum	110.4	123.2	125.4	128.8	128.8	125.4

Table 4-8. Summary of Turbidity and Total Residual Chlorine Measurements for 1989.

Sample Date	Turbidity (NTU) 1	7	11	8	Sample Date	Total Residual Chlorine (mg/l) 1	7	11	8
01/18/89	0.7	0.7	0.8	0.7	01/18/89	<0.05	<0.05	<0.05	<0.05
02/23/89	0.8	0.6	0.8	0.9	02/23/89	<0.05	<0.05	<0.05	<0.05
03/15/89	1.8	1.4	1.5	1.4	03/15/89	<0.05	<0.05	<0.05	<0.05
04/12/89	1.2	1.3	1.2	1.1	04/12/89	<0.05	<0.05	<0.05	<0.05
05/25/89	2.2	--	--	--	05/25/89	<0.05	--	--	--
06/15/89	1.8	--	--	--	06/15/89	<0.05	--	--	--
07/27/89	1.4	1.3	1.4	1.2	07/27/89	<0.05	<0.05	<0.05	<0.05
08/29/89	1.0	1.0	1.0	1.0	08/29/89	<0.05	<0.05	<0.05	<0.05
09/19/89	0.9	0.9	0.9	0.9	09/19/89	<0.05	<0.05	<0.05	<0.05
10/30/89	1.0	1.0	1.0	1.0	10/30/89	<0.05	<0.05	<0.05	<0.05
11/15/89	1.0	1.0	1.0	1.0	11/15/89	<0.05	<0.05	<0.05	<0.05
12/14/89	1.0	1.0	1.0	1.0	12/14/89	<0.05	<0.05	<0.05	<0.05
Mean	1.2	1.0	1.1	1.0	Mean	-	-	-	-
SD	0.45	0.24	0.22	0.18	SD	-	-	-	-
Maximum	2.2	1.4	1.5	1.4	Maximum	-	-	-	-
Minimum	0.7	0.6	0.8	0.7	Minimum	-	-	-	-

Table 4-9. Summary of Copper Measurements for 1989.

Copper (ug/l)

Sample Date	1	7	11	11M	11B	8
01/18/89	2.2	0.9	1.1	1.1	1.1	0.8
02/23/89	0.9	1.3	1.1	2.9	1.3	0.8
03/15/89	1.4	1.4	1.6	1.3	1.3	1.6
04/12/89	1.5	1.7	1.7	1.7	1.3	1.5
05/25/89	2.0	--	--	--	--	--
06/15/89	1.8	--	--	--	--	--
07/27/89	2.0	1.8	1.5	1.7	1.5	1.5
08/29/89	1.2	0.9	0.9	1.1	0.9	1.1
09/19/89	1.2	1.1	1.2	1.0	0.9	1.0
10/30/89	1.7	1.8	1.8	1.6	1.6	1.8
11/15/89	0.9	0.8	1.0	1.6	1.8	0.8
12/14/89	1.8	1.8	2.3	2.0	2.0	2.3
Mean	1.6	1.4	1.4	1.6	1.4	1.3
SD	0.42	0.39	0.42	0.53	0.34	0.48
Maximum	2.2	1.8	2.3	2.9	2.0	2.3
Minimum	0.9	0.8	0.9	1.0	0.9	0.8

Table 4-10. Summary of Nickel and Zinc Measurements for 1989.

Sample Date	Nickel (ug/l) 1	7	11	8	Sample Date	Zinc (ug/l) 1	7	11	8
01/18/89	1.2	1.6	2.1	2.5	01/18/89	14.0	14.0	15.0	13.0
02/23/89	0.8	0.9	1.0	1.3	02/23/89	9.0	9.0	9.0	8.0
03/15/89	0.9	0.5	0.9	0.5	03/15/89	9.0	10.0	9.0	10.0
04/12/89	--	0.8	0.3	0.4	04/12/89	8.0	8.0	6.0	7.0
05/25/89	0.5	--	--	--	05/25/89	11.7	--	--	--
06/15/89	0.3	--	--	--	06/15/89	6.3	--	--	--
07/27/89	1.2	0.5	0.4	0.2	07/27/89	2.7	2.3	2.3	2.1
08/29/89	1.1	0.6	0.5	0.5	08/29/89	3.6	4.1	4.0	4.4
09/19/89	0.6	0.2	0.3	0.2	09/19/89	4.9	6.7	4.0	6.0
10/30/89	0.2	0.1	<0.1	<0.1	10/30/89	4.4	4.1	5.2	3.8
11/15/89	0.4	0.1	0.3	0.4	11/15/89	3.0	5.2	4.0	4.9
12/14/89	0.5	0.2	0.1	<0.1	12/14/89	4.7	5.4	5.7	4.3
Mean	0.7	0.6	0.6	0.6	Mean	6.8	6.9	6.4	6.4
SD	0.34	0.44	0.59	0.72	SD	3.45	3.28	3.52	3.09
Maximum	1.2	1.6	2.1	2.5	Maximum	14.0	14.0	15.0	13.0
Minimum	0.2	0.1	<0.1	<0.1	Minimum	2.7	2.3	2.3	2.1

Samples below detection limit were considered as one-half for calculation of means.

Table 4-11. Summary of Iron and Lead Measurements for 1989.

Sample Date	Iron (ug/l) 1	7	11	8	Sample Date	Lead (ug/l) 1	7	11	8
01/18/89	50.3	52.4	48.3	49.9	01/18/89	3.3	3.0	1.7	1.5
02/23/89	34.8	49.4	39.5	35.4	02/23/89	1.5	2.0	1.7	1.6
03/15/89	87.4	81.8	80.4	86.9	03/15/89	1.1	2.2	1.7	1.1
04/12/89	67.0	77.0	66.0	76.0	04/12/89	1.5	1.7	1.6	1.1
05/25/89	110.0	--	--	--	05/25/89	2.6	--	--	--
06/15/89	110.0	--	--	--	06/15/89	1.8	--	--	--
07/27/89	40.0	28.0	34.0	28.0	07/27/89	0.8	0.9	1.1	1.0
08/29/89	47.0	50.0	53.0	47.0	08/29/89	0.9	0.3	0.5	0.7
09/19/89	23.0	27.0	30.0	30.0	09/19/89	1.5	1.4	1.3	1.4
10/30/89	21.0	51.0	49.0	52.0	10/30/89	0.9	0.8	0.7	0.6
11/15/89	74.0	74.0	74.0	65.0	11/15/89	0.4	0.6	0.1	0.2
12/14/89	46.0	54.0	52.0	57.0	12/14/89	0.6	0.4	0.2	0.8
Mean	59.2	54.5	52.6	52.7	Mean	1.4	1.3	1.1	1.0
SD	29.40	17.76	15.72	18.30	SD	0.81	0.84	0.61	0.41
Maximum	110.0	81.8	80.4	86.9	Maximum	3.3	3.0	1.7	1.6
Minimum	21.0	27.0	30.0	28.0	Minimum	0.4	0.3	0.1	0.2

Table 4-12. Summary of Cadmium and Chromium Measurements for 1989.

Sample Date	Cadmium (ug/l) 1	7	11	8	Sample Date	Chromium (ug/l) 1	7	11	8
01/18/89	0.2	0.3	0.1	0.2	01/18/89	0.1	0.1	<0.1	<0.1
02/23/89	<0.1	0.1	0.1	<0.1	02/23/89	0.1	0.3	0.1	0.1
03/15/89	0.1	0.1	0.2	<0.1	03/15/89	<0.1	<0.1	<0.1	<0.1
04/12/89	<0.1	0.3	0.1	0.1	04/12/89		0.2	<0.1	<0.1
05/25/89	0.1	--	--	--	05/25/89	0.1	--	--	--
06/15/89	1.2	--	--	--	06/15/89	<0.1	--	--	--
07/27/89	0.2	<0.1	0.2	0.1	07/27/89	1.8	0.4	0.2	<0.1
08/29/89	0.3	<0.1	0.5	0.5	08/29/89	0.1	<0.1	<0.1	0.1
09/19/89	0.2	0.3	0.1	0.2	09/19/89	0.1	0.1	0.1	0.2
10/30/89	<0.1	<0.1	<0.1	<0.1	10/30/89	<0.1	<0.1	<0.1	<0.1
11/15/89	<0.1	<0.1	<0.1	<0.1	11/15/89	<0.1	<0.1	<0.1	<0.1
12/14/89	<0.1	<0.1	<0.1	0.3	11/15/89	<0.1	<0.1	<0.1	<0.1
Mean	0.2	0.1	0.2	0.2	Mean	0.2	0.1	0.1	0.1
SD	0.32	0.13	0.14	0.16	SD	0.51	0.14	0.07	0.07
Maximum	0.3	0.3	0.5	0.5	Maximum	1.8	0.4	0.2	0.2
Minimum	<0.1	<0.1	<0.1	<0.1	Minimum	<0.1	<0.1	<0.1	<0.1

Samples below detection limit were considered as one-half for calculation of means.

Table 4-13. Summary of Oil and Grease, and Ammonia Measurements for 1989.

Sample Date	Oil & Grease (mg/l) 1	7	11	8	Sample Date	Ammonia (mg NH_3 - N/l) 1	7	11	8
01/18/89	<0.5	<0.5	<0.5	<0.5	01/18/89	<0.01	<0.01	<0.01	<0.01
02/23/89	<0.5	<0.5	<0.5	<0.5	02/23/89	0.02	0.02	0.02	0.02
03/15/89	<0.5	<0.5	<0.5	<0.5	03/15/89	0.02	0.01	0.01	0.01
04/12/89	<0.5	<0.5	<0.5	<0.5	04/12/89	0.01	0.02	0.01	0.01
05/25/89	<0.5	<0.5	<0.5	<0.5	05/25/89	<0.01	--	--	--
06/15/89	<0.5	--	--	--	06/15/89	<0.01	--	--	--
07/27/89	<0.5	--	--	--	07/27/89	<0.01	<0.01	<0.01	<0.01
08/29/89	<0.5	<0.5	<0.5	<0.5	08/29/89	<0.01	<0.01	<0.01	<0.01
09/19/89	<0.5	<0.5	<0.5	<0.5	09/19/89	0.06	0.06	0.06	0.06
10/30/89	<0.5	<0.5	<0.5	<0.5	10/30/89	0.07	0.07	0.07	0.07
11/15/89	<0.5	<0.5	<0.5	<0.5	11/15/89	0.04	0.04	0.04	0.04
12/14/89	<0.5	<0.5	<0.5	<0.5	12/14/89	0.03	0.03	0.03	0.03
Mean	-	-	-	-	Mean	0.02	0.03	0.03	0.03
SD	-	-	-	-	SD	0.02	0.02	0.02	0.02
Maximum	-	-	-	-	Maximum	0.07	0.07	0.07	0.07
Minimum	-	-	-	-	Minimum	<0.01	<0.01	<0.01	<0.01

Samples below detection limit were considered as one-half for calculation of means.

Table 4-14. Summary of Nitrate and Total Phosphorus Measurements for 1989.

Sample Date	Nitrate (mg/l) 1	7	11	8	Sample Date	Total Phosphorus (mg/l) 1	7	11	8
01/18/89	0.30	0.25	0.22	0.21	01/18/89	<0.1	<0.1	<0.1	<0.1
02/23/89	0.14	0.14	0.14	0.14	02/23/89	<0.1	<0.1	<0.1	<0.1
03/15/89	0.13	0.13	0.13	0.13	03/15/89	<0.1	<0.1	<0.1	<0.1
04/12/89	0.09	0.09	0.09	0.09	04/12/89	<0.1	<0.1	<0.1	<0.1
05/25/89	0.05	--	--	--	05/25/89	<0.1	--	--	--
06/15/89	<0.01	<0.01	<0.01	<0.01	06/15/89	<0.1	--	--	--
07/27/89	<0.01	<0.01	<0.01	<0.01	07/27/89	<0.1	<0.1	<0.1	<0.1
08/29/89	<dl	<dl	<dl	<dl	08/29/89	<0.1	<0.1	<0.1	<0.1
09/19/89	0.03	0.03	0.03	0.03	09/19/89	na	na	na	na
10/30/89	0.09	0.09	0.09	0.09	10/30/89	0.13	0.12	<0.1	<0.1
11/15/89	0.09	0.08	0.08	0.09	11/15/89	0.1	0.11	0.1	0.13
12/14/89	0.10	0.10	0.10	0.10	12/14/89	<0.1	<0.1	<0.1	0.13
Mean	0.09	0.09	0.09	0.09	Mean	--	--	--	--
SD	0.08	0.07	0.06	0.06	SD	--	--	--	--
Maximum	0.30	0.25	0.22	0.21	Maximum	0.13	0.12	0.1	0.13
Minimum	<0.01	<0.01	<0.01	<0.01	Minimum	<0.1	<0.1	<0.1	<0.1

Samples below detection limit were considered as one-half for calculation of means.

Table 4-15. Summary for Orthophosphate and Sulfate Measurements for 1989.

Sample Date	Orthophosphate (mg/l) 1	7	11	8	Sample Date	Sulfate (mg/l) 1	7	11	8
01/18/89	0.03	0.03	0.03	0.03	01/18/89	11.5	11.5	12.0	12.8
02/23/89	<0.01	<0.01	<0.01	<0.01	02/23/89	13.8	13.9	14.6	13.9
03/15/89	<0.01	<0.01	<0.01	<0.01	03/15/89	12.6	12.7	13.0	12.7
04/12/89	<0.01	<0.01	<0.01	<0.01	04/12/89	12.5	13.1	13.7	12.6
05/25/89	<0.01	--	--	--	05/25/89	8.8	--	--	--
06/15/89	<0.01	--	--	--	06/15/89	7.5	--	--	--
07/27/89	<0.01	<0.01	<0.01	<0.01	07/27/89	8.2	8.3	8.4	8.3
08/29/89	<0.01	<0.01	<0.01	<0.01	08/29/89	8.6	8.5	8.5	9.1
09/19/89	<0.01	<0.01	<0.01	<0.01	09/19/89	19.9	20.2	20.0	20.6
10/30/89	<0.01	<0.01	<0.01	<0.01	10/30/89	9.4	12.5	10.3	9.8
11/15/89	<0.01	<0.01	<0.01	<0.01	11/15/89	8.3	8.3	8.5	8.6
12/14/89	<0.01	<0.01	<0.01	<0.01	12/14/89	9.4	9.5	9.6	9.5
Mean	--	--	--	--	Mean	10.9	11.9	11.9	11.8
SD	--	--	--	--	SD	3.35	3.45	3.47	3.51
Maximum	0.03	0.03	0.03	0.03	Maximum	19.9	20.2	20.0	20.6
Minimum	<0.01	<0.01	<0.01	<0.01	Minimum	7.5	8.3	8.4	8.3

Table 4-16. Summary of Total Dissolved and Total Suspended Solids Measurements for 1989.

Sample Date	Total Dissolved Solids (mg/l) 1	7	11	8	Sample Date	Total Suspended Solids (mg/l) 1	7	11	8
01/18/89	97.0	85.0	96.0	99.0	01/18/89	1.0	1.2	1.3	1.2
02/23/89	86.0	80.0	90.0	76.0	02/23/89	4.6	1.2	<0.5	0.6
03/15/89	56.0	60.0	59.0	65.0	03/15/89	2.3	0.8	<0.5	0.9
04/12/89	100.0	104.0	100.0	92.0	04/12/89	3.5	3.4	3.2	3.9
05/25/89	92.0	--	--	--	05/25/89	6.8	--	--	--
06/15/89	109.0	--	--	--	06/15/89	9.4	--	--	--
07/27/89	67.0	66.0	69.0	68.0	07/27/89	2.5	2.5	2.4	2.6
08/29/89	82.0	85.0	85.0	91.0	08/29/89	4.8	4.7	4.6	4.7
09/19/89	75.0	76.0	74.0	78.0	09/19/89	3.6	3.8	3.4	3.4
10/30/89	78.0	83.0	82.0	85.0	10/30/89	2.4	3.0	2.6	2.7
11/15/89	77.0	81.0	85.0	83.0	11/15/89	2.6	2.9	3.0	2.7
12/14/89	82.0	85.0	86.0	82.0	12/14/89	0.8	1.4	0.7	1.5
Mean	83.4	80.5	82.6	81.9	Mean	3.7	2.5	2.2	2.4
SD	14.03	11.27	11.73	10.08	SD	2.35	1.23	1.34	1.28
Maximum	109.0	104.0	100.0	99.0	Maximum	9.4	4.7	4.6	4.7
Minimum	56.0	60.0	59.0	65.0	Minimum	0.8	0.8	<0.5	0.6

Samples below detection limit were considered as one-half for calculation of means.

Table 4-17 Quarterly Drinking Well Monitoring

Measurements January - December 1989

Date	pH	Alkalinity*	Nitrogen*	T-PO4*	O-PO4*
03/15/89	7.81	38.0	na	<0.1	na
06/15/89	8.24	37.1	0.06	<0.1	<dl
09/19/99	na	na	0.19	<0.1	na
12/14/89	8.52	39.0	0.02	<0.1	<dl

*mg/l

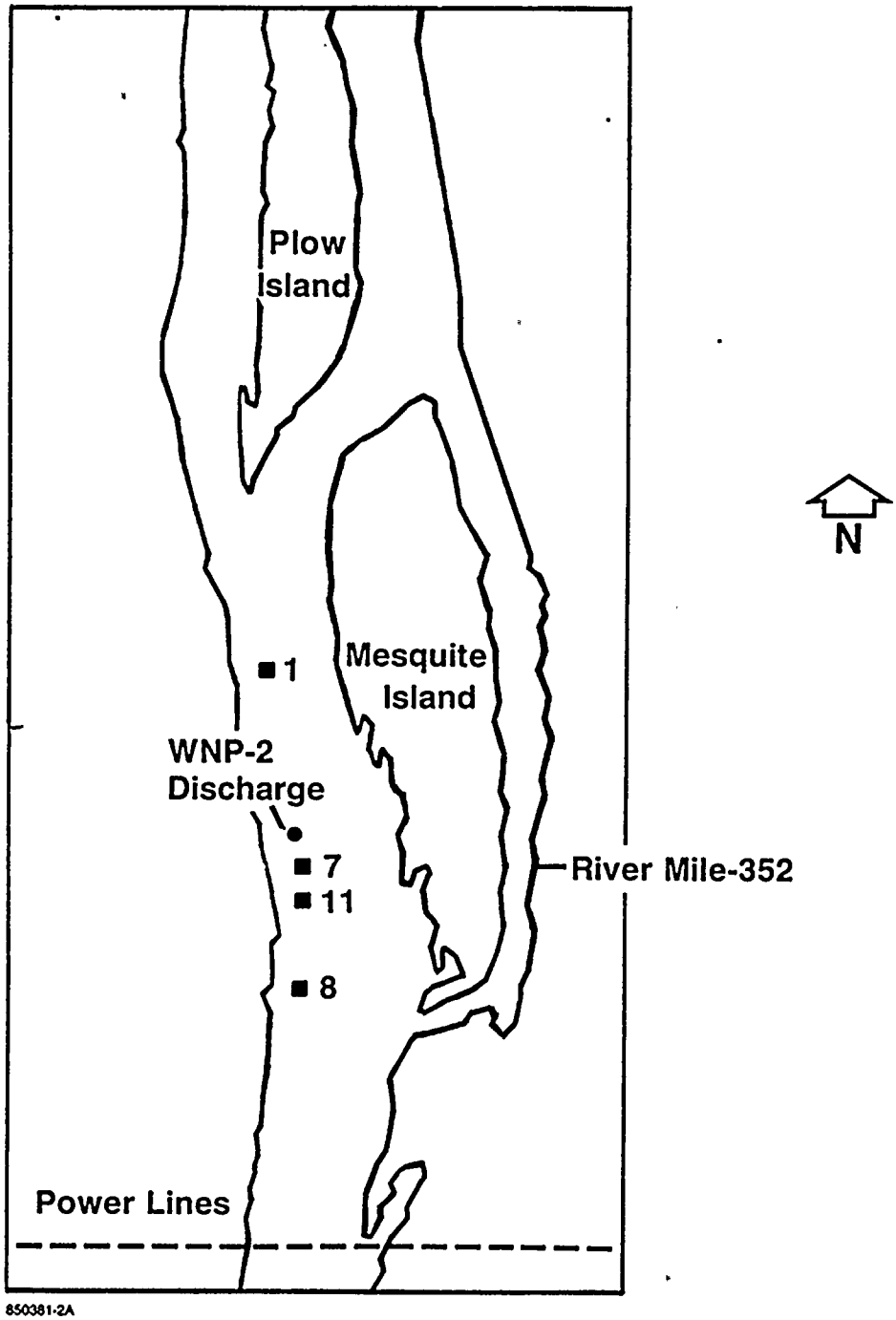

Figure 4-1 Location of Sampling Stations in the Columbia River

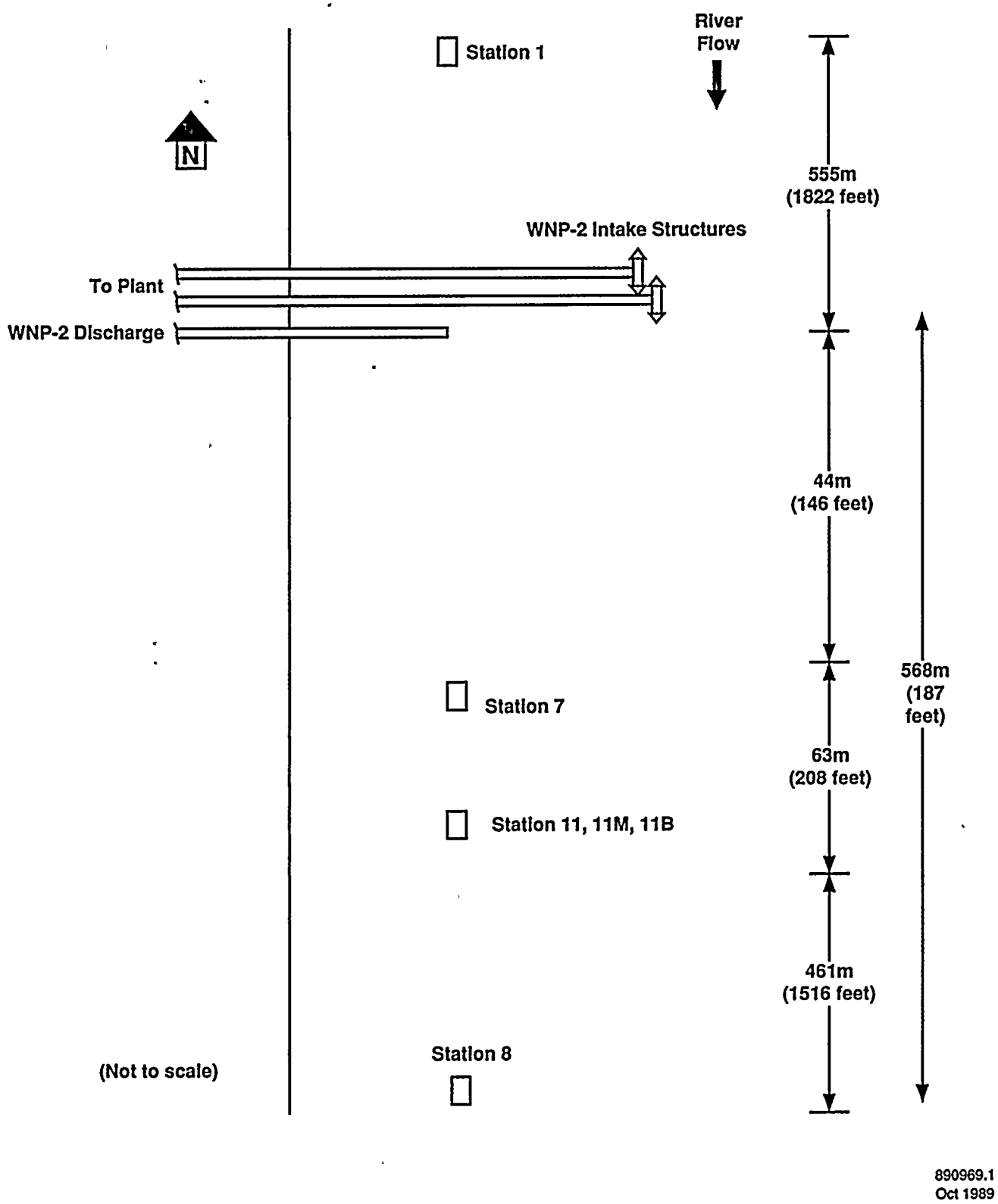

Figure 4-2 Sampling Station Locations for Water Chemistry

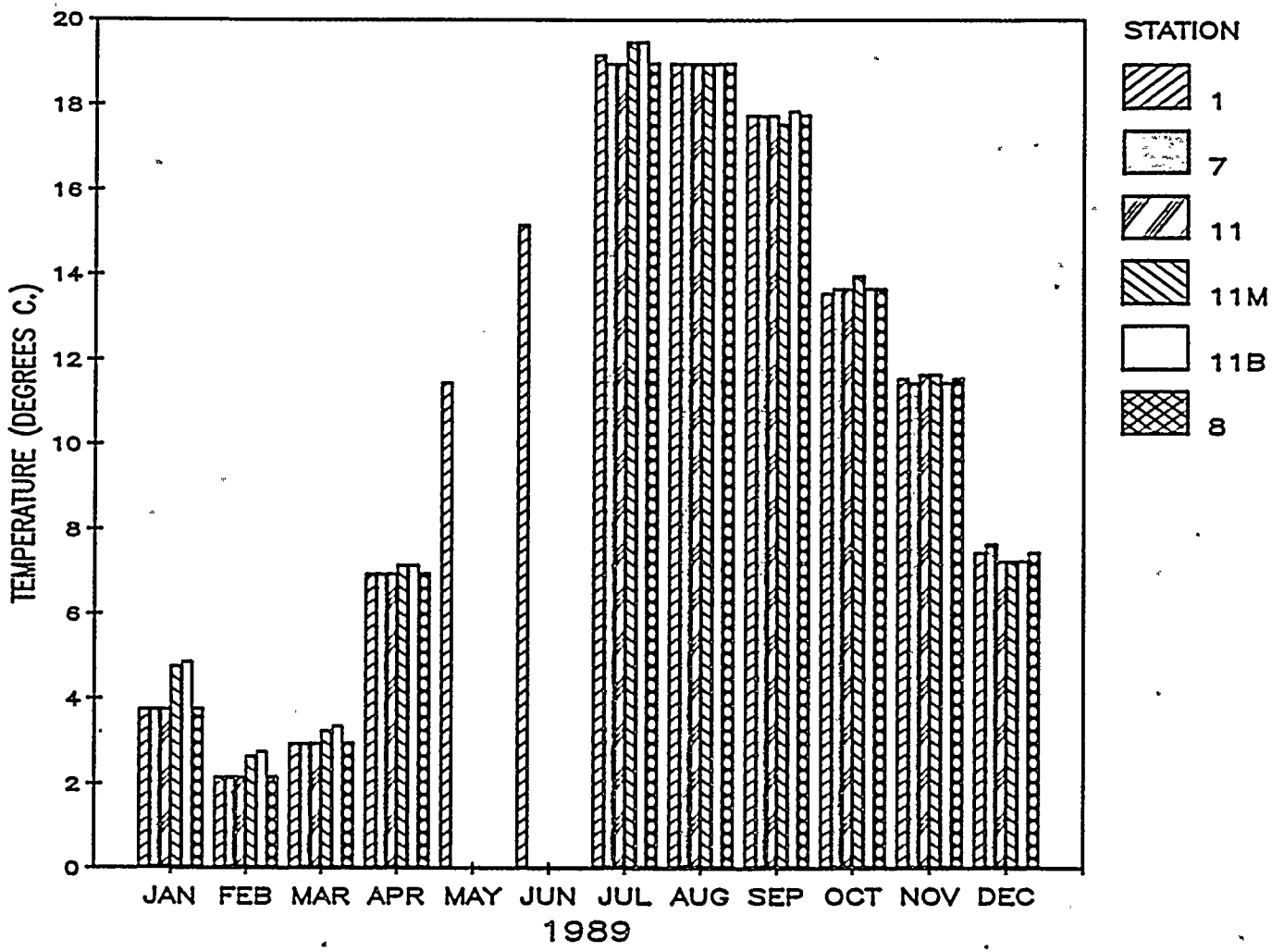

Figure 4-3 Columbia River Temperature Measurements at Six Stations During 1989

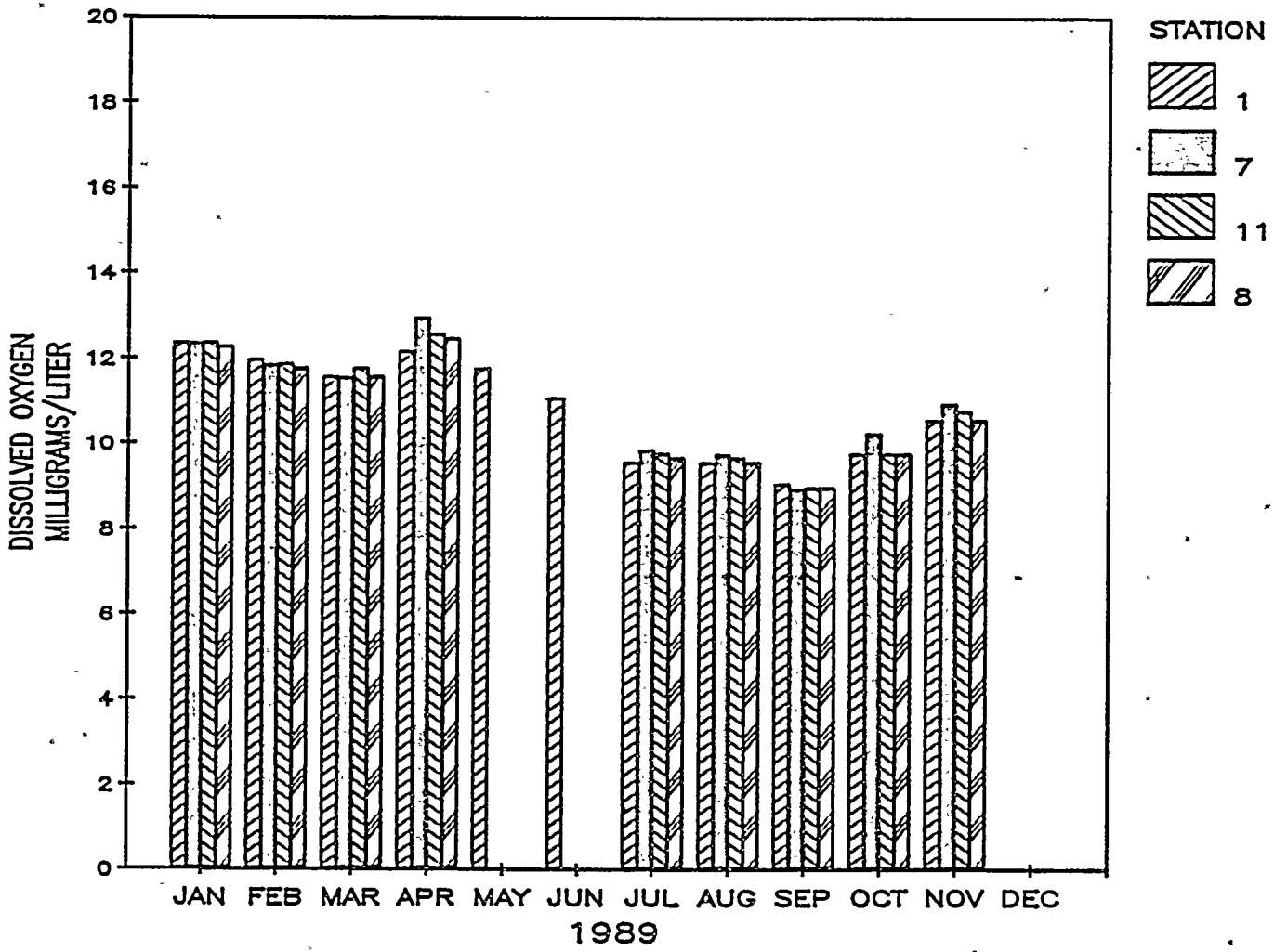

Figure 4-4 Columbia River Dissolved Oxygen Measurements at Four Stations During 1989

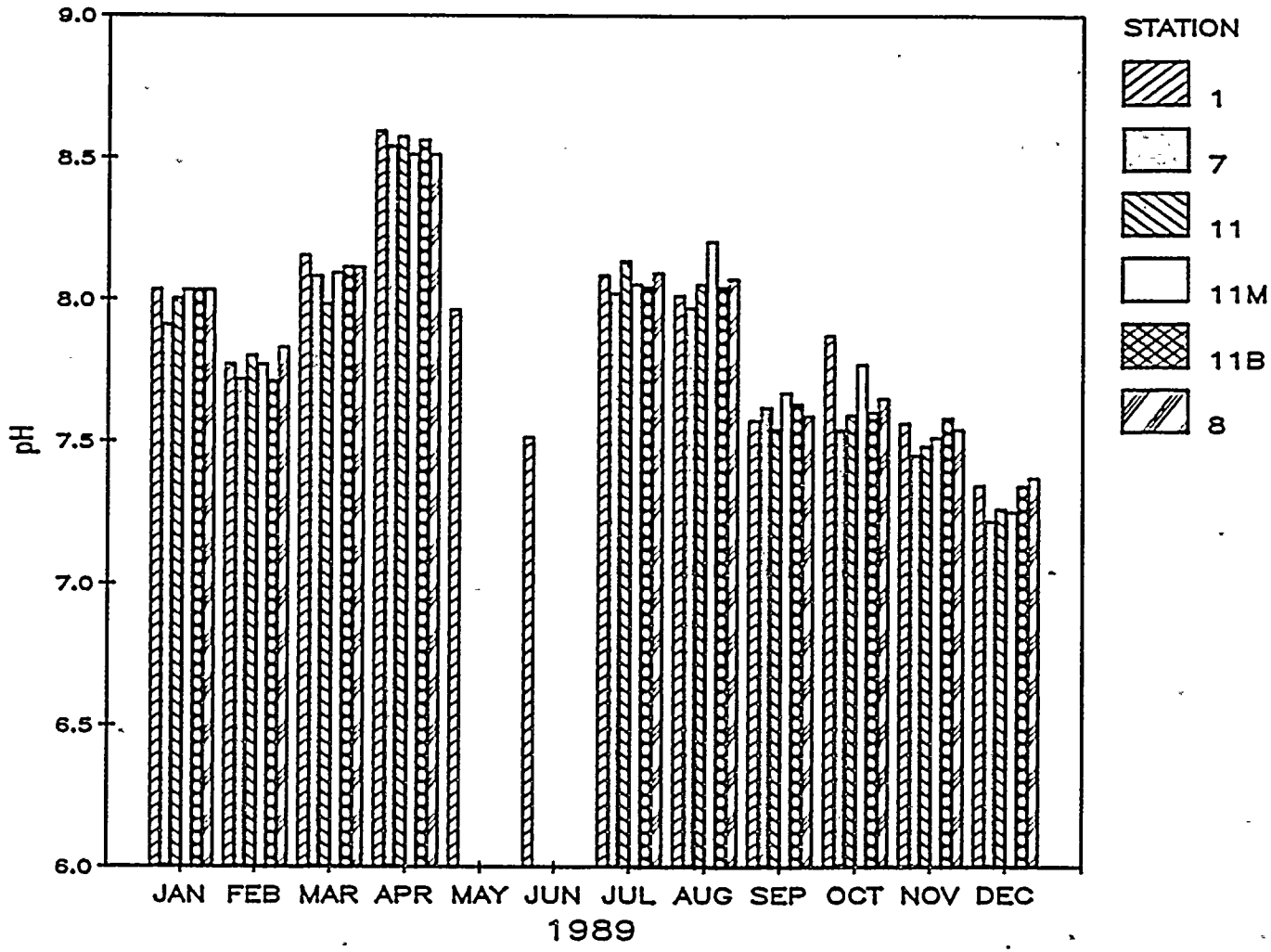

Figure 4-5 Columbia River pH Measurements at Six Stations During 1989

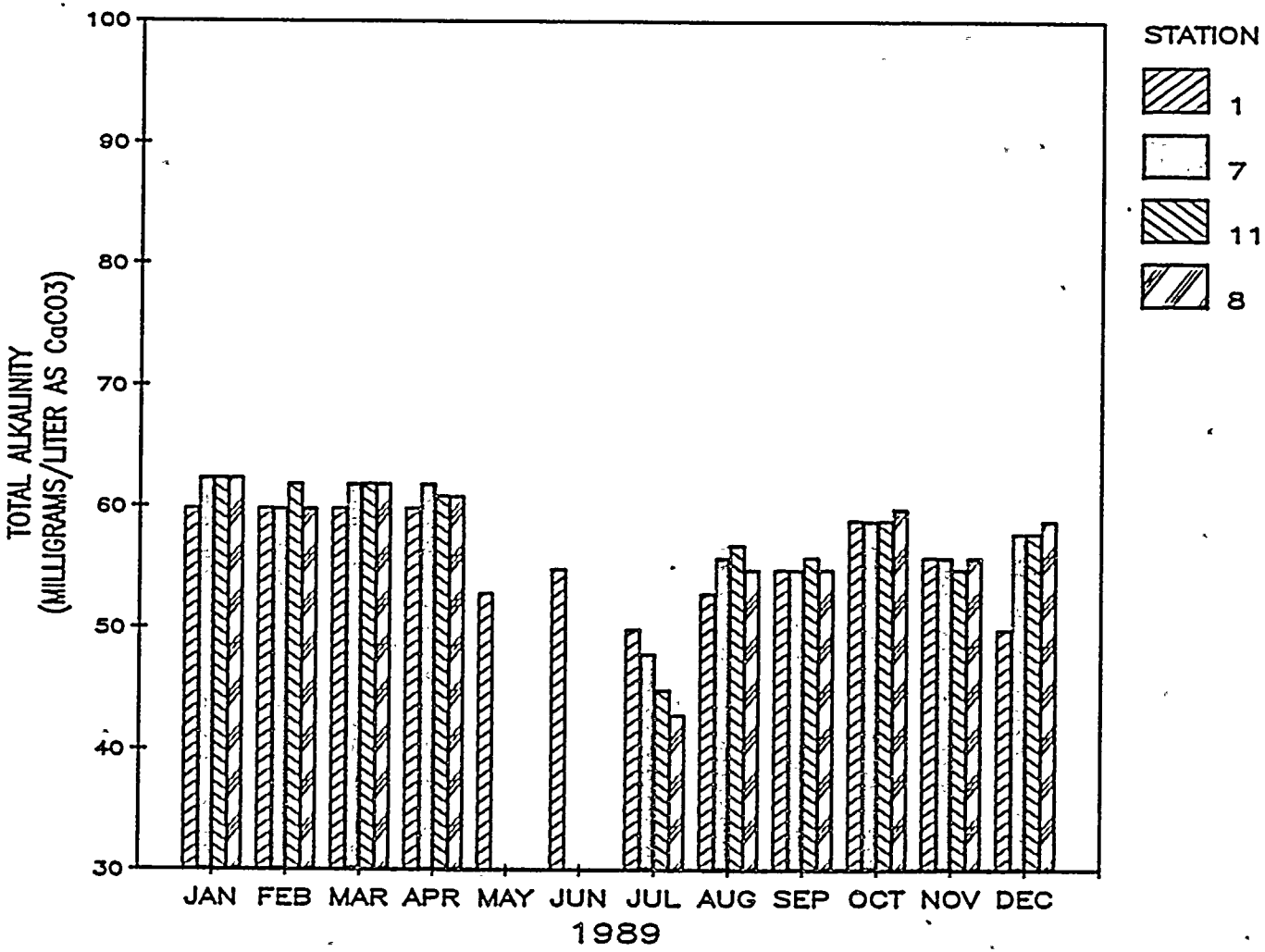

Figure 4-6 Columbia River Total Alkalinity Measurements at Four Stations During 1989

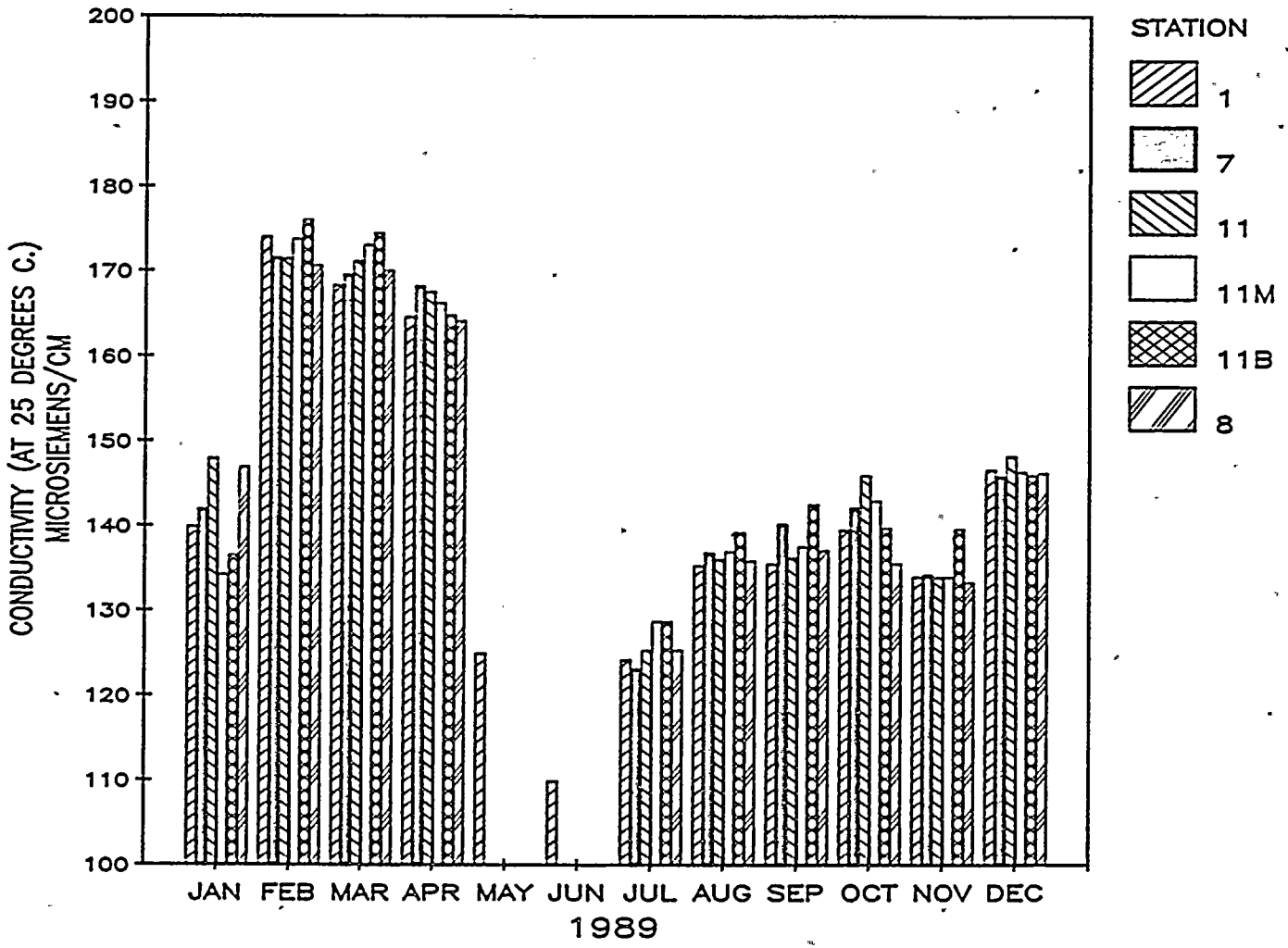

Figure 4-7 Columbia River Conductivity Measurements at Six Stations During 1989

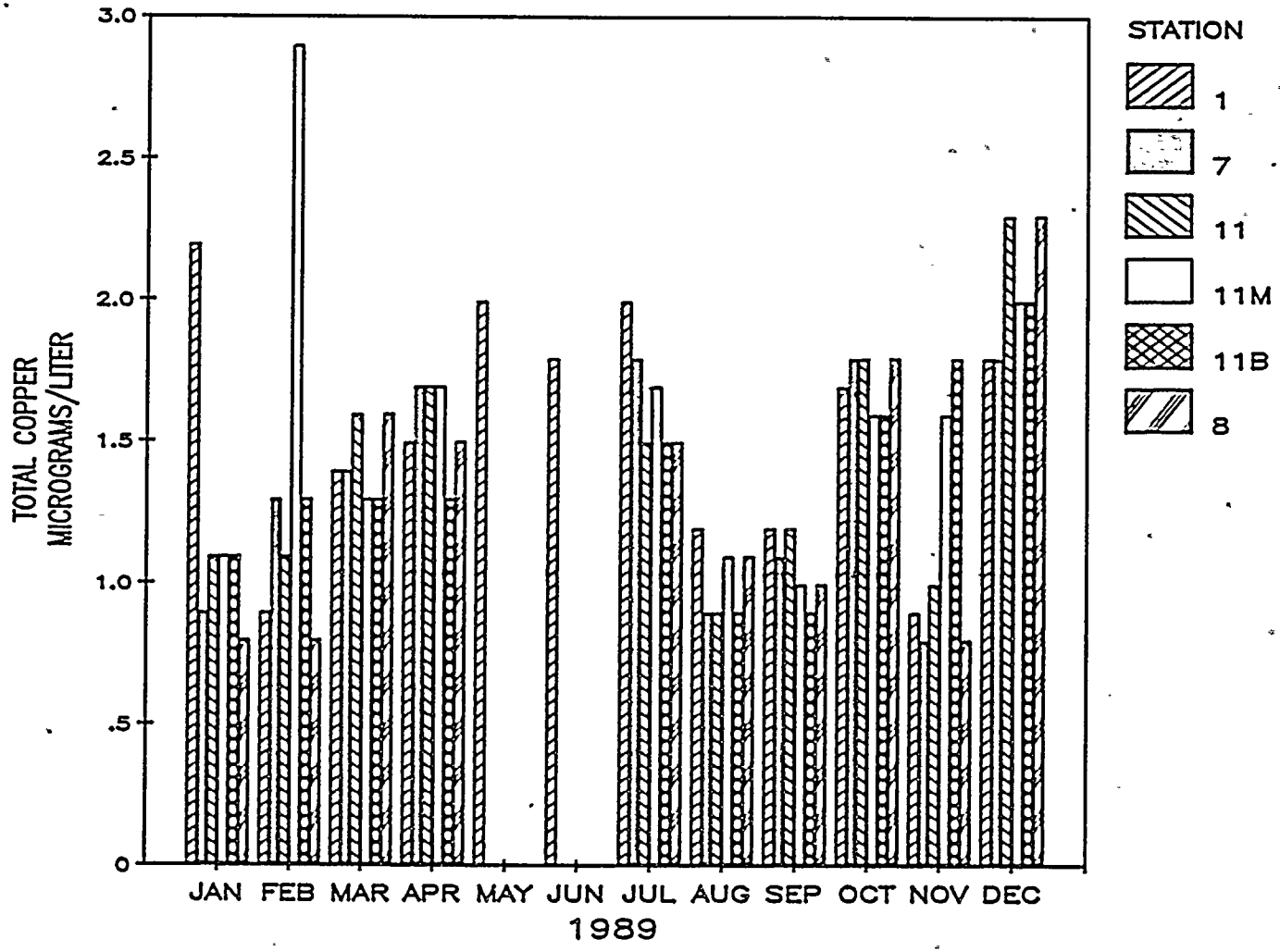

Figure 4-8 Columbia River Total Copper Measurements at Six Stations During 1989

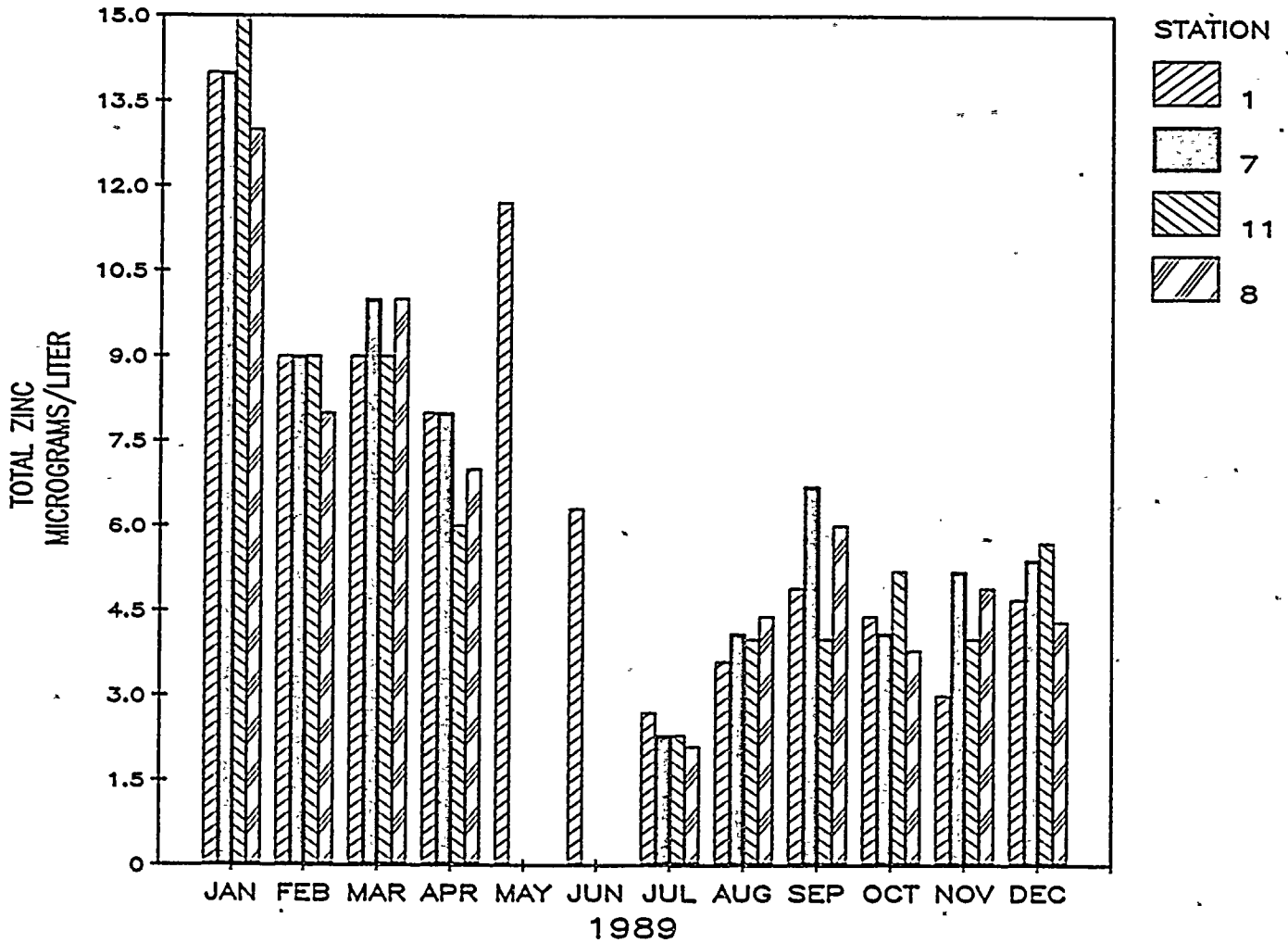

Figure 4-9 Columbia River Total Zinc Measurements at Four Stations During 1989

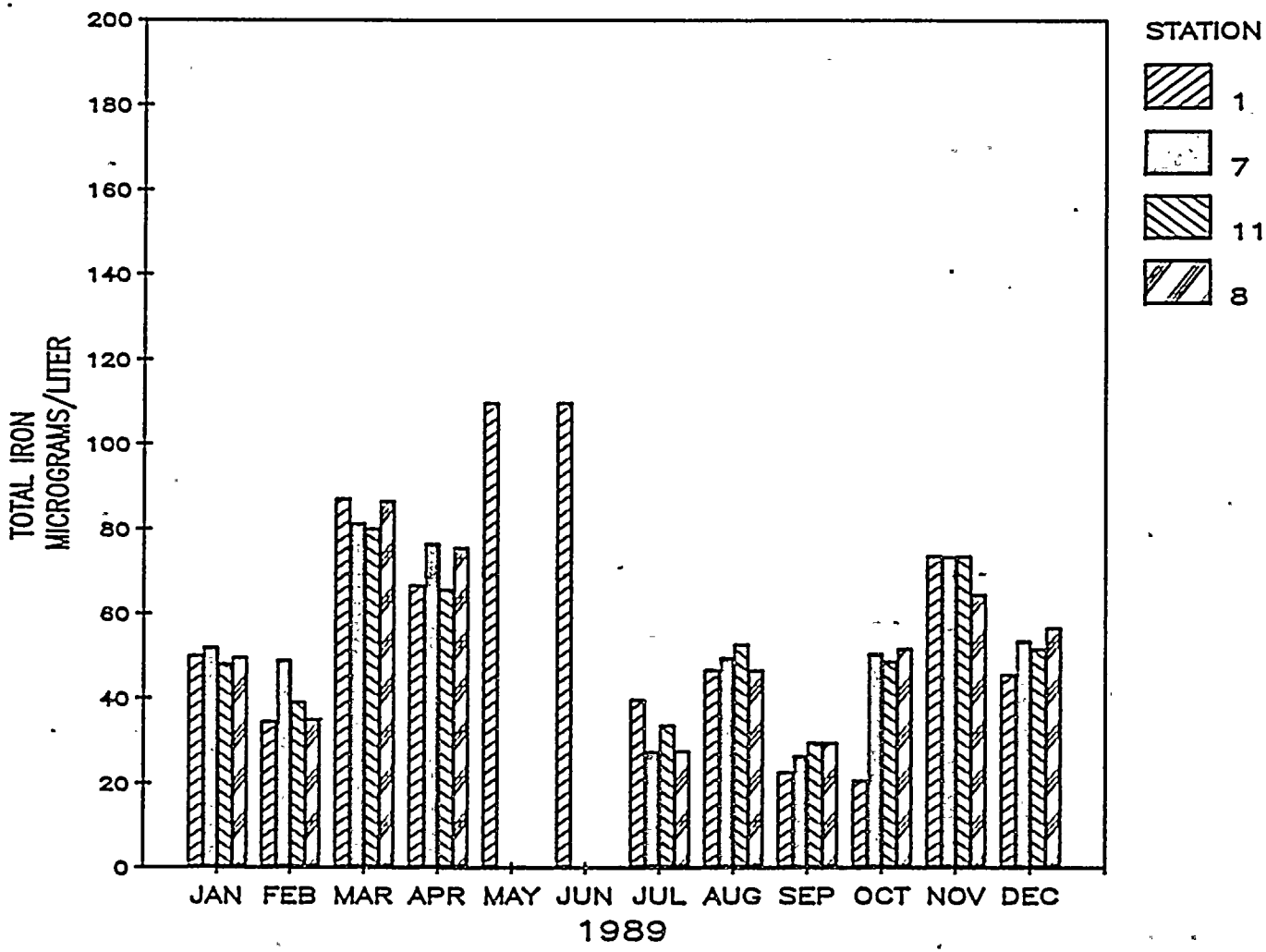

Figure 4-10 Columbia River Total Iron Measurements at Four Stations During 1989

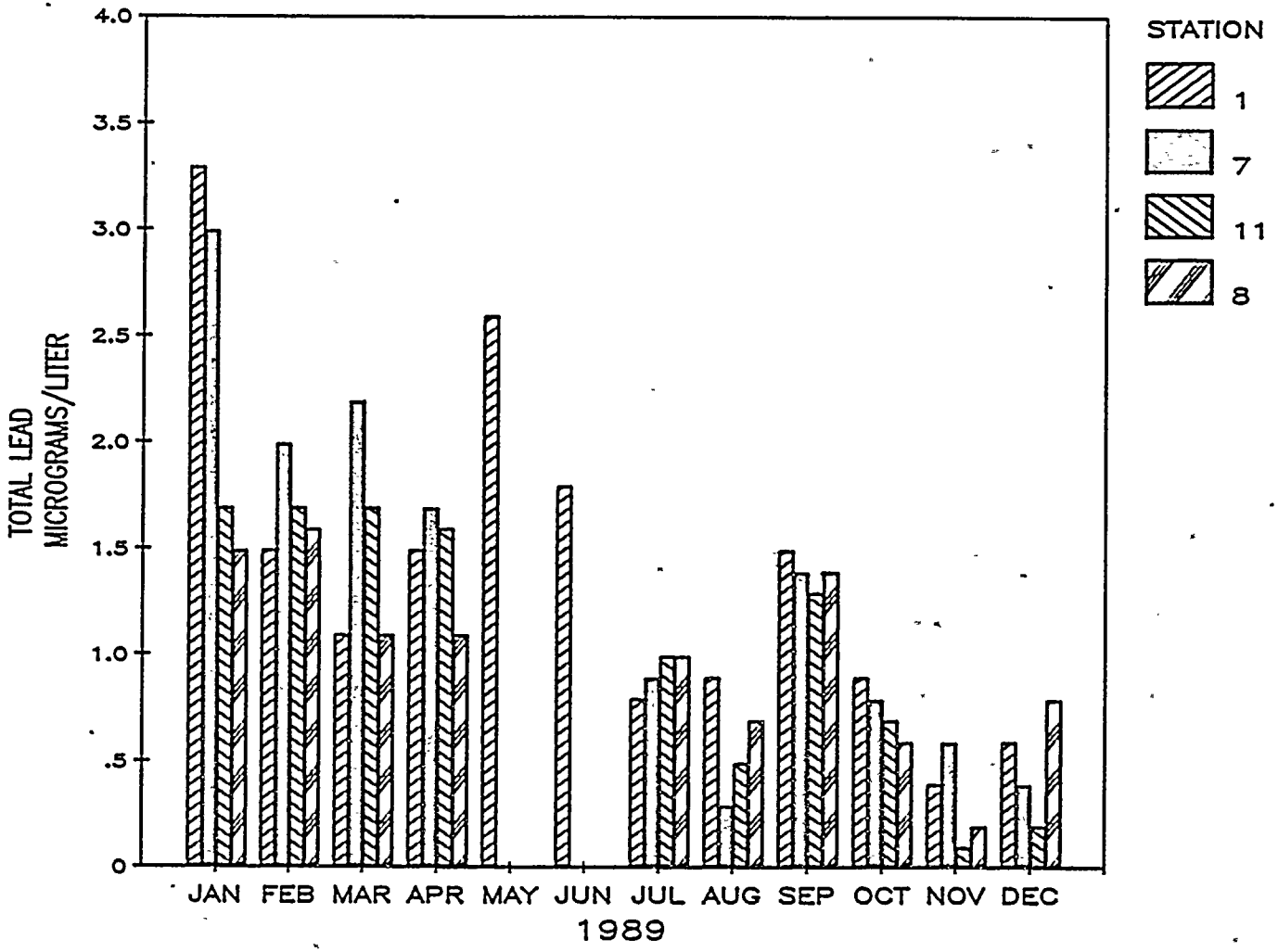

Figure 4-11 Columbia River Total Lead Measurements at Four Stations During 1989

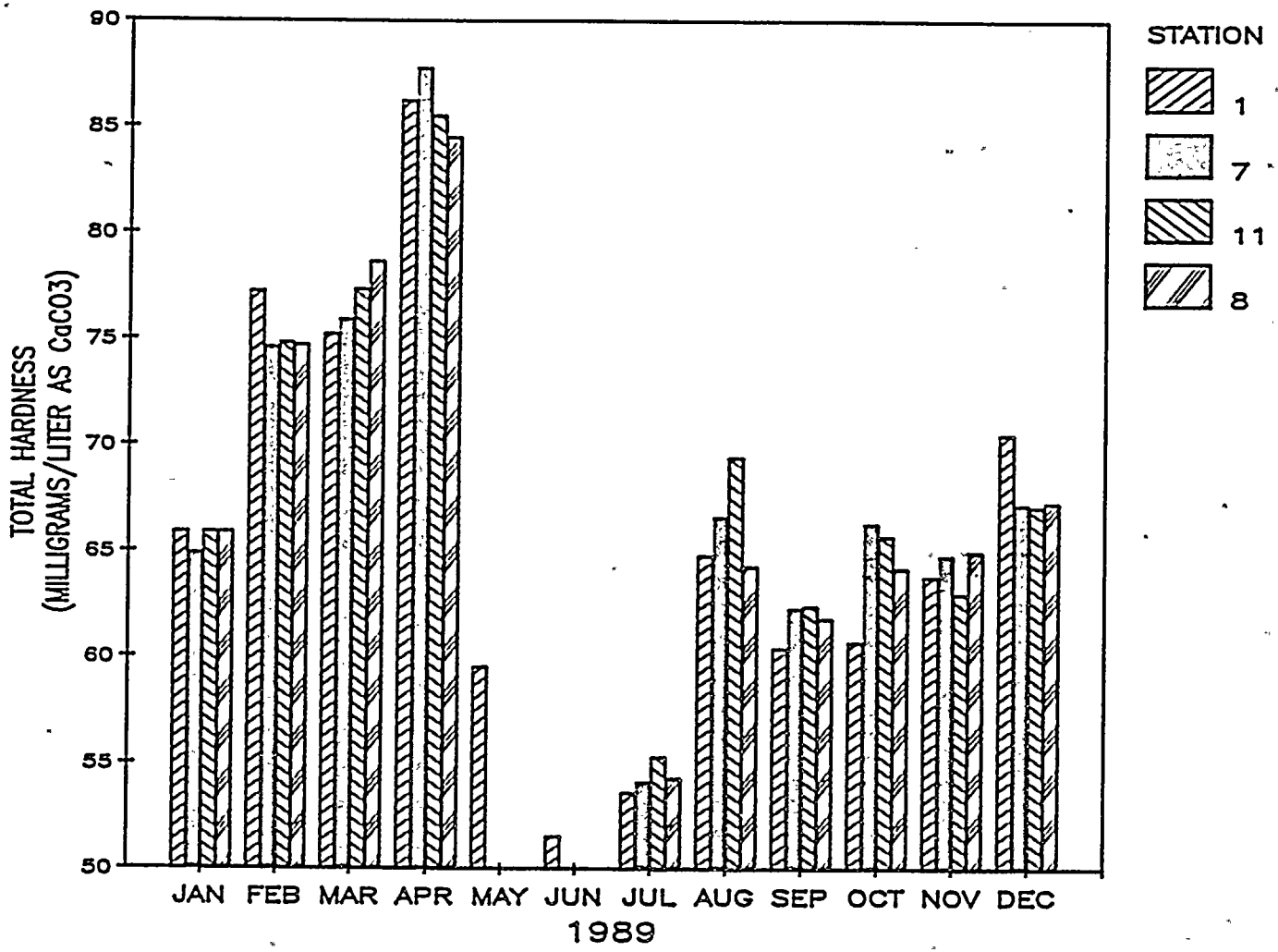

Figure 4-12 Columbia River Total Hardness Measurements at Four Stations During 1989

