SHOVEL LOGGING AND SOIL COMPACTION: A CASE STUDY

By

Rick F. Floch

A PAPER

submitted to

Department of Forest Engineering

Oregon State University

Corvallis, Oregon 97331

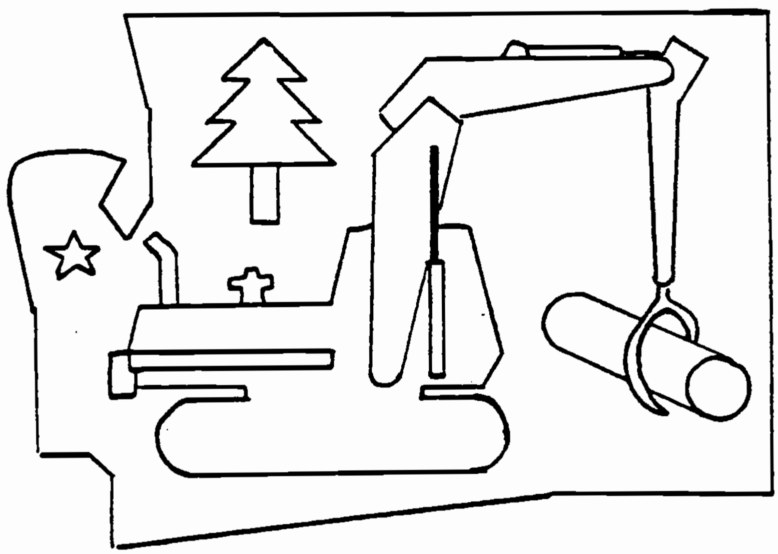
in partial fulfillment of
the requirements for the
degree of

Master of Forestry

Completed May, 1988

SHOVEL LOGGING AND SOIL COMPACTION:

A CASE STUDY



BY

RICK FLOCH

GRADUATE STUDENT

OREGON STATE UNIVERSITY

ABSTRACT

Shovel logging is a relatively new ground-based method of yarding timber. It involves moving logs from stump to landing by successive swinging with a hydraulic excavator modified into a log loader by replacing the shovel bucket with a grapple. Loaders used in shovel yarding can weigh in excess of 100,000 pounds so that the opportunity for soil compaction is great.

This study measured the amount of soil compaction that occurs with shovel yarding. The study was done on the Quinault District of the Olympic N.F. in Washington state. The results show that 20.5% of the total area logged consisted of shovel paths. Soil bulk densities in the shovel tracks when compared to undisturbed areas within the unit showed a statistically significant increase of about 7.5%. Soil compaction did not seem to increase after the initial pass up to seven passes.

Production rate for the shovel was 7.8 net mbf/hour. Logging with the shovel cost $18.57/mbf less than yarding the same unit with a Washington 208 slackline yarder.

Three methods of economically analyzing the effects of soil compaction were reviewed and the idea that the value of soil compaction involves more than just the dollar value lost due to future decreased

timber production was proposed. Values such as existence value, option value and quasi-option value need to also be considered in any decision allowing soil compaction to occur.

DEDICATION

To my children,

LUKE, JENNIFER, and JACOB

and hopefully, their children.

I only hope they will someday be able to forgive my generation for all we are stealing from them.

ACKNOWLEDGEMENTS

I would first like to thank the USDA-Forest Service for providing me with the opportunity to participate in the two-year Advanced Technical Specialty Development Program here at Oregon State University. Without this opportunity, this project would not have been possible.

From the Quinault Ranger Station, I would especially like to thank Ranger John Henshaw, who originally conceived the idea for this study. Also, I would like to thank Francis Friddle and Stewart Carlson - Sale Administrators who kept me supplied; Mel Davis for the initial work of picking the potential sites; Nancy Benson - silviculturist, for spending time on silvicultural prescriptions; Nancy Sturhan - soil scientist, for her thoughts and conversation; Pam Trudeau - mother, research assistant, and soil scientist- for her hard work and excellent conversation; Donna Witt - District BMA who arranged to let me stay near the study area; and finally for Charlene Hunt who did a mammoth job of preparing and sending me the scaling information.

From the Timber Sale Purchaser - Mayr Bros. Logging Co. - I would like to thank Geary E. Lutz, shovel operator and Bill Hickson, Wood's Foreman for their cooperation, information and advice.

I would particularly like to thank the members of my graduate committee - Professors Henry A. Froehlich, Eldon A. Olsen and Rebecca Johnson. Their guidance and suggestions were crucial to the success of this project.

Also, I would like to thank Don Studier for the encouragement and support he gave me during the project and to Joel Krause, Tom Durston and Tom Lowe, my fellow students who spent four very strenuous days at Quinault helping with the data collection. Without their help, the field study would never have been done. Special thanks also to Phillip McColley, research scientist at the Wenatchee Forest Science Lab in Wenatchee, Wa., who supplied the replacement nuclear densiometer at the last minute.

Finally, I would like to especially thank my wife and three children for putting up with the past 18 months - particularly during the month I spent at Quinault and for the many late nights and weekends spent at my second home, Peavy Hall Dungeon.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

Shovel logging involves moving logs from stump to landing by successive swinging with a hydraulic excavator. The excavator, or "shovel," is modified into a log loader by replacing the shovel bucket with a grapple.

Within the past ten years, to reduce cost and increase production in forest operations, shovel logging has seen widespread and increasing use, particularly on the Olympic Peninsula of the state of Washington (Fisher, 1986).

Up until 1986, the Quinault Ranger District of the Olympic National Forest had permitted almost no shovel logging. Areas that were flat enough to allow mechanized harvesting generally had been logged with a highlead yarding system. This was to prevent unacceptable soil damage caused by tractors and skidders making repeated trips over typically very moist forest soils. At the request of John Henshaw, District Ranger on the Quinault Ranger District, this study was undertaken as a graduate student's research project. Ranger Henshaw desired to know more about the environmental affects of shovel logging on the Quinault

Ranger District. Of particular concern was the question whether the cost savings with shovel yarding, when compared to highlead yarding, was greater than the values lost due to increased compaction.

1.2 Need

Loaders used in shovel yarding can weigh in excess of 100,000 pounds. The potential for compaction with this system can, thus, be quite significant. Because compaction can have substantial negative long-term effects on tree growth and other elements of the ecosystem, any decision about using this system must first carefully weigh the apparent up-front benefits of using this system against the possible adverse long-term effects that may result. To do this, the potential cost savings with shovel yarding, the amount of compaction that may result and the value of this compaction all need to be assessed.

1.3 Objectives

The objectives of this research project are:

For a shovel logged unit;

1.) Estimate the amount of compaction that occurs.

2.) Estimate the production rate.

3.) Estimate the difference in logging costs between shovel logging and highlead logging.

4.) Compare the cost savings of shovel logging with the values lost due to increased compaction.

1.4 Scope

This study reports on soil compaction resulting from logging with a shovel. It is designed to measure the production rate, unit cost and amount of soil compaction that results when a Cat 235 hydraulic excavator is used to yard logs. It is a case study limited to one site, one specific type of equipment, and one type of yarding method.

1.5 Literature Review

Considerable research has been done on the effects timber harvesting has on forest soils. Naturally occurring forest soils of the Pacific Northwest are generally low in bulk density and soil strength and have high rates of infiltration. Because of this particular combination of characteristics, these soils are easily compacted, disturbed and displaced during timber harvesting activities (Froehlich and McNabb, 1983).

Soil disturbance involves mixing of the litter and soil layer in place, whereas displacement involves horizontal movement of the soil. Soil compaction involves reducing porosity and subsequently increasing bulk density.

1.5.1 Site Disturbance

Research involving the effects of timber harvesting on soils frequently investigates the amount of area that is impacted or disturbed by the operation.

In 1947, E.N. Munns reported that compaction to a depth of 10 inches using relatively light logging equipment in California was found to still exist two years after logging had been done. On another logging job, he reported that tractor trails and roads covered 25-40% of the logged area.

Garrison and Rummel (1951) measured ground disturbance immediately after logging with tractors on ponderosa pines ranges in eastern Oregon and Washington. They reported 21% of a tractor logged area was disturbed with 50% of the disturbed area considered deep disturbance. Similarly, Fowells and Shubbert (1951) and Wooldridge (1960) reported 22% and 22.2% of the total area of tractor logged areas exposed to mineral soil. Other researchers have reported similar findings:

- in a study done in South Carolina and Virginia, 32% of a tractor logged area consisted of primary and secondary skid roads (Hatchell, Ralston and Foil, 1970).
- 16% to 27% of the area consisted of skid trails in tractor thinned units in an Oregon study (Aulerich, Johnson and Froehlich, 1974).

- 23% of a rubber tire skidded area was disturbed and 19.5% of the area consisted of skid trails (Cambell, Willis and May, 1973).

- tractor skid roads in S.E. Washington measured 26% of the total area logged (Steinbrenner and Gessel, 1955).

- 65% of the total area in a tractor logged unit in the Oregon Cascades had some kind of disturbance with 28% of the area in skid trails (Dyrness, 1965).

- 13.6% of the total area logged in an Oregon coast study was disturbed using a low ground pressure skidder and preplanned skid trails (Sidle and Drlica, 1981).

- Dyrness (1965) compared tractor yarding with highlead yarding in the Oregon Cascades. He divided the extent of soil surface disturbance into 4 categories and estimated the percent of the total area that was in each category for three highlead yarded units. He also measured the average bulk density in each category. His results follow:

CATEGORY	SOIL SURFACE DISTURBANCE (% OF TOTAL AREA)* UNIT 1	2	3	BULK DENSITY (G/CC)
UNDISTURBED	58.1	50.7	62.7	0.753
SLIGHTLY DISTURBED	21.0	24.5	18.9	0.785
DEEPLY DISTURBED	9.6	13.6	5.8	0.990
COMPACTED	9.6	7.1	10.7	0.952

*The areas represented by the difference between the total and 100% are non-soil areas, i.e., rocks/streams.

- Another study, involving a comparison of skyline yarding and skidding was done in Mississippi by Miller and Sirois (1986). For the skyline yarded area, cable corridors involved 9.2% of the total area. Fifty-eight percent of these corridors were either compacted or deeply disturbed. Thus, 5.3% of the harvest unit may be adversely affected.

1.5.2 Soil Compaction

Much work has also been done on investigating the relationship between logging and soil compaction. The degree to which a soil is compacted by logging equipment depends on many factors. The amount and type of pressure and vibration applied, the depth and nature of the surface litter, the soil texture and structure and the soil moisture level during compaction have all been identified as important variables (Adams and Froehlich, 1981). Because bulk density increases with compaction, the change in bulk density is often used to describe soil compaction.

Steinbrenner and Gessel (1955) quantitatively studied soil disturbance due to tractor logging in S.E. Washington state. They reported an average increase in bulk density for all skid trails of 34.9%. Bulk densities in timber adjacent to the logged units ranged from 0.479 to 1.1173 g/cc. Bulk density measurements in skid trails ranged from 0.763 to 1.394 g/cc.

Dyrness (1965) reported before-logging bulk densities in tractor logged units measured 0.657 g/cc and after logging, measured 0.975 g/cc. Other studies have reported similar trends in compaction:

- Aulerich, Johnson and Froehlich (1974) - reported compaction using tractors to thin young-growth Douglas fir as:

	BULK DENSITY INCREASE (%)	
	0-15 cm	15-30 cm
Major skid trails	21	17
Secondary skid trails	16	12
Lightly used trails	13	6

- Gent, Ballard and Hasson (1983) - reported that whole-tree and tree-length yarding with tractors in North Carolina significantly increased bulk density of skid trails to a depth of 30.5 cm:

	BULK DENSITY (g/cc)			
Depth (cm)	0-7.6	7.6-15.2	15.2-22.9	22.9-30.5
Preharvest	1.04	1.26	1.38	1.45
Postharvest	1.43	1.56	1.62	1.68

- Moehring and Rawls (1970) - bulk density in the 0-2 inch layer of skid trails during wet weather logging with tractors increased 13% compared to undisturbed adjacent areas (1.4 versus 1.24 gm/cc).

