WASHINGTON STATE HIGHWAY DEPARTMENT RESEARCH PROGRAM REPORT 14.2

VEGETATIVE COVER FOR HIGHWAY RIGHTS-OF-WAY

FINAL REPORT

RESEARCH PROJECT

JULY 1978

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16. Abstract

A six-year study of landscape plant establishment on roadsides as affected by a number of environmental conditions was initiated in April, 1970. The relationships between plant survival and soil texture, soil temperature, soil moisture, and exposure were evaluated. The affect of exposure on percent ground coverage of various grass species used in erosion control was also evaluated.

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FINAL REPORT

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VEGETATION COVER FOR HIGHWAY RIGHTS-OF-WAY

WASHINGTON STATE HIGHWAY COMMISSION
in cooperation with the
FEDERAL HIGHWAY COMMISSION

July 1976

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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SUMMARY

Highway construction inevitably involves large cut and fill slopes along the roadside. In order to revegetate these slopes with woody plant materials, we need to accurately estimate plant survival rates on each slope. With this knowledge, we can determine the number of plants required to achieve the necessary erosion control and the desired visual effect. Project HR 465, begun in 1970, studied the effects of environmental conditions on plant survival at a number of test locations in both eastern and western Washington.

The study involved survival rates for test-planted Douglas fir, shore pine, vine maple, salal, Aaron's beard (St. Johnswort), rhododendrons, and a number of grasses. Plantings were made in spring and fall in order to compare survival rates for seasonal plantings.

The major factors affecting the survival and growth of the test seedlings were those which influenced soil moisture. Earlier studies have reported that intensity of sunlight influences soil temperature, which in turn influences soil mositure (Hursh 1949, Wang 1953, and Cooper 1961). Data collected in the current study tends to support these reports. Areas receiving the lowest intensity of sunlight tended to have higher soil moisture and the highest rate of plant survival.

Seasonal planting was also important. Douglas fir, shore pine, and vine maple planted in the fall had higher survival rates than spring plantings, while only salal planted in the spring survived. However, locations with the highest Douglas fir survival rates also had the highest survival rates for salal.

In most areas where soil moisture during early August was 5 percent or greater, more than half the fall-planted Douglas fir survived. Where early August soil moisture was below 5 percent, between 0 and 15 percent of fall-planted Douglas fir and around 25 percent of shore pine survived. Vine maple survival was over 30 percent where early August soil moisture was 5 percent or more, with partial shade during the day. In areas with early August soil moisture around 5 percent, but without shade, no vine maple survived. When grass coverage was 80 percent or more, survival rates for all test plant species decreased.

Douglas fir and salal planted within a native red alder stand had higher survival rates than those planted next to the alder stand. Vine maple survived best outside, but adjacent to, the red alder stand.

A survey of erosion control grass percent-coverage in western Washington showed perennial grass coverage highest on north exposures, with west exposures second, followed by south and east exposures with about equal coverage. In eastern Washington, flat areas had highest coverage followed by (in decreasing order) north, west, east, and south exposures.

CONCLUSIONS AND RECOMMENDATIONS

The study was divided into three sections dealing with different plant types in various locations in eastern and western Washington. These divisions are covered in detail in the DISCUSSION portion of the report. Conclusions are listed by Study Section, and overall recommendations are presented.

CONCLUSIONS

Study Section I

Study Section I involved planting Douglas fir, shore pine, vine maple, salal, and Oregon grape at fourteen locations in western Washington. A fifteenth location was used to study these and other plants. In each of these areas, factors affecting plant growth were studied including: directional exposure (north-facting, etc.), percent slope, shade coverage, grass coverage, soil texture, soil pH, soil temperature, and soil moisture. The following conclusions were reached:

1. Fall-planted Douglas fir, shore pine, and vine maple had higher survival rates than spring plantings.

2. Spring-planted salal had higher survival rates than fall plantings.

3. Areas with highest Douglas fir survival rates also had the best salal survival.

4. Where early August soil moisture was 5 percent or more, fall-planted Douglas fir survival exceeded 50 percent. Early August soil moisture below 5 percent usually produced survival rates between zero and 15 percent.

5. Fall planted shore pine survival was around 25 percent. Where August soil moisture approached or exceeded 5 percent, with less than 80 percent grass coverage, survival increased to 50 percent or better.

6. Partially shaded sites where early August soil moisture approached 5 percent had fall-planted vine maple survival rates above 30 percent. Unshaded areas with 5 percent moisture had zero vine maple survival.

7. Fall-planted Aaron's beard survival was over 75 percent.

Study Section II

Study Section II had three parts. The first part studied the effects of partial shade from a native red alder stand on plantings of Douglas fir, shore pine, vine maple, and salal, all with a northern exposure. The second part studied survival characteristics of native rhododendron

planted in a mature Douglas fir stand. The third part involved seeding six areas in eastern Washington with thickspike wheatgrass, Indian ricegrass, and spiny hopsage. The following conclusions were reached:

1. Douglas fir and salal survival within the alder stand was nearly twice as high as plantings next to the stand. Vine maple showed opposite results, with about half as many plants surviving within the alder stand.

2. Shore pine survival was about equal within and next to the alder stand.

3. Rhododendrons planted under a mature stand of Douglas fir showed slightly over 10 percent survival.

4. On silt loam soils, thickspike wheatgrass establishment was higher than either Indian ricegrass or spiny hopsage.

Study Section III

Study Section III involved observation of the degree of ground coverage by erosion control grasses and other plants. More than 5,000 observations were made throughout Washington State. The following conclusions were reached:

1. In eastern Washington, erosion control grasses showed similar percentages of ground cover on north and south exposures. However, north exposure coverage was primarily perennial grasses, while downy brome, an annual grass, predominated on south exposures.

2. In western Washington, north exposures showed the highest percentage of ground cover for perennial grasses, with west second, followed by east and south with about equal coverage. Annual grass coverage was about equal for all exposures.

RECOMMENDATIONS

In proposed planting areas, percent soil moisture and erosion grass coverage should be observed and recorded. These measurements are used to predict anticipated survival rates for fall-planted Douglas fir, shore pine, and vine maple, and for spring-planted salal. In areas with less than 80 percent erosion control grass coverage, we can expect the following survival rates (percentages):

EXPECTED SURVIVAL PERCENTAGE

Species	Early August Soil Moisture 3% – 5%		Early August Soil Moisture 5% – 10%	
	Spring Planted	Fall Planted	Spring Planted	Fall Planted
Douglas fir	1	10	30	55
Shore pine	20	55	25	60
Vine maple	1	15	30	40 (with shade during part of day.)
Oregon grape	None Planted	20	None Planted	70
Salal	0	0	25 (50% with partial shade.)	0

DISCUSSION

INTRODUCTION

Since the late nineteenth century, the motoring public has increasingly expected highways to be not only a functional means of transportation, but a pleasing visual experience as well. Highway landscape planting using reforestation techniques can be a tool that will enchance the beauty of the natural landscape, create wildlife habitat, and soften the visual impact of highway construction.

Highway microenvironments are extremely variable due to the large cut and fill slopes produced during construction. To revegetate these slopes, we need an accurate estimate of the expected plant survival rate on a given slope. The estimated survival rates could eliminate planting certain types of seedlings in areas of low anticipated survival.

Project HR 465 was initiated in 1970 to meet the need for estimating plant survival in Washington State.

STUDY OBJECTIVES

The original objective of HR 465 was to plant one site in western Washington and another in eastern Washington, evaluate which plant species were best suited for each location, and use the data obtained as a basis for roadside planting throughout the state.

