Riparian Vegetation Recovery in the Blast and Airfall Tephra Zones of Mount St. Helens, Washington

by

Christen W. Kiilsgaard

A THESIS

Submitted to

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Riparian vegetation patterns within the blast, downstream of blast, and airfall tephra zones of Mount St. Helens are related to initial and secondary volcanic disturbance, post-eruption fluvial landforms, channel geometry, and streamflow characteristics. Vegetation patterns were determined from species presence observed on transects across landforms developed along the streams. Distinct species distribution patterns were found on three common geomorphic landforms: active channel, lower terrace-floodplain and upper terrace. Plant cover and species diversity vary greatly among landforms and among volcanic disturbance zones. Vegetation recovery was negligible recovery at the most severely impacted sites but approached pre-eruption values in the Airfall Tephra

Zone. The large between- and within-site variation in vegetation parameters is controlled by fluvial erosion and sedimentation affecting substrate stability and microsite suitability. At all sites, vegetation establishment near the active channel is greatly restricted by fluvial erosion and tephra deposition. Rhizomatous and prolifically seeding species were most common on highly altered landforms.

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This thesis is dedicated to my family, Sarah and Carl.

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INTRODUCTION

Response of riparian vegetation in coniferous forest ecosystems to volcanic disturbance has been conjectured but not examined in detail (Franklin *et al*. 1985; Means *et al*. 1982). Initial observations of riparian vegetation following the 1980 eruptions of Mount St. Helens, Washington indicated that recovery would be accelerated along stream channels relative to upland areas due to erosion of tephra mantles by surface water and to favorable moisture conditions (Moir and Mitchell, unpublished data; Means *et al*. 1982). However, the abundance of riparian vegetation declined after the first growing season because hillslope sediments were transported into stream channels burying established vegetation and increasing channel instability (Kiilsgaard *et al*. 1986).

The 1980 volcanic events at Mount St. Helens dramatically changed the system of sediment production and transport by altering hillsope hydrology, channel characteristics, and sediment availability in a 600^2

kilometer area around the mountain (Janda and Swanson 1986; Martinson _et_ _al_. 1984; Lisle _et_ _al_. 1983).

Remobilization of tephra varies substantially from one drainage to another, depending on basin-specific volcanic impacts on sediment supply, storage, pre-eruption topography, and vegetaton condition before the eruption (Janda and Swanson 1986). In a small watershed (2.4 km^2) within the Blast Zone, 834,000 m^3 of tephra were deposited in the basin. Subsequent debris slides, rill and inter-rill erosion processes carried 103,000 m^3 of the tephra sediment to the stream channel in the first year after the eruption (Smith 1984).

Riparian vegetation response to stream channel alteration varies widely and is affected by a variety of primary and secondary volcanic disturbances, including complete burial by debris avalanches, scouring by lahars, high levels of wood and sediment input to Blast Zone channels and a rain of tephra in the Airfall Tephra Zone beyond the perimeter of the Blast Zone (fig. 1). Subsequent plant recovery depends on: intensity of initial disturbance, temperature and depth of initial deposit, intensity and persistence of secondary processes such as, erosion, deposition and sediment transport, and proximity to seed source.

Vegetation recovery within the three drainages of this study (fig.1, table 1) is highly variable because of the strong influence of geomorphic processes. In intensively impacted stream channels with high levels of secondary tephra deposition input, such as Bean Creek, the original channel and riparian vegetation were completely obliterated. Here, lateral channel cutting and continual remobilization of tephra retard plant establishment. The intensity of volcanic disturbances diminishes outward from the mountain. Along Clearwater Creek, channel form was altered but not completely destroyed. The blast toppled mature conifers into the stream, greatly increasing channel complexity and affecting channel stability. Vegetation recovery is considerably advanced within this more stable riparian zone. The Elk Creek drainage, in the Airfall Tephra Zone, was little modified by the volcanic events. Tephra deposition within this zone was insufficient to trigger modification of channel morphology and riparian vegetation except on surfaces adjacent to the active channel. Elk Creek plant cover and species richness approach values of undisturbed forested riparian areas reported in the literature (Lee 1983; Campbell and Franklin 1979; Hawk and Zobel 1974).

This study considers recovery of riparian vegetation in three drainages in the northeast of Mount St. Helens for the period 1981-1985. The specific objective is to