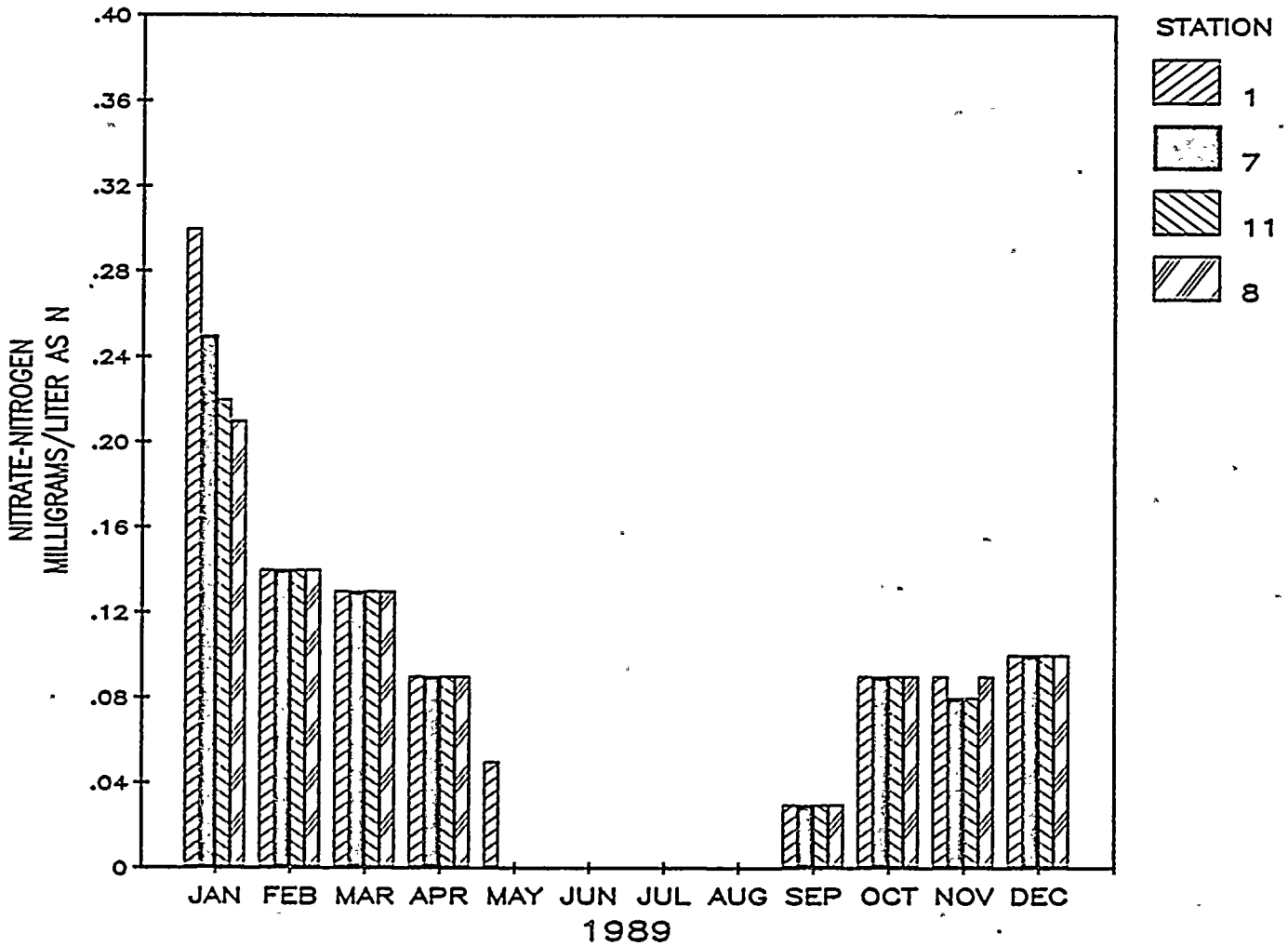

Figure 4-13 Columbia River Nitrate - Nitrogen Measurements at Four Stations During 1989

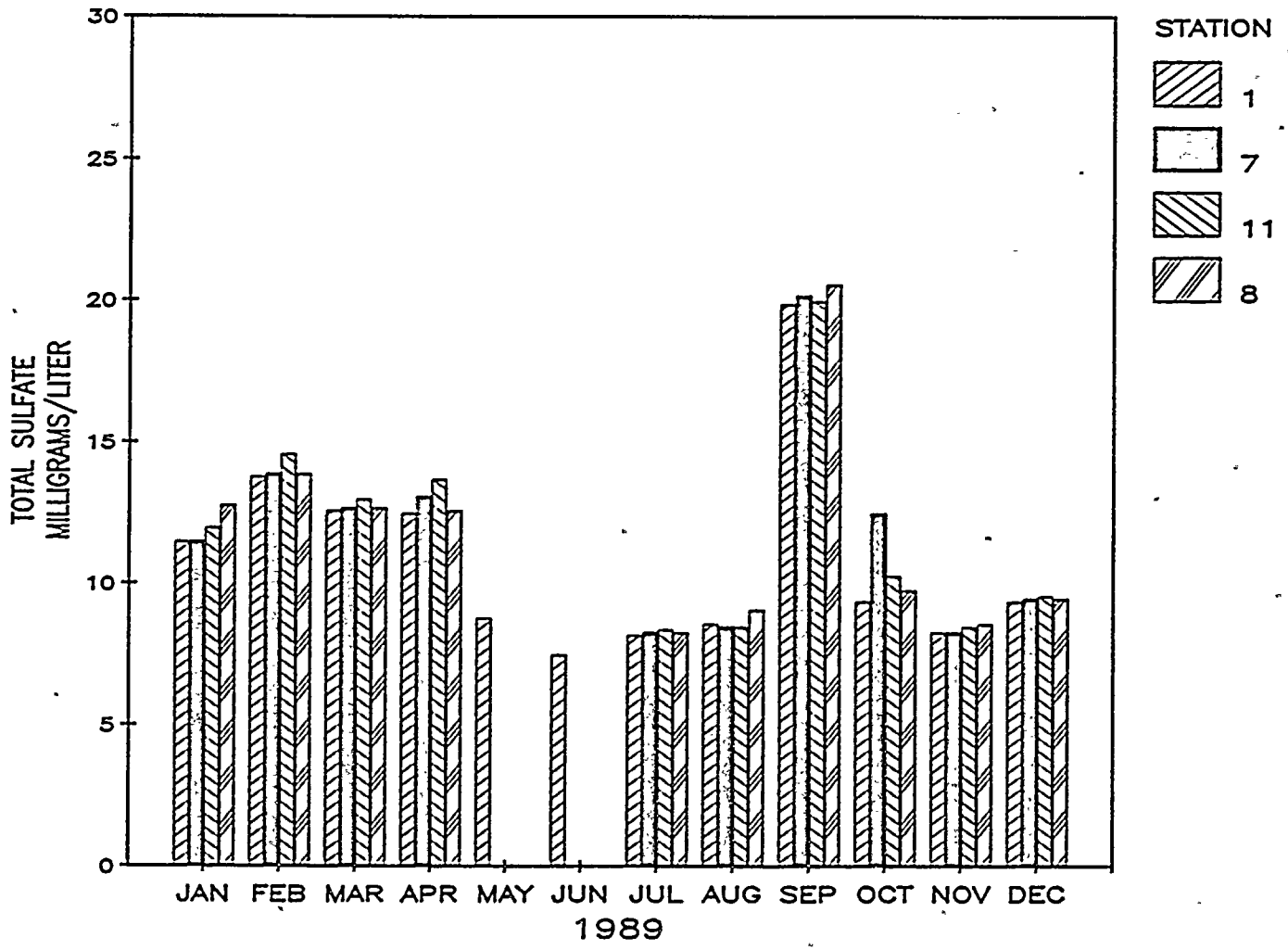

Figure 4-14 Columbia River Total Sulfate Measurements at Four Stations During 1989

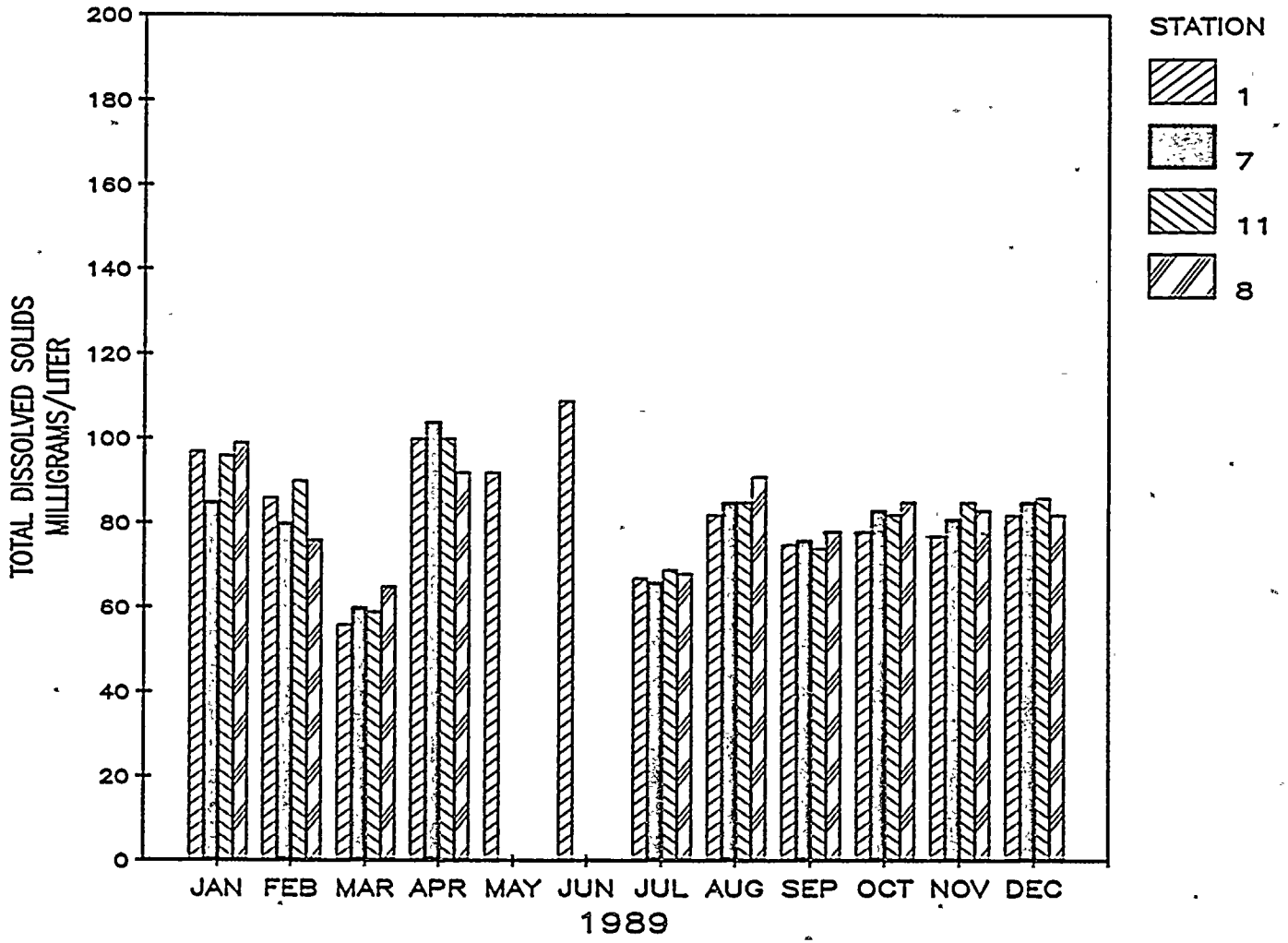

Figure 4-15 Columbia River Total Dissolved Solids Measurements at Four Stations During 1989

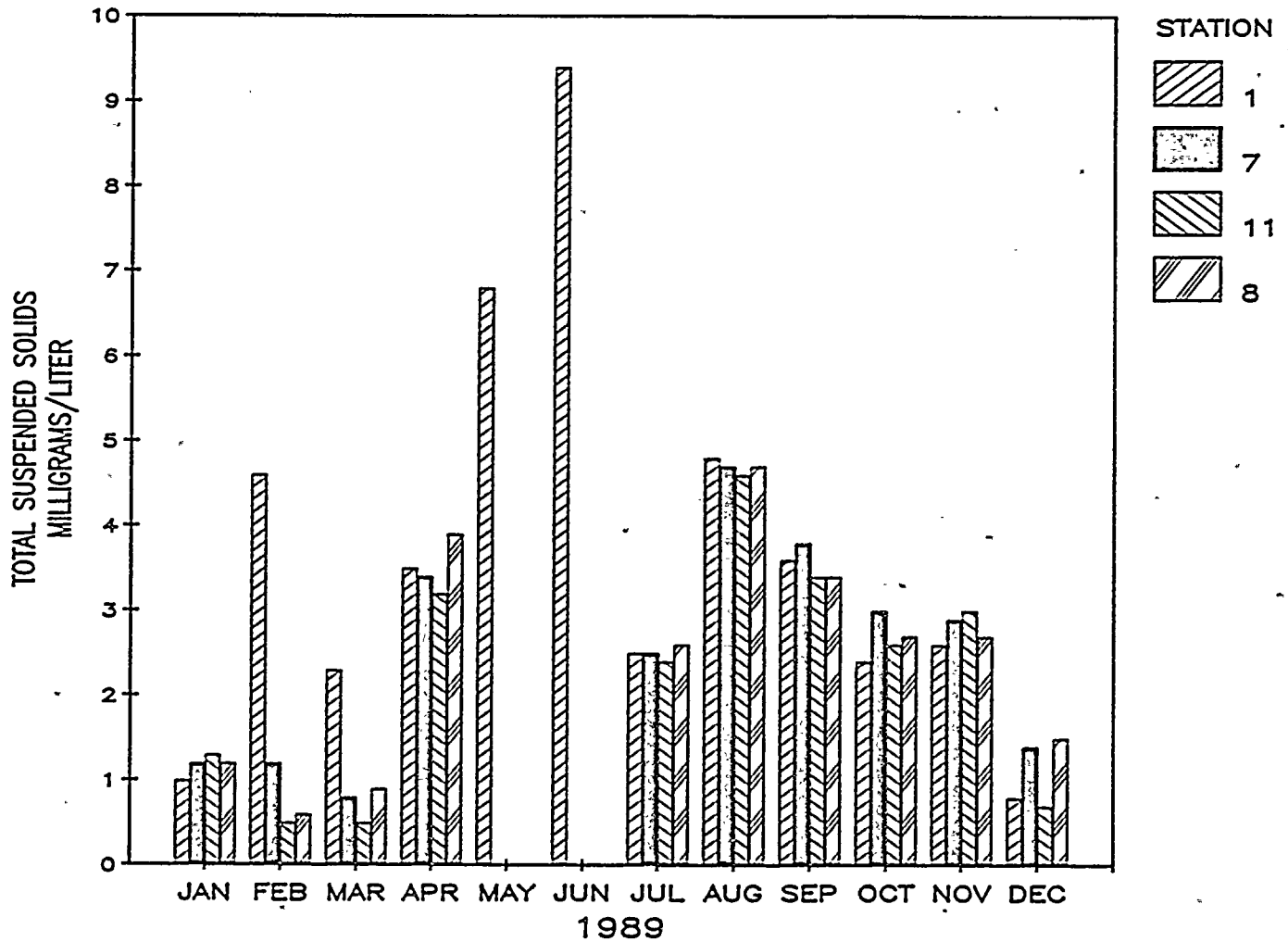

Figure 4-16 Columbia River Total Suspended Solids Measurements at Four Stations During 1989

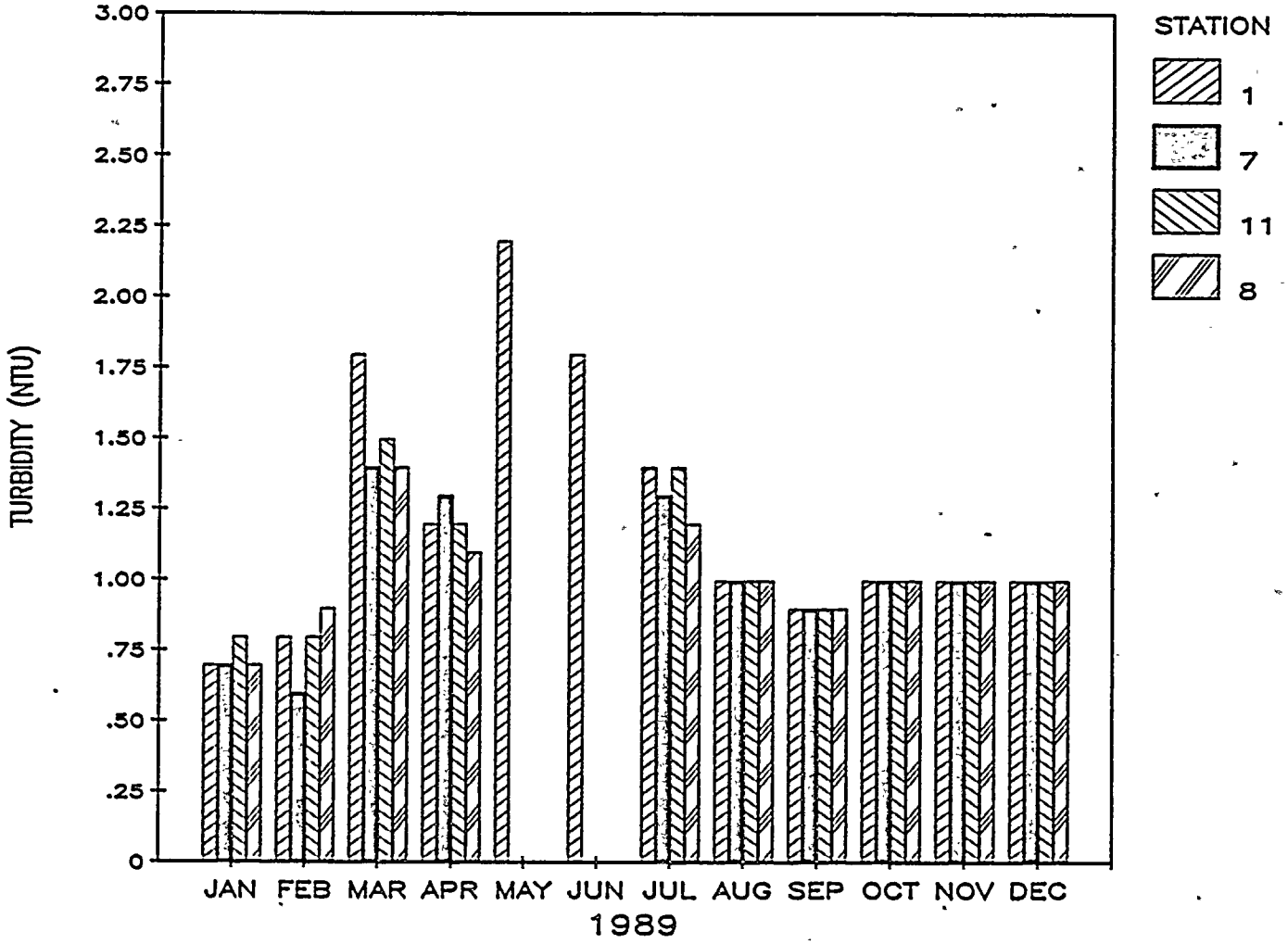

Figure 4-17 Columbia River Turbidity Measurements at Four Stations During 1989

5.0 COOLING TOWER DRIFT STUDIES

5.1 INTRODUCTION

The cooling tower drift studies were designed to identify any impact of cooling tower operation upon the surrounding plant communities, as well as any edaphic impacts. The program includes the measurement of herbaceous and shrub canopy cover, shrub density, herbaceous phytomass, vegetation chemistry and soil chemistry. Soil chemical parameters measured include pH, carbonate, bicarbonate, sulfate, chloride, sodium, potassium, calcium, magnesium, copper, zinc, lead, chromium, nickel, cadmium, and conductivity. Vegetation chemistry includes extractable sulfate, chloride and total copper. This study provides post-operational data for comparisons with preoperational data and meets the requirements of Washington State Energy Facility Site Evaluation Council (EFSEC) Resolutions 193 and 194 dated May 26, 1981.

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

5.2 MATERIALS AND METHODS

5.2.1 Herbaceous Canopy Cover

Fifty microplots (20 cm x 50 cm) were placed at 1-m intervals on alternate sides of the herbaceous transect (Figure 5-2). Canopy cover was estimated for each species occurring within a microplot using Daubenmire's (1968) cover classes. Data were recorded on standard data sheet.

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

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

5.2.2 Herbaceous Phytomass

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

Sample bags were transported to the laboratory, opened, and placed in a drying oven at 50°C for 24 hours. Following drying, the bags were removed singly from the oven and their contents immediately weighed to the nearest 0.1 g. Laboratory quality assurance consisted of independently reworking 10 percent of the phytomass samples to assess data validity and reliability.

5.2.3 Shrub Canopy Cover

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

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

5.2.4 Shrub Density

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

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

5.2.5 Soil Chemistry

At each of the fifteen grassland and shrub stations, five soil samples were collected from the top 15 cm of soil with a clean stainless steel trowel. The samples were placed in 250 ml sterile plastic cups with lids, labeled and refrigerated at 4°C. Sixteen parameters were analyzed in each sample including pH, bicarbonate, carbonate, conductivity, sulfate, chloride, copper, zinc, nickel, cadmium, lead, chromium, calcium, magnesium, sodium and potassium. Samples were analyzed for pH, bicarbonate, carbonate, sulfate, chloride and conductivity according to Methods of Soil Analysis (1965). Samples for cadmium and lead were analyzed by graphite furnace atomic absorption spectroscopy according to Methods For Chemical Analysis of Water and Wastes (USEPA 1983). The remaining elements were analyzed by inductively coupled plasma emission spectroscopy (ICPES) (USEPA 1983). Aliquots of soil for trace metal analyses were digested according to Gilman (1989). Preservation times and conditions, when utilized, were according to USEPA (1983).

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

5.2.6 Vegetation Chemistry

Samples of Bromus tectorum, Poa sandbergii, Artemisia tridentata and Purshia tridentata were collected at each station. Two species were substituted at some of the stations due to absence of one or more of those listed above. Substitute species were Phlox longifolia and Sisymbrium altissimum. Samples were collected at the same time as soil samples and as close to the soil sampling station as possible. Sufficient quantities of leafy material of each species were collected to yield at least five grams of dry weight. The clipped material was sealed in a plastic bag, labeled and refrigerated at 4°C until 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 USEPA (1983). Copper was analyzed by ICPES according to USEPA (1983).

5.3 RESULTS AND DISCUSSION

During the 1989 season, 58 plant taxa were observed in the study area. These are presented in Table 5-1. Table 5-2 lists by year the species of vascular plants observed during field activities from 1975-1989.

5.3.1 Herbaceous Cover

Herbaceous cover data for 1989 are summarized in Tables 5-3 and 5-4. Figures 5-3, 5-4, 5-5, and 5-6 provide a comparison with the data of previous years.

Total herbaceous cover averaged 73.5% in 1989 which represents a marked increase over 1988 (32.5%). As in previous years, the dominant annual grass was Bromus tectorum with 24.1% followed by Festuca octoflora with 0.25%. Perennial grasses averaged 32.5% in comparison to 11.63% in 1988. Poa sandbergii (29.3%) was the dominant perennial grass at most stations followed by Stipa comata (2.1%).

Total annual forb cover averaged 11.3%, up from the 5.0% measured in 1988. Draba verna was the dominant component with 3.5% followed by Holosteum umbellatum (1.9%) and Microsteris gracilis with 1.7%.

Perennial forb cover increased 28% over 1988 (5.4% vs. 4.2%). The dominant species were Aster canescens (1.6%), Cymopterus terebinthinus (1.3%) and Oenothera pallida (0.9%).

Species frequency values (%) for each station were similar to previous years and are summarized in Table 5-5. The greatest diversity of species was observed at Station SO2 (20) while the smallest was observed at Station SO7 (4).

Growing season precipitation increased 37% in 1989 over 1988 (14.0 vs 10.2 cm), while mean herbaceous cover increased 126% over 1988 (73.5% vs 32.6%). Mean temperature during the growing season was 4.5°C in 1989 vs. 5.7°C in 1988.

5.3.2 Herbaceous Phytomass

Mean production of herbaceous phytomass in 1989 was 85.5 gm/m2. At grassland stations, phytomass production averaged 90.5 g/m2 while at shrub stations it was 79.9 g/m2. Production varied widely among stations from a low of 39.8 g/m2 at Station SO4 to a high of 174.3 g/m2 at Station GO1. Mean herbaceous phytomass production at grassland stations and at shrub stations for 1989 is shown graphically in Figures 5-8 and 5-9 and is summarized in Table 5-6. Table 5-7 presents mean phytomass values for each station in each year since 1975. Mean herbaceous phytomass and percent herbaceous cover for each station from 1980 through 1989 are presented graphically in Figures 5-10 through 5-24.

5.3.3 Shrub Cover and Density

There are four shrub species in the study area: Artemisia tridentata, Purshia tridentata, Chrysothamnus nauseosus and Chrysothamnus viscidiflorus. Eriogonum niveum (a subshrub) and Opuntia polyacantha (a cactus) are also present, however, they are not included in the cover data. During a 1984 August range fire, all viable shrubs were completely destroyed at Stations S02 and S04, while the only individuals surviving at Station S01 were isolated clumps of low growing Eriogonum niveum.

Shrub density and cover data continue to reflect recovery from the 1984 fire. Percent cover measurements taken in 1989 are very similar to those measured in 1988 with an overall slight decrease in average cover (1.63% versus 1.75%). Shrub density increased slightly at Stations S03 and S05, remained the same at Stations S01 and S04 and decreased slightly at Station S02. Shrub density data for 1989 is summarized in Table 5-8 while shrub density data at each station from 1980 through 1989 is presented in Figure 5-25. Shrub cover data for 1989 is summarized in Table 5-9 while Figure 5-26 presents mean shrub cover values measured from 1975 through 1989. Shrub cover and density at each station for 1989 are presented graphically in Figure 5-27.

5.3.4 Soil Chemistry

The results of the 1989 soil chemical analyses are presented in Table 5-10 and are shown graphically in Figures 5-28 through 5-57.

Most metallic element concentrations were within the ranges observed in previous years. Concentrations of nickel, copper, lead, zinc, chromium, sodium and calcium were generally lower than we have observed in past data. Bicarbonate, conductivity, and pH data was similar to that observed in previous years. A decrease in pH at Station G03 was evident for the fifth straight year, although, pH was also lower than ever recorded at the other original grassland monitoring Stations (G01, G02 and G04). Chloride and sulfate concentrations were also generally lower than we have observed in previous years' data.

5.3.5 Vegetation Chemistry

The results of the 1989 vegetation chemical analyses are presented in Table 5-11 and shown graphically in Figures 5-58 through 5-78.

Total vegetation copper concentrations were generally lower than we have previously observed in all of the species examined (as was total soil copper). Extractable chloride concentrations were generally within the ranges observed in previous years, while extractable sulfate concentrations were much lower than in previous years except at Station S04 for *Poa sandbergii*.

5.4 SUMMARY AND CONCLUSIONS

A 37% increase in precipitation during the 1988-89 growing season was associated with a 126% increase in mean herbaceous cover over 1988 (Figure 5-7). A corresponding increase in herbaceous phytomass was observed at all Stations. Soil and vegetation copper concentrations were generally lower than has been observed in previous years as were soil nickel, lead, zinc, chromium, sodium and calcium. Soil and vegetation chloride and sulfate concentrations were also generally lower than we have observed in previous years. The remaining analytes were generally within the ranges previously observed. Changes in vegetation cover and density recorded in 1989 appear to be climatically induced and no signs of adverse impacts from the operation of WNP-2 cooling towers are evident.

Shrub cover and density data continue to reflect recovery from the 1984 range fire with little change in cover and density evident at most stations.

No adverse trends or impacts upon soil or vegetation chemistry are apparent from the six years of operational data.

5.5 COOLING TOWER DRIFT MODEL VALIDATION STUDY

5.5.1 Introduction

This study was implemented in January 1989 and was designed to measure the levels of and determine the rate of airborne salt deposition originating from the WNP-2 cooling tower plume. Information acquired from the initial ten months of this study is currently being evaluated to determine its adequacy with regards to validation of a salt emission and deposition model which used plant operating and meteorological data. This program is performed to comply with EFSEC Resolution No. 239.

5.5.2 Methods and Materials

Preliminary sample collection began in January 1989. Two collection vessels were placed at each of 16 sampling locations for a total of 32 samplers. One sample station is located directly adjacent to the WNP-2 cooling towers. Seven stations are located at approximately half-mile intervals along a northwest transect originating at the cooling towers. Another seven stations lie at half-mile intervals along a south-southeast transect. The remaining location is a control station located at the old Hanford Townsite, approximately eight miles north of WNP-2. An additional pair of cylinders are kept in the laboratory as a building control. A map of the sample locations is provided in Figure 5-79.

The collection vessel consists of an open-topped linear polyethylene cylinder with vertical sides and a flat bottom. The cylinder is six inches in diameter and eighteen inches high. A support stand positions the cylinder such that its bottom is eighteen inches above ground level. A metal bird ring is positioned above the cylinder to help prevent interference from birds. The cylinder is also covered with a screen to prevent sample contamination from bird droppings and insects. Figure 5-80 illustrates a typical sample collector.

5.5.3 Sample Preparation and Collection

Sample collection occurs monthly (every 30 ± 2 days). In the laboratory, the cylinders are thoroughly washed and rinsed, and then filled with four liters of deionized water. They are then transported to the field and placed in the support stands. During the summer months, the samplers are to be periodically checked to insure an adequate liquid level is maintained. An antifreeze, isopropyl alcohol, was initially used during the winter months. This was discontinued, however, due to its general ineffectiveness and also to prevent additional sources of potential contamination. After approximately 30 days in the field, the cylinders are covered, exchanged with clean samplers, and transported back to the laboratory. Any evidence of contamination (insects, bird droppings) is noted and recorded. A 500 milliliter aliquot will then be taken for analysis and the remaining sample discarded.

5.5.4 Sample Measurements and Analysis

The samples were measured for pH and conductivity. pH measurements were made with an Orion "Ross" combination electrode. Conductivity was measured using a YSI Model 34 conductivity meter. Alkalinity was also determined using a titrimetric method. The samples were analyzed for chloride and sulfate using a Dionex 4000i ion chromatograph. A Perkin-Elmer P-40 inductively-coupled plasma atomic emission spectrometer was utilized for the analysis of sodium, magnesium and calcium. Copper analysis was performed using a Perkin-Elmer 4000 atomic absorption spectrophotometer equipped with a Perkin-Elmer HGA-400 graphite furnace.

5.6 BIBLIOGRAPHY

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NUS Corporation, Annual Report for the PVNGS Salt Deposition Monitoring Program January-December 1986; April 1987.

Table 5-1 Vascular Plants Observed During 1989 Field Work

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

Table 5-1. (Continued)

	Common Name
FABACEAE	Pea Family
Astragalus purshii Dougl.	Wooly-pod milk-vetch
Astragalus sclerocarpus Gray	Stalked-pod milk-vetch
Psoralea lanceolata Pursh	Lance-leaf scurf-pea
HYDROPHYLLACEAE	Waterleaf Family
Phacelia hastata Dougl.	Whiteleaf phacelia
Phacelia linearis (Pursh) Holz.	Threadleaf phacelia
LILIACEAE	Lily Family
Brodiaea douglasii Wats.	Douglas' brodiaea
Calochortus macrocarpus Dougl.	Sego lily
Fritillaria pudica (Pursh) Spreng.	Chocolate lily
LOASACEAE	Blazing-star Family
Mentzelia albicaulis Dougl.	White-stemmed mentzelia
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach	White-stemmed globe-mallow
ONAGRACEAE	Evening-primrose Family
Oenothera pallida Lindl. var. *pallida*	White-stemmed evening-primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat
POACEAE	Grass Family
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron dasystachyum (Hoak.) Scribn.	Thick-spiked wheatgrass
Agropyron spicatum (Pursh) Scribn. & Smith	Bluebunch wheatgrass
Bromus tectorum L.	Cheatgrass
Festuca octoflora Walt.	Six-weeks fescue
Koeleria cristata Pers.	Prairie Junegrass
Oryzopsis hymenoides (R&S) Ricker	Indian ricegrass

Table 5-1. (Continued)

	Common Name
Poa sandbergii Vasey	Sandberg's bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush squirreltail
Stipa comata Trin & Rupr.	Needle-and-thread
POLEMONIACEAE	Phlox Family
Gilia minutiflora Benth.	Gilia
Gilia sinuata Dougl.	Shy gilia
Microsteris gracilis (Hook.) Greene var. *humilior* (Hook.) Cronq.	Pink microsteris
Phlox longifolia	Long-leaf phlox
POLYGONACEAE	Buckwheat Family
Eriogonum niveum Dougl.	Snow buckwheat
Rumex venosus Pursh	Wild begonia
RANUNCULACEAE	Buttercup Family
Delphinium nuttallianum Pritz. ex Walpers	Larkspur
ROSACEAE	Rose Family
Purshia tridentata (Pursh) DC.	Antelope bitterbursh
SANTALACEAE	Sandalwood Family
Comandra umbellata (L.) Nutt.	Bastard toad-flax
SAXIFRAGACEAE	
Ribes aureum Pursh	Golden current
SCROPHULARIACEAE	Figwort Family
Penstemon acuminatus Dougl.	Sand-dune penstemon
VALERIANACEAE	Valerian Family
Plectritis macrocera T&G	Longhorn plectritis

Table 5-2 Vascular Plants Observed During 1975-1989 Field Work

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

Table 5-2. (Cont'd)

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

Table 5-2. (Cont'd)

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

Table 5-2. (Cont'd)

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

Table 5-3 Herbaceous Cover for Fifteen Sampling Stations-1989

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07	AVERAGE G01-S07	AVERAGE G01-G04	AVERAGE S01-S05	AVG. G01-G04 S01-S05
Annual Grasses																			
Bromus tectorum	22.50	13.20	65.85	3.05	20.80	34.65	38.05	12.05	21.85	12.40	12.45	8.65	32.90	15.00	47.65	24.07	26.15	17.65	21.43
Festuca octoflora	0.00	0.00	0.00	0.00	1.55	0.45	0.00	0.00	0.00	0.10	0.00	1.60	0.00	0.00	0.00	0.25	0.00	0.34	0.19
Total Annual Grass Cover	22.50	13.20	65.85	3.05	22.35	35.10	38.05	12.05	21.85	12.50	12.45	10.25	32.90	15.00	47.65	24.32	26.15	17.99	21.62
Perennial Grasses																			
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.75	0.00	0.00	1.25	0.00	0.00	0.87	0.00	2.60	1.44
Oryzopis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.75	0.00	0.00	0.00	0.22	0.00	0.65	.36
Poa sandbergii	60.40	59.60	0.05	34.55	36.75	4.90	32.05	47.80	8.30	15.30	64.00	12.25	0.00	26.45	37.50	29.33	38.65	19.97	28.27
Stipa comata	0.00	0.00	0.00	15.00	0.00	11.30	0.00	1.15	0.00	0.00	0.00	0.00	0.00	3.90	0.00	2.09	3.75	0.00	1.67
Total Perennial Grass Cover	60.40	59.60	0.05	49.55	36.75	16.20	32.05	48.95	8.30	29.55	64.00	13.00	1.25	30.35	37.50	32.50	42.40	23.22	31.74
Annual Forbs																			
Amsinckia lycopsoides	0.10	0.00	0.15	0.00	0.30	0.00	0.50	0.00	0.05	0.00	0.00	0.00	0.30	0.05	0.00	0.10	0.06	0.07	0.07
Chenopodium leptophyllum	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.09	0.00	0.02	0.01
Cryptantha circumscissa	0.00	0.05	0.00	0.00	0.35	0.05	0.00	0.00	0.20	0.10	0.00	0.05	0.05	0.00	0.00	0.06	0.01	0.08	0.05
Descurainia pinnata	0.00	0.00	0.00	0.00	0.30	0.00	0.05	0.05	1.75	0.85	0.00	1.35	0.55	0.80	4.35	0.67	0.00	0.90	0.50
Draba verna	3.10	1.85	12.40	1.85	2.50	8.05	3.45	3.85	2.30	1.20	5.80	0.25	5.85	0.00	0.00	3.50	4.80	3.08	3.84
Franseria acanthacarpa	0.00	0.05	2.40	0.20	0.10	0.45	1.00	0.30	0.70	0.35	0.00	0.25	0.10	0.00	0.00	0.39	0.66	0.28	0.45
Gilia sinuata	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.05	0.05	0.25	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.06	0.03
Holosteum umbellatum	2.40	0.60	11.50	0.20	1.00	2.70	1.95	2.40	0.80	2.05	1.00	0.15	2.05	0.00	0.00	1.92	3.68	1.21	2.31
Mentzelia albicaulis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.05	0.10	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.04	0.02
Microsteris gracilis	1.15	1.15	10.95	0.00	0.50	1.60	0.65	0.95	5.45	0.10	0.70	1.40	0.95	0.00	0.00	1.70	3.31	1.72	2.43
Phacelia linearis	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.20	1.35	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.31	0.18
Plantago pategonica	3.55	0.35	0.00	0.55	0.00	0.00	0.00	2.15	0.00	0.00	4.90	0.00	0.60	0.00	0.40	0.83	1.11	1.10	1.11
Salsola kali	2.15	1.25	2.10	0.05	3.05	0.60	2.35	1.35	0.75	0.60	0.30	2.40	0.05	0.00	0.00	1.13	1.39	0.82	1.07
Sisymbrium altissimum	0.40	0.30	2.65	0.00	0.05	0.10	1.85	2.15	0.20	0.00	0.30	0.50	0.55	0.00	0.40	0.63	0.84	0.31	0.54
Tragopogon dubius	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05			
Total Annual Forb Cover	12.85	5.90	42.20	2.85	8.85	13.55	13.05	13.95	12.50	6.95	13.05	6.45	11.10	0.85	5.15	11.28	15.88	10.00	12.61
Perennial Forbs																			
Achillea millefolium	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	2.55	0.00	2.50	0.00	0.00	0.00	0.36	0.08	1.01	0.59
Aster canescens	1.85	0.30	0.05	0.40	3.15	0.60	11.30	2.75	1.90	0.05	0.20	0.70	0.25	0.00	0.00	1.57	0.65	0.62	0.63
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.07	0.00	0.15	0.08
Balsamorhiza careyana	0.00	0.00	0.00	0.00	2.00	0.35	0.00	0.00	0.00	0.00	0.30	3.10	0.30	0.00	0.00	0.40	0.00	0.74	0.41
Brodiaea douglasii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Comandra umbellata	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crepis atrabarba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95	0.00	0.00	0.00	0.00	0.13	0.00	0.39	0.22
Cymopterus terebinthinus	1.60	0.10	0.00	0.00	0.00	8.65	0.00	0.05	0.00	8.95	0.00	0.00	0.00	0.05	0.00	1.29	0.43	1.79	1.18
Oenothera pallida	0.00	0.05	0.00	1.25	0.00	0.00	0.00	6.95	2.50	2.95	0.00	0.00	0.00	0.00	0.00	0.91	0.33	1.09	0.75
Phlox longifolia	0.35	0.65	0.00	1.05	1.25	0.45	1.60	0.80	0.05	0.00	1.95	1.15	0.00	0.05	0.00	0.62	0.51	0.63	0.58
Rumex venosus	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Total Perennial Forb Cover	3.85	1.10	0.05	3.00	6.45	10.40	12.90	10.60	4.45	14.50	4.40	8.20	0.55	0.10	0.00	5.37	2.00	6.42	4.46
Total Herbaceous Cover	99.60	79.80	108.15	58.45	74.40	75.25	96.05	85.55	47.10	63.50	93.90	37.90	45.80	46.30	90.30	73.47	86.43	57.63	70.43

Table 5-4 Mean Herbaceous Cover for 1975 Through 1989

CLASS	YEAR	S01	S02	S03	S04	S05	X S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-5	G05	G06	G07	G08	XG	XSG
AG	1975	49.90	35.30	43.80						43.00	43.90	43.00								43.45	43.18
PG	1975	0.60	2.00	4.50						2.37	3.70	5.50								4.60	3.26
AF	1975	14.60	11.70	11.70						12.67	29.50	13.00								21.25	16.10
PF	1975	4.30	0.90	1.80						2.33	1.50	2.10								1.80	2.12
ALL	1975	69.40	49.90	61.80						60.37	78.60	63.60								71.10	64.66
AG	1976	50.70	40.90	34.30						41.97	71.20	51.60								61.40	49.74
PG	1976	0.40	10.50	10.30						7.07	4.40	3.10								3.75	5.74
AF	1976	5.50	5.30	7.20						6.00	11.90	8.50								10.20	7.68
PF	1976	0.00	0.50	0.20						0.23	0.00	0.20								0.10	0.18
ALL	1976	56.60	57.20	52.00						55.27	87.50	63.40								75.45	63.34
AG	1977	1.35	0.65	1.90						1.30	5.20	1.45								3.33	2.11
PG	1977	0.35	11.30	8.28						6.64	3.25	2.90								3.08	5.22
AF	1977	0.25	0.05	0.90						0.40	2.40	9.35								5.88	2.59
PF	1977	0.55	0.60	1.42						0.86	0.05	6.30								3.18	1.78
ALL	1977	2.50	12.60	12.50						9.20	10.90	20.00								15.45	11.70
AG	1978	51.00	67.00	51.00						56.33	68.00	42.00								55.00	55.80
PG	1978	3.00	18.00	11.00						10.67	8.00	7.00								7.50	9.40
AF	1978	38.00	10.00	33.00						27.00	23.00	25.00								24.00	25.80
PF	1978	8.00	0.00	5.00						4.33	2.00	3.00								2.50	3.60
ALL	1978	100.00	95.00	100.00						98.33	101.00	77.00								89.00	94.60
AG	1979	25.00	29.00	9.00						21.00	31.00	10.00								20.50	20.80
PG	1979	1.00	18.00	11.00						10.00	7.00	5.00								6.00	8.40
AF	1979	2.00	4.00	10.00						5.33	43.00	33.00								38.00	18.40
PF	1979	11.00	0.00	3.00						4.67	0.00	7.00								3.50	4.20
ALL	1979	39.00	51.00	33.00						41.00	81.00	55.00								68.00	51.80
AG	1980	50.40	51.80	24.30	56.20	56.40	47.82			47.82	64.30	77.80	73.80	12.30	57.05					57.05	51.92
PG	1980	1.00	7.20	23.30	10.90	0.10	8.50			8.50	28.30	64.00	0.10	26.60	29.75					29.75	17.94
AF	1980	7.50	4.20	22.50	3.40	14.10	10.36			10.36	7.30	5.00	28.70	4.90	11.48					11.48	10.86
PF	1980	2.20	2.20	4.70	4.60	1.80	3.10			3.10	0.40	0.00	0.00	4.60	1.25					1.25	2.28
ALL	1980	61.20	65.40	74.80	75.10	72.40	69.78			69.78	100.30	146.80	102.60	48.40	99.53					99.53	83.00
AG	1981	74.80	54.60	66.50	49.80	76.20	64.38			64.38	77.40	84.00	88.40	48.90	74.68					74.68	68.96
PG	1981	0.10	4.70	14.30	5.80	0.00	4.98			4.98	19.60	25.90	0.00	36.70	20.55					20.55	11.90
AF	1981	5.30	3.50	18.20	1.20	12.50	8.14			8.14	15.90	11.90	17.50	5.90	12.80					12.80	10.21
PF	1981	0.00	3.20	0.70	4.90	0.50	1.86			1.86	0.20	0.00	0.00	1.90	0.53					0.53	1.27
ALL	1981	80.20	66.00	99.70	61.70	89.20	79.36			79.36	113.10	121.80	105.90	93.40	108.55					108.55	92.33
	1982	51.50	25.80	36.60	32.70	20.00	33.32			33.32	42.20	45.50	51.00	22.90	40.40					40.40	36.47
	1982	0.40	6.40	17.90	4.30	0.80	5.96			5.96	11.20	11.60	0.10	31.30	13.55					13.55	9.33
	1982	4.60	4.20	7.50	1.60	17.30	7.04			7.04	9.70	4.60	4.60	4.10	5.75					5.75	6.47
	1982	0.20	4.30	0.70	6.20	1.00	2.48			2.48	0.30	0.00	1.30	3.80	1.35					1.35	1.98
	1982	56.70	40.70	62.70	44.80	39.10	48.80			48.80	63.40	61.70	57.00	62.10	61.05					61.05	54.24
AG	1983	53.80	37.60	33.65	36.75	31.85	38.73	38.73	49.50	39.55	62.75	17.55	42.34							42.34	40.33
PG	1983	2.15	7.70	14.45	6.40	1.29	6.40	6.40	2.10	15.75	0.00	25.50	10.84							10.84	8.37
AF	1983	8.20	7.85	12.55	3.45	22.35	10.88	10.88	18.70	8.85	8.65	6.65	10.71							10.71	10.81
PF	1983	0.70	3.10	1.05	4.40	1.95	2.24	2.24	0.65	0.05	2.10	4.00	1.70							1.70	2.00
ALL	1983	64.85	56.25	61.70	51.00	57.44	58.25	58.25	70.95	64.20	73.50	53.70	65.59							65.59	61.51
AG	1984	41.50	32.75	39.35	36.30	36.50	37.28	37.28	60.85	71.30	60.85	9.60	50.65							50.65	43.22
PG	1984	1.85	8.80	11.55	8.55	0.40	6.23	6.23	1.20	4.45		25.00	10.22							10.22	6.87
AF	1984	12.35	8.10	11.10	4.00	13.40	9.79	9.79	20.65	9.70	19.45	7.95	14.44							14.44	11.86
PF	1984	0.30	4.00	0.75	6.55	0.65	2.45	2.45	0.70	0.20	1.10	1.25	0.81							0.81	1.72
ALL	1984	56.00	53.65	62.75	55.40	50.95	55.75	55.75	83.40	85.65	81.40	43.80	73.56							73.56	63.67
AG	1985	2.10	2.15	14.60	4.95	27.05	10.17	10.17	8.00	8.10	18.30	7.25	10.41							10.41	10.28
PG	1985	1.05	4.70	17.85	2.40	1.85	5.57	5.57	9.20	17.95	0.00	13.90	10.26							10.26	7.66
AF	1985	0.70	1.35	9.40	2.30	4.75	3.70	3.70	18.20	8.15	7.55	3.05	9.24							9.24	6.16
PF	1985	0.00	1.35	1.15	3.00	0.25	1.15	1.15	0.80	0.10	2.35	0.90	1.04							1.04	1.10
ALL	1985	3.85	9.55	43.00	12.65	33.90	20.59	20.59	36.20	34.30	28.20	25.10	30.95							30.95	25.19
AG	1986	17.45	1.95	7.20	11.45	13.05	10.22	10.22	9.40	4.65	13.25	7.35	8.66							8.66	9.53
PG	1986	2.20	10.75	17.25	9.85	1.30	8.27	8.27	19.85	38.65	0.00	26.00	21.13							21.13	13.98
AF	1986	25.40	16.65	38.10	10.25	16.70	21.42	21.42	27.65	34.15	25.45	8.70	23.99							23.99	22.56
PF	1986	1.15	5.35	2.30	9.15	1.25	3.84	3.84	1.80	1.95	0.05	2.55	1.59							1.59	2.84
ALL	1986	46.20	34.70	64.85	40.70	32.30	43.75	43.75	58.70	79.40	38.75	44.60	55.36							55.36	48.91
AG	1987	28.90	9.95	7.80	19.05	33.40	19.82	19.82	23.85	9.45	51.65	4.65	22.40							22.40	20.97
PG	1987	3.60	21.90	42.65	19.55	2.30	18.00	18.00	32.45	58.79	0.05	45.95	34.31							34.31	25.25
AF	1987	12.56	8.50	10.80	6.55	11.40	9.96	9.96	10.30	11.32	14.00	3.25	9.72							9.72	9.85
PF	1987	5.00	6.00	2.00	10.40	1.75	5.03	5.03	0.90	1.90	0.15	1.55	1.13							1.13	3.29
ALL	1987	50.06	46.35	63.25	55.55	48.85	52.81	52.81	67.50	81.46	65.85	55.40	67.55							67.55	59.36
AG	1988	13.80	5.05	8.10	13.80	10.15	10.18	10.40	12.24	10.51	22.95	10.10	16.75	4.80	13.65	11.95	19.20	15.85	10.40	14.00	12.32
PG	1988	1.75	8.40	11.95	9.40	3.35	6.97	16.85	17.50	9.89	17.85	21.70	0.05	30.20	17.45	9.50	12.05	10.45	14.30	14.51	12.34
AF	1988	6.08	5.25	3.60	3.10	4.00	4.41	0.00	0.35	3.20	6.30	16.15	7.55	1.80	7.95	1.20	1.45	12.35	6.12	6.61	5.16
PF	1988	11.55	15.75	2.10	4.85	3.25	7.50	0.10	0.00	5.37	0.20	2.00	0.00	4.40	1.65	15.25	8.70	2.45	4.34	4.34	4.79
ALL	1988	33.18	34.45	25.75	31.15	20.75	29.06	27.35	30.09	28.96	47.30	49.95	24.35	41.20	40.70	37.90	41.40	41.10	32.52	39.47	34.60
AG	1989	21.85	12.50	12.45	10.25	32.90	17.99	15.00	47.65	21.80	22.50	13.20	65.85	3.05	26.15	22.35	35.10	38.05	12.05	26.52	24.05
PG	1989	8.30	29.55	64.00	13.00	1.25	23.22	30.35	37.50	26.28	60.40	59.60	0.05	49.55	42.40	36.75	16.20	32.05	48.95	37.94	32.54
AF	1989	12.50	6.95	13.05	6.45	11.10	10.01	0.85	5.15	8.01	12.85	5.90	42.20	2.85	15.95	8.85	13.55	13.05	13.95	14.15	11.48
PF	1989	4.45	14.50	4.40	8.20	0.55	6.42	0.10	0.00	4.60	3.85	1.10	0.05	3.00	2.00	6.45	10.40	12.90	10.60	6.04	5.23
ALL	1989	47.10	63.50	93.90	37.90	45.80	57.64	46.30	90.30	60.69	99.60	79.80	108.15	58.45	86.50	74.40	75.25	96.05	85.55	84.66	73.31