- Hatchell, Ralston and Foil (1970) - for tree-length tractor logging in S. Carolina and Virginia, primary skid trails had a mean bulk density of 1.08 g/cc compared to 0.75 g/cc in undisturbed areas.

- Gent, Ballard, Hasson and Cassel (1984) - found significant increases in bulk density in the upper 0.3 m of soil beneath primary skid trails:

	Bulk Density With Soil Depth			
Depth (cm)	0-8	8-15	15-23	23-30
Preharvest (g/cc)	1.12	1.39	1.54	1.52
Postharvest (g/cc)	1.52	1.67	1.66	1.61

1.5.3 Effects of Multiple Passes

Research results have also shown that only a few passes over the same area with typical ground-based yarding systems can increase bulk density to near its maximum density:

- Steinbrenner (1955) - reported that on dry soil, 4 trips with a tractor reduced infiltration rates by 80 % and that one trip on wet soil was equivalent to 4 trips on dry soil.

- Hatchell, Ralston and Foil (1970) - in a vehicular compaction test, reported an average of 2.5 trips resulted in soil densities within 10% of the maximum attained.

- Lenhard (1986) - investigated the changes in physical properties of a forest soil during vehicular compaction. After only 4 passes using an unloaded rubber tired skidder, bulk density reached a maximum. The distribution of pore sizes in the soil continued to change with additional trips even though total porosity remained constant.

1.5.4 Effects on Long Term Productivity

Numerous studies have established that compaction, once done, not only may last a long time, but also can reduce future plant production. Compaction can alter basic physical properties of the soil such as texture, structure, strength, density and moisture content. These properties control root penetration, aeration and moisture and nutrient uptake for plants and thus, can affect growth rates of plants.

- Perry (1964) - found 54% growth reduction in old road ruts in a 26 year old loblolly pine plantation. He projected that 40 years would be required for natural reestablishment of normal percolation rates in these places.

- Hatchell, Ralston and Foil (1970) - using regression, estimated that 18 years would be needed for bulk densities under log decks to return to original levels. They also reported that height growth of trees in skid trails was significantly less than trees growing in undisturbed areas.

- Dickerson (1976) - reported that after 5 years, average bulk density was still 11% greater than for undisturbed areas (20% was measured directly after logging) after tree length rubber tired skidder logging in Mississippi. He estimated recover to undisturbed levels in 12 years.

- Youngberg (1959) - studied the growth of Douglas-fir seedlings planted in tractor logged areas in Lane Co. Oregon. Soil bulk densities in skid roads, skid road berms and on undisturbed cutover areas were:

		BULK DENSITY (g/cc)	
	Depth (cm)	Plantation #1	Plantation #2
Skid Road	0-15	1.58	1.52
	15-30	1.73	1.59
Berm	0-15	1.01	0.89
	15-30	1.05	0.88
Cutover	0-15	0.87	0.88
	15-30	0.98	0.88

Height growth after 2 years for seedlings in the undisturbed areas was significantly greater than in both the berm and tractor roads at the 1 % level.

- Froehlich (1979) - In a study done on the Ochoco NF of Oregon, soil densities in skid trails at 7.6 and

15.9 centimeter depths and 22.9 and 30.5 centimeter depths were 18% and 9% greater, respectively, than those of adjacent, undisturbed soils 16 years after logging with tractors in an old-growth ponderosa pine partial cut. Moderately impacted trees had a 6% reduction in growth rate and heavily impacted trees showed a 12% reduction over this 16 year period.

- Wert and Thomas (1981) - For a tractor logged area in the coast range of Oregon, overall growth reduction 37 years after logging resulted in an 11.8% volume loss in production. Twenty-five percent of the entire area was still heavily compacted with recovery only in the surface 15 cm.

- Froehlich and Robbins (1983) - Average bulk density increases of 15.4 and 27.5% relative to adjacent undisturbed soils were found for skid trails in lodgepole and ponderosa pine study areas in the southern Washington Cascades 25 years after harvesting. For the ponderosa pine study area, this increase in bulk density was strongly correlated with reduction in volume. At the average increase in soil density of 15%, the volume growth reduction was 20%. For the lodgepole study area, the effect of soil displacement overshadowed any relationship between bulk density and growth. There was a strong correlation between organic matter content and growth, however, indicating that removal of nutrientrich surface soil during timber harvesting activities may significantly affect site productivity for the lodgepole sites.

- Helms and Hipkin (1986) - intensively studied a 1.2 acre site within a 16 year old pine plantation in California. Bulk density increased 30% in a skid trail compared to soils of lowest bulk density measured. They also stated that in the skid trail, 15 years after planting establishment, a 29% reduction in mean tree volume, combined with 37% mortality, resulted in a reduction of 55% in volume per unit area.

1.5.5 Research Done On Shovel Logging

Fisher (1986), analyzing cone penetrometer readings on a 29 acre shovel logged unit in southwestern Oregon, reported a 27 percent increase in soil strength between visible machine track areas and post-yarded non-track areas. Fisher also estimated without measuring, that the area of land subjected to machine tracks was less than 5 percent, due to a high truck road density and the fact that much yarding could be done from the road. A time study and regression techniques were also used to develop equations for predicting yarding production.

In another report, Hemphill (1986) suggested that soil disturbance is much less with shovel logging than with conventional skidders, based on his observation that travelling is only done by the unloaded shovel, making only two passes on each track.

A time study done in Alaska (Starnes, 1985) identified 8 elements in the yarding cycle of a shovel yarding operation. Three equations were developed to estimate delay-free production and an estimate of the financially optimum road spacing also was made.

Webster (1986), in a study on the Olympic National Forest in Washington, compared soil compaction created by shovel, cat and highlead yarding. For the shovel yarded unit in the study, bulk density in the shovel paths, at a depth of 15-20 cm below groundlevel, increased by 60%, from 0.5 g/cc to 0.8 g/cc. Only 9% of the total area was compacted, however.

A study done on the Hoh District of the Olympic Area, Washington State DNR (Halloin, 1987) measured the extent of yarding trails created by shovel logging and the types of logging related soil impacts that occur. Two units were logged with a shovel. The combined average for both units showed that 21.5% of the area was occupied by yarding trails. Similarly, 12.9% of the area was considered compacted and 8% of the area was considered detrimentally compacted. These were subjective measurements using predefined soil condition classes - undisturbed, compacted and displaced. Compacted soil areas were then identified as low, medium and high, with medium and high considered as detrimental compaction.

Thus, much of the research done on shovel logging to date has emphasized production with very little quantitative research having been done on the effects of shovel logging on soil compaction - the overall objective of this project.

2.0 FIELD STUDY DESIGN

2.1 Study Area Selection

A list of several possible areas that could be shovel yarded was prepared by district personnel at the Quinault Ranger Station during the winter of 1986-87. Each of these areas consisted of a unit or part of a unit presently uncut but under contract to be logged during the summer of 1987. For each of these areas, a purchaser had shown some interest in yarding with a shovel, also. In the spring of 1987, each area was field checked and the most appropriate unit - Unit #4, Backstretch Timber Sale - was selected. This particular unit was selected based on its size, location and time of planned logging.

2.2 Study Area Description

Unit #4 was originally planned to be yarded with a highlead system, but this was modified to allow the west half of the unit to be yarded with a shovel.

Elevation at the top of the site was 1080 feet above sea level. Average slope was 15 percent. Approximately half of the site was flat, with the rest varying from 10 to 20 percent. Some steep pitches into short draws ranged up to 50 percent slope. The site was roughly triangular in shape with roads bounding approximately 80 percent of the perimeter (Figure 2.1). Aspect was west to southwest.

The unit was classified as a Pacific silver fir/Oregon oxalis plant association. A timber cruise estimated that net total volume for the 29 acre unit was 2018 mbf: 762 mbf of western hemlock and 1256 mbf of pacific silver fir.

Soil inventories show that for this area, surface soils are generally very gravelly silt loams and subsoils are variable layers of fines, sands, gravels and cobbles. The soil is well drained, with water moving freely in surface soils and moderately freely in the subsoils. Surface soil layers are from less than 61 cm to 152 cm thick and subsurface soil layers are from 213 cm to 305 cm thick. Both surface and subsoil layers are considered slightly sticky to sticky and nonplastic to plastic (Jennings, May, Sheehy and Darling, 1982).

2.3 Logging Operation Description

The field study took place during the month of August, 1987. The shovel operation included a shovel operator and shovel - a Cat 235 hydraulic excavator with a Young boom and grapple. The shovel did both the yarding and loading in this particular operation.

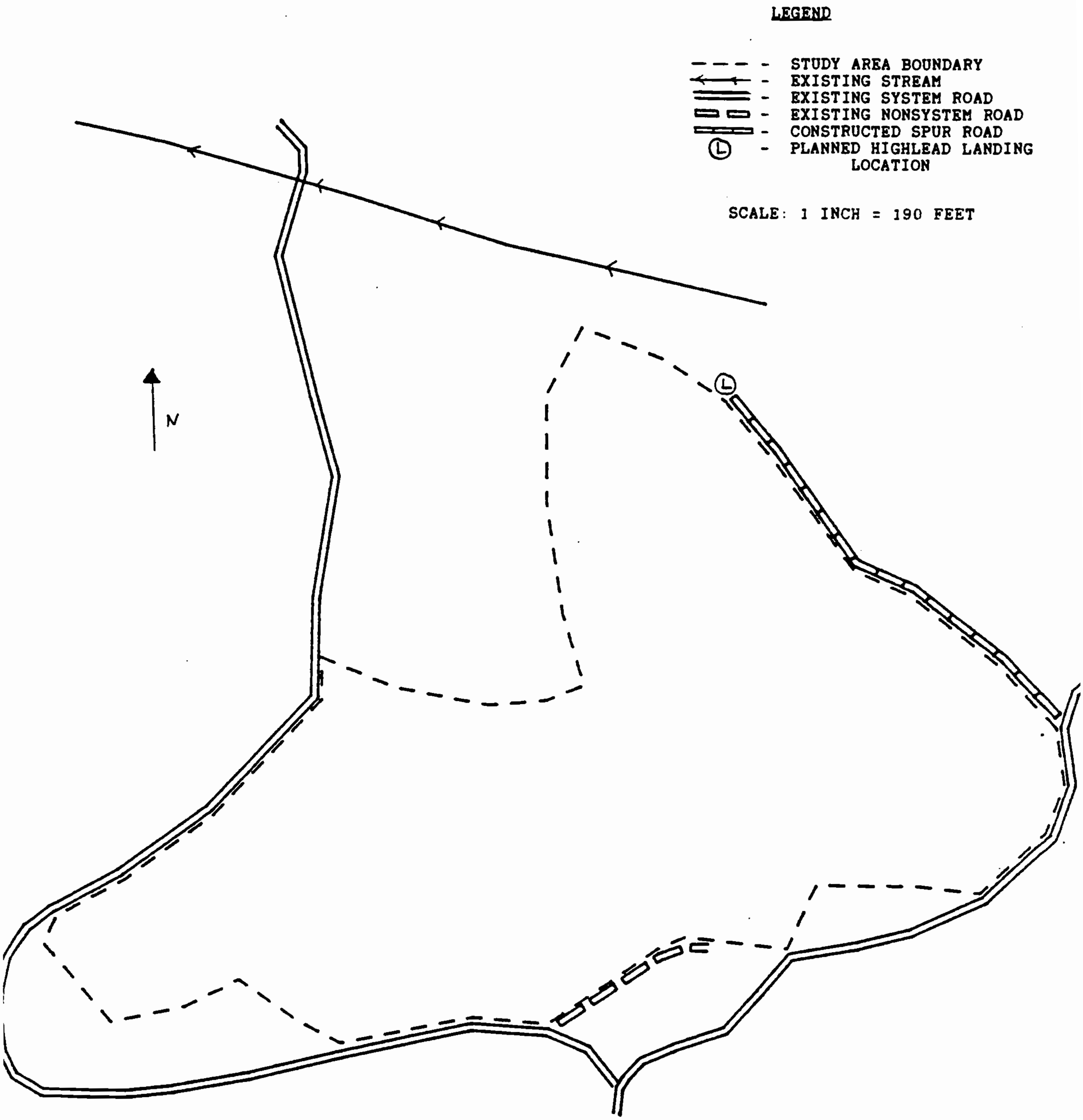


Figure 2.1 SCALED MAP OF STUDY AREA - BACKSTRETCH #4 COMPACTION STUDY - QUINAULT RANGER DISTRICT, OLYMPIC NF.