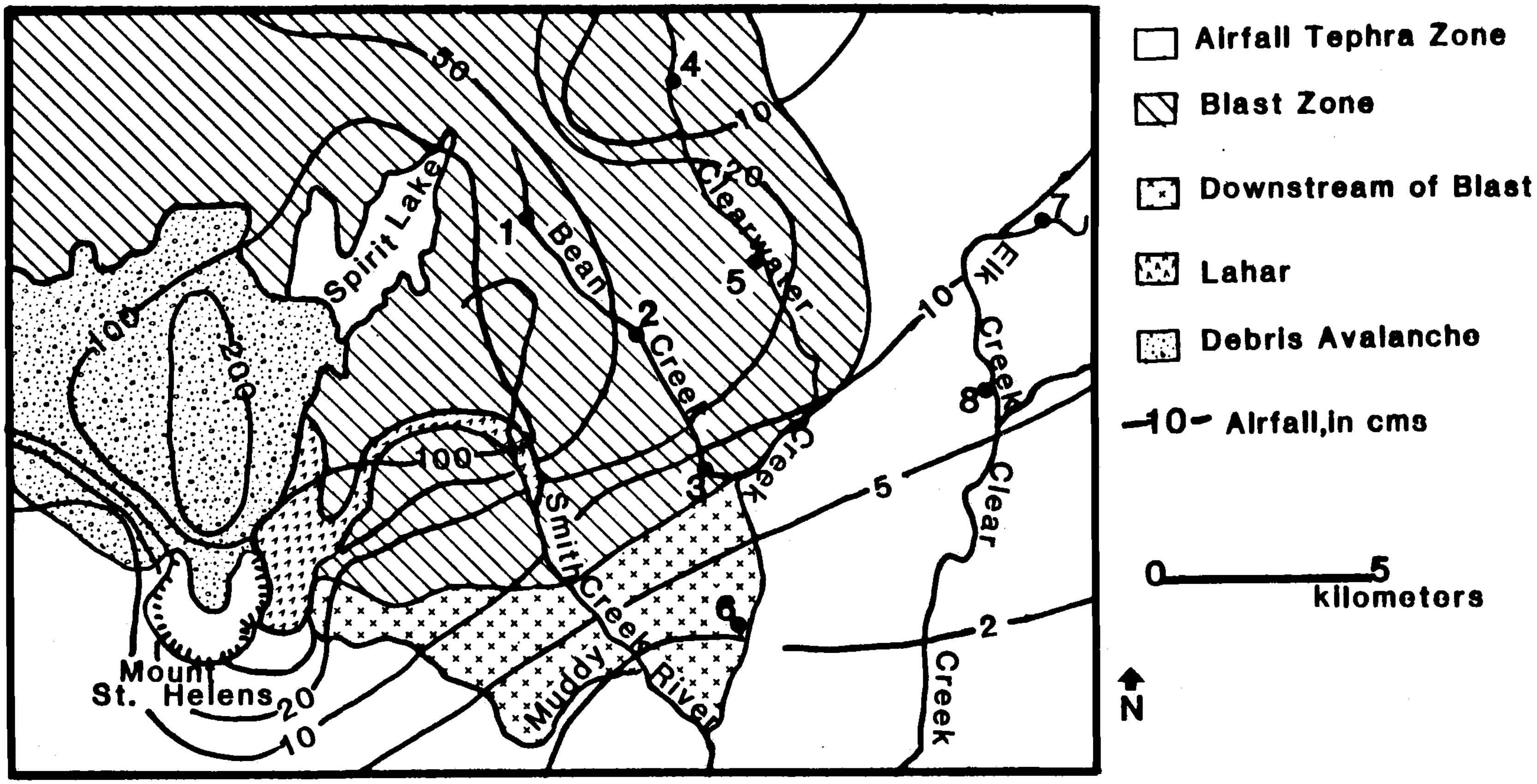

FIG. 1. Location of Mount St. Helens study sites altered by the lateral blast, downstream tephra deposition and airfall tephra deposition from the 1980 eruptions (after Martinison *et al*. 1984).

Table 1. Characteristics of the study sites' riparian vegetation and stream channel environments (after Swanson et al. unpublished manuscript).

Site	Number on Study Site Map	Volcanic Disturbance Classification	Stream Order	Drainage Area(ha)	Initial degree of Resetting of Vegetation	Initial Change in Channel Complexity	Stability of Channel Location	Change in Sediment Load	
								Magnitude	Duration
Upper Bean	1	Blast Zone	2	110	extensive, some resprouting of shrubs on upper terraces	decreased by debris flow	high	moderate	decades
Middle Bean	2	Blast Zone	3	820	complete removal of all vegetation	decreased by debris flow	low	very high	many decades
Lower Bean	3	Blast Zone	5	6,860	extensive, some remnant vegetation on upper terraces	decreased by sediment deposition	low	high	decades
Upper Clearwater	4	Blast Zone	3	1,060	extensive, some resprouting shrubs around fallen trees	increased by fallen trees	high	moderate	years
Middle Clearwater	5	Blast Zone	4	3,840	extensive, remnant vegetation on streambank	increased by fallen trees	high	moderate	years
Lower Clearwater	6	Downstream of Blast Zone	5	10,120	lower terraces buried by sediment, upper terraces intact	decreased by sediment deposition	low	high	decades
Upper Elk	7	Airfall Tephra Zone	2	200	minimal	minimal	high	minimal	years
Lower Elk	8	Airfall Tephra Zone	4	2,170	slight, some lower terrace burial	minimal	high	slight	years

measure the rate of riparian vegetation recovery across gradients of disturbance severity and watershed size. This involved identifying the relationship between fluvially-induced disturbances and vegetation response, and determining vegetation establishment within the riparian zone.