In December 1971, the project objective was changed and fourteen additional sites were planted in western Washington to provide data on a variety of sets of environmental conditions.

The new study objectives use plants as monitors of the microenvironment. A plant with a given survival rate under one set of environmental factors should have a similar survival rate at a different location, but influenced by similar environmental factors. Environmental factors examined in this study were slope exposure, soil temperature, soil moisture, soil texture, and completion of erosion control grasses.

METHODS AND PROCEDURES

Investigation began in the spring of 1970 and was composed of three sections.

Section I

Section I of the study consisted of planting test seedlings in formal plot areas or sites. Vine maple, salal, shore pine, Douglas fir, and Oregon grape were planted in fourteen sites in the spring of 1972. All were planted bare-root except the salal, which was grown from seed in clumps enclosed in a 6 x 6 cm wood collar.

In the fall of 1973, the same species were planted on the same fourteen sites to compare survival with the spring planting. Site locations are shown in Figure 1.

Site 15 was planted during December 1970 with bare-root Aaron's beard, Douglas fir, Lawson cypress (false cypress), mountain hemlock, Oregon grape, paper birch, Point Reyes ceanothus, redtwig dogwood, salal, and shore pine.

Data collected at sites 1 through 14 included:

1. Percent slope and exposure by observation.

2. Soil pH and texture determined by the Bouyoucos Hydrometer Method (Bouyoucos 1953).

3. Soil temperature was measured with a standard centigrade thermometer in buried 6 cm and 12 cm tubes.

4. Soil moisture was determined by the difference in wet and air-dried soil weights.

5. Percentage of ground coverage was visually estimated in each one-foot square portion of a 2-foot by 2-foot plot.

Section II

Near Olympia, in western Washington, Section II of the study consisted of recording survival rates of salal, shore pine, Douglas fir, and vine maple planted within and next to an alder stand. and field-collected native rhododenron seedlings (up to 15 cm) planted within three stands of mature Douglas fir.

Six highway cut slopes located between Yakima and Ellensburg on Interstate 82 in eastern Washington (Figure 2) were seeded with thickspike wheatgrass, Indian ricegrass, and spiny hopsage. One-square-meter test plots were seeded with field collected Indian ricegrass (15 pounds/acre), thickspike wheatgrass (30 pounds/acre), and spiny hopsage (15 pounds/acre) along with 10-20-20 fertilizer (300 pounds/acre) and 38-0-0 fertilizer (200 pounds/acre).

Section III

Section III of the study consisted of inventorying the ground coverage percentage of erosion control grasses planted throughout the state. Ground cover percentage was visually estimated using a four-foot square divided into 4 one-foot sections.

SECTION 1 – DISCUSSION AND RESULTS

Sites 1 through 6 were generally north or south-facing slopes, while sites 9 through 13 faced east or west. Sites 7, 8, 14, and 15 were flat. Site characteristics are listed in Table 1. Shade

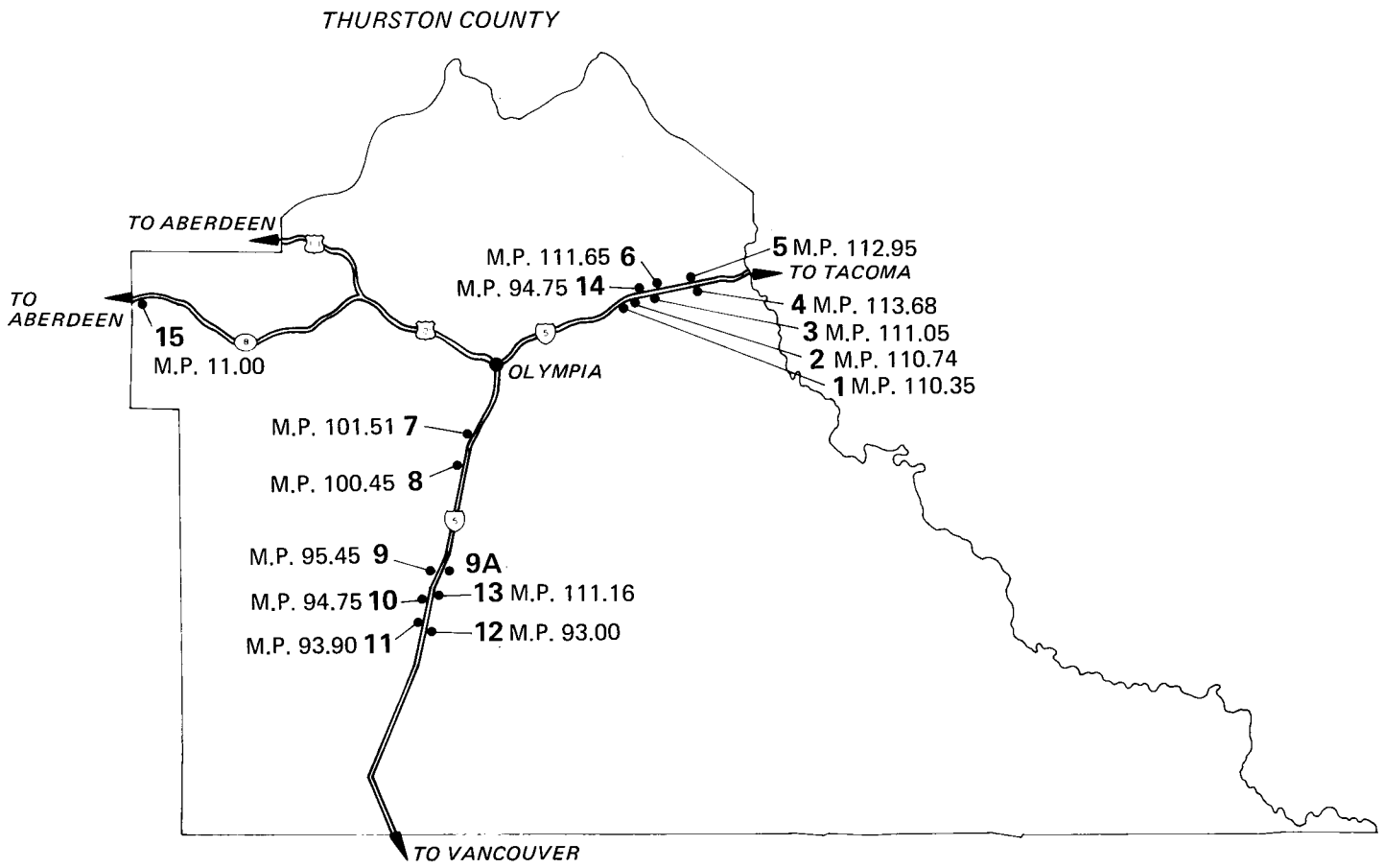

Figure 1 – Western Washington Test Site Locations (Sites 1 through 15)