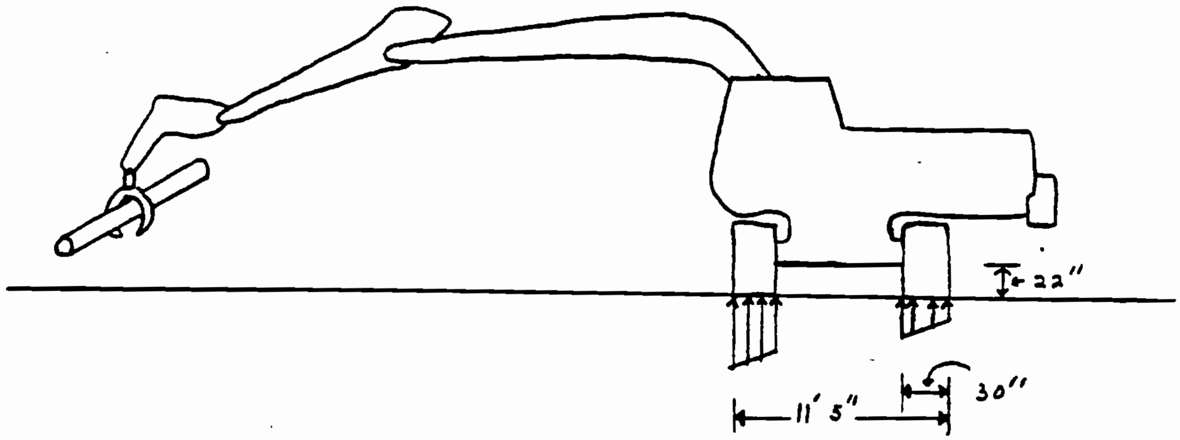
As a comparison, the highlead operation would have included the use of a Washington 208 slackline yarder with a crew of 7 - a yarder operator, rigging slinger, chaser at the landing, two choker setters, a hook tender and a loader operator.

The Cat 235 shovel had track dimensions of 30 inches in width and 198 inches in length. Pressure under the tracks assuming no load, flat ground and an even pressure distribution (Caterpillar Performance Handbook, Edition 17) would be approximately 9 pounds per square inch (psi). As shown in Figure 2.2, however, the pressure distribution is typically not constant under the tracks, particularly with a load in the grapple. This could result in pressures being developed under the tracks in excess of 9 pounds per square inch. Measured from the leading edge of the tracks, the Young boom had a length of approximately 30 feet when fully extended. The operator had shovel logged before and was an experienced operator.

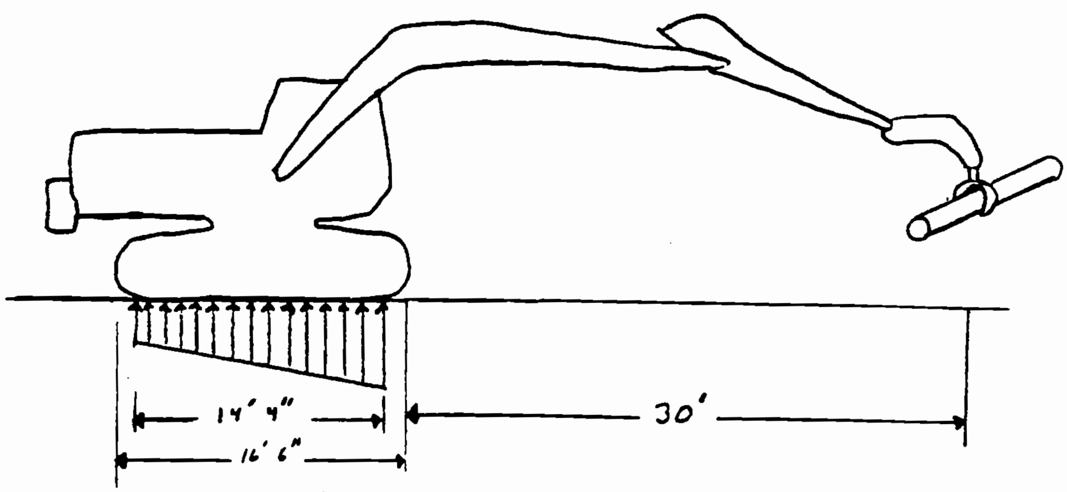
2.4 Measurements Taken

2.4.1 Shovel Paths

To find out how much of the study area was traveled over by the shovel during the yarding operation, the study site was first traversed using a hand compass and



BOOM AT RIGHT ANGLE TO TRACK PATH.



BOOM PARALLEL TO TRACK PATH.

Figure 2.2 TRACK AND BOOM DIMENSIONS OF THE SHOVEL. Theoretical pressure distribution under the rigid frame tracks is shown by the vertical arrows under the tracks (Lysne and Burditt, 1983). Longer arrows represent greater pressure.

measuring tape. As each shovel path was made, its location was flagged on the ground with flagging. At the same time, the number of passes over each path was recorded on a paper map of the study area. At the end of each day, the paths were traversed using a hand compass and steel tape. From this data, a map of each path location and the number of passes per path could then be plotted to scale later. Width of the path was recorded at every point where soil compaction measurements were taken (see next section) so that an average width by number of passes per path and a weighted total average width could be determined. From this, the percent of total area consisting of paths could then be estimated.

2.4.2 Soil Compaction

Bulk density was selected as the measure of soil compaction for this study because it can be measured rapidly and accurately and provides a basis for comparison with other research studies of soil compaction.

Two different nuclear density meters were used to measure bulk densities - a double-probed meter that measured densities horizontally between two probes inserted to various depths into the ground and a probeless meter that used the airgap backscatter method to measure density. The original plan was to use only the double-probed meter. However, as the time approached to start the field study, this meter developed some mechanical problems and the probeless meter was substituted at the last minute. During the data collection phase of the study, another double-probed meter was located and, for comparison purposes, it was decided to use both meters.

To determine any increase in soil compaction, a group of soil bulk density measurements were taken at various cross sections normal to the shovel paths. At each cross section, measurements were taken in the following spots.

1.) In each track of the shovel.

2.) Between the tracks.

3.) Next to one outside edge of a track (1.5 - 2.5 ft.)

4.) A spot nearby in the unit, undisturbed by machine activities. (Because of the work involved with each measurement, this measurement was not always taken at each point).

These measurements would then be averaged for each location and compared to see if bulk density had increased. Location #4 was considered the uncompacted measurement with which all other measurements would be compared (Figure 2.3). Location #1 was selected to show the worst possible case where compaction should be the greatest. Locations #2 and #3 were selected to provide additional information on what effect the tracks may have at a distance laterally out from the track edge.

The points along the shovel paths where the bulk density measurements were to be taken were first located systematically on the plotted paper map of the shovel path locations. Then, from this map, the measurement points were located in the field using a measuring tape.

No attempt was made to differentiate between paths sections where the shovel moved, only, and where it stopped to swing yards. This was because the shovel would move only a few feet at a time between places where it stopped to swing logs and delineating these areas on the ground was not possible.

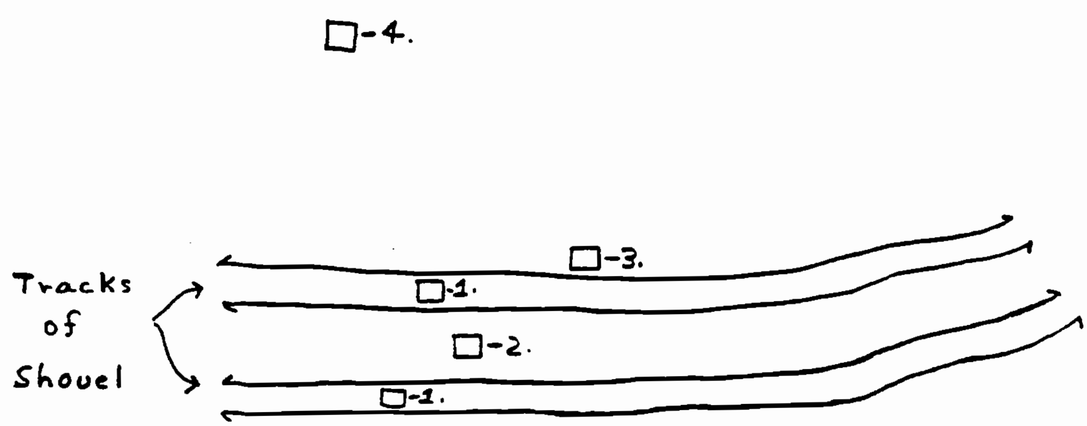


Figure 2.3 DIAGRAM SHOWING LOCATION OF EACH GROUP OF BULK DENSITY MEASUREMENTS.

At each point where groups of measurements were to be taken, slash and other debris were first cleared away. Then, at each location described above, a 2 foot square area was cleared down to mineral soil and duff depth to mineral soil was recorded using a steel tape measure. Following this, a wet bulk density measurement was taken using the probeless meter. Next, using the double-probed meter, wet bulk density measurements at 4, 8 and 12 inches down from the soil surface were taken. Finally, soil samples using a push-probe were taken from the 0-6 and 6-12 inch soil depths.

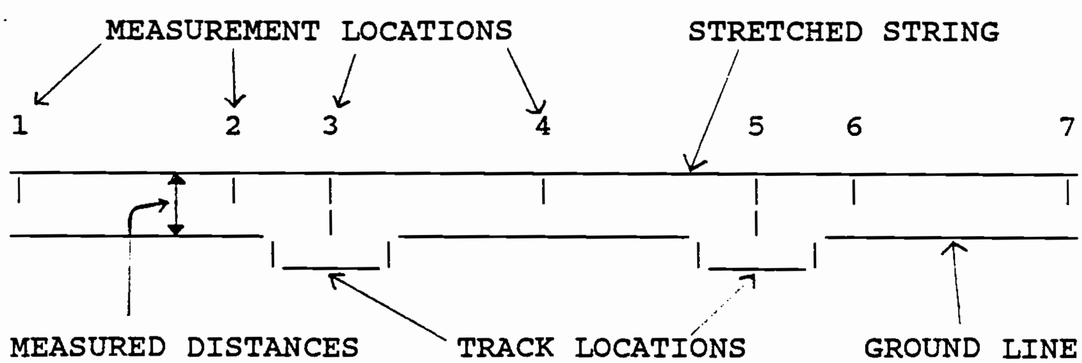


Figure 2.4 DIAGRAM SHOWING LOCATION OF MEASUREMENTS TAKEN ACROSS PATH PROFILES. (Numbers represent location of each measurement.)