STUDY AREA

Bean, Clearwater, and Elk Creek drainages are located approximately 11, 14 and 20 km, respectively, northeast of Mount St. Helens (fig. 1). The mainstem channels of Bean and Clearwater Creek are fifth order (Strahler 1957) tributaries to the Muddy River draining the northeastern section of the mountain. The mainstem channel of Elk Creek is a fourth order channel draining into Clear Creek which then flows into the Muddy River.

The characteristics of riparian environments and channel morphology within the study drainages have been broadly classified and described with respect to reestablishment of riparian vegetation; change in channel form, structural complexity and stability, and the magnitude and duration of high sediment flows (Swanson, unpublished manuscript). Table 1 summarizes these conditions for the study sites.

Climate in the study area is distinctly maritime, cool and moist with tempered extremes. Mean annual temperature recorded at Spirit Lake Ranger Station (975 m in elevation) was 5.6 C with a mean January low of -2 C and a mean high of 22.3 C in July. Average annual precipitation is heavy, ranging from 165 cm to more than 356 cm, with 75 percent of the precipitation occurring between October and April, much of it falling as snow

(U.S.D.A. Forest Service 1981).

Pre-eruption forested vegetation within the Bean, Elk and Clearwater Creek drainages ranged from *Tsuga heterophylla* Zone communities in lower reaches to the wetter and cooler *Abies amabilis* Zone communities near stream headwaters. Upslope forest communities within this zone were principally mixed coniferous forests composed of *Thuja plicata, Tsuga heterophylla, Pseudotsuga menziesii, Pinus contorta*, and *Abies* spp. (Halpern and Harmon, 1983).

METHODS

In 1981, seven sites were selected for this research. An additional site, lower Bean Creek, (site 3, fig. 1) was added in 1983. Study site locations were chosen to represent increasing stream order and drainage basin size within the Blast and Airfall Tephra Zones. At each site, three permanent transects, each one meter wide, were established perpendicular to the main highwater channel. Length of transects varied according to stream order but all transects extended well beyond the normal flood zone.

A series of one meter square sample plots was established at five meter intervals along each transect. The first sample plot along each transect began at the water's edge on fully exposed soil surfaces. At each plot, an estimate of plant species aerial cover, geomorphic surface type, erosion/sedimentation regime, and vegetation microsite (rooting medium) were determined.

Four geomorphic surface types were recognized and defined by hydrologic interaction: depositional bar, active channel, lower terrace or floodplain, and upper terrace. Estimates of flow duration and flooding frequency are the independent parameters employed to characterize these surfaces.

Depositional bars occur within the active channel and generally correspond to a water level slightly higher than low flow (Hupp 1983). Active channels represent the surface that is wholly or partly covered by stream flow and extends to the break in slope of the lower terrace. Floodplains, or lower terraces, are flat surfaces inundated every one to three years (Hupp and Osterkamp 1985). Flooding activity on lower terraces described in this study is much more frequent, occurring several to many times a year. Flood duration and intensity is much less on lower terraces than in the active channel. Upper terraces are incised former floodplains and occur at various heights above the present lower terraces. Flood frequency is low, and depends on local conditions. In general, the upper terraces have not been inundated since 1981.

Plant cover estimates were made for each plot. Cover classes were estimated at 1% intervals up to 5% cover, and at 5% intervals thereafter. Overstory cover was included in the estimate permitting total plot cover to exceed 100%. Additionally, each species was noted as being either residual (established before the eruption) or established from seed. Several important rhizomatous species (e.g., various species of *Carex* or *Rubus*) were excavated to determine if the plant was a seedling or represented vegetative expansion of an established plant.

Three microsite groups were recorded for each plot: residual soil, reworked tephra, and woody or rocky debris. Residual soil microsites are those where pre-eruption soil is exposed and potentially colonized by plants. Reworked tephra microsites consist mostly of alluvial or colluvial deposits. Woody or rocky debris microsites are those where the rooting medium is on top of downed logs, under elevated logs, or in former exposed stream beds with rocky debris.

Comparisons of plant abundance and species richness among geomorphic surfaces and years of the study are tested by Duncan's multiple range test (Sokal and Rohlf 1981). All analyses were performed using SPSS programs (Nie *et al*. 1975).

The degree of plant establishment was based on an importance value, determined by summing species frequency with mean plant cover. Importance values were summarized for each plant by combining plots by geomorphic surface type.

RESULTS

Vegetation Recovery by Disturbance Zone

Mean percent plant cover was significantly greater in the Airfall Tephra Zone than in either the Blast (upper and middle Clearwater sites and Bean drainage) or Downstream of Blast Zones (101-130% vs 5-37, 2-17 and 42-46%; $P<0.01$; fig. 2). Similarly, by 1983, cover at the Clearwater Blast Zone sites was significantly greater ($P<0.01$) than at the Bean drainage sites. Plant cover relationships between the Clearwater Blast Zone and Downstream of Blast Zones exhibit a reversed trend. In 1981 and 1982, cover was signifcantly greater ($p<.05$) at the Downstream of Blast Zone site, however, by 1985 plant cover within the Blast Zone nearly equaled that of the downstream site (37% vs 46%). The pattern of increased plant cover shows a strong positive relationship with the gradient of diminished disturbance severity following primary volcanic effects, as well as increased time since disturbance.