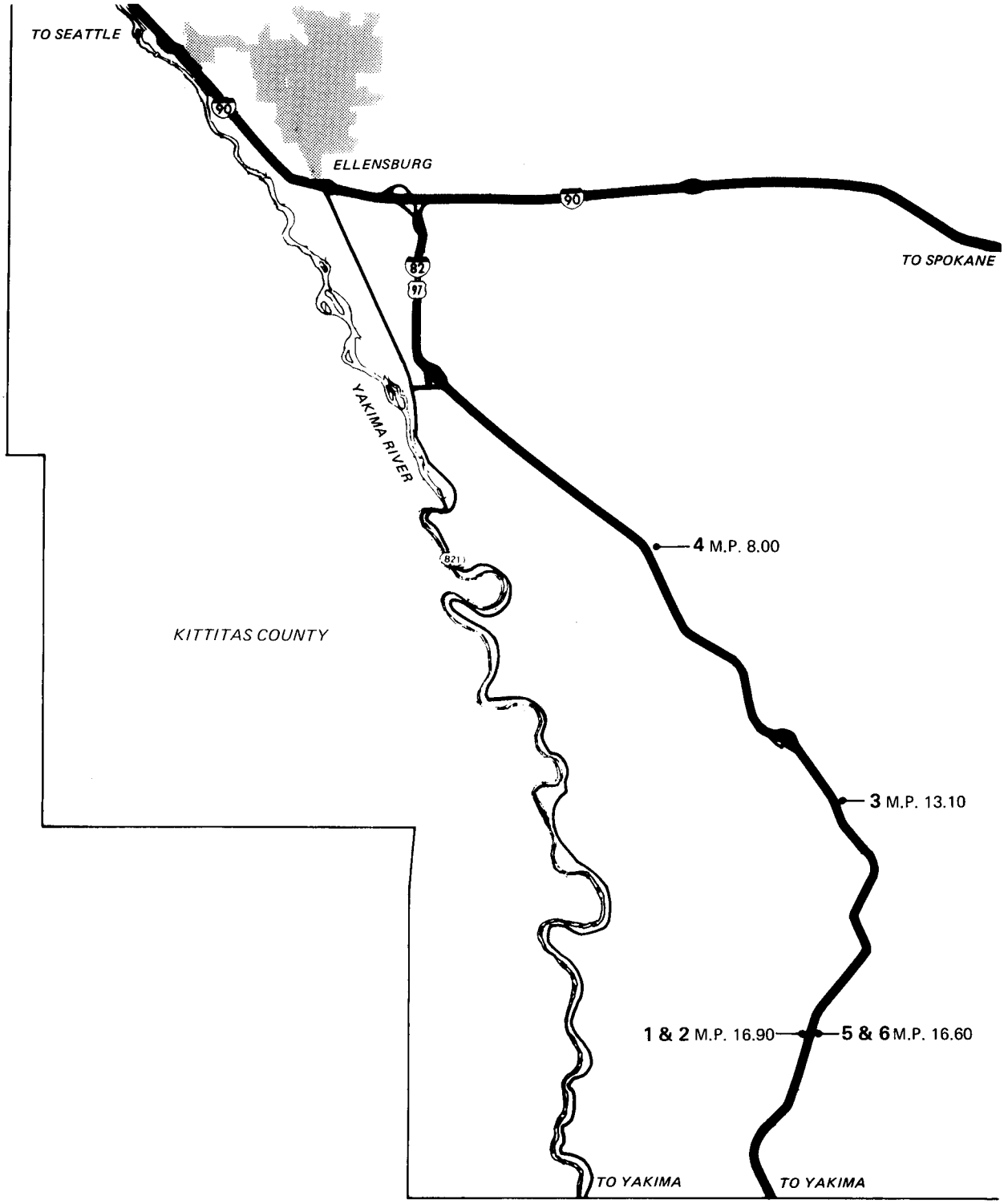

Figure 2 – Eastern Washington Test Site Locations (Sites 1 through 6)

listed in Table 1 was provided by large Douglas fir and red alder trees outside the highway right-of-way fence, and by shrubs, principally Scotch broom and hazelnut, within the right-of-way.

Table 1. Test Site Characteristics

Site No.	Exposure	Percent Slope	Shade	Percent Grass Coverage	Soil Texture	Soil pH	August Soil Moisture (minimum percent)
1.	N 25° W	22	Yes	70	Loam	5.8	1.0
2.	N 15° W	2	Yes	70	Sandy loam	5.5	7.0
3.	N 22° W	7	No	68	Sandy loam	5.6	Almost zero
4.	N 15° W	21	No	65	Sandy loam	5.7	3.0
5.	S 13° E	18	No	76	Loamy sand	5.8	2.5
6.	S 15° E	2	No	75	Sandy loam	5.5	2.0
7.	Flat area	0	No	72	Loamy sand	5.6	3.5
8.	Flat area	0	Yes	44	Sandy loam	5.4	3.5
9.	S 65° E	10	No	40	Sandy loam	6.1	2.5
10.	S 82° E	11	Yes	69	Sandy loam	5.6	6.8
11.	S 75° E	18	Yes	13	Sandy loam	5.3	6.0
12.	S 77° W	8	Yes	97	Sandy loam	5.4	25.5
13.	N 80° W	17	No	71	Sandy loam	5.7	15.5
14.	Flat area	0	No	45	Sandy loam	5.7	2.0
15.	Flat area	0	No	65	Sandy loam	5.6	2.0

Soil Texture

Soil texture and pH were similar for all plots. Soil samples were tested using 1/4 inch and No. 10 screens. Soils from sites 1 through 6 and 14 had a high percentage of particles larger than 1/4 inch. Detailed soil texture characteristics are included in the Appendix.

Site 11 soil was similar in texture to the other sites, but was red rather than brown. This red soil did not support a good stand of erosion control grass, but was supporting a dense stand of Douglas fir seedlings.

Soil Temperature

Soil temperature was measured at 6 cm and 12 cm depths. Charts of the results at sites 1 through 13 are included in the Appendix. Soil temperature was not recorded at sites 14 and 15.

Soil Moisture

Soil moisture was measured at depths between 3 cm and 6 cm. Temperature and moisture charts for each site are included in the Appendix.

Soil moisture for sites 2, 10, 11, 12, and 13 remained relatively higher during summer months than the other sites. Site 12, which had nearly 100 percent grass coverage and relatively high soil moisture during the summer months, produced a dense mat of grass which shaded out the plantings.

Exposure

Lowest Douglas fir survival rates generally occurred on south-facing slopes and flat areas. Site 8 (flat but shaded by large trees and shrubs) had better survival rates for vine maple, shore pine, and Douglas fir than flat, unshaded site 7, probably due to higher summer soil moisture at site 8 (see charts in Appendix).

Survival Rates at Sites 1 through 14

Survival percentages after two winters and two summers for fall and spring plantings of Douglas fir, shore pine, vine maple, and salal are shown in Table 2. Approximately fifty plants of each species were planted at each site.

Table 2. Survival Percentages* at Sites 1 through 14

Survival of spring- and fall-planted Douglas fir, shore pine, vine maple, and salal, and fall-planted Oregon grape after two summers and two winters.

Site	Douglas Fir		Shore Pine		Vine Maple		Salal		Oregon Grape	Minimum August
No.	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Fall only	Soil Moisture %
1.	17	96	51	73	13	27	3	0	70	1.0
2.	20	53	28	34	35	None planted	0	0	14	7.0
3.	0	8	8	34	4	0	0	0	33	Almost zero
4.	16	15	10	60	0	0	6	0	16	3.0
5.	0	0	0	0	0	0	0	0	0	2.5
6.	0	3	24	60	0	0	0	0	28	2.0
7.	0	2	18	8	11	34	6	0	21	3.5
8.	0	8	22	63	0	57	0	0	23	3.5
9.	16	19	30	24	0	15	0	0	36	2.5
10.	62	93	0	96	60	96	30	0	82	6.8
11.	31	75	51	55	85	100	20	0	75	6.0
12.	16	50	0	21	0	6	0	0	38	25.5
13.	63	68	10	32	16	78	66	0	None planted	15.5
14.	2	8	6	3	0	0	0	0	4	2.0

*About 50 plants of each type were planted at each site.