Table 5-5 Mean Frequency Values (%) by Species for Each Sampling Station - 1989

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
Annual Grasses															
Bromus tectorum	98	96	98	62	88	98	98	74	98	58	96	76	98	56	98
Festuca octoflora					52	8				4		44			
Perennial Grasses															
Agropyron spicatum										32			2		
Oryzopis hymenoides										6		2			
Poa sandbergii	96	100	2	98	68	14	68	78	20	42	98	42		64	92
Stipa comata				80		26		8						12	
Annual Forbs															
Amsinckia lycopsoides	4		6		2		10		2				12	2	
Cryptantha circumscissa	2			14	2		2	8	4		2	2			
Cryptantha pterocarya															
Descurainia pinnata					12		2	2	30	24		44	12	22	58
Draba verna	84	74	94	64	80	88	88	94	72	28	96	10	86		
Franseria acanthicarpa	2	46	8	4	18	30	12	28	14		10	4			
Gilia sinuata					16			2	2	10					
Holosteum umbellatum	66	24	96	8	30	78	58	76	32	32	40	6	82		
Layia glandulosa	2														
Mentzelia albicaulis								2	2	4			2		
Microsteris gracilis	36	46	94		20	64	16	38	88	4	28	46	38		
Phacelia linearis			2		2				8	44					
Plantago pategonica	54	14		22				26			86	24			6
Salsola kali	76	50	28	2	38	24	46	26	30	14	12	66	2		
Sisymbrium altissimum	16	12	56	2	4	44	36	8	8		2	20	22	6	
Perennial Forbs															
Achillea millefolium				2						8		6			
Aster canescens	14	2	2	6	20	4	72	16	28	2	8	18	10		
Astragalus Purshii															
Astragalus sclerocarpus						4						2			
Balsamorhiza careyana					4	4					2	10	2		
Comandra umbellata					2										
Crepis atrabarba											10				
Cymopterus terebinthinus	6	4				22	2			22				2	
Oenothera pallida		2		20				40	22	22					
Phlox longifolia	14	26		12	2	8	34	32	2		30	36		2	
Rumex venosus	2														
Total Species Per Site	14	14	11	14	19	17	13	16	17	20	13	18	15	9	4

Table 5-6 Mean Terrestrial Phytomass for 1989

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/09	G01	6-12	17.4	173.9
05/09	G01	32-14	16.6	166.0
05/09	G01	31-4	19.9	199.3
05/09	G01	1-9	5.3	52.9
05/09	G01	18-9	27.9	279.2
		AVG	17.4	174.3
		STD	7.3	72.7

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/02	G02	3-9	3.7	37.2
05/02	G02	27-8	3.6	36.0
05/02	G02	26-4	10.8	108.3
05/02	G02	17-6	5.5	55.2
05/02	G02	9-18	9.2	91.8
		AVG	6.6	65.7
		STD	2.9	29.3

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/09	G03	39-2	13.7	137.4
05/09	G03	19-2	14.5	144.9
05/09	G03	2-11	8.9	89.4
05/09	G03	17-3	14.6	146.0
05/09	G03	33-5	0.8	7.8
		AVG	10.5	105.1
		STD	5.3	52.9

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/02	G04	13-3	5.0	49.9
05/02	G04	20-4	4.4	44.0
05/02	G04	43-8	6.1	60.9
05/02	G04	14-11	3.9	39.4
05/02	G04	37-6	5.3	53.1
		AVG	4.9	49.5
		STD	0.7	7.4

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/10	G05	3-6	6.4	64.4
05/10	G05	27-8	3.8	37.5
05/10	G05	18-7	1.8	18.1
05/10	G05	4-12	3.7	37.3
05/10	G05	31-2	5.9	58.7
		AVG	4.3	43.2
		STD	1.7	16.7

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/09	G06	33-5	6.6	65.7
05/09	G06	19-2	0.6	5.6
05/09	G06	2-11	7.7	77.0
05/09	G06	17-3	15.3	153.3
05/09	G06	39-2	0.4	3.6
		AVG	6.1	61.0
		STD	5.5	55.1

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/12	G07	3-6	8.8	88.0
05/12	G07	31-2	10.0	99.6
05/12	G07	27-8	11.4	113.7
05/12	G07	18-7	14.1	140.8
05/12	G07	4-12	12.4	123.5
		AVG	11.3	113.1
		STD	1.8	18.4

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/10	G08	5-6	2.7	27.3
05/10	G08	19-9	8.2	81.6
05/10	G08	2-8	21.6	215.9
05/10	G08	23-7	5.1	51.2
05/10	G08	3-9	18.5	185.4
		AVG	11.2	112.3
		STD	7.5	74.8

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/08	S01	17-3	4.9	48.5
05/08	S01	39-2	2.3	22.9
05/08	S01	19-2	4.3	42.8
05/08	S01	33-5	11.5	115.0
05/08	S01	2-11	4.0	40.2
		AVG	5.4	53.9
		STD	3.2	31.7

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/08	S02	33-5	8.8	87.6
05/08	S02	17-3	6.3	62.6
05/08	S02	19-2	3.5	35.1
05/08	S02	2-11	3.7	36.6
05/08	S02	39-2	14.2	142.2
		AVG	7.3	72.8
		STD	4.0	39.7

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/11	S03	4-12	2.8	28.0
05/11	S03	27-8	11.0	109.8
05/11	S03	18-7	8.3	83.0
05/11	S03	31-2	8.7	86.5
05/11	S03	3-6	2.8	27.9
		AVG	6.7	67.0
		STD	3.3	33.2

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/03	S04	6-12	2.7	27.3
05/03	S04	18-9	1.9	18.8
05/03	S04	1-9	5.6	56.2
05/03	S04	32-14	0.6	5.7
05/03	S04	31-4	9.1	90.9
		AVG	4.0	39.8
		STD	3.0	30.5

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/04	S05	17-6	5.0	50.1
05/04	S05	3-9	17.5	175.2
05/04	S05	9-18	10.9	109.1
05/04	S05	26-4	7.5	74.9
05/04	S05	27-8	10.9	109.0
		AVG	10.4	103.7
		STD	4.2	42.1

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/04	S06	37-7	2.7	26.7
05/04	S06	2-8	9.3	92.7
05/04	S06	17-3	17.1	170.6
05/04	S06	11-6	7.4	73.7
05/04	S06	44-12	0.0	0.0
		AVG	7.3	72.7
		STD	5.9	59.0

DATE	SITE	PLOT	WT.(g)	WT./ SQ.METER
05/11	S07	2-11	21.1	211.2
05/11	S07	39-2	7.6	75.7
05/11	S07	19-2	16.2	162.1
05/11	S07	17-3	14.4	143.8
05/11	S07	33-5	15.5	154.6
		AVG	14.9	149.5
		STD	4.4	43.5

Phytomass Summary

MEAN G01-G08	90.5	Grams/sq. meter
MEAN S01-S07	79.9	Grams/sq. meter
MEAN B01-B05	80.4	Grams/sq. meter

Table 5-7 Comparison of Herbaceous Phytomass for 1975 Through 1989

Mean Dry Weight (g/m^2)

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

Table 5-8 Summary of Shrub Density for 1989

Station	Species	1	2	3	4	Total	S/Ha	S/a
S01	Artemisia tridentata	4	2	4	0	10	100	40
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	2	1	0	1	4	40	16
						14	140	56
						Total	S/Ha	S/a
S02	Artemisia tridentata	0	1	0	0	1	10	4
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						1	10	4
						Total	S/Ha	S/a
S03	Artemisia tridentata	10	15	6	18	49	490	196
	Chrysothamnus nauseosus	4	1	2	2	9	90	36
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						58	580	232
						Total	S/Ha	S/a
S04	Artemisia tridentata	1	2	1	6	10	100	40
	Chrysothamnus nauseosus	0	0	0	0	0	0	0
	Chrysothamnus viscidiflorus	0	0	0	0	0	0	0
	Purshia tridentata	0	0	0	0	0	0	0
						10	100	40
						Total	S/Ha	S/a
S05	Artemisia tridentata	0	0	0	0	0	0	0
	Chrysothamnus nauseosus	0	0	4	1	5	50	20
	Chrysothamnus viscidiflorus	0	0	0	1	1	10	4
	Purshia tridentata	1	1	4	0	6	60	24
						12	120	48

Table 5-9 Summary of Shrub Cover (%) at Five Stations for 1989

Shrub Cover (%)

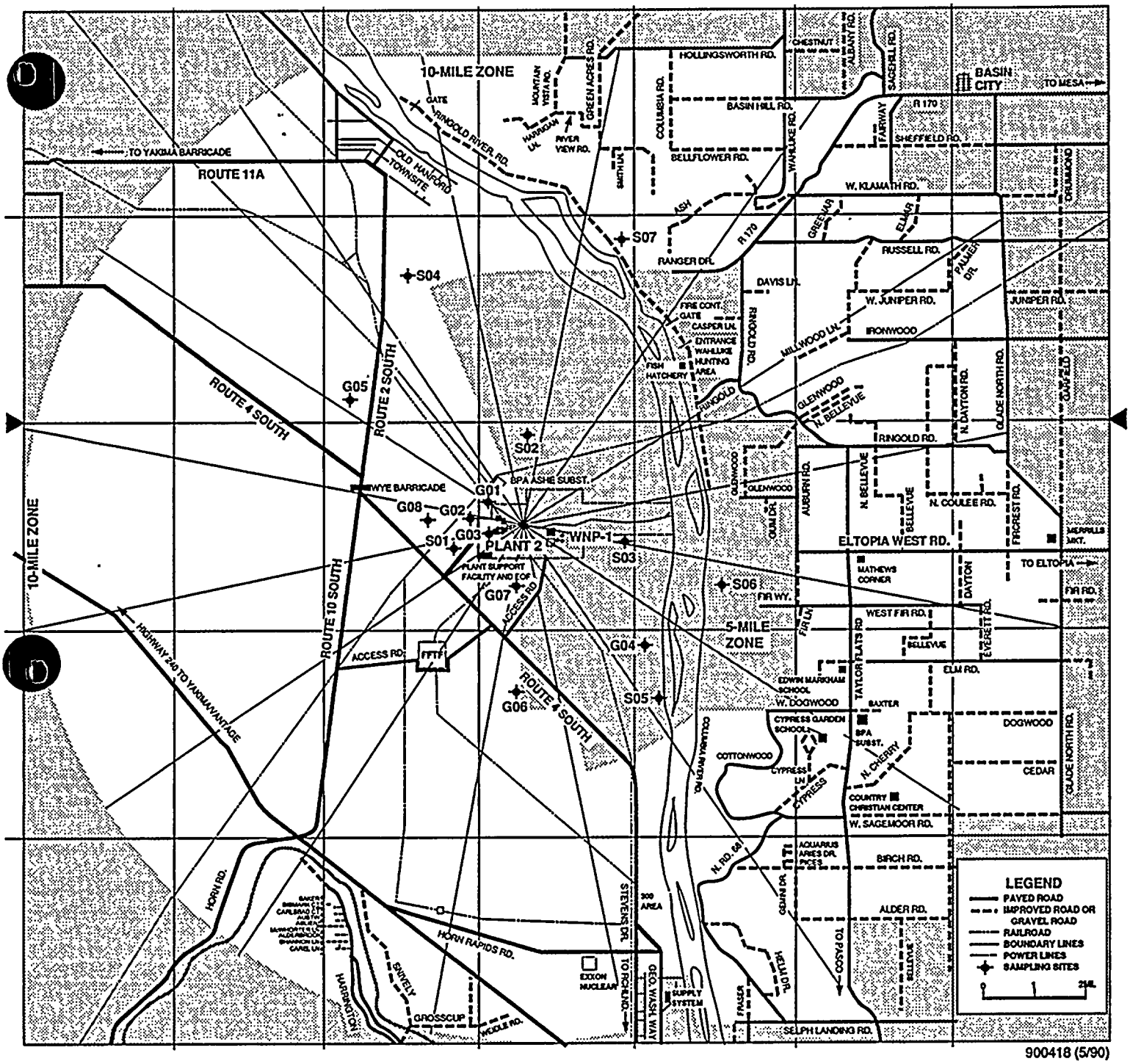
Shrubs	S01	S02	S03	S04	S05	X
Artemisia tridentata	-	-	5.94	-	-	5.94
Chrysothamnus nauseosus	-	-	1.10	-	0.64	0.87
Chrysothamnus viscidiflorus	-	-	-	-	0.21	0.21
Purshia tridentata	0.28	-	-	-	-	0.28
Total Shrub Cover	0.28	0.00	7.04	0.00	0.85	7.30

Table 5-10 Summary of Soil Chemistry for 1989

	G01	G02	G03	G04	G05	G06	G07	G08	S01	S02	S03	S04	S05	S06	S07
pH (1:2 soil-water)	6.60	6.24	6.50	6.27	6.83	6.35	6.54	7.04	6.23	7.17	6.68	6.75	6.55	6.87	7.36
Conductivity (1:2 soil-water) microsiemens/cm	21.2	18.0	19.6	16.2	28.4	12.8	19.2	25.6	24.6	23.4	21.4	52.6	15.8	32.2	43.8
Sulfate ug/gm	1.21	0.75	2.31	0.51	1.15	0.45	0.68	0.67	1.82	0.99	1.35	7.97	0.58	0.84	0.75
Chloride ug/gm	0.71	0.25	0.62	0.47	0.56	0.26	0.42	0.32	0.72	0.56	0.78	1.57	0.32	0.41	1.08
Copper ug/gm	8.15	8.31	7.18	6.51	7.74	7.44	7.19	7.49	8.66	6.01	7.49	6.96	6.26	7.32	11.6
Lead ug/gm	0.90	0.94	1.24	1.39	1.38	1.03	1.09	0.84	1.26	0.65	0.77	0.78	0.83	1.1	1.29
Cadmium ug/gm	0.05	0.06	0.13	0.04	0.04	0.03	0.04	0.03	0.03	0.01	0.03	0.02	0.03	0.03	0.05
Chromium ug/gm	5.77	6.57	3.35	2.66	4.2	1.75	3.63	5.76	5.65	4.61	3.59	4.52	2.34	4.24	13.04
Nickel ug/gm	8.44	7.54	6.68	5.62	7.14	6.45	6.54	8.18	7.89	7.23	7.61	7.21	5.83	7.4	12.58
Zinc ug/gm	38.10	36.91	35.37	31.81	30.4	32	35	32.8	39.69	20.97	36.00	29.83	30.49	34.1	43.4
Sodium %	0.010	0.010	0.010	0.010	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010	0.010	0.01	0.01
Potassium %	0.120	0.220	0.140	0.110	0.15	0.12	0.35	0.19	0.170	0.080	0.140	0.150	0.120	0.23	0.23
Calcium %	0.17	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.08	0.06	0.06	0.06	0.08	0.11
Magnesium %	1.01	0.55	0.41	0.34	0.45	0.9	0.42	0.42	0.44	0.34	0.36	0.36	0.35	0.43	0.66
Bicarbonates (meq/HCO3/gm)	0.0018	0.0011	0.0012	0.0005	0.0025	0.0008	0.0011	0.0032	0.0012	0.0027	0.0014	0.0023	0.0007	0.0020	0.0060

Table 5-11 Summary of Vegetation Chemistry for 1989

	SITE	POSA	BRTE	SIAL	PHLO	PUTR	ARTR	AGSP	CHNA	CHVI	GRSP
Copper (ug/gm)	G01	0.80	0.95	1.10	0.95						
	G02	0.95	1.45	0.90	3.2						
	G03	1.00	1.40	1.10		1.1					
	G04	0.85	1.20	1.10	1.05						
	G05	0.9	1.15			3.2	2.8				
	G06	0.9	1.15				1.95			1.25	
	G07	0.9	1.1				2			2.05	
	G08	1	1	0.9	1						
	S01	0.70	1.10	1.25	1.2						
	S02	0.80	0.90		.8	0.9					
	S03	0.65	1.20		1.20		2.40				
	S04	1.05	1.25	0.85	1.15						
	S05	1.15	1			1.25	2.25				
	S06	0.85	1				1.75			1.35	1.4
	S07		1.2				1.7				1.4
	B01	0.65	1.05			1	1.9				
	B02	0.85	1.45			0.8	1.65				
	B03	1.05	0.55			1.55	1.15				
	B04	1.50	1.05			1.15	1.9				
	B05	0.60	1.10				2		1.2		
Extractable Sulfate	G01	0.004	0.006	0.141	0.004						
	G02	0.004	0.005	0.079	0.008						
	G03	0.005	0.004	0.225		0.005					
	G04	0.005	0.003	0.079	0.005						
	G05	0.003	0.007			0.004	0.003				
	G06	0.008	0.003				0.004			0.001	
	G07	0.004	0.005				0.004			0	
	G08	0.003	0.003	0.139	0.003						
	S01	0.005	0.004	0.083	0.003						
	S02	0.003	0.004		0.005	0.004					
	S03	0.004	0.006		0.005		0.001				
	S04	0.144	0.003	0.129	0.005						
	S05	0.003	0.003			0.004	0.002				
	S06	0.004	0.006				0.004			0.005	0.073
	S07		0.009				0.001	0.01			0.12
	B01	.004	0.008			0.000	0.009				
	B02	.005	0.002			0.044	0.005				
	B03	.000	0.006			0.008	0.004				
	B04	.009	0.007			0.005	0.000				
	B05	.000	0.003						0		
Extractable Chloride	G01	0.20	0.22	0.58	0.09						
	G02	0.16	0.06	0.34	0.07						
	G03	0.09	0.27	0.78		0.22					
	G04	0.25	0.22	0.26	0.08						
	G05	0.17	0.15			0.09	0.47				
	G06	0.26	0.14				0.49			0.04	
	G07	0.22	0.25				0.03			0.39	
	G08	0.15	0.17	0.01	0.09						
	S01	0.15	0.21	0.59	0.07						
	S02	0.20	0.10		0.08	0.04					
	S03	0.20	0.12		0.06	0.06	0.56				
	S04	0.21	0.31	0.41	0.09						
	S05	0.16	0.22			0.06	0.5				
	S06	0.11	0.11				0.57			0.65	1.07
	S07		0.18				0.36	0.22			1.34
	B01	.12	0.08			0.06	0.6				
	B02	.12	0.09			0.03	0.45				
	B03	.12	0.04			0.61	0.1				
	B04	.17	0.12			0.06	0.79				
	B05	.12	0.06						0.32		

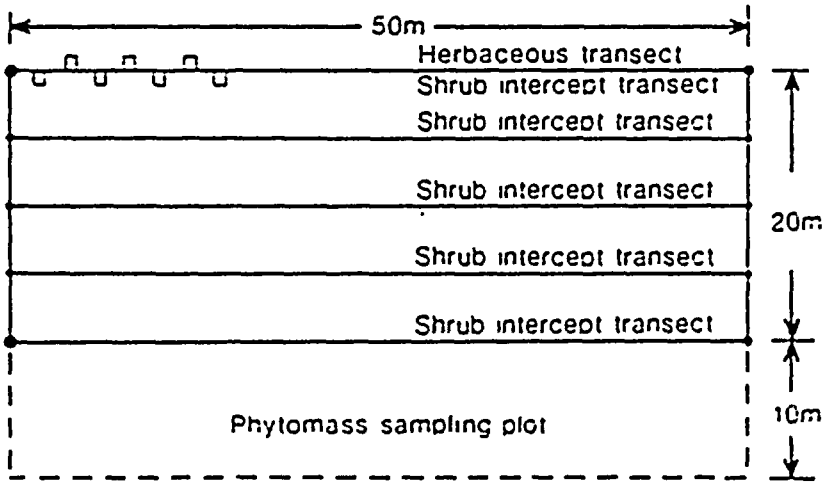


1 thru 8 G0 = Grassland Site

1 thru 7 S0 = Shrub Site

Figure 5-1 Soil and Vegetation Sampling Location Map

Shrub Community



Herbaceous Community

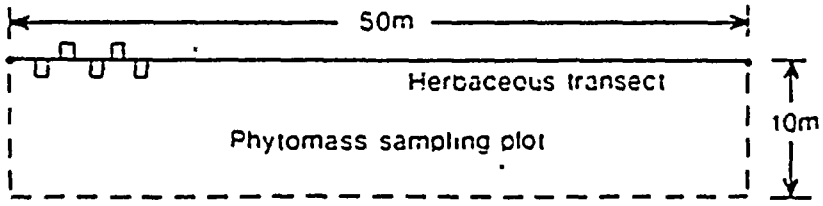


Figure 5-2 Layout of Vegetation and Solid Sampling Plots

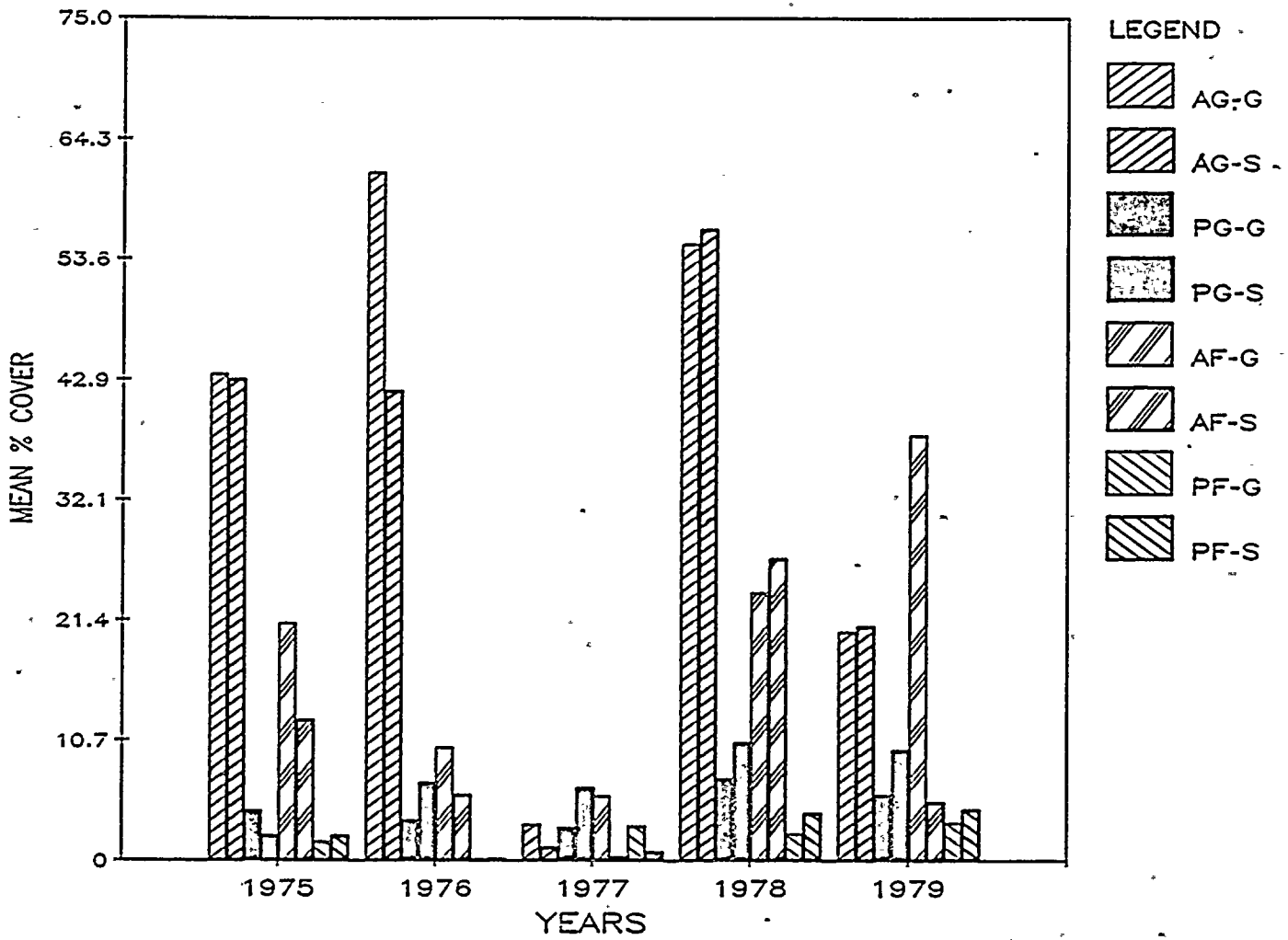


Figure 5-3 Mean Herbaceous Cover for 1975 Through 1979

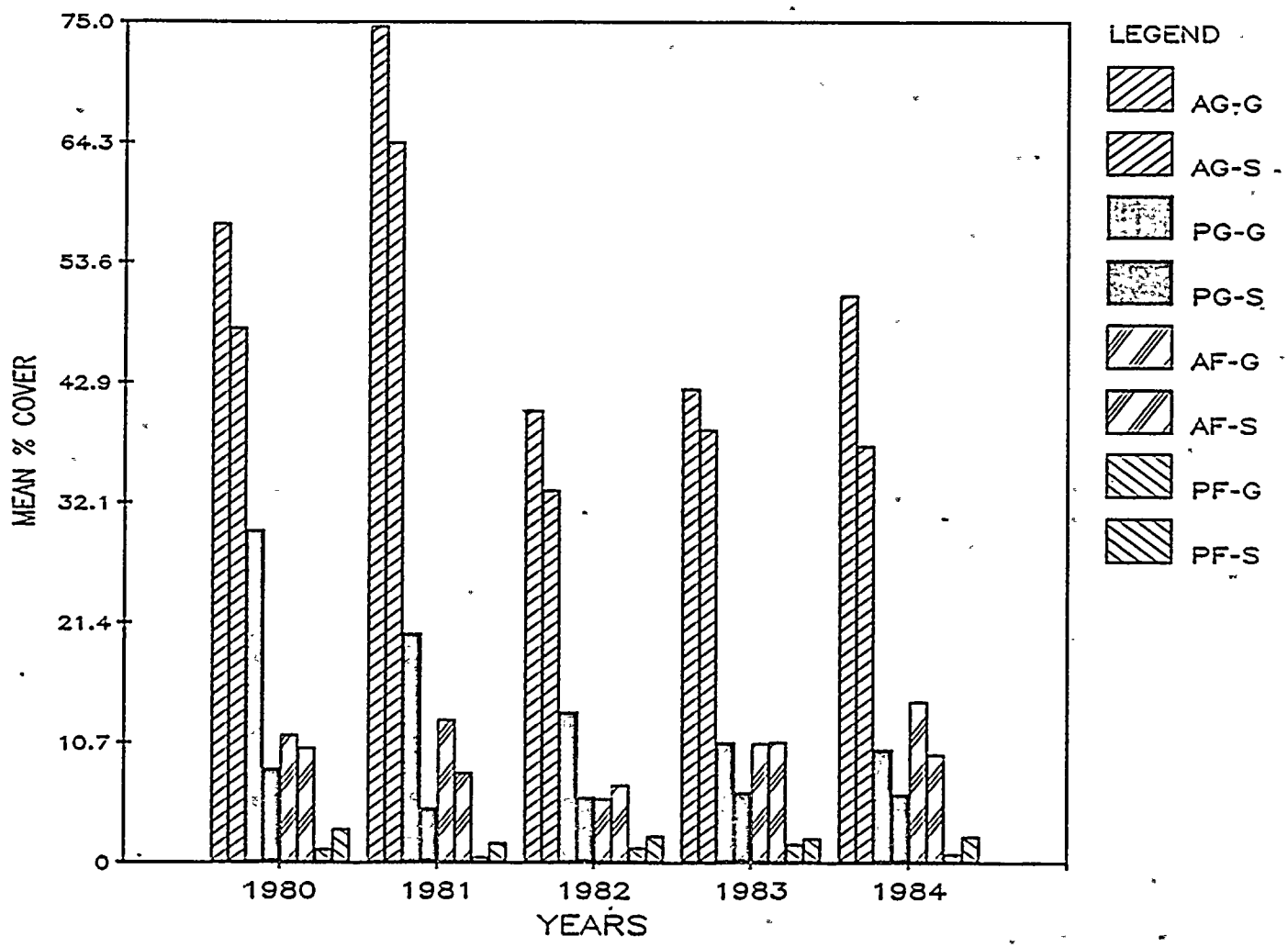


Figure 5-4 Mean Herbaceous Cover for 1980 Through 1984

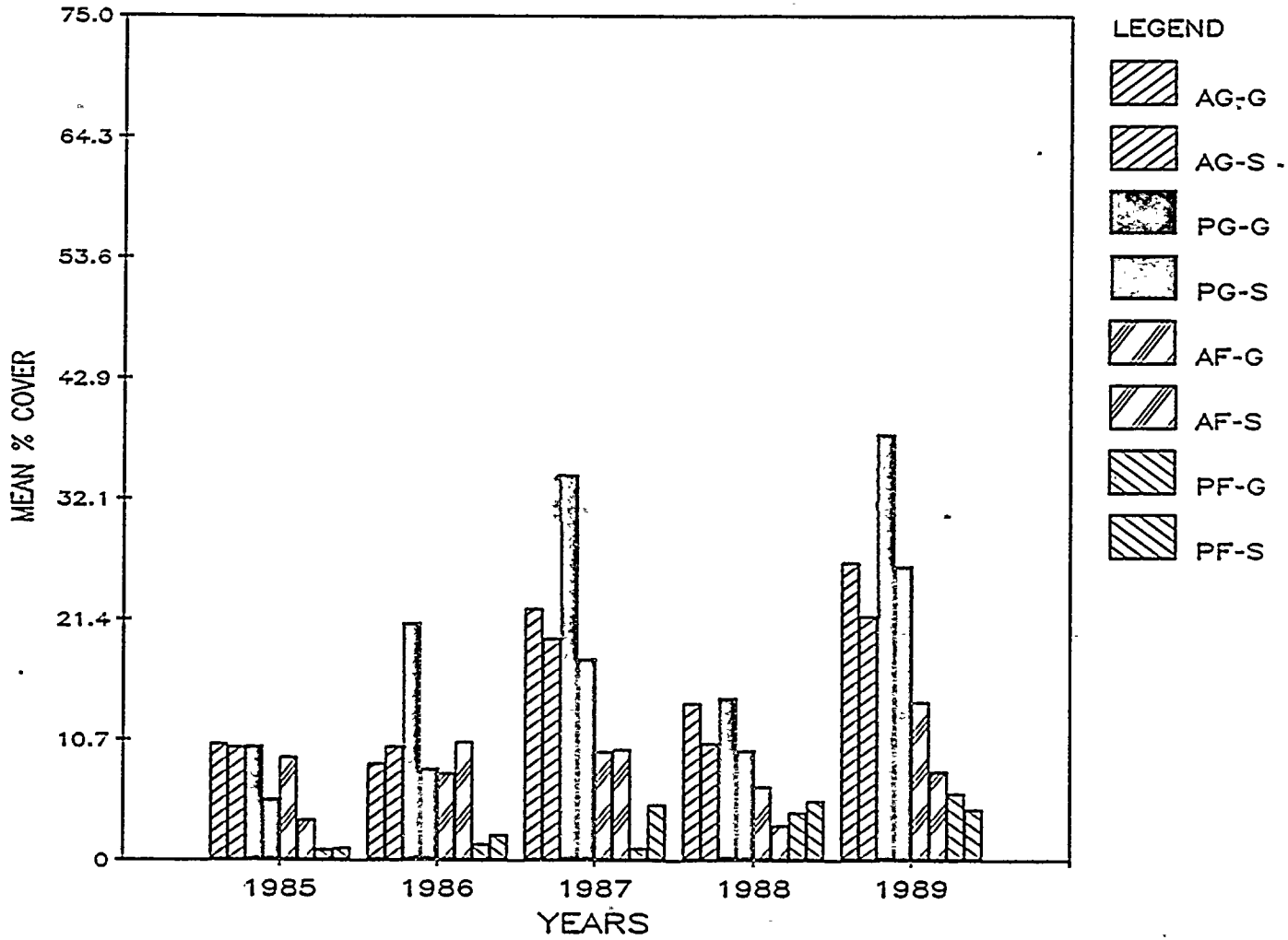


Figure 5-5 Mean Herbaceous Cover for 1985 Through 1989

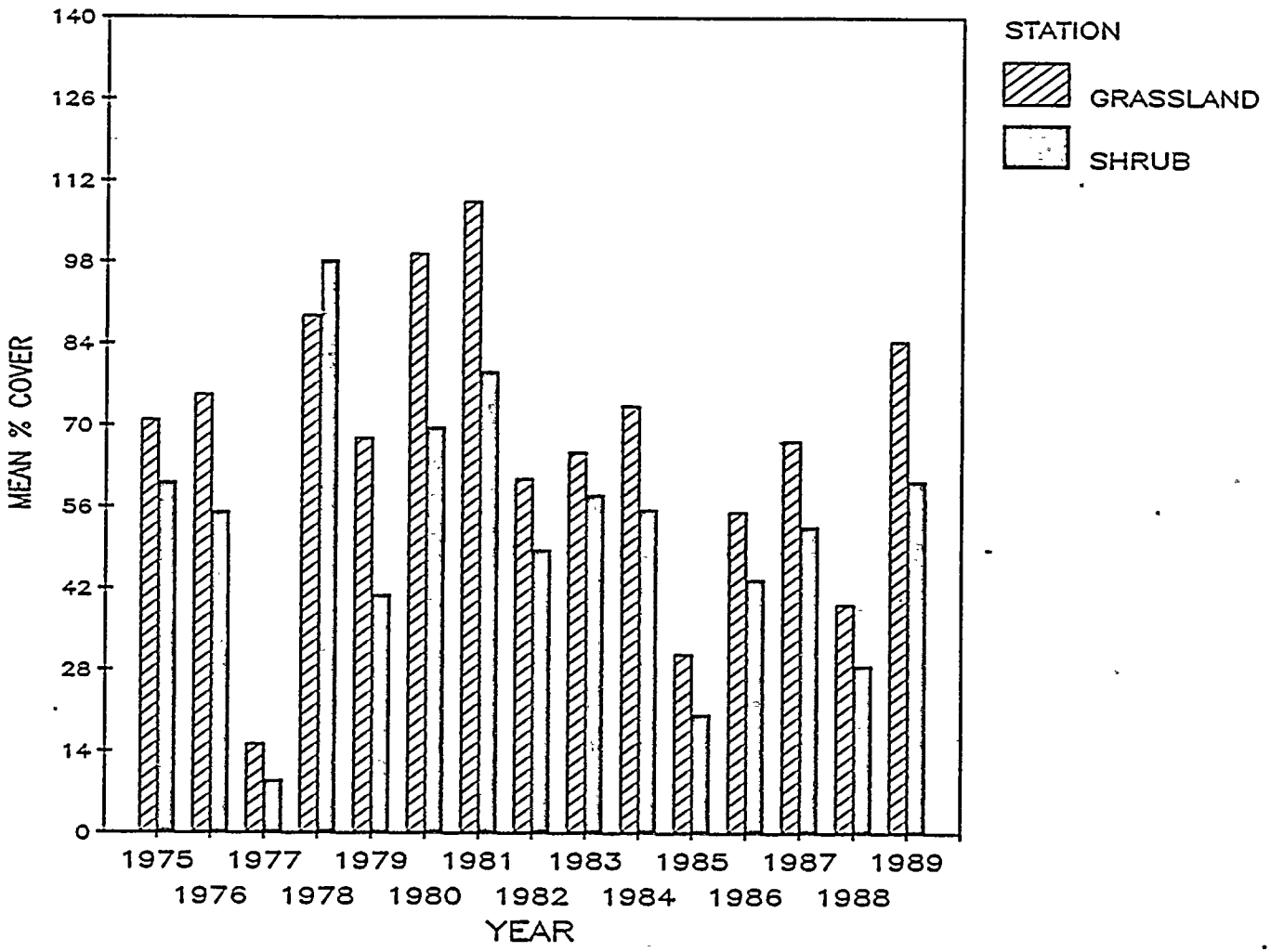


Figure 5-6 Mean (%) Herbaceous Cover for 1975 Through 1989

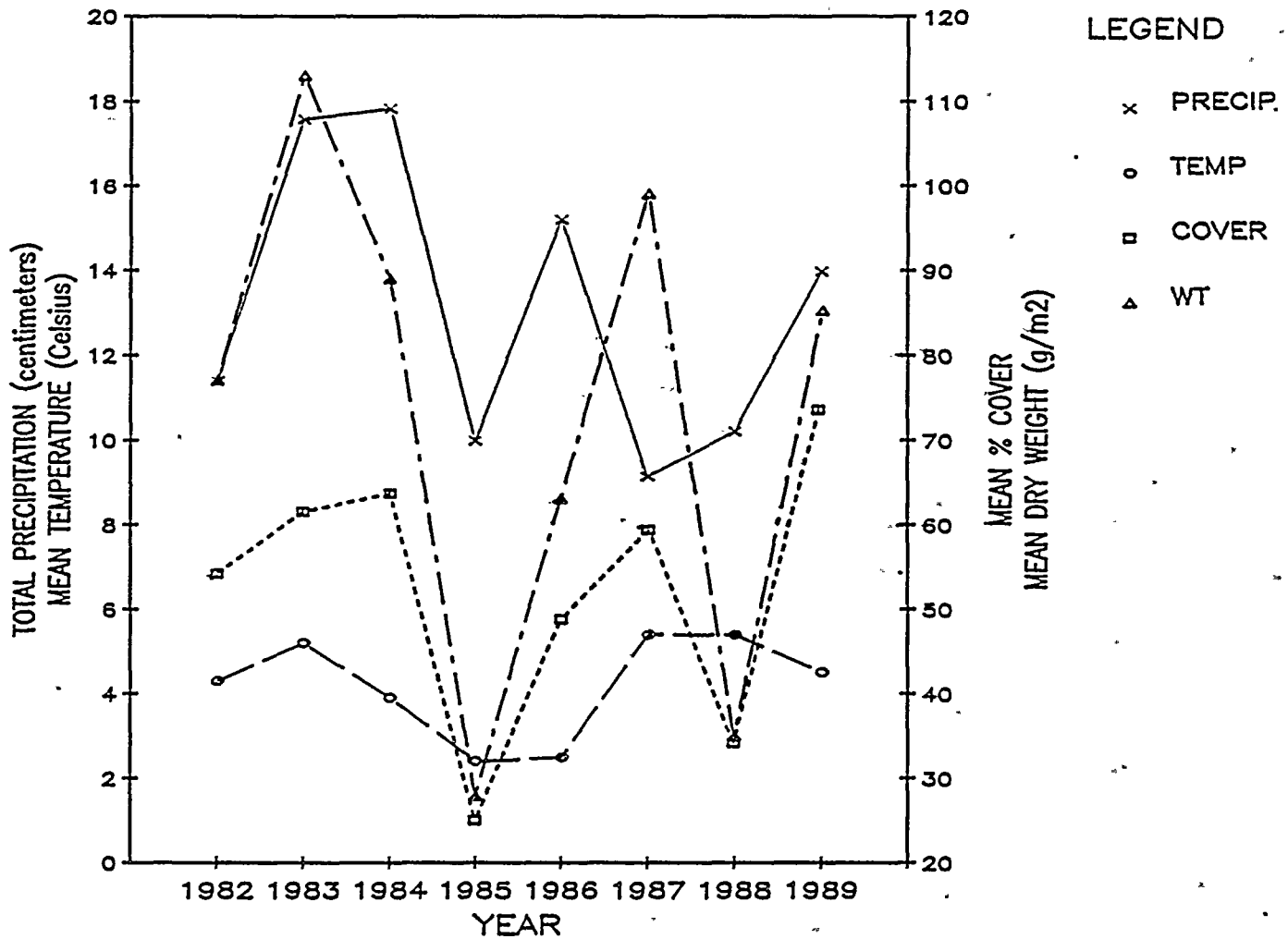


Figure 5-7 Mean Herbaceous Cover, Total Precipitation, and Mean Temperature From 1982 Through 1989

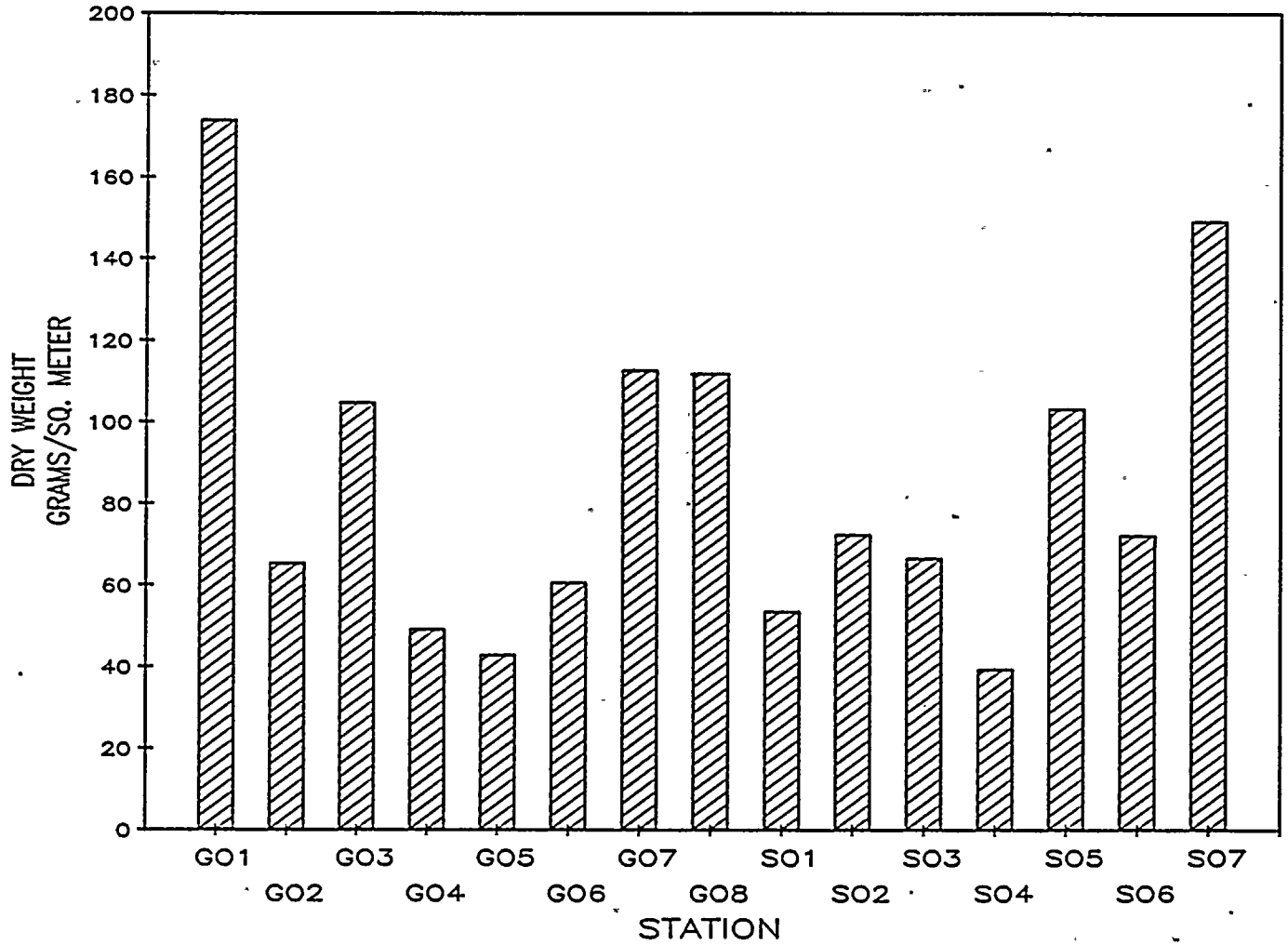


Figure 5-8 Mean Herbaceous Phytomass for May 1989

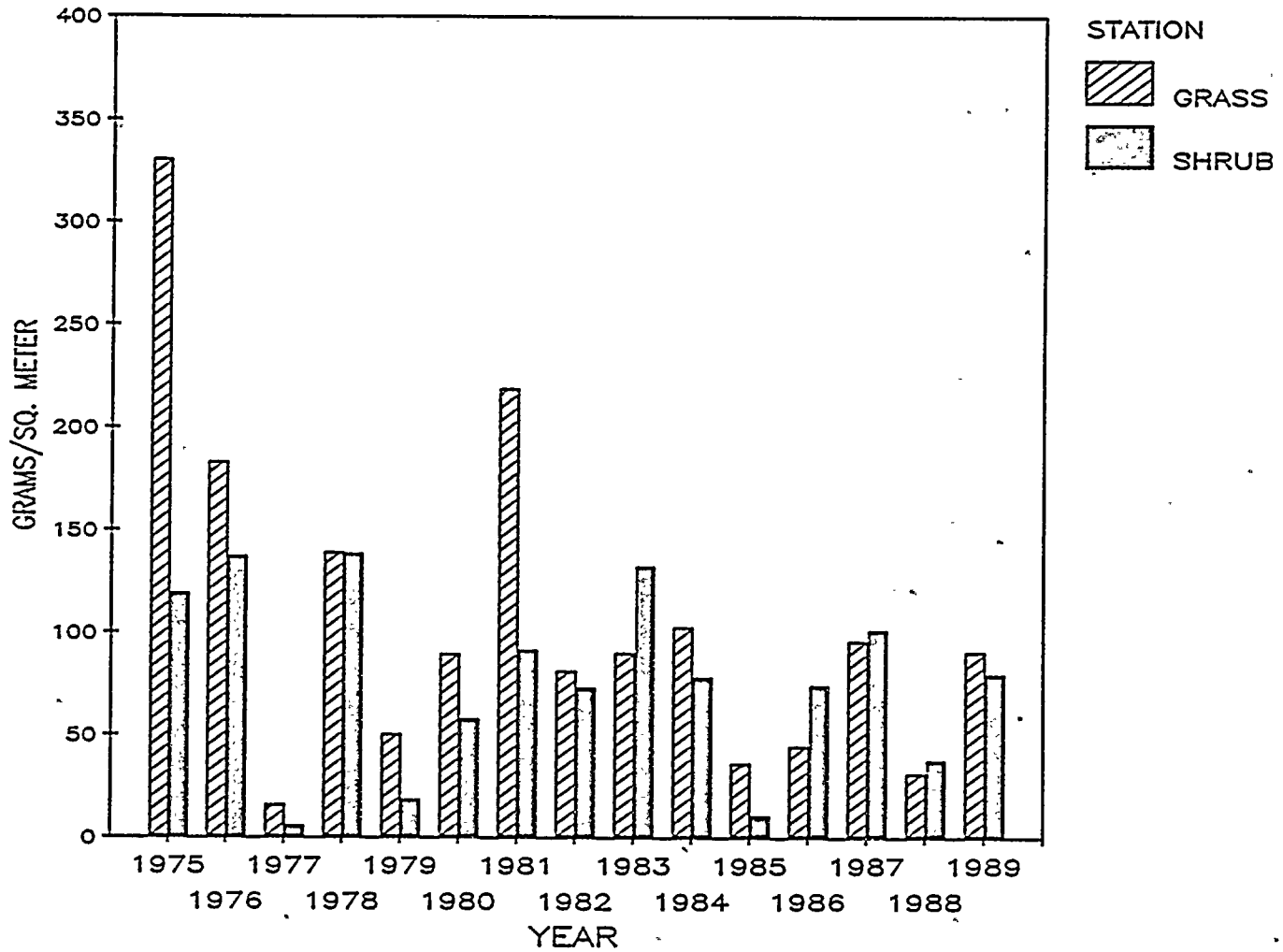


Figure 5-9 Mean Herbaceous Phytomass at Grassland and Shrub Stations for 1975 Through 1989

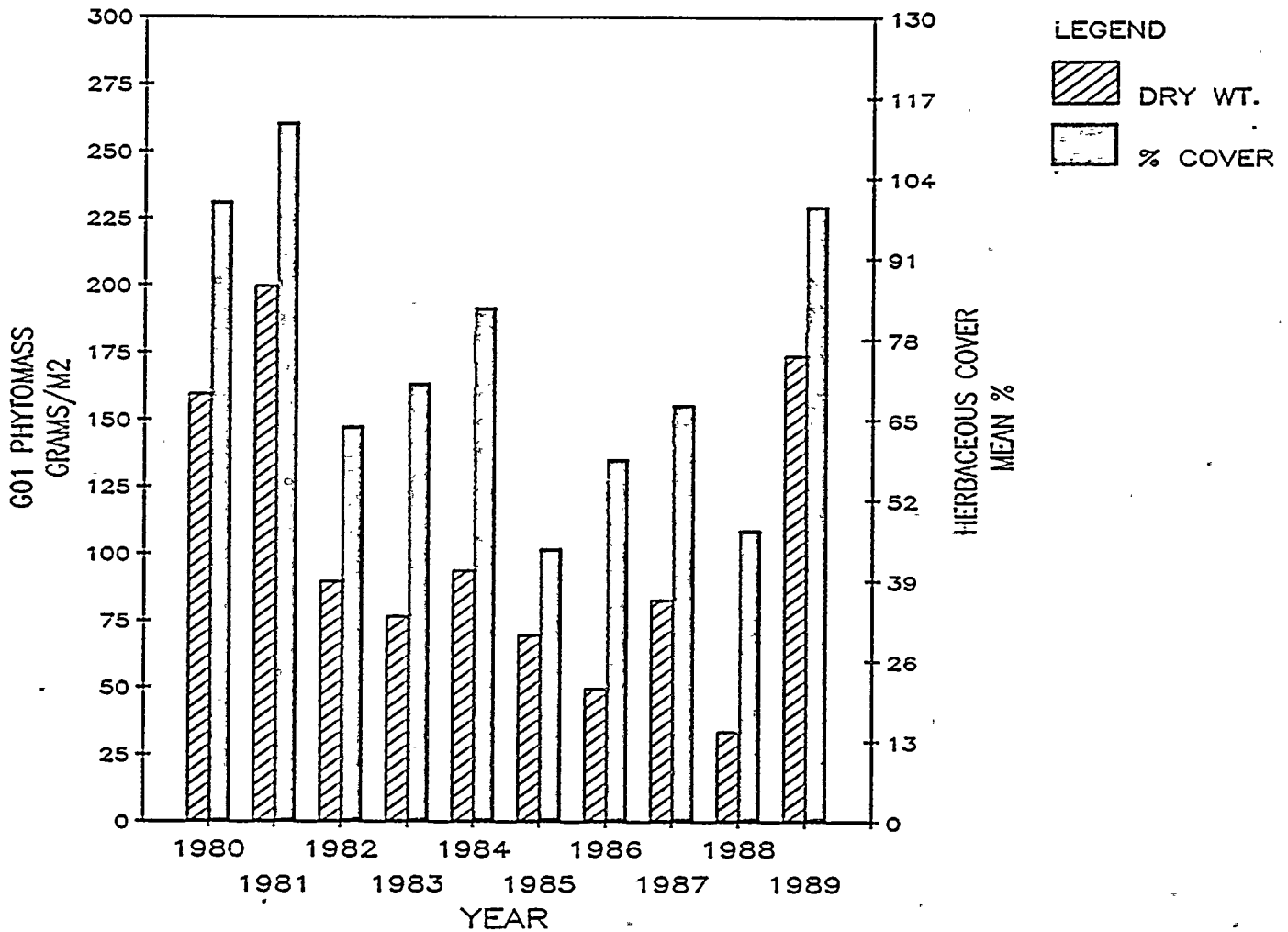


Figure 5-10 Mean Herbaceous Cover and Phytomass for Station G01 for 1980 Through 1989

