Effects of Mechanical Site Preparation on Selected Physical Properties of Four Volcanic Ash Influenced Forest Soils in Northern Idaho

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AUTHORIZATION TO PROCEED WITH FINAL DRAFT:

The thesis of Harold P. Collins for the Master of Science Degree with major in Soil Science and titled "Effects of Mechanical Site Preparation on Selected Physical Properties of Four Volcanic Ash Influenced Forest Soils in Northern Idaho" was reviewed in rough draft form by each committee member as indicated by the signitures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the committee; permission was also given to schedule the final examination:

Major Professor Roger W. Harder Date 1/6/83

Committee Members Maynard A. Fosberg Date 1/5/83

[signature] Date 1/6/83

REVIEW OF FINAL DRAFT:

Department Head Gary A. Lee Date 2/3/83

College Dean A. F. Branen Date 2/9/83

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Major Professor Roger W. Harder Date Jan. 19, 1983

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Graduate School Dean ________________ Date __________

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ABSTRACT

Mechanical site preparation and its effects were studied on four volcanic ash influenced forest soils. Changes in bulk density, soil porosity, moisture characteristics, and volcanic ash thickness were evaluated at three slash disposal and one brush disposal site.

Areal extent for both treatments averaged 43 percent of the total areas studied. Bulk density increased an average of 20 percent in the upper 18 cm (7 in) of the volcanic ash horizon and averaged 10 percent to a depth of 38 cm (15 in) among all sites.

Soil displacement averaged 13 cm (5.1 in) within the brush disposal site and 6.5 cm (2.6 in) among the slash disposal sites. Soil displacement due to brush removal resulted in a 40 percent reduction in available water. Available water loss averaged 12 percent among the slash disposal sites. Macro porosity was reduced 23 percent in the track rut disturbance class.

INTRODUCTION

Successful reforestation of harvested forest lands by natural or artificial methods often depends upon the removal of competing vegetation or physical obstacles hindering regeneration. Quite often this is accomplished through mechanical site preparation techniques. Observed reductions in tree seedling establishment and growth has prompted an interest among forest land managers to investigate and document soil disturbances resulting from this practice.

The objectives of this study were to identify and evaluate alterations in the physical properties of forest soils following mechanical site preparation. The soils selected have a surface horizon of weathered volcanic ash and are known to exhibit reforestation problems following this treatment. The volcanic ash horizon uniformly covers extensive forest lands in northern Idaho. Changes in the physical condition of this horizon resulting from compaction, displacement, and profile mixing have been suggested for the measured decline in seedling growth.

Historically, much of the literature documenting soil compaction, soil displacement, and tree seedling growth losses has dealt with post-harvest soil conditions, with limited information pertaining directly to the effects of mechanical site preparation. This study describes and documents the changes in the soil physical properties of four volcanic ash influenced forest soils resulting from slash and brush disposal activities.

Four hypotheses were studied: First, mechanical site preparation increases soil bulk density above the natural state. Second, the amount of logging slash removed during disposal operations influences the magnitude of soil compaction. Third, alterations occur in soil pore space, moisture retention and water availability. In addition, the redistribution of top soil influences the magnitude of change in these parameters. Fourth, it was hypothesized that the density of slash and brush would determine the total area impacted.

The results of this study can be of use in the prediction of the potential impacts of mechanical site preparation on other forest soil types which are influenced by weathered volcanic ash. This study has also established a data base which can aid future programs characterizing the impacts of mechanical site preparation on the success of tree seedling establishment, survival and growth.

LITERATURE REVIEW

Crawler tractors are widely used in mechanical site preparation activities on forest lands in northern Idaho. Shubert and Adams (1975), describe this form of site preparation as providing optimum conditions for tree seedling establishment and early growth. Benefits include: increased soil moisture, reduction of pest habitats, lowering of the fuel hazard, and elimination of competing vegetation. The opportunity to dispose of volumes of large woody material in which bark beetles might breed represents a highly important advantage in terms of forest management (Smith, 1962). In addition, the churning action by mechanized equipment creates a favorable seedbed. Churning allows for the incorporation of surface organic materials into the soil, speeding mineralization and nutrient availability (Moehring, 1969).

The primary efforts of mechanical site preparation are directed at the removal of physical obstacles to planting or natural regeneration (slash disposal) and the destruction of competing vegetation (brush disposal). Mechanical site preparation methods are chiefly used in situations where prescribed burning or use of herbicides are unsafe or ineffective (Smith, 1962).

Slash disposal reduces the potential fuel hazard and aids in the prevention of forest fires. Mechanical slash disposal methods are associated with partial cutting practices and involve the burning of piled slash. Following timber harvest operations there is usually a high volume of fuel distributed in such a way that it hampers the construction of fire lines (Smith, 1962). Crawler tractors fitted with modified blades, push the logging debris into windrows or individual piles which are later burned

Figure 1. Crawler tractor equipped with modified blade used in slash disposal operations.

(Figure 1). This activity exposes the mineral soil providing a favorable seedbed and a temporarily competition-free environment for seedling establishment.

Brush disposal involves the uprooting and removal of vegetation by crawler tractors equipped with a brush rake. The brush rake removes the brush and roots from the soil profile without excessive displacement of the surface horizon (Figure 2). Openings are created in the brush canopy by removing the vegetation in strips. Cleared strips are typically 3-5 m (10-15 ft) wide and spaced at 6-15 m (20-50 ft) intervals (Shubert and Adams, 1975).

Figure 2. Crawler tractor equipped with a brush rake.

Historically, much of the literature documenting soil compaction, soil displacement, and timber growth losses has dealt with post-harvest soil conditions. Therefore, only limited information is available as to the additional soil disturbances that result from mechanical site preparation.

Garrison and Rummell (1951) have reported that crawler tractors cause the most serious soil disturbances, with additional soil damage resulting when blades are used for pushing soil, boulders and stumps. Bullard and Burke (1957) found that the appearance of compacted soils indicated horizontal slippage in addition to vertical compression. They observed that hard brick-like cakes of soil formed to a depth of 10 cm (4 in) between the cleats of the crawler treads. Davies et al. (1973) support these observations and concluded that slippage strongly influenced soil compaction.

Studies evaluating the effects of repeated tractor trips on soil physical properties have demonstrated that increased bulk density reduced water infiltration rates and soil porosity. Steinbrenner (1955) found that four trips with a crawler tractor (18 metric tons), reduced the macro pore space of a soil from 26 to 17 percent in the upper 8 cm (3 in) and that water infiltration rates were reduced from 80 to 10 cm (32 to 4 in) per minute when the soil was dry. He noted that one trip had the same effect when the soil was wet. Another study by Steinbrenner and Gessel (1955) found that soils on tractor logged areas in southwestern Washington showed a 22.7 percent increase in bulk density, a 35 percent loss in permeability and a 10 percent decrease in macro pore space. Similar results have been documented on forest soils throughout the United States (Lull, 1959; Hatchell et al., 1970; Froelich, 1979, 1980; Lenhard, 1979; Bruer, 1980; and Dickerson, 1976).

Several studies have documented changes in soil physical properties on volcanic ash influenced soils following timber harvest operations (Dyrness, 1965; Froelich, 1979, 1980; Sidle and Drlica, 1981; Kuennen et al., 1979; Cullen and Montagne, 1981; and Breuer, 1981-82[1]). These studies showed that bulk density seldom exceeded 0.90 gcm^{-3} following compaction. Although this value of bulk density would not hamper root penetration directly, it has been suggested that the subsequent 40 percent reduction in macro pore space and 30 percent reduction in permeability would influ-

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[1]Breuer, D. W. 1982. Personal Communication. Soil Scientist, Potlatch Corporation, Lewiston, ID.

ence seedling growth and survival. Froelich (1979) reported a 10 percent reduction in tree growth with a 15 percent increase in bulk density on a volcanic ash influenced soil in western Oregon. Breuer (1981) reported that the volcanic ash horizon was more favorable to tree growth than many of the underlying subsoils. He noted a 12 percent decrease in the height growth of Pseudotsuga menziesii (Douglas fir) seedlings planted where the volcanic ash horizon was less than 15 cm (6 in).

Additional studies have reported the biological significance of soil loss on seedling growth as a result of mechanical site preparation. Most of the nutrient capitol of forest soils is contained in the living and dead organic materials of the first few cm of the surface horizon. As early as 1944, Lebaron found that although scarification enhanced the germination of Picea banksiana (jack pine) and Picea mariana (black spruce), it caused the seedlings to grow poorly and show signs of nutrient deficiencies. Adams (1978) reported that inefficient windrowing caused the removal of 7.5 cm (3 min) of topsoil, redistributing 2360 $kgha^{-1}$ (536 $lbsac^{-1}$) of soil nitrogen. This was a 25 percent decrease in total soil nitrogen and a 15 percent reduction in the total potential soil volume available for tree rooting. Brendermuehl (1969) found that the removal of 2.5 cm (1.0 in) or more, reduced the weight yields of Pinus eliotii (slash pine) by correlating with the reduced nitrogen and organic matter content of the soil. Moehring (1970) noted that soil displacement usually represented a permanent reduction in site productivity because site recovery is limited by factors of soil formation.

Other significant impacts on seedling growth and site productivity are related to the microflora of the forest sites. Harvey (1980) reported that the symbiotic fungi forming mychorrhizae are associated with downed woody materials. This woody material may then be removed or brought to the surface during slash disposal operations. The imbeded materials provide optimum moisture and nutrient reservoirs and when brought to the surface desiccation occurs and microbial activity declines.

Guild (1971) evaluated the practices of windrowing slash on forest soils in New Zealand. He found that windrowing reduced the potential plantable area and created an ideal habitat for rabbits, increasing the damage to young crops. In addition, the large expanse of open country would influence the wind-firmness of subsequent timber crops, increasing the risk of stand collapse.

METHODS AND PROCEDURES

Site Selection

Four study areas were located on the Clearwater National Forest in northern Idaho (Figure 3). Site selection was limited to: 1) soils noted for high timber production, 1.83 m^3/ha/yr (160 ft^3/ac/yr), 2) soils having a surface horizon of weathered volcanic ash (Fosberg et al., 1982) and 3) soils known to have reforestation problems following mechanical site preparation. A complete soil profile description, taxonomic classification, physical analysis, and site descriptions are presented in Appendix 1.

Two mechanical site preparation practices were addressed in this study; slash disposal and brush disposal. The slash disposal study areas, Bovill, Nan Creek, and Bess Creek, are located on the Palouse and Pierce ranger districts. These sites are *Thuja plicata*/*Pachistima myrsinites* (western red cedar/pachistima) habitat types (Daubenmire, 1968) and had been harvested in 1979 by partial cutting methods using crawler tractors.

The Bovill site on the Palouse district prior to harvest was a dense, mixed, uneven-aged stand composed of *Abies grandis* (grand fir), *Pseudotsuga menziesii* (Douglas fir), *Thuja plicata* (western red cedar), and *Larix occidentalis* (western larch). Average bole diameters ranged 13 to 38 cm (5 to 15 in). In 1979 a salvage-release cut was applied to eliminate inferior trees and improve stand conditions. This site occurs on gently to moderately rolling upland hills at an elevation of 921 m (2800 ft). The subsoil underlying the volcanic ash horizon has developed from alluvium highly influenced by Palouse loess, Columbia River basalts and siltite (Dechert, 1981). Slopes range 0 to 15 percent.

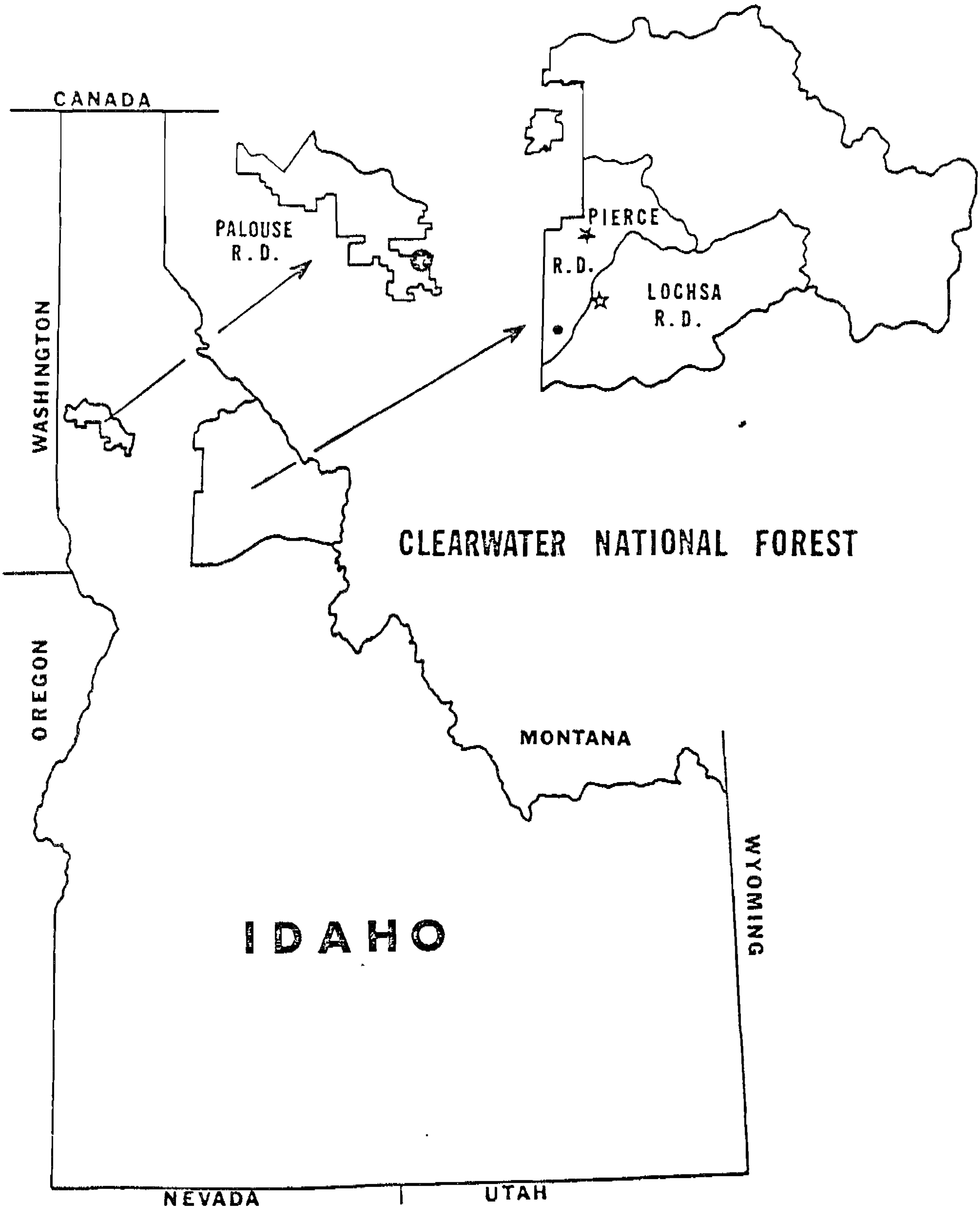

Figure 3. Location of study sites, Clearwater National Forest. ✪ Bovill, ● Nan Creek, ★ Bess Creek, ☆ Canyon Meadows.

The Nan Creek site on the Pierce district was shelterwood cut in 1979. This site was a mixed, even-aged stand of Abies grandis and Thuja plicata with limited regeneration in the understory. Average bole diameters ranged 50 to 76 cm (20-30 in) and ages 90 to 110 years. This site occurs on moderate rolling upland hills at an elevation of 1121 m (3400 ft). The subsoil underlying the volcanic ash horizon has developed from alluvium of unknown origin. Slopes range 10 to 20 percent.

The Bess Creek site on the Pierce district was an old growth stand of Thuja plicata with no reproduction in the understory. This site was shelterwood cut in 1979. The site occurs on a steep mountain slope at an elevation of 1303 m (3900 ft). The subsoil underlying the volcanic ash had developed in granitic parent materials of the Idaho Batholith formation. Slopes range 20 to 40 percent.

Canyon Meadows, Lochsa district, was selected as the brush disposal study area. It had been noted that severe reforestation problems were associated with the granitic derived soils found in this area.[2] This site was clearcut in 1966 and prescription burned in 1967. The habitat type is Abies grandis/Pachistima myrsinites (Daubenmire, 1968). As a result of the prescription burn in 1967 a dense canopy of Ceanothus velutinus (shiny leaf ceanothus) had since developed and dominated the site. Prior to the brush disposal activity the brush canopy attained a height of 2 m (6 ft) and covered 80 percent of this site. Two attempts were made to regenerate this site, the first in 1967 and the second in 1973. Both plantings failed due in part to heavy brush competition. This site occurs on moderately

[2] Wilson, D. 1981. Personal communication. Soil Scientist, USDA Forest Service, Clearwater National Forest.

rolling upland hills at an elevation of 1394 m (4250 ft). The subsoil underlying the volcanic ash had developed from granitic parent material of the Idaho Batholith formation. Slopes range 10 to 30 percent.

Tables 1 and 2 provide a brief summary of the physiographic conditions and treatment history of each site.

Experimental Design

Slash Disposal

Sampling design

Three subsites, 1 ha (2.5 ac) in size, were located within each slash disposal study area after the harvest operation but prior to the slash disposal treatment. Fifty-five 1/120 ha (1/300 ac) plots were established within each subsite at 8 m (25 ft) intervals along five predetermined tran-

Table 1. Description of study sites.