Fall plantings of Douglas fir, shore pine, and vine maple generally survived better than spring plantings. Fall-planted salal did not survive at any site.

Sites with soil moisture of 5 percent or less in early August had the lowest survival rate (except site 1). All sites except 5, 7, and 14 had better than 20 percent survival of planted shore pine. Oregon grape survival was low where shore pine survival was low. Salal survived best on those sites where Douglas fir survival was highest.

Survival Rates at Site 15

Table 3 shows survival rates for site 15, a flat area with no shade and 65 percent coverage of erosion control grasses, which was planted in fall 1970. After five years, Aaron's beard (St. Johnswort) had the highest survival (78 percent) followed by shore pine (53 percent), Oregon grape (32 percent), Lawson cypress (false cypress) (17 percent), Douglas fir (8 percent), and paper birch and redtwig dogwood (both 1 percent).

Table 3. Survival Percentages of Materials Planted at Site 15 in Fall 1970

Species	No. Planted	Percent Survival					
		4/22/71	11/12/71	8/17/73	8/6/73	8/21/74	1/19/76
Aaron's beard (St. Johnswort)	275	99	96	Not Recorded	90	80	78
Douglas fir	200	45	13	Not Recorded	4	Not Recorded	8
Lawson cypress (false cypress)	200	59	Not Recorded	Not Recorded	50	Not Recorded	17
Mountain hemlock	100	93	Not Recorded	Not Recorded	0	0	0
Oregon grape	150	56	30	Not Recorded	30	Not Recorded	32
Paper birch	300	87	Not Recorded	Not Recorded	17	1	1
Point Reyes ceanothus	200	43	20	Not Recorded	0	0	0
Redtwig Dogwood	250	99	44	18	20	1	1
Salal	200	51	Not Recorded	Not Recorded	0	0	0
Shore pine	200	73	55	54	53	53	53

SECTION 1 – CONCLUSIONS

1. Fall-planted Douglas fir, shore pine, and vine maple had higher survival rates than spring plantings.

2. Spring-planted salal had higher survival rates than fall plantings.

3. Areas with highest Douglas fir survival rates also had the best salal survival.

4. Where early August soil moisture was 5 percent or more, fall-planted Douglas fir survival was above 50 percent. Early August soil moisture below 5 percent generally produced Douglas fir survival rates between zero and 15 percent.

5. Where early August soil moisture was between 3 and 5 percent, fall-planted shore pine survival was around 55 percent. Where early August soil moisture exceeded 5 percent, with less than 80 percent grass coverage, survival was 60 percent.

6. Partially shaded sites, where soil moisture approached 5 percent during early August, had fall-planted vine maple survival rates above 30 percent. Unshaded areas with 5 percent moisture had zero vine maple survival.

7. Fall-planted Aaron's beard survival was over 75 percent.

SECTION II – DISCUSSION AND RESULTS

Study Section II involved survival rates of Douglas fir, shore pine, vine maple, and salal within and next to an alder stand; survival of rhododendron seedlings in a Douglas fir stand; and survival of Indian ricegrass, thickspike wheatgrass, and spiny hopsage on highway cuts.

Douglas fir, shore pine, vine maple, and salal were planted in the fall on a north exposure within and next to a stand of red alder with trees up to ten feet tall. After three years, Douglas fir and salal survived best within the alder stand, while shore pine survived equally well within and next to the alders. Vine maple survival was best next to the alder stand. Survival percentages are listed in Table 4.

Table 4. Survival Percentages In and Near a Red Alder Stand
(Average for 16 plants of each species at each location)

Species	Within Alder Stand			Full Sunlight Next to Alder Stand		
	7/28/72	2/22/73	12/75	7/28/72	2/22/73	12/75
Salal	100	75	44	100	69	25
Douglas fir	94	87	44	62	56	19
Shore pine	69	56	37	37	37	31
Vine maple	63	25	25	91	75	44

Rhododendron plants were put out in three areas within a mature stand of Douglas fir. After planting, a large population of mountain beavers was observed in areas 2 and 3. The animals injured or destroyed many of the plants over the three-year study period, making the results less conclusive than anticipated. In area 1, the surviving plants (12 percent) more than doubled in size (from 15 cm to 46 cm) during the study period, but never flowered. Survival percentages are listed in Table 5.

Table 5. Survival Percentages of Rhododendron Planted in Fall 1971

Area	Number Planted	5/19/72	8/31/72	5/25/73	8/21/74	9/29/75
1	42	71	64	52	24	12
2	43	74	28	23	7	2
3	30	70	37	17	10	5

Thickspike wheatgrass, Indian ricegrass, and spiny hopsage were seeded in six areas with similar silt loam soil. Indian ricegrass and spiny hopsage are natives in adjacent sandy soils. Thickspike wheatgrass establishment was higher than either Indian ricegrass or spiny hopsage (see Table 6).

Table 6. Grass Establishment on Highway Cuts

Area	Species	Number of Seedlings/square meter			
		4/13/73	5/31/73	8/8/73	4/16/75
1.	Thickspike wheatgrass	Note 1	Note 1	Note 1	23
	Indian ricegrass	Note 1	Note 1	Note 1	None
	Spiny hopsage	22	11	2	None
2.	Thickspike wheatgrass	Note 1	Note 1	Note 1	29
	Indian ricegrass	Note 1	Note 1	Note 1	None
	Spiny hopsage	17	11	4	None
3.	Thickspike wheatgrass	Note 1	Note 1	Note 1	7
	Indian ricegrass	Note 1	Note 1	Note 1	5
	Spiny hopsage	16	4	None	None
4.	Thickspike wheatgrass	Note 1	Note 1	None	None
	Indian ricegrass	Note 1	Note 1	None	None
	Spiny hopsage	None	None	None	None
5.	Thickspike wheatgrass	Note 1	Note 1	Note 1	None
	Indian ricegrass	Note 1	Note 1	Note 1	None
	Spiny hopsage	2	None	None	None
6.	Thickspike wheatgrass	Note 1	Note 1	Note 1	20
	Indian ricegrass	Note 1	Note 1	Note 1	None
	Spiny hopsage	2	None	None	None

Note 1. Additional seedling emergence data is unavailable for the first three reading dates due to difficulty in differentiating between grass seedling types.

SECTION II – CONCLUSIONS

1. Douglas fir and salal survival within an alder stand was nearly twice as high as plantings next to the stand. Vine maple showed opposite results – nearly twice as many plants survived outside and adjacent to the alder stand.

2. Shore pine survival was about equal within and next to the alder stand.

3. A little over ten percent of rhododendrons planted within a mature Douglas fir stand survived.

4. On silt loam soils, thickspike wheatgrass establishment was higher than either Indian ricegrass or spiny hopsage.

SECTION III – DISCUSSION AND RESULTS

Ground coverage of erosion control grasses was observed in both eastern and western Washington (see Table 7).