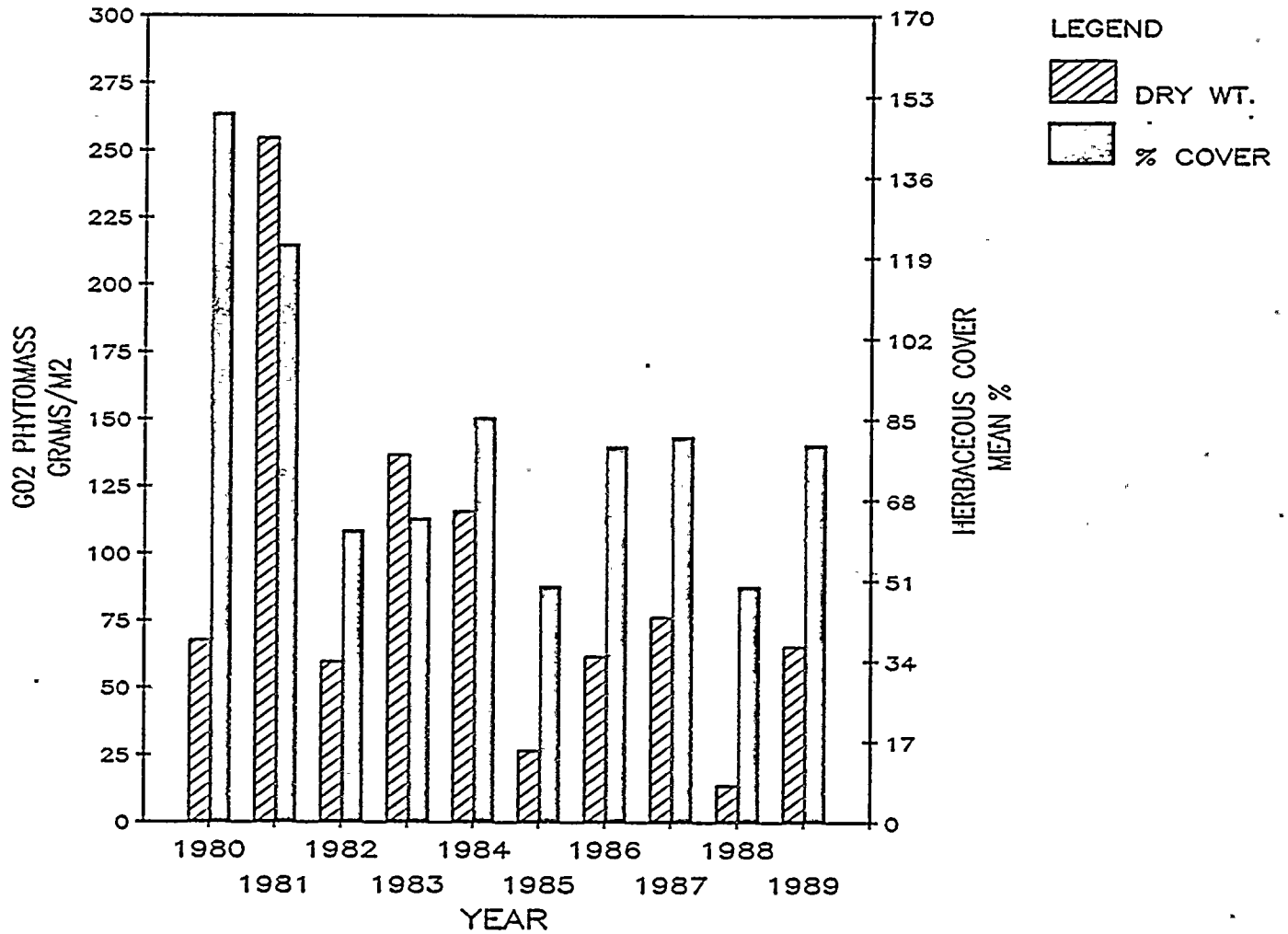


Figure 5-11 Mean Herbaceous Cover and Phytomass for Station G02 for 1980 Through 1989

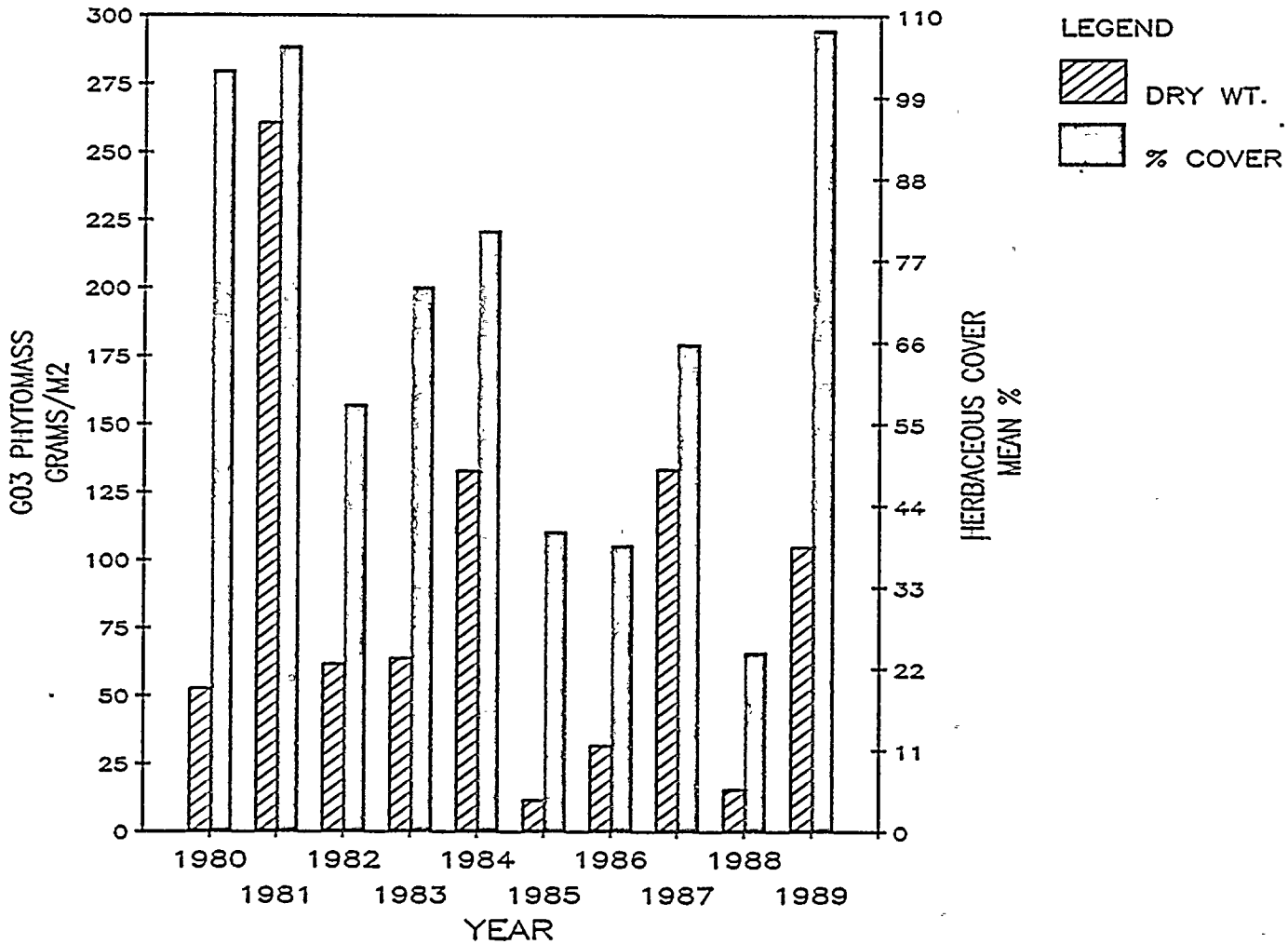


Figure 5-12 Mean Herbaceous Cover and Phytomass for Station G03 for 1980 Through 1989

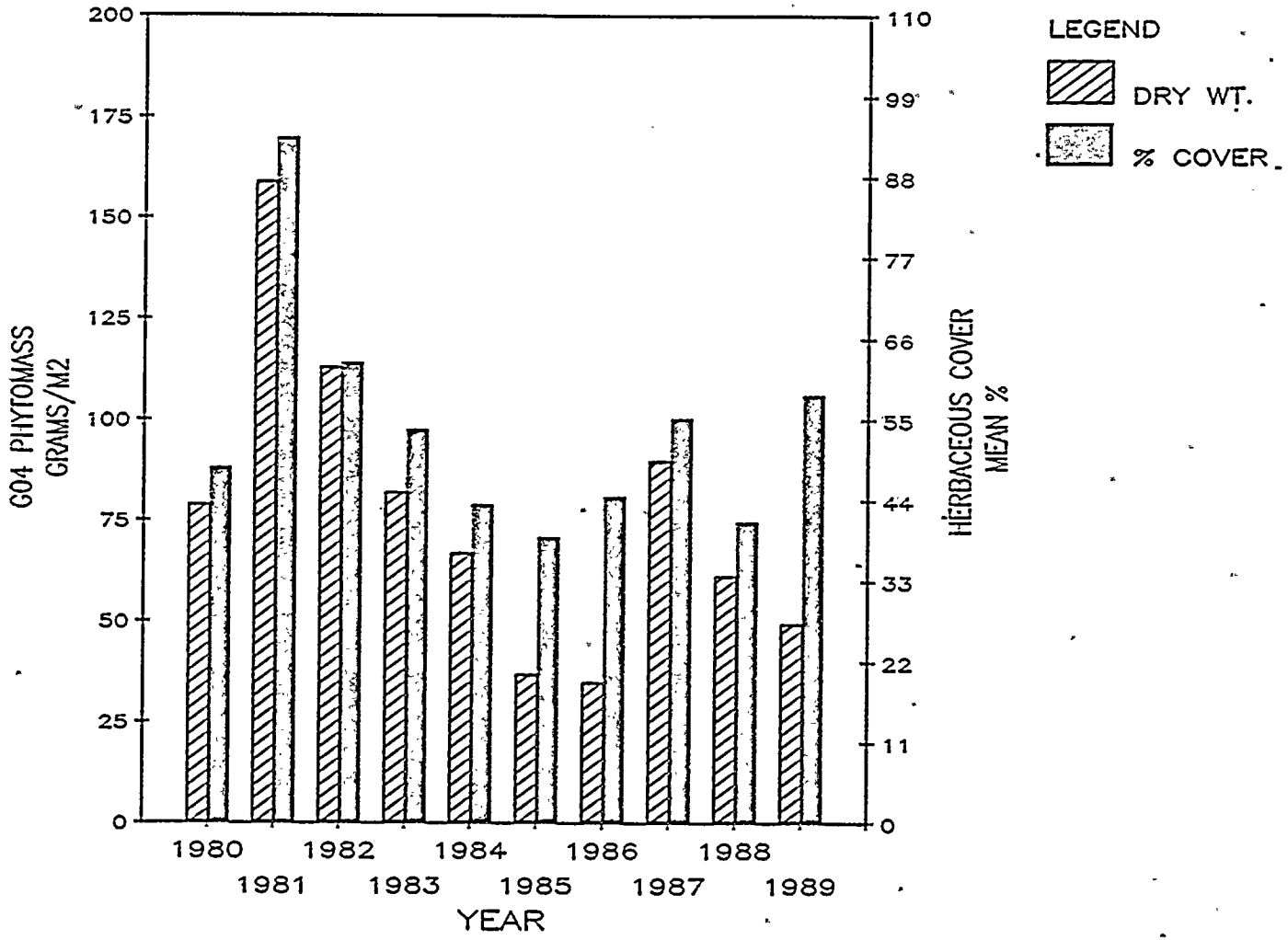


Figure 5-13 Mean Herbaceous Cover and Phytomass for Station G04 for 1980 Through 1989

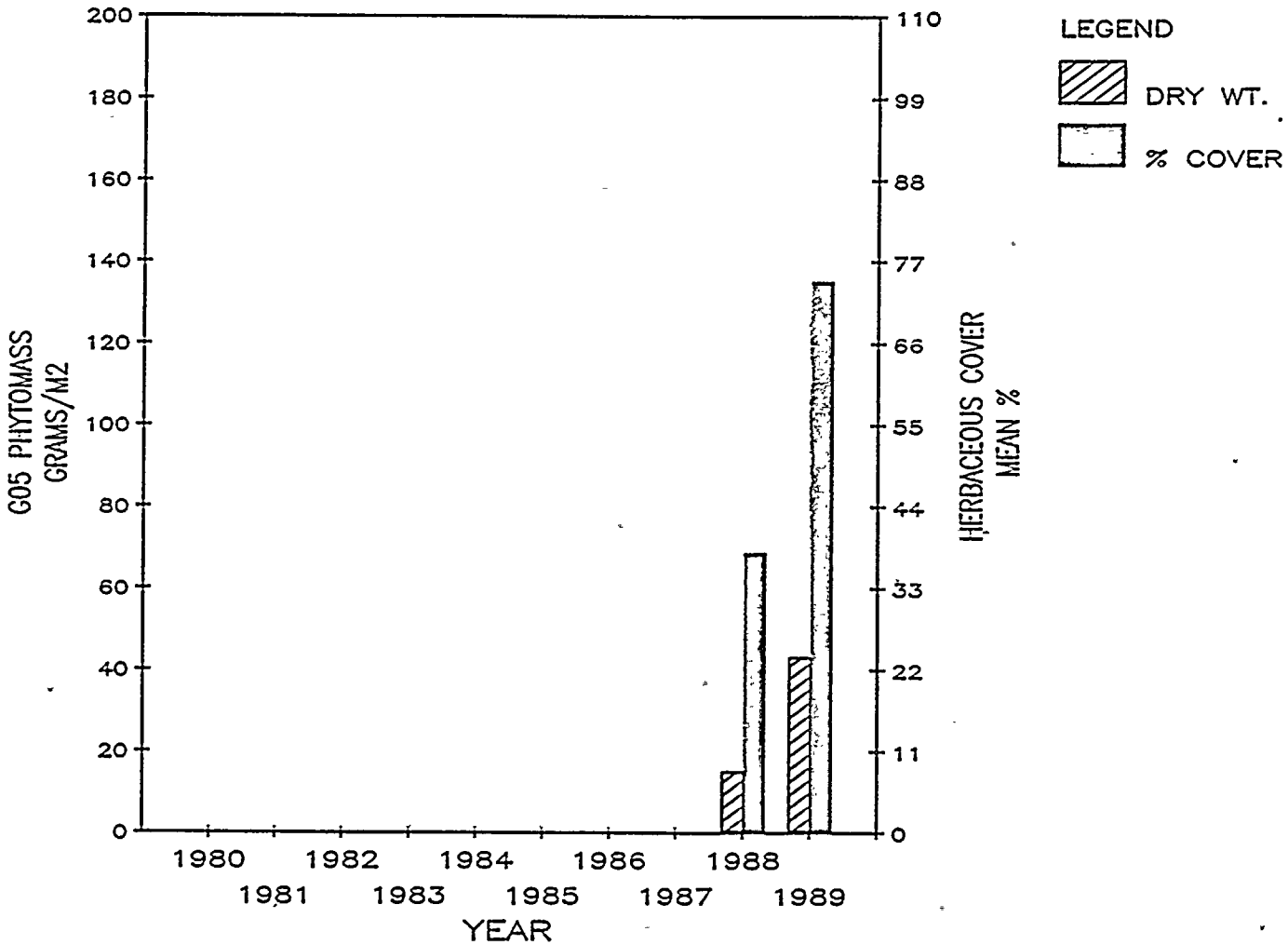


Figure 5-14 Mean Herbaceous Cover and Phytomass for Station G05 for 1980 Through 1989

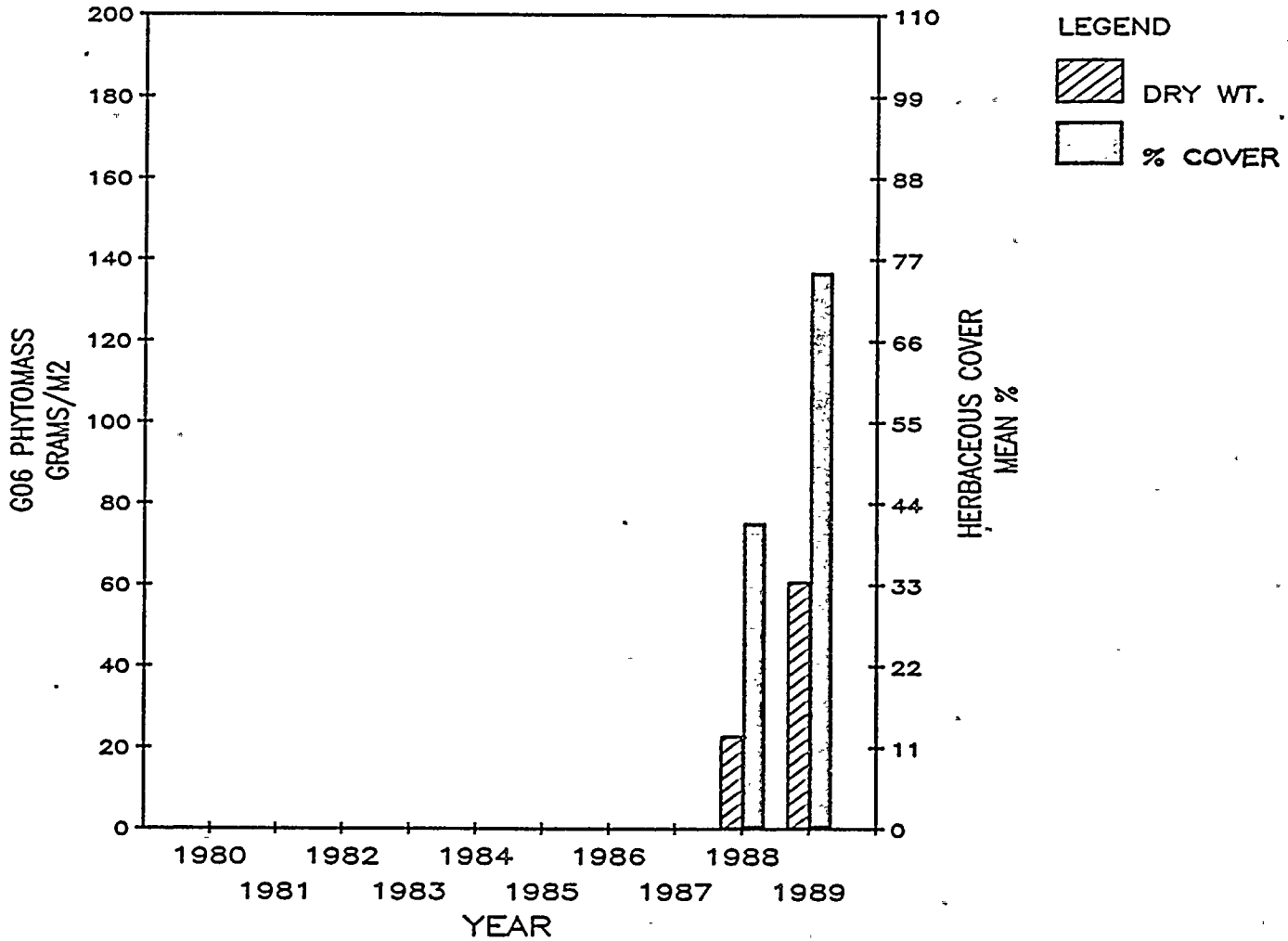


Figure 5-15 Mean Herbaceous Cover and Phytomass for Station G06 for 1980 Through 1989

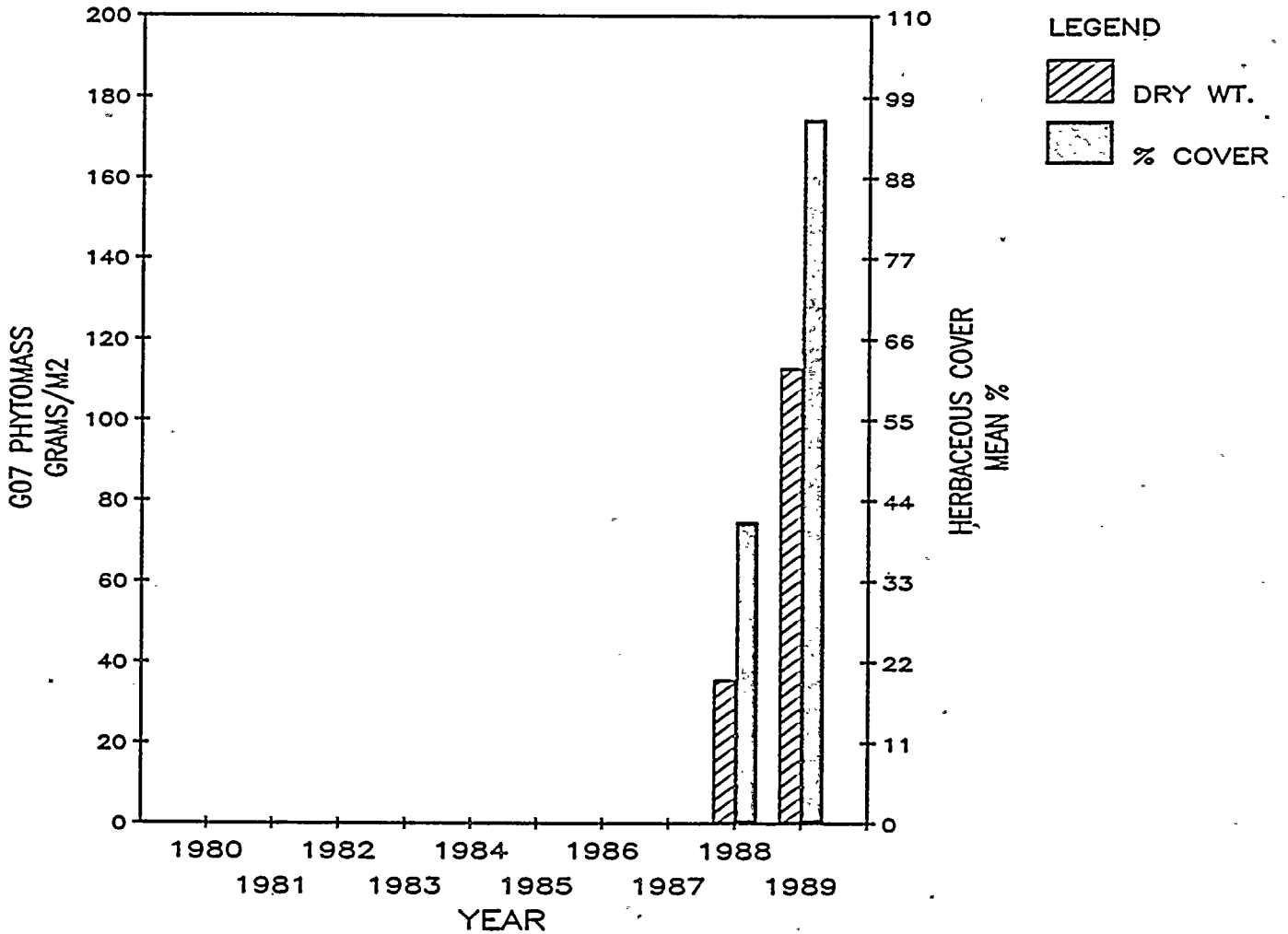


Figure 5-16 Mean Herbaceous Cover and Phytomass for Station G07 for 1980 Through 1989

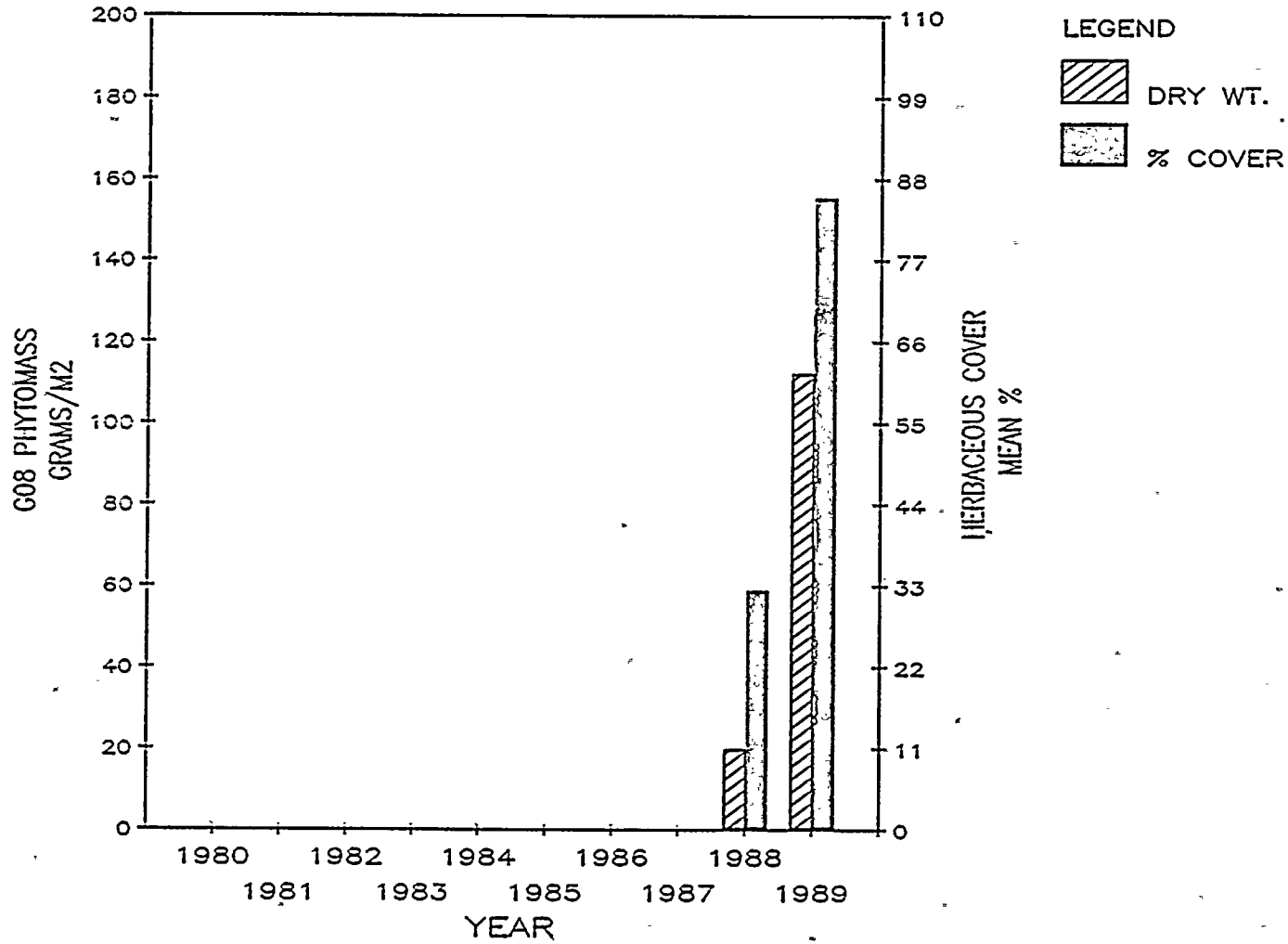


Figure 5-17 Mean Herbaceous Cover and Phytomass for Station G08 for 1980 Through 1989

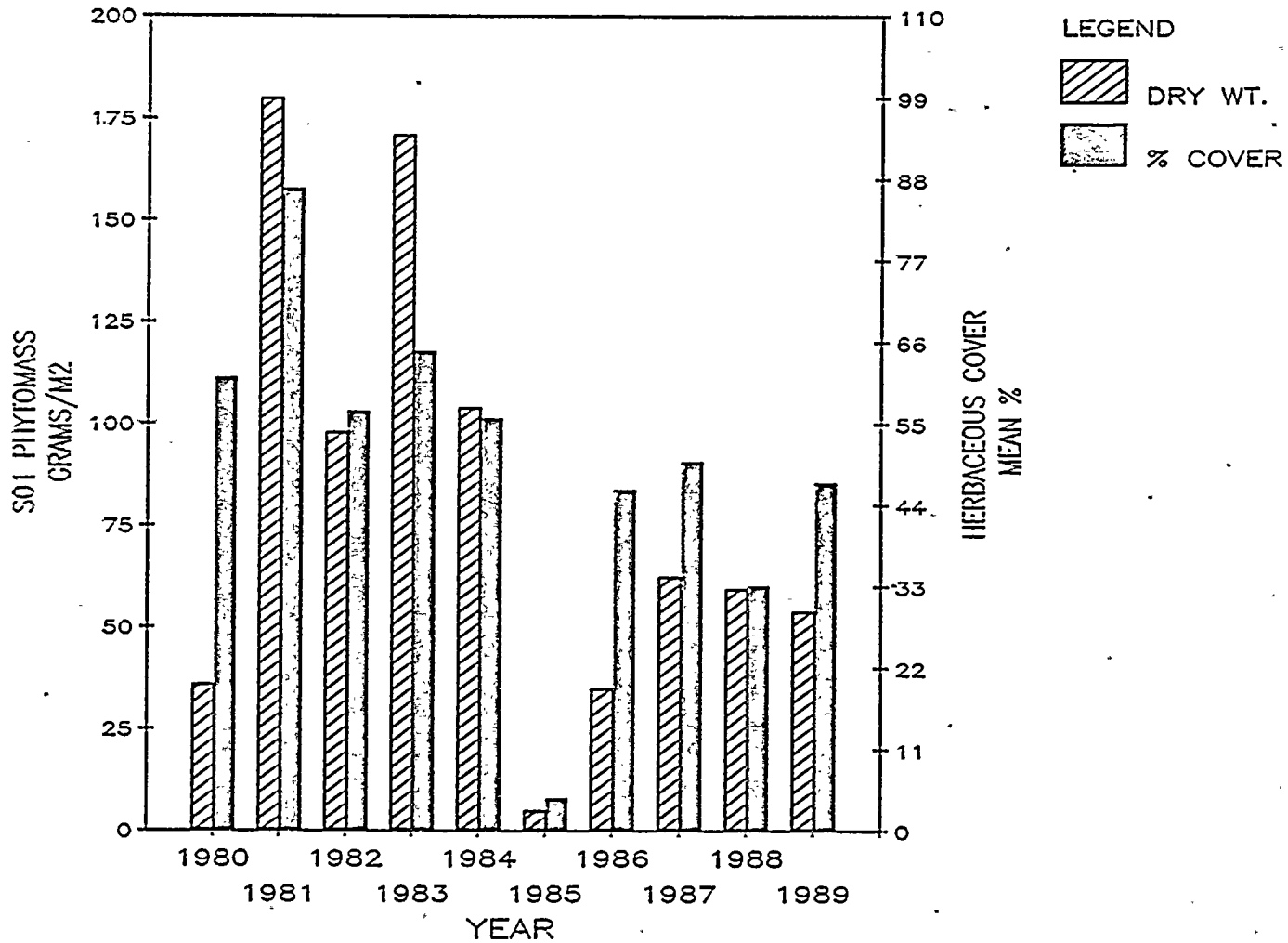


Figure 5-18 Mean Herbaceous Cover and Phytomass for Station S01 for 1980 Through 1989

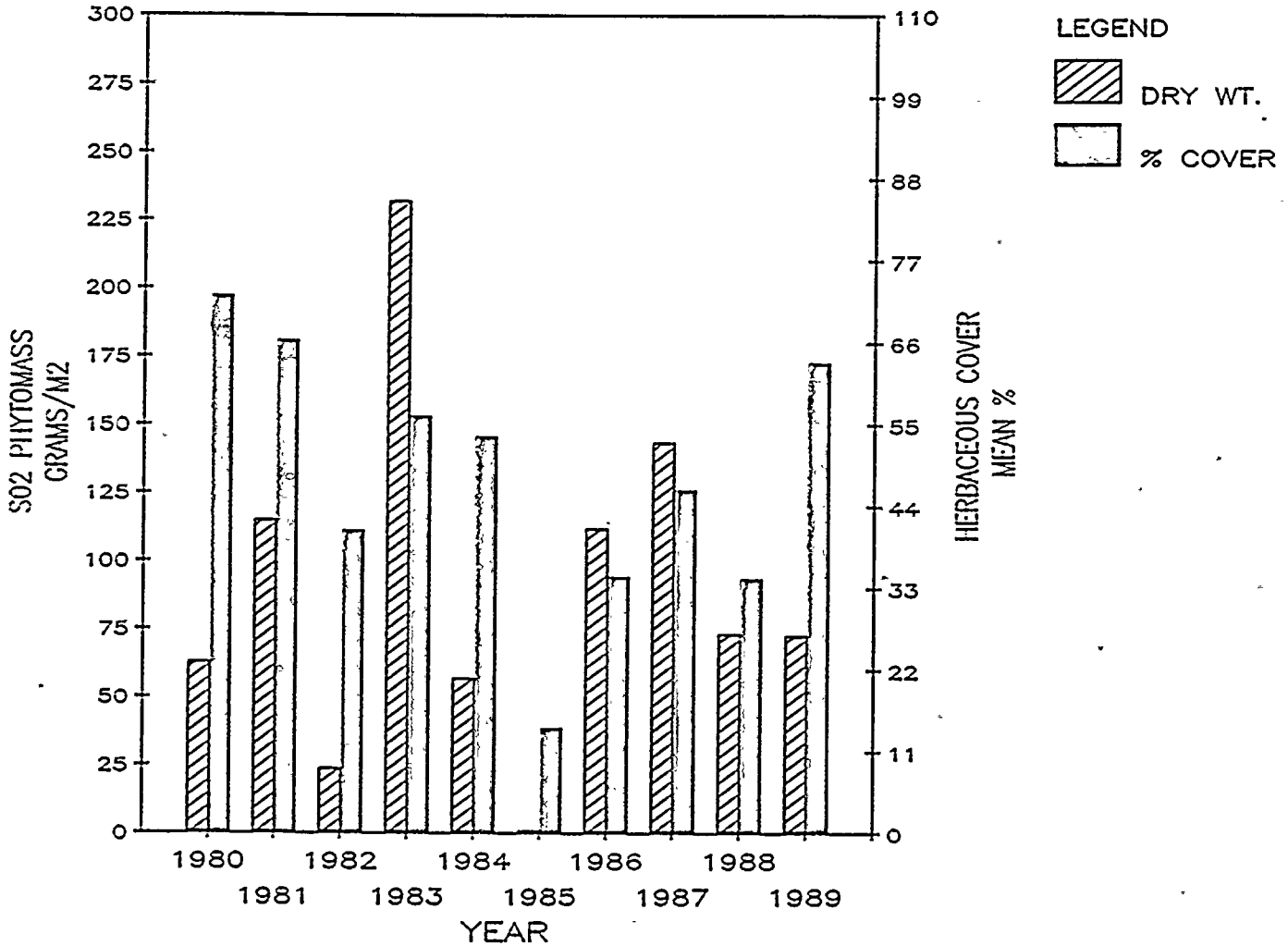


Figure 5-19 . Mean Herbaceous Cover and Phytomass for Station S02 for 1980 Through 1989

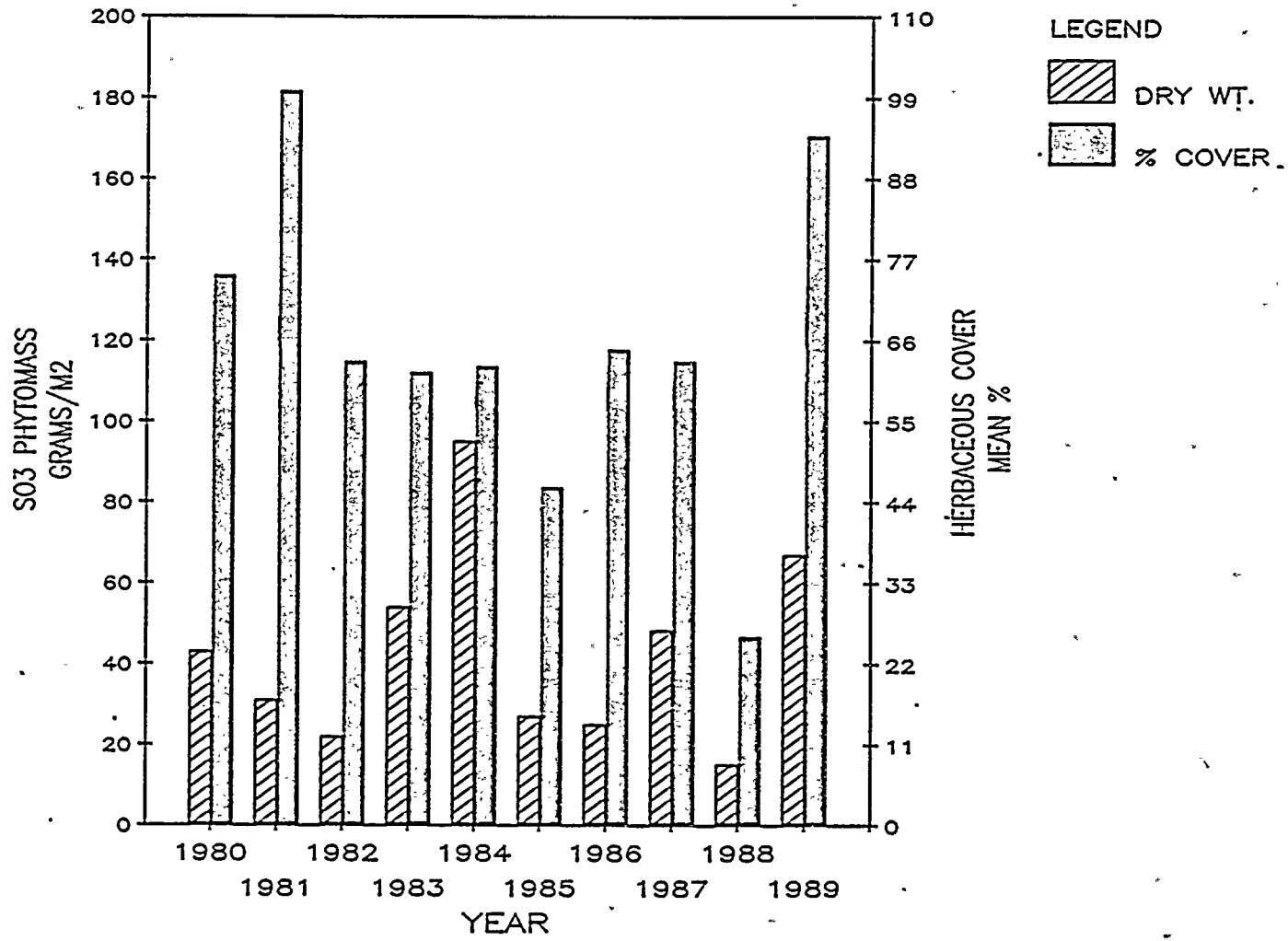


Figure 5-20 Mean Herbaceous Cover and Phytomass for Station S03 for 1980 Through 1989

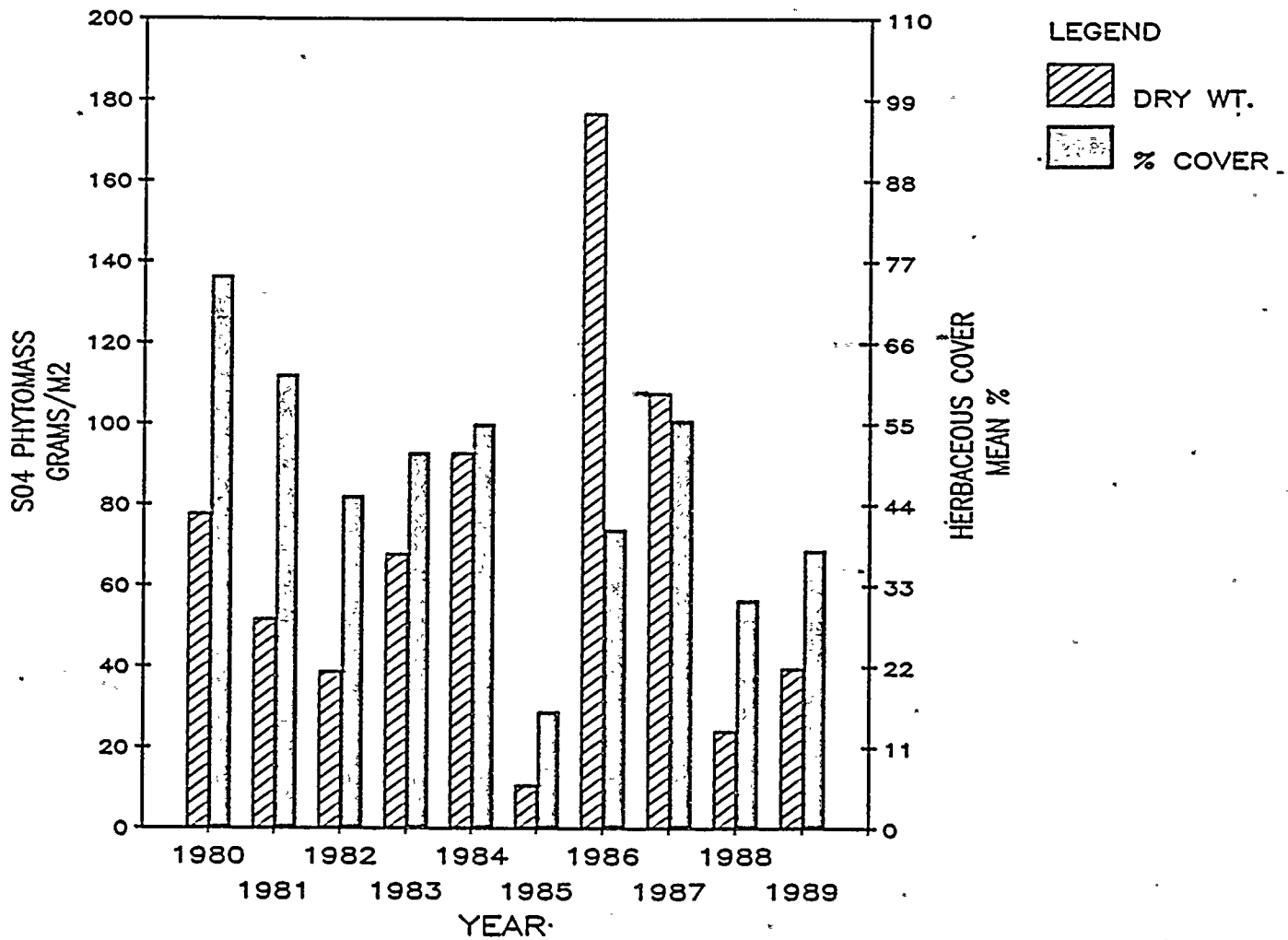


Figure 5-21 Mean Herbaceous Cover and Phytomass for Station S04 for 1980 Through 1989

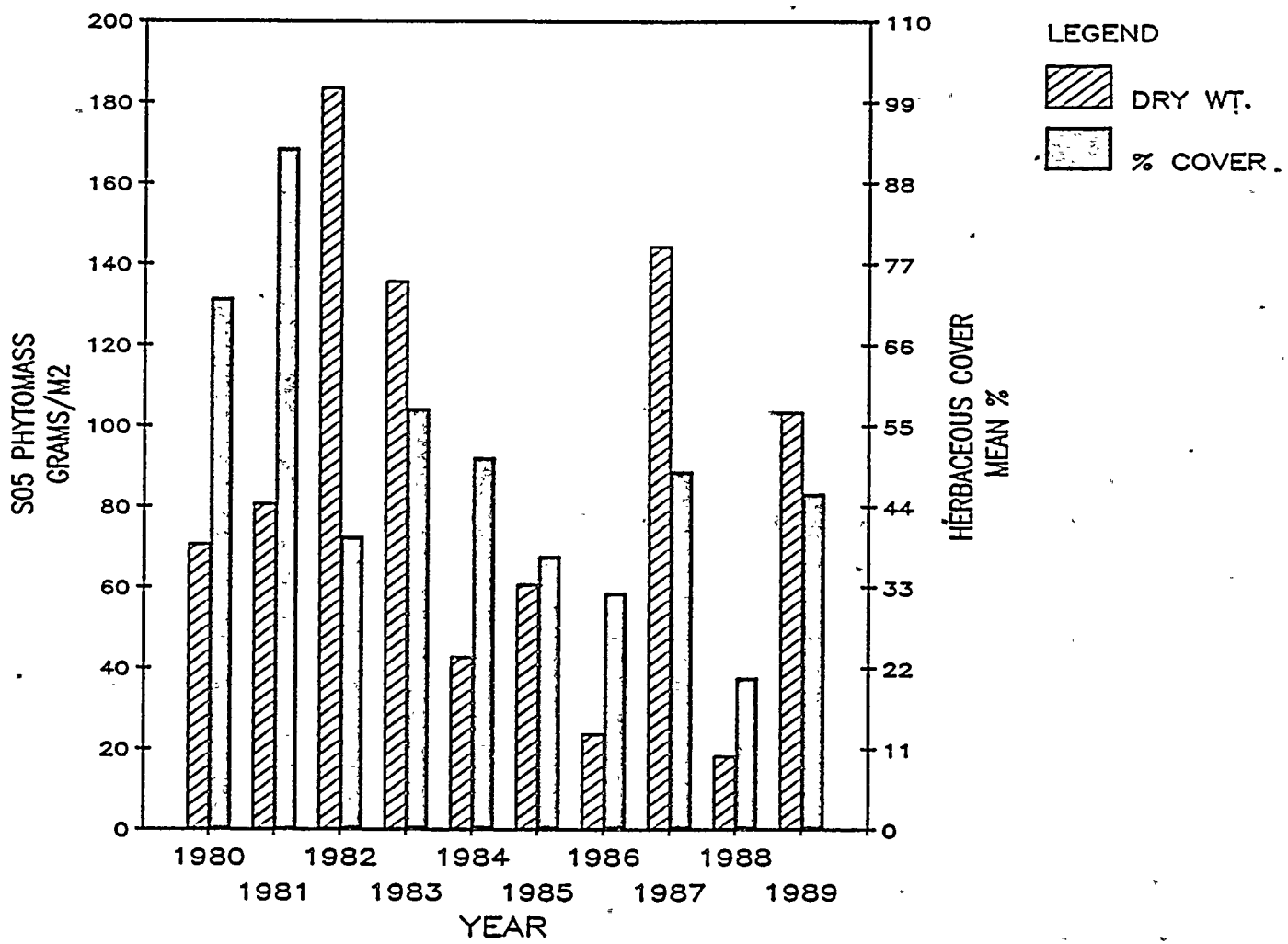


Figure 5-22 Mean Herbaceous Cover and Phytomass for Station S05 for 1980 Through 1989

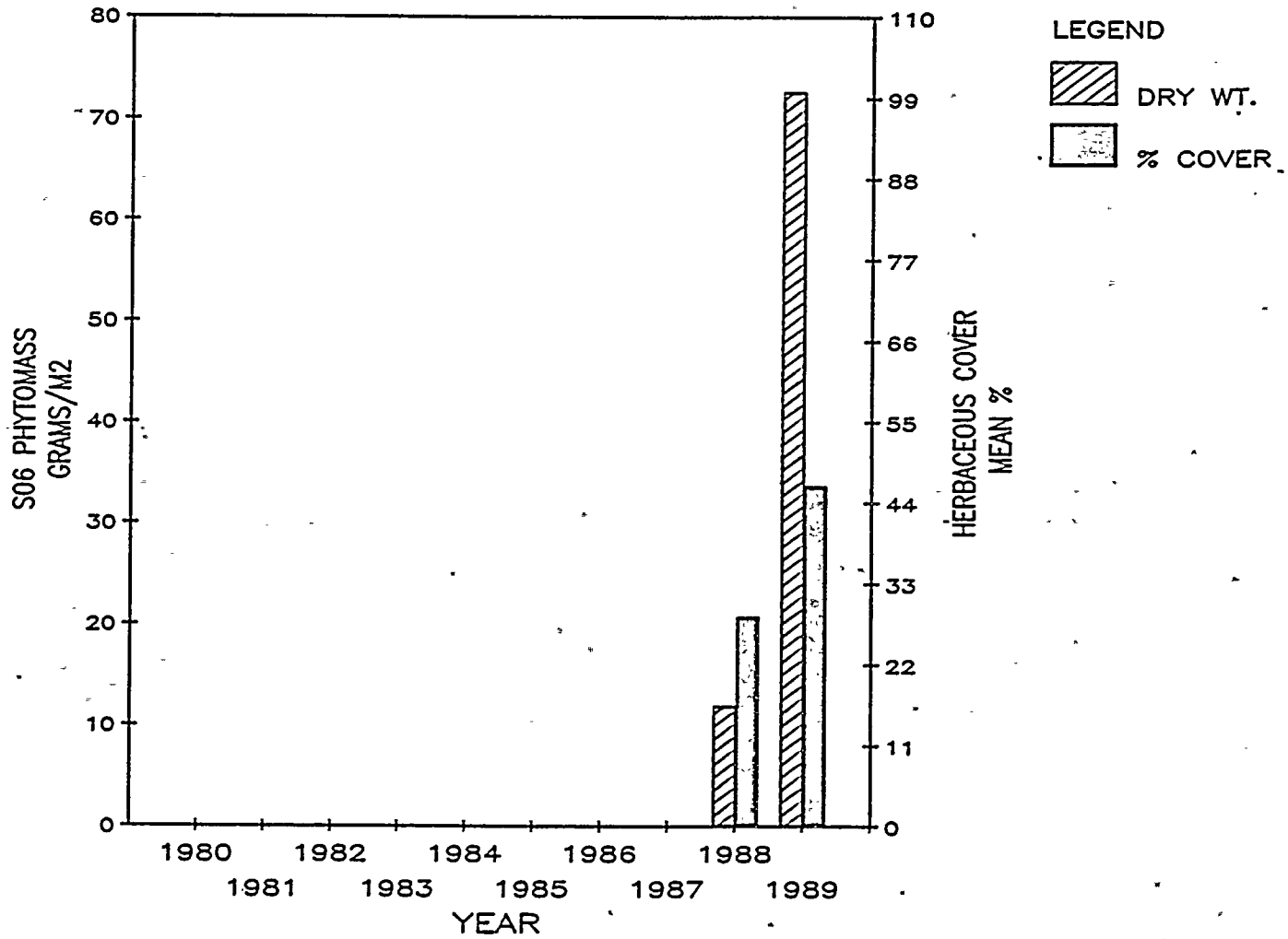


Figure 5-23 Mean Herbaceous Cover and Phytomass for Station S06 for 1980 Through 1989

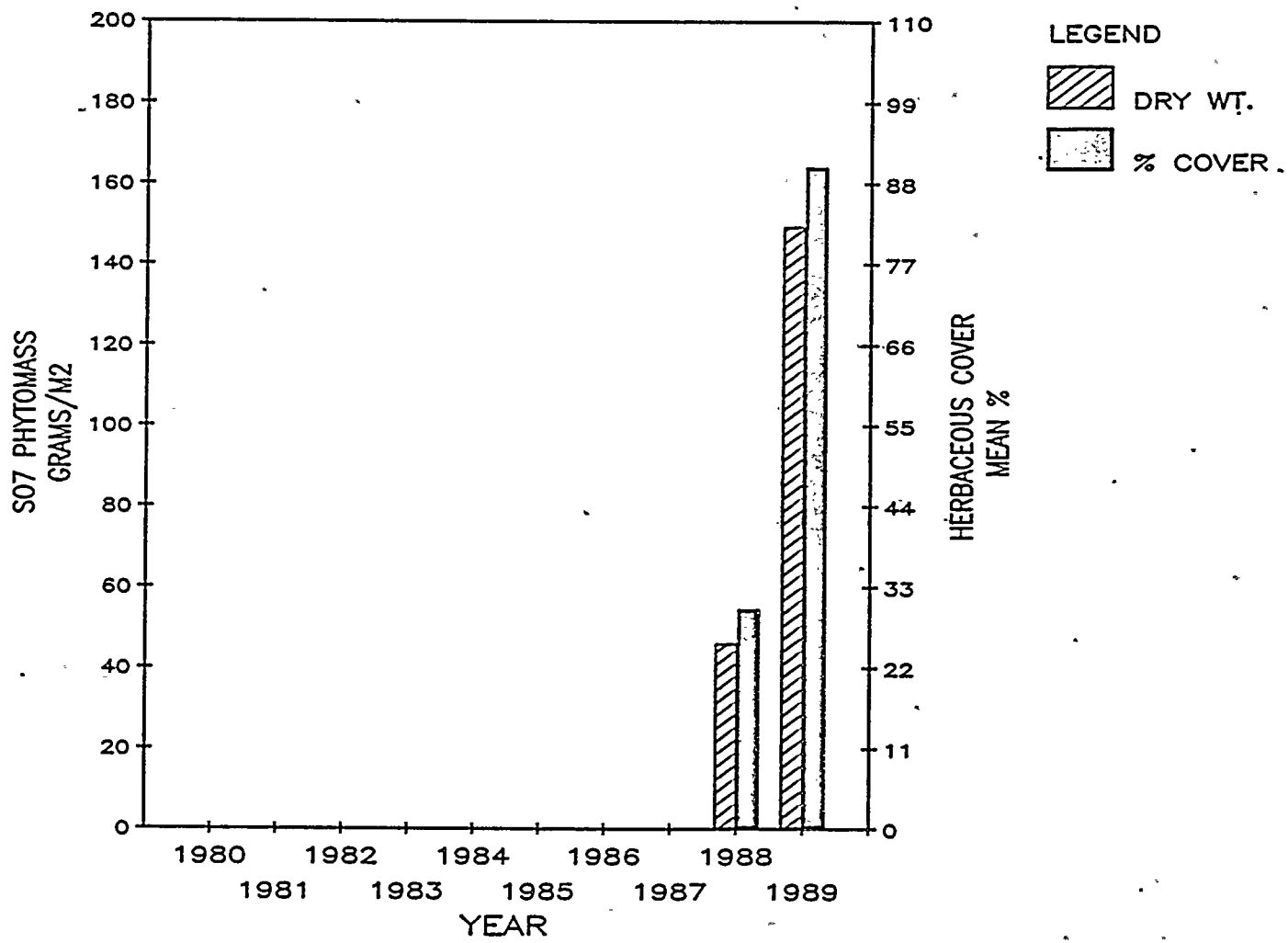


Figure 5-24 Mean Herbaceous Cover and Phytomass for Station S07 for 1980 Through 1989