Site	Bovill	Nan Creek	Bess Creek	Canyon Meadows
District	Palouse	Pierce	Pierce	Lochsa
Habitat Type	*T. plicata* *P. myrsinites*	*T. plicata* *P. myrsinites*	*T. plicata* *P. myrsinites*	*A. grandis* *P. myrsinites*
Land Form	rolling hills	rolling hills	mount. slope	rolling hills
Elemation, m	921	1121	1303	1394
Aspect	east	south	north	north/south
Thickness of Volcanic Ash Horizon, cm	40	38	41	44
Underlying Parent Material	loess	alluvium	granite	granite
Soil Taxonomy				
USDA Textural Class (Surface)	silt loam	silt loam	loam	sandy loam
Classification	Andeptic Fragiboralf	Andeptic Glossoboralf	Typic Vitrandept	Typic Vitrandept

Table 2. Summary of treatment history.

Site	Bovill	Nan Creek	Bess Creek	Canyon Meadows
Harvest Method	Selection (1979)	Shelterwood (1979)	Shelterwood (1979)	Clearcut (1966)
Machine Type	Crawler Tractor	Crawler Tractor	Crawler Tractor	Crawler Tractor
Prior Site Preparation	none	none	none	Prescribed burn (1967)
Recent Treatment	Slash disposal (1980)	Slash disposal (1980)	Slash disposal (1980)	Brush disposal (1981)
Machine Type	Cat. D-4	JD 450-B Cat. D-4	Cat. D-4	Cat. D-6
Moisture Content During Treatment	54%	40%	40%	unknown

Fuel load strata

Each plot was stratified into one of three fuel load classes; low, moderate, or high. The fuel load represents the amount of logging debris distributed over the sample plot during the timber harvest operation, and was determined by measuring the volume of each piece of downed woody material in the plot (Brown, 1974, 1980[3]; Anderson, 1978). The volume of slash less than 8 cm (3 in) in diameter was determined by two 2 m (6 ft) line transects within the sample plot. The fuel load class was the total

Table 3. Fuel load classes.

	t/ha	ton/ac
Low	<22	<11
Moderate	23-109	11-50
High	110+	50+

[3] Brown, J. K. 1980. Personal Communication. U.S.D.A. Forest Service, Clearwater National Forest, Orofino, ID.

volume of slash in the 1/120 (1/300 ac) plot. Fuel load classes used in this study are presented in Table 3. Appendix 3 presents a sample calculation for determining the fuel load class.

Soil Physical Properties Measured

Thirty plots from each fuel load class were chosen at random and soil physical properties evaluated. In addition, plots which showed no sign of the harvest activity were selected to represent the natural soil state and were categorized as undisturbed. Soil bulk density was chosen as the major criterion for evaluating soil disturbances because it is a good indicator of the extent of alterations of the soil environment. Additional soil properties measured were soil pore space, soil water retention, available soil water, and thickness of the weathered volcanic ash horizon.

Bulk density

Five bulk density core samples were collected from each plot, one from the surface, then at 9 cm (3.5 in) intervals to a depth of 38 cm (15 in). A cylindrical metal sampler was driven into the soil to the desired depth and a 70.7 cc intact soil core extracted. The samples were dried at 105°C (221°F) and weighed. The bulk density was calculated as the oven dried soil mass divided by the volume of the core (Blake, 1965).

Volcanic ash thickness

The thickness of the volcanic ash horizon was recorded before and after the site preparation activity so that bulk density samples collected following the operation could be taken at given depths measured from the same reference point in the soil profile. This procedure allowed for better evaluation of density changes and gave some insight as to the amount and degree of soil displacement.

Soil porosity

Total pore space was determined from the relationship between soil density and particle density (Vomocil, 1965). Total pore space is defined as the percentage of the bulk volume not occupied by solids and was calculated from the following equation:

$$Tp = 100\ (1 - \frac{Bd}{Pd})$$

Where: Tp = total pore space

Bd = bulk density

Pd = particle density

Macro porosity was determined from the amount of the water-free pore space at the 60 cm tension obtained from moisture release curves (Vomocil, 1965).

Moisture characteristics

Moisture retention of triplicate samples of ground sieved soil from the volcanic ash horizon of each site was determined at 1/60, 1/10, 1/3, 1, 5, and 15 bar tensions and at 1/3 and 15 bar tensions for each subsoil horizon (U.S. Salinity Laboratory Staff, 1954). Samples were placed in rubber retainer rings, saturated for 24 hours and placed on a ceramic plate. The ceramic plate was placed in a pressure apparatus and pressurized using N_2 gas to the equivalent of the desired tension. The pressure was maintained until hydraulic equilibrium was reached, then weighed, oven dried at 105°C (221°F) and weighed again. Percent moisture by volume was calculated by multiplying the percent moisture by weight by the average bulk density determined from the statistical model of each study area.

The amount of available soil water was estimated for the volcanic ash and subsoil horizons. Available water was described as the difference in moisture content between the 1/3 and 15 bar tensions and was reported as a depth value by multiplying each moisture volume by the thickness of each horizon.

Areal Extent of Activity

The areal extent of the slash disposal activity was determined as the ratio of the number of sample plots which had been treated compared to the total number of plots. The overall area treated and that by fuel load class were calculated from the following equations:

$$\text{Overall area: } \frac{\text{number of plots treated}}{\text{total number of plots}} \times 100$$

$$\text{By Fuel Load Class: } \frac{\text{plots treated in Fuel Class}}{\text{total number of plots}} \times 100$$

Slash Disposal Activity

Access roads and landings were not sampled because these features of the harvest activity were purposely disturbed and compacted during the timber harvest operations.

Following sampling of the post-harvest and undisturbed soil conditions, the slash at each site was piled by crawler tractors rated in the 8.2 metric ton (9.0 ton) class exerting a track pressure of .51 $kgcm^{-2}$ (7.2 $lbsin^{-2}$). Individual piles were constructed in a random manner at the discretion of the operators.

Brush Disposal

Sampling design

In 1980, a Caterpillar D-6 (18 metric tons) rated with a ground pressure of 0.63 $kgcm^{-2}$ (8.8 $lbsin^{-2}$) and equipped with a 4 m (12 ft) brush rake, uprooted vegetation in strips on a 75 ha (150 ac) clearcut harvest unit. From this unit four ridge complexes were selected at random and served as replicate subsites. Prior to sampling, the width, length, and slope of each cleared strip was measured and recorded. Each cleared strip was stratified into two classes: Slope position; ridge (R), upper 1/3 (U), middle 1/3 (M), and lower 1/3 (L) and Disturbance Class; Track rut - path of tractor tread, Inter-track - area between track ruts, and Post-harvest - area where brush remained. Paired classes, i.e. slope position-disturbance class, represented a plot where data was collected. A total of 130 plots were established and sampled. Appendix 4 presents the sampling design and plot locations.

Soil physical properties measured

Bulk density, thickness of the volcanic ash horizon, soil porosity, and moisture retention properties were analyzed by the methods previously discussed. Three bulk density samples were collected with an impact core sampler, one from the surface, then at 9 cm (3.5 in) intervals to a depth of 23 cm (9 in). Moisture retention was determined from intact 70.7 cc soil cores at 1/60, 1/10, 1/3, 1, 5, and 15 bar tensions. Ten soil cores from bulk density classes of 0.60-0.70, 0.71-0.80, and 0.81-0.90 gcm^{-3} of the volcanic ash horizon and ten from the subsoil horizons at soil densities of 1.15 and 1.35 gcm^{-3} were collected with an impact core sampler. Samples were saturated for 72 hours, placed on a ceramic plate and analyzed by the methods previously discussed. Triplicate samples of ground sieved soil from all horizons were analyzed and used for comparisons with undisturbed soil cores.

Statistical Analysis

The data collected were analyzed by the Statistical Analysis Systems package (Helwig et al., 1976). Statistical analysis of the slash disposal activity was an Analysis of Variance for a split plot design (Snedecor and Cochran, 1973; Tarng, 1981[4]). Response was blocked on the factor of time of data collection.

Analysis of the brush disposal activity was an Analysis of Variance for a complete randomized block (Snedecor and Cochran, 1973; Tarng[4], 1981).

Type IV sums of squares and significance levels at $\alpha = .05$ and $\alpha = .10$ were used to evaluate the main effects and variable interactions.

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[4]Tarng, S. 1981. Personal Communication. Statistical Analyst, University of Idaho, Moscow, ID.

RESULTS AND DISCUSSION

Slash Disposal

Areal extent of activity

Although the slash disposal operation of each site was conducted by different operators, the magnitude of the area affected was quite similar (Table 4). An objective of this study was to evaluate the relationship between fuel load concentrations and intensity of the slash disposal activity. The hypothesis that higher fuel load concentrations would be subject to more intensive treatment compared to lower fuel concentrations was not verified. Each fuel load class had a similar proportion of plots treated within each site.

Soil displacement

The average amount of soil displaced was almost identical among all sites. Soil displacement was determined as the difference between thickness measurements of the volcanic ash horizon recorded prior to and follow-

Table 4. Summary of area treated and soil displacement.

Site		Bess Creek	Bovill	Nan Creek
Percent of site treated		38	44	46
Percent area by Fuel class (mT/ha)	I- < 23	12	7	12
	M- 24-114	13	19	22
	H- >115	14	18	12
Soil displaced (cm)		5.5 ± 10.7	6.7 ± 14.8	7.2 ± 12.7

*Confidence limits given at α = .10 level.

Figure 4. Redistribution of soil due to vertical placement of the dozer blade.

Figure 5. Soil displaced due to pivot turn.

ing the slash disposal activity. The average thickness of the volcanic ash horizon was 36 ± 2 cm (14 ± .8 in) following timber harvest and an average of 41 ± 1.3 cm (16 ± .5 in) in the undisturbed areas among all sites. Following slash disposal 30 percent of the sample plots had a volcanic ash thickness less than 27 cm (11 in). Soil was removed as well as deposited at these sample points. A high degree of variability was found among post-slash treatment measurements. Variability was attributed to horizontal slippage of vehicle tracks, pivot turns, and vertical placement of the dozer blade into the surface horizon. The redistribution of soil, as depicted in Figures 4 and 5, was dependent upon the magnitude of these factors. The distances that soil was moved during site preparation were not measured in this study. Since soil was not removed from the site, displacement would be important at the microsite level. The importance of soil displacement at the microsite level can be related to the impact on other soil resources which would be associated with seedling growth. Specifically, these are nutrient availability (Adams, 1978), moisture retention and availability (Ziemer, 1978), and a reduction in the total potential soil volume available for tree rooting (Guild, 1971).

Bulk density

Changes in bulk density resulting from the slash disposal operations were evaluated as a function of the time the samples were collected (before or after the treatments), depth at which the samples were obtained, fuel load class, and thickness of the volcanic ash horizon.

Undisturbed, post-harvest, and post-slash disposal bulk density profiles of each site are presented in Figures 6 through 8. Bulk density values reported at the 27 cm (11 in) and 38 cm (15 in) depths are the

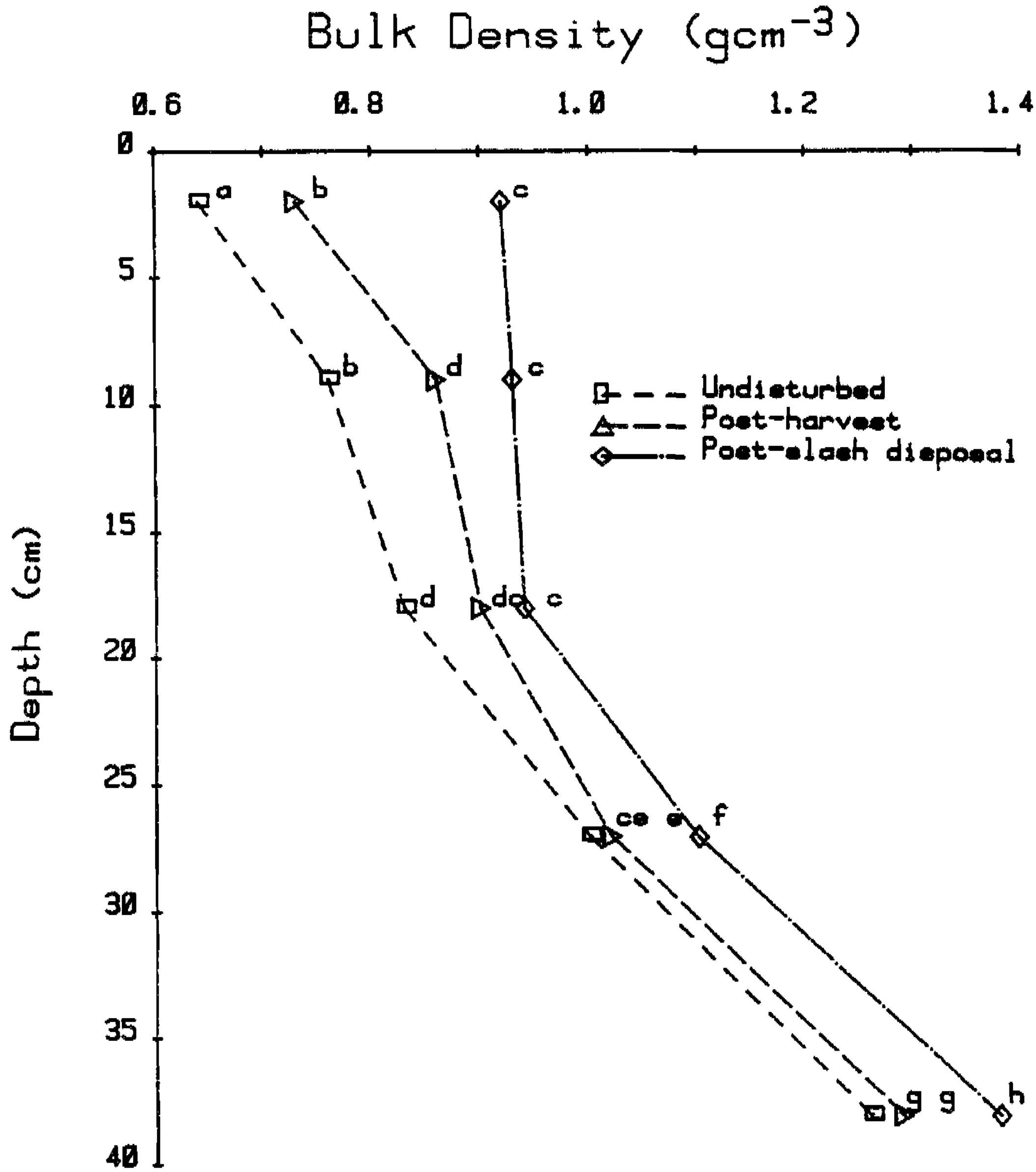

Figure 6. Bulk density profiles for the Bovill slash disposal site. Points with the same letter are not significantly different at the α = .05 level.

combined average of the volcanic ash and subsoil horizons overlapping at these points.

As a result of the timber harvest operations, bulk density increased 10 percent in the upper 18 cm (7 in) of the soil profiles at both the Bovill and Nan Creek sites. No significant change in bulk density below 18

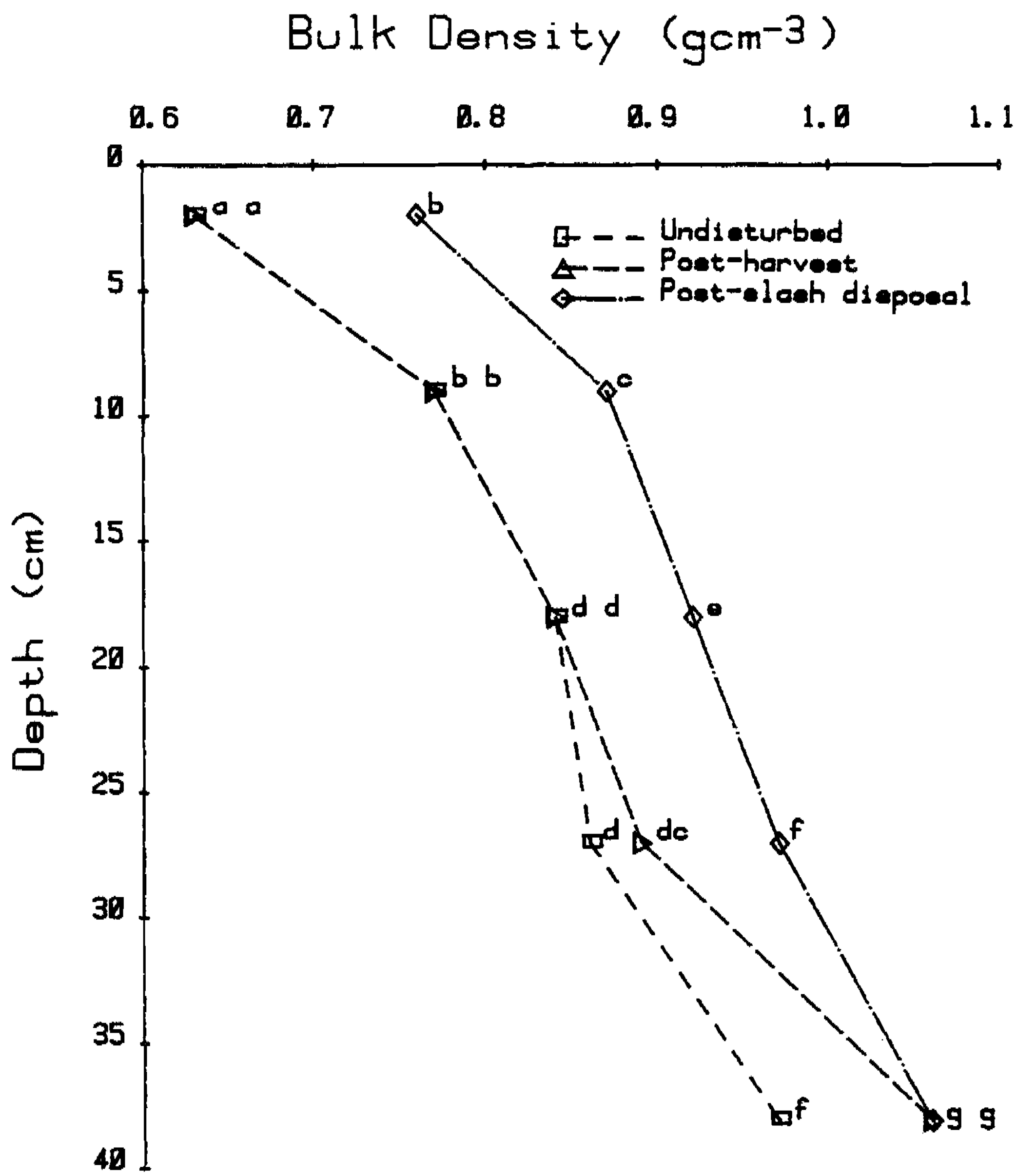

Figure 7. Bulk density profiles for the Bess Creek slash disposal site. Points with the same letter are not significantly different at α = .05 level.