Table 7. Ground Cover Percentage of Erosion Control Grasses

Species	Percent Ground Cover				
	North Exposure	South Exposure	West Exposure	East Exposure	Flat
(2,992 observations in eastern Washington)					
Crested wheatgrass	6.0	4.0	3.0	2.0	6.0
Hard fescue	4.0	0.5	2.0	2.0	9.0
Downy brome	0.7	6.0	3.0	4.0	0.5
(2,660 observations in western Washington)					
Perennial grass*	52	25	37	27	
Dandelion	4	10	19	15	
Annual grass	15	11	13	16	

*Red fescue, perennial rye, and Colonial bentgrass

In eastern Washington, crested wheatgrass and hard fescue (both perennial grasses) coverage was highest on north exposures and flat areas. Coverage of downy brome, an annual grass, was highest on south exposures. Other plants occasionally observed were: big sagebrush, green rabbitbrush, gray rabbitbrush, yellow flowering peppergrass, wild lettuce, basin wild rye, Sherman big bluegrass, and bulbous bluegrass. Study observations are summarized in Table 7.

In western Washington, perennial grass (red fescue, perennial rye, and Colonial bentgrass) coverage was highest on northern exposures followed by western exposures. Dandelion coverage was lowest on north exposures, and total plant cover was about equal for north and west exposures. The following plants were also observed, but coverage data was extremely low: buckthorn plantain, sheep sorrel, mayweed, Scotch broom, field horsetail, creeping buttercup, wild strawberry, Canadian thistle, Japanese clover, red clover, Himalayan blackberry, and western bracken fern.

SECTION III – CONCLUSIONS

1. In eastern Washington, erosion control grasses showed similar percentages of ground cover on north and south exposures. However, north exposure coverage was primarily perennial grasses, while downy brome, an annual grass, predominated on south exposures.

2. In western Washington, north exposures showed the highest percentage of ground cover for perennial grasses, with west second, followed by east and south with about equal coverage. Annual grass coverage was about equal for all exposures.

APPENDIX A

SOIL MOISTURE AND SOIL TEMPERATURE CHARTS

SITES 1 THROUGH 13

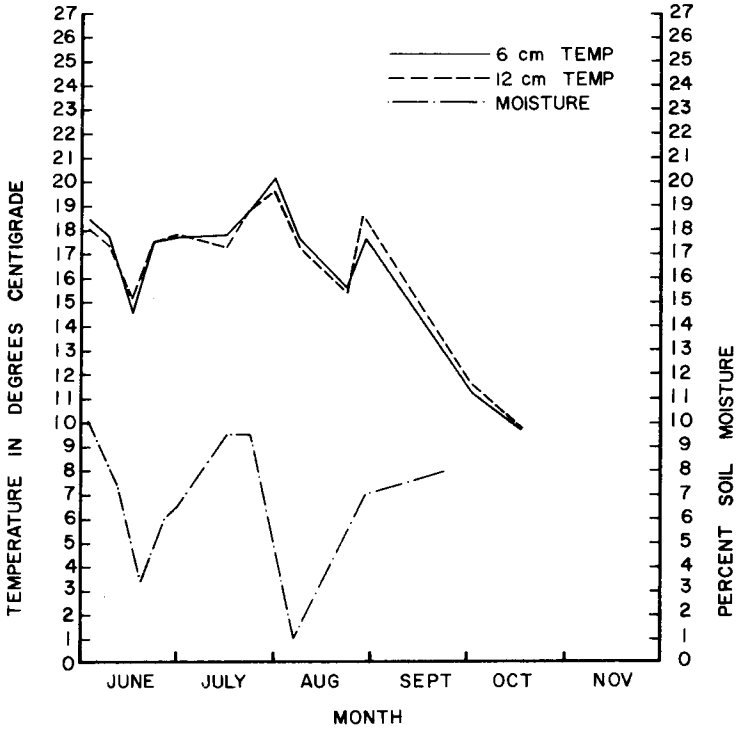

Figure A-1 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 1.

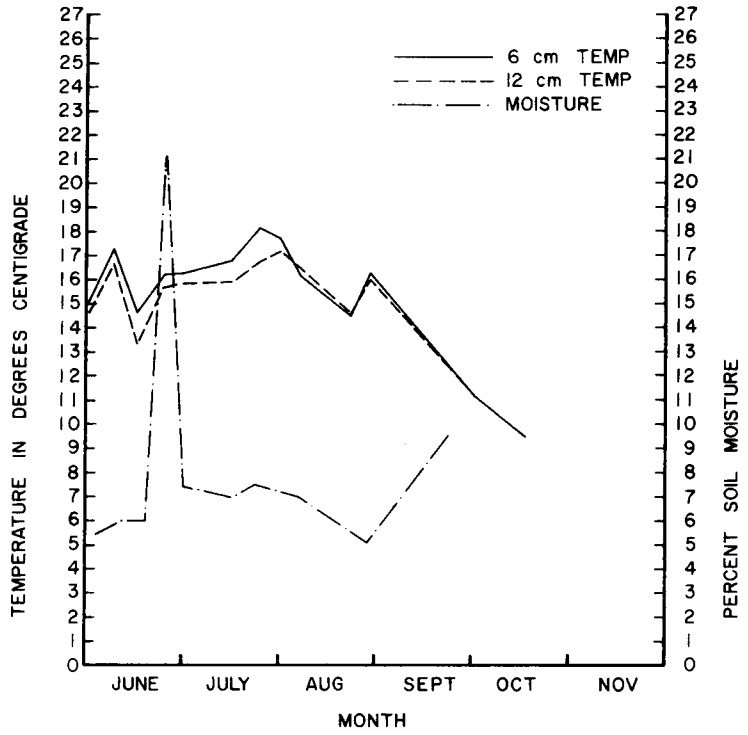

Figure A-2 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 2.

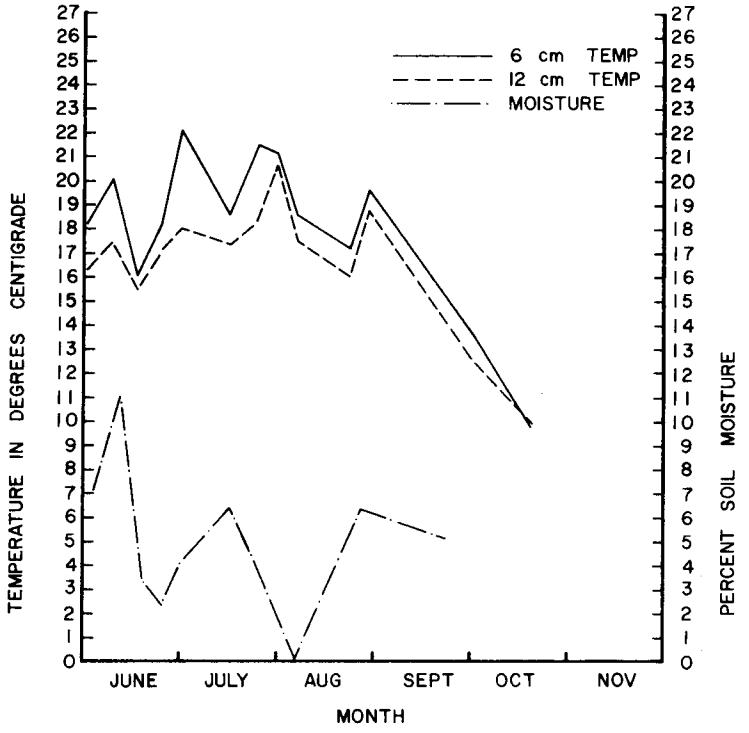

Figure A-3 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 3.