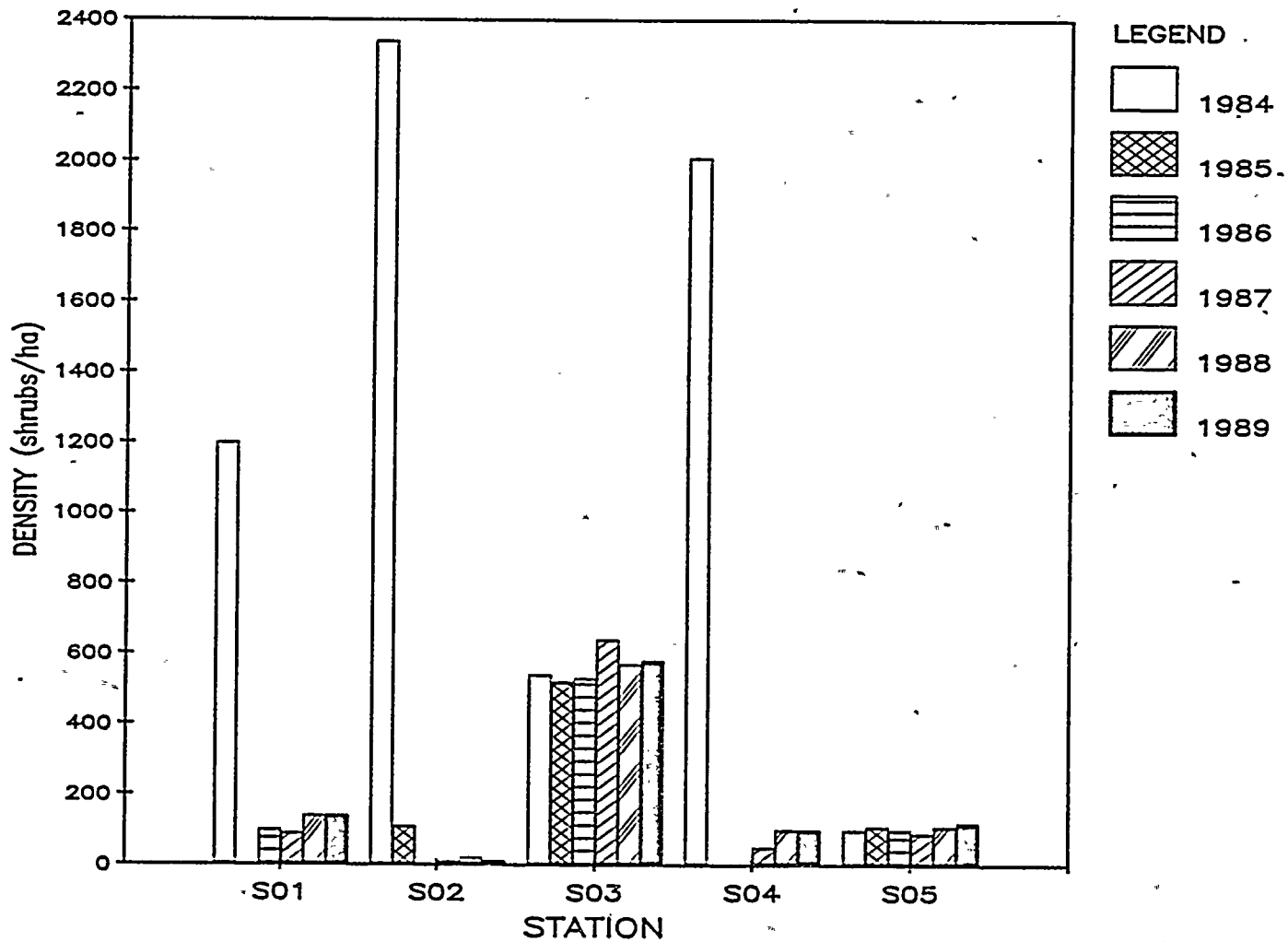


Figure 5-25 Shrub Density at Five Stations for 1984 Through 1989

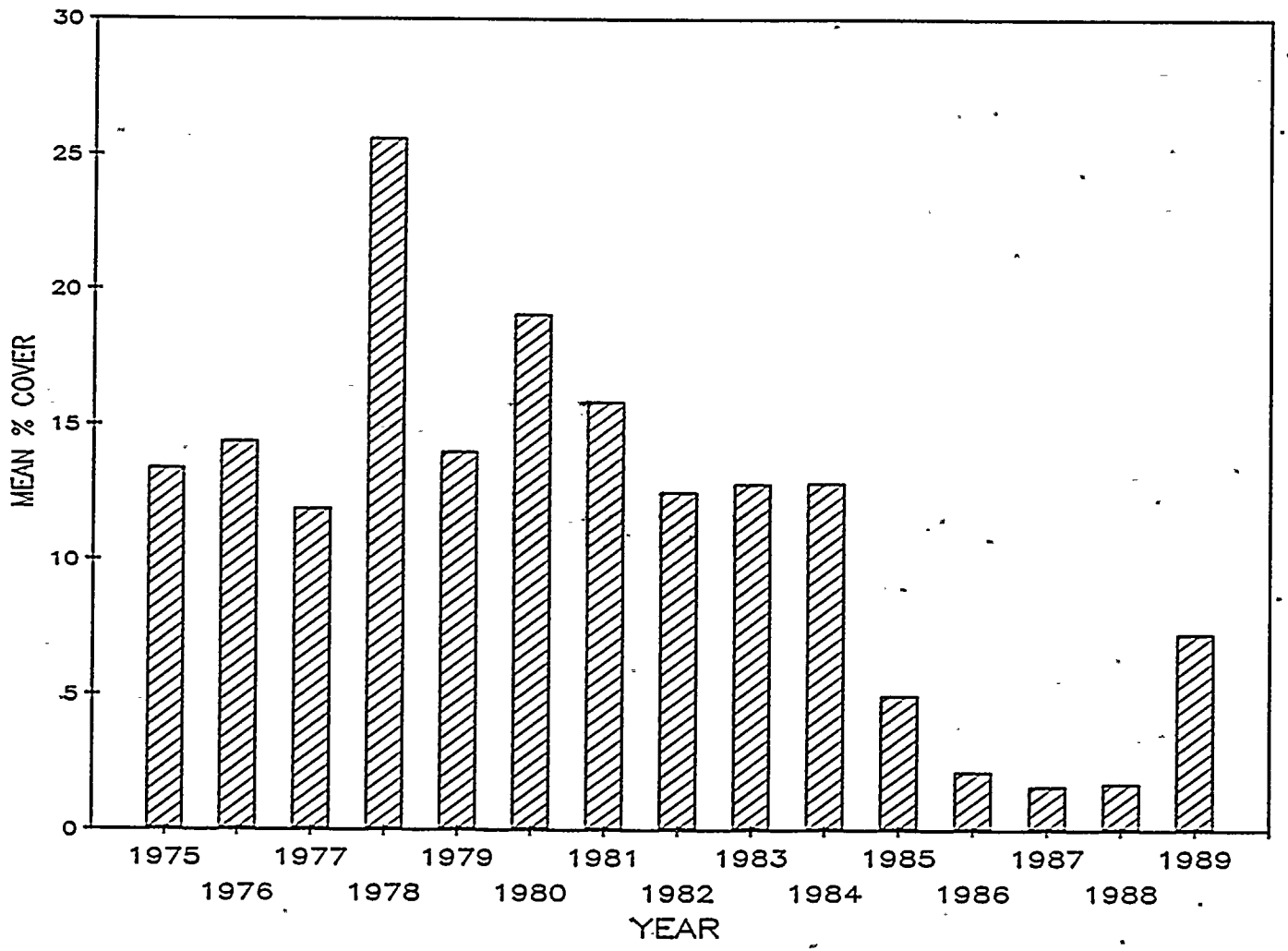


Figure 5-26 Mean Total Shrub Cover for 1975 Through 1989

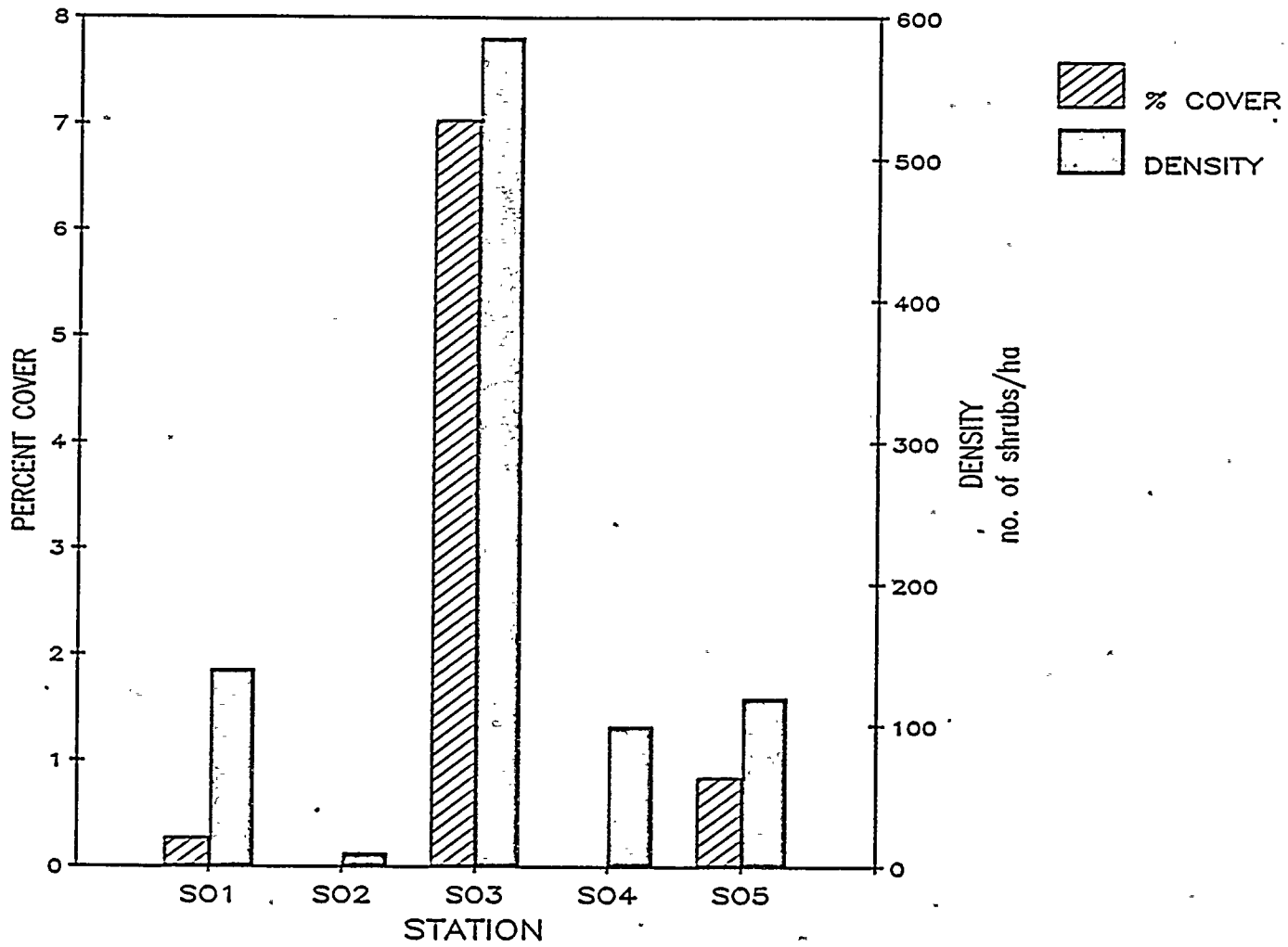


Figure 5-27 Shrub Cover and Density for Five Stations for 1989

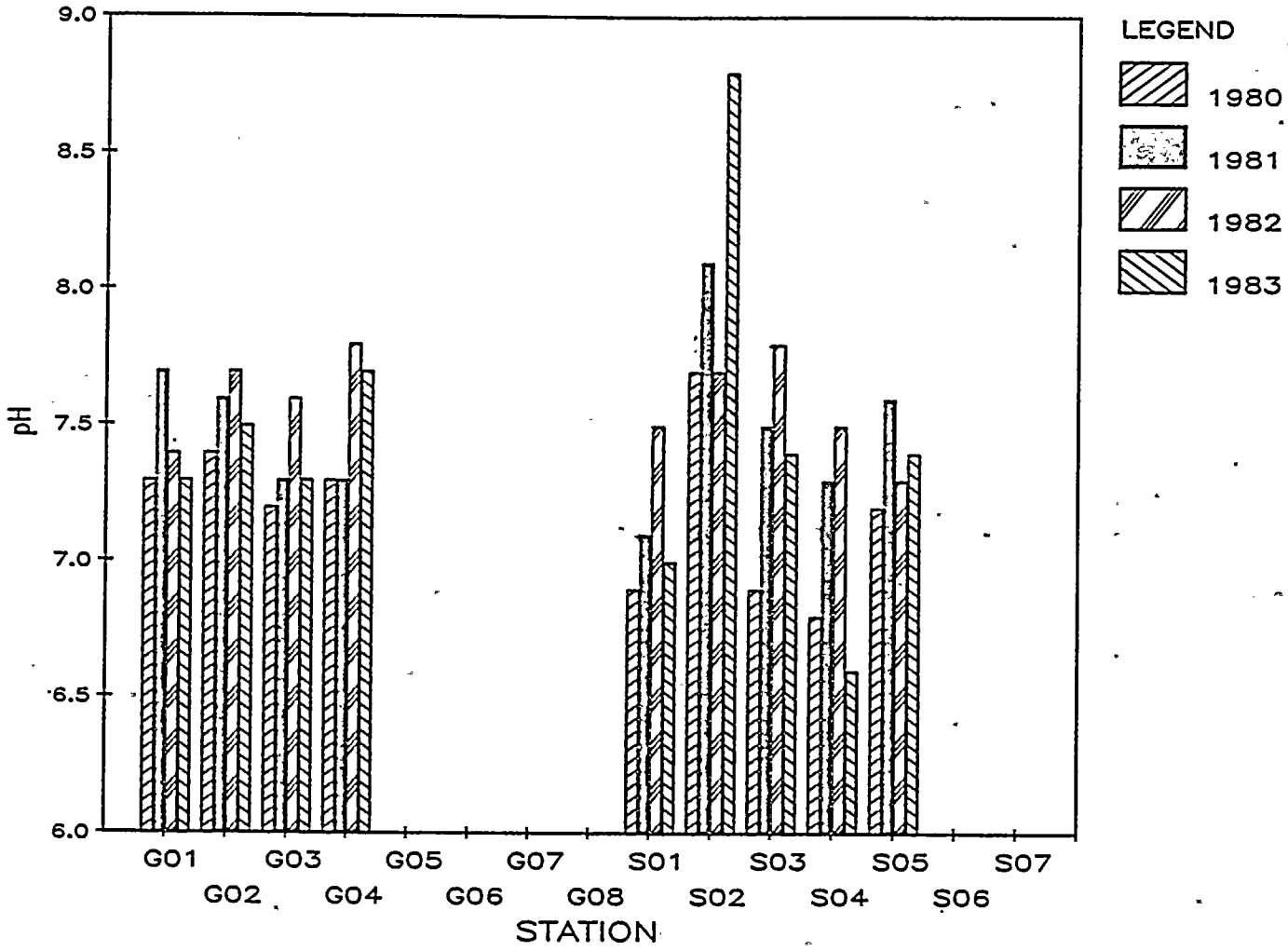


Figure 5-28 Soil pH for 1980 Through 1983

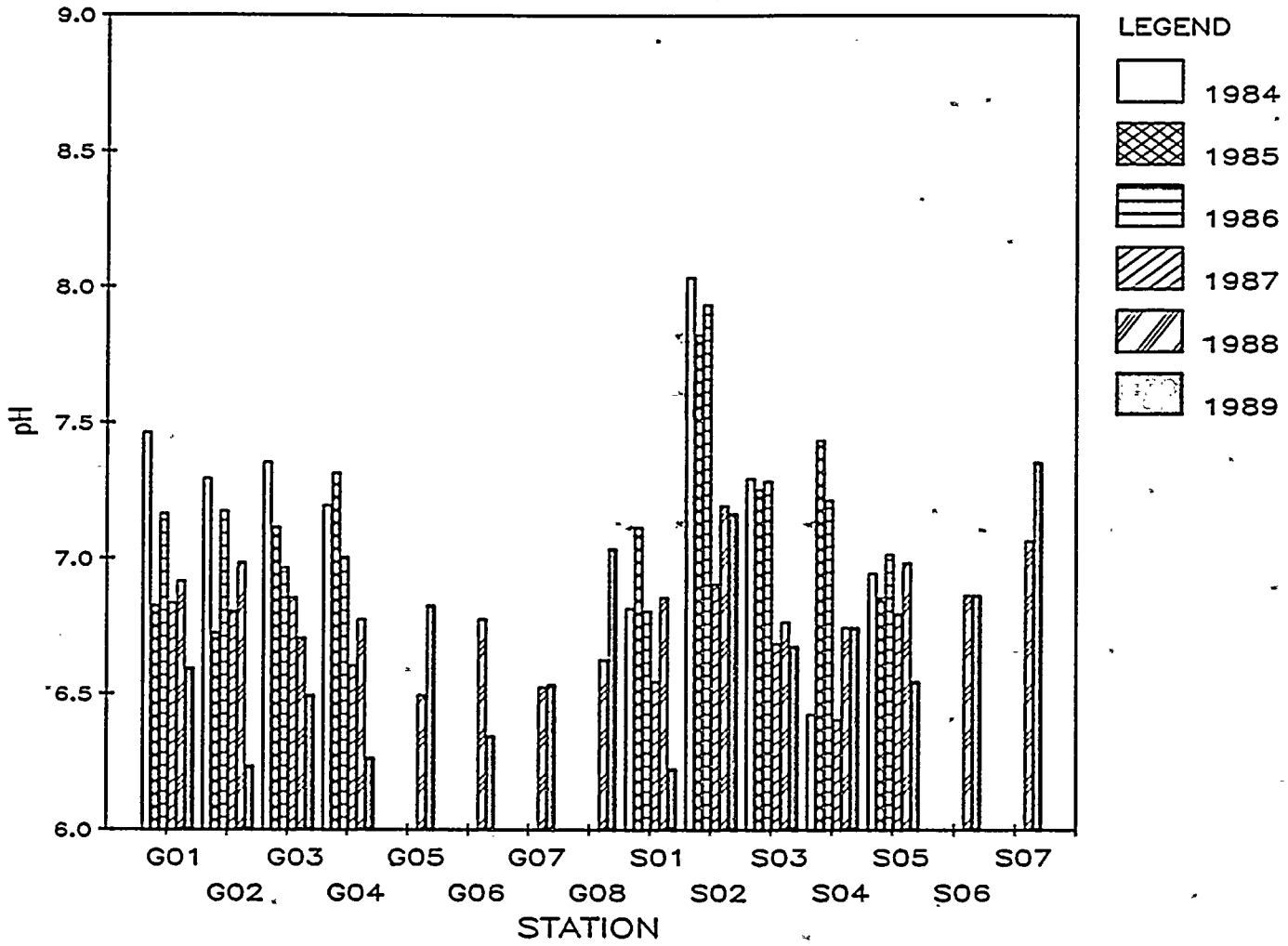


Figure 5-29 Soil pH for 1984 through 1989

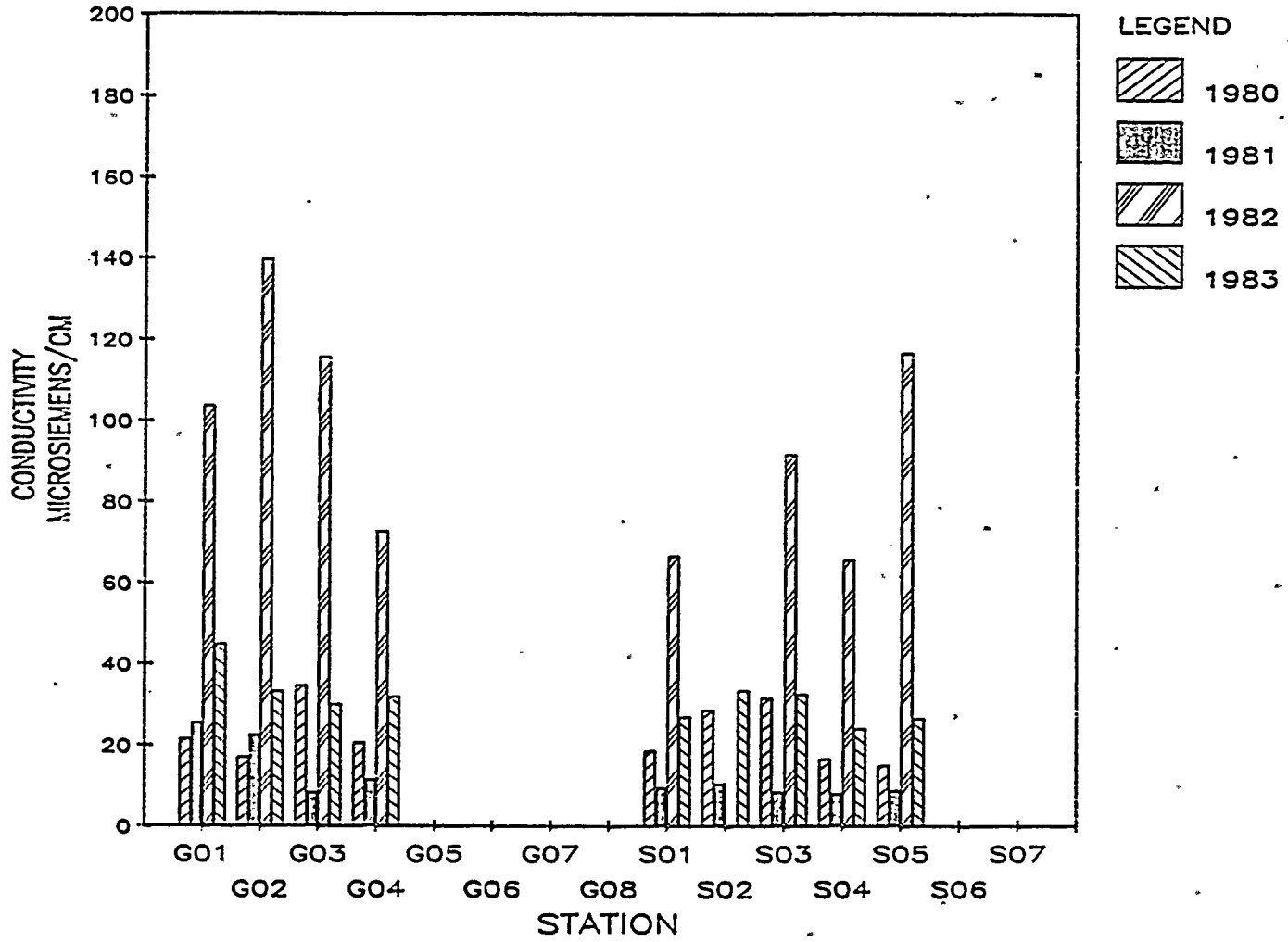


Figure 5-30 Soil Conductivity for 1980 Through 1983

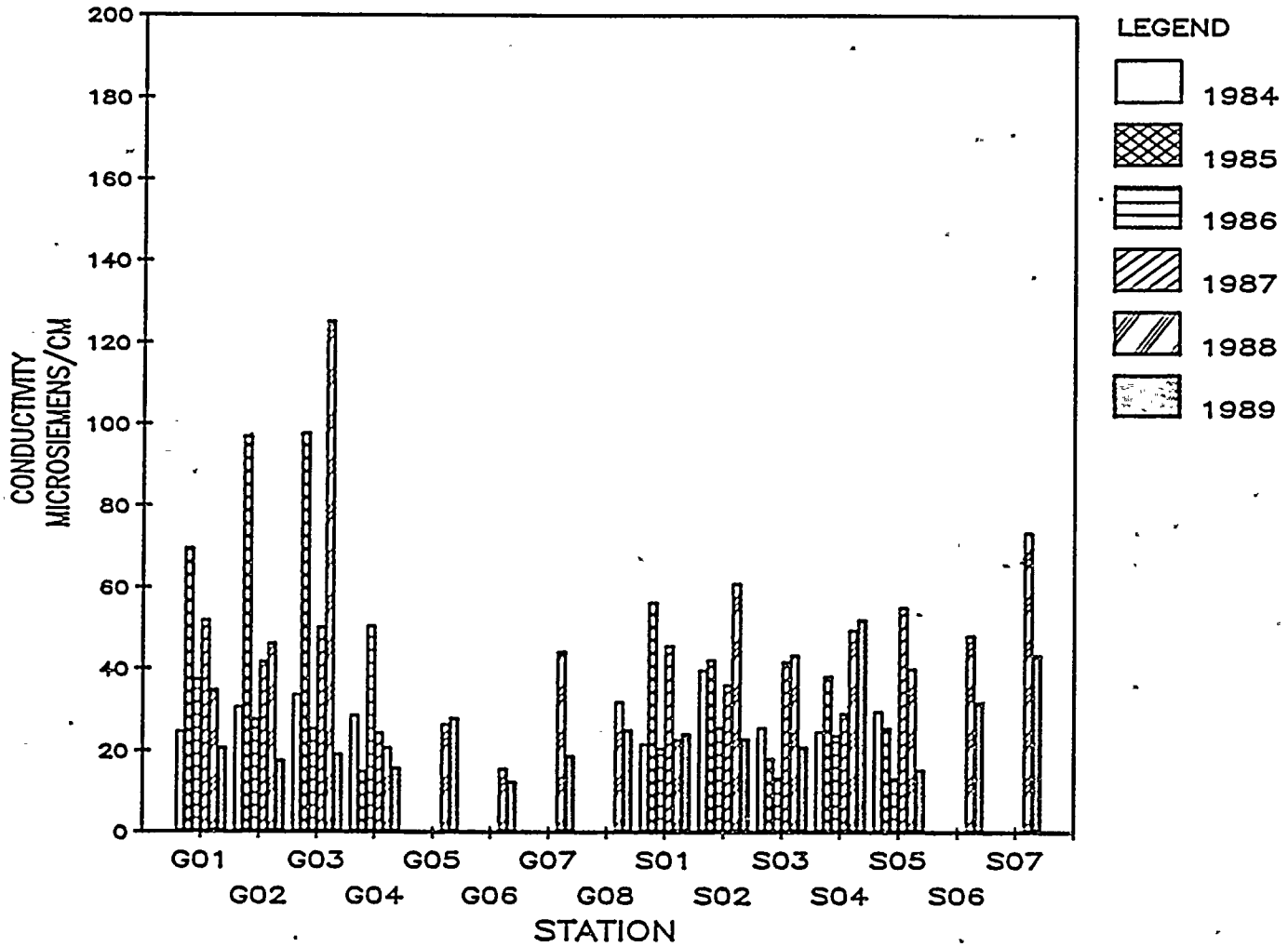


Figure 5-31 Soil Conductivity for 1984 Through 1989

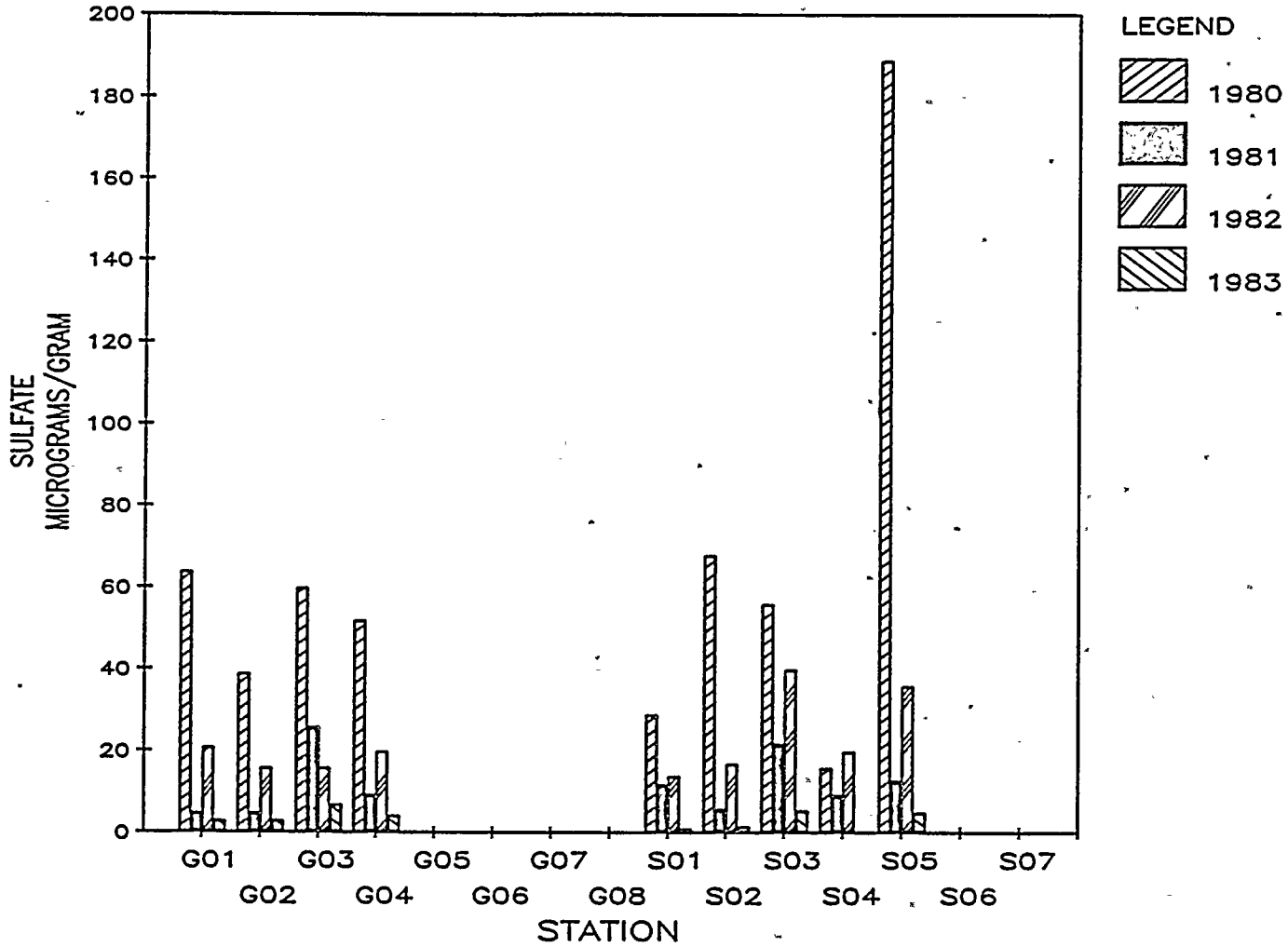


Figure 5-32 Soil Sulfate for 1980 Through 1983

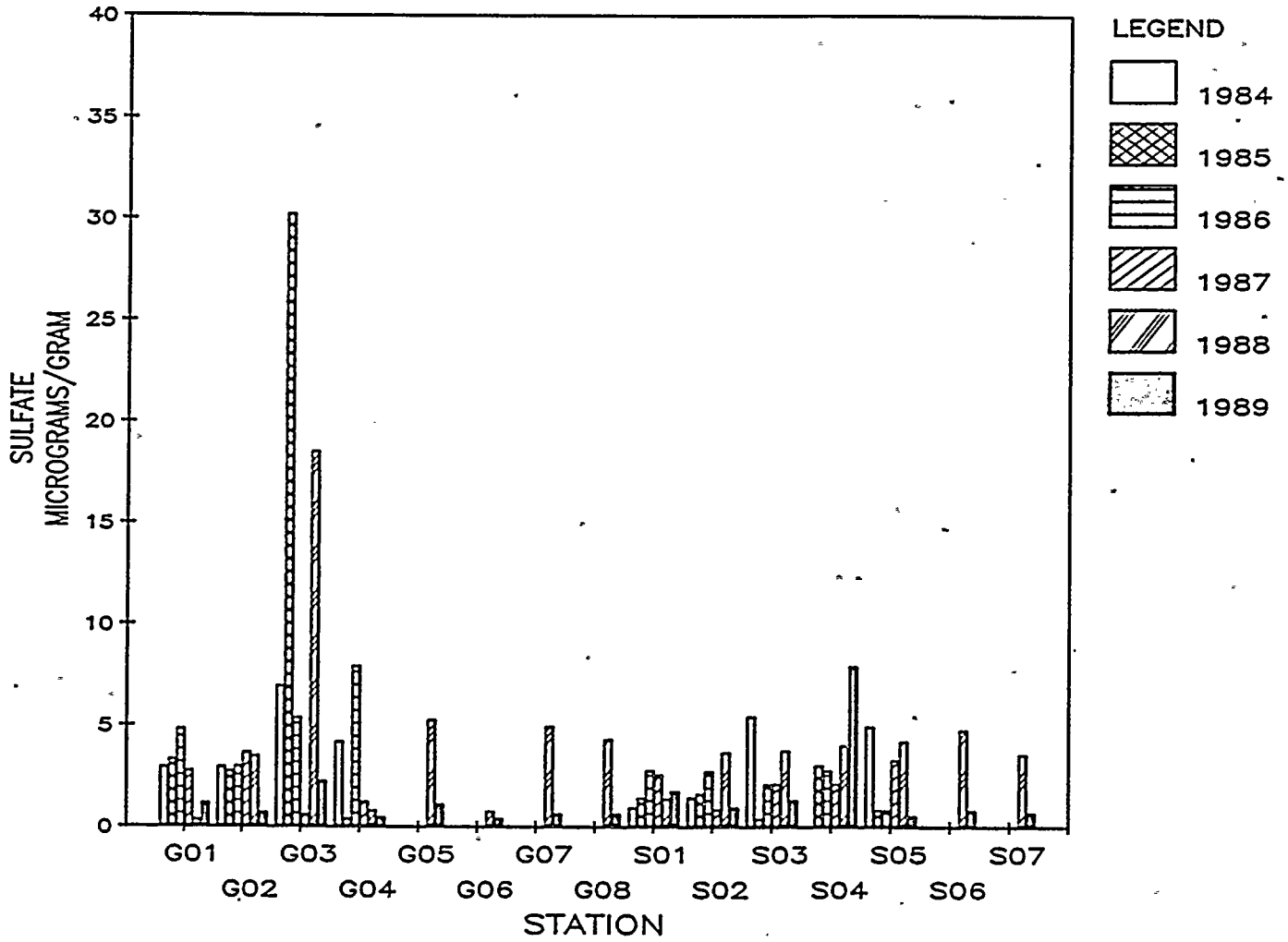


Figure 5-33 Soil Sulfate for 1984 Through 1989

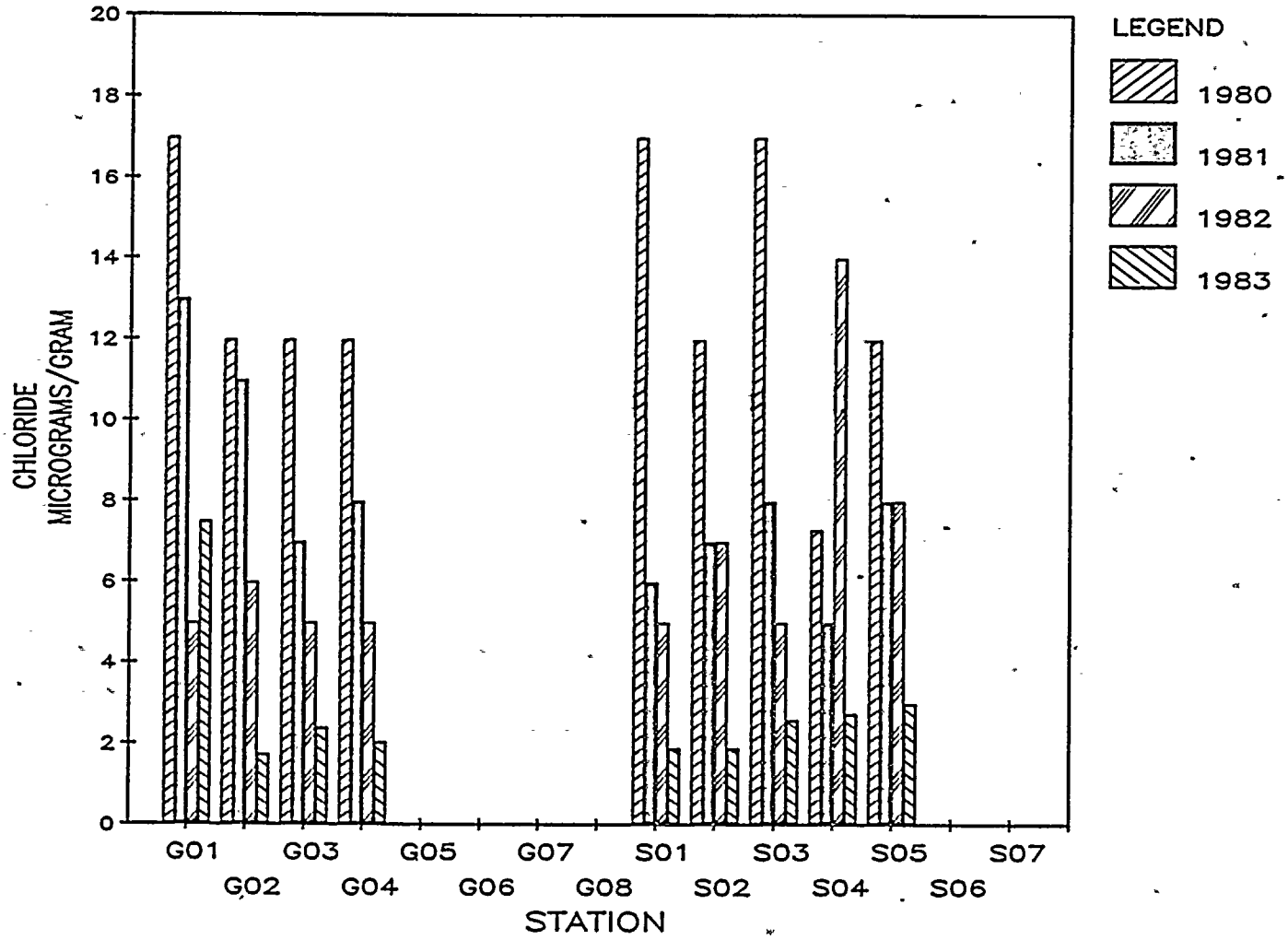


Figure 5-34 Soil Chloride for 1980 Through 1983

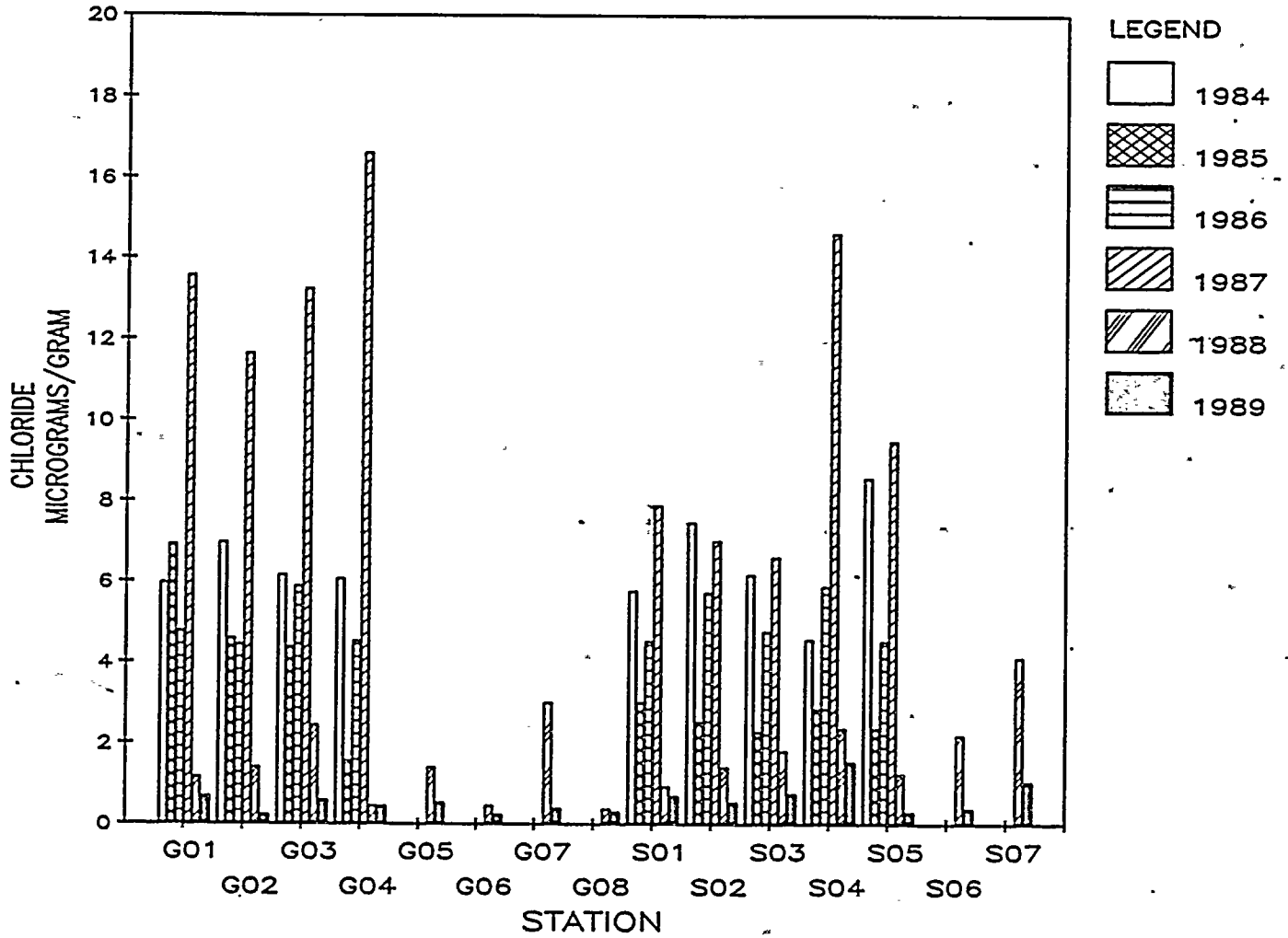


Figure 5-35 Soil Chloride for 1984 Through 1989

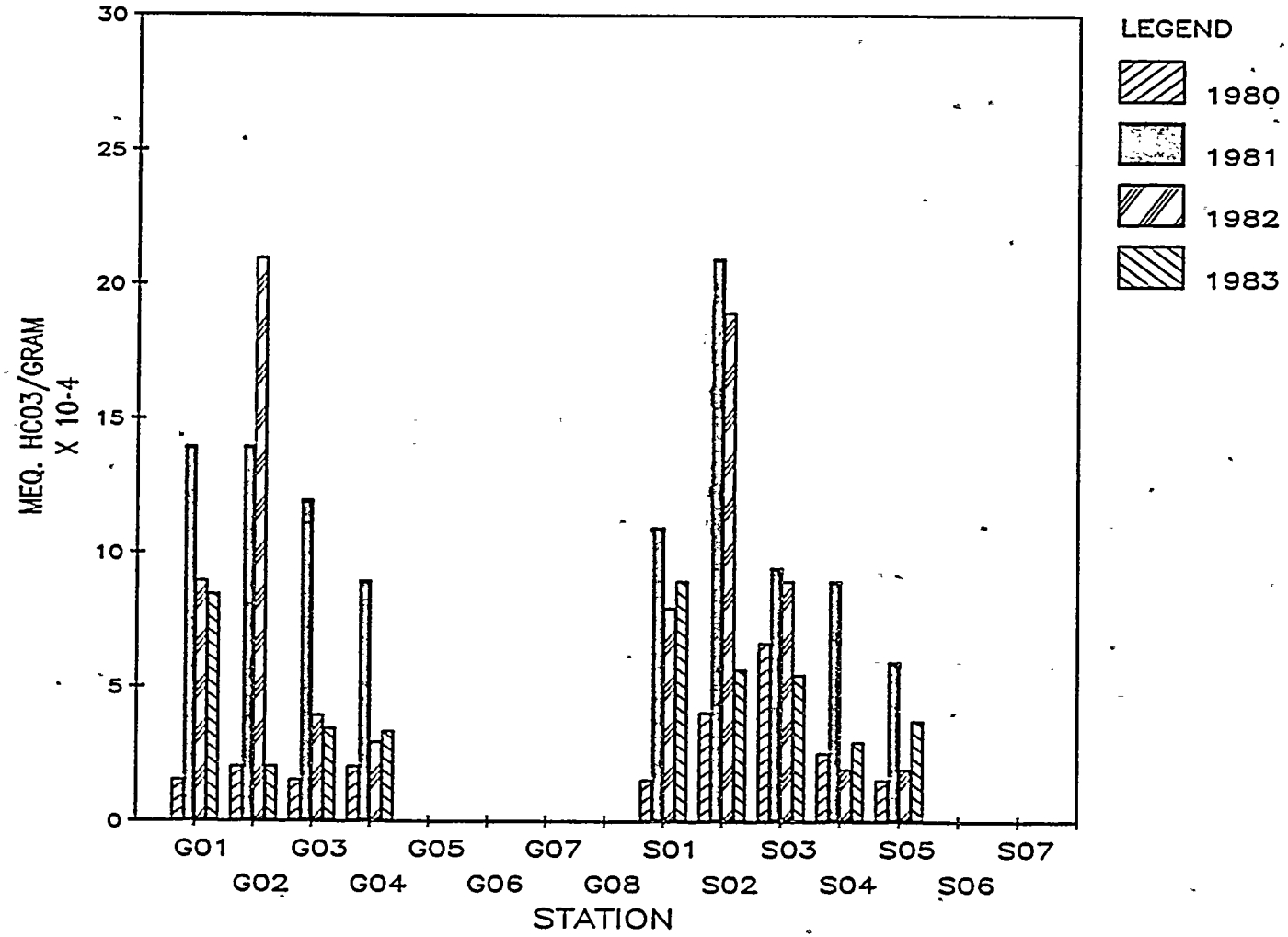


Figure 5-36 Soil Bicarbonate for 1980 Through 1983

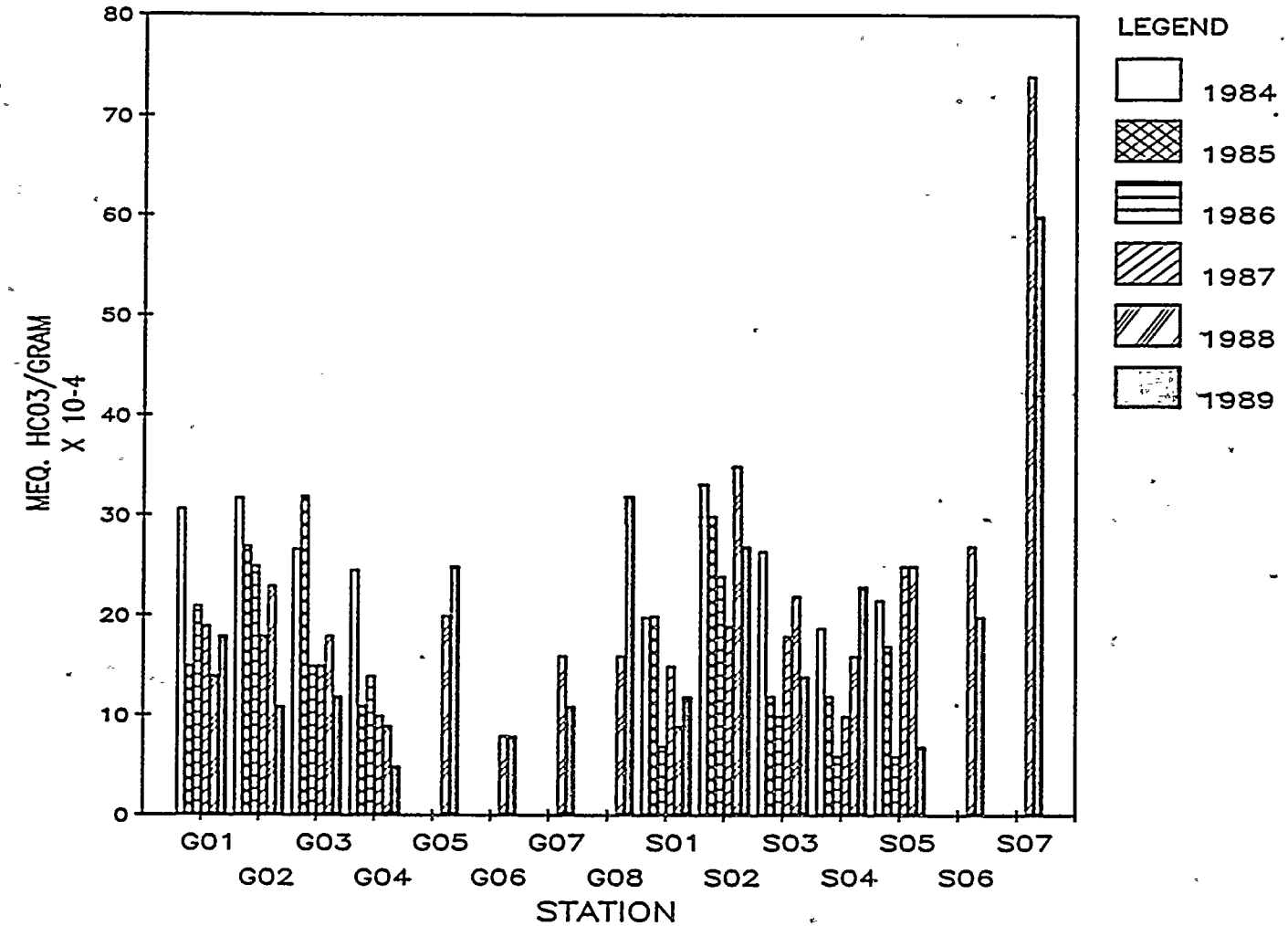


Figure 5-37 Soil Bicarboante for 1984 Through 1989.