cm was evident. The Bess Creek site exhibited no significant change in bulk density as a result of timber harvest. Additional soil disturbances resulting from the slash disposal treatments were found to compound existing levels of compaction. The average increase in bulk density among all sites was 20 percent in the upper 18 cm (7 in) and 10 percent from 18 cm to

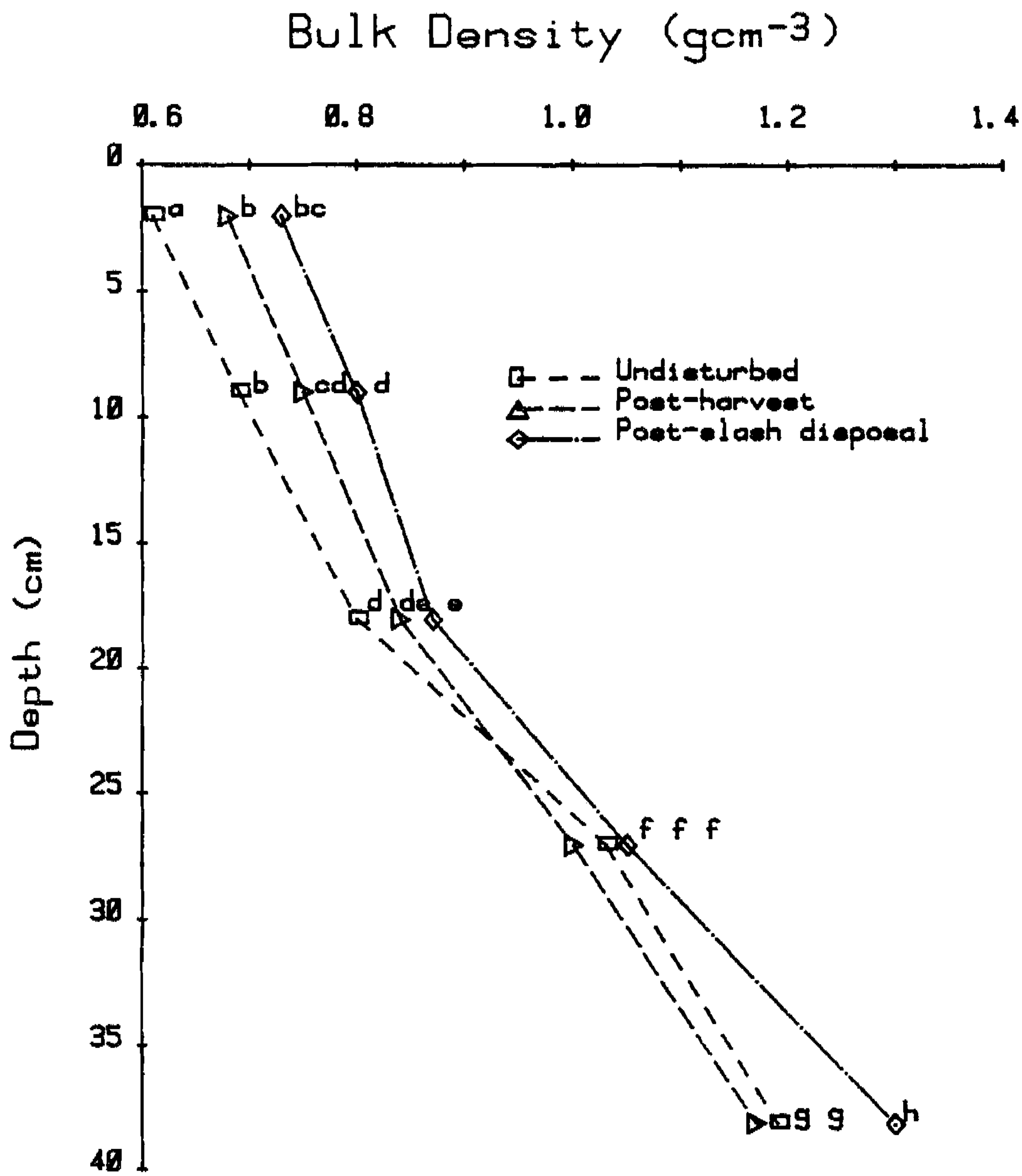

Figure 8. Bulk density profiles for the Nan Creek slash disposal site. Points with the same letter are not significantly different at the α = .05 level.

38 cm (15 in).

The Bovill and Bess Creek sites exhibited the greatest increases in bulk density as a result of the slash disposal activity. Wet soil conditions at Bovill and destruction of the strong granular structure at Bess Creek are the probable causes. Slash disposal at the Bovill site occurred in mid-September during a period of high rainfall. Soil moisture at that time was 54 percent by volume, comparable to the 1/10 bar tension (Figure 12). Bulk density at the surface increased 44 percent as compared to that of the undisturbed state and averaged 14 percent to the 38 cm depth.

At the Bess Creek site particle aggregation was better developed than at either Bovill or Nan Creek. It was hypothesized that as the dozer blade moved through and mixed the volcanic ash horizon, soil aggregation was destroyed resulting in the densification of this horizon. In addition, the ground pressures applied by the crawler tractors compounded the compaction of the volcanic ash. Bulk density increased 21 percent in the surface of the volcanic ash horizon and averaged 11 percent to a depth of 27 cm (11 in). Significant changes in bulk density were not found at the 38 cm (15 in) depth.

Nan Creek displayed similar trends as that of Bovill, with a progressive increase in soil compaction after each treatment.

The magnitude of soil compaction was not influenced by the fuel load concentration (Figure 9). Post-harvest bulk densities among the moderate and high fuel load classes were significantly (α = .05) different from the low fuel load class but not different from each other. The low fuel load class was commonly located on primary and secondary skid trails. This would account for the higher initial densities of this class at each site. Evaluation of post-slash disposal bulk densities shows that all fuel load classes responded similarly as a result of this activity. Bulk density increased an average of 13 percent above the post-harvest density for all fuel classes among all sites. Significance levels are not provided for the Bovill site because the statistical analysis showed this interaction was not significant. However, it is apparent that this site responded similarly.

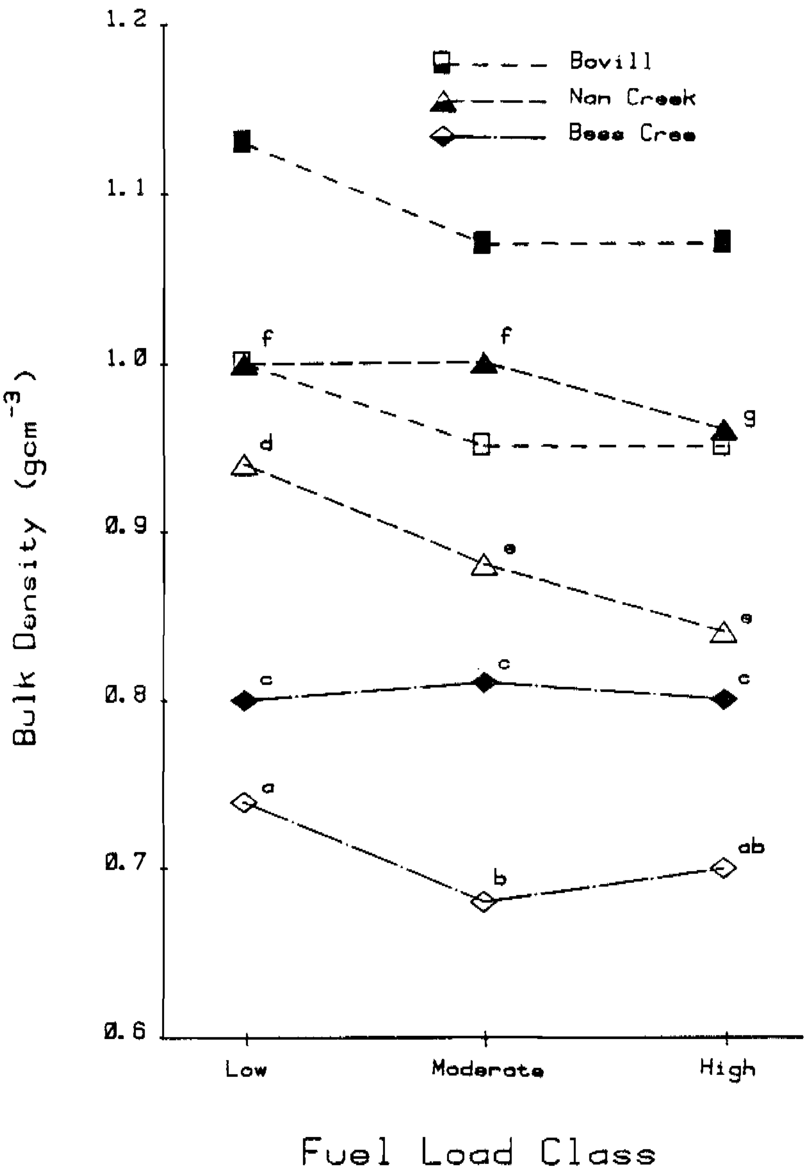

Figure 9. Influence of fuel concentration on bulk density. Darkened points represent post-slash treatments. Points with the same letter are not significantly different at α = .05 level. LSD values are not provided for the Bovill site because this interaction was not statistically significant.

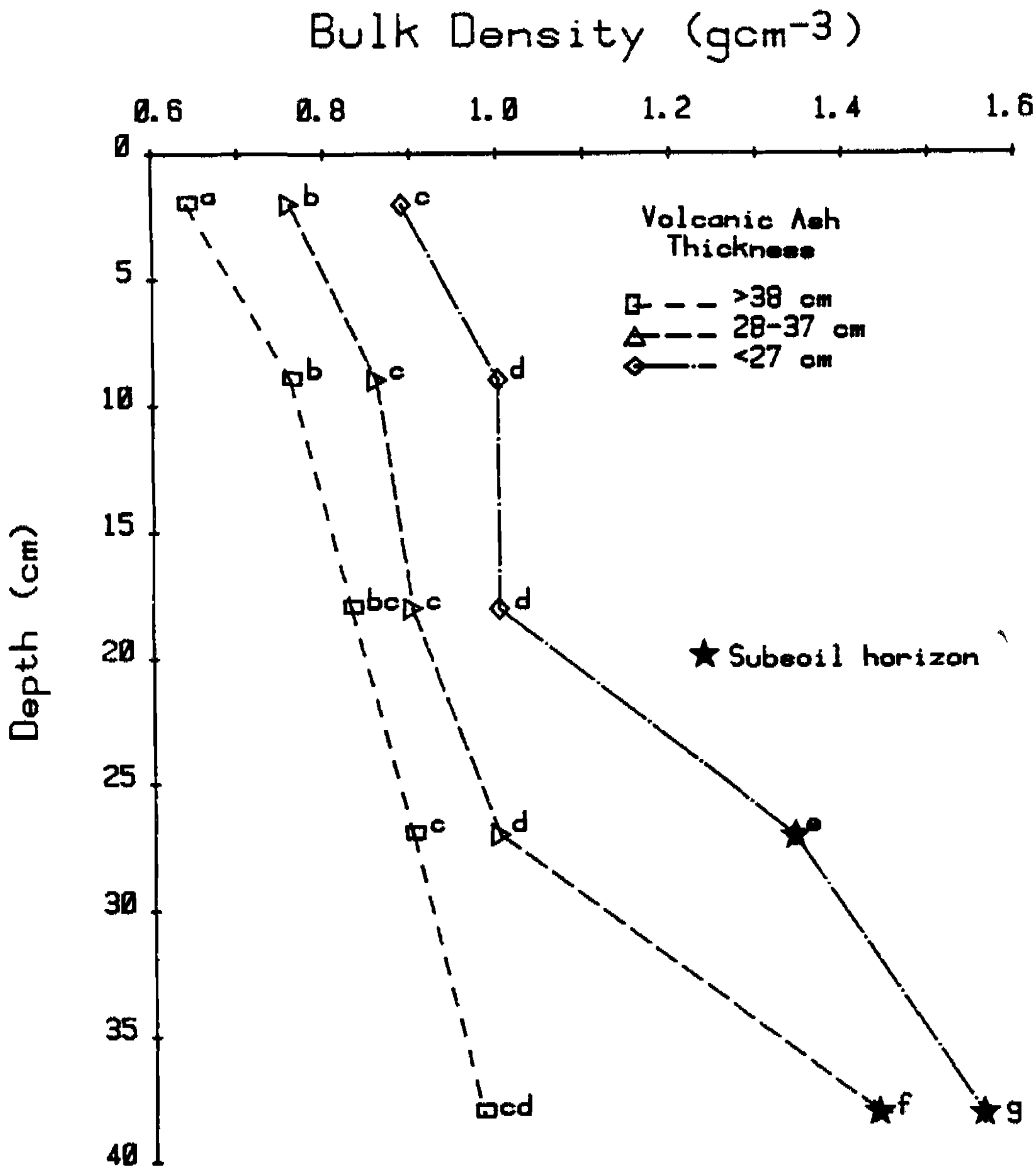

Figure 10. Influence of the volcanic ash horizon thickness on the magnitude of soil density. Points with the same letter are not different at α = .05 level.

An attempt was made to correlate the changes in bulk density with the thickness of the volcanic ash horizon. This correlation was only found to be significant at the Bovill site (Figure 10). Values reported in each thickness class are the combined effects of the harvest and slash disposal treatments. When the volcanic ash horizon was less than 27 cm (11 in), bulk density in the surface 18 cm (7 in) increased 30 percent above the undisturbed profile. Below 18 cm the apparent increase in bulk density was the result of soil displacement where the more dense subsoil horizons were closer to the surface. The Nan Creek site showed similar differences in bulk density below 18 cm (7 in) (Figure 11). The Bess Creek site showed no

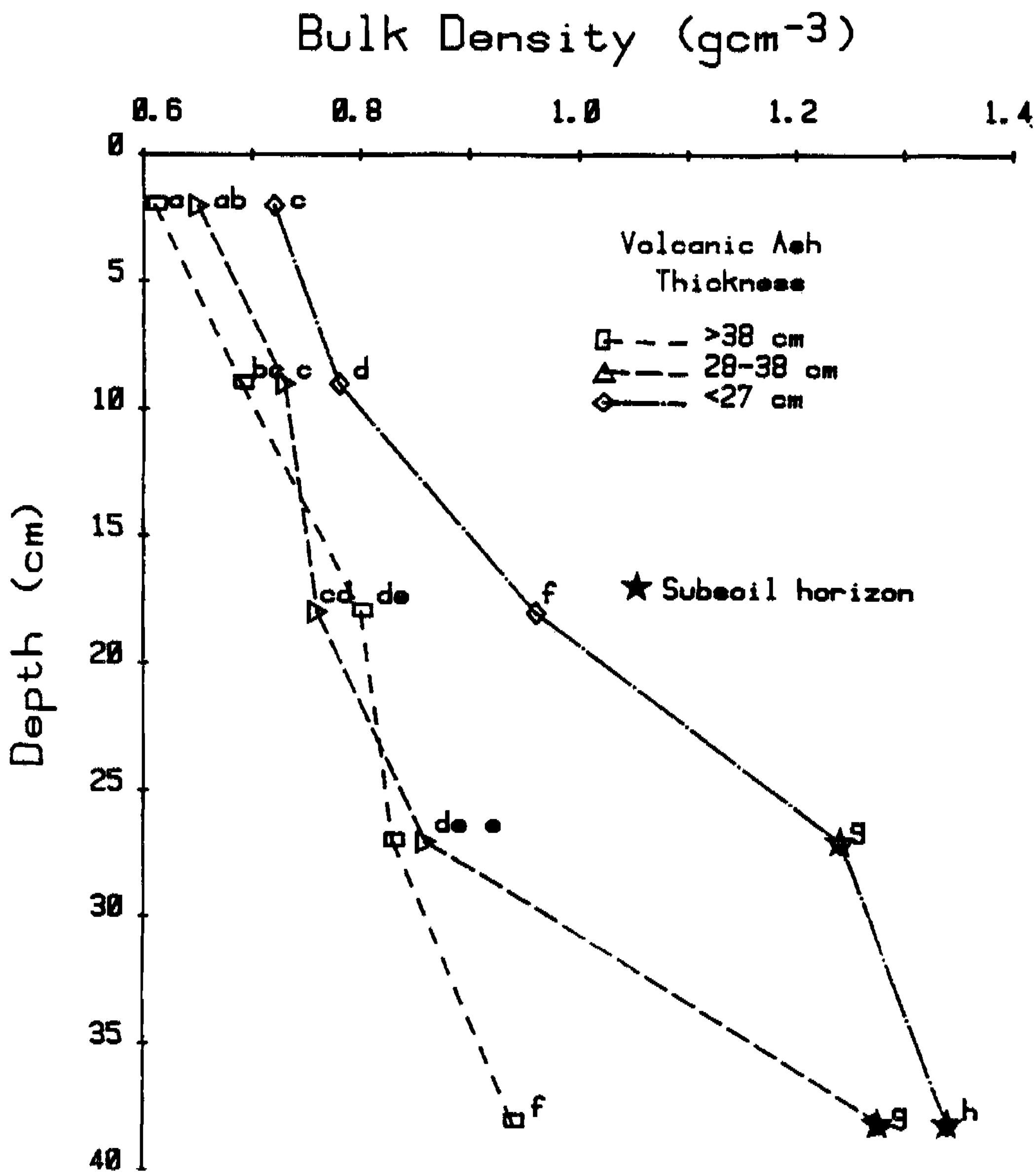

Figure 11. Influence of the Volcanic ash horizon thickness on the magnitude of soil density, Nan Creek site. Points with the same letter are not significantly different at $\alpha = .05$ level.

significant correlation to volcanic ash thickness.