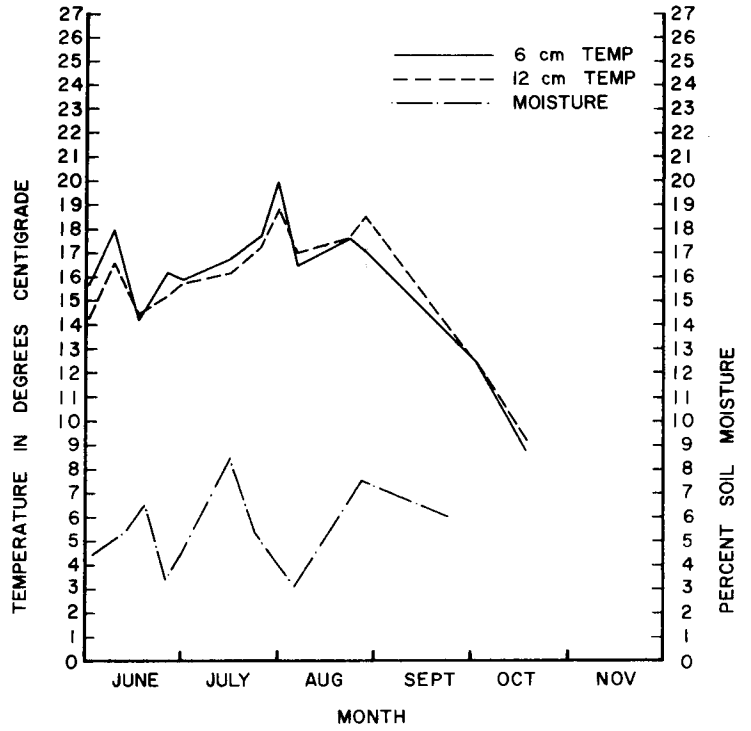

Figure A-4 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 4.

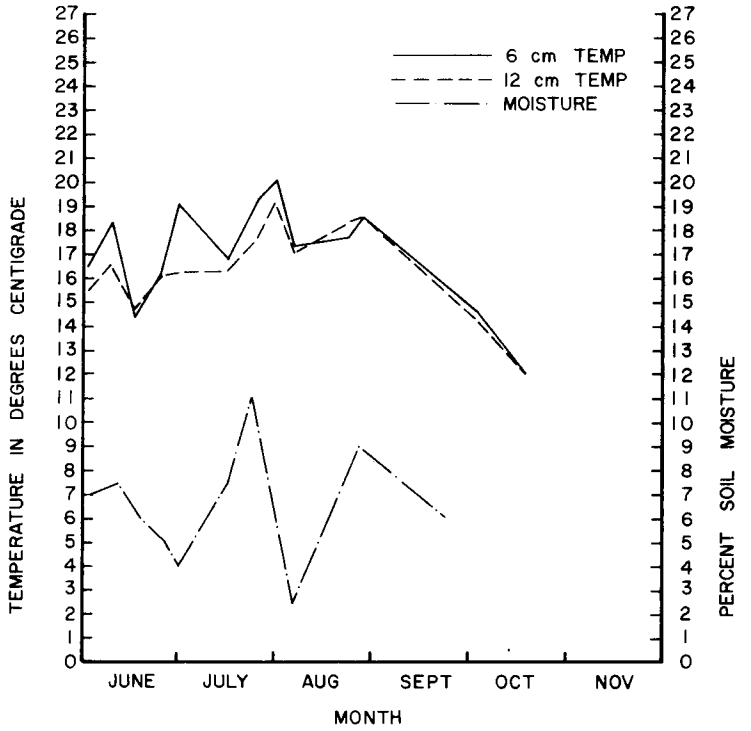

Figure A-5 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 5.

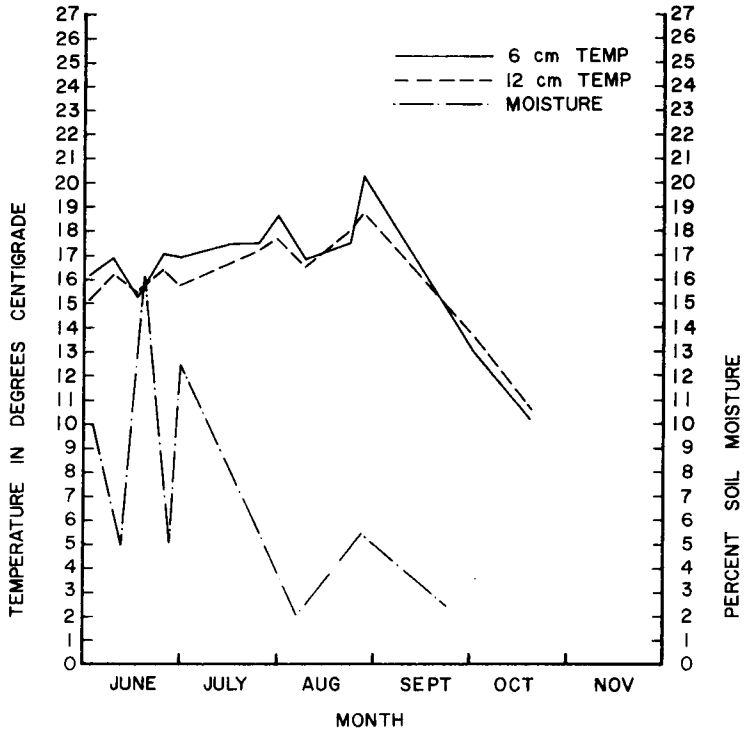

Figure A-6 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 6.

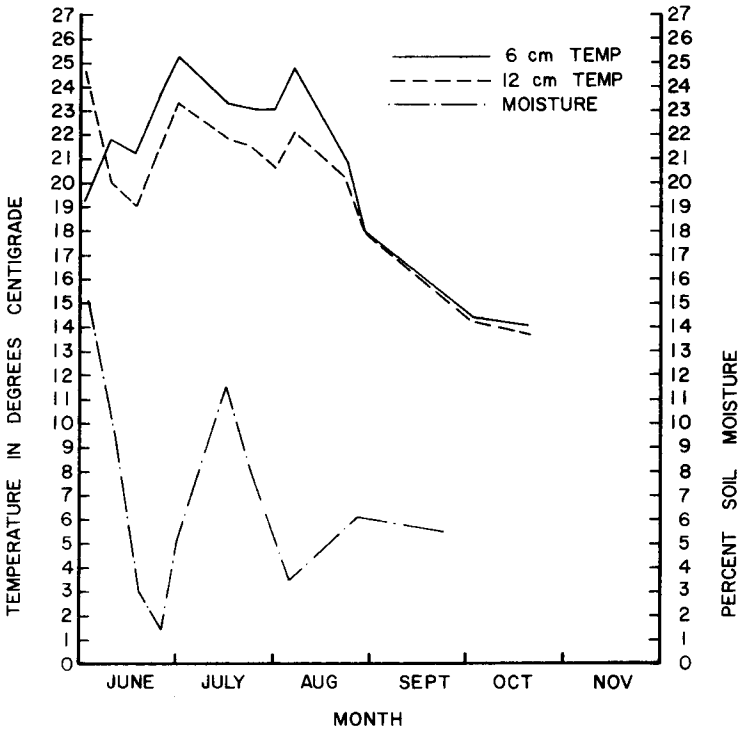

Figure A-7 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 7.