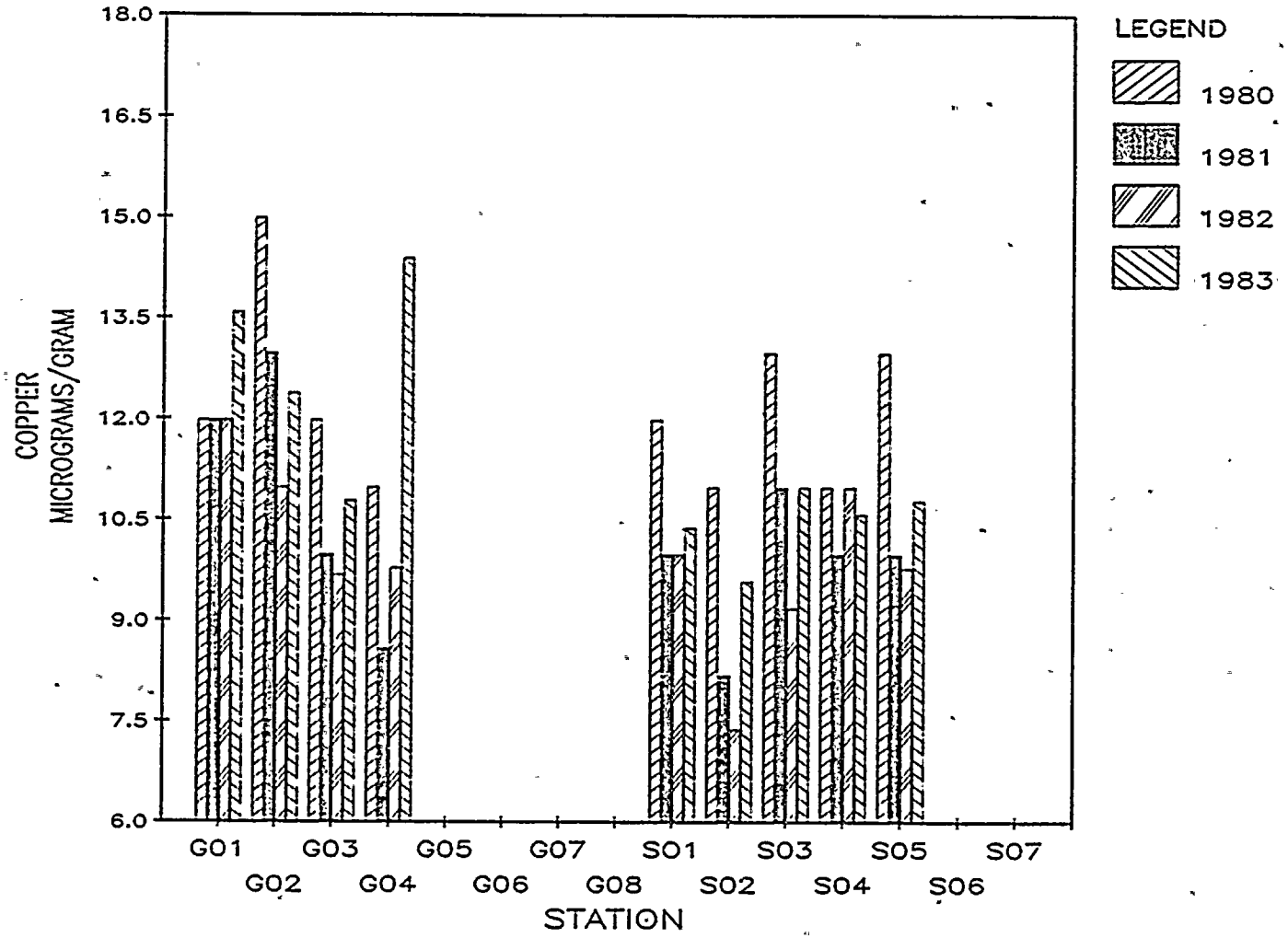


Figure 5-38 Soil Copper for 1980 Through 1983

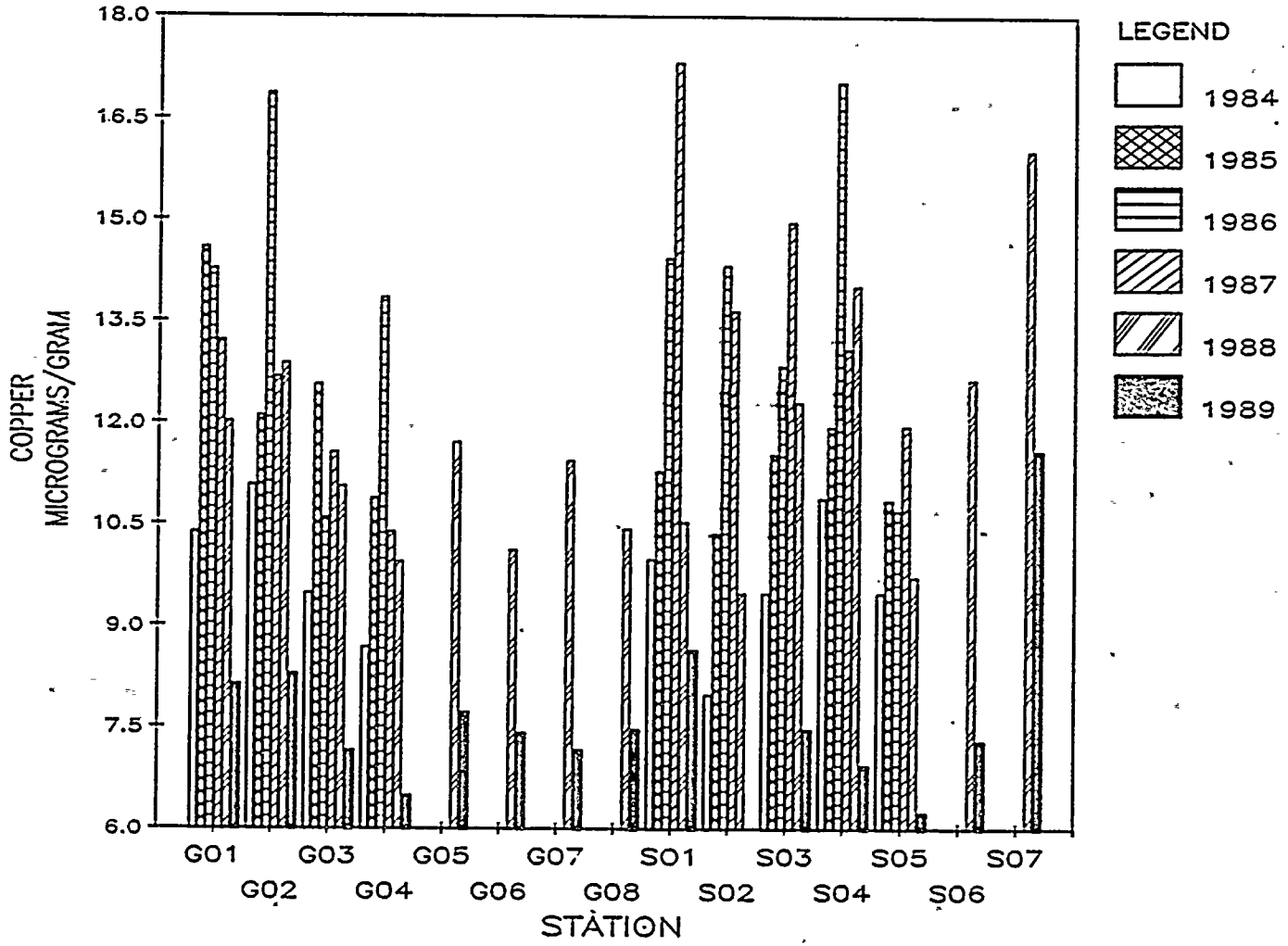


Figure 5-39 Soil Copper for 1984 Through 1989

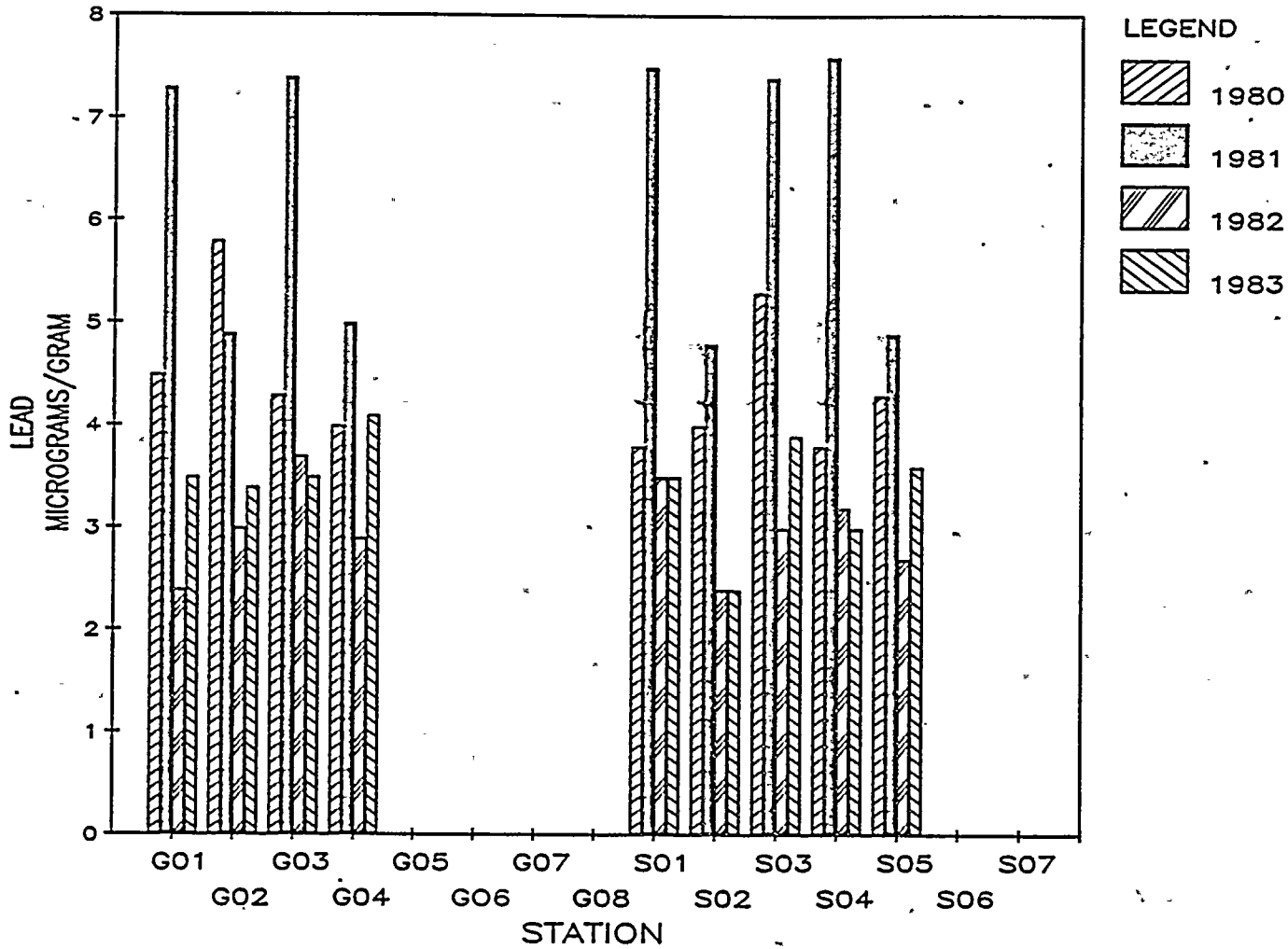


Figure 5-40 Soil Lead for 1980 Through 1983

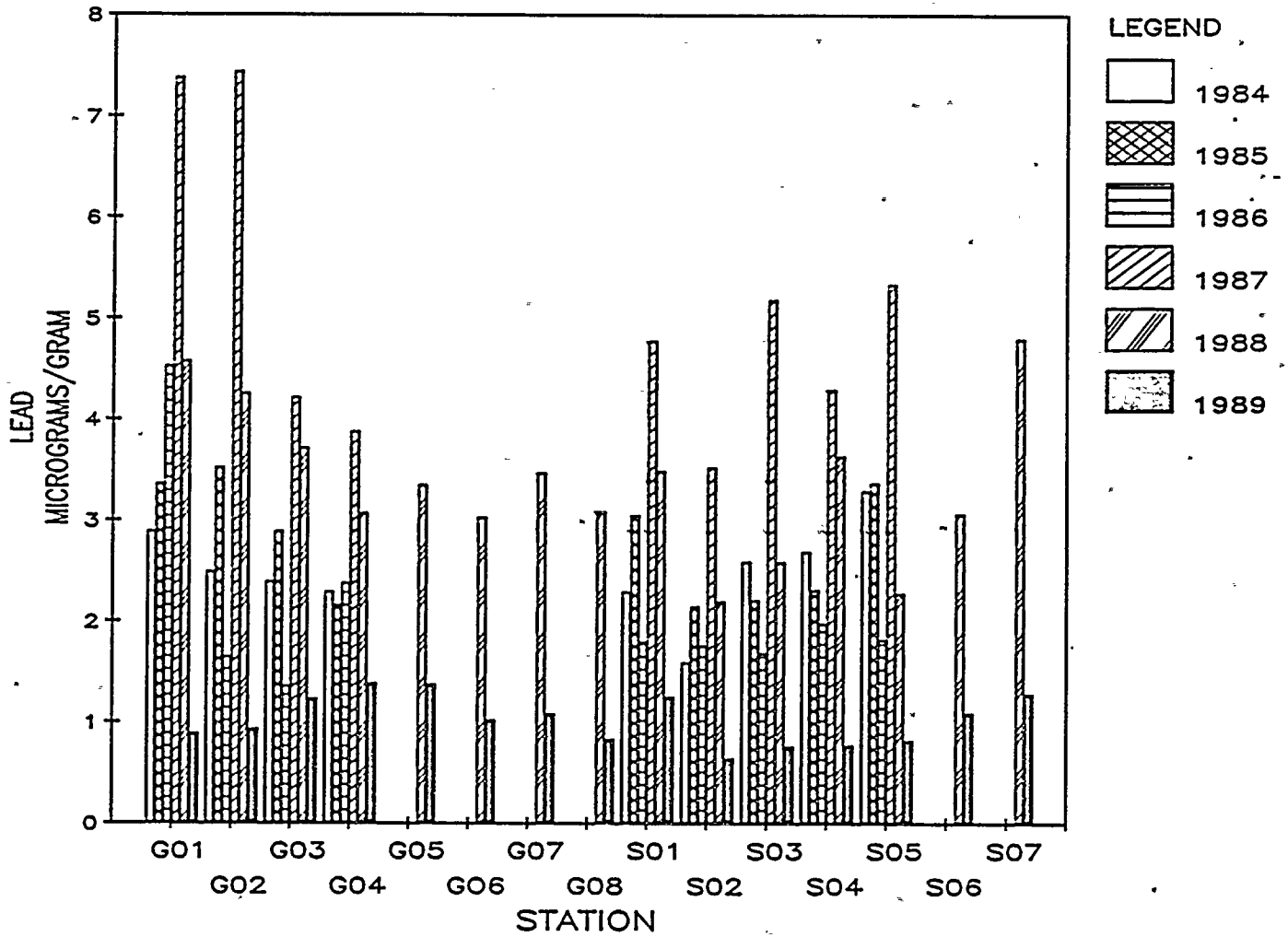


Figure 5-41 Soil Lead for 1984 Through 1989

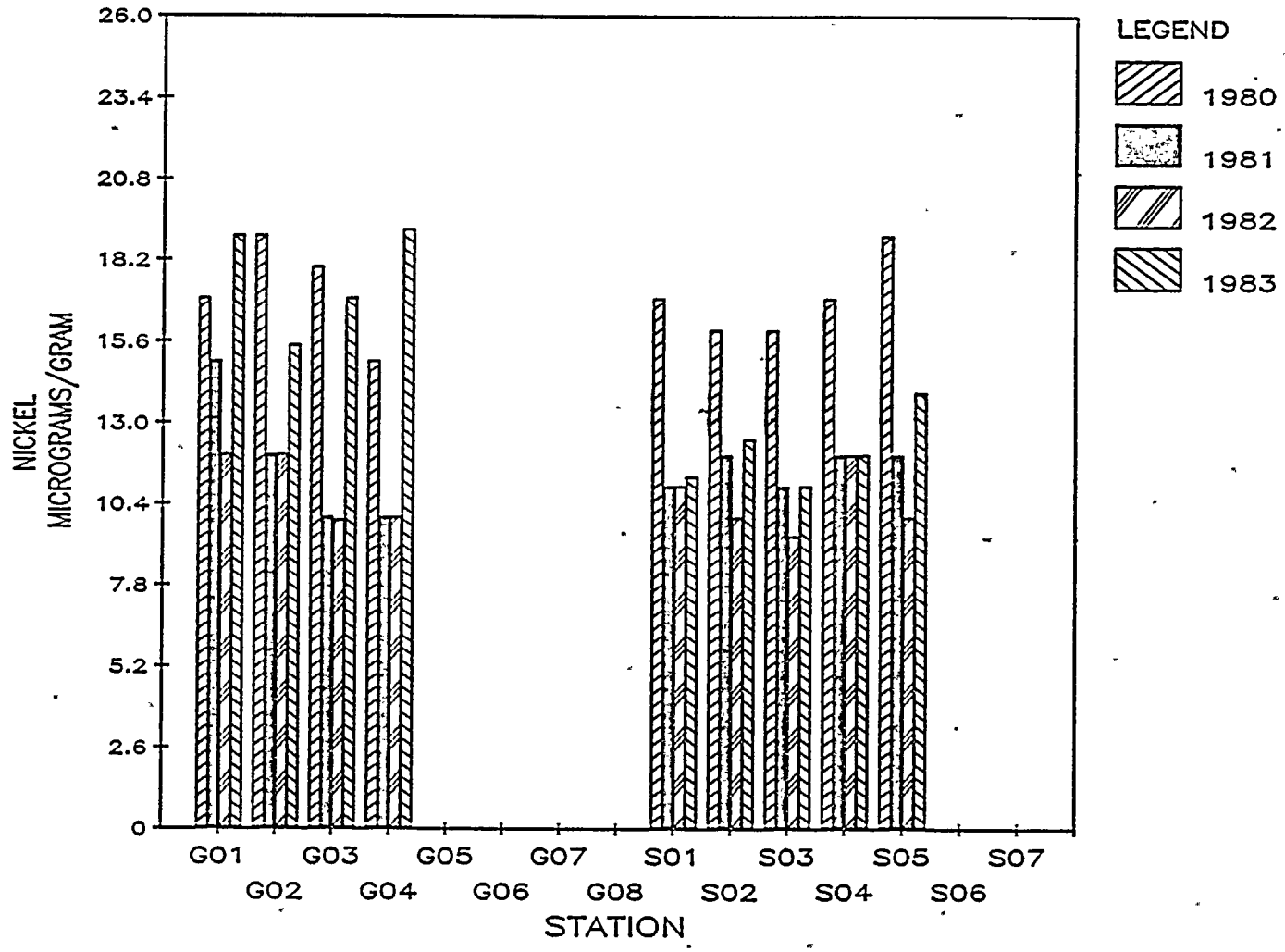


Figure 5-42 Soil Nickel for 1980 Through 1983

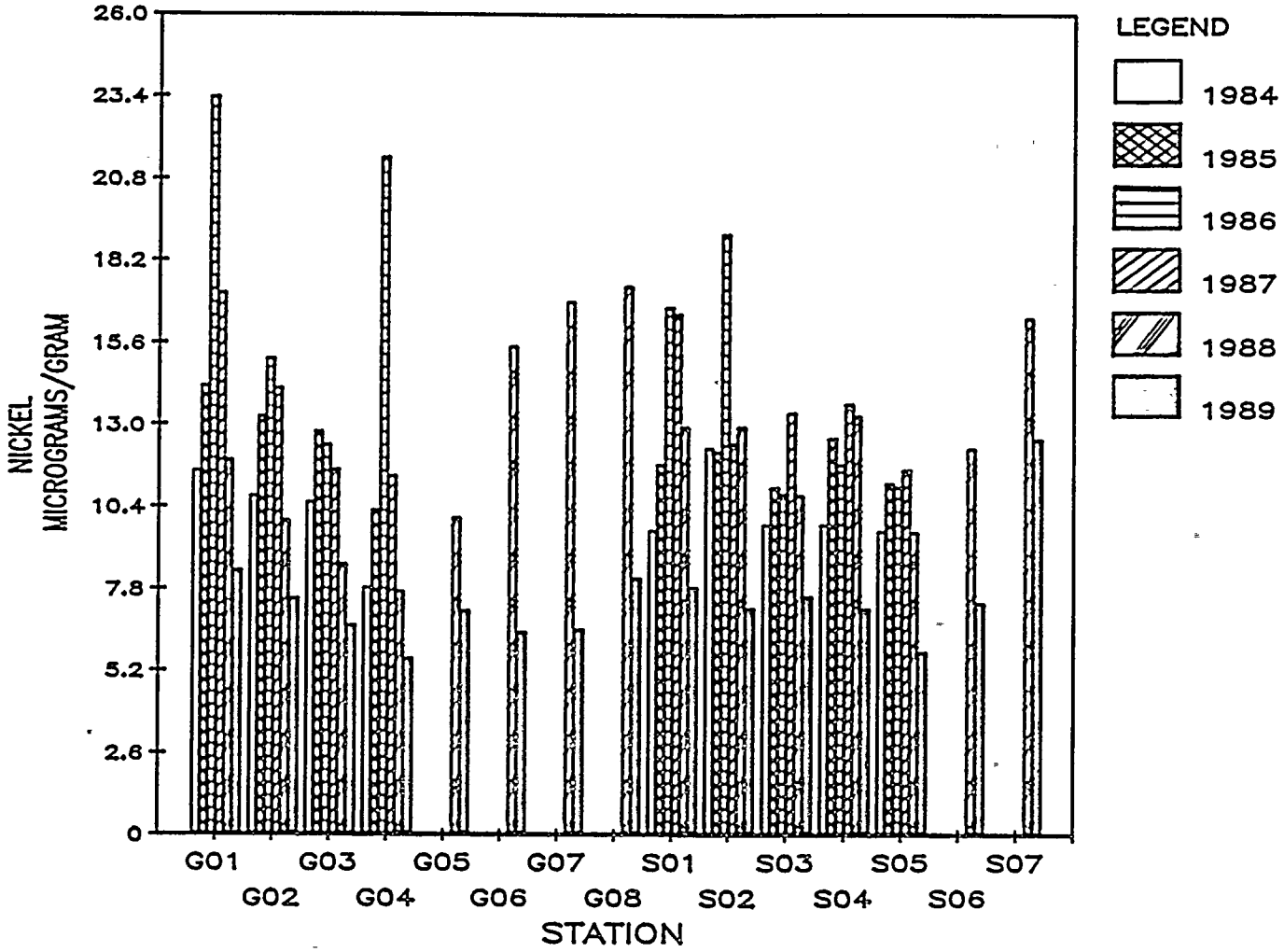


Figure 5-43 Soil Nickel for 1984 Through 1989

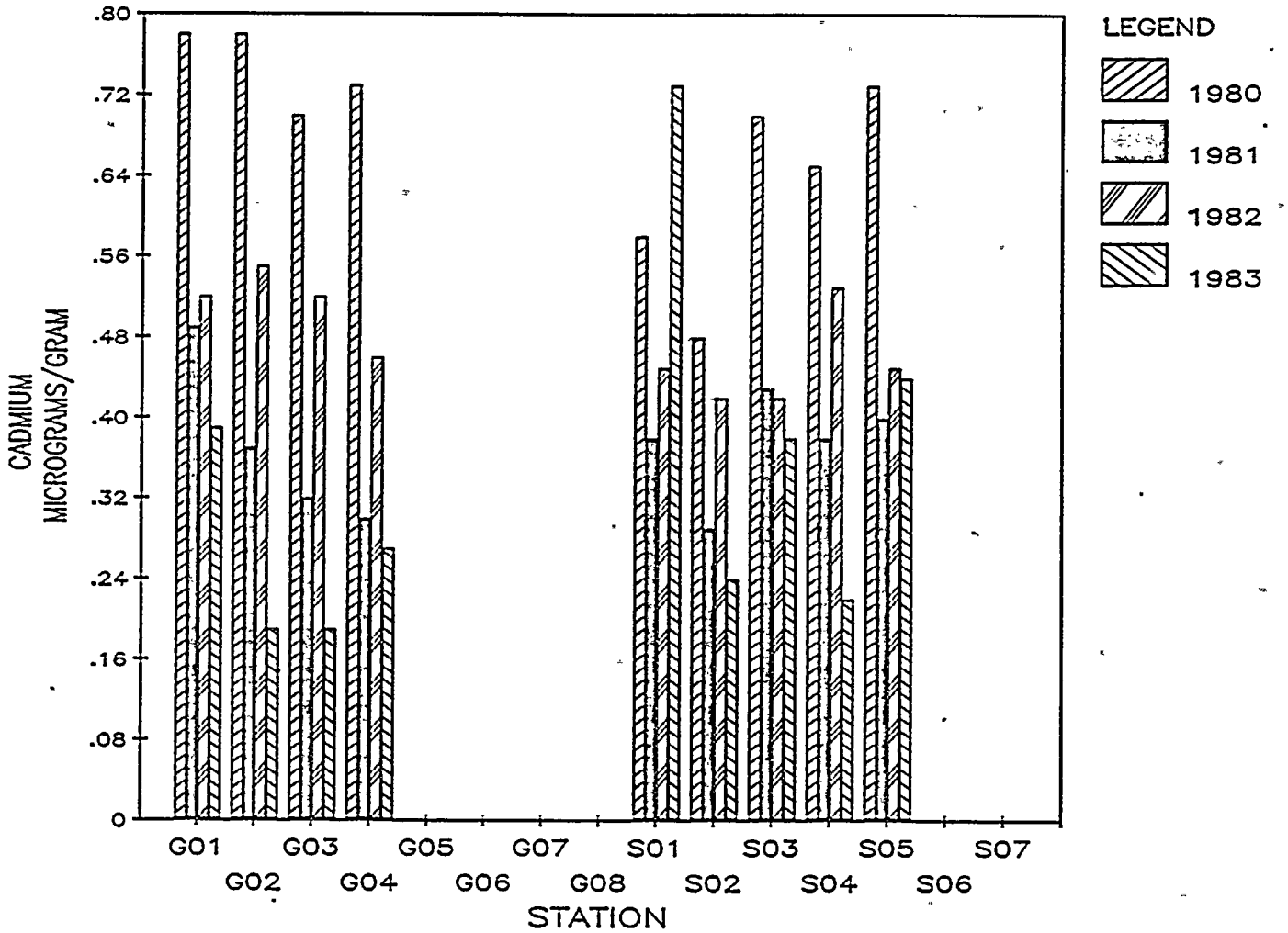


Figure 5-44 Soil Cadmium for 1980 Through 1983

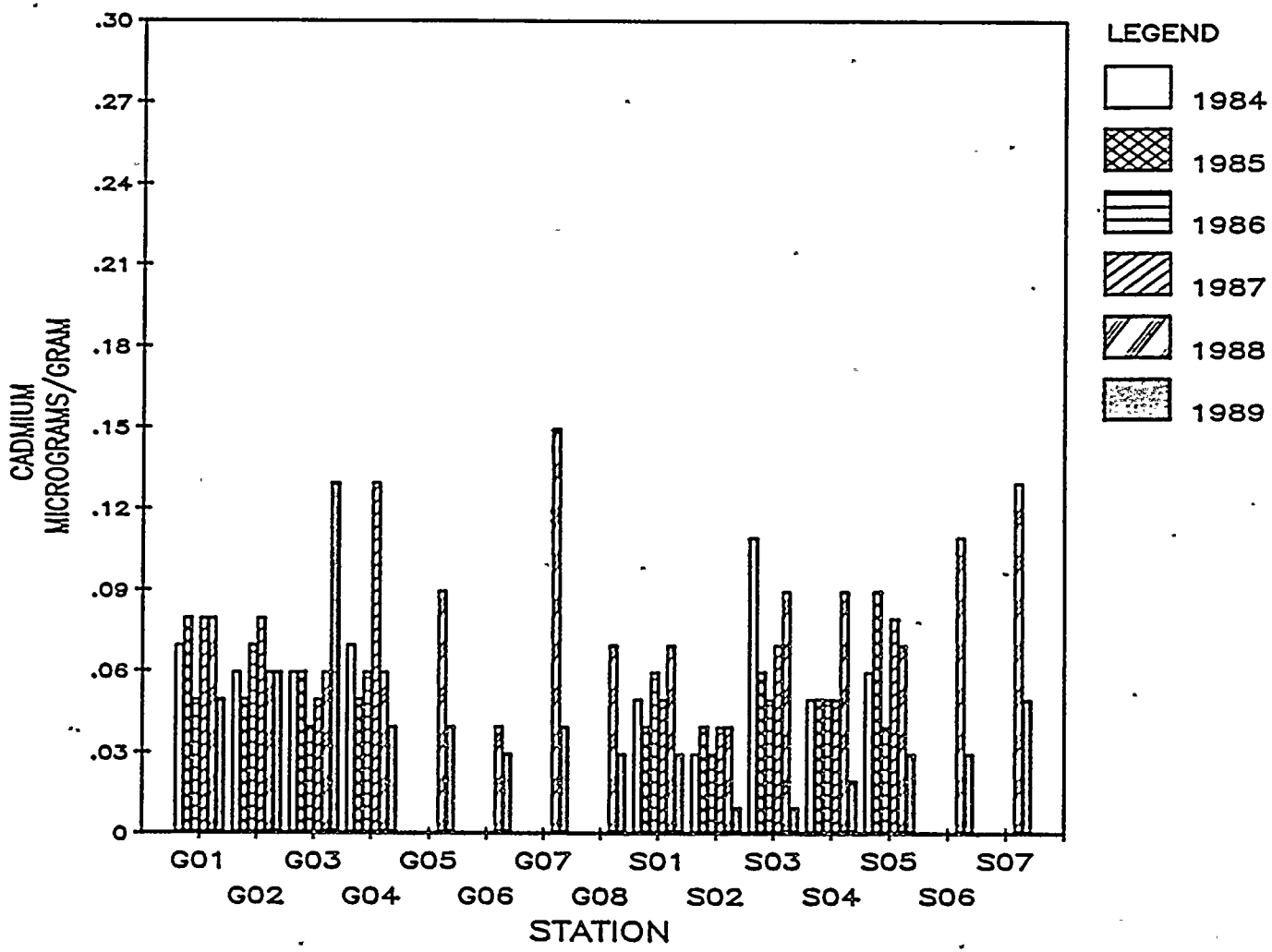


Figure 5-45 Soil Cadmium for 1984 Through 1989

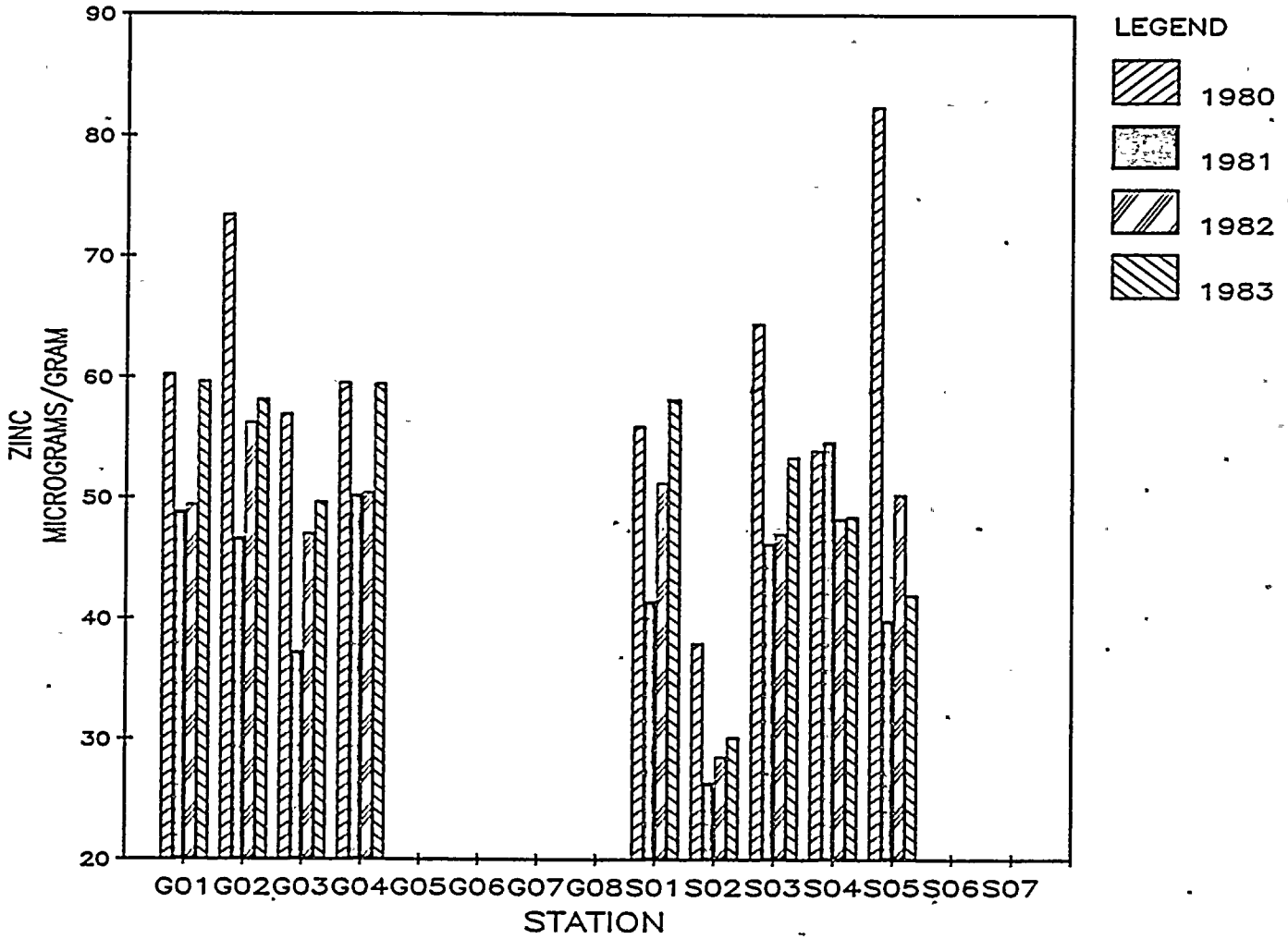


Figure 5-46 Soil Zinc for 1980 Through 1983

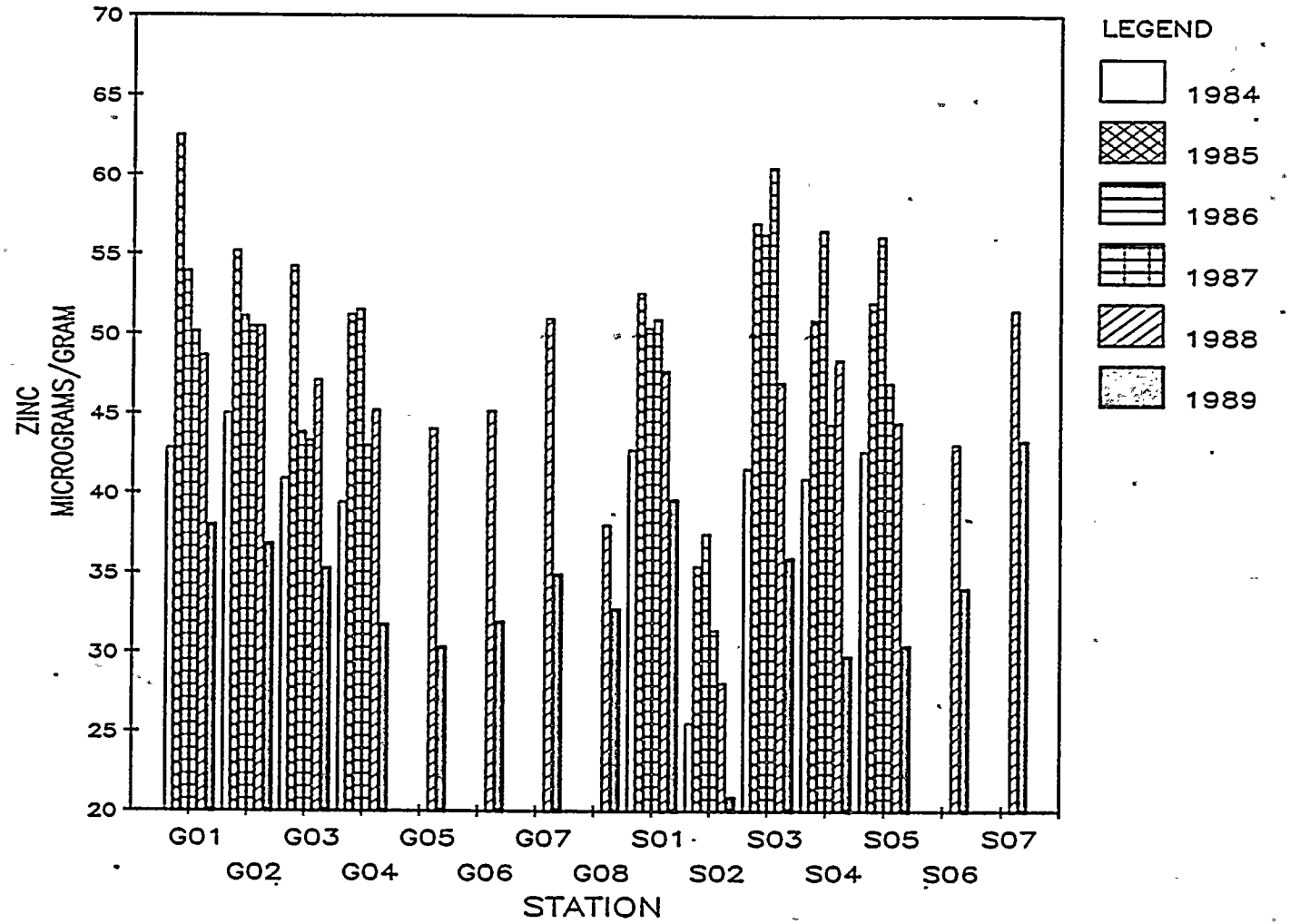


Figure 5-47 Soil Zinc for 1984 Through 1989

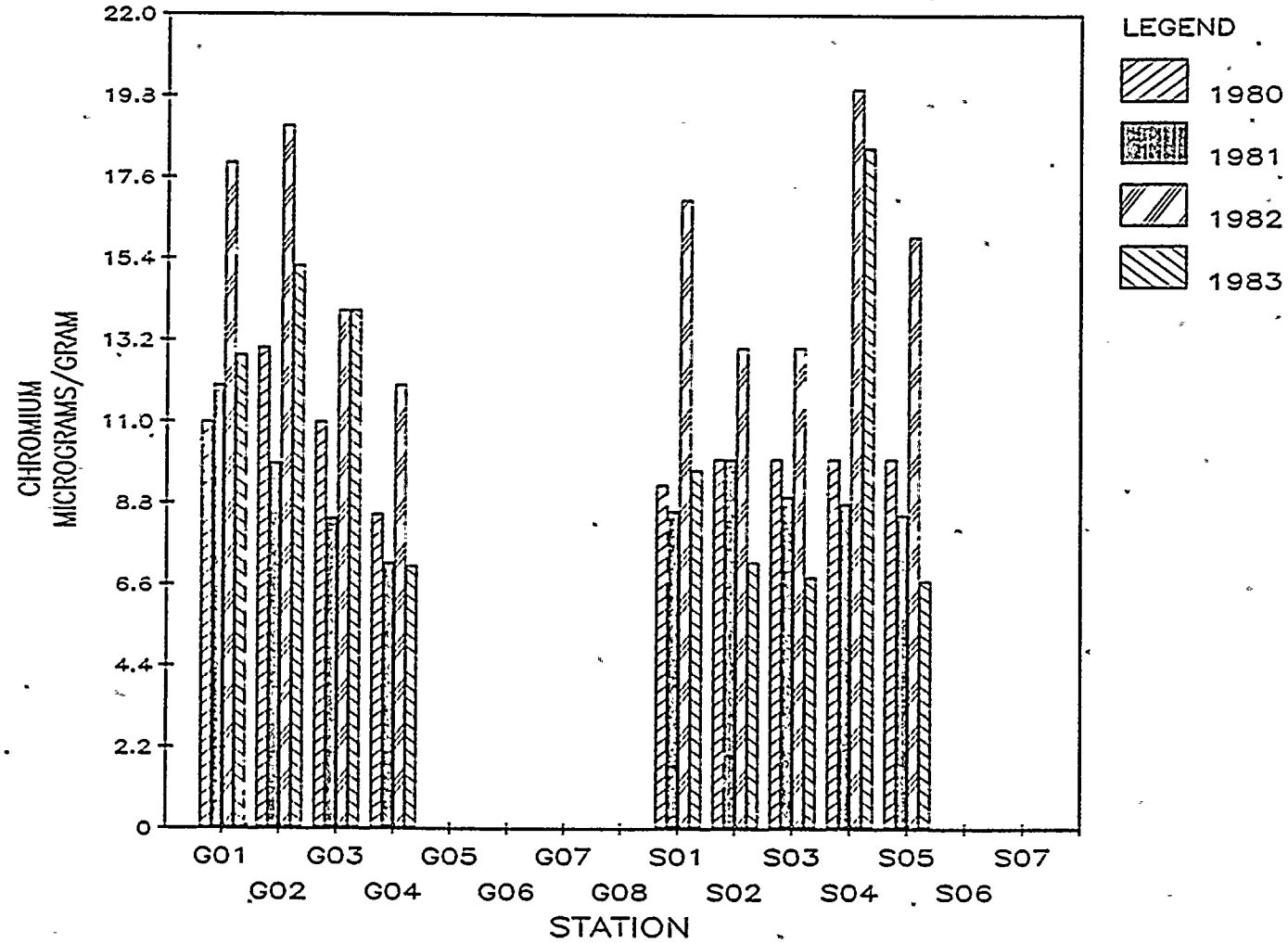
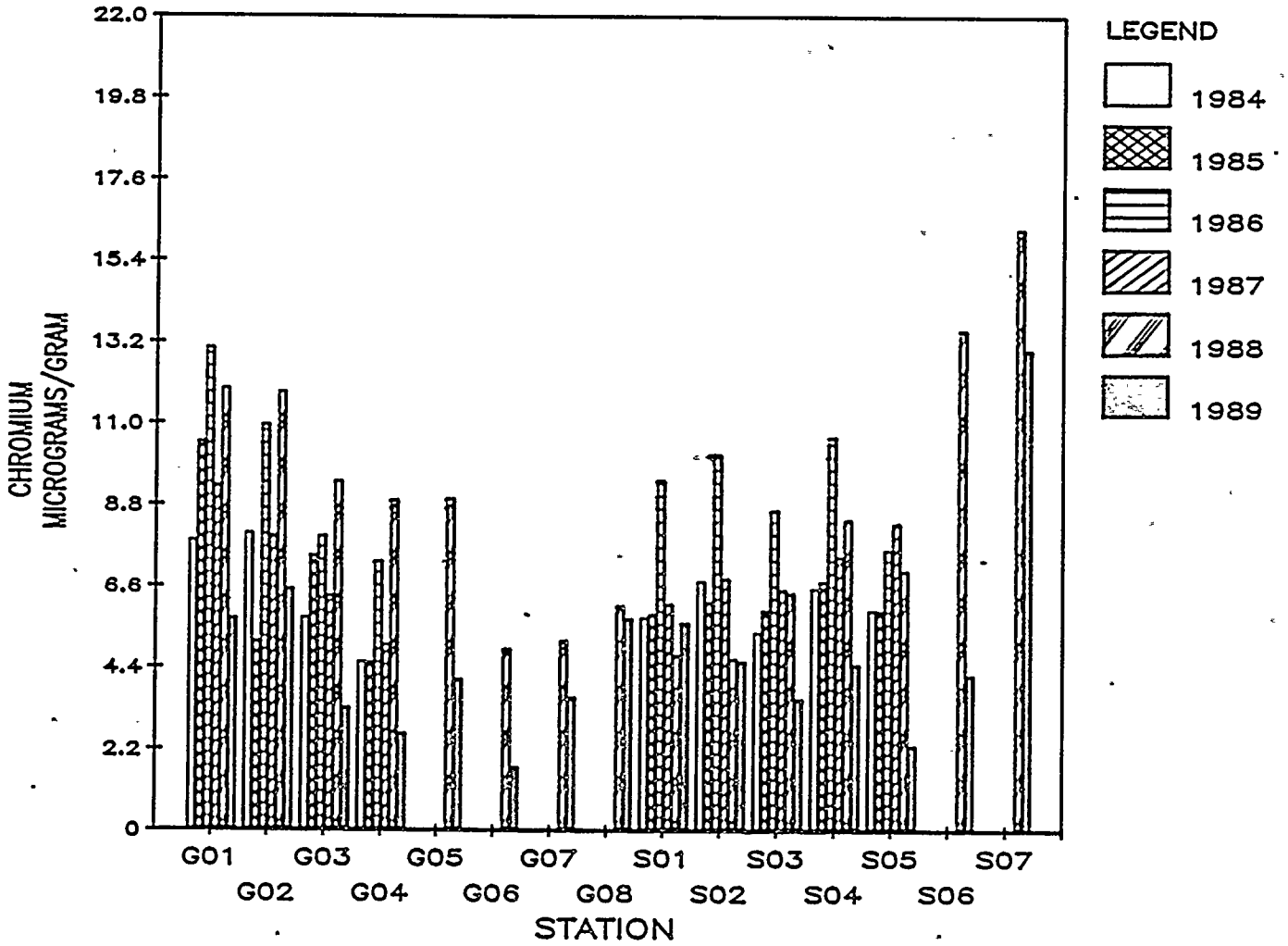


Figure 5-48 Soil Chromium for 1980 Through 1983



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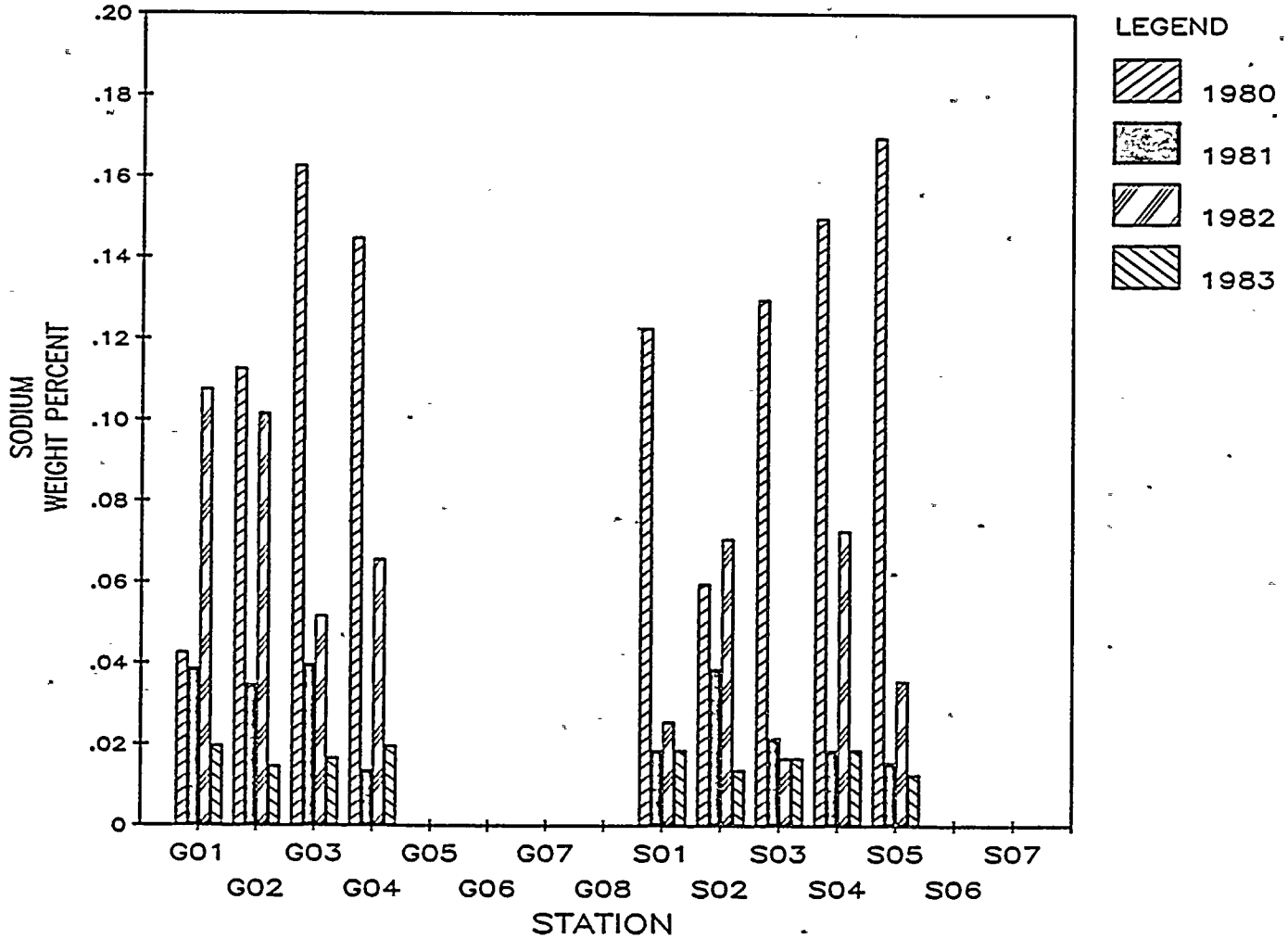