The general form of the dozer blade used in slash disposal activities and its movement through the soil profile are illustrated in Figure 11. As observed in the field numerous scour pans were formed (Figure 12, point A; Figure 12a). It was felt that the scour pan was produced in the same way a plow pan is formed in agricultural soils. Nichols et al. (1958) showed that as a plow moves through the soil, soil is pushed ahead forming a wedge or cone. The cone is compressed until the resistance to compression exceeds the shear value. A block of soil is then sheared off. The resulting compacted area in the plowsole is caused by downward pressures and is similar to that depicted at point A (Figure 12). Scourpan formation would account for the bulk density increases at the 27 cm (11 in) and 38 cm (15 in) depths found in the soil profiles of the Bovill and Nan Creek sites (Figures 6-8). The level of formation within the soil profile would be dependent upon depth of blade placement and thickness of the volcanic ash horizon. The scourpan was only noted at the Bovill and Nan Creek sites indicating formation was only prominent in fine textured soils. Continuing, point B represents soil mixing caused by the angle and placement of the blade; Point C shows the point of compressional forces.

Moisture characteristics

Moisture release characteristics of the volcanic ash horizon were evaluated for each slash disposal site (Figure 13). Percent moisture by volume was determined by multiplying the average bulk density of the undisturbed ash horizon of each site by the respective moisture by weight value. Bovill and Bess Creek are similar in their moisture retention properties. In contrast, the Bess Creek site showed a reduced water reten-

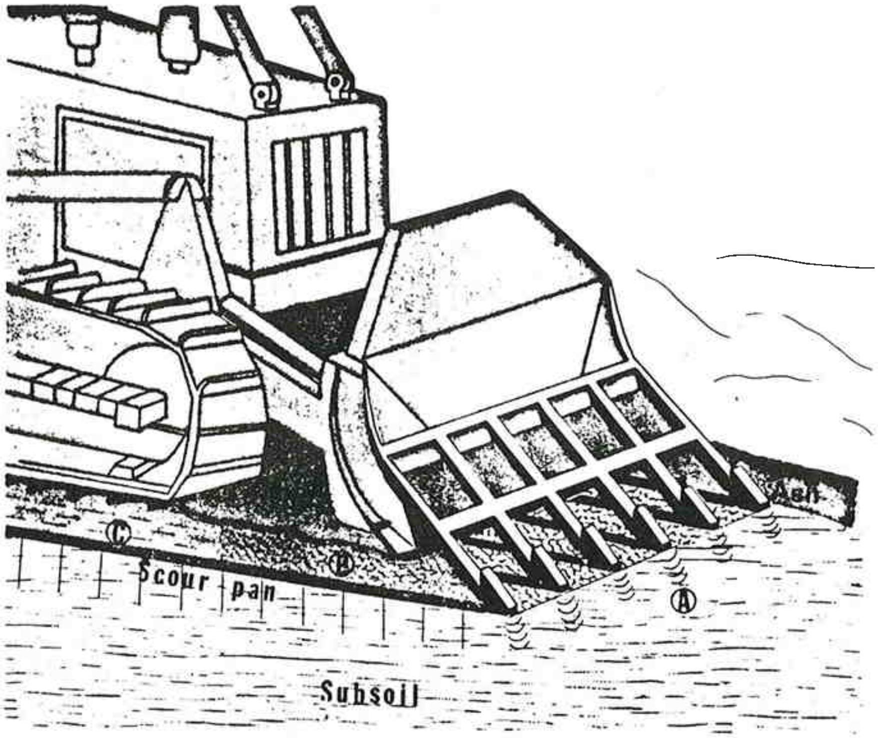

Figure 12. General form of the dozer blade and movement through the soil profile.

Figure 12a. Field observation of scour pan.

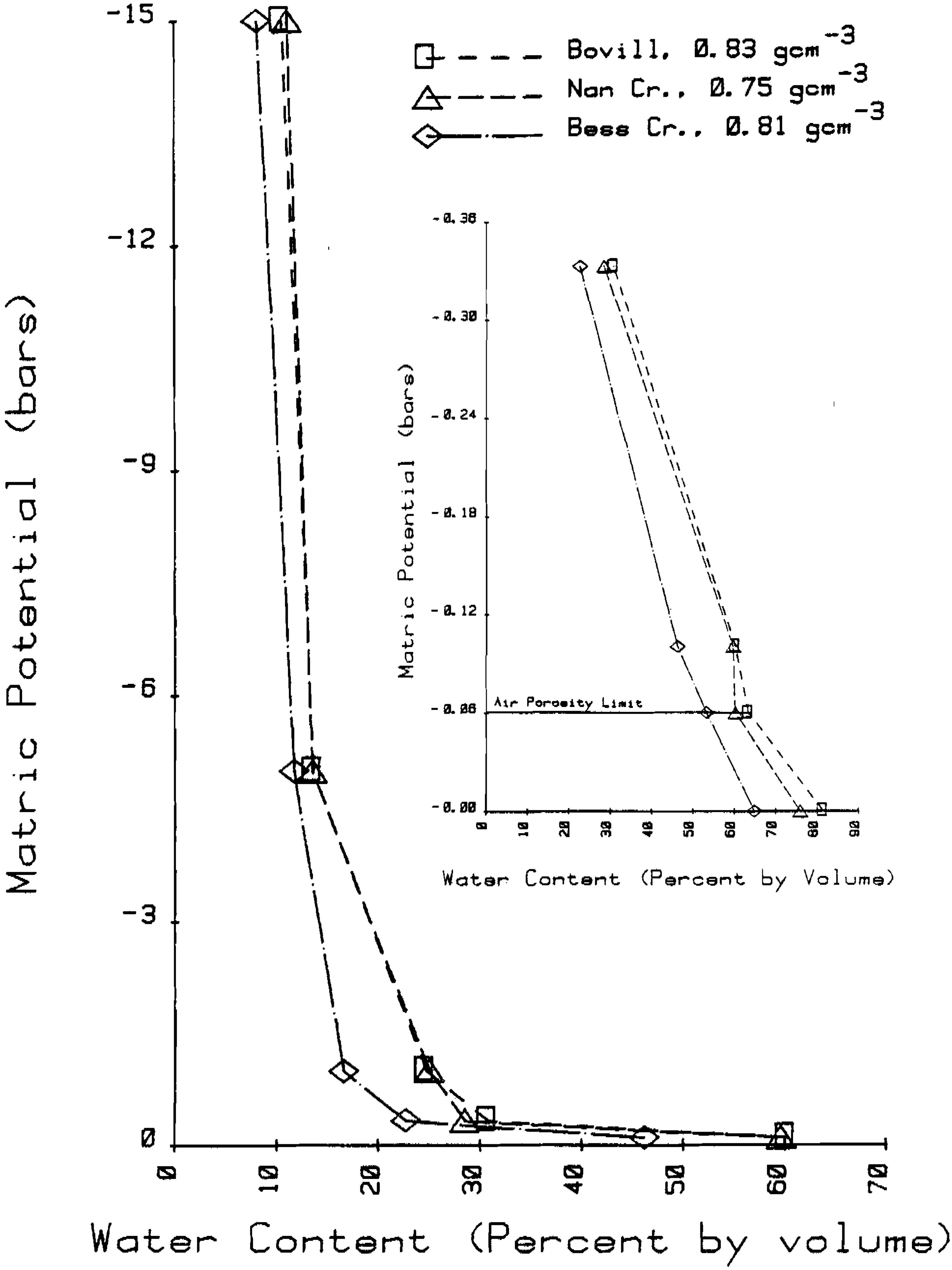

Figure 13. Moisture retention of the volcanic ash horizon for the slash disposal site. Bovill, Nan Creek, Bess Creek.

tion capacity at low negative potentials, characterizing the coarse nature (loam vs silt loam) of the volcanic ash horizon at this site. The volcanic ash horizon at both Bovill and Nan Creek retained 23 percent more water by volume at the 1/3 bar potential than that of the Bess Creek site. Compaction would decrease the number and size of pores, increasing the retention of water at higher potentials, reducing available soil water (Froelich et al., 1980).

Estimation of available soil water for the volcanic ash and subsoil horizons showed that the Bovill and Nan Creek sites had 4.7 times more available water than that of Bess Creek site (Table 5). The volcanic ash horizon of the Bess Creek site retains 65 percent of the available water in the soil profile. It is apparent that soil displacement at the microsite level would have a greater impact on the amount of available water at Bess Creek than either Bovill or Nan Creek. Reductions in available soil water resulting from soil displacement at the microsite level averaged 12 percent among all sites (Table 6). Caution is advised when extrapolating these values of water loss to actual field conditions. Available water at all sites was based on laboratory analyses at a common reference moisture volume at the -1/3 bar potential. Therefore, water losses are theoretical assuming that soil moisture levels among classes were the same. However, compaction and soil displacement create variations in infiltration, evaporation and moisture redistribution, which influence the availability of water under field conditions.

Soil Porosity

Total pore space was determined from the inverse relationship with bulk density; subsequently, any change in bulk density results in a corre-

Table 5. Theoretical amount of available water present in the soil profiles of the Bovill, Nan Creek and Bess Creek slash disposal sites based on laboratory analysis.

Site	Bovill	Nan Creek	Bess Creek
Volcanic ash thickness (cm)	40.0	38.0	41.0
Bulk density (gcm^{-3})	0.83	0.78	0.73
Cm water	7.9	6.9	5.4
*Subsoil			
2EB & 2E (cm)	45.0	2Btb 87.0	2Bw 16.0
Bulk density (gcm^{-3})	1.63	1.25	1.12
Cm water	14.0	31.7	2.0
2Bxt (cm)	66.0	----	2C 17.0
Bulk density (gcm^{-3})	1.80	----	1.40
Cm water	16.9	----	0.9
Total Profile			
Thickness (cm)	151.0	125.0	74.0
Cm water	38.8	38.6	8.3

*Average thickness within the soil profile.

Table 6. Theoretical change in available soil water following the harvest and slash disposal treatments.

Disturbance Class	Undisturbed	Post-harvest	Slash Disposal
Percent Area			
Bovill	35.0		44.0
Nan Creek	31.0		46.0
Bess Creek	33.0		38.0
Volcanic Ash Thickness (cm)			
Bovill	39.5	33.0	30.5
Nan Creek	37.6	35.6	30.5
Bess Creek	41.0	41.0	35.5
Bulk Density (gcm^{-3})			
Bovill	0.83	0.88	0.97
Nan Creek	0.78	0.81	0.86
Bess Creek	0.73	0.84	0.86
Cm Water			
Bovill	7.9	7.0	7.1
Nan Creek	6.9	6.7	6.1
Bess Creek	5.4	5.4	4.7
Percent Loss			
Bovill	----	11.4	10.1
Nan Creek	----	0.3	11.6
Bess Creek	----	0.0	13.0

sponding change in pore space. Reductions in pore space averaged 5 percent for all sites, with the highest reductions occurring at the 2 cm (surface) depth of the Bovill and Bess Creek sites. These were 11 and 8 percent reductions respectively (Appendix 5). Evaluation of macro pore space for the volcanic ash horizon was obtained from the desorption data presented in Figure 13. Macro pore space accounted for 22 percent of the total pore volume for both the Bovill and Nan Creek sites and 18 percent for that of Bess Creek. Reductions in macro pore space was not determined for these sites because ground sieved samples were used in the determination of moisture release curves. Kuennen et al. (1979) reported a 40 percent reduction in macro pore space with a 20 percent increase in bulk density on a volcanic ash soil in western Montana. The initial bulk density was 0.95 gcm^{-3}. In addition, Froelich et al. (1980) reported a 43 percent reduction in macro pore space in the surface 6 cm (2.5 in) of compacted soils in northern California. Bulk densities averaged <1.1 gcm^{-3} after compaction.

Brush Disposal

Areal extent of activity

Evaluation of the brush disposal activity showed that 57 percent of the 75 ha (150 ac) study area remained untreated. Openings were created in the brush canopy by removing the vegetation in strips. The typical cleared strip was characterized by the following dimensions: length - 18 ± 1.5 m (55 ± 5 ft), width - 4 ± .5 m (12 ± 1.5 ft), with a slope average of 20 percent. The track rut disturbance class comprised 65 percent of the cleared strip with the remaining area classified by the inter-track disturbance class.

Soil displacement

Analyses among disturbance classes showed a significant ($\alpha = .01$) reduction in the thickness of the volcanic ash horizon as a result of the brush disposal activity (Figure 14). The post-harvest (brush) disturbance class was used as the reference profile from which soil displacement was compared. The thickness of the volcanic ash horizon was uniform within

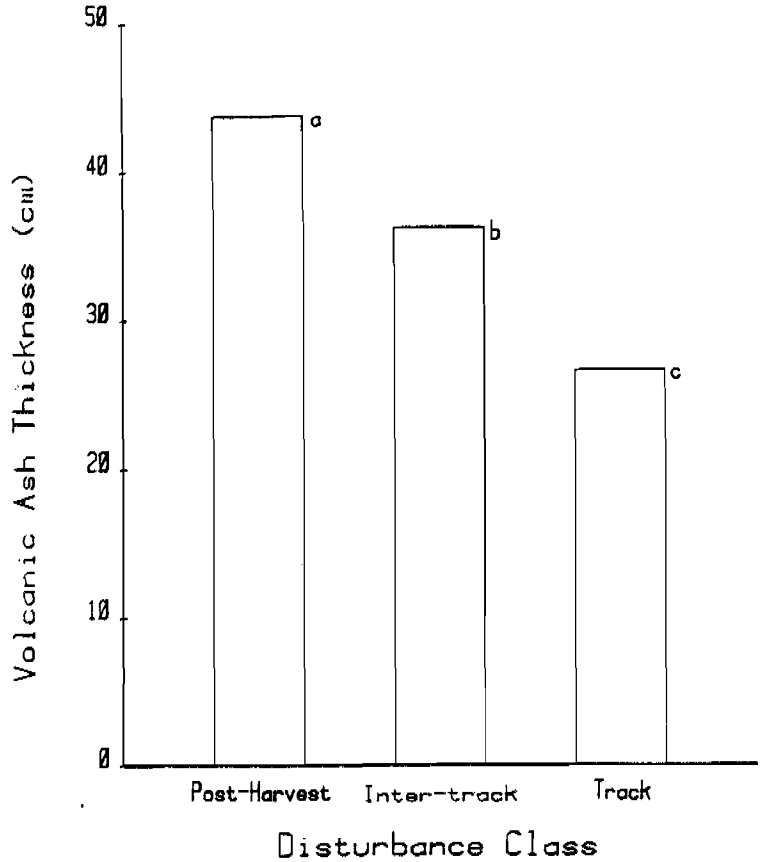

Figure 14. Thickness of the volcanic ash horizon in each disturbance class. Points with the same letter are not significantly different at the α = .05 level.

this class, 43.7 ± 2.2 cm (17.2 ± .9 in), and was assumed to be close to the natural state. Reconstruction of the brush disposal activity indicated that as the brush rake uprooted vegetation in the downslope direction, soil was displaced and redeposited along the sides and at the end of the cleared strip (Figure 15). The greatest amount of soil displacement, 17.0 ± 2.2 cm (6.7 ± .9 in), occurred in the track rut disturbance class. An additional 7.5 ± 2.3 cm (3.0 ± .9 in) of soil was displaced in the inter-track disturbance class. The average volume of soil displaced in the treated area was 9.8 ± 1.6 m^3 (299 ± 49 ft^3) per strip. Further, the cleared strips repre-

Figure 15. View of typical cleared strip.

sented 43 percent of the study area. The impact of this soil displacement can be related to the growth and survival of tree seedlings. Growth reductions have been correlated to the changes in nutrient availability (Moehring, 1969; Adams, 1978), water retention and availability (Youngberg, 1959; Froelich et al., 1980), and soil volume available for rooting (Guild, 1971; Adams, 1978).