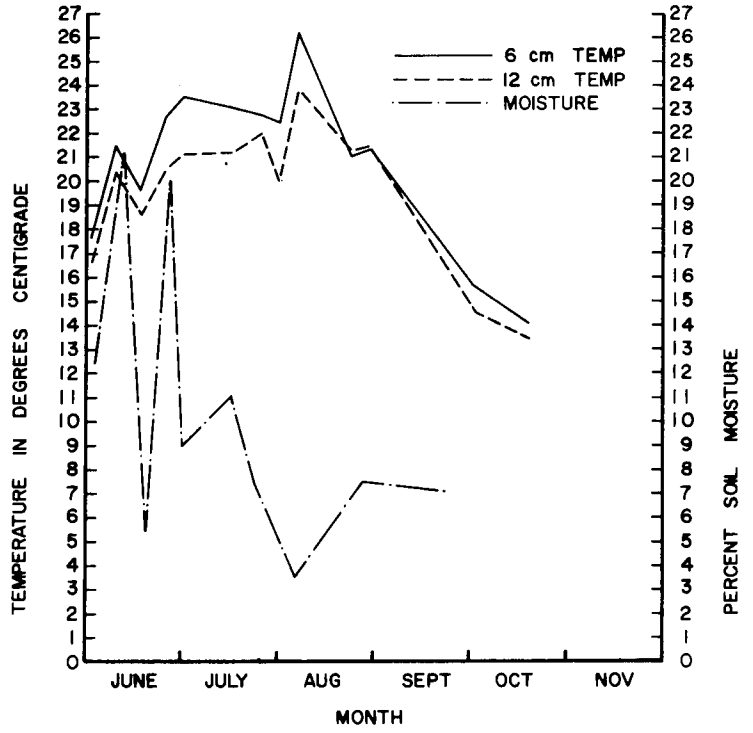

Figure A-8 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 8.

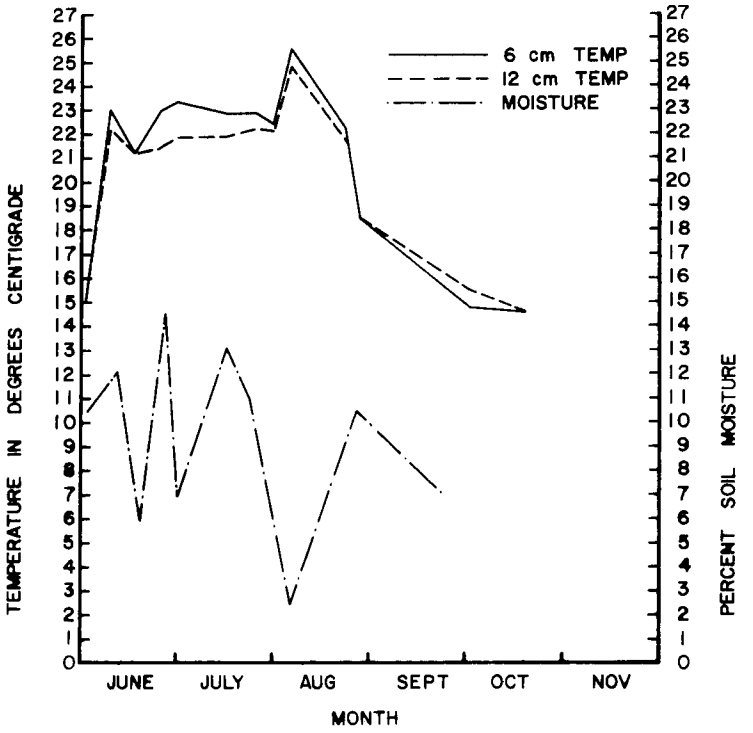

Figure A-9. – Soil Temperature Readings, 1972-75, and Soil Moisture readings at 3-6 Centimetres, 1973-75, for Site 9.

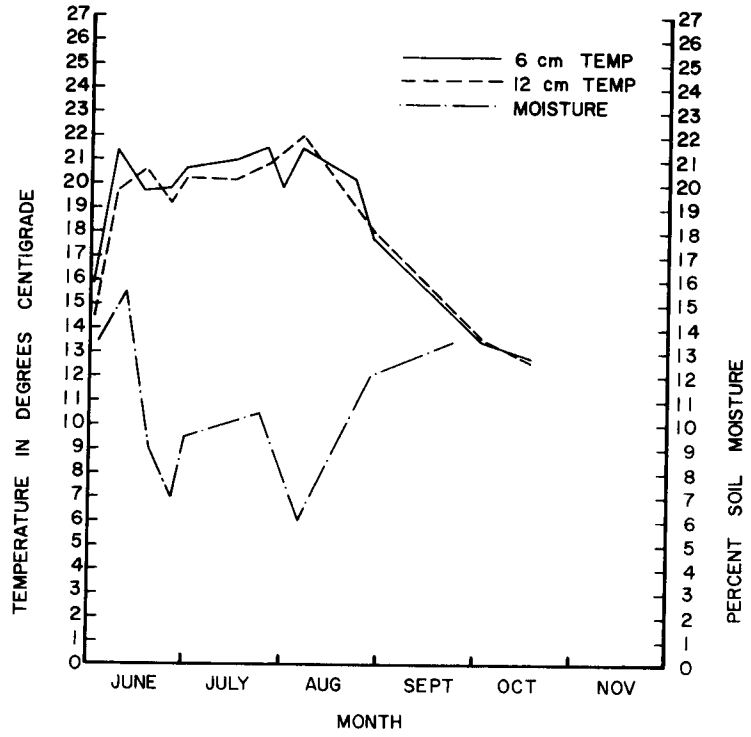

Figure A-10 – Soil Temperature Readings, 1972-75, and Soil Moisture Readings at 3-6 Centimetres, 1973-75, for Site 10.

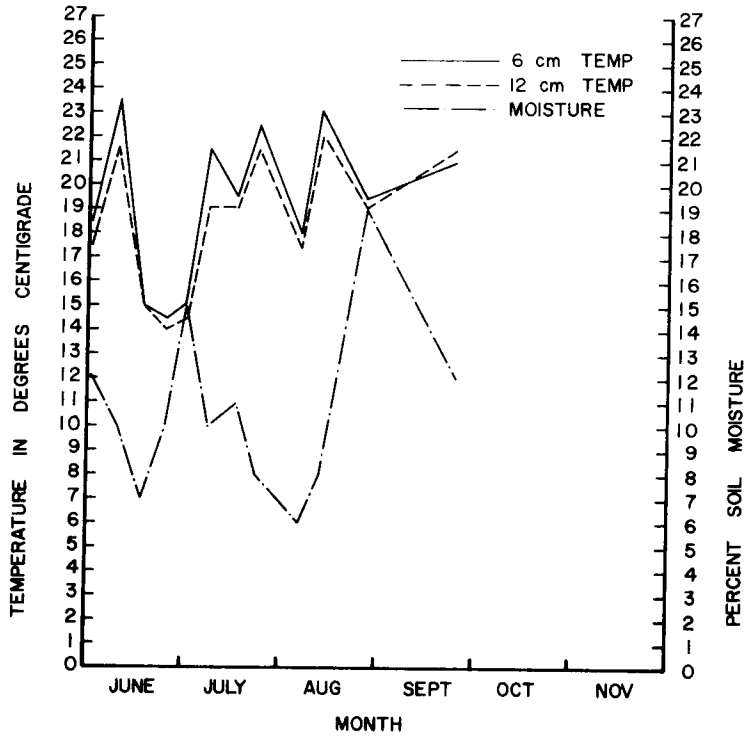

Figure A-11 – Soil Temperature Readings, 1975, and Soil Moisture Readings at 3-6 Centimetres, 1975, for Site 11.