Figure 5-50 Soil Sodium for 1980 Through 1983

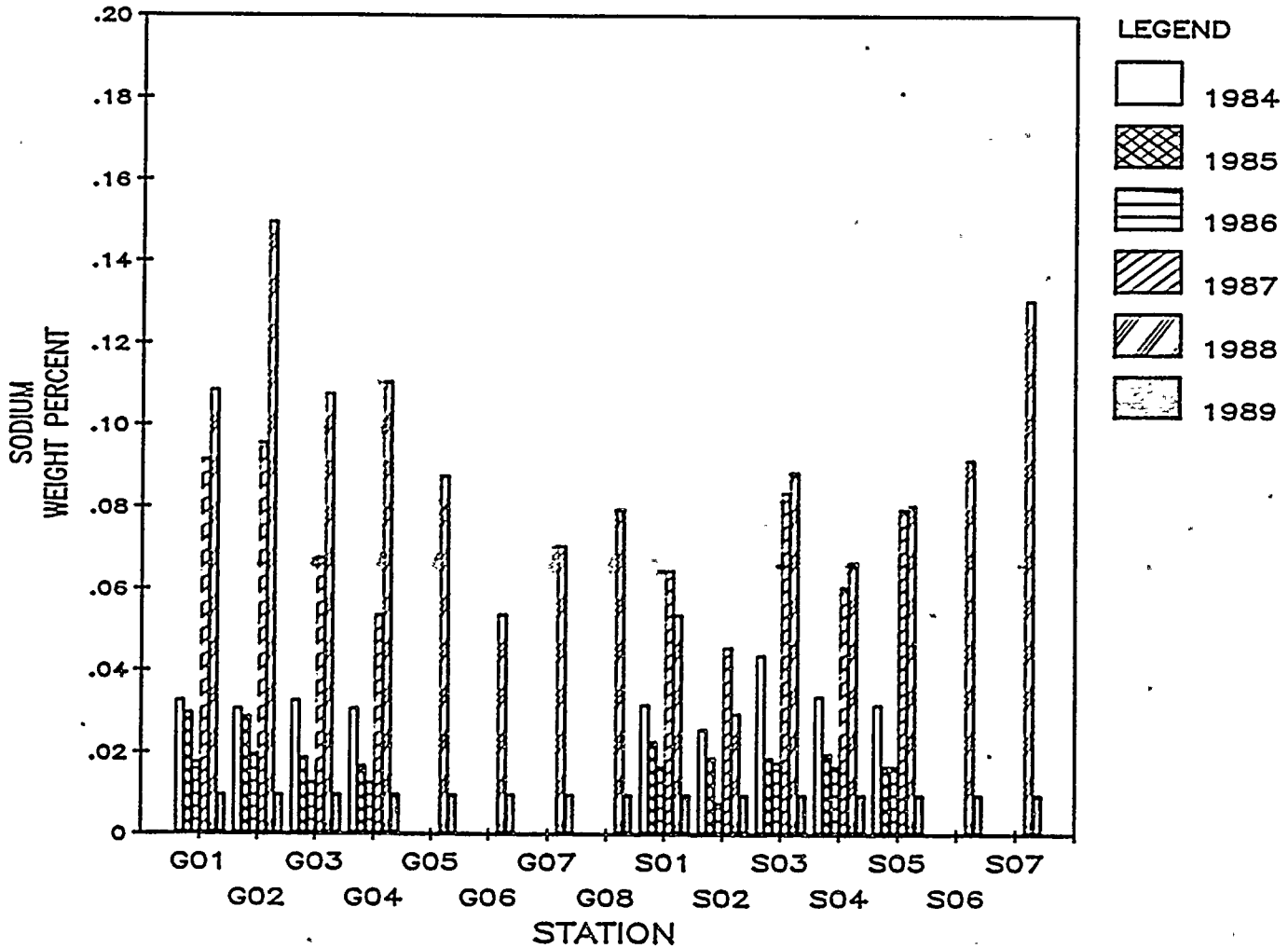

Figure 5-51 Soil Sodium for 1984 Through 1989

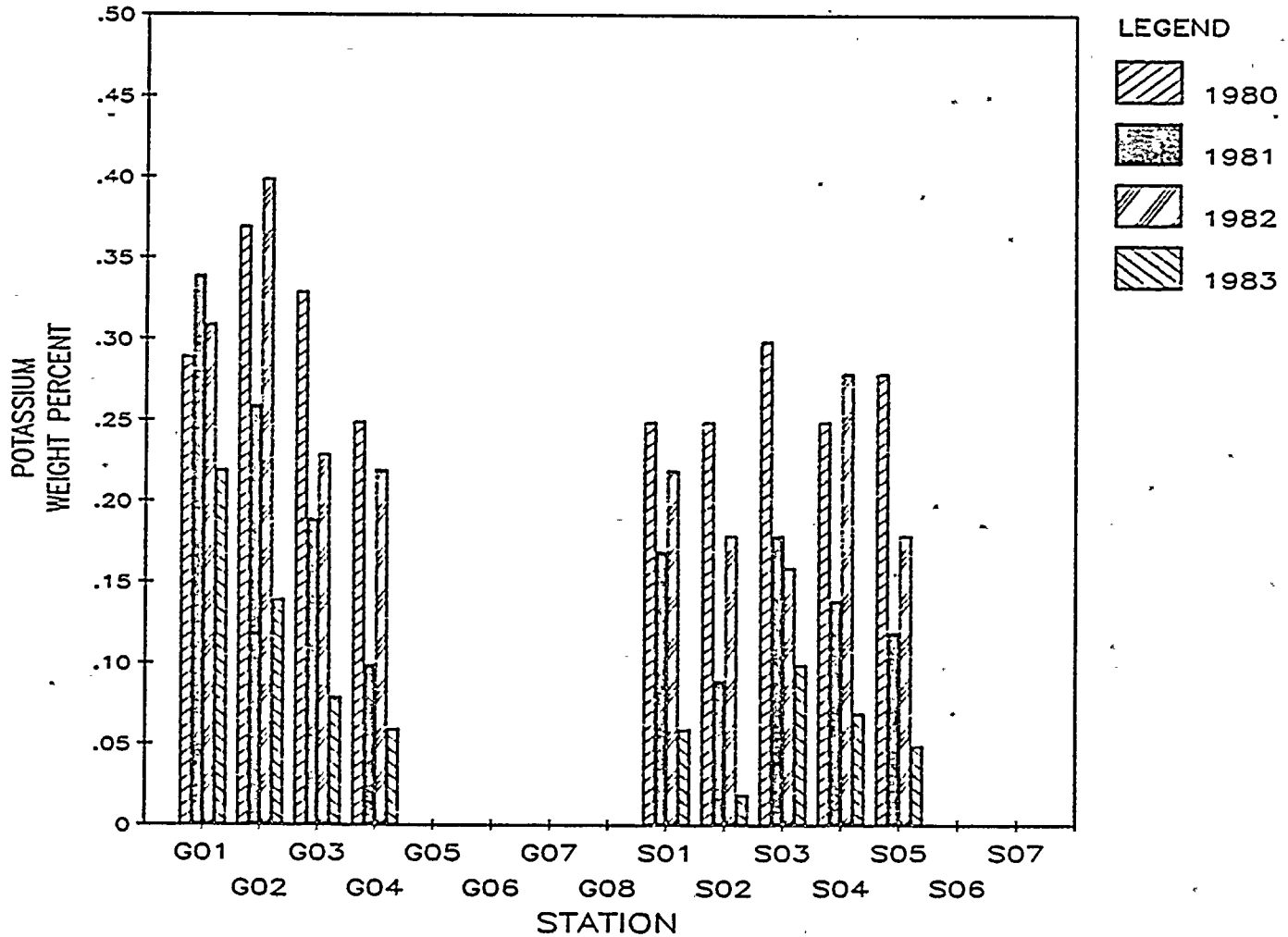

Figure 5-52 Soil Potassium for 1980 Through 1983

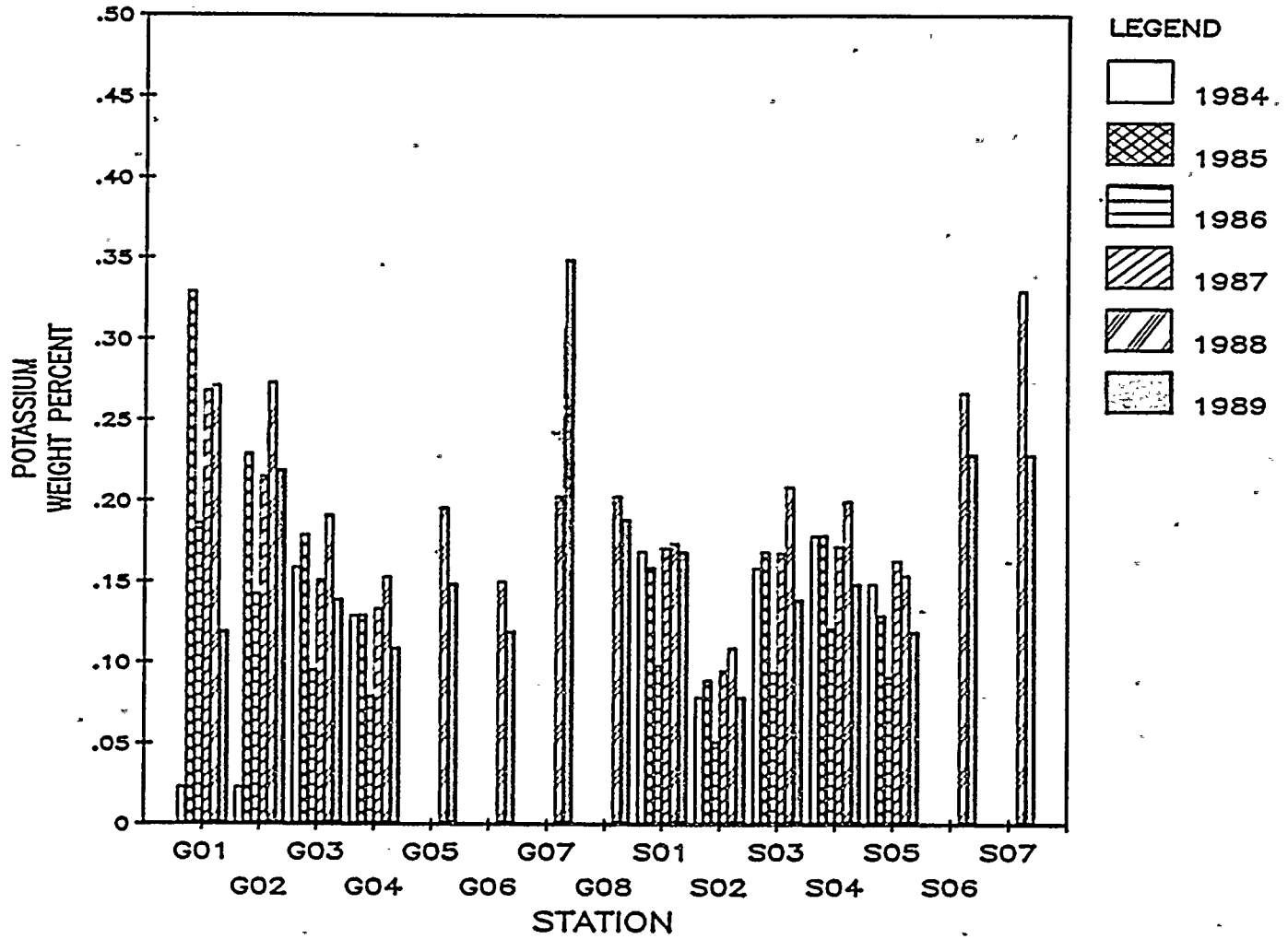

Figure 5-53 Soil Potassium for 1984 Through 1989

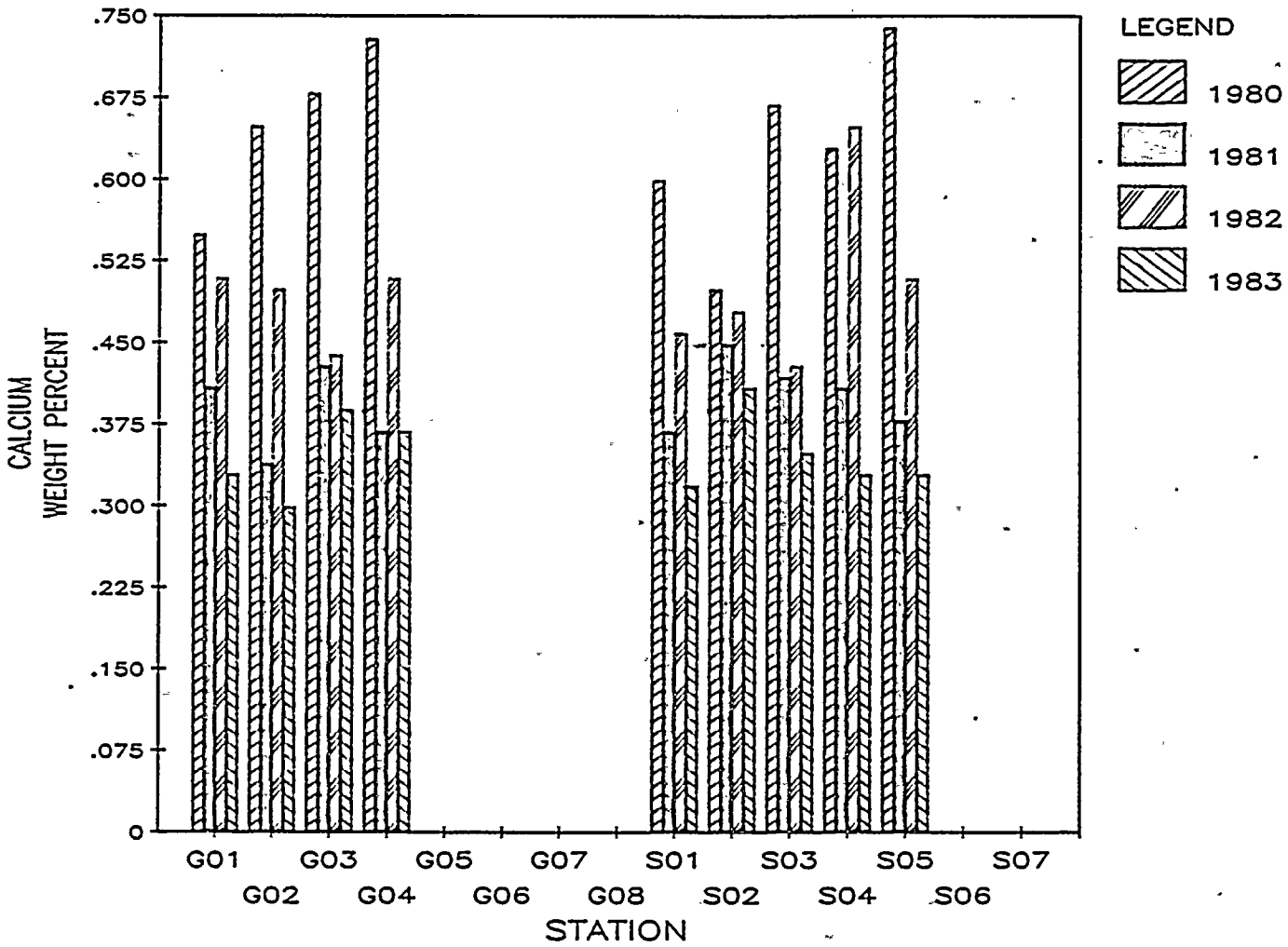

Figure 5-54 Soil Calcium for 1980 Through 1983

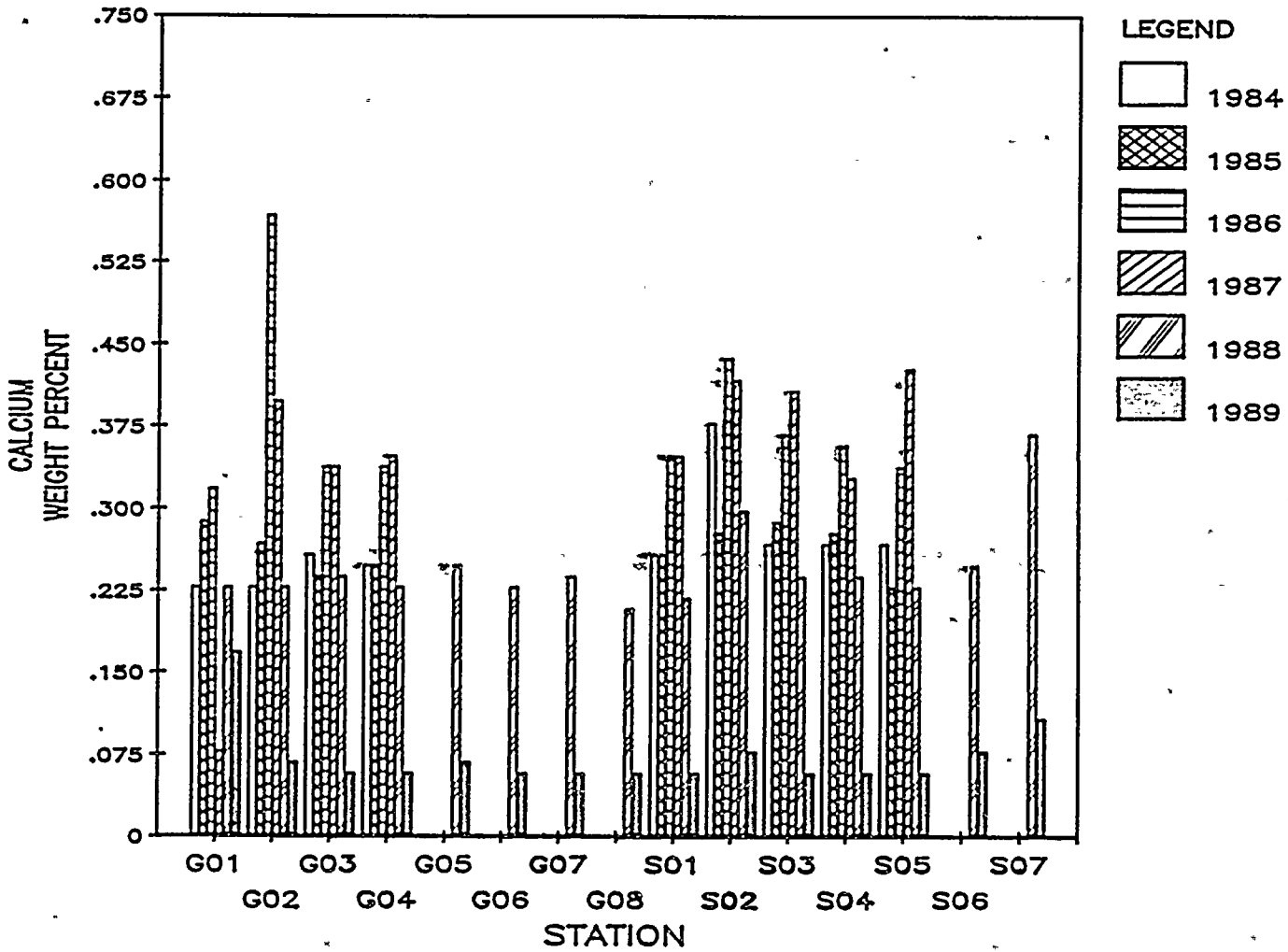

Figure 5-55 Soil Calcium for 1984 Through 1989

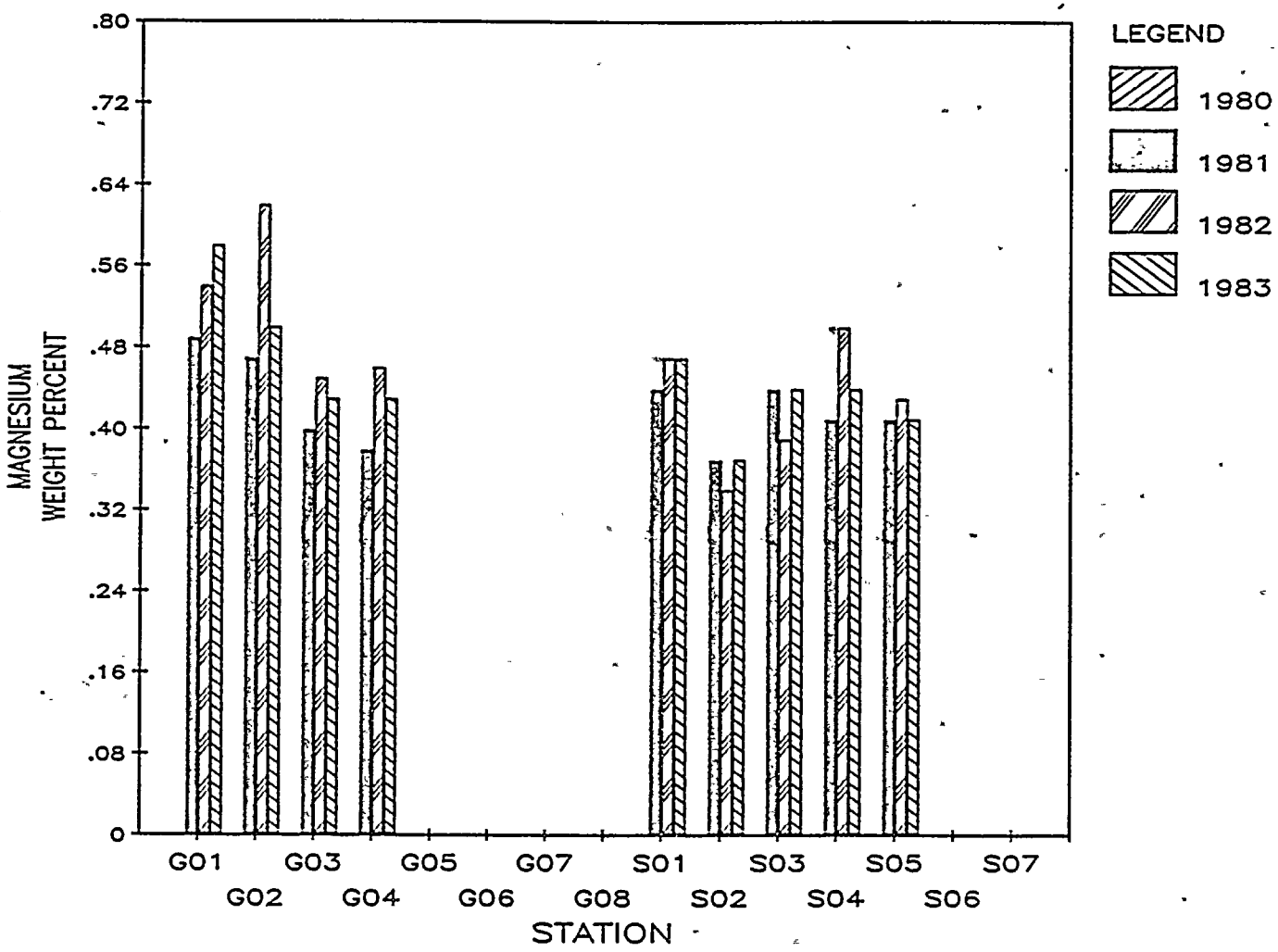

Figure 5-56 Soil Magnesium for 1980 Through 1983

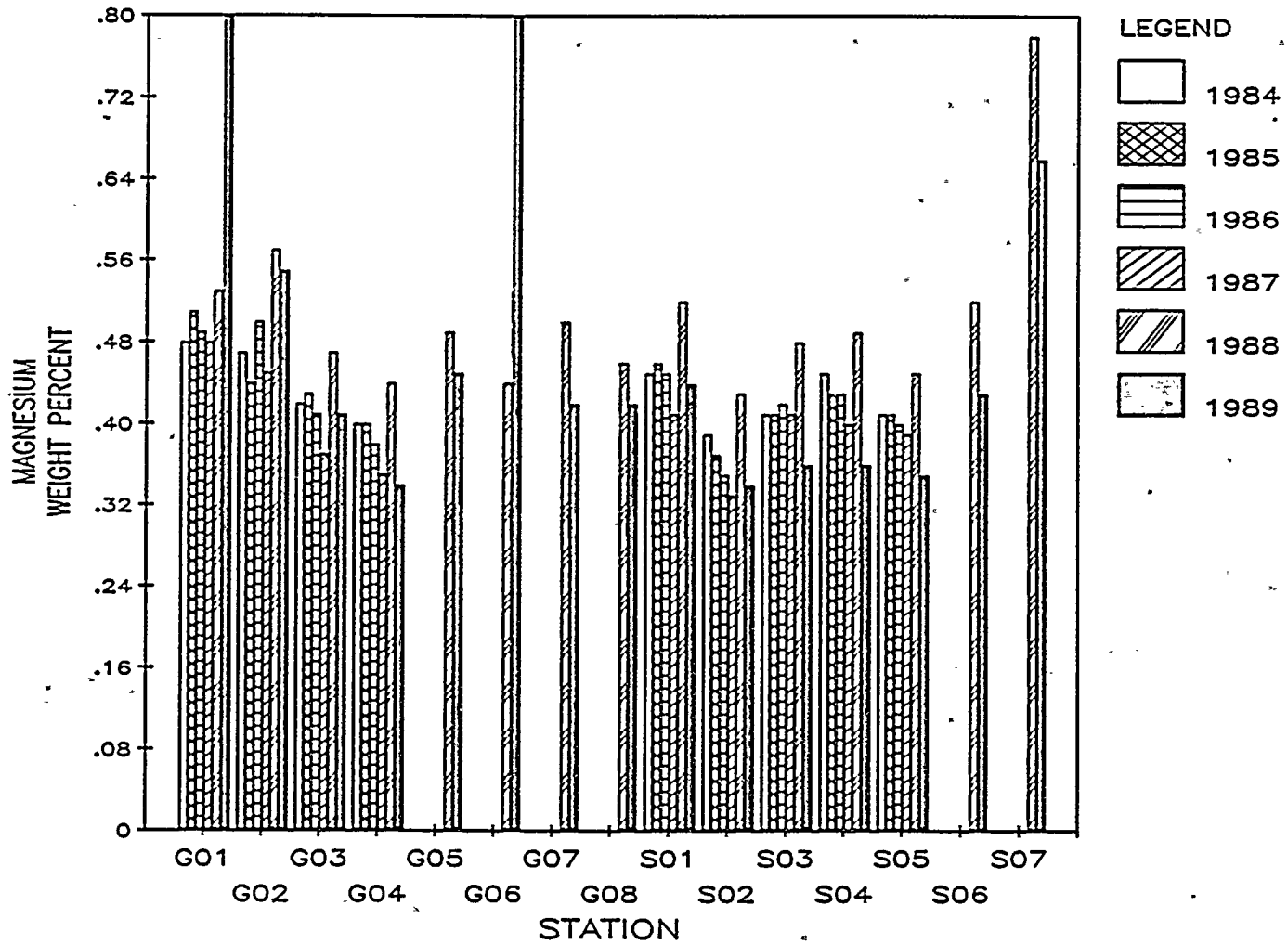

Figure 5-57 Soil Magnesium for 1984 Through 1989

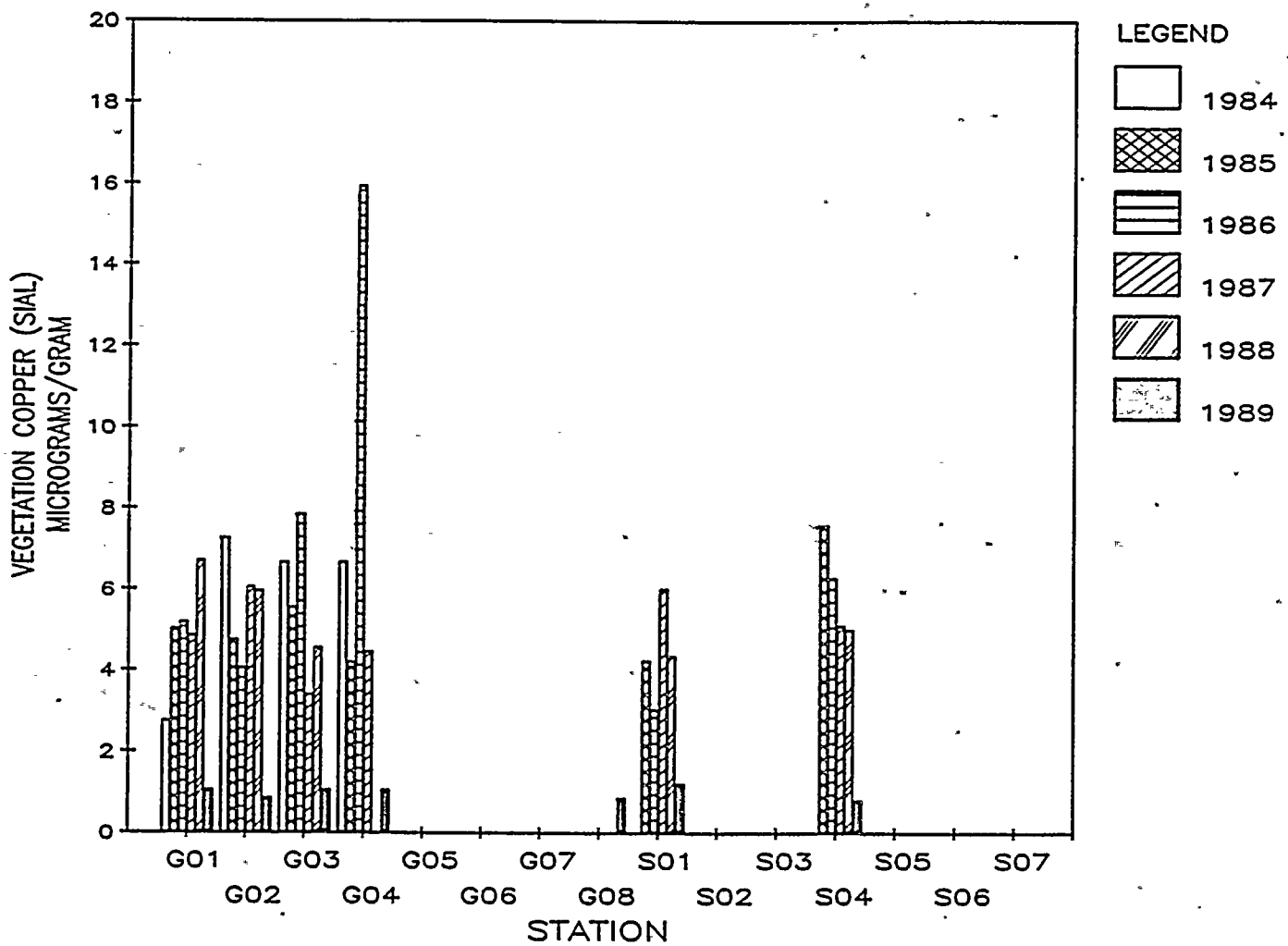

Figure 5-58 Copper Concentration (ug/g) in Sisymbrium altissimum by Station for 1984 Through 1989

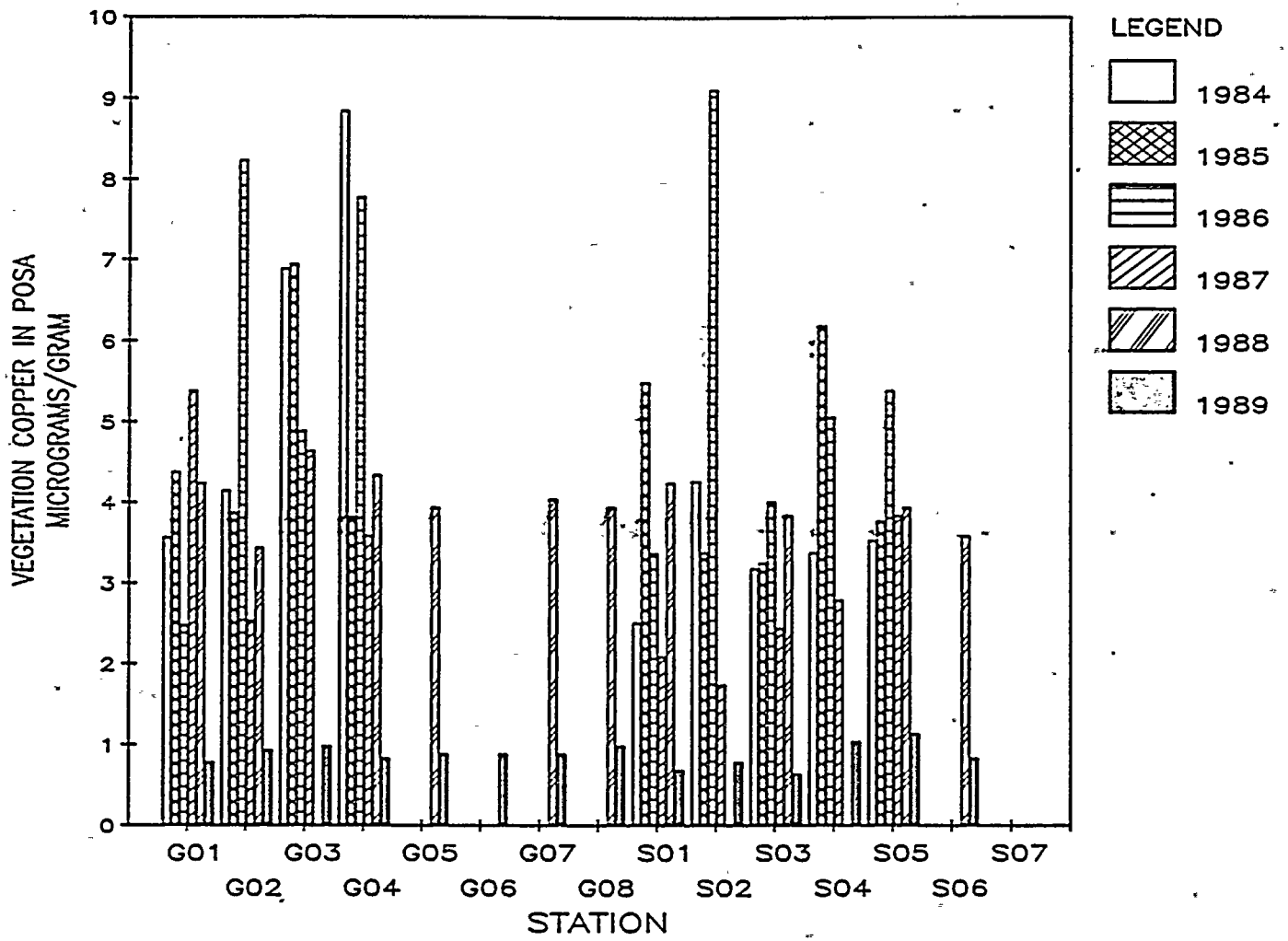

Figure 5-59 Copper Concentration (ug/g) in Poa sandbergii by Station for 1984 Through 1989

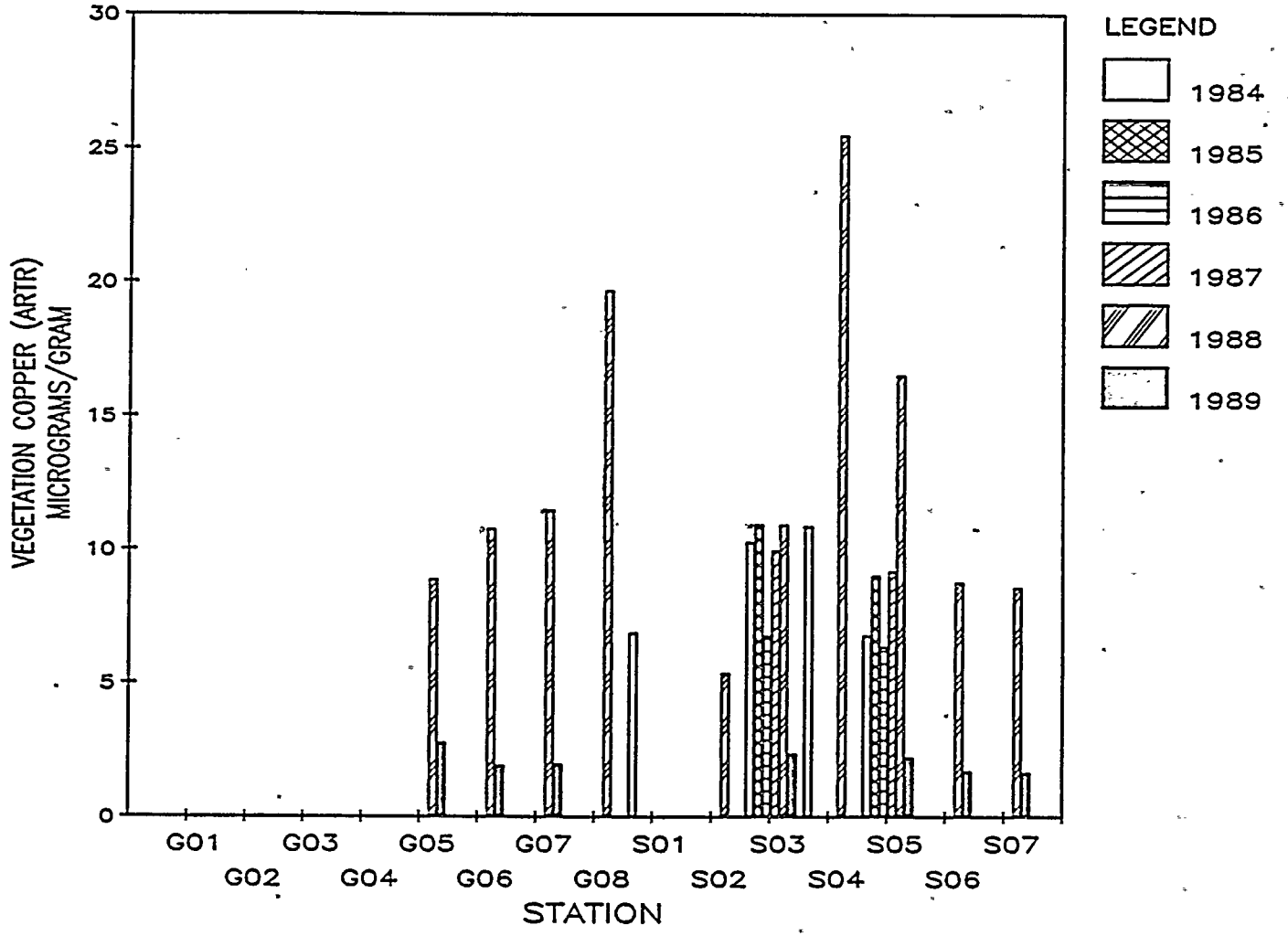

Figure 5-60 Copper Concentration (ug/g) in *Artemisia tridentata* by Station for 1984 Through 1989

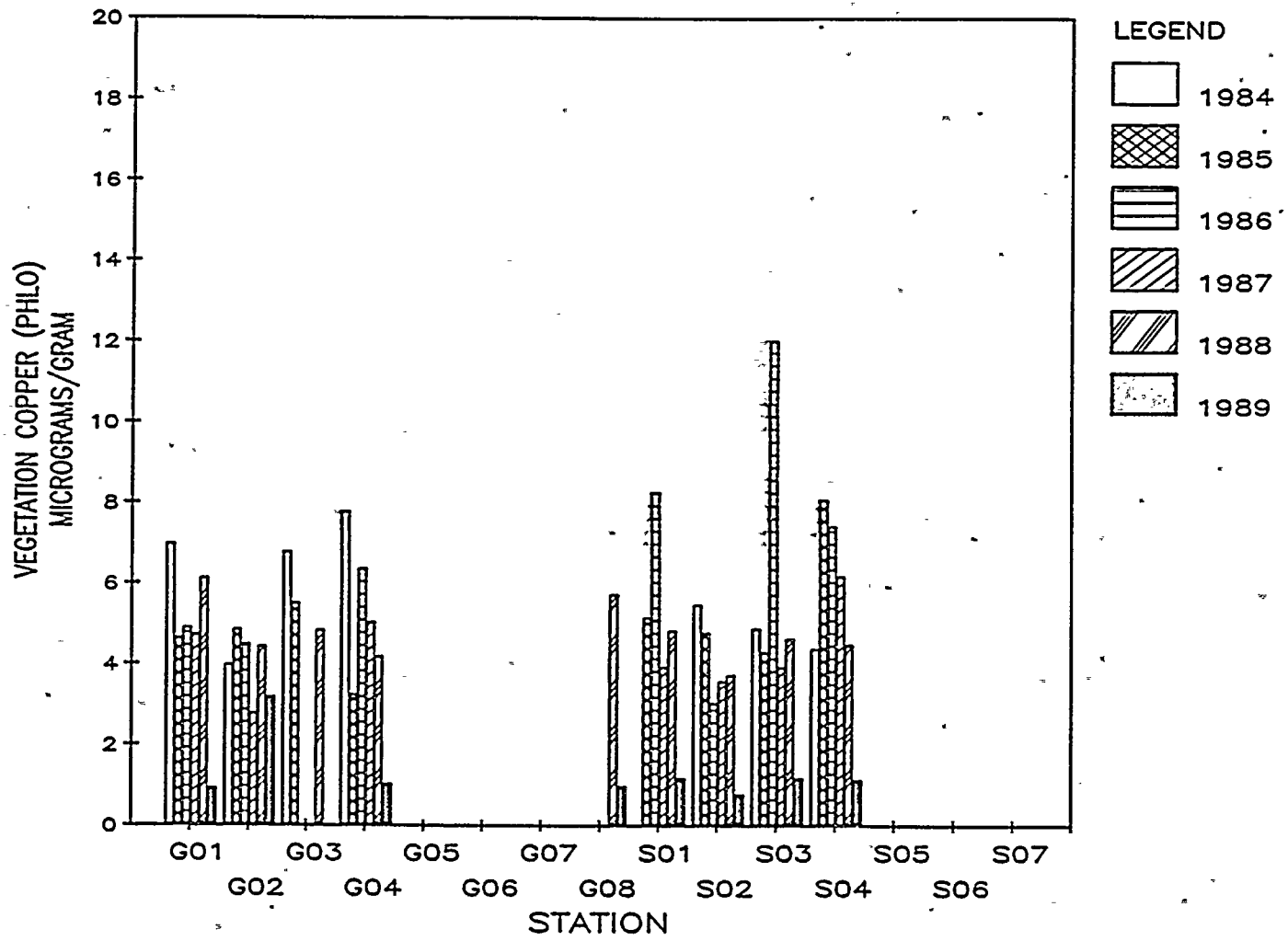

Figure 5-62 Copper Concentration (ug/g) in Phlox longifolia by Station for 1984 Through 1989

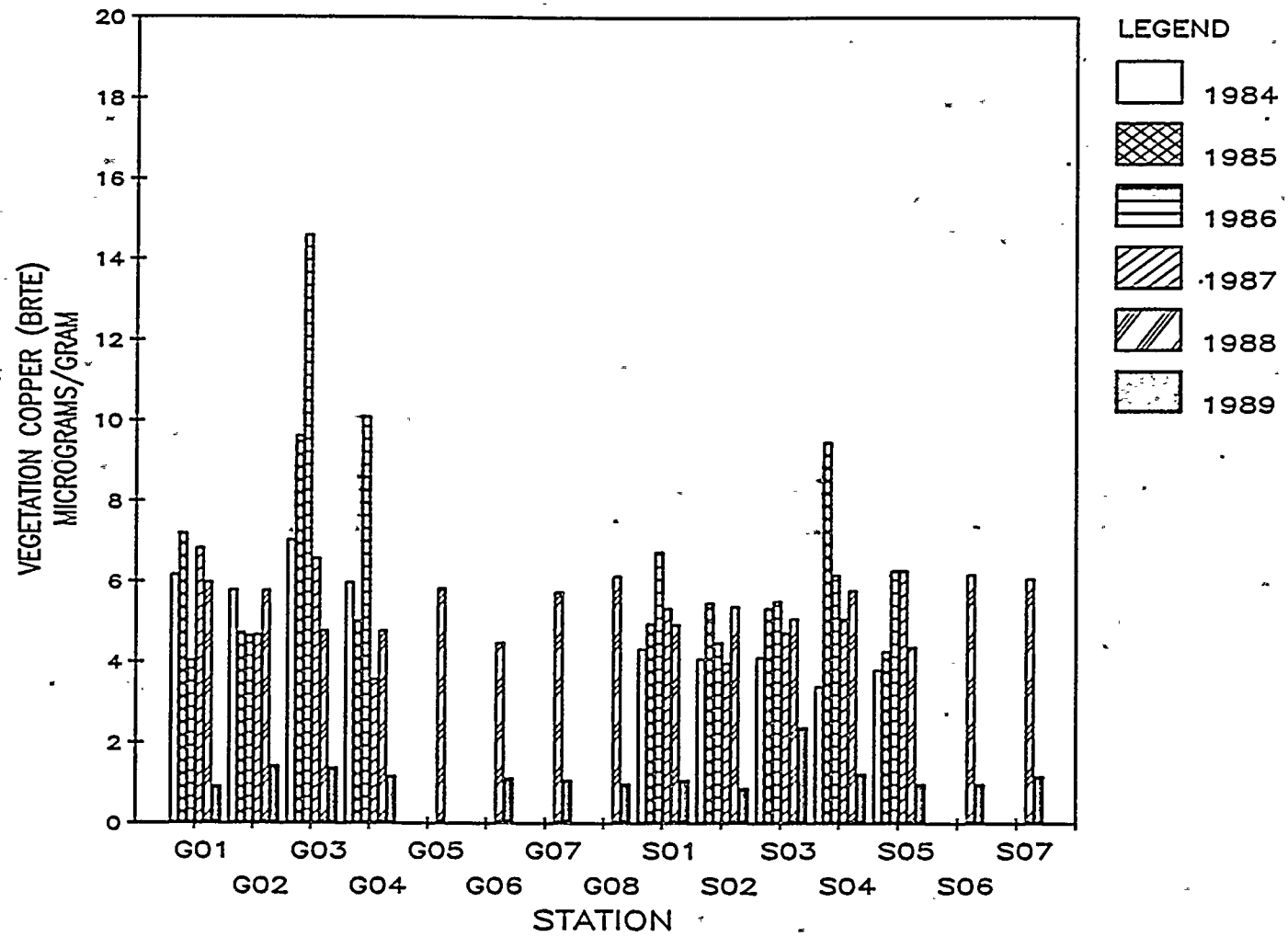

Figure 5-63 Copper Concentration (ug/g) in Bromus tectorum by Station for 1984 Through 1989

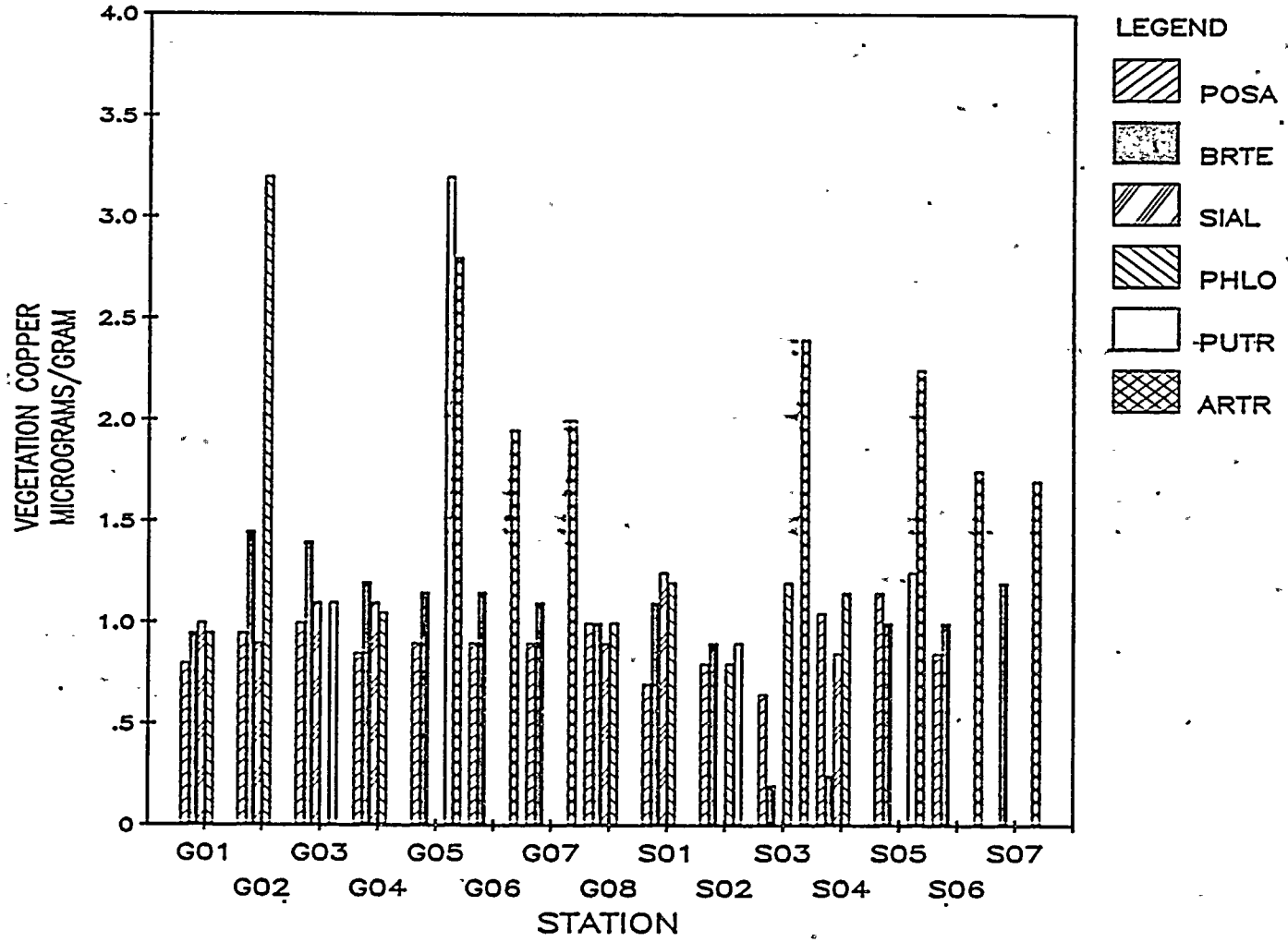

Figure 5-64 Total Vegetation Copper for May 1989

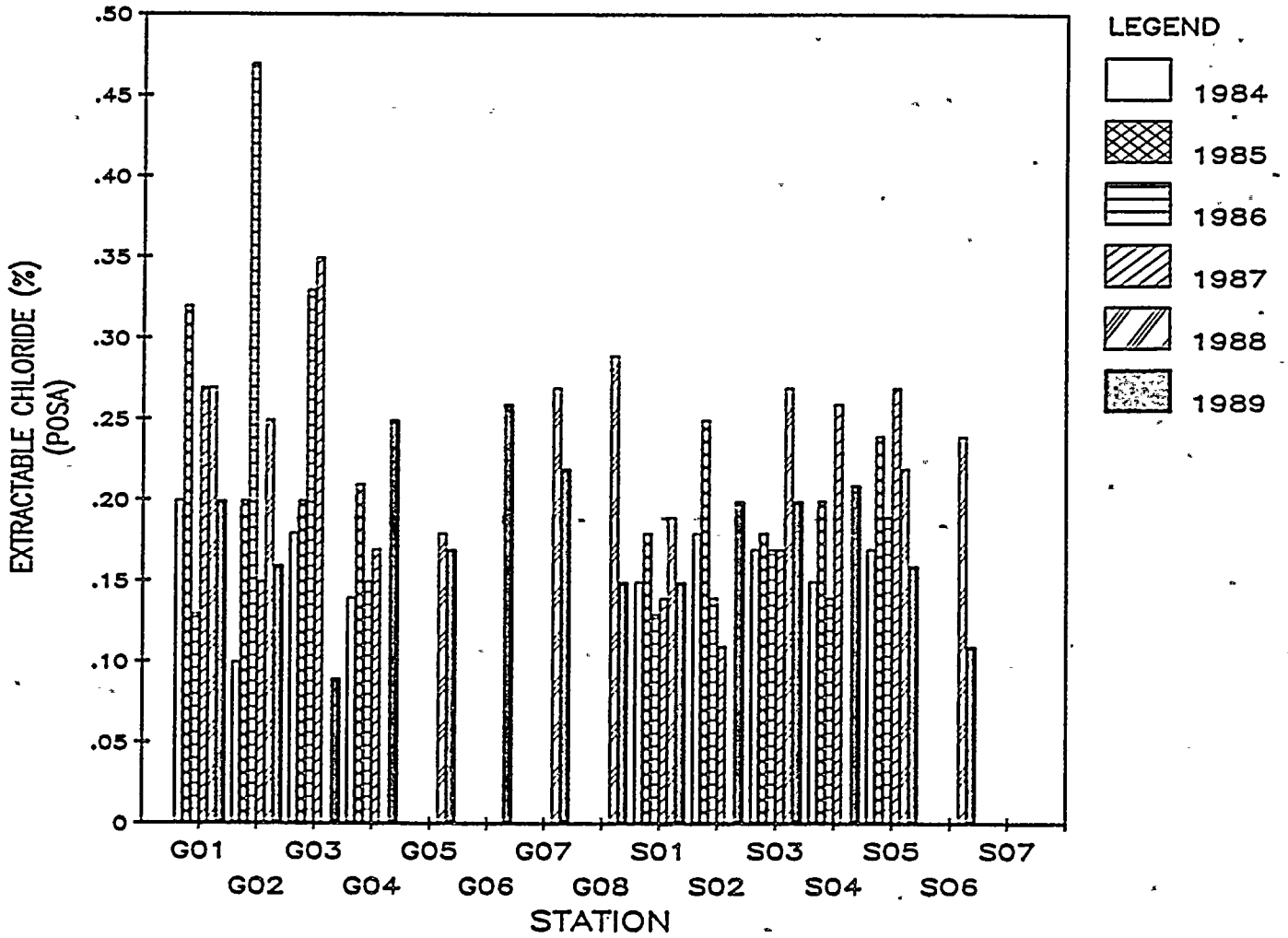

Figure 5-65 Chloride Concentration (%) in Poa sandbergii by Station for 1984 Through 1989

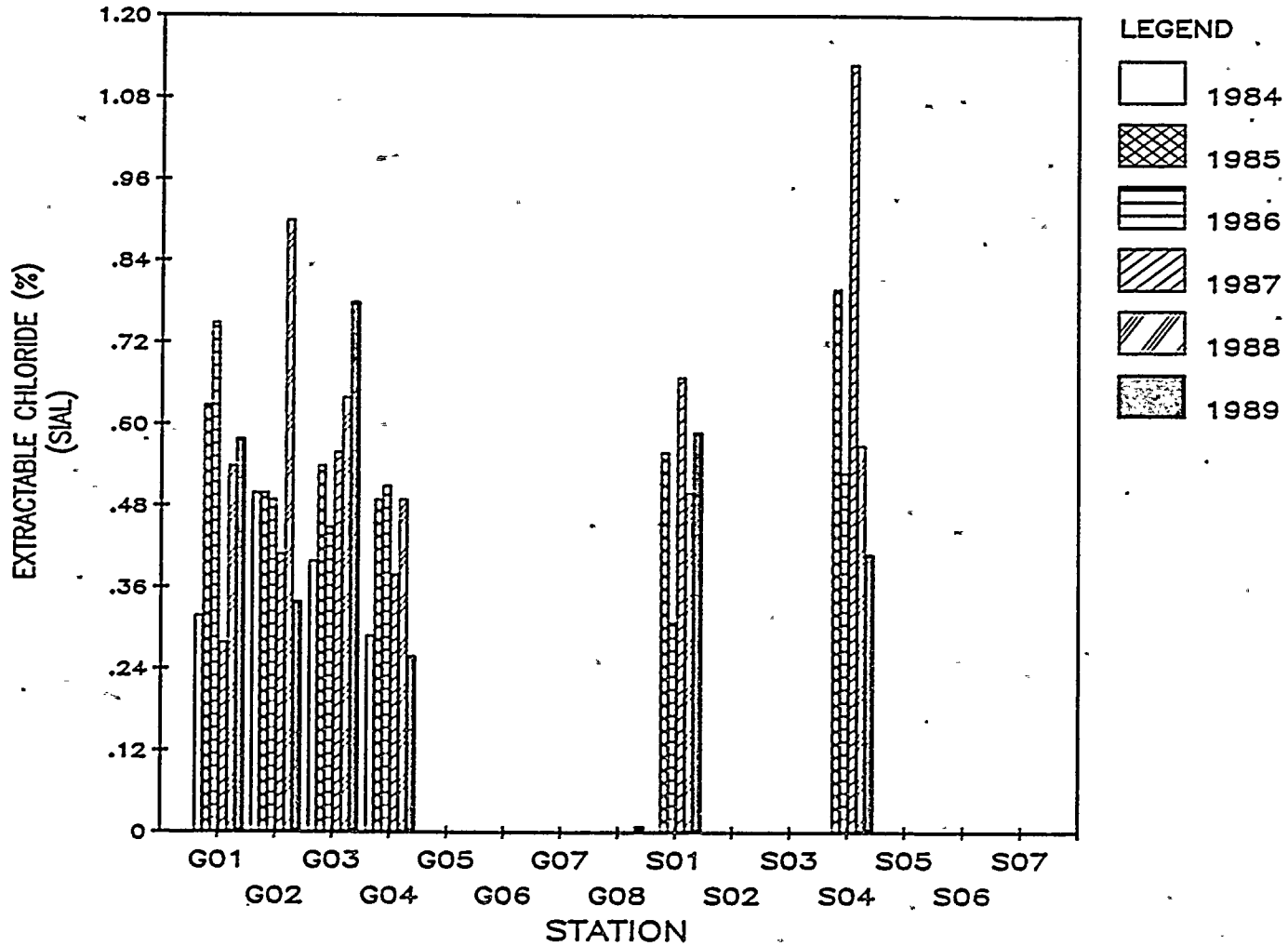

Figure 5-66 Chloride Concentration (%) in Sisymbrium altissimum by Station for 1984 Through 1989

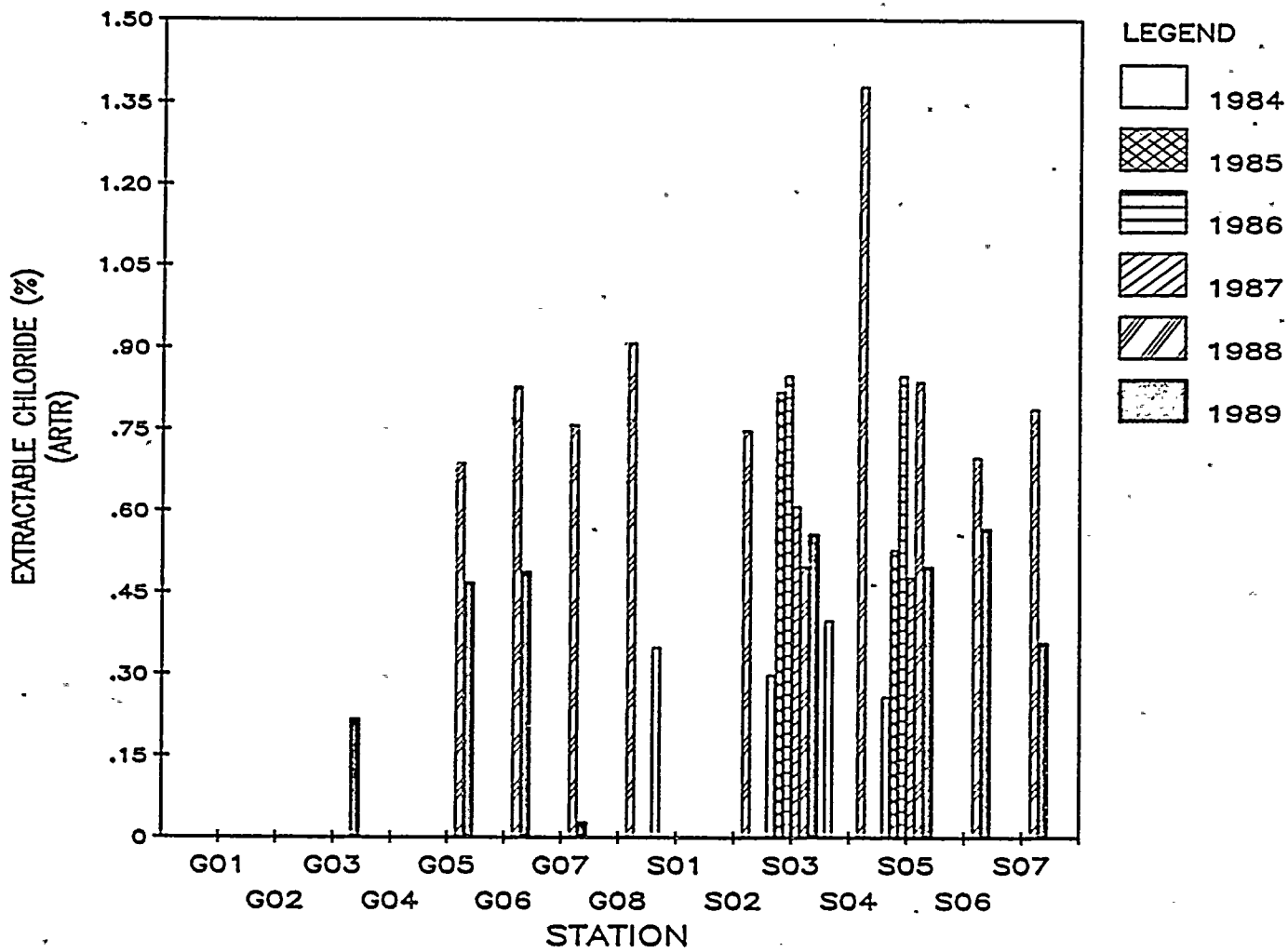

Figure 5-67 Chloride Concentration (%) in *Artemisia tridentata* by Station for 1984 Through 1989

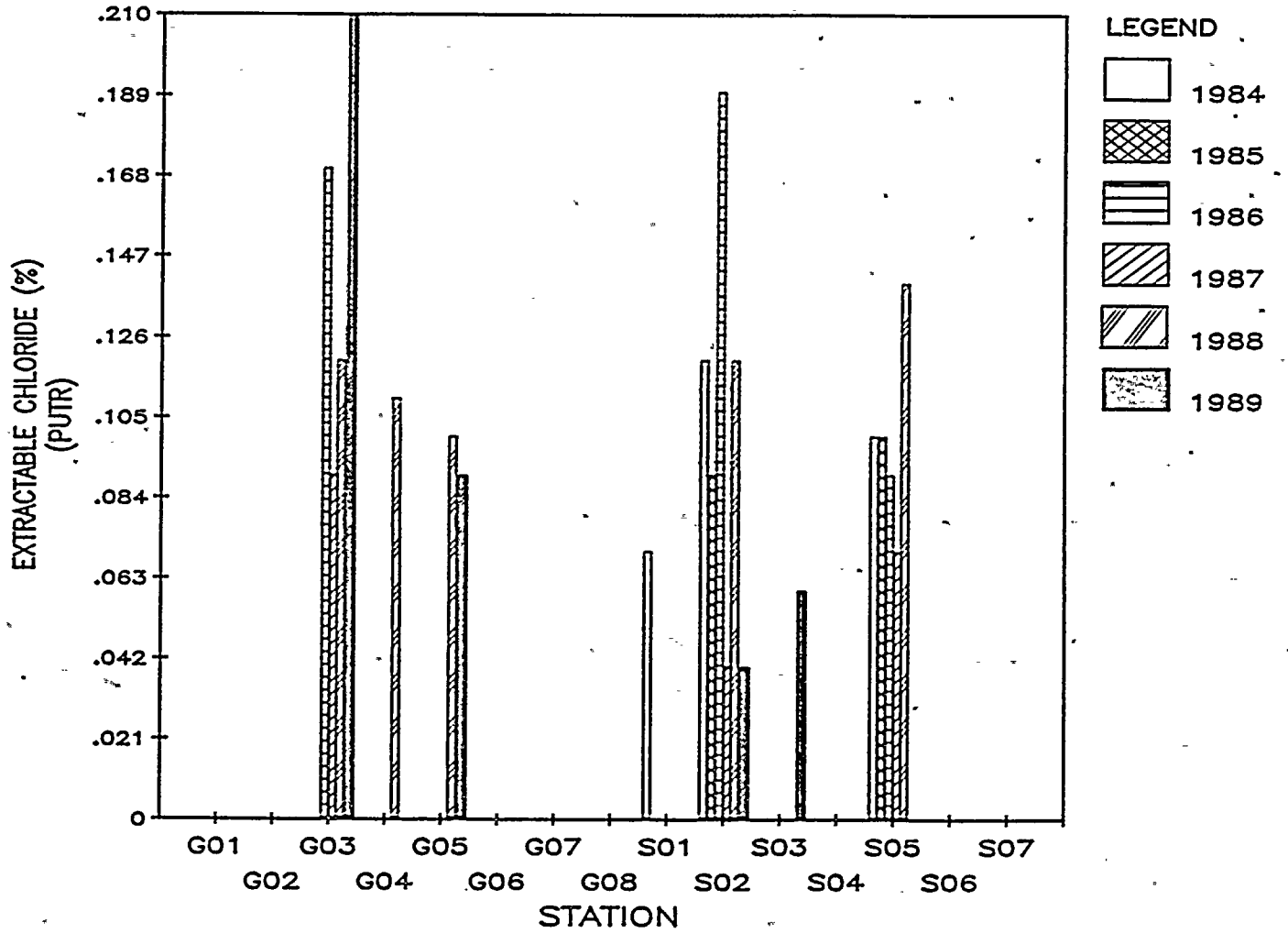

Figure 5-68 Chloride Concentration (%) in Purshia tridentata by Station for 1984 Through 1989