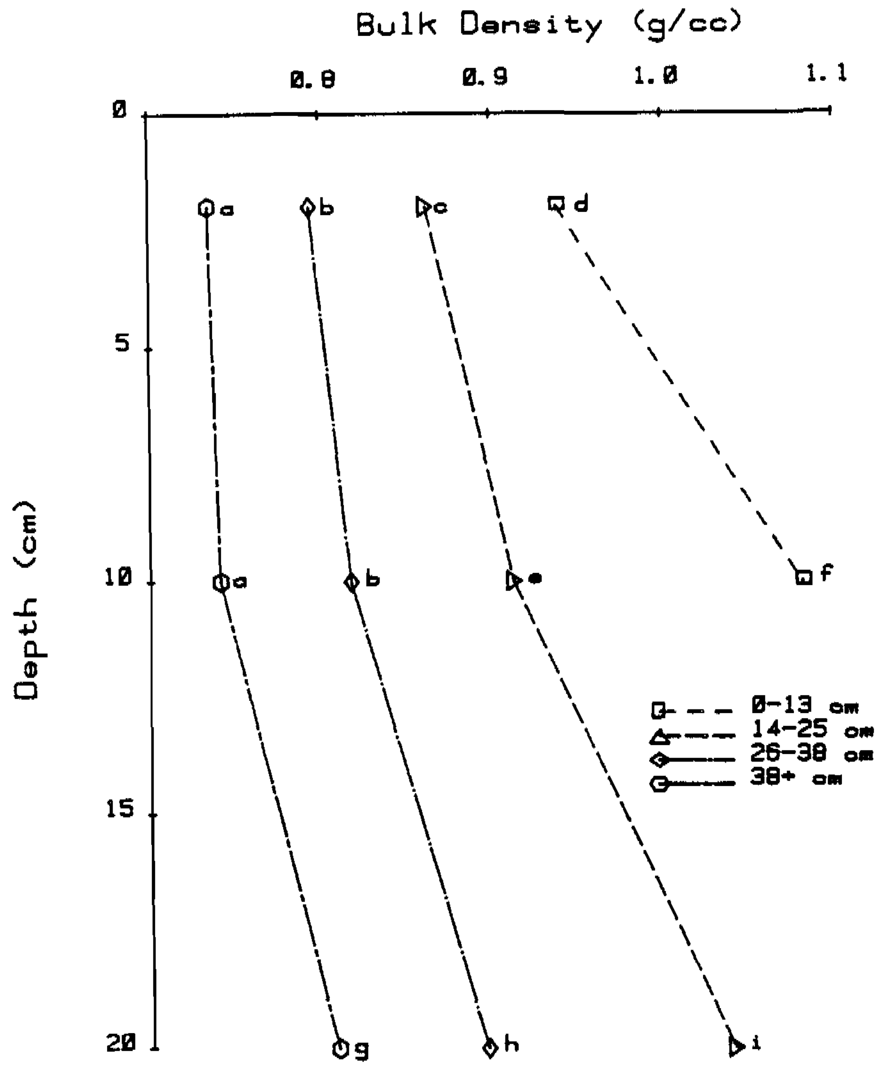

Figure 16. Bulk density profiles by volcanic ash thickness classes. Points with the same letter are not significantly different at $\alpha = .05$ level.

Bulk density

The magnitude of soil compaction was correlated to the thickness of the volcanic ash horizon (Figure 16). Although Figure 16 is a compilation of all disturbance classes, it was inferred that soil losses resulting from the brush disposal activity influence bulk density. Significant ($\alpha = .05$) increases in bulk density occurred as the volcanic ash horizon thickness decreased. Sample collection depths were measured from the surface of the existing soil profiles so bulk density comparisons were not made at the same reference point in the soil profiles. Differences that were found may be inherent differences of the lower horizons as well as those of compaction. The bulk density profile characterized by the 38 cm ash thickness class was used as the reference soil profile. Therefore, point "g" (0.81 ± .02 gcm^{-3}) was assumed to be the highest natural bulk density of this soil type. Comparisons among thickness classes indicate that as the thickness of the volcanic ash decreased, bulk density increased correspondingly.

Evaluation among the disturbances classes showed that significant (α = .05) increases in bulk density occur following treatment. The post-harvest bulk density was 0.75 ± 0.01 gcm^{-3} when averaged over the surface 23 cm (9 in). Post-brush disposal bulk densities were 0.90 ± 0.01 gcm^{-3} for the track rut and 0.83 ± 0.02 gcm^{-3} for the inter-track disturbance classes. These were 20 and 11 percent increases respectively. Soil compaction was attributed to the ground pressures exerted by the crawler tractor, since the natural bulk density was assumed not to exceed 0.81 gcm^{-3}.

Moisture characteristics

Evaluation of the undisturbed moisture release data provided information concerning changes in soil moisture respective to changes in bulk density (Table 7). Analyses among the bulk density classes showed that moisture retention was affected at the soil moisture potentials of -1/60 and -1/10 bars. Comparisons among classes indicate that water movement was influenced by the changes in pore space and pore continuity as bulk density increased. Moisture retention at the -1/60 and -1/10 bar potentials increased an average of 7 percent above the moisture held in the 0.70 gcm^{-3} bulk density class. After the macro pores had drained (1/10 bar), moisture retention was similar and independent of bulk density

Table 7. Comparison of moisture retention by volume among bulk density classes and ground samples.

Water Potential (bars)	----gcm^{-3}---- 0.60-0.70		0.71-0.80		0.81-0.90		Ground Sample
	----% Moisture----						
0	63.4	4.6[a]	62.7	4.6[a]	60.4	4.6[a]	90.7
-1/60	45.0	5.4[b†*]	48.0	5.4[c†]	48.8	5.4[c*]	67.3
-1/10	37.5	3.0[d†*]	40.2	3.0[e†]	40.7	3.0[e*]	58.5
-1/3	30.3	2.5[f]	32.0	2.5[f]	30.0	2.5[f]	27.1
-1	20.4	2.5[g]	22.1	2.5[g]	20.3	2.5[f]	18.1
-5	16.3	2.3[h]	17.9	2.3[h]	16.3	2.3[h]	16.2
-15	13.7	2.2[i]	14.3	2.2[i]	14.8	2.2[i]	15.2

* Significantly different from "b,d" at LSD α = .05.
† Significantly different from "b,d" at LSD α = .10.

because of the relatively small difference in micro pore space between density classes (Figure 17).

Comparisons among the undisturbed core samples and those of the ground and sieved samples, showed differences ranging from zero to 30 percent. The greatest differences occurred at the lower negative potentials. These comparisons show that the moisture characteristics of the undisturbed soil cores were more conservative in the estimation of soil water at low negative potentials than were the ground and sieved samples.

Similar trends in moisture retention were found in the analyses of the subsoil horizons. Moisture release curves for the 2B2 and 2C horizons are presented in Appendix 6.

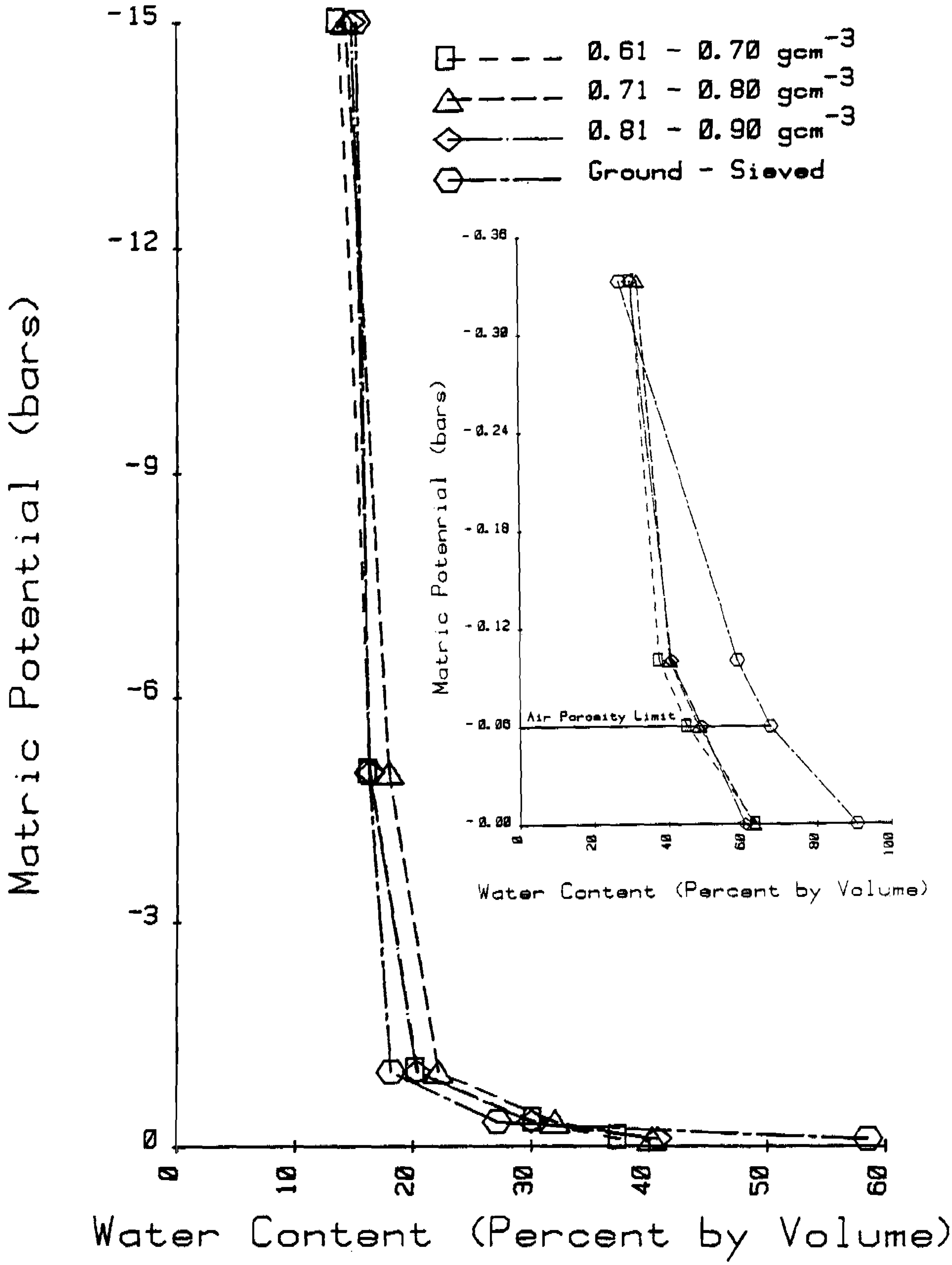

Figure 17. Comparison of moisture retention by bulk density classes and ground samples.

Available soil water was evaluated over the soil profile thicknesses remaining following the brush disposal activity (Table 8). The post-harvest soil profile was used as the standard reference because it was assumed to approximate the natural state. Two features of the data pre-

Table 8. Theoretical change in available water in the soil profiles of the post-harvest, track rut and inter-track disturbance classes based on laboratory analysis.

Disturbance Class	Post-harvest	Inter-track	Track rut
Volcanic ash thickness (cm)	43.7	36.2	26.6
Bulk density (gcm^{-3})	0.75	0.83	0.90
Cm water	7.3	6.0	4.4
*Subsoil			
2B2	10.2	10.2	20.2
Bulk density (gcm^{-3})	1.12	1.12	1.12
Cm water	1.5	1.5	1.5
2C	20.3	20.3	20.3
Bulk density (gcm^{-3})	1.40	1.40	1.40
Cm water	1.8	1.8	1.8
Total Profile			
Thickness (cm)	74.2	66.7	57.1
Cm water	10.6	9.3	7.7

* Average thickness within the soil profile.

sented describe the influence of the brush disposal activity on soil water storage. First, the volcanic ash horizon retains 62 percent of the available water stored in the post-harvest soil profile. Secondly, soil loss which occurred from the brush disposal activity resulted in significant reductions in available water. Available soil water was reduced an average of 22 percent in the treated areas. This was a net volume loss of 1.7 m^3 (3.6 ft^3) of water per cleared strip. The abrupt textural change between genetic horizons has the potential to reduce or stop the redistribution of water upward from lower horizons, indicating that the "realized" water loss may be higher (Baver, Gardner, and Gardner, 1972). This condition would then lower the overall effective water content within the soil profile, placing more emphasis on the water supply of the volcanic ash horizon.

Caution should be used when extrapolating these values of water loss to actual field conditions. Available water at all sites and disturbance classes was based on a common reference moisture volume at the -1/3 bar potential. Reductions in available water are theoretical, assuming that soil moisture levels among disturbance classes in the field are the same. Compaction and soil displacement create variations in infiltration, evaporation and moisture redistribution within the soil profile of each disturbance class.

Soil porosity

Soil porosity is inversely related to bulk density, any change in the physical arrangement of soil particles through the alteration of soil structure or by compaction results in a change in soil porosity. The greatest reduction in pore space occurred in the thinnest volcanic ash horizon and track rut disturbance class. Reductions in total pore space rarely exceeded 10 percent (Appendix 7).

Macro porosity in the surface 23 cm (9 in) was reduced an average of 23 percent in the track rut disturbance class (Table 9). Reduced porosity results in decreased aeration. Cullen and Montagne (1981) evaluated compacted volcanic ash soils in western Montana. They suggested that a 19 percent reduction in pore space would reduce gaseous diffusion by 34 percent. It was assumed that as water retention increased because of an increase in micro pores, the amount of air-filled pore space (macro pore) was reduced limiting gaseous diffusion. In addition, Froelich et al. (1980) reported that altered pore size distribution resulting from compaction was associated with a change in soil moisture release curves. Water was held more tenaciously at greater negative potentials, so less water would be available for tree growth.

Table 9. Percent soil porosity by disturbance class.

Disturbance Class	Total	Macro pore	Micro pore
Post-harvest	69.7 ± 1.0	16.3	53.4
Inter-track	66.4 ± 1.0	13.1	53.3
Track rut	63.3 ± 1.0	12.5	50.8

Confidence limits at $\alpha = .05$.

SUMMARY AND CONCLUSIONS

This study was designed to assess the changes in the physical properties of four forest soils having a surface horizon of weathered volcanic ash and known regeneration problems following mechanical site preparation.

The soil disturbances resulting from the slash and brush disposal activities can be grouped into two classes. First, displacement of the volcanic ash horizon resulted in reductions in the effective rooting volume, important for nutrient and water storage properties. Secondly, alteration of soil structure by compaction influenced changes in soil aeration, moisture retention, and bulk density.

Slash and brush disposal treatments resulted in significant changes in soil physical properties when compared to the undisturbed and post-harvest soil conditions. Changes in the soil physical properties were evaluated as a function of sample depth, thickness of the volcanic ash horizon, and disturbance classes for the brush disposal site. Additional variables of fuel load and time of sample collection (i.e. post-harvest and post-slash disposal) enhanced the analysis of the slash disposal treatment areas.

4.1 Summary of slash disposal treatment

1.) Area extent of activity

-High fuel load densities were not preferentially treated over lower fuel concentrations.

-Total area treated averaged 43 percent among all sites.

2.) Soil displacement.

-Averaged 6.5 cm ± 12.7 cm (2.6 in ± 5.0 in) among all sites.

-Displacement occurred from vertical placement of the dozer blade, pivot turns, and horizontal slippage of vehicle tracks.

3.) Soil bulk density.

-Magnitude of the resulting bulk densities were not dependent upon fuel load concentration. All classes showed a significant 13 percent increase in bulk density above the post-harvest bulk density, among all sites.

-Bulk density increases were highest at the surface of both Bovill and Bess Creek, 26 and 21 percent respectively. Nan Creek density increases were 7 percent to 27 cm (11 in).

-Scour pans were observed at Bovill and Nan Creek, indicating formation was prominent only in fine textured soils.

4.) Soil porosity.

-Reductions in total pore space averaged 5 percent among all sites.

-Macro pore volume accounted for 22 percent of the total pore space at the Bovill and Nan Creek sites, and 18 percent for that of Bess Creek.

5.) Moisture characteristics.

-Moisture retention properties for the volcanic ash horizon of Bovill and Nan Creek were the same.

-The volcanic ash horizon at Bess Creek retained 36 percent less water below 1/3 bar tension than Bovill or Nan Creek. Characterized coarse nature of the volcanic ash horizon at this site.

-Soil displacement reduced the theoretical amount of available water by 12 percent among all sites.

4.2 Summary of brush disposal treatment

1.) Area extent of activity.

-Cleared strips were characterized by the following dimensions; length 18 m (55 ft), width 4 m (12 ft).

-Total area treated was 43 percent.

- a. 57 percent untreated.
- b. 28 percent in the track rut class.
- c. 15 percent in the inter-track class.

2.) Soil displacement.

- -Soil was lost from the site, being piled at the end of the cleared strip.
- -A 39 percent reduction in the track rut and 17 percent reduction in the inter-track disturbances were found following treatment.
- -The average volume of soil displaced was 9.8 ± 1.6 m^3 (299 ± 49 ft^3) per cleared strip.

3.) Bulk density.

- -Increases were highest in the track rut disturbance class showing a 20 percent increase above the post-harvest bulk density of 0.75 gcm^{-3}.
- -Bulk density increased as the thickness of the volcanic ash horizon decreased.

4.) Soil porosity.

- -Reductions in total pore space rarely exceeded 10 percent.
- -The track rut disturbance class showed a 23 percent reduction in macro pore space when compared to the post-harvest class, inter-track area showed a 20 percent reduction in macro pore space.

5.) Moisture characteristics.

- -Comparisons among density classes showed that moisture retention increased 7 percent above the soil density class of 0.70 gcm^{-3} below a -1/10 bar potential. No significant differences were evident above -1/10 bar potential.
- -Available water decreased an average of 22 percent within the treated area.
- -The track rut disturbance class showed a 40 percent reduction in available water.