Vegetation Recovery by Geomorphic Surface

Mean plant abundance varies greatly within a site and between sites (table 2). Plant abundance values within the Clearwater and Bean Creek drainages show a trend of increasing cover away from the active channel.

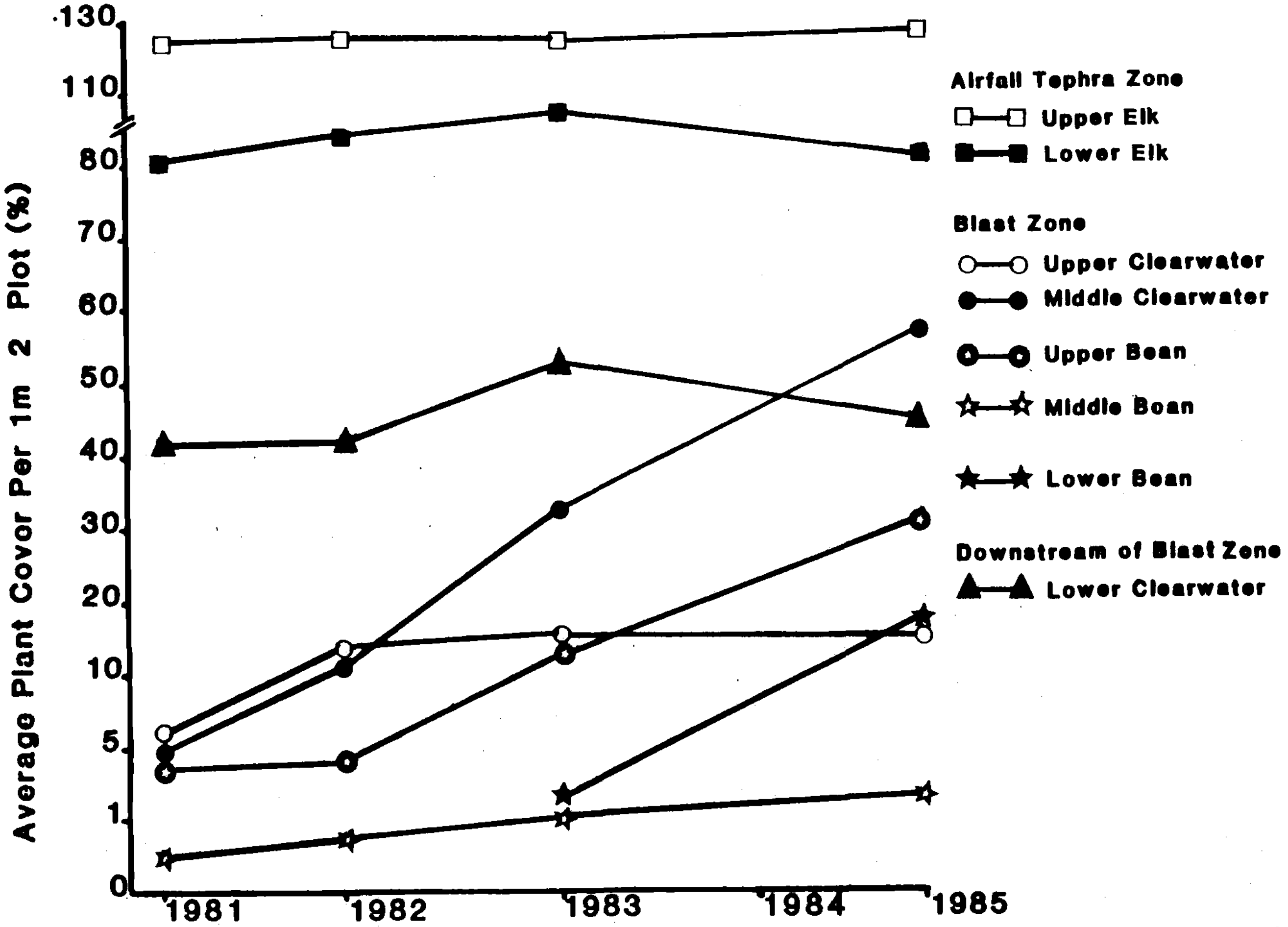

FIG. 2. Average plant cover values for study sites. Bean Creek drainage represents Blast Zone disturbance with heavy secondary tephra deposition. Upper and Mid Clearwater are Blast Zone sites with moderate primary and secondary tephra deposition. Lower Clearwater Creek is an Downstream of of Blast Zone site with minimal primary deposition but heavy secondary deposition. Elk Creek is in a part of the Airfall Tephra Zone that was minimally disturbed by primary or secondary tephra deposition.

Table 2. Mean percent plant cover by geomorphic surface for study site drainages.