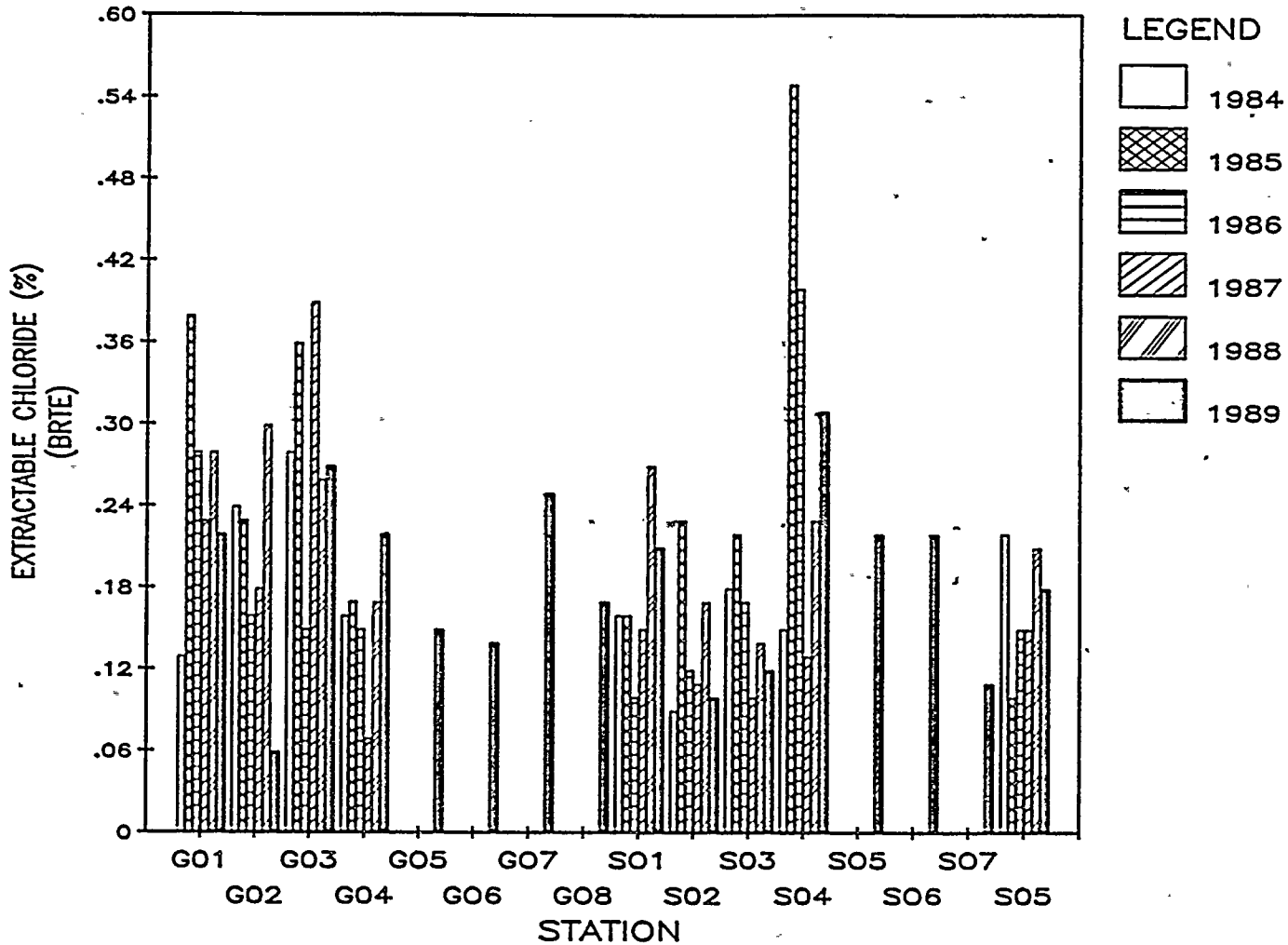

Figure 5-69 Chloride Concentration (%) in Bromus tectorum by Station for 1984 Through 1989

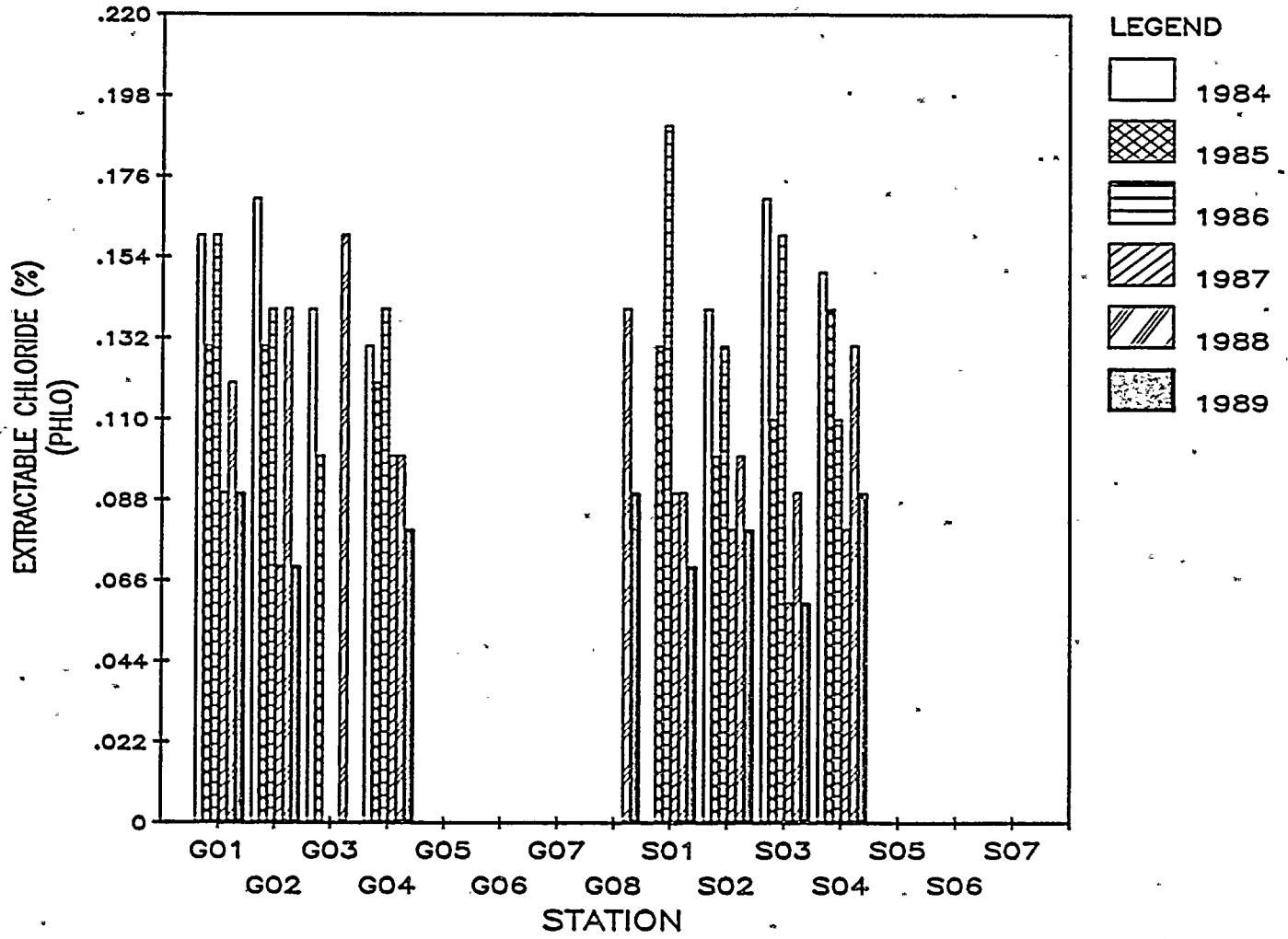

Figure 5-70 Chloride Concentration (%) in Phlox longifolia by Station for 1984 Through 1989

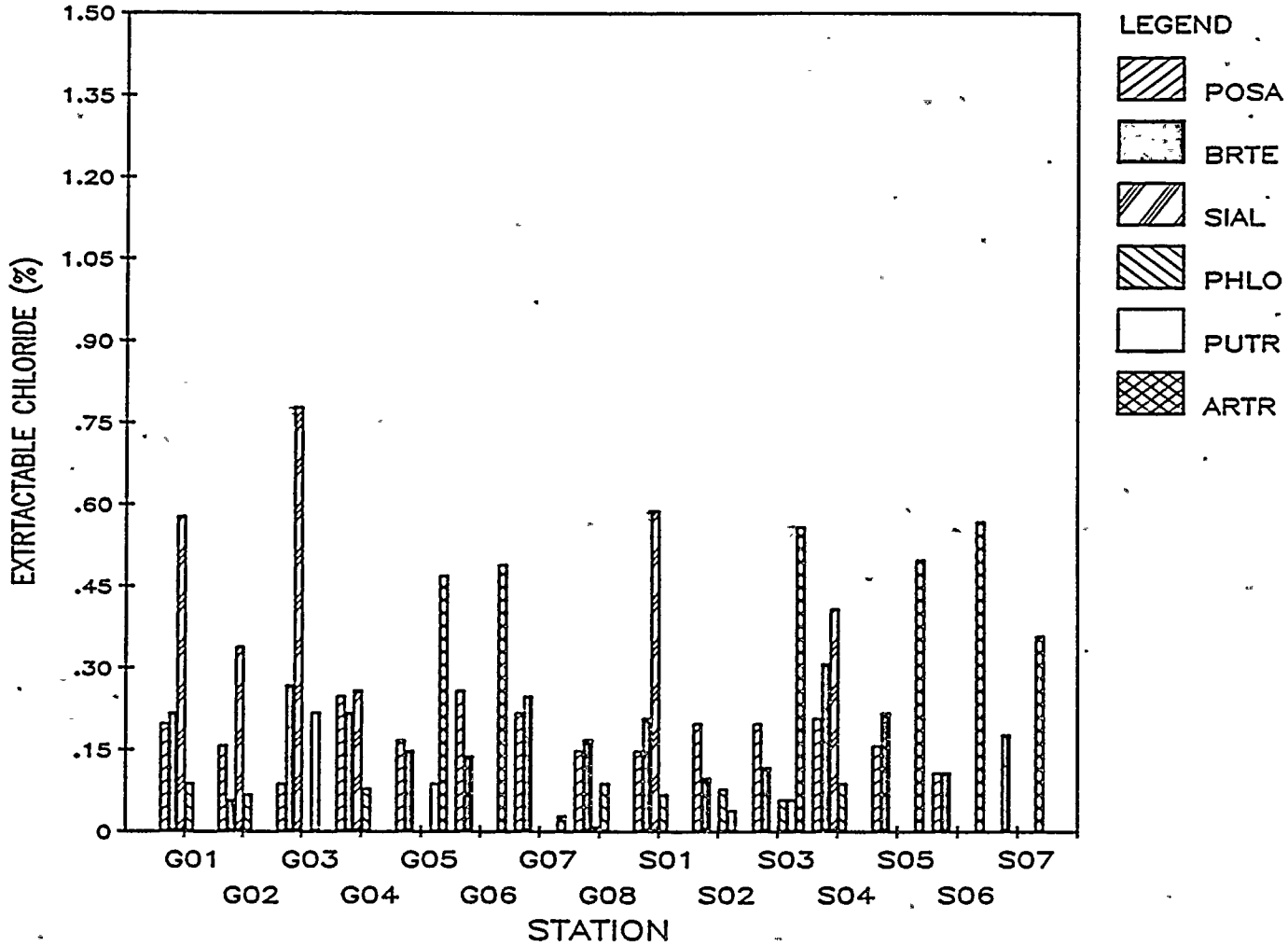

Figure 5-71 Total Vegetation Chloride for May 1989

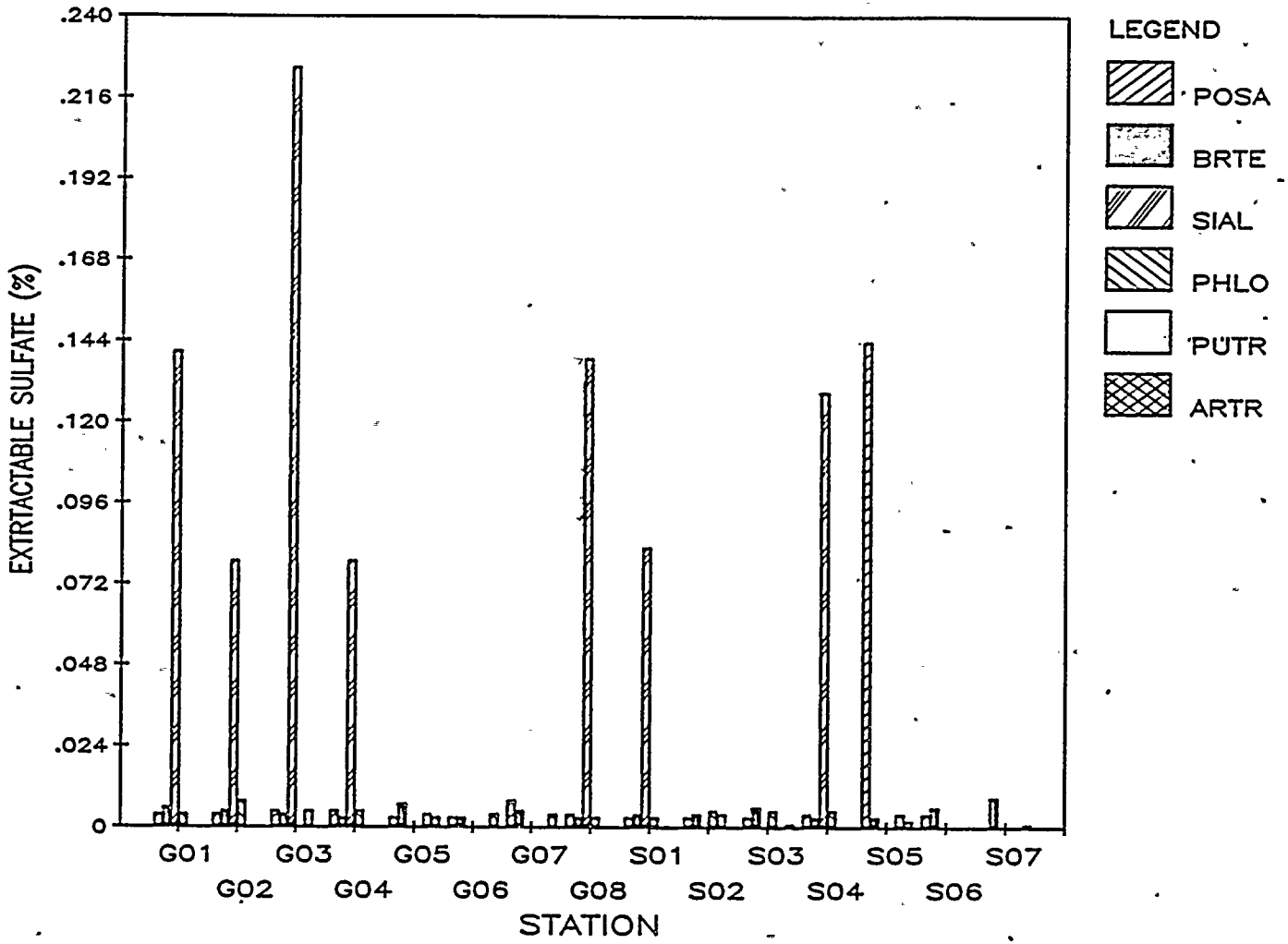

Figure 5-72 Total Vegetation Sulfate for May 1989

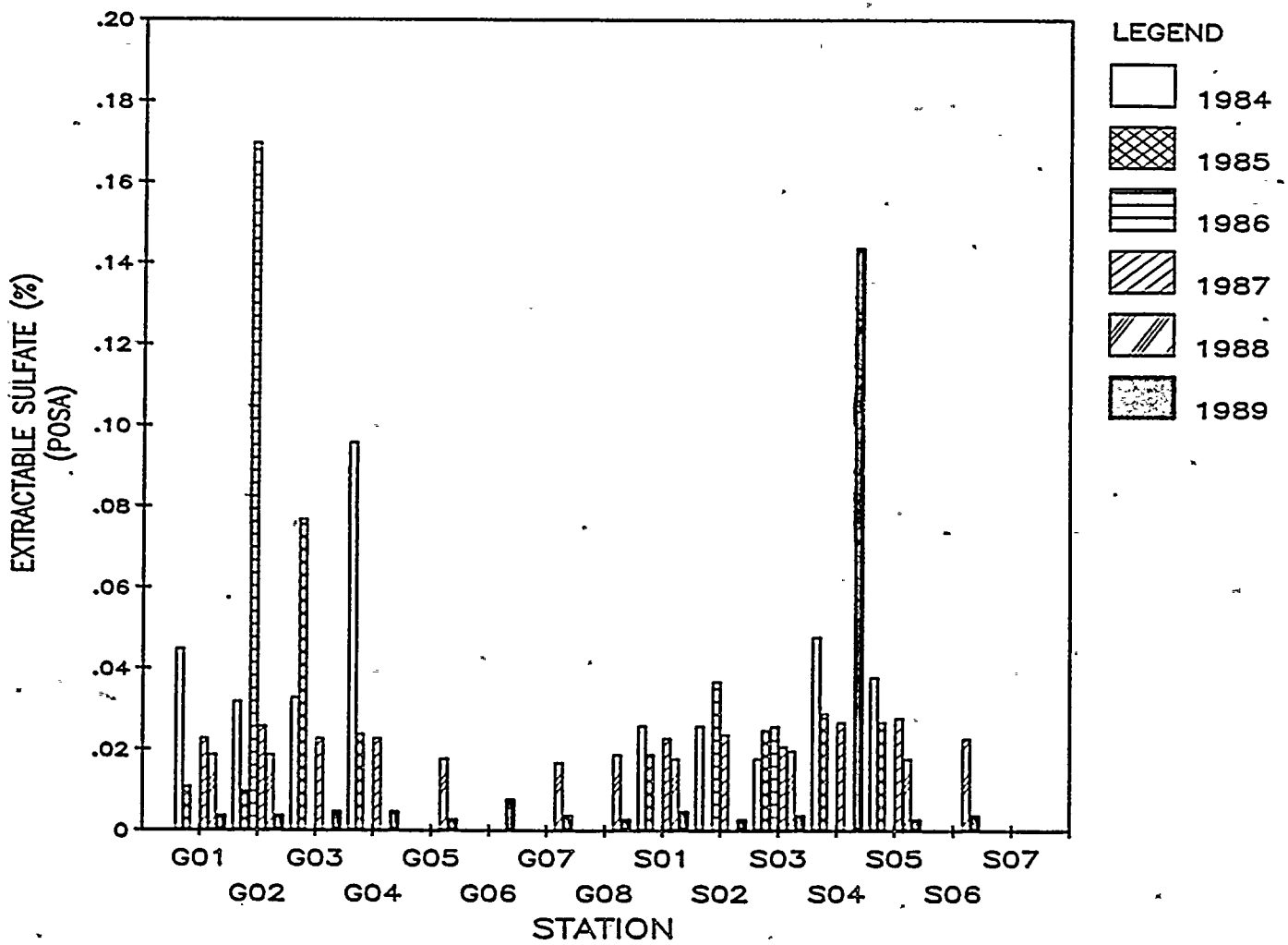

Figure 5-73 Sulfate Concentrations (%) in Poa sandbergii by Station for 1984 Through 1989

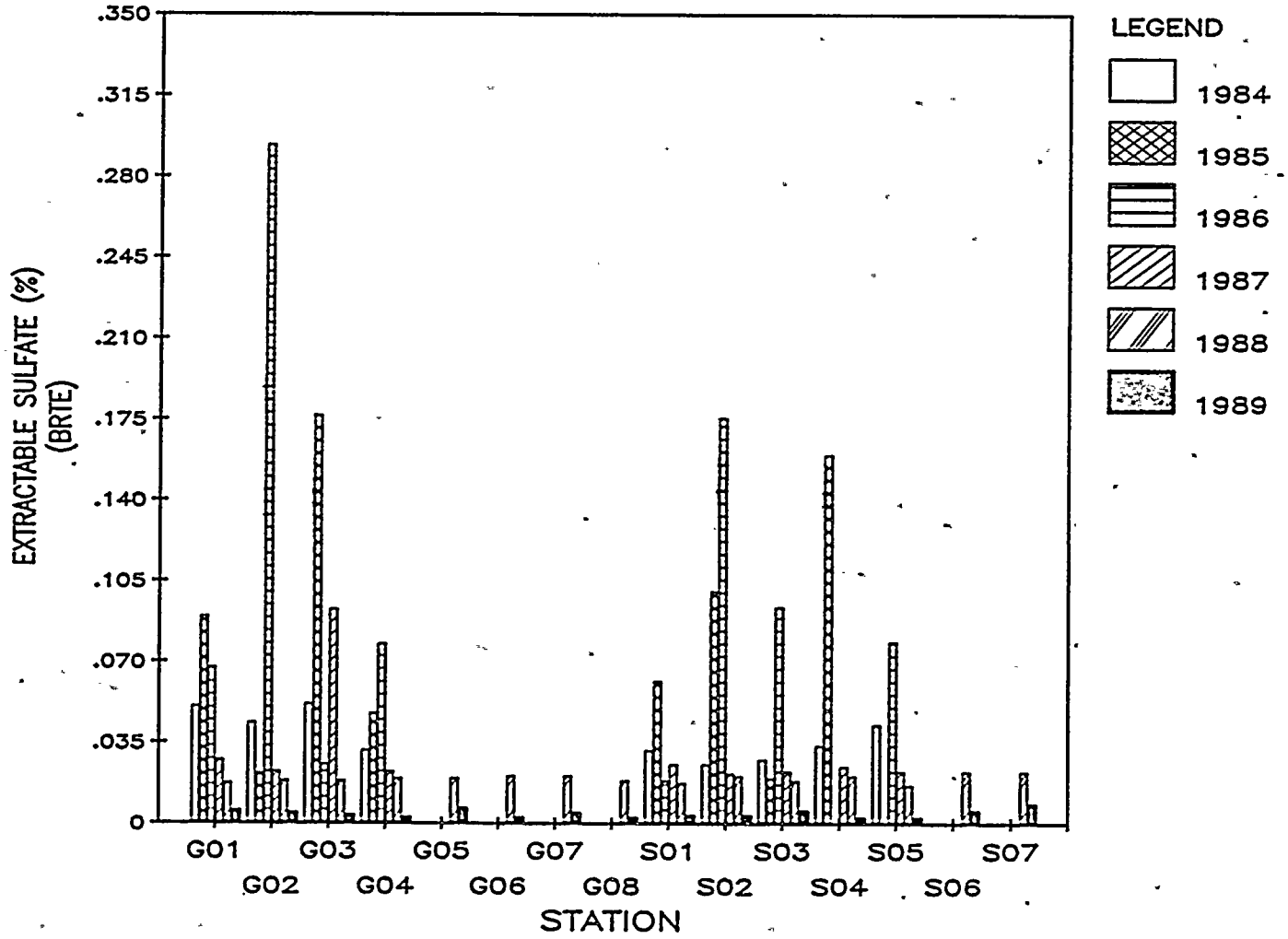

Figure 5-74 Sulfate Concentration (%) in Bromus tectorum by Stationfor 1984 Through 1989

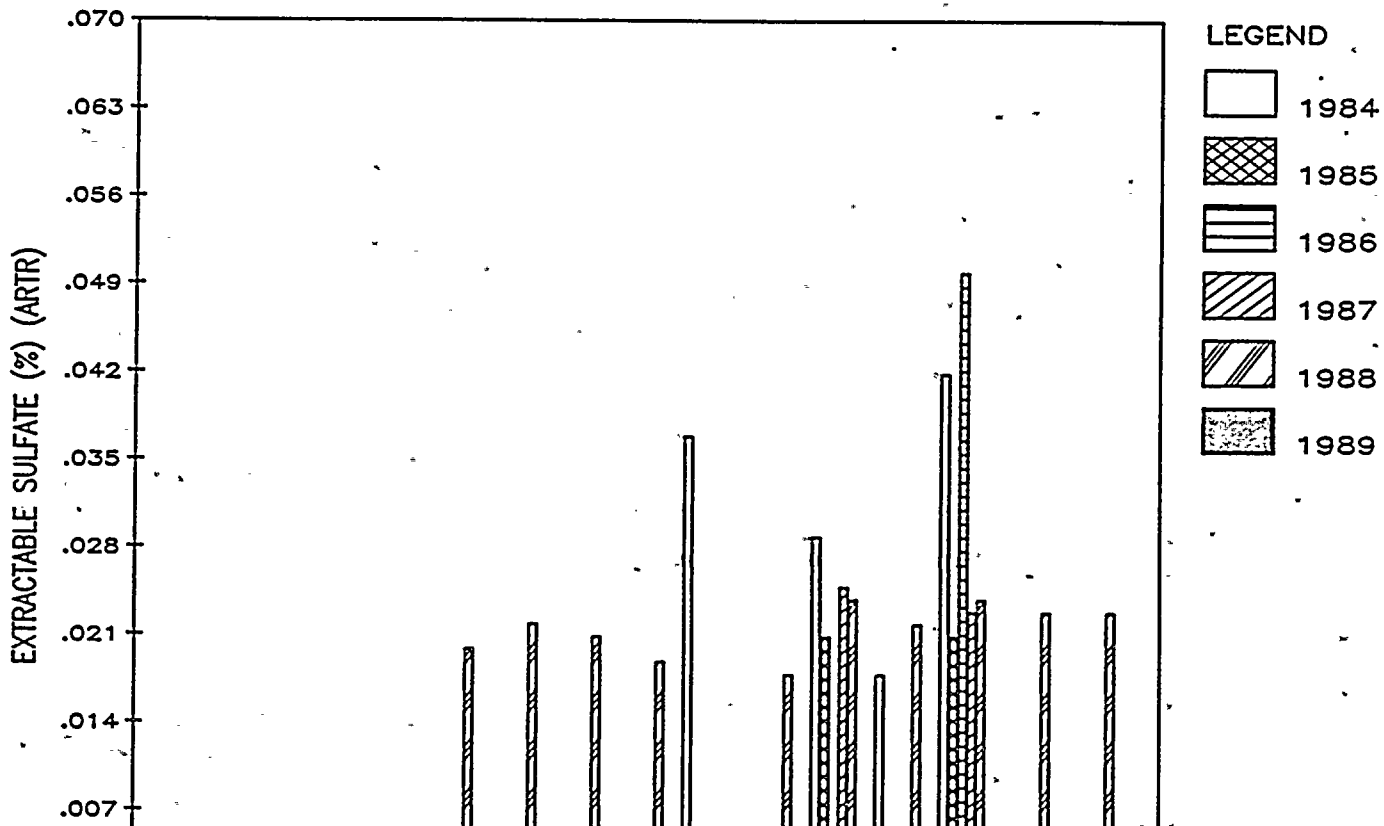

Figure 5-75 Sulfate Concentration (%) in Artemisia tridentata by Station for 1984 Through 1989

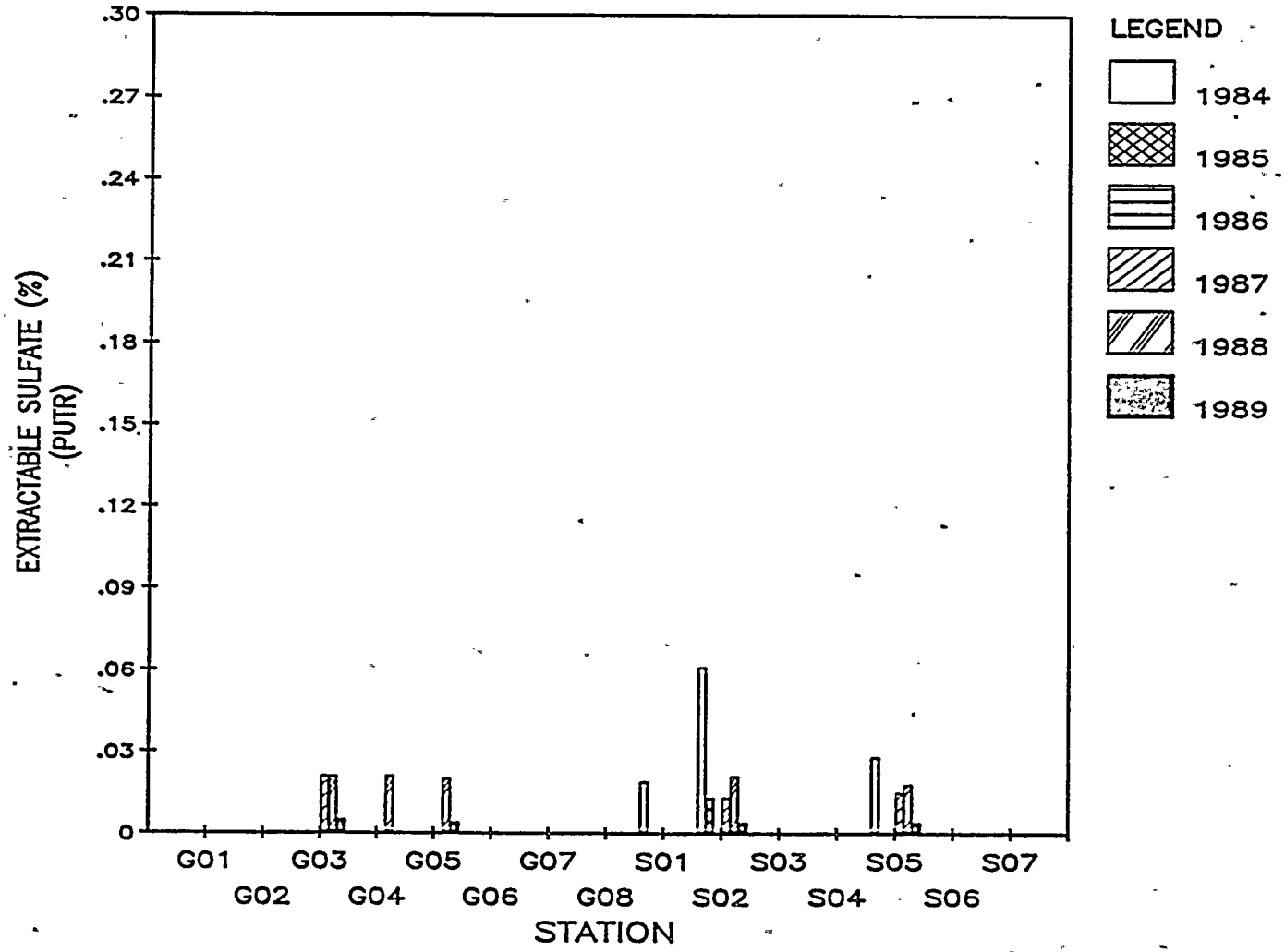

Figure 5-76 Sulfate Concentration (%) in *Purshia tridentata* by Station for 1984 Through 1989

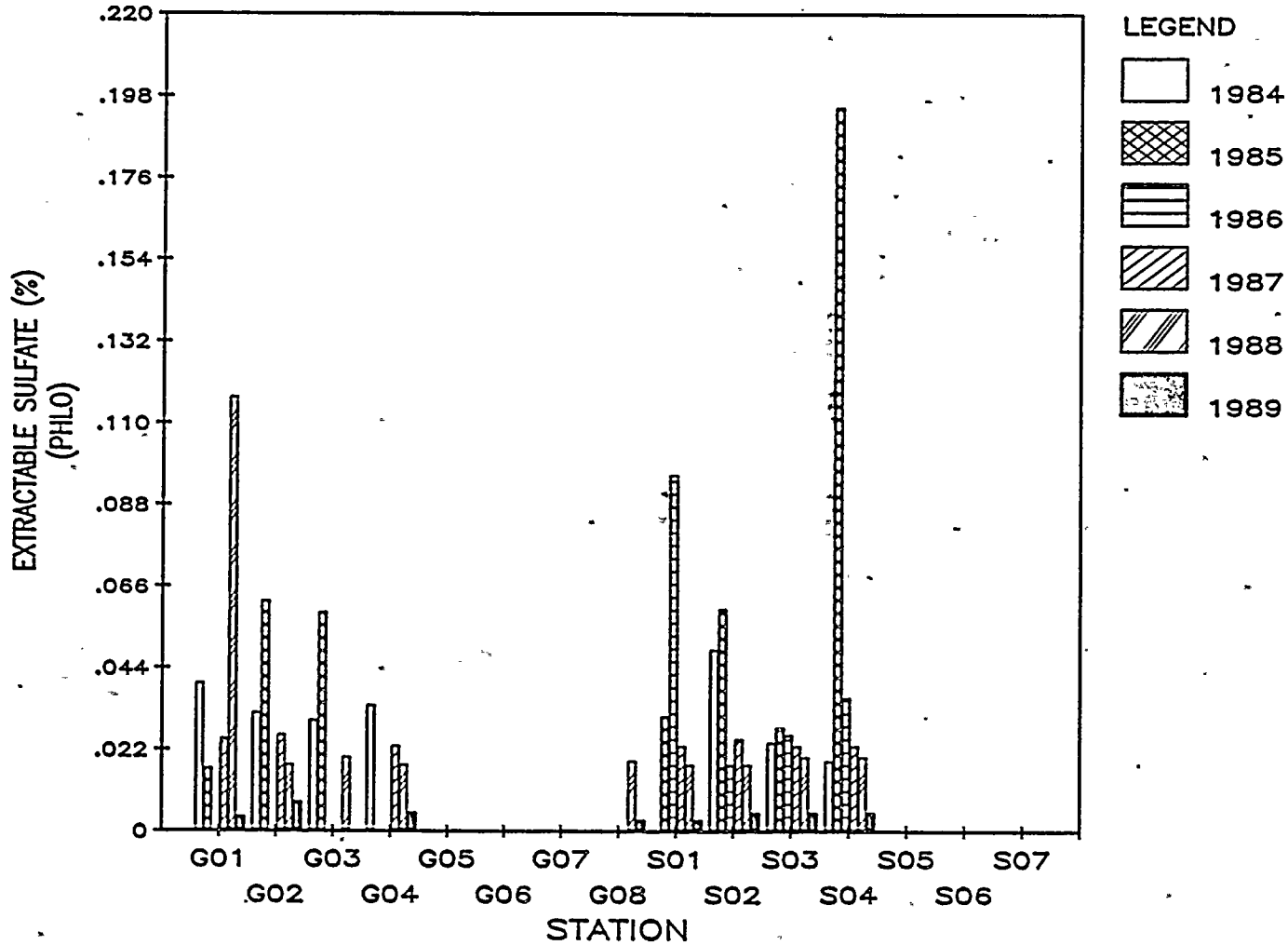

Figure 5-77 Sulfate Concentration in Phlox longifolia by Stationfor 1984 Through 1989

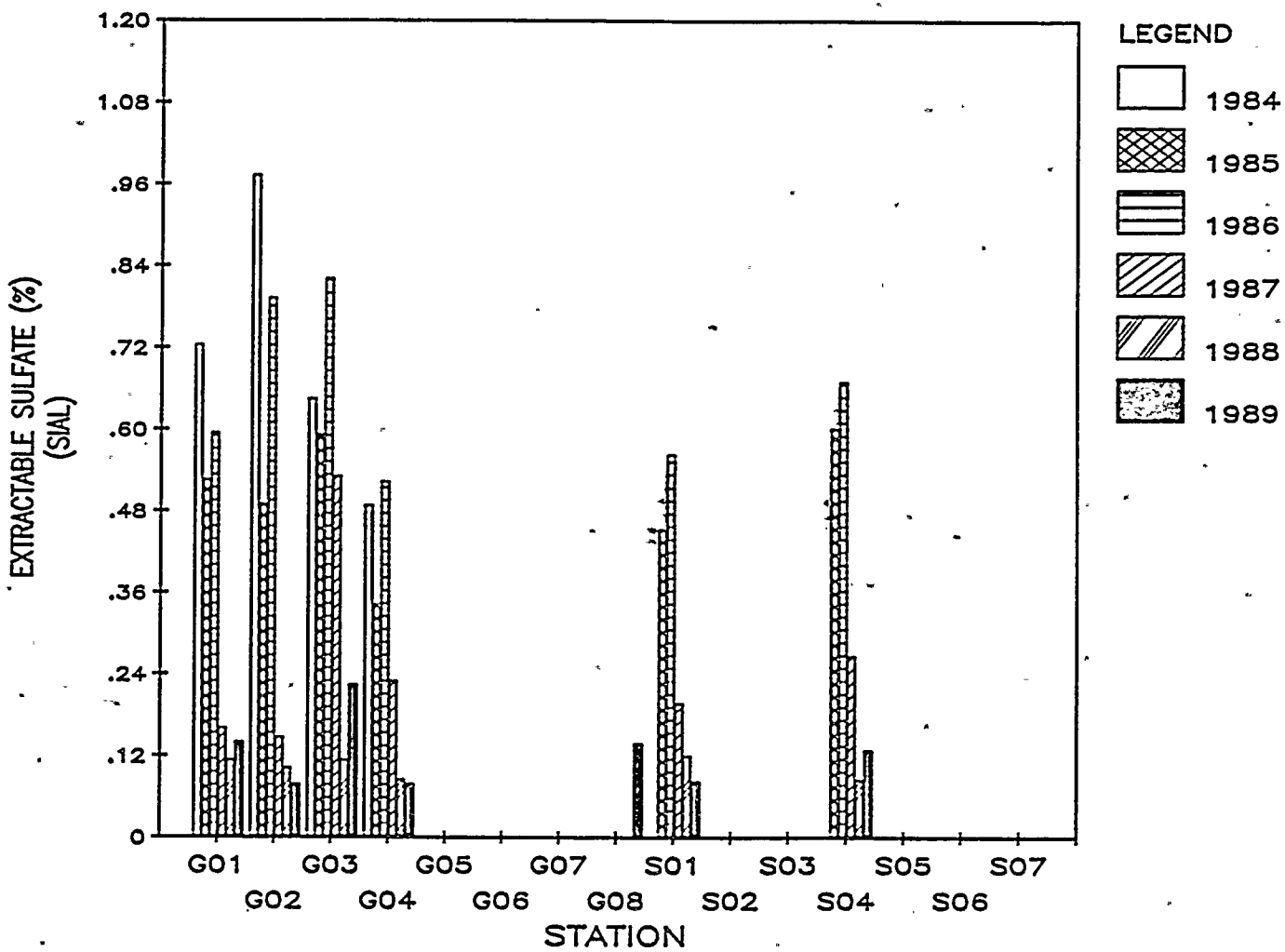

Figure 5-78 Sulfate Concentrations (%) in Sisymbrium altissimum by Station for 1984 Through 1989

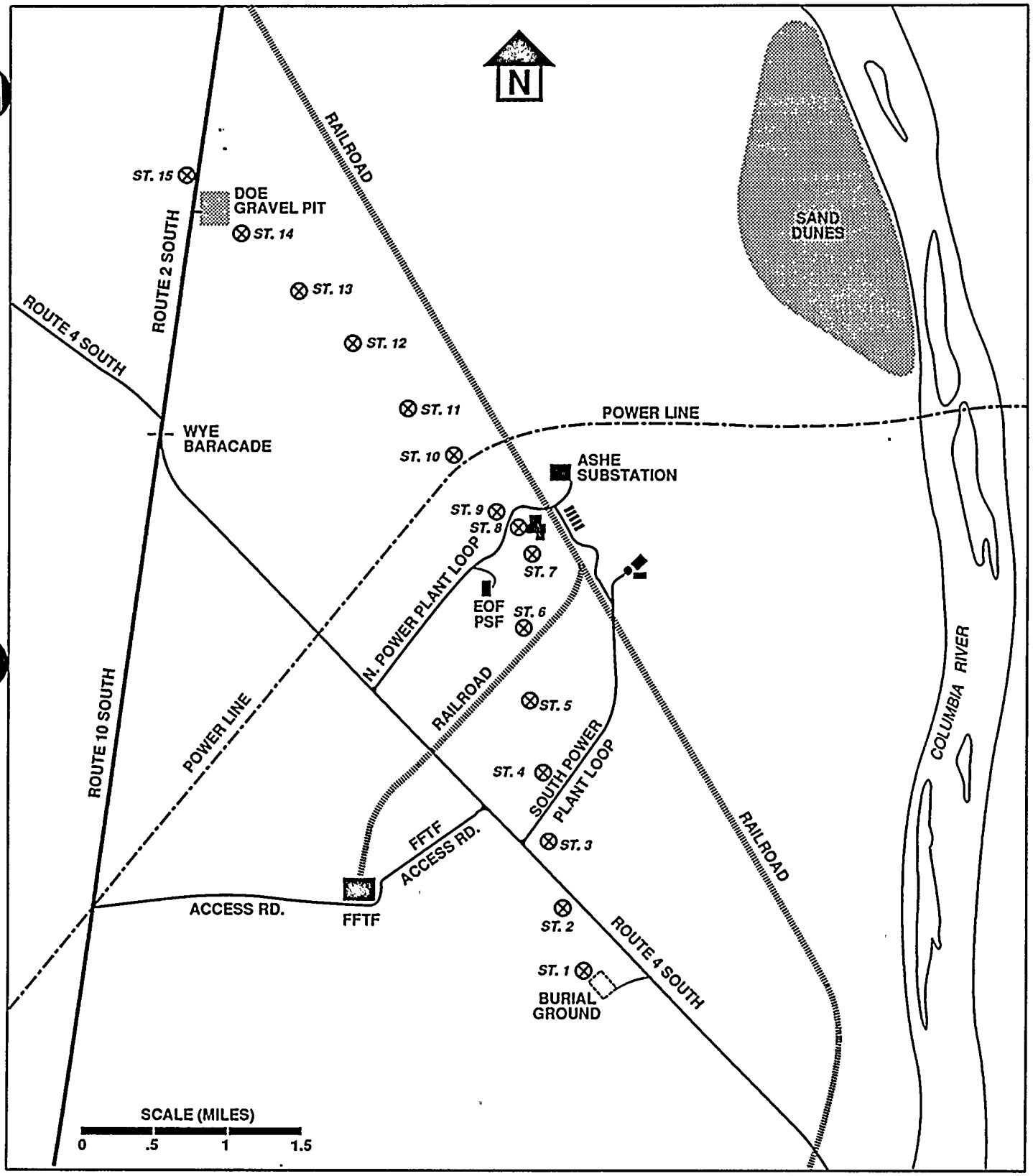

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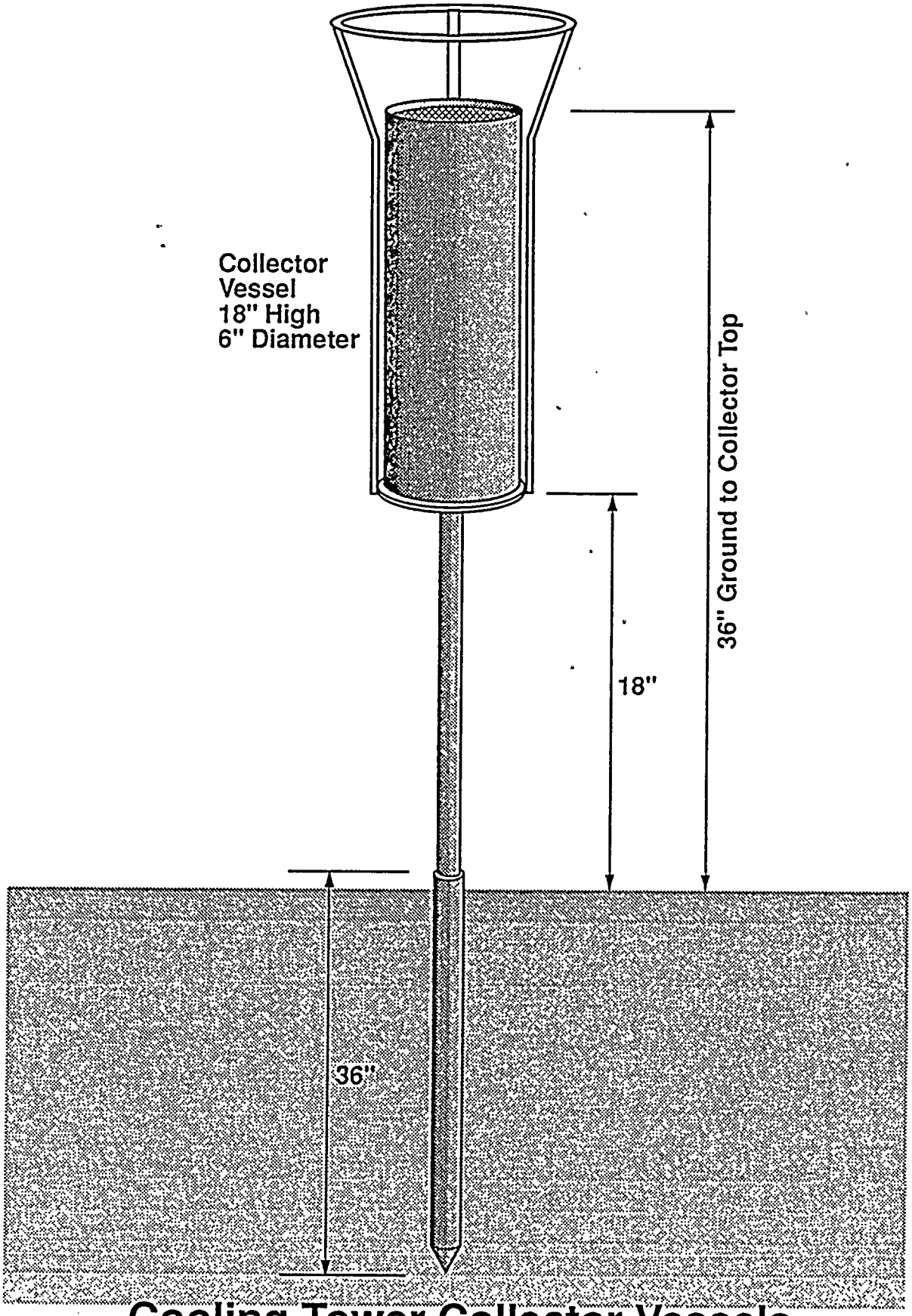
Figure 5-79 Location Map of Cooling Tower Drift Monitoring Sites



Cooling Tower Collector Vessels

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Figure 5-80 Cooling Tower Drift Collection Vessel

7.0 CORBICULA CLAM SURVEYS

7.1 INTRODUCTION

The Asiatic clam (*Corbicula fluminea*) is an introduced species which has caused problems at electrical generating plants throughout the country. Extensive fouling by relic shells have reduced cooling water flow rates in safety-related systems necessitating plant shutdowns in the southeast. Because of these problems, the Nuclear Regulatory Commission issued Inspection and Enforcement Bulletin 81-03 in April, 1981. This bulletin requires holders of operating licenses to inspect these systems for the presence of the bivalve.

7.2 MATERIALS AND METHODS

Surveys of the tower make-up (TMU) pump pit, the circulating water pumphouse and the main condenser water boxes are conducted at least once a year. A cooling tower was also inspected this year after a cleaning crew reported finding shells. The inspections of the circulating water pumphouse was done by inspecting the screens as they were pulled out for cleaning. The TMU pump pit was inspected by SCUBA divers.

7.3 RESULTS AND DISCUSSION

An extensive inspection of the main condenser water boxes, conducted during the annual refueling outage, revealed one relic shell and no living *Corbicula*. Several relic shells were found on the screens removed from the circulating water pumphouse. In the TMU pump pit, divers removed a population of clams and modifications are being made to negate the reestablishment of a *Corbicula* population there.

8.0 AERIAL PHOTOGRAPHY PROGAM

8.1 INTRODUCTION

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

8.2 MATERIALS AND METHODS

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

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

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

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

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

8.3 RESULTS AND DISCUSSION

The overflight was performed by the contractor, Photography Plus of Umatilla, Oregon. The photographs were received at the Environmental Laboratory on May 24. The initial examination of the flightlines was to determine the quality of the photographs, which was found to be generally good. A second, more detailed examination followed for the purpose of interpretation.

Inspection of the photographs revealed that the vegetation surrounding WNP-2 was generally healthy. The large shrubs *Artemisia tridentata* and *Purshia tridentata* were mostly limited to isolated individuals or small clusters because the flightlines cover the area that had burned in the 1984 range fire. The medium sized shrubs, *Chrysothamnus nauseosus* and *Chrysothamnus viscidiflorus*, were more numerous. Smaller forbs such as *Phlox longifolia* and *Salsola kali* and immature shrubs cannot be differentiated according to species as they were too small for the 1:6,000 scale of the photographs. Many small shrubs were noted on the northern half of flightline 2. An inspection of several areas along the flightline revealed that these shrubs were immature specimens of *Artemisia*.

Grasses were found to grow in greater density in the low areas between and on the slopes of the small rolling hills surrounding WNP-2. Density in flat, open areas was low, appearing in the photos as a pinkish hue in areas. No attempt was made at determining species from the photographs. The growth patterns of the grasses will be compared with later photographs to determine if any changes are occurring.

None of the photographs revealed areas of vegetation in stress and growth patterns remained consistent on all flightlines. No adverse impact was evident from the operation of WNP-2.

8.4 BIBLIOGRAPHY

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

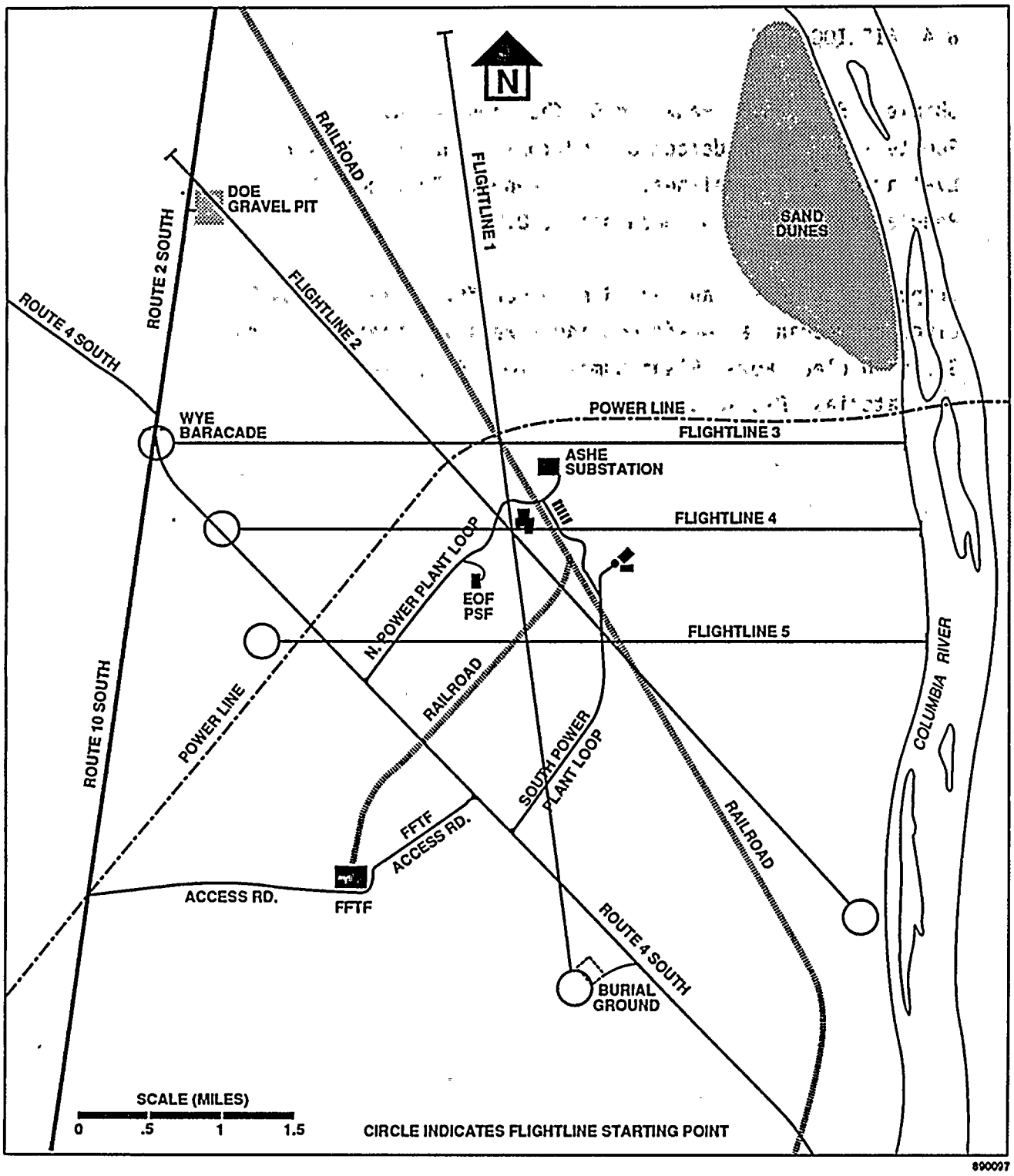
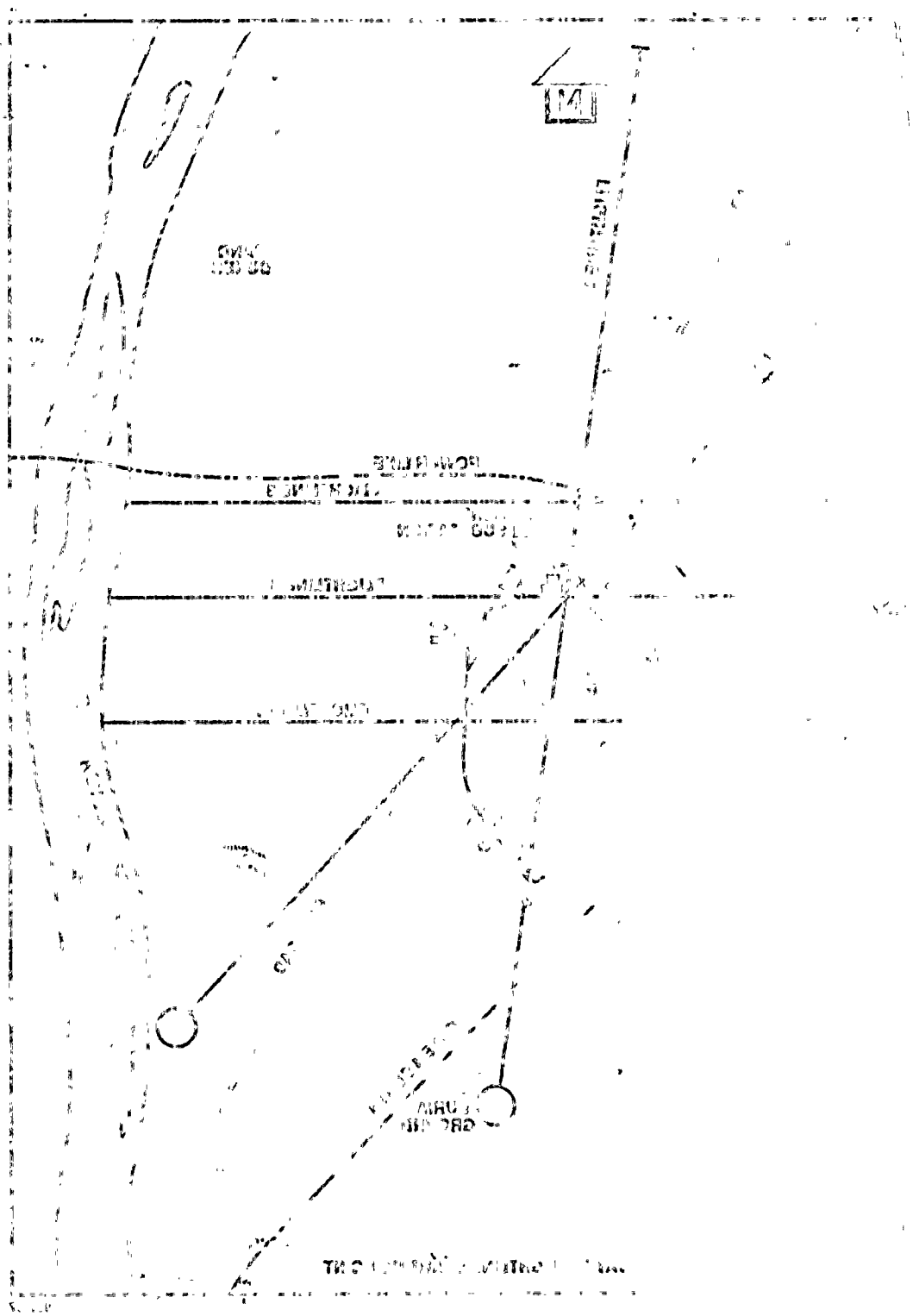
Figure 8-1 Aerial Photography Flightlines