Caution should be used when extrapolating these values of water loss to actual field conditions. Available water at all sites and disturbances classes were determined from the reported changes in soil physical properties and are based on a common reference moisture volume at the -1/3 bar potential. Reductions in available water are theoretical, assuming that soil moisture levels among disturbance classes in the field are the same. Compaction and soil displacement create variations in infiltration, evaporation and moisture redistribution within the soil profile.

Conclusions

1.) Slash and brush disposal treatment resulted in significant soil density increases.

2.) Fuel load concentrations did not influence the magnitude of bulk density.

3.) Scour pans were formed in fine-textured soils, as observed at Bovill and Nan Creek.

4.) The volume of soil displaced during brush disposal activities is greater than that of slash disposal treatments.

5.) Soil displacement and compaction result in the reduction of available soil water.

Recommendations

Significant changes in soil physical properties were found following the slash and brush disposal activities described in this study.

Further study is needed to determine:

- the influence of soil changes on tree seedling establishment and growth,
- moisture losses under field conditions,
- area extent and importance of scour pan formation,
- the magnitude of operator-related soil disturbances and,
- effectiveness of treatments.

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APPENDIX 1

Soil Profile Descriptions and Physical Analysis

Helmer Variant Silt Loam 80-ID-29130

Classification: medial over loamy, mixed Andeptic Paleboralf, fragipan phase.

General Site Characteristics

Location: Latah County, Idaho; 2 miles west of Bovill, Idaho
Forest: Clearwater National Forest
Area: Palouse District
Described By/Date: Hal Collins on October 30, 1981
Parent Rock/Material: Mazama volcanic ash over loess mixed with alluvium overlying basalt
Habitat Type: (Thuja plicata) western red cedar/(Pachistima myrsinities) pachistima habitat type; (Abies grandis) grand fir, (Larix occidentalis) western larch, (Pinus monticola) western pine; (Vaccinium ovatum) huckleberry, (Asarum caudatum) ginger, (Galium boreale) bedstraw, golden thread,
Topography: mountain/loess sheet, slope, single slopes-gently sloping, uniform

Landform: mountain/loess sheet	Climate: Frigid, udic
Weathering: normal	Precipitation: 41.5 cm
Formation Name: Columbia River Basalt, Palouse Loess	Erosion: very slight
Slope: 5 %, 150 m, upper 1/3	Infiltration: slow
Aspect: east	Permeability: low
Elevation: 921 m	Storage:
Soil Depth: 60+ cm	Drainage: somewhat poorly
Eff. Rooting Depth:	Air Temp: 8 deg. C
Litter Type: duff	Soil Temp at 20 inches:
Surface Rock: none	Salt/Alkal: nonsaline

Remarks:

Pedon Description

Bs1 0-20 cm. Dark brown to brown (7.5YR 4/4) silt loam, dark brown to brown (7.5YR 4/4) moist; very fine granular structure; loose, very friable, slightly sticky and nonplastic; no clay films; many very fine discontinuous exped pores; many very fine and fine, common medium, and few coarse roots; noneffervescent; no gravels.

Bs2 20-41 cm. Strong brown (7.5YR 5/6) silt loam, dark brown to brown (7.5YR 4/4) moist; very fine granular structure; loose, very friable, slightly sticky and nonplastic; no clay films; many very fine discontinuous exped pores; many very fine and fine, common medium, and few coarse roots; noneffervescent; krotovina 3 inches in diameter; clear smooth boundary.

80-ID-29130 (cont.)

2Bwb 41-53 cm. Very pale brown (10YR 7/3) silt loam, light yellowish brown (10YR 6/4) moist; weak subangular blocky structure; slightly hard, slightly sticky and nonplastic; no clay films; common very fine discontinuous exped pores; many very fine and fine, common medium, and few coarse roots; noneffervescent; abrupt wavy boundary.

2EBb 53-71 cm. Brown (7.5YR 5/4) B material and very pale brown (10YR 7/4) silt loam, dark brown to brown (7.5YR 4/4) B material, moist, and light yellowish brown (10YR 6/4) matrix, moist; weak subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; no clay films; many very fine, common fine discontinuous exped pores; many very fine and fine, few medium roots; noneffervescent; clear wavy boundary.

2Eb 71-86 cm. Brown (7.5YR 5/4) B material and pink (7.5YR 7/4) matrix, silt loam, dark brown to brown (7.5YR 4/4) B material, moist, and brown (7.5YR 5/4) matrix, moist; weak subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; no clay films; few very fine and fine discontinuous inped pores; many very fine, common fine, and few medium roots; noneffervescent; clear wavy boundary.

2Btxb1 86-107 cm. Brown (7.5YR 5/4) matrix, silt loam, dark brown to brown (7.5YR 4/4) matrix, moist; coarse angular blocky structure; extremely hard, brittle, slightly sticky and nonplastic; few moderately thick clay films lining ped faces; few fine discontinuous inped pores; few very fine and fine roots; noneffervescent; reddish brown (5YR 4/4) clay films and dark brown to brown (7.5YR 4/4) moist, clay films; pink (7.5YR 7/4) silt coatings, brown (7.5YR 5/4) moist, silt coatings; abrupt smooth boundary.

2Btxb2 107-127 cm. Dark brown to brown (7.5YR 4/4) silt loam, dark brown to brown (7.5YR 4/4) moist; very coarse angular blocky structure; extremely hard, brittle, slightly sticky and slightly plastic; many thick clay films lining ped faces; few fine discontinuous inped pores; no roots; organic matter staining; dark reddish brown (5YR 3/4) clay films, dark brown to brown (7.5YR 4/4) moist; pinkish gray (7.5YR 7/2) silt coatings, brown (7.5YR 5/4) moist; noneffervescent; black (7.5YR 2/0) organic matter coatings; clear wavy boundary.

2Btxb3 127-152 cm. Brown (7.5YR 5/4) silty clay loam, dark brown to brown (7.5YR 4/4) moist; coarse angular blocky structure; extremely hard, brittle, slightly sticky and slightly plastic; continuous thick clay films lining ped faces; few fine discontinuous inped pores; no roots; noneffervescent; thick organic matter stainings; dark reddish brown (5YR 3/4) clay films, dark brown to brown (7.5YR 4/4) moist; black (10YR 2/1) organic matter coatings; clear wavy boundary.

Pedon: Helmer Variant Silt Loam 80-ID-29130 Date: February 1982

Sample No.	Horizon	Depth (cm)	pH paste	EC*10³ (mmhos/cm)	% Water at Saturation	Available P (ppm)	Sesquioxides: Di-Citrate Fe (%)	Sesquioxides: Extract Al (%)	Sesquioxides: Pyrophosphate Fe (%)	Sesquioxides: Extract Al (%)	Spodic
1	Bs1	0- 20	6.30	0.17	88	2.9					
2	Bs2	20- 41	6.46	0.08	75	7.6					
3	2Bwb	41- 53	5.48	0.08	38	0.9					
4	2EBb	53- 71	5.25	0.10	42	2.7					
5	2Eb	71- 86	4.92	0.20	34	3.1					
6	2Btxb1	86-107	5.04	0.07	44	4.6					
7	2Btxb2	107-127	4.91	0.09	42	0.7					
8	2Btxb3	127-152	5.26	0.08	44	7.1					

Sample No.	Exchangeable Ions: Ca	Exchangeable Ions: Mg	Exchangeable Ions: Na	Exchangeable Ions: K	Ext. Acidity: H	CEC	Base Saturation	OM	OC	N	C:N	Soil Fraction	NaF pH
	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	%	%	%	%	ratio		
1	4.75	0.74	0.20	0.80	20.30	26.7	24	4.40	2.56	nd	--	1.00	10.95
2	4.13	1.01	0.20	0.90	17.60	23.2	26	1.86	1.08	nd	--	1.00	11.01
3	2.75	1.01	0.20	0.30	6.20	9.1	41	0.55	0.32	nd	--	1.00	8.97
4	3.00	20.50	0.20	0.20	7.50	11.8	76	0.79	0.46	nd	--	1.00	8.68
5	3.75	20.50	0.20	0.20	10.10	15.8	71	0.53	0.31	nd	--	1.00	8.75
6	3.88	12.25	0.20	0.20	11.20	15.6	60	0.41	0.24	nd	--	1.00	9.07
7	3.38	3.08	0.20	0.20	10.30	13.9	40	0.40	0.23	nd	--	1.00	8.62
8	6.00	4.50	0.30	0.20	8.80	16.5	56	0.40	0.23	nd	--	1.00	8.91

Remarks: CEC's were leached with 10% acidified NaCl.
CEC's were run on the Technicon Autoanalyzer.
nd - not determined
Available P extracted with sodium acetate.

Analysis by: A. Falen, D. Eisinger, H. Collins

Pedon: Helmer Variant Silt Loam 80-ID-29130 Date: April 1982

Depth	VCS	CS	MS	FS	VFS	TS	TSi	TC	Gravel & Stone >2 mm		Textural
	Particle Size Distribution (mm)										
	2-1.0	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	2-0.05	0.05-0.002	<0.002	wt.	vol.	Classes
cm	%								%		
0- 20						26.80	64.54	8.66			Silt Loam
20- 41						24.79	66.92	8.30			Silt Loam
41- 53						27.15	61.17	11.68			Silt Loam
53- 71						21.69	63.59	14.72			Silt Loam
71- 86						19.82	59.24	20.94			Silt Loam
86-107						21.60	52.08	26.32			Silt Loam
107-127						23.68	48.68	27.64			Clay Loam
127-152						21.01	46.68	32.31			Clay Loam

Depth	CoSi	Msi	Fsi	Bulk Density		Water Content 1/3	15	Liquid Limit	Plastic Limit	Plastic Index
	Silt Size Distribution (mm)									
	0.05-0.02	0.02-0.005	0.005-0.002	Clod	Core	Bar	Bar			
cm	%			g/cc		%		%		
0- 20						46.4	12.1			
20- 41						33.2	10.8			
41- 53				1.61		24.0	5.6			
53- 71				1.62		25.6	5.9			
71- 86				1.67		26.1	6.8			
86-107				1.78		26.5	10.1			
107-127				1.80		22.4	10.1			
127-152				1.83		26.9	12.8			

Remarks: Samples were run by the pipette method.
Bulk density were run by Mike Mumm.

Analysis by: Debbie Eisinger

Unnamed Silt Loam 80-ID-25151 (Nan Creek)

Classification: medial over loamy, mixed, frigid Andeptic Glossoboralf.

General Site Characteristics

Location: Idaho County, Idaho; section 5, T. 33N., R. 6E., photo no 676-281.
Forest: Clearwater National Forest
Area: Pierce District
Described By/Date: Hal Collins on September 27, 1980.
Parent Rock/Material: Mazama ash/alluvium
Habitat Type: (Thuja plicata) western red cedar/(Pachistima myrsinities) Pachistima habitat type; (Pinus monticola) western white pine, (Abies grandis) grand fir, (Larix occidentalis) western larch, (Clintonia uniflora) queencup beadlily, goldenthread, (Asarum caudatum) ginger, (Adenocaulon bicolor) trail plant.
Topography: mountain, slope, rolling-undulating, uniform-smooth.

Landform: mountain	Climate: Frigid, udic
Weathering: normal	Precipitation: 100 cm (snow)
Formation Name:	Erosion: not eroded
Slope: 10%, 150 m, center 1/3	Infiltration: slow
Aspect: south rolling	Permeability: med. rapid
Elevation: 1121 m	Storage:
Soil Depth:	Drainage: well drained
Eff. Rooting Depth:	Air Temp: 7 deg. C
Litter Type: duff	Soil Temp at 20 inches:
Surface Rock: class 1	Salt/Alkal: none

Remarks:

Pedon Description

A 0-18 cm. Dark brown (7.5YR 3/4) silt loam, dark reddish brown (5YR 2.5/2) moist; weak granular structure; friable, very friable, slightly sticky and nonplastic; no clay films; abundant very fine discontinuous random exped pores; common very fine and fine roots; noneffervescent.

Bs 18-48 cm. Strong brown (7.5YR 5/6) silt loam, yellowish red (5YR 4/6) moist; weak subangular blocky structure; friable, friable, slightly sticky and nonplastic; abundant very fine discontinuous random exped pores; common very fine and fine roots; no clay films; noneffervescent; abrupt smooth boundary.

80-ID-25151 (cont.)

2Btb1 48-63 cm. Strong brown (7.5YR 5/6) silty clay, dark reddish brown (5YR 3/4) moist; medium subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; common thin clay films lining ped faces; few very fine discontinuous random exped pores; few very fine and medium roots; noneffervescent; reddish brown (5YR 4/4) clay skins, dark reddish brown (5YR 3/4) moist; abrupt smooth boundary.

2Btb2 63-81 cm. Strong brown (7.5YR 5/6) silty clay, reddish brown (5YR 4/4) moist; medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; common thin clay films lining ped faces; few fine discontinuous random pores; few fine roots; noneffervescent; reddish brown (5YR 4/4) clay skins; gradual wavy boundary.

2Btb3 81-104 cm. Strong brown (7.5YR 5/6) silty clay, dark reddish brown (5YR3/4) moist; medium subangular blocky structure; hard, very firm, slightly sticky and slightly plastic; many moderately thick clay films lining ped faces; few fine discontinuous random pores; few fine and medium roots; noneffervescent; reddish brown (5YR 4/4) clay skins; gradual irregular boundary.

2Btb4 104-135+ cm. Yellowish red (5YR 5/6) clay, dark red (2.5YR 3/6) moist; medium subangular blocky structure; hard, very firm, slightly sticky and slightly plastic; many moderately thick clay films lining ped faces; few fine discontinuous random pores; few fine roots; noneffervescent; yellowish red (5YR 5/8) clay skins; gradual wavy boundary.

Pedon: Unnamed Silt Loam 80-ID-25151 (Nan Creek) Date: February 1982

Sample No.	Horizon	Depth	pH paste	$EC*10^3$	% Water at Saturation	Available P	Sesquioxides: Di-Citrate Fe	Sesquioxides: Extract Al	Sesquioxides: Pyrophosphate Fe	Sesquioxides: Extract Al	Spodic
		cm		mmhos/cm		ppm	%	%	%	%	
1	A	0- 18	*5.73	0.10	--	2.1					
2	Bs	18- 48	6.10	0.31	88	1.7					
3	2Btb1	48- 63	5.08	0.09	51	5.7					
4	2Btb2	63- 81	4.98	0.06	56	5.9					
5	2Btb3	81-104	5.00	0.06	59	9.4					
6	2Btb4	104-135+	4.98	0.06	56	5.6					

Sample No.	Exchangeable Ions: Ca	Exchangeable Ions: Mg	Exchangeable Ions: Na	Exchangeable Ions: K	Ext. Acidity: H	CEC	Base Saturation	OM	OC	N	C:N	Soil Fraction	NaF pH
	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	%	%	%	%	ratio		
1	8.75	4.30	0.10	0.80	34.90	58.6	29	20.66	12.01	nd	--	1.00	9.53
2	3.75	0.84	0.20	0.20	23.70	28.4	17	5.68	3.30	nd	--	1.00	10.45
3	2.00	1.43	0.10	0.40	13.80	17.3	22	1.00	0.58	nd	--	1.00	8.66
4	2.88	2.88	0.20	0.30	13.30	14.4	32	0.65	0.38	nd	--	1.00	8.73
5	3.50	3.90	0.10	0.30	12.90	19.5	37	0.70	0.41	nd	--	1.00	8.65
6	2.75	2.45	0.10	0.30	8.80	14.8	39	0.54	0.31	nd	--	1.00	8.76

Remarks: CEC's were leached with 10% acidified NaCl.
CEC's were run on the Technicon Autoanalyzer.
nd - not determined
Available P extracted with sodium acetate.
* 1:5 pH

Analysis by: A. Falen, D. Eisinger, H. Collins

Pedon: Unnamed Silt Loam 80-ID-25151 (Nan Creek) Date: April 1982

Depth	VCS	CS	MS	FS	VFS	TS	TSi	TC	Gravel & Stone >2 mm wt.	vol.	Textural Classes
	Particle Size Distribution (mm)										
	2-1.0	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	2-0.05	0.05-0.002	<0.002	wt.	vol.	Classes
cm	%								%		
0- 18						17.92	65.52	16.56			Silt loam
18- 48						10.72	61.59	27.69			Silt loam
48- 63						12.95	43.49	43.56			Silty Clay
63- 81						10.60	43.07	46.33			Silty Clay
81-104						11.79	43.30	44.91			Silty Clay
104-135+						19.53	36.60	43.86			Clay

Depth	CoSi	Msi	Fsi	Bulk Density Clod	Core	Water Content 1/3 Bar	15 Bar	Liquid Limit	Plastic Limit	Plastic Index
	Silt Size Distribution (mm)									
	0.05-0.02	0.02-0.005	0.005-0.002	Clod	Core	Bar	Bar			
cm	%			g/cc		%		%		
						30.0	15.2			
						29.3	14.8			
						31.1	16.6			
						26.4	15.2			

Remarks: Samples were run by the pipette method. Analysis by: Debbie Eisinger

Unnamed Loam 80-ID-18124 (Bess Creek)

Classification: medial over loamy, mixed, frigid, Typic Vitrandept.