Geomorphic Surface	Upper Drainage				Middle drainage				Lower Drainage			
	1981	1982	1983	1985	1981	1982	1983	1985	1981	1982	1983	1985
BEAN DRAINAGE												
Active Channel	2.5 a	2.5 a	0.7 a	1.5 a	0.2 a	0.5 a	0.7 a	1.4 a	--	--	1.0 a	0.4 a
	(0-5)	(1-5)	(0-3)	(1-15)	(0-2)	(0-3)	(0-3)	(0-5)			(0-3)	(0-6)
Lower Terrace	2.3 a	8.0 b	25.0 b	55.7 b	0.4 a	0.8 a	1.0 a	2.0 a	--	--	2.2 a	6.6 b
	(1-5)	(0-23)	(0-55)	(29-80)	(0-1)	(0-4)	(0-5)	(0-15)			(0-19)	(0-25)
Upper Terrace	7.5 b	2.5 a	10.8 b	36.7 b	1.0 a	0.8 a	1.7 a	0.5 a	--	--	5.4 a	48.1 c
	(0-29)	(2-19)	(3-45)	(0-82)	(0-6)	(0-2)	(0-5)	(0-2)			(1-16)	(3-122)
CLEAR WATER DRAINAGE												
Active Channel	10.3 a	25.0 a	25.3 a	3.3 a	6.2 a	10.7 a	19.6 a	31.4 a	0.7 a	1.2 a	1.7 a	2.1 a
	(0-37)	(0-100)	(0-101)	(0-23)	(0-54)	(0-83)	(0-103)	(0-85)	(0-8)	(1-76)	(3-81)	(2-143)
Lower Terrace	3.3 b	12.2 b	17.9 a	3.0 a	6.6 a	11.7 a	29.8 a	70.6 b	20.3 b	16.5 b	24.4 b	24.6 b
	(0-7)	(1-40)	(1-83)	(0-25)	(0-32)	(0-87)	(0-101)	(1-150)	(0-132)	(1-84)	(1-114)	(0-110)
Upper Terrace	4.2 b	5.4 b	5.3 b	43.7 b	3.8 a	12.0 a	46.8 b	72.7 b	103.8 c	107.3 c	132.8 c	110.0 c
	(0-13)	(0-25)	(1-13)	(1-96)	(0-7)	(1-76)	(3-81)	(2-143)	(12-179)	(23-208)	(11-194)	(8-184)
ELK DRAINAGE												
Active Channel	125.0 a	110.6 a	120.0 a	115.2 a					76.9 a	55.5 a	56.9 a	21.5 a
	(20-154)	(30-187)	(10-246)	(61-199)					(0-196)	(1-133)	(0-178)	(0-120)
Lower Terrace	126.3 a	123.2 a	129.3 a	146.0 a					43.5 b	71.8 a	91.4 b	68.3 b
	(105-160)	(95-168)	(95-175)	(110-180)					(0-194)	(0-200)	(0-206)	(0-191)
Upper Terrace	118.4 a	145.6 a	132.3 a	158.3 a					121.8 c	147.6 c	161.4 c	169.6 c
	(116-250)	(114-245)	(99-224)	(113-228)					(79-193)	(98-212)	(97-232)	(98-210)

Note: The range in cover is indicated in parentheses below the mean. Numbers followed by the same letter within a column are not significantly different (p=0.05; Duncan's multiple range test).

Distinction in plant establishment by geomorphic surface was generally not apparent in 1981 or 1982, with the exception of the lower Clearwater site where the upper terraces are sufficiently removed from the active channel to preclude extensive alluvial tephra deposition. By 1985, all sites except middle Bean had much greater vegetation development on the upper terraces than in the active channel.

The lower intensity of volcanic events in the Airfall Tephra Zone is mirrored in high and unchanging plant cover for the upper Elk Creek site (table 2). However, the cumulative effect of stream transported tephra to downstream areas, and concomitant increased channel instability, reduces plant cover within the active channel and produces a pattern of plant cover changes at the lower Elk Creek site similar to the low gradient Clearwater and Bean Creek sites.

Fluvial remobilization of tephra influences plant establishment through the creation of new microsites. Table 3 shows the importance of microsites relative to their areal extent. Microsites containing residual soil, which are areally the least extensive, have the highest plant cover values. A common feature of microsites with residual soil is that they occupy relatively steep slopes (generally exposed former stream banks or upturned root

Table 3. Proportion of total plant cover and non-vegetated plots by occurrence on microsites.

Site Microsite Group	No. Plots	% Total Microsites	% Total Plant Cover	% Non Vegetated Plots
UPPER BEAN				
Reworked Tephra	56	75%	52%	37%
Residual Soil	8	11	40	0
Woody Debris	11	14	8	27
MIDDLE BEAN				
Reworked Tephra	78	63	55	70
Residual Soil	0	0	0	0
Woody Debris	46	37	45	74
LOWER BEAN				
Reworked Tephra	53	69	20	38
Residual Soil	9	12	71	11
Woody Debris	15	19	9	40
UPPER CLEARWATER				
Reworked Tephra	77	75	41	25
Residual Soil	7	7	45	0
Woody Debris	22	18	14	45
MIDDLE CLEARWATER				
Reworked Tephra	76	72	71	21
Residual Soil	13	12	26	0
Woody Debris	17	16	3	73
LOWER CLEARWATER				
Reworked Tephra	92	73	15	35
Residual Soil	19	15	82	0
Woody Debris	15	12	3	53
UPPER ELK				
Reworked Tephra	6	7	5	50
Residual Soil	71	82	91	1
Woody Debris	9	11	4	44
LOWER ELK				
Reworked Tephra	48	42	23	37
Residual Soil	46	40	60	4
Woody Debris	20	18	17	54

wads) which preclude heavy tephra deposition. Microsites that are depositional in character (primary or secondary tephra deposits) which are most abundant in the study area, are not yet conducive to extensive plant establishment. This is particularly apparent in the Bean drainage where deposit thicknesses are commonly greater than one to two meters. Here, secondary geomorphic processes have had little effect in liberating residual rootstocks or exposing pre-eruption soil.

Species richness, expressed by species number, within the riparian zone follows the pattern of plant abundance with increased diversity on infrequently flooded geomorphic surfaces (fig. 3). The two exceptions to this trend are the upper Bean and middle Clearwater sites where fluvial erosion has exposed residual soil on former stream banks. Sites in the Airfall Tephra Zone had significantly greater mean species richness than Blast Zone sites (average richness 4.67 vs 1.91; $P<0.01$). Similarly, species richness in the Downstream of Blast Zone was significantly greater than Blast Zone sites (4.39 vs 1.91; $P<0.01$). Differences in species richness within the Blast Zone sites and between the Downstream of Blast and Airfall Tephra Zone sites were not statistically significant.

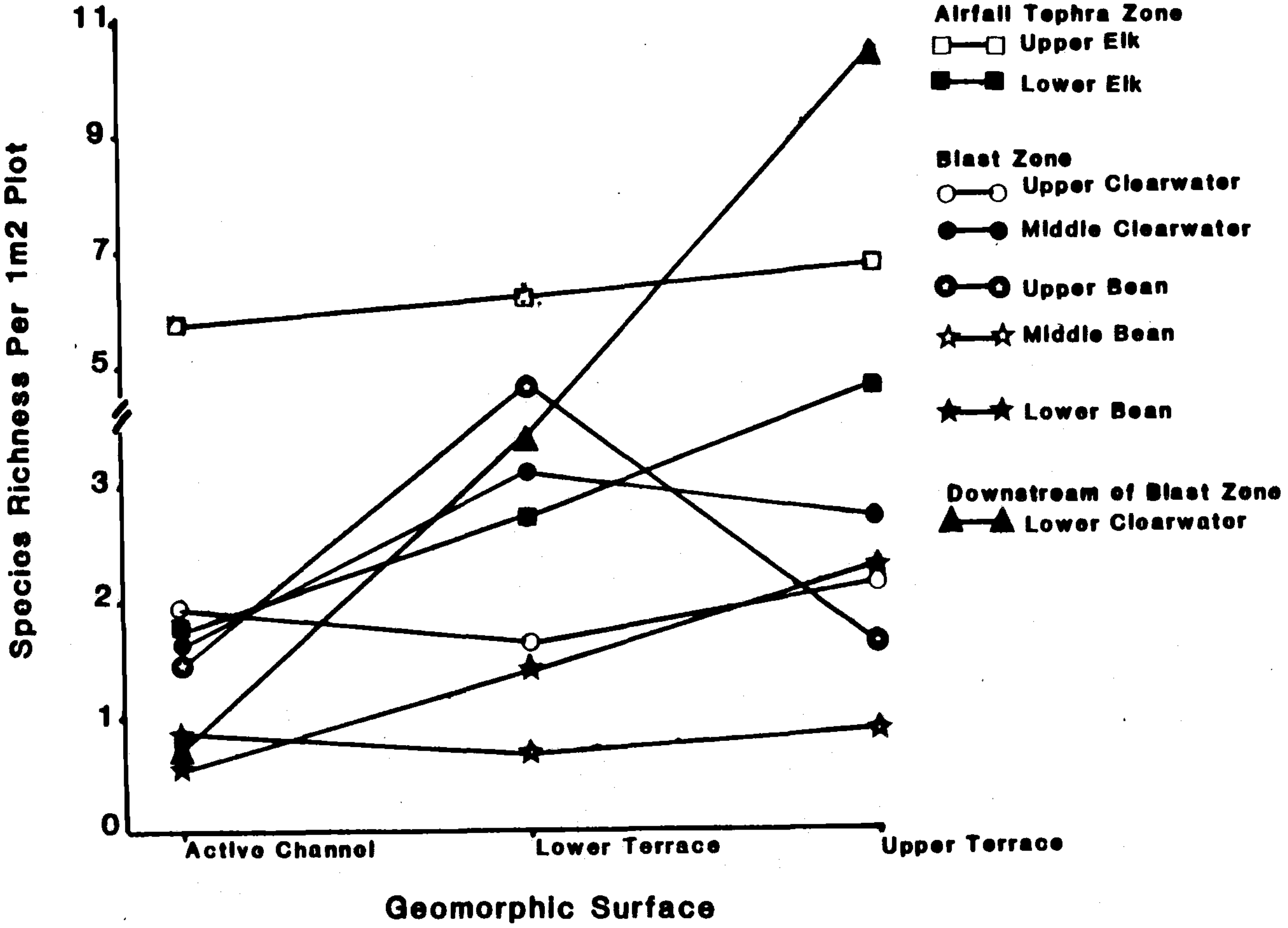

FIG. 3. Mean species richness by geomorphic surface for study sites. Values represent averages from the four years of the study.