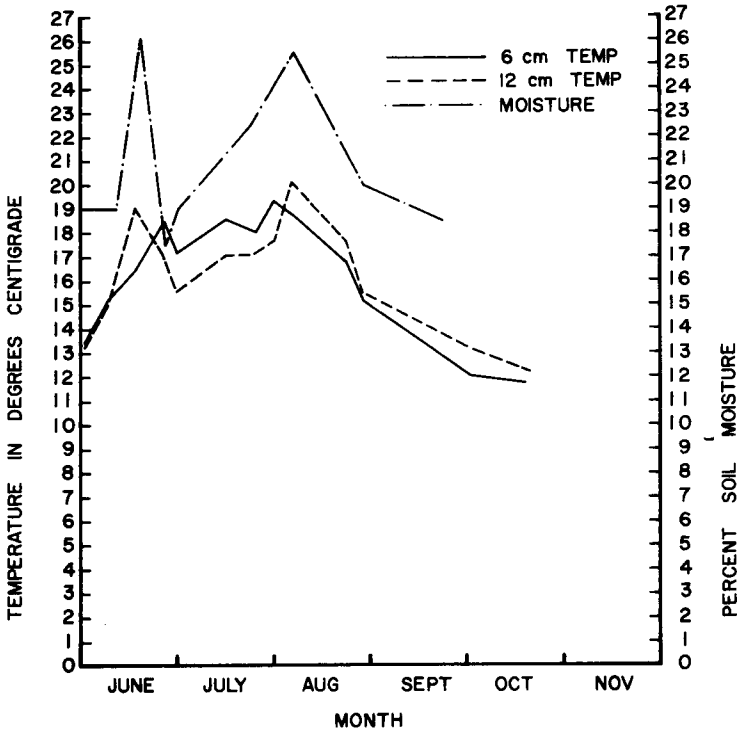

Figure A-12 – Soil Temperature Readings, 1975, and Soil Moisture Readings at 3-6 Centimetres, 1975, for Site 12.

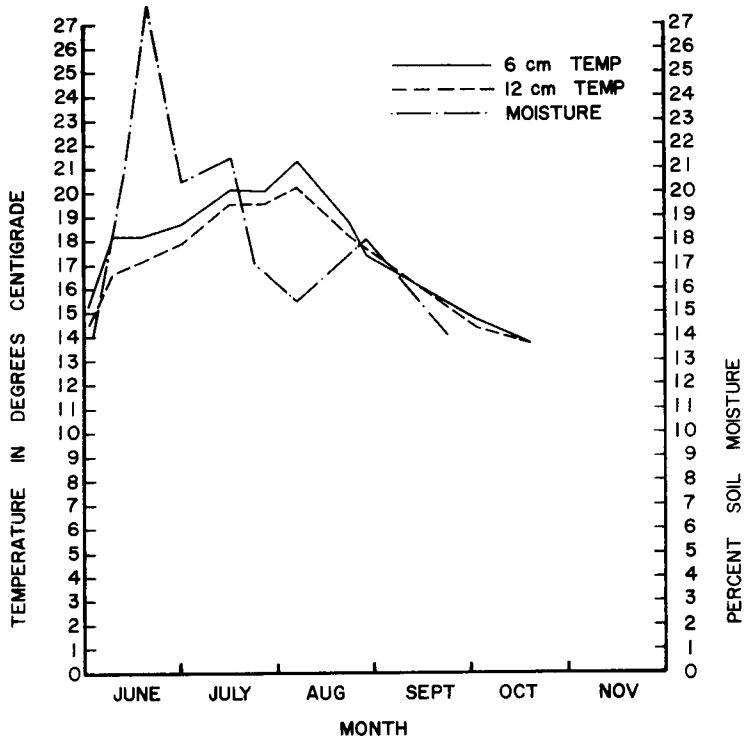

Figure A-13 – Soil Temperature Readings, 1975, and Soil Moisture Readings at 3-6 Centimetres, 1975, for Site 13.

APPENDIX B

SOIL PARTICLE SIZE AND pH
FOR SITES 1 THRU 14

SITE NUMBER	PERCENT PASSING SCREENS		pH	PERCENT			TEXTURE
	1/4"	NO. 10		SAND	SILT	CLAY	
1	63	78	5.8	51.2	31.0	17.8	LOAM
2	48	61	5.5	59.2	27.0	13.8	SANDY LOAM
3	75	56	5.6	56.2	28.0	15.8	SANDY LOAM
4	68	66	5.7	69.2	19.0	11.8	SANDY LOAM
5	67	73	5.8	81.2	14.0	4.8	LOAMY SAND
6	50	50	5.5	54.2	31.0	14.8	SANDY LOAM
7	100	100	5.6	78.2	15.0	6.8	LOAMY SAND
8	100	95	5.4	70.2	19.0	10.8	SANDY LOAM
9	97	89	6.1	76.2	15.0	8.8	SANDY LOAM
10	95	97	5.6	66.2	21.0	12.8	SANDY LOAM
11	100	100	5.3	63.2	23.0	13.8	SANDY LOAM
12	100	99	5.4	65.2	20.0	14.8	SANDY LOAM
13	98	60	5.7	67.2	20.0	12.8	SANDY LOAM
14	69	71	5.7	54.2	31.0	14.8	SANDY LOAM

APPENDIX C

COMMON AND BOTANICAL NAMES OF
SPECIES MENTIONED

COMMON NAME	BOTANICAL NAMES
Aaron's beard (St. Johnswort)	Hypericum calycinum
Alder, red	Alnus rubra
Bentgrass, colonial	Agrostis tenuis
Blackberry, Himalayan	Rubus thursanthus
Bluegrass, bulbous	Poa bulbosa
Bluegrass, big	Poa ampla
Bracken fern, western	Pteridium aquilinum pubescens
Brome, downy	Bromus tectorum
Buttercup, creeping	Ranunculus repens
Camomile, mayweed	Anthemis cotula
Ceanothus, Point Reyes	Ceanothus gloriosus
Clover, red	Trifolium pratense
Clover, black medic (Japanese)	Medicago lupulina
Dandelion, common	Taraxacum officinale
Dogwood, red twig (red-osier)	Cornus stolonifera
Doublas fir, common	Pseudotsuga taxifolia
Cypress, Lawson (false cypress)	Chamaecyparis lawsoniana
Fescue, hard	Festuca ovina duriuscula
Fescue, red	Festuca rubra
Hazelnut, western	Corylus cornuta californica
Hemlock, mountain	Tsuga mertensiana
Hopsage, spiny	Grayia spinosa
Horsetail, field	Equisetum arvense
Maple, vine	Acer circinatum
Oregon grape	Mahonia aquifolium
Pepperweed, clasping	Lepidium perfoliatum
Pine, shore	Pinus contorta
Plantain, buckthorn	Plantago lanceolata
Rabbitbrush, Douglas	Chrysothamnus nauseosus
Rabbitbrush, Douglas	Chrysothamnus viscidiflorus
Rhododendron, coast California	Rhododendron macrophyllum
Ricegrass, Indian	Oryzopsis, Hymenoides
Ryegrass, perennial	Lolium perenne
Sagebrush, big	Artemisia tridentata
Salal	Gaultheria shallon
Scotch broom	Cytisus scoparius
Sheep sorrel	Rumex acetosella
Strawberry, bracted	Fragaria bracteata
Thistle, Canada	Cirsium arvense
Wheatgrass, crested	Agropyron cristatum
Wheatgrass, thickspike	Agropyron dasystachrum
Wildrye, basin	Elymus cinereus

APPENDIX D

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