General Site Characteristics

Location: Idaho County, Idaho; Bess Creek, section 8, T. 36N., R. 6E., photo no 676-182.
Forest: Clearwater National Forest
Area: Pierce District
Described By/Date: Hal Collins on September 6, 1980.
Parent Rock/Material: Mazama ash/granite (decomposed)
Habitat Type: (Thuja plicata) western red cedar/(Pachistima mrysinities) Pachistima habitat type; (Pinus monticola) western white pine, (Abies grandis) grand fir, (Larix occidentalis) western larch, (Psuedotsuga menziesii) Douglas fir, (Clintonia uniflora) queencup beadlily, golden thread, (Smilacina stellata) Solomen seal, (Acer) mountain maple, (Asarum caudatum) ginger, (Peramium decipiens) rattlesnake plantain, (Galium boreale) bedstraw.
Topography: mountain, slope, single slopes-steep, convex

Landform: mountain	Climate: Frigid, udic
Weathering: normal	Precipitation: 114 cm
Formation Name: Idaho Batholith	Erosion: slight
Slope: 32%, 300m, center 1/3	Infiltration: slow
Aspect: north	Permeability: mod. rapid
Elevation: 1341 meters	Storage:
Soil Depth: 74 cm	Drainage: well drained
Eff. Rooting Depth:	Air Temp: 7 deg. C
Litter Type: duff	Soil Temp at 20 inches:
Surface Rock: very slight	Salt/Alkal: none

Remarks:

Pedon Description

A 0-15 cm. Dark brown to brown (10YR 4/3) silt loam, dark brown (7.5YR 3/2) moist; strong medium granular structure; noncoherent, friable, slightly sticky and nonplastic; no clay films; common fine discontinuous random exped interstitial pores; common very fine, few fine roots; noneffervescent;

Bs1 15-33 cm. Brown (7.5YR 5/4) silt loam, dark brown (7.5YR 3/4) moist; weak fine granular structure; noncoherent, very friable, slightly sticky and nonplastic; no clay films; common fine discontinuous random exped interstitial pores; common fine and mediu, few coarse roots; noneffervescent; abrupt wavy boundary.

80-ID-18124 (cont.)

Bs2 33-41 cm. Brown (7.5YR 5/4) silt loam, dark yellowish brown (10YR 3/4) moist; weak fine granular structure; noncoherent, very friable, nonsticky and nonplastic; no clay films; few fine, common very fine discontinuous random exped interstitial pores; common fine and medium, few coarse roots; noneffervescent; 40 percent coarse fragments; abrupt wavy boundary.

2Bwb 41-57 cm. Yellowish brown (10YR 5/4) sandy loam, dark brown to brown (10YR 4/3) moist; massive single grained structure; loose, loose, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped interstitial pores; few fine roots; noneffervescent; 40 percent coarse fragments; gradual wavy boundary.

2BCb 57-74 cm. Very pale brown (10YR 7/4) coarse loamy sand, yellowish brown (10YR 5/4) moist; massive single grained structure; loose, loose, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped interstitial pores; few very fine roots; noneffervescent; krotovinia greater than 2 inches; discontinuous broken boundary.

2Cb 74+ cm. White (2.5Y 8/2) coarse sand, very pale brown (10YR 7/4) moist; massive single grained structure; loose, loose, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped interstitial pores; few very fine roots; krotovinia 2 inches; discontinuous broken boundary.

Pedon: Unnamed Loam 80-ID-18124 (Bess Creek) Date: February 1982

Sample No.	Horizon	Depth	pH paste	$EC*10^3$	% Water at Saturation	Available P	Sesquioxides: Di-Citrate Fe	Sesquioxides: Extract Al	Sesquioxides: Pyrophosphate Fe	Sesquioxides: Extract Al	Spodic
		cm		mmhos/cm		ppm	%	%	%	%	
1	A	0-15	5.81	0.24	68	4.1					
2	Bs1	15-33	5.91	0.22	57	4.6					
3	Bs2	33-41	6.03	0.09	44	1.6					
4	2Bw	41-57	6.04	0.09	44	3.4					
5	2BC	57-74	5.78	0.09	32	2.2					
6	2C	74+	5.85	0.07	32	1.9					

Sample No.	Exchangeable Ions: Ca	Exchangeable Ions: Mg	Exchangeable Ions: Na	Exchangeable Ions: K	Ext. Acidity: H	CEC	Base Saturation	OM	OC	N	C:N	Soil Fraction	NaF pH
	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	meq/100 gms	%	%	%	%	ratio		
1	5.13	0.53	0.10	0.40	21.00	27.0	22	6.70	3.90	nd	--	1.00	10.73
2	3.00	0.45	0.10	0.30	18.10	19.3	18	2.91	1.69	nd	--	1.00	11.23
3	2.63	0.58	0.20	0.30	9.90	10.0	27	1.17	0.68	nd	--	1.00	10.18
4	2.25	0.56	0.20	0.30	6.70	9.3	33	0.70	0.41	nd	--	1.00	9.40
5	2.13	0.56	0.10	0.20	3.00	6.4	50	0.36	0.21	nd	--	1.00	8.48
6	2.25	0.60	0.10	0.20	0.90	5.5	78	0.11	0.07	nd	--	1.00	8.34

Remarks: CEC's were leached with 10% acidified NaCl.
CEC's were run on the Technicon Autoanalyzer.
nd - not determined
Available P extracted with sodium acetate.

Analysis by: A. Falen, D. Eisinger, H. Collins

Pedon: Unnamed Loam 80-ID-18124 (Bess Creek) Date: April 1982

Depth	VCS	CS	MS	FS	VFS	TS	TSi	TC	>2 mm		Textural
	Particle Size Distribution (mm)								Gravel & Stone		
	2-1.0	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	2-0.05	0.05-0.002	<0.002	wt.	vol.	Classes
cm	%								%		
0-15						48.35	37.81	13.84			Loam
15-33						43.25	49.07	7.68			Loam
33-41						59.06	31.32	9.63			Sandy Loam
41-57						69.43	20.73	9.84			Sandy Loam
57-74						75.03	15.74	9.23			Sandy Loam
74+						80.48	12.09	7.43			Loamy Sand

Depth	CoSi	Msi	Fsi	Bulk Density		Water Content 1/3	Water Content 15	Liquid Limit	Plastic Limit	Plastic Index
	Silt Size Distribution (mm)									
	0.05-0.02	0.02-0.005	0.005-0.002	Clod	Core	Bar	Bar			
cm	%			g/cc		%		%		
						27.9	12.3			
						26.8	12.8			
						27.1	12.0			
						16.6	4.8			
						8.0	4.1			
						7.7	3.7			

Remarks: Samples were run by the pipette method. Analysis by: Debbie Eisinger

Unnamed Silt Loam 82-ID-18126 (Canyon Meadows)

Classification: medial over loamy, mixed, frigid Typic Vitrandept.

General Site Characteristics

Location: Clearwater County, Idaho; one mile south of Canyon Meadows work center section 9, T. 34N., R. 7E, photo 781-236.
Forest: Clearwater National Forest
Area: Lochsa District
Described By/Date: Hal Collins on September 15, 1982.
Parent Rock/Material: weathered Mazama ash over decomposed granite.
Habitat Type: (Abies grandis) grand fir/(Pachistima mrysinities) Pachistima habitat type, (Psuedotsuga menziesii) Douglas fir, (Larix occidentalis) western larch, (Pinus monticola) western white pine, (Vaccinium ovatum) huckleberry, (Symphoricarpus albus) snowberry, (Xerophyllum tenax) beargrass.
Topography: mountain, top, complex slopes-hilly, concave

Landform: mountain	Climate: Frigid, udic
Weathering: normal	Precipitation: 100 cm (snow)
Formation Name: Idaho Batholith	Erosion: slight
Slope: 20%,20m,brow	Infiltration: slow
Aspect: southwest	Permeability: moderate
Elevation: 1394 meters	Storage:
Soil Depth: 58 cm	Drainage: well drained
Eff. Rooting Depth:	Air Temp: 7 deg. C
Litter Type: duff	Soil Temp at 20 inches:
Surface Rock: very slight	Salt/Alkal: none

Remarks:

Pedon Description

Bs1 0-10 cm. Dark brown to brown (7.5YR 4/4) silt loam, dark reddish brown (5YR 3/2) moist; weak very fine granular structure; loose, very friable, nonsticky and nonplastic; no clay films; common very fine discontinuous random exped pores; many very fine, fine, and medium roots; noneffervescent;

Bs2 10-25 cm. Dark brown to brown (7.5YR 4/4) silt loam, dark reddish brown (5YR 3/3) moist; weak very fine granular structure; loose, very friable, nonsticky and nonplastic; no clay films; common fine discontinuous random exped pores; many very fine, fine, and medium roots; noneffervescent; gradual smooth boundary.

82-ID-18126 (cont.)

Bs3 25-38 cm. Brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 3/4) moist; weak very fine granular structure; loose, very friable, nonsticky and nonplastic; no clay films; few fine, common very fine discontinuous exped pores; common very fine, fine, and medium roots; noneffervescent; gradual smooth boundary.

2Bbw 38-48 cm. Brown (7.5YR 5/4) gravelly sandy loam, dark brown (7.5YR 3/4) moist; weak very fine granular structure parting to single grained structure; loose, very friable, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped pores; common very fine, fine, and medium roots; noneffervescent; abrupt smooth boundary.

2BCb 48-58 cm. Very pale brown (10YR 7/3) gravelly sandy loam, yellowish brown (10YR 5/4) moist; massive single grained structure; loose, loose, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped pores; few very fine and fine roots; noneffervescent; abrupt smooth boundary.

2Cb 58+ cm. White (2.5Y 8/2) gravelly loamy sand, very pale brown (10YR 7/4) moist; massive single grained structure; loose, loose, nonsticky and nonplastic; no clay films; many very fine discontinuous random exped pores; few very fine and fine roots; noneffervescent; abrupt smooth boundary.

Pedon: Unnamed Silt Loam 82-ID-18126 (Canyon Meadows)

Date: October 1982

Sample No.	Horizon	Depth	pH paste	$EC \times 10^3$	% Water at Saturation	Available P	Sesquioxides: Di-Citrate Fe	Extract Al	Pyrophosphate Fe	Extract Al	Spodic
		cm		mmhos/cm		ppm	%				
H-1	Bs1	0-10	5.1	0.10	101	3.3					
2	Bs2	10-25	5.4	0.07	76	4.7					
3	Bs3	25-38	5.3	0.05	51	3.9					
4	2Bbw	38-48	4.9	0.08	40	3.5					
5	2BCb	48-58	5.1	0.09	43	9.0					
6	2Cb	58+	5.2	0.09	42	2.9					

Sample No.	Exchangeable Ions: Ca	Mg	Na	K	Ext. Acidity: H	CEC	Base Saturation	OM	OC	N	C:N	Soil Fraction	NaF pH
	meq/100 gms						%	%			ratio		
H-1	2.5	0.6	0.1	0.4	12.4	27.6	23	15.9	9.2	Nd	-	0.80	11.2
2	1.1	0.3	0.1	0.2	11.3	25.0	13	7.0	4.1	Nd	-	0.81	11.5
3	0.4	0.2	0.1	0.1	nil	12.2	100	1.4	0.8	Nd	-	0.78	11.1
4	0.3	0.2	0.1	0.1	nil	7.4	100	0.4	0.2	Nd	-	0.72	9.9
5	0.3	0.2	0.1	0.1	nil	8.5	100	0.6	0.4	Nd	-	0.63	10.9
6	0.2	0.1	0.1	0.1	nil	5.5	100	0.2	0.1	Nd	-	0.58	9.6

Remarks: CEC's were leached with 10% acidified NaCl
CEC's were run on the Technicon Autoanalyzer
Extractable cations were run on the ICP
Ca+Mg+Na+K / Ca+Mg+Na+K+H times 100= B.S.
Nd-not determined

Analysis by: Debbie Eisinger

Pedon: Unnamed Silt Loam 82-ID-18126 (Canyon Meadows) Date: October 1982

	Particle Size Distribution (mm)								Gravel & Stone		
Depth	VCS	CS	MS	FS	VFS	TS	TSi	TC	>2 mm		Textural
	2-1.0	1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	2-0.05	0.05-0.002	<0.002	wt.	vol.	Classes
cm	%								%		
0-10						39.47	51.91	8.62	20		Silt loam
10-25						44.05	51.67	4.28	19		Silt loam
25-38						56.84	38.06	5.10	22		Sandy loam
38-48						71.77	25.73	2.50	28		Gr. sandy loam
48-58						61.10	34.16	4.74	37		Gr. sandy loam
58+						80.56	17.98	1.46	42		Gr. loamy sand

	Silt Size Distribution (mm)					Water Content		Liquid	Plastic	Plastic
Depth	CoSi	Msi	Fsi	Bulk Density		1/3	15	Limit	Limit	Index
	0.05-0.02	0.02-0.005	0.005-0.002	Clod	Core	Bar	Bar			
cm	%			g/cc		%		%		
0-10						50.2	19.3			
10-25						38.0	23.5			
25-38						25.7	14.0			
38-48						19.3	10.8			
48-58						15.6	7.7			
58+						12.9	5.0			

Remarks: Mechanicals were run by the centrifuge method
Water content-Anita Falen

Analysis by: Debbie Eisinger

APPENDIX 2

Sampling Design, Slash Disposal

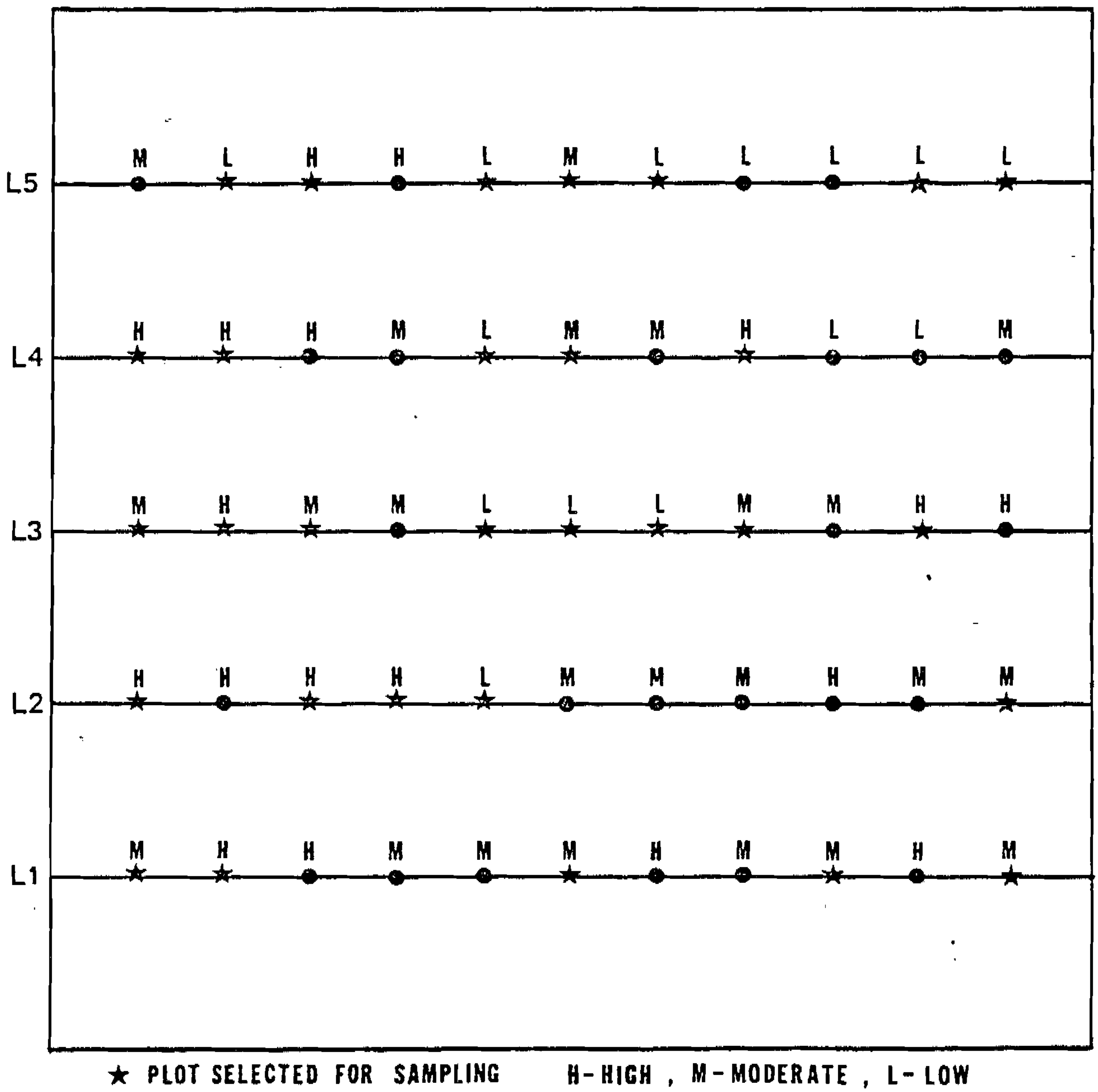
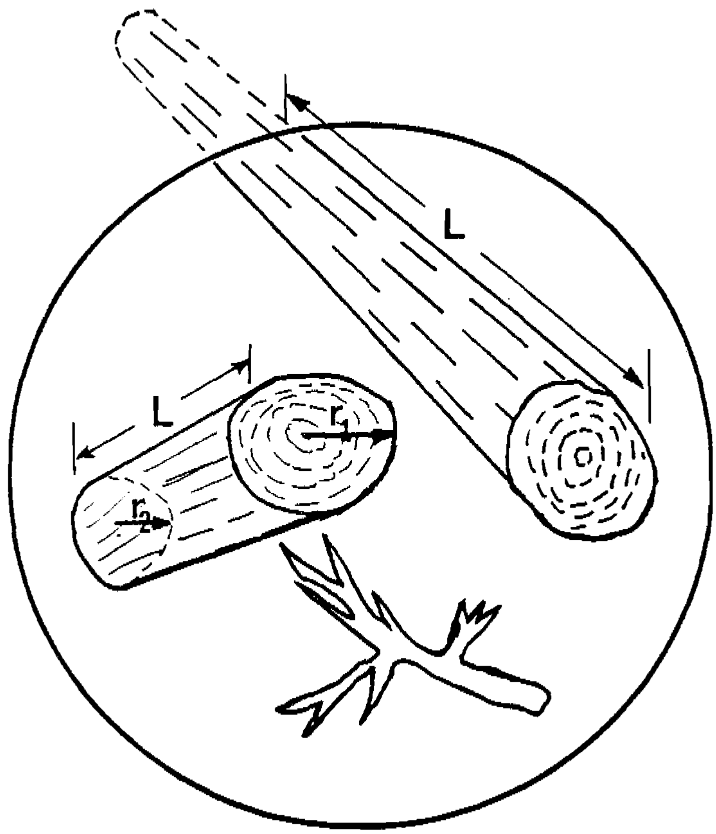


Figure 18. Sampling Design, Slash Disposal.