Floristic response

Species composition within the Elk Creek drainage is comparable to that found at undisturbed, forested riparian zones of similar elevations in the Pacific Northwest (Campbell and Franklin 1979; Lee 1983). Understory vegetation is dominated by shrubs, primarily *Vaccinium ovalifolium* and *Rubus spectabilis* with *V. membranaceum* and *Ribes lacustre* being important contributors (table 4). Herbaceous vegetation is most diverse at the margins of the active channel, where colonization favors those plants adapted to fluvial disturbance. Along Elk Creek, the strongly rhizomatous *Petasites frigidus* dominates these margins. Overstory vegetation at the upper watershed stream site is primarily dominated by conifers, with *Tsuga heterophylla* and *Abies amabilis* locally important. At the lower watershed site the coniferous overstory is replaced by *Alnus rubra, Acer macrophyllum* and *A. circinatum* on the active channel and lower terrace surfaces. Upper terrace forests include *Populus trichocarpa* and conifers.

Plant cover in riparian areas within the Blast Zone is composed of plants resistant to hydraulic disturbance or by plants that readily colonize from wind-borne seeds (table 4). Many important colonizers are ruderal species which commonly establish on recently disturbed upland forest sites e.g., *Epilobium angustifolium, Senecio*

Table 4. Percent frequency and importance values for the 10 most commonly occurring species by geomorphic surfaces in the study area drainages. Importance values (I.V.) are calculated by adding percent frequency to mean percent cover for each species. Residual species which survived the 1980 disturbances (indicated by a (+); wind or water dispersed species are indicated by a (*).

LIFE FORM	ACTIVE CHANNEL		LOWER TERRACE		UPPER TERRACE		TOTAL	
SPECIES	FREQ	I.V.	FREQ	I.V.	FREQ	I.V.	FREQ	I.V.
BLAST ZONE- BEAN DRAINAGE								
TREES								
Acer circinatum +	--	--	4	14	4	7	3	10
SHRUBS								
Rubus spectabilis *	2	2	6	26	5	8	3	18
Rubus ursinus *	10	22	6	7	1	3	5	13
Rubus parviflorus +	--	--	2	4	6	17	3	12
Vaccinium ovalifolium +	--	--	6	11	10	26	5	12
HERBS & GRASSES								
Anaphalis margaritacea *	11	12	17	19	16	24	15	19
Epilobium angustifolium *	6	7	6	13	10	16	10	17
Agrostis alba *	11	13	9	12	19	12	19	12
Equisetum arvense *	6	7	9	18	4	11	4	11
Senecio sylvaticus *	4	19	2	4	4	6	4	6
BLAST ZONE- UPPER & MIDDLE CLEARWATER SITES								
SHRUBS								
Rubus spectabilis *	47	73	22	42	28	41	25	48
Salix sitchensis *	--	--	21	55	8	13	12	37
HERBS								
Equisetum arvense *	40	58	48	101	32	69	36	77
Epilobium angustifolium *	20	22	26	53	44	59	31	47
Anaphalis margaritacea *	--	--	30	38	36	45	24	33
Pteridium aquilinum *	7	8	18	25	20	64	10	33

Table 4. continued.

Stachys cooleyae +	20	30	18	21	12	49	18	32
Petasites frigidus+	27	34	11	16	16	23	16	22
Cirsium arvense *	20	24	7	8	24	29	16	21
Carex mertensii *	27	31	11	20	16	20	16	19
DOWNSTREAM OF BLAST ZONE- LOWER CLEARWATER SITE								
Trees								
Alnus rubra +	17	18	37	45	71	144	35	68
Acer circinatum +	4	6	12	18	33	85	13	41
Shrubs								
Rubus parviflorus +	--	--	12	33	42	52	9	19
Oplopanax horridum+	--	--	--	--	25	44	5	7
Herbs								
Epilobium angustifolium *	15	18	19	24	-	-	13	15
Petasites frigidus +	5	6	14	29	25	28	14	15
Tiarella unifoliata+	--	--	5	6	58	60	13	14
Carex mertensii *	5	6	19	20	12	13	12	13
Senecio sylvaticus*	11	12	9	10	8	10	10	11
Athyrium felix-femina +	--	--	--	--	37	45	7	8
AIRFALL TEPHRA ZONE- ELK DRAINAGE								
TREES								
Alnus rubra +	33	101	41	121	19	82	33	109
Alnus sinuata +	15	109	22	100	2	37	12	98
Tsuga heterophylla+	18	18	33	86	42	106	36	78
Abies amabilis +	--	--	18	21	25	66	13	35
SHRUBS								
Rubus spectabilis +	18	40	70	115	25	42	35	68
Vaccinium ovalifolium +	--	--	44	72	39	77	26	59
Ribes lacustre +	--	--	11	69	31	40	14	33
Vaccinium membranaceum +	--	--	11	21	19	39	10	27
Rubus parviflorus +	5	22	16	37	9	11	12	23
HERBS								
Petasites frigidus+	10	82	15	18	11	22	13	43

sylvaticus, *S. jacobea*, *Cirsium arvense* and *Anaphalis margaritacea*.

Plants with extensive rhizome systems e.g.,*Equisetum arvense*, *Pteridium aquilinum*, *Petasites frigidus*, *Carex* spp. and *Rubus* spp. are favored within the active channels of the Blast and Downstream of Blast Zones. Most stems sprout from older root stocks whose previous aerial shoots were frequently abraided to the soil surface during conditions of high sediment transport. On hydraulically stressed geomorphic surfaces, plants which survive highwater flows have roots and rhizomes that hold the substrate in place. Differentially, the surrounding substrate is eroded, leading to a strongly clumped habit. Herbaceous vegetation is concentrated around the bases of shrub clumps where flood debris has accumulated. Most herbaceous and pioneer tree species (*Alnus rubra*) have high frequencies but low importance values, indicating ability to colonize as seedlings but an inability to survive high water events. Species importance increases for most plants on the lower and upper terraces. Greater substrate stability on these surfaces also results less clumping of plants.

DISCUSSION

In the dramatically altered drainage basins of Mount St. Helens, flooding streams carry sediment loads several orders of magnitude greater than they did prior to the eruption (Janda *et al*. 1984). Sediment erosion, transport, and deposition affects plant establishment in several ways. Erosion of tephra-covered surfaces exposes residual soil, providing a nutrient rich substrate for germinants, and liberates buried root stocks. High water flows may also transport stems that have pre-formed root primordia (particularly willow species) which subsequently colonize surfaces by vegetative propagation. Conversely, redeposited sediments hinder plant recovery by burial of seedlings or beneficial microsites. Thus, fluvial processes have diverse and important influences on riparian vegetation recovery at Mount St. Helens.

Pre-eruption channel morphology also influences vegetation recovery. Narrow valley floors, steep-side slopes and high- gradient streams, typically found in upper watersheds, promote rapid transport of sediment to downstream reaches. At these lower-gradient, higher-order downstream sites, sediment can accumulate in extensive areas above the active channel, but below bankfull level. Sedimentation, lateral cutting, and frequent inundation deter plant establishment. Lower duration and intensity of flooding and concomitant sediment deposition, which diminishes laterally away from the active channel, are probable causes for the progressive increase of plant abundance on elevated geomorphic surfaces.

Vegetation recovery is also enhanced on substrates stabilized by large, woody debris in many of the channels. This is particularly apparent at the middle Clearwater site where blowndown trees are commonly greater than one meter in diameter and forty meters long. Because the majority of these trees were thrust over intact, stems remain attached to the root wad and are relatively immobile. High stream flow following the 1980 eruptions subsequently oriented many of the trees at an acute angle to the streambank. Downed trees have remained in place anchored by their massive root wads. The positioning of the trees diverts flows away from the streambank aiding in streambank stabilization. Downed logs away from the active channel are also important stabilizing agents. These logs trap sediments and serve as important sediment storage sites (Smith 1984). If not subjected to frequent flooding and fluvial reworking, these storage areas can be sites for plant colonization.

The mechanisms of species response within the riparian zone vary and relate to the physical environment of the geomorphic surface, vigor of residual plant, and availability of sources of new propagules. Certain species are better adapted than others for establishment in disturbed environments. Generally, these species are characterized by rapid growth, rapid completion of life cycle, maximum seed production, and long range seed dispersal (Grime 1979). Three such species, *Epilobium angustifolium*, *Anaphalis margaritacea*, and *Senecio sylvaticus* are important colonizers of newly formed tephra surfaces.

Establishment of pioneer tree species (primarily *Alnus rubra* and *A. sinuata*) may be episodic due to variable seed production and dispersal (Walker *et al*. 1986). *Alnus* seed disperses by both wind and water and successful colonization may depend on flood waters depositing the corky seeds beyond the frequently reworked surfaces. The establishment of *Alnus*-dominated stands on lower terraces may be a two-step process whereby a few initial colonizers act as seed sources for a second, denser stand. This nucleation process has been observed on Alaskan river flood plains (Walker *et al*. 1986) and on sand dunes (Yarranton and Morrison 1974). The presence of shrubby vegetation also aides in the nucleation process as shrubs trap rafted seeds and shelter seedlings from abrasive flood waters.

CONCLUSION

Riparian vegetation recovery reflects lower frequency and intensity of flooding at distances removed from the active channel. This is particularly apparent in low gradient, higher order streams where sediment accumulation has produced extensive areas of newly-formed terraces above the active channel but below bank- full level. Here, the magnitude and frequency of flooding is a major barrier to plant establishment. Substrate stability and concurrent plant establishment may be enhanced by the presence of large woody debris. Plant cover within the riparian zone comes largely from species which can survive bank full inundation by resprouting, underground vegetative spread, or prolific seeding capacity. Flooding frequency and intensity largely controls species composition and establishment pattern.

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