To measure the extent to which the shovel tracks sank into the ground, profiles across the pathways of the shovel and perpendicular to the direction of travel were taken at each group of measurements. A string was stretched across the shovel path approximately parallel to the ground. Using a steel tape measure, the perpendicular distance from the string to the ground surface was measured at select places along the string as shown in the diagram below (Fig. 2.4). At each measurement place, the tape was inserted down through the slash and surface debris until it firmly met up against the surface of the duff layer. Locations #1 and #7 were considered the original ground level. Locations #2 and #6 were selected to show any difference next to the outside edge of the tracks. Locations #3, #5 and #4 were selected to show any differences in the tracks and between the tracks, respectively.

2.4.3 Time and Motion

In order to derive production rates and per unit costs for shovel yarding, total time spent yarding and total volume yarded were needed. A time and motion study was designed to do this, taking advantage of the fact that someone had to be on the sight at all times during the yarding operation in order to record the paths of the shovel.

For the time and motion study, the yarding activity was divided into four parts - moving, swinging, trail preparation and delays. Each part was defined as follows:

Moving - this activity included all time when the shovel tracks were moving and the grapple was unloaded. It started when the tracks first moved and ended when the tracks stopped. Examples would be moving from log to log along each path, moving between paths, moving to go load out trucks and moving from the landing area each morning out into the unit and back again at the end of the shift.

Swinging - this activity included all time when the shovel was moving logs from one spot to another. It started when the tracks stopped moving just before a log was picked up and ended when the tracks started moving after releasing a log. Short moves by the shovel when a log was in the grapple were also included in this activity along with the times when slash was being moved in order to locate logs. The number of logs swung was recorded at this time, also.

Trail Preparation - this activity included all time the shovel spent preparing the path before it moved forward. This involved moving slash and debris and pulling stumps when necessary. It started when the grapple picked up slash, stumps or other debris and ended when the machine either moved or when the grapple picked up a log. This activity could occur in the middle of a swinging activity, also. Moving logs out of the pathway was considered a swinging operation, however.

<u>Delays</u> - this activity included all time from the start of work each day until the end of work the same day when the shovel was not doing any of the other three activities.

A special form was made to record times for the different activities and an ordinary wristwatch was used as a timer. The start time for the shift was recorded and then as each new activity started, the time was again recorded. The difference between this time and the previous time was the duration of the previous activity. The form had columns for activity, ending time for each activity, duration of each activity, the number of pieces swung during each swing activity and a remarks column. (See Appendix A for a sample copy of the form.)

Time spent loading was not recorded. For this particular operation, loading was done on an irregular basis. Sometimes it was at the end of the shift, sometimes on weekends, sometimes the following day with no yarding taking place at all, and once, another loader was even used for an afternoon while the Cat 235 yarded. Because of this irregularity, the data recorder was not always on the site during loading so no data was recorded.

2.5.4 Production

Adding together the times spent for each yarding activity, the total time spent yarding could be calculated. Each truckload of logs hauled from the study site was scaled so that gross and net volume hauled could be tabulated from the scale tickets later. From this information, the production per hour could then be calculated for the shovel.

From empirical appraisals for the shovel yarding system and the highlead yarding system, hourly rates for each system could be derived. Using production estimates for the highlead system from the operator, the two systems could then be compared and the difference in logging costs could be calculated.

3.0 RESULTS OF FIELD STUDY WITH DISCUSSION AND INTERPRETATION

3.1 Shovel Paths

Total traversed area of the study site was approximately 17.4 acres. With approximately 5 acres left to be yarded, the shovel broke down, requiring major repairs and the decision was made to terminate the yarding part of the study. All measurements that follow are with respect to the 12.4 acre area logged up to the breakdown.

During the yarding operation, it was observed that the operator used several different strategies to move the logs to the landings. The particular strategy he used seemed to depend on such things as unit topography and shape, the need to keep the log load count up for each day, early shut-off for fire restrictions and the need to keep roads open at the end of the day.

On flat ground, he would sometimes follow a relatively straight-line pattern where he would clear a path from the haul road perpendicular out to about the center of the unit, stacking logs in piles adjacent to the path, with the logs situated parallel to the path. Then he would turn around and start back, moving the piles of logs back to the road, sometimes one pile at a time, and sometimes accumulating the piles as he moved toward the road (Figure 3.1 - Letter A). This would usually result in pathways being traveled two or more times, depending on whether he accumulated the logs as he come back to the road or brought them back by individual piles or groups of piles .

Another pattern the operator would sometimes follow was a rectangular pattern where he would leave the road at one spot and work out to the center of the unit, then parallel to the road for a ways and then back to the road at a place further on down the road from where he entered the unit (Figure 3.1 - Letter B). This appeared to help the operator move logs to the road for loading fairly rapidly and even allow for both loading out trucks and yarding while waiting for trucks to return, depending on how small the rectangular pattern was. This type of pattern resulted in from one to several passes being made over the same path .

Small draws, short steep pitches, and odd-shaped corners would also dictate the pattern used, but it was generally one of the two mentioned above. Two draws originated in the lower part of the unit and opened out onto the road crossing the bottom of the unit (Figure 3.1 - Letter D). The operator worked around the top edges of these draws, placing the logs down into the draws toward the road as far as possible. Then, from the road, the operator would load the logs from the

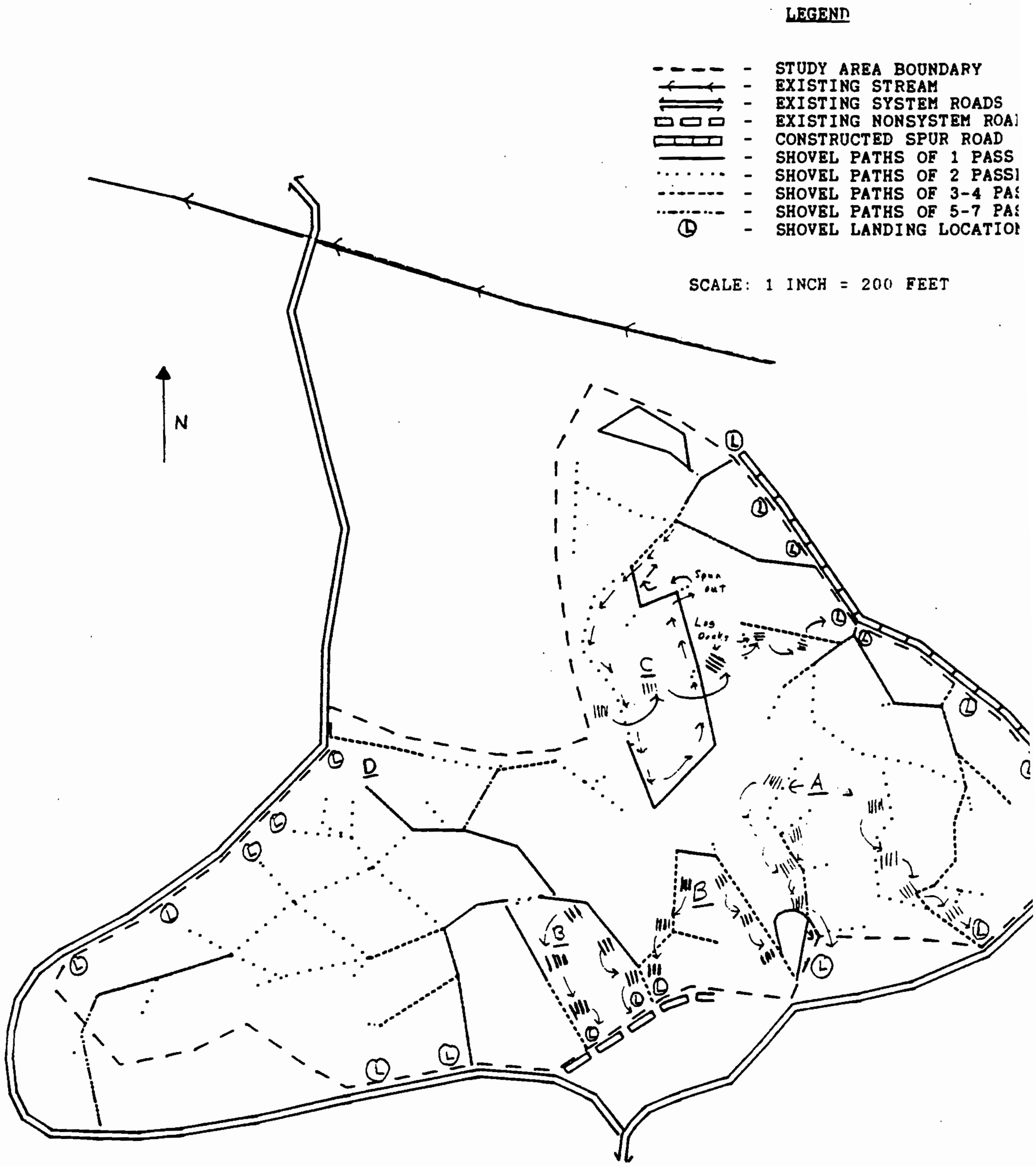


Figure 3.1 LOCATION OF SHOVEL PATHS WITH RESPECT TO THE NUMBER OF PASSES MADE PER PATH. Letters indicate areas where different yarding techniques occurred.

draws onto the trucks. Moving up into the draws was often necessary to accomplish this.

Only one time did the operator use a snake-like pattern, and that was with uphill yarding on a steep pitch of about 25% slope (Figure 3.1 - Letter C). Here, the shovel was unable to move directly up the slope due to lack of traction. The operator worked across the slope, moving logs from the downhill side to the uphill side of the shovel. Because of the slope, the operator had to pull out numerous stumps on the uphill side of the path to make sure the shovel would not tip over. Because of the danger of logs sliding back down the hill into the cab from above, the operator had to place the logs at an angle slightly across the slope and he had to make sure they would not slide out. Pulling stumps and careful placement of logs, along with trying to manuever on the sidehill involved considerable additional time. At the end of this particular pass, the shovel was unable to turn and go on up the hill because of lack of traction. He had to move back down the hill and travel on a previous path to get up above the log piles, requiring even more time .

One-pass paths (approximately one/fifth of the total path length - Table 3.1) involved those times when the operator made the rectangular patterns requiring only one trip or times when his pass tied in to previously made paths. Two-pass paths (approximately two/fifths of the total length) mostly involved working out into a particular area and then coming back swinging all the logs with one return pass. Pathways that had more than 2 passes usually resulted because either; an area was not completely yarded before the end of the day necessitating additional trips the following day; the shovel stopped yarding and went to load trucks; or because the operator did not move all the decks along a path to the landing in one pass. The maximum number of passes/path recorded was seven.

It was observed that the average path width (Table 3.1) increased with the number of passes per path due to both the difficulty the operator had in following previous paths and the twisting and turning of the shovel during operation. The weighted average width for all paths was 13.7 feet, compared to the measured machine track width of 11.3 feet. Distance between paths varied and ranged from as little as 25 feet to over 100 feet (Figure 3.1).

At the end of logging, approximately 20.5% of the area consisted of shovel paths. As a comparison, studies done observing skidders have measured the area involving skid trails to range from 13% using preplanned skid trails (Sidle and Drlica, 1981) to over 30% (Hatchell, Ralston and Foil, 1970).

TABLE 3.1 PASSES/PATH, LENGTH AND WIDTH OF PATHS MADE BY CAT 235 SHOVEL.

PASSES/PATH AND LENGTH OF MACHINE PATHS:

PASSES/PATH	LENGTH OF PATHS	PERCENT TOTAL LENGTH
1	1755 FT.	21.9
2	3387 FT.	42.3
3	776 FT.	9.7
4	910 FT.	11.4
5	157 FT.	1.9
6	692 FT.	8.6
7	335 FT.	4.2
	TOTAL = 8012 FT.	100.0

AVERAGE WIDTH OF MACHINE PATHS:

PASSES/PATH	AVERAGE WIDTH (FT.)	STD. DEV.	AREA OF PATHS (ACRES)
1	12.35	1.17	0.50
2	13.58	2.13	1.06
3-4	13.84	2.34	0.54
5-7	15.78	3.76	0.43
		TOTAL AREA =	2.53 ACRES

WEIGHTED AVERAGE WIDTH ALL PATHS = 13.7 FT.

PERCENT OF TOTAL AREA IN PATHS = 20.5 %

Twenty-five percent is considerably greater than the 5% that Fisher (1986) reported. However, his study area had a fairly high haul road density where the shovel was apparently able to yard much of the unit from the road edges. Also, some areas were steep enough that the shovel operator could flip logs downhill a considerable distance, thus widening the distance between shovel paths and reducing the amount of ground traveled by the shovel.

With roads on three sides of this unit, road density was high here, too. Thus, with units larger than this one, an even greater area in shovel paths would be expected.

The results of the duff depth measurements at each wet bulk density measurement location are presented in Table 3.2 below. The measured duff depth was least in the tracks and greatest between the tracks.

TABLE 3.2 AVERAGE DUFF DEPTH

LOCATION	AVERAGE DEPTH (IN.)		STD. DEV.
IN TRACKS	3.17	(N = 104)	2.90
BETWEEN TRACKS	5.30	(N = 47)	3.97
NEXT TO TRACKS	3.53	(N = 34)	2.13
UNDISTURBED AREAS	3.97	(N = 30)	2.42

In the tracks, it was observed that the duff layer had been compacted and partially or completely removed in some places. Pressure under the tracks due to the combined weight of the machine plus load along with the twisting, turning and slipping of the tracks could account for this. Surface disturbance caused by the tracks twisting and moving debris could account for the increased thickness measured between the tracks.

3.2 Soil Compaction

Because the logs were not dragged behind the machine but rather lifted off the ground or frequently dragged on top of other logs when moved, the paths made by the shovel showed little surface disturbance, particularly on level ground. However, when operating on slopes, it was observed that surface disturbance increased, mostly due to the increased frequency of stump pulling and the slipping and sliding that the tracks experienced in manuevering up and across steep slopes. From the results of the track profile data (Table 3.3), the tracks of the shovel created depressions of about 4 inches below the general surface of the ground and pushed up the ground between the tracks about 1.5 inches above the general ground surface (Figure 3.2).

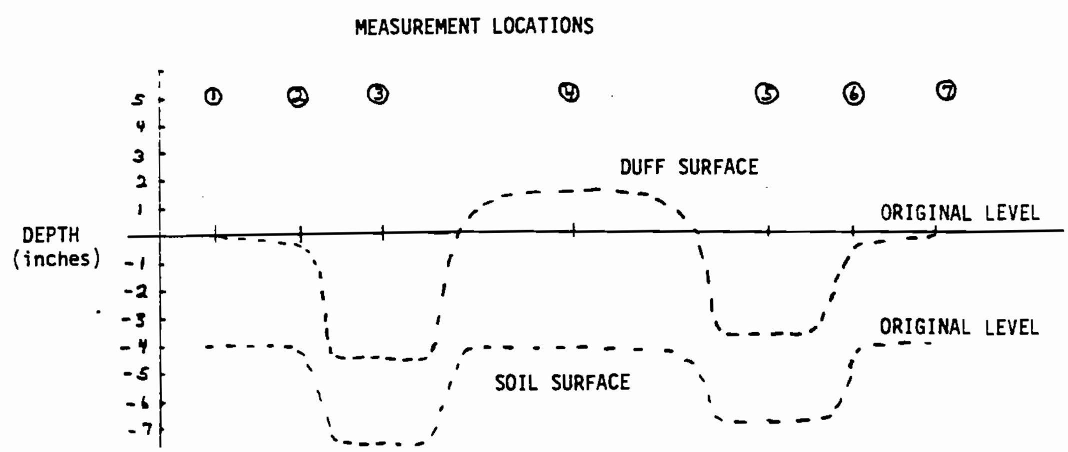


Figure 3.2 PLOT SHOWING AVERAGE DEPTH SHOVEL TRACKS SUNK INTO THE SURFACE OF THE SOIL DURING YARDING. Numbered locations correspond with those of Figure 2.4.

The ground was very uneven over all of the study area. Large mounds of earth were scattered over the area suggesting that this stand regenerates by blowdown. Partially buried rotting logs and partially decaying root wads were also frequently encountered on the site which further supported this. The uneven surface of this area contributed to the high standard deviations calculated in Table 3.3.

TABLE 3.3 AVERAGE DISTANCE FROM STRING TO DUFF SURFACE.

	PROFILE POSITION						
	1	2	3	4	5	6	7
AVE. DIST. TO GRND. (INCHES)	13.1	13.5	17.7	11.8	16.8	13.7	13.0
STD. DEV.	3.43	5.15	5.70	5.37	5.24	5.2	4.15

During trail preparation, it was observed that the operator would remove only enough slash and debris to make sure there were no hazards in the way. Rotten logs, small trees, broken off tops, small stumps, stump holes and limbs were left, creating a very uneven surface for the tracks of the shovel to pass over. Thus, the weight of the shovel plus load was seldom evenly distributed under the tracks of the shovel. Because of this uneven distribution and possible high variation in measurements, the track areas were the most heavily sampled of the four sampling locations.

The probeless meter used to measure soil bulk density was the Model C-200 Nuclear Density Moisture Meter made by Seaman Nuclear Corp. This meter uses the airgap backscatter method to measure density. Two readings were made at each plot. One recorded the radiation backscatter with the meter in direct contact with the soil. The other recorded the radiation backscatter at an air gap of approximately 1-3/4 inches. The ratio of these two readings produces a smooth single density calibration regardless of soil type (Operator's Manual, Seaman Nuclear Corp.) The depth to which this meter reads is variable depending on density and moisture. The more dense the material, the shallower the density measurement; and more moist the material, the shallower the moisture measurement.

Because soil moistures were encountered that far exceeded what this meter was calibrated for, only the wet bulk density measurements were used. These wet density readings were then adjusted based on actual soil moistures measured from soil samples taken in the field and dried in the lab later. The following formula was used to make this adjustment:

$$\text{DRY BULK DENSITY} = \frac{\text{WET BULK DENSITY}}{\underset{\text{(as a decimal)}}{(\text{MOISTURE CONTENT} + 1.0)}}$$

The following table (Table 3.4) compares the changes in bulk density for the different locations sampled against the undisturbed areas sampled using the probeless meter.

TABLE 3.4 SOIL DENSITY USING PROBELESS METER (BACKSCATTER METHOD).

LOCATION	AVERAGE MEASURED BULK DENSITY (G/CC)	NET CHANGE (G/CC)	PERCENT CHANGE (%)
IN TRACKS (N=104)	0.642 (0.09)*	+0.046	+7.72**
BETWEEN TRACKS (N=47)	0.609 (0.10)	+0.013	+2.18
NEXT TO TRACKS (N=34)	0.595 (0.10)	-0.001	-0.17
UNDISTURBED AREAS (N=30)	0.596 (0.07)		

*(standard deviation) **(significant difference at 1%)

Using a pooled t test, a statistically significant increase in compaction (7.7 % at alpha = .01) occurred in the tracks compared to undisturbed areas. An increase was also measured in the area between the tracks and a slight decrease was measured at the edge of the tracks, neither of which were statistically significant.

The double-probed meter used was the MC-1 Moisture/Density guage made by Campbell Pacific Nuclear Corporation. Similar to the probeless guage, this guage measured density and moisture using radioactive sources. With the two probes, density measurements between two points at the same level were possible. Density measurements were obtained by deriving a ratio of the field count from the guage to the standard count of the guage, and then using this ratio along with a calibration curve to read wet bulk density directly.

For this particular guage, a calibration curve for a typical forest soil had previously been developed and was used to derive all wet bulk densities. Once the wet bulk density was known, dry bulk density was then calculated using the measured soil moisture values and equation presented above.

Table 3.5 compares bulk densities for the different locations sampled with the measurements from the undisturbed areas. Measurements at 4, 8 and 12 inches below ground were made.

Again using a pooled t test, a statistically significant increase (alpha = 0.10) in compaction was measured in the tracks at all three levels below ground. An increase was also measured between the tracks and a decrease was measured next to the tracks, each at all three levels and each not statistically significant, at least at a level less than 0.10.

Table 3.6 relates the number of passes made on each path to the average bulk density measured. From the literature review, it was shown that only a few passes

TABLE 3.5 SOIL DENSITY USING DOUBLE-PROBED METER.

SOIL DEPTH (INCHES)	MEAN BULK DENSITY (G/CC)	NET CHANGE (G/CC)	PERCENT CHANGE (%)	SIGNIF. LEVEL
UNDISTURBED AREAS-				
4 (N=21)	0.602 (0.09)	-	-	-
8 (N=21)	0.650 (0.10)	-	-	-
12 (N=21)	0.699 (0.09)	-	-	-
BETWEEN TRACKS-				
4 (N=34)	0.603 (0.10)	+0.001	+0.1	>0.40
8 (N=34)	0.678 (0.10)	+0.028	+4.31	0.15
12 (N=33)	0.727 (0.09)	+0.028	+4.01	0.15
NEXT TO TRACKS-				
4 (N=25)	0.581 (0.12)	-0.021	-3.49	0.30
8 (N=25)	0.636 (0.11)	-0.014	-2.15	0.40
12 (N=25)	0.691 (0.11)	-0.008	-1.14	0.40
IN TRACKS-				
4 (N=80)	0.647 (0.14)	+0.044	+7.30	0.10
8 (N=80)	0.714 (0.13)	+0.064	+9.85	0.02
12 (N=80)	0.754 (0.11)	+0.055	+7.87	0.025

over the same area with typical ground-based yarding systems can increase bulk density to near its maximum attainable density. Shovel yarding, however, is not like other ground-based yarding systems.

As already explained, the shovel basically sits in one spot and rocks back and forth as it moves logs. Much dynamic loading occurs under the tracks along with vibration caused by the motor and sudden movement. Thus, it would seem that just one pass would be enough

TABLE 3.6 COMPARISON OF AVERAGE BULK DENSITY IN TRACKS BY NUMBER OF PASSES MADE WITH SHOVEL.

PROBELESS METER --

NO. OF PASSES	BULK DENSITY (G/CC)	STD. DEV.	
1	0.633	0.132	(N=20)
2	0.641	0.095	(N=40)
3-4	0.617	0.085	(N=20)
5	0.667	0.104	(N=24)

DOUBLE-PROBED METER --

NUMBER OF PASSES	BULK DENSITY (G/CC) AT EACH DEPTH 4 IN.	8 IN.	12 IN.
1 (N=18)	0.656 (0.113)	0.695 (0.084)	0.735 (0.072)
2 (N=26)	0.635 (0.151)	0.733 (0.132)	0.764 (0.117)
3-4 (N=16)	0.578 (0.148)	0.613 (0.139)	0.657 (0.127)
5+ (N=20)	0.645 (0.138)	0.715 (0.106)	0.759 (0.097)

(standard deviation)

to compact the soil to near its maximum amount. The data in Table 3.6 seems to suggest this. There seems to be no increase in bulk density as the number of passes increased beyond the first pass, suggesting that whatever compaction is going to occur, occurs with the first pass. However, bulk densities measured were far below what would be considered maximum bulk densities for typical highly compacted forest soils - anywhere from about 1 g/cc (Dyrness, 1965) to more than 1.5 g/cc (Gent, Ballard and Hasson, 1983). These low densities in this study are typical of soils with a high organic matter content.

Furthermore, since this type of yarding does not involve dragging the logs behind the machine, the shovel paths typically remain covered with debris during the yarding, except when the shovel turns or spins its tracks. Thus, the stumps, logs, slash and duff that the shovel travels over may tend to reduce the amount of compaction that can occur by spreading the load out beyond the surface area under the tracks.

3.3 Time and Motion

The yarding scenario consisted of starting on the road and first clearing all logs and enough slash from the proposed path to reveal any stumps that might need to be either pulled out or driven around to allow safe passage of the shovel. Once all logs that were reachable were stacked perpendicular to and along the edge of the road, the shovel would move several feet off the road onto the path and begin clearing the next part of the path. All logs within reach would be stacked behind the shovel on the pile at the road.

Moving only a few feet at a time, this procedure would continue until the operator could no longer reach the pile at the road edge. At this point, he would start a new log pile where he was and then move forward, extending the path and stacking any logs back on this new pile until it, too, was out of reach. This sequence was repeated until the end of the path was reached. Then, the operator would start back, swinging the piles toward the road. The number of times each log was handled was equal to the number of piles it was placed in before it reached the landing (including the landing pile).

Moves during the first pass generally were less than the length of the tracks. Time spent moving (Table 3.7) involved about 11% of the total yarding time and included time spent going unloaded from the work area back out to the road to load trucks. Because of the shape of the unit and the considerable amount of road adjacent to the unit, this moving time was usually less than about 5 minutes per round trip.

However, because of the high cutbank on the road along the west side of the unit, there were no landings available for decking logs here. When the yarding operation got to this part of the unit, logs were landed against the cutbank and in the roadway. Thus, each time the road become plugged, the shovel had to travel out across the unit to the road in the southwest corner, down the road to the west side of the unit and load out trucks to open the road before the end of the shift.

TABLE 3.7 TIME PER ACTIVITY BY HOURS AND PERCENT OF TOTAL TIME.

ACTIVITY	TIME/ACTIVITY	PERCENT TOTAL TIME
MOVING	7.36 HRS.	11.10 %
SWINGING	44.73 HRS.	67.45 %
TRAIL PREP.	6.25 HRS.	9.43 %
DELAYS	7.98 HRS.	12.02 %
TOTAL =	66.32 HRS.	100.00 %

SUMMARY:

TOTAL NUMBER OF TIMES A LOG WAS SWUNG = 5711 TIMES
TOTAL NUMBER OF DAYS SPENT LOGGING = 14 DAYS
AVERAGE OPERATING HOURS/DAY = 4.73 HRS./DAY

Once the logs had been decked along a path, the operator would start moving them back to the road. He would position the shovel between the last two piles at the end of the path and them start moving the logs from the last pile to the next-to-the-last pile. This usually involved just dragging as many logs as he could grasp in the grapple from the furthest away pile up along side the shovel and onto the next closer pile without turning them end-for-end. Then, he would grab the near end of these just moved logs and push them as far on to this pile as possible. After moving the furthest pile onto the next closer pile, he would them move up between the next two piles and start again. This type of yarding pattern - paths perpendicular to the haul road - seems to be complimented by this type of yarding - keeping the logs on one side of the machine and moving them parallel to the path toward the haul road. Not having to lift the log up off the ground and then swinging it from one side of the shovel to the other, as would be required in an S-shaped yarding pattern, would seem to be faster, particularly with old growth timber such as this was. No measurements to support this were taken, however.

Each time a log was moved, it was counted. The total number of times a log was moved equalled 5711 times (Table 3.7). From the scale records, only 1632 logs were hauled from the unit so that on the average, each log was moved about 3.5 times. Time spent swinging accounted for about 67% of the total yarding time. Besides just moving logs, swinging also included any delimbing that the operator did with the shovel. This was done in one of three ways; by standing the log up on end and running the grapple down it; by dragging the log across the ground; and by moving the grapple across the log as it lay on the ground.

No record of how much time was spent delimbing was recorded and trying to record it would be difficult. Just the act of swinging the log from one pile across the ground to the next pile results in a certain amount of delimbing. Trying to determine what is intentional delimbing and what results from the swinging operation would be very difficult. However, only incidental limbing with a powersaw was needed at the landings.

Of the total time spent yarding, just over 9% of the time was spent in trail preparation. In making a new path, the operator had to clear out enough slash and debris from in front of the shovel to ensure safe passage. Stumps too tall to straddle or that were in the way of the tracks had to be either pulled out or traveled around. This machine could pull most small stumps directly out of the ground. Although no measurements were made of the size of the stumps being removed, 12 inch stumps were not uncommon.

In removing stumps, the operator would generally pull them out, use the grapple to claw some of the soil from the root wad and then lift them up and drop them a few times to remove still more of the soil from the root wad. Then, he would stack the root wad off to one side and continue on. In all, 55 stumps were pulled out during trail preparation.

Observing the operation, it was not always obvious when he was moving slash to locate the logs (a swinging operation) or when he was moving slash to clear a path (a trail preparation operation). Thus, the swinging and trail preparation recorded times are not separated exactly the way they really happened.

Delays accounted for about 12% of the total yarding time. The shovel engine would overheat on warm days and the operator spent a total of about 2.6 hours clearing the radiator of debris and allowing the engine to idle until it cooled down enough to continue operating. Towards the end of the project, the radiator was flushed out with water under pressure and this problem was solved. Scheduled lubrication of the boom and minor repairs such as fixing two broken hydraulic hoses on the grapple and tightening loose bolts and a loose ring on a hydraulic ram involved another 2.1 hours of delays.

Personal time, lunch time, time spent reconning and planning the next path, and time spent talking to the foreman and other visiting workers involved another 2.8 hours of delay time. The rest of the time (0.5 hrs.) involved such things as refastening a door on the side of the shovel that kept coming open, giving the branding hammer to the sawyer and clearing a stick from the undercarriage. Delay time did not include any time spent during the day loading trucks and did not include any times before the machine started in the morning or after it quit at the end of the shift. Thus, any fueling and maintenance done during these times was ignored.

3.4 Production

From the scaling data, the following information was recorded.

TOTAL NUMBER OF LOADS HAULED.........126	LOADS
TOTAL NUMBER OF LOGS HAULED.........1632	LOGS
GROSS VOLUME HAULED...............684930	BF
NET VOLUME HAULED.................519574	BF
PERCENT DEFECT........................24	%
NET VOLUME/ACRE.....................41901	BF/ACRE
NET VOLUME/LOAD......................4124	BF/LOAD
AVERAGE NUMBER OF LOGS/LOAD...........13	LOGS/LOAD
AVERAGE LOG DIAMETER (SMALL END)......15	INCHES
GROSS VOLUME YARDED/HOUR...........10328	BF/HR
NET VOLUME YARDED/HOUR..............7834	BF/HR
LOG LOADS YARDED/HR..................1.9	LOADS/Hr

AVERAGE NUMBER OF TIMES EACH LOG WAS SWUNG = 3.49 TIMES

The net volume per acre based on scale records was 41.9 mbf/acre. Using the total yarding time of 66.3 hours and the total net volume hauled of 519.6 mbf, volume yarded/hour for this particular machine and unit averaged 7.8 mbf/hour or 1.9 truckloads per hour.

Empirical appraisals were done for both the highlead yarder and shovel to determine hourly machine rates. These machine rates were then used to derive costs used for comparison purposes. The Production And Cost Program (PACE) developed by Dr. John Sessions and J.B. Sessions (1985) at Oregon State University, was used to calculate machine rates. For each piece of equipment, ownership costs, operating costs and labor costs were calculated based on required input costs. These input costs came from a variety of sources including actual loggers, equipment manufacturers and Forest Service cost guides.

Computer generated listings of the results of the Pace calculations are displayed in Appendix B. The first two pages of the appendix are the results of the shovel empirical appraisal. A summary of ownership, machine and labor costs is presented followed by detailed lists of cost inputs and results for each category of costs. The yarder empirical appraisal involves the next four pages - two for the yarder and two again for the shovel used as a loader, only. This was done to reflect lower maintenance costs and longer life for the shovel when it is used only as a loader.

Calculated machine hourly rates were:

SHOVEL = $87.86/HR

YARDER = $270.32/HR

Logging activities associated with both systems were the same - road construction, felling, yarding, loading and hauling. Some of these operations were identical with respect to total costs and were not included in the estimate of costs used to evaluate the two systems. These operations included:

- Felling - fallers would fall the stand to minimize breakage and generally on the contour of the slope for both systems.

- Road construction - for this study, no new roads were built other than what was planned for the original system.

- Hauling - highlead yarding required only one landing while shovel yarding used several landings along the roads adjacent to the unit. Distance hauled, however, was almost identical in each system so that this cost was assumed to be the same.

The following items were considered in calculating the difference in logging costs:

- Machine rates - empirically estimated.

- Move-in and Move-out costs - The highlead system had to move both a loader and yarder while the shovel system moved only a shovel.

- Slash disposal - shovel yarding involved several additional landings along the road requiring additional roadside cleanup. Slash disposal for the unit was the same for both systems and not included in the cost estimates.

- Road maintenance - shovel yarding involved hauling over additional roads that required additional road maintenance.

- Loading - This cost was included because the hourly rate for the loader differs between the two systems and, also, the time required to load for each system is different. With shovel yarding, the shovel loads only when trucks are at the site. With highlead yarding, the loader not only loads trucks but has to move the logs from the landing as they are yarded in, an additional cost.

A summary of these costs follows on the next page. For analysis purposes, the net difference in per unit costs is the critical value. For this particular study, the highlead system cost $18.57/mbf more than the shovel system.

- SHOVEL/HIGHLEAD LOGGING COST SUMMARY -

	SHOVEL	HIGHLEAD
TOTAL MACHINE COSTS		
$87.86/HR * 66.3 HR =	$5827	
2.5 LOADS/HR * 5436 BF/LOAD = 13590 BF/HR YARDED		
684930 BF TOTAL/13590 BF.HR = 50.4 HR TOTAL		
$270.32/HR * 50.4 HR =		$13624 **
LOADING		
$87.86 * 126 LDS/3.0 LDS/HR =	$3690 ***	
$75.91 * 50.4 HR =		$3826
MOVING IN/RIG/UNRIG/MOVE OUT	$477	$3772
SLASH DISPOSAL	$1406	-
ROAD MAINTENANCE	$177	-
TOTAL =	$11577	$21222

519574 NET BF HAULED

COST/MBF FOR COMPARISON = $22.28/MBF $40.85/MBF

** (A highlead production rate of 2.5 loads/hour was obtained from the purchaser.)

*** (an average loading rate of 3 trucks/hr was used, based on limited observation at the site.)

5.5 The Values Associated With Soil Compaction

Several tools are available for use in tilling compacted soil with reasonable success. A winged-subsoiler attachment for common logging tractors has been tested and consistently fractured over 80% of a one foot deep layer of compacted soil. Costs for deep tillage of skidtrails are similar to other forms of mechanical site preparation. Long-term effects of tillage on compacted soils, however, have not been studied (Froehlich and McNabb, 1983).

In deciding how much soil compaction to allow before some sort of remedial measures need to be taken to restore the soil to its original productivity, the value of soil compaction needs to assessed. Often this is done indirectly by evaluating the effects of soil compaction.

With respect to the literature, at least three ways of evaluating the effects of soil compaction were found. Stewart (1986) developed a model that would predict net present value of a stand-level harvest plan, accounting for potential volume losses due to harvest-related soil compaction. By running the model with and without the effects of compaction, the difference in net present value and the amount of volume lost to compaction can be estimated. As he reports, this "...difference represents the present value of the additional cost that you could afford to spend on a yarding system to eliminate the effects of compaction." While this model requires a considerable amount of input, it has the advantage of being able to test the sensitivity of net present worth to changes in skid trail spacing, different yarding systems and different assumptions about growth loss.

Another technique that concentrates only on predicting volume losses was used on the Quilcene Ranger District of the Olympic N.F. in Washington state (Jennings, 1984). This method estimated growth loss on a unit logged with a feller/buncher and clambunk. The increase in bulk density was 44.3% for the unit (initial B.D. = 0.70 g/cc - final B.D. = 1.01 g/cc). Using data from Adams and Froehlich (1981), leader growth for the future stand was estimated at 79% of original leadergrowth. Site index was then reduced to 79% of its original index and volume production for this new site index was calculated. The percent growth loss was then estimated, comparing the volumes from the original site index and adjusted site index. For the particular unit analyzed, this volume reduction was 32%.

A third technique, similar to Stewart's but requiring fewer inputs, is from an unpublished paper by John J. Garland, Extension Timber Harvesting Specialist at Oregon State University. This technique evaluates two different yarding systems using net present value. As an example, assume the following situation, using the results of this research project for some of the input:

- A mill pays $220/mbf, increasing at an annual real rate of 2%. (Two per cent reflects the historical average.)
- Real interest rate = 4%. (A reasonable rate for Federal Government projects.)
- Shovel logging cost = $100/mbf.
- Highlead yarding cost = $118.57/mbf (A difference of $18.57/mbf based on this research.)
- Volume/acre for the existing stand = 41.9 mbf/acre.
- Volume/acre for the future stand = 91.45 mbf/acre at year 75 (an estimate based on the Quinault Ranger District silviculturist's estimate for this area).
- Regeneration harvest now and at 75 years.
- Future volume loss due to compaction with the shovel at first entry = 2%.
- Highlead yarding causes negligible compaction.

The 2% volume reduction above was based on an overall measured soil bulk density reduction for the study area along with research done on the Yakima Indian Reservation by Froehlich and Robbins (1983). In their study, the species studied was ponderosa pine and values were based on a 15% increase in density where bulk density was slightly greater than 1 g/cc.

The assumption that no compaction occurs with highlead yarding was made to demonstrate Garland's method as originally developed. In general, however, this is not true. From the literature review, highlead and skyline systems can both cause significant amounts of compaction and disturbance, similar to shovel logging.

To show how Garland's method works, a spreadsheet (Table 3.8) was used to show the economic summaries of these two logging systems based on the above scenario. A third system, a fictitious shovel with no compaction, is included as part of this method to be used for comparison purposes. Definitions of the columns in each system are as follows:

Year = the year logging occurs.

Volume Loss = the percent loss in volume/acre due to the system.

Volume = volume/acre of the stand being harvested.

Log Price = price the mill will pay/mbf for logs with the real price increase.

Price-Cost = (Log Price - logging cost/mbf).

Net Per/Acre Value = Volume * (Price-Cost).

NPV/Acre = Net Per/Acre Value discounted to present.

Referring to Table 3.8, using the highlead system, PNV/acre is $8365. With the shovel, it is $9148, an increase of $783. Thus, even though volume harvested from the future stand was 2% less, the less expensive logging cost with the shovel gave a greater per acre

Table 3.8 AN ECONOMIC COMPARISON BETWEEN TWO DIFFERENT YARDING SYSTEMS - SHOVEL VERSUS HIGHLEAD.

INTEREST RATE =	4 %
MILL PRICE =	220 $/MBF AT 2%/YR INCREASE
LOGGING COSTS =	100 $/MBF - SHOVEL
	118.57 $/MBF - HIGHLEAD
VOLUME AT YR. 0 =	41.9 MBF/ACRE
VOLUME AT YR. 75 =	91.45 MBF/ACRE
VOLUME LOSS % =	2 %

DIFFERENCE		
783 $/ACRE	NPV - SHOVEL W/COMPACTION =	9148 $/ACRE
0 $/ACRE	NPV - HIGHLEAD - NO COMPACTION =	8365 $/ACRE
867 $/ACRE	NPV - SHOVEL W/O COMPACTION =	9232 $/ACRE

SHOVEL

YEAR	VOLUME LOSS %	VOLUME MBF/ACRE	LOG PRICE $/MBF	PRICE - COST $/MBF	NET PER/ACRE VALUE	NPV/ACRE
0	0	41.9	220	120	5028	5028
75	2	89.621	971	871	78060	4120
					TOTAL =	9148

HIGHLEAD

YEAR	VOLUME LOSS %	VOLUME MBF/ACRE	LOG PRICE $/MBF	PRICE - COST $/MBF	NET PER/ACRE VALUE	NPV/ACRE
0	0	41.9	220	101.43	4250	4250
75	0	91.45	971	852.43	77955	4115
					TOTAL =	8365

SHOVEL WITH NO COMPACTION

YEAR	VOLUME LOSS %	VOLUME MBF/ACRE	LOG PRICE PER/MBF	PRICE - COST	NET PER/ACRE VALUE	NPV/ACRE
0	0	41.9	220	120	5028	5028
75	0	91.45	971	871	79653	4204
					TOTAL =	9232

return. Had the shovel caused no compaction, the per acre return would have been $867 or a difference of $84/acre. As with Stewart, Garland concludes that this $84 represents the maximum amount of money the operator could spend to rehabilitate the compacted areas and still be cost effective. This is true only if the decision involves one system and the money available can completely rehabilitate the soil. To understand this, Table 3.9 was developed.

This table shows the cash flows over the 75 year period for each alternative. Costs are separated from revenues to better show what is happening. Looking at the shovel example with compaction, volume/acre in the second harvest is slightly less than maximum due to compaction. This volume loss is worth $94/acre. Because of the reduced volume, the total logging cost will be slightly less than if the maximum volume were available - $10/acre - so that the difference is $84/acre which agrees with the difference between the two shovel options.

Now, suppose the operator spends $84/acre and rehabilitates the site to 100% of the original condition. Then, at the second harvest, the maximum volume will be available. The revenue gain will be $94/acre and the additional yarding cost will be $10/acre so that the operator will break even. If it takes more than $84/acre to rehabilitate the site, then the operator will not be able to recapture the rehabilitation investment. If it takes less, then the operator will come out ahead.

Table 3.9 TIME LINE WITH CASH FLOWS FROM TABLE 3.8

SHOVEL W/COMPACTION

COSTS	41.9*100 = $4190	89.63*100 =$8963	(PV = $473)
YEAR	0	75	
REVENUE	41.9*220 = $9218	89.63*971 = $87021	(PV = $4593)

PV - TOTAL REVENUE = $13811/ACRE
PV - TOTAL COST = $4663/ACRE

NPV TOTAL = $9148/ACRE

****

HIGHLEAD W/O COMPACTION

COSTS	41.9*118.57 = $4968	91.45*118.57 =$10843	(PV = $572)
YEAR	0	75	
REVENUE	41.9*220 = $9218	91.45*971 = $88798	(PV = $4687)

PV - TOTAL REVENUE = $13905/ACRE
PV - TOTAL COST = $5540/ACRE

NPV TOTAL = $8365/ACRE

****

SHOVEL W/O COMPACTION

COSTS	41.9*100 = $4190	91.45*100 =$9145	(PV = $483)
YEAR	0	75	
REVENUE	41.9*220 = $9218	91.45*971 = $88798	(PV = $4687)

PV - TOTAL REVENUE = $13905/ACRE
PV - TOTAL COST = $4673/ACRE

NPV TOTAL = $9232/ACRE

If the decision involves two systems and how much money can be spent to rehabilitate the soil back to its original condition, then a slightly different interpretation occurs. Again, looking at Table 3.9, if the shovel is used to log, then the amount that can be spent on rehabilitation is not just the difference in net present value between the highlead and the shovel - \$783/acre. Using the shovel saves a considerable amount in yarding costs - \$877/acre - but loses \$94/acre in volume due to compaction. The operator can now spend up to \$867/acre, assuming the soil is 100% rehabilitated, and just break even with the highlead system since an additional \$84/acre will be received at year 75. If the operator has to spend more than this, then the highlead system is more economical. If the operator can spend less and still achieve 100% rehabilitation, then they will come out ahead.

Thus, this type of analysis can help to decide how much to spend on rehabilitation. None of these methods, however, measures the real value of soil compaction. The last two methods can measure one effect of compaction, the reduction in future volume, but the value of this volume represents only one part of the total value of compaction.

Value, the worth of something to a particular individual at a given place and moment in time, is a human perception and only relative, at best (Davis and Johnson, 1986). Different perspectives establish different categories of values. For instance, social values often come about subjectively based on what is good for the whole of society (number of jobs, income distribution, cost distribution, etc.). Religious and moral values are usually based on a more spiritual and philosophical level (fundamental rights and wrongs).

Within the narrow framework of most economic theory, something has value when it generates utility within the person evaluating it, either directly or indirectly. The measure of economic value is determined by the amount of money, goods and/or time an individual is willing to give up to have or use the goods or services they want.

In large, competitive markets, the free market value, or price, is typically used to estimate the economic value of many goods and services. Here, the value received for a unit of product at the margin will equal the cost of resources given up so that competitive market prices, as such, reasonably measure what consumers are willing to pay for goods and services.

However, the price paid for the use - use price - of many resources and services available on public lands does not often equal the value received so that price times quantity is not a good measure of their value.

Examples would be picture taking, animal watching, hiking and dispersed recreation where the price is typically zero, and timber harvesting in a less than perfectly competitive market where bid price is less than willingness to pay. To further compound the problem, additional values called non-use or intrinsic values resulting from future concerns about the resource are often an important part of the total value of these resources. These non-use values are categorized as option and existence values (Rockland, 1985).

Option value represents the value an individual places on the availability of resource use in the future and it reflects uncertainty about the future demand and supply of the resource. The value of the option of future use is termed "ordinary option value". Where new information is expected in the future and therefore, a value exists from holding off a decision about use until that information becomes available, this value is called "quasi-option" value.

Existence value represents the willingness to pay to ensure that a resource will exist in the future, though the individual will never use it themselves. This value is generally motivated by altruism or the unselfish concern for other people.

In researching the literature, no studies were found that involved trying to estimate existence, option and quasi-option values of soil compaction. Lack of any research done to date does not imply, however, that the value of soil compaction does not include these values. Certainly, people are concerned about the productivity of forest land - particularly public-owned forest land - even though they may never visit or use all parts of it themselves. Just knowing that the productivity of some of this land will be impaired for a considerable length of time into the future through logging, people might be willing to pay money to keep it at its highest productivity for future generations to enjoy. Thus, the value of soil compaction could have an existence value attached to it.

With respect to quasi-option value, much is still unknown about the effects of soil compaction on future tree growth. Thus, there is a value in not allowing compaction to occur until more is known so that better decisions about it can be made in the future. Option value, too, may be a value to consider in evaluating soil compaction. While soil compaction is not irreversible, certainly once the next generation of trees is re-established, reversing compaction through some kind of mechanical means would be difficult until after the next harvest. Not knowing how valuable future lost production might be to future generations may make option value a very real value to consider.

Just as values like existence value and option value for soil compaction have not presently been estimated, it may also not be possible to estimate them for some time into the future due to the difficulty our present system of economics has in evaluating many intrinsic values. (Appendix C discusses this problem at some depth for those interested.)

However, land managers need to be aware of these additional values when making decisions about whether to allow soil compaction to occur and whether to rehabilitate it afterwards, particularly given the uncertainty of predicting future effects of soil compaction for areas where information is not available.

4.0 SUMMARY AND MANAGEMENT CONSIDERATIONS

4.1 SUMMARY

The overall purpose of this study was to obtain more quantitative information on the environmental and economic considerations of shovel logging. A summary of the research findings follows.

- 1.) Of the total area logged, 20.5% was taken up by shovel paths - 64% of these paths had 2 or less passes on them. Average path width was 13.7 feet.
- 2.) Of the total yarding time, 11% was spent moving the shovel; 68% was spent swinging logs; 9% was spent preparing pathways; and 12% was spent in delays.
- 3.) The operation averaged 1.9 truckloads/hour (7.8 net mbf/hour) and each individual log was moved approximately 3.5 times from stump to landing.
- 4.) Soil bulk densities in undisturbed areas averaged 0.596 g/cc using a probeless nuclear density meter and using a double-probed guage, averaged 0.602, 0.650 and 0.699 g/cc at 4, 8 and 12 inch depths below ground, respectively.
- 5.) For the probeless meter, soil bulk density was significantly higher (7.7%) under the shovel

tracks than compared to undisturbed areas. For the double-probed meter, soil bulk density under the tracks was also significantly higher (7.3, 9.85 and 7.87% at 4, 8, and 12 inch depths below ground, respectively).

- 6.) Soil compaction did not seem to increase after the initial pass. Sample size was small, however, and this needs to be studied further.
- 7.) Equipment exists for restoring compacted soil through tillage with winged subsoilers.
- 8.) For this study, logging with a Cat 235 shovel cost $18.57/mbf less than with a Washington 208 slackline yarder.
- 9.) The value of soil compaction involves more than measuring the dollar value lost due to future timber production. Existence value, option value and quasi-option value all need to be considered when making the decision to allow soil compaction to occur without rehabilitating it afterwards.

4.2 MANAGEMENT CONSIDERATIONS

1.) Based on this study, selecting highlead yarding over shovel yarding due to increased soil compaction with shovel yarding does not seem warranted. Shovel yarding is cheaper than highlead yarding and the amount of compaction and disturbance that occurs is comparable to highlead yarding.

2.) Restricting the number of passes per path may not reduce compaction because the maximum amount seems to occur with the first pass. Keeping paths spread as far apart as is feasible would reduce the area impacted, however.

3.) With respect to the management of National Forest lands, the National Forest Management Act of 1976 requires National Forests to be managed under the principles of multiple use and sustained yield without permanent impairment of the land's productivity and to maintain or improve soil productivity (FSM 2520.2 Supplement 50). Given this requirement, the following need to be considered when selecting from possible yardings systems:

a.) When faced with a decison about whether to use a yarding system that is more expensive but causes less compaction or using a yarding system that is less expensive but causes more compaction, the land manager must realize that it is not a decision to be made based only on economics. Economics is somewhat amoral (lacking many moral sensibilities) and nature-less in that it is not capable of measuring all the different values associated with the presence of soil compaction - at least not at the present time.

b.) The standard for allowable soil compaction set by the Forest Service is: ""Leave a minimum of 80% of an activity area in a condition of acceptable productivity potential for trees and other managed vegetation following land management activities" (FSM 2521.1.1). This standard, while inconsistent with NFMA, is perhaps necessary given that in cutting timber, a certain amount of productivity impairment is inevitable (roads, landing, skid trails). However, this standard is not a license to compact soil just because one system is less expensive than another to operate.

Knowingly compacting soil (even when it is within Forest Service guidelines) when a less destructive but more expensive system is available may be stealing from future generations in the form of increased revenue now at the expense of lost timber production in the future. This inequitable distribution of benefits and costs, where present owners gain in the form of increased revenue and future owners lose in the form of decreased production, needs to be corrected. Therefore, it is recommended that whenever the decision to select a less expensive yarding system over more expensive systems is made, even when the risk of compaction is equivalent, the money saved in costs should be spent rehabilitating the soil back to its original condition or even improving it, as the law requires.

An alternative to this might be to collect an amount equal to the future value of the timber production lost to compaction plus whatever addition dollar value can be attached to the existence value, option value and quasi-option value of soil compaction. This collected money could be invested and at the time of the next harvest, it could be paid to that generation to compensate them for their losses due to compaction.

4.) Finally, a good job of up-front planning with respect to layout needs to be done. Unit size and spur road location need to be carefully thought out to prevent situations that are dangerous (slopes greater than 20%) or unproductive with respect to yarding distance. Adequate planning can reduce the area covered by shovel tracks. A brief but concise report done by Starnes (1987) is recommended in assisting sale planners with this task.

5.0 ADDITIONAL RESEARCH NEEDS.

5.1 COMPACTION/GROWTH STUDIES

The location of the study area - the Olympic Peninsula - has its own unique climate and biology. Undisturbed soil bulk density readings were some of the lowest recorded compared to what is available in the literature. Natural regeneration by blowdown, with its turning over and "fluffing" of the soil periodically, may account for this. Tree species on the site are not typical species that have been studied for the affects of compaction on growth. Average rainfall here is considerable compared to areas where compaction/growth studies have been done. Because of these reasons, predicting reductions in tree growth due to increases in soil bulk density based on past research is risky business, at best. Thus, there is a need for more research in the area of compaction and its affect on growth, particularly on sites where productivity is high, such as the Olympic Peninsula.

5.2 ADDITIONAL SHOVEL LOGGING STUDIES

This is the first shovel logging study on soil compaction that has used nuclear density meters. More studies need to be done to verify the results of this study before they should be used to set future land managment practices. Of particular concern is finding out what the relationship is between the amount of slash and duff under the tracks of the shovel and the amount of compaction that occurs.

6.0 REFERENCES

Adams, Paul W. and Henry A. Froehlich, 1981. Compaction of Forest Soils, PNW 217.

Aulerich, D. Edward, Norman K. Johnson and Henry Froehlich, 1974. Tractors or Skyline: What's Best for Thinning Young- growth Douglas Fir?. For. Ind. Mag., 101(12):42-45.

Campbell, Robert G., James R. Willis and Jack T. May, 1973. Soil Disturbance by Logging with Rubber-tired Skidders. J. Soil Water Cons., 28:218-220.

Caterpillar Performance Handbook, Edition 17, 1986. Caterpillar Inc., Peoria, Illinois, U.S.A.

Davis, L.S. and K. N. Johnson, 1986. Forest Management, 3rd Edition, McGraw Hill Book Company.

Dickerson, B.P., 1976. Soil Compaction after Tree-length Skidding in Northern Mississippi. Soil Sci. Soc. Am. J., 40:965-966.

Dyrness, C.T., 1965. Soil Surface Conditions Following Tractor and Highlead Logging in the Oregon Cascads. J. For., 63:272-275.

Fisher, James G., 1986. Logging With a Hydraulic Excavator: A Case Study. O.S.U. Dept. of For. Eng., Master's Thesis.

Fowells, H. A. and G.H. Shubert, 1951. Natural Reproduction in Certain Cutover Pine-fir Stands in California. Jour. Forestry 49:192-196.

Froehlich, H.A., 1979. Soil Compaction From Logging Equipment: Effects on Growth of Young Ponderosa Pine. J. Soil Water Conser. 34:276-278.

Froehlich, Henry A. and David H McNabb, 1983. Minimizing Soil Compaction in Pacific Northwest Forests. A paper presented at the 6th North American Forest Soils Conference on Forest Soils and Treatment Impacts.

Froehlich, H.A. and Richard W. Robbins, 1983. The Influence of Soil Compaction on Young Tree Growth on the Yakima Indian Reservation. Final Report to the Confederated Tribes and Bands of the Yakima Nation under Contract No. T-82-6745.

Garrison, G.A. and R.S. Rummell, 1951. First year Effects of Logging in Ponderosa Pine Forest Ranges of Oregon and Washington. J. For., 49:708-713.

Gent, J.A. Jr., R. Ballard and A.E. Hassan, 1983. The Impact of Harvesting and Site Preparation on the Physical Properties of Lower Coastal Plain Forest Soils. Soil Sci. Am. J., 47:595-598.

Gent, J.A. Jr., R. Ballard, A.E. Hassan and D.K. Cassel, 1984. Impact of Harvestion and Site Preparation on the Physical Properties of Piedmont Forest Soils. Soil Sci. Soc. Am. J., 48:173-177.

Halloin, Louis, 1987. Shovel Logging: Soil, Terrain, and Timber Suitability. Washington State DNR, Forest Land Management Division.

Hatchell, G.F., C.W. Ralston and R.R. Foil, 1970. Soil Disturbance in Logging. J. For., 68:772-775.

Helms, John A. and C. Hipkin, 1986. Effects of Soil Compaction on Tree Volume in a California Ponderosa Pine Plantation. West. J. Appl. For. 1:121-124.

Hemphill, Dallas C., 1986. Shovel Logging. Logging Industry Research Assoc. of New Zealand, Technical Release, Vol. 8, No. 1.

Jennings, Wesley, Meredith May, Gwen Sheehy and Nancy Darling, 1982. Olympic N.F. Soil Resource Inventory Update Report, a Forest Service unpublished report.

Jennings, Wesley, 1984. Soil Compaction in Perspective - A Report in Support of the Doghair Program. Quilcene Ranger District, Olympic N. F.

Lenhard, R.J., 1986. Changes in Void Distribution and Volume During Compaction of a Forest Soil. Soil Sci. Soc. Am. J. 50:462-464.

Lysne, D. H., and A. L. Burditt, 1983. Theoretical Ground Pressure Distributions of Log Skidders. Transactions of the ASAE, Vol. 26, No. 5, pp. 1327-1331.

Moehring, D.M. and J.K. Rawls, 1970. Detrimental Effects of Wet Weather Logging. J.F. 68:166-167.

Miller, James H. and Donald L. Sorois, 1986. Soil Disturbance by Skyline Yarding VS. Skidding in a Loamy Hill Forest. Soil Sci. Soc. Am. J. 50:1577-1583.

Munns, E.W., 1947. Logging Can Damage the Soil. J.F. 45:513

Perry, T.D., 1964. Soil Compaction and Loblolly Pine Growth. Tree Plant. Notes, 67:9.

Rockland, David B., 1985. The Economic Benefits of A Fishery Resource: A Practical Guide. Sport Fishing Institute, Technical Report I, SFI Economics Program.

Seaman Nuclear Corp. Operators Manual - Model C-200 Nuclear Density Moisture Asphalt Meter. Oak Creek, Wisconsin.

Sessions, J. and J.B. Sessions, 1985. Production and Cost Evaluation - User's Manual, Draft #2. Oregon State University.

Sidle, R.C. and D.M. Drlica, 1981. Soil Compaction From Logging with a Low Ground Pressure Skidder in the Oregon Coast Range. Soil Sci. Soc. Am. Proc., 45:1219-1224.

Starnes, L.W., 1985. Preliminary Time Study Loader Swing Yarding. Timber Management Staff Report - Chatman Area - Tongass National Forest, Alaska.

Starnes L.W., 1987. Shovel Logging FEI Update - 1987. Regional Office, Region 6, USFS, Portland, Oregon.

Steinbrenner, E.C., 1955. The Effect of Repeated Tractor Trips on the Physical Properties of Forest Soils. N.W. Sci., 219:155-159.

Steinbrenner, E.G. and S.P. Gessel, 1955. The Effect of Tractor Logging on Physical Properties of Some Forest Soils in S. W. Washington. Soil Sci. Soc. Am. Proc., 