APPENDIX 3

Sample Calculation of Fuel Load Classes

Sample Plot, Fuel Load Calculation:



Plot Size: 1/120 hectare

$$\underset{(m^3)}{\text{Fuel Volume}} = \frac{r_1^2 + r_2^2}{2} \pi L$$

$$\underset{\text{*(Tons/ha.)}}{\text{Fuel Load}} = \underset{m^3}{\text{Fuel Volume}} \times \underset{kg/m^3}{^{®}\text{Species Wt.}} \times \underset{ha.}{\text{Area}}$$

*metric ton
® See Table 10.

Table 10. Approximate Weights of Wood.

Species	Green	12 % Moisture
	-------------Kg/m^3-------------	
Pinus monticola	560 (35)	430 (27)
Pinus ponderosa	720 (45)	450 (28)
Larix occidentalis	770 (48)	580 (36)
Pseudotsuga menziesii	610 (38)	500 (31)
Abies grandis	720 (45)	450 (28)
Picea englemannii	630 (39)	370 (23)
Thuja plicata	430 (27)	370 (23)
Tsuga heterophylla	660 (41)	460 (29)
Pinus contorta	630 (39)	460 (29)

Taken from the Foresters Field Handbook (1971). Values in parenthesis are $lbcuft^{-1}$.

APPENDIX 4

Sampling Design, Brush Disposal

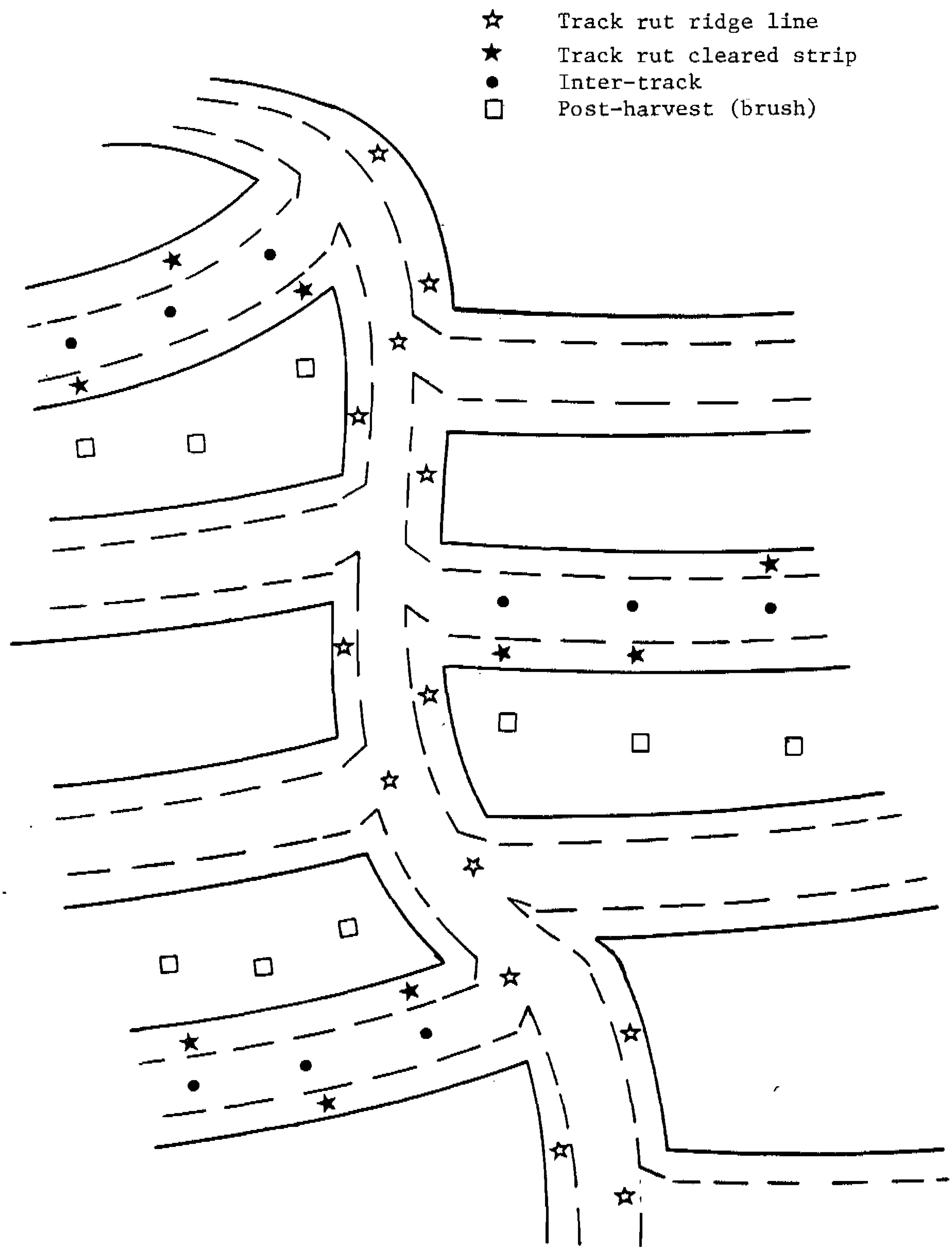


Figure 20. Sampling design brush disposal sites.

APPENDIX 5

Soil Porosity, Slash Disposal

Table 11. Changes in soil porosity as a function of fuel load, volcanic ash thickness and depth in the soil profile, slash disposal.

Depth and Time

	Depth (cm)	2	9	18	27	36
Bovill	P-H	70.2±2.3	64.9±2.3	63.3±2.3	58.4±2.3	51.3±2.3
	P-SD	62.5±3.5	62.0±2.3	61.6±2.3	55.1±2.3	47.9±2.3
Nan Creek	P-H	72.2±2.0	69.4±2.0	65.7±2.0	59.2±2.0	56.0±2.0
	P-SD	70.2±3.7	67.8±3.1	64.5±2.0	57.1±2.0	51.0±2.0
Bess Creek	P-H	78.8±2.8	73.5±2.1	71.4±2.1	69.0±2.1	63.3±2.1
	P-SD	72.2±2.8	68.6±2.8	67.4±2.8	65.7±2.1	63.7±2.1

Volcanic Ash Thickness and Depth

Bovill	+37	70.6±3.5	66.1±3.0	63.7±3.0	63.3±3.0	60.0±3.0
	28-36	69.0±3.0	64.9±2.3	63.3±2.3	59.6±2.3	45.7±2.3
	<27	63.7±3.5	59.2±3.5	59.2±3.5	49.4±3.5	41.1±3.5
Nan Creek	+37	70.2±5.0	68.6±4.3	68.2±3.7	66.1±3.7	61.6±3.7
	28-36	75.5±3.0	70.2±3.1	69.0±3.1	64.9±3.1	51.7±3.1
	<27	70.6±3.7	68.2±3.7	60.8±3.7	53.2±3.7	49.4±3.7
Bess Creek	+37	76.7±2.8	71.0±2.8	69.8±2.8	69.4±2.8	65.7±2.8
	28-36	74.7±4.2	71.8±4.2	68.6±4.2	65.3±4.2	59.2±4.2

Fuel Load and Time

	Fuel Load	Low	Moderate	High
Bovill	P-H	58.8±3.0	61.2±2.0	61.2±2.0
	P-SD	53.9±2.3	56.3±2.0	56.3±2.0
Nan Creek	P-H	61.6±2.0	64.1±2.0	65.7±2.0
	P-SD	58.4±2.0	58.8±2.0	60.8±2.0
Bess Creek	P-H	69.8±2.8	72.2±2.1	71.4±2.1
	P-SD	67.4±2.8	67.0±2.8	67.4±2.1

P-H = Post-harvest. P-SD = post-slash disposal.
Confidence limits given for the α = .05 level.

APPENDIX 6

Moisture Release Curves, Brush Disposal

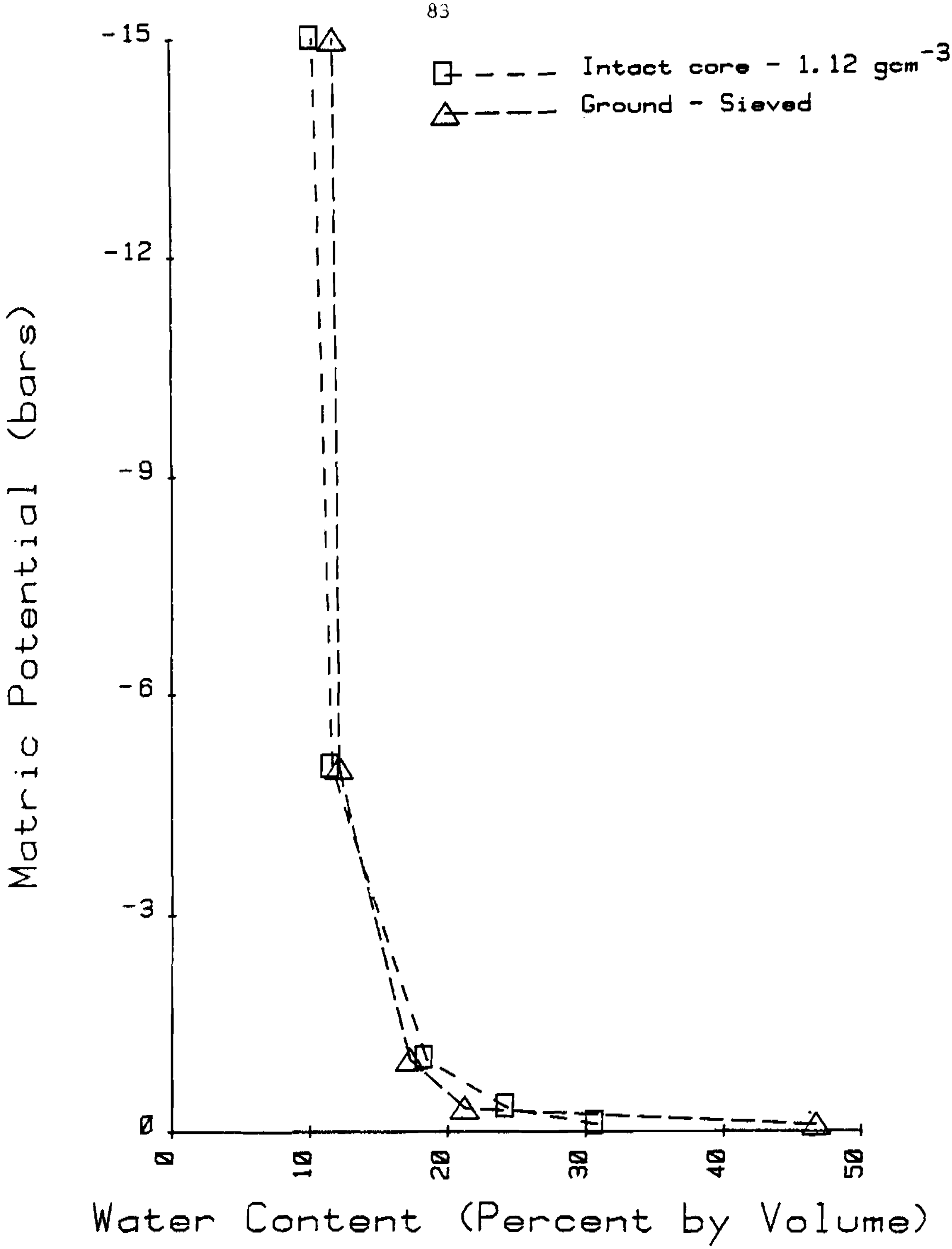


Figure 21. Comparison of moisture retention of the 2B2 horizon by soil density class, intact core and standard laboratory method.

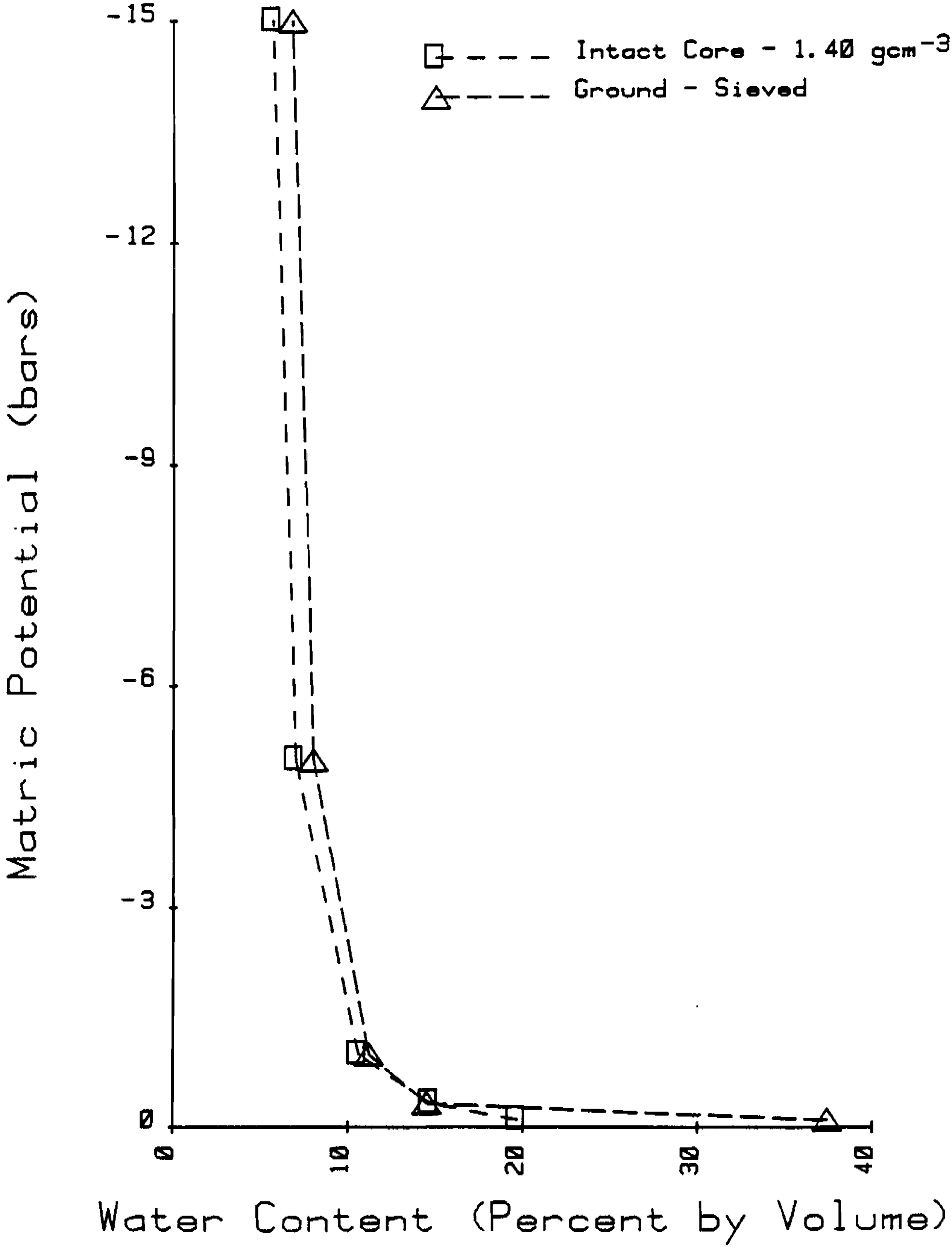


Figure 22. Comparison of moisture retention of the 2C horizon by soil density class, intact core and standard laboratory method.

APPENDIX 7

Soil Porosity, Brush Disposal

Table 12. Changes in soil porosity in relation to the thickness of the volcanic ash and position in the soil profile, brush disposal.

Volcanic Ash Thickness (cm)	Soil Porosity Total	Macro	Micro
<13	59.4±2.0	10.7	48.7
14-25	62.3±1.0	11.2	51.1
26-38	66.1±1.0	13.1	53.0
38+	69.2±1.0	16.2	53.0

Volcanic Ash Thickness (cm)		<13	14-25	26-38	38+
Depth (cm)					
	Total	62.0	65.0	67.8	70.2
2	Macro	11.2	12.8	16.0	16.5
	Micro	50.8	52.2	51.8	53.7
	Total	56.0	63.1	67.0	70.0
10	Macro	10.0	12.5	13.3	16.4
	Micro	46.0	50.6	53.7	53.6
	Total	----	58.0	63.7	67.2
20	Macro	----	10.4	12.6	13.4
	Micro	----	47.6	51.1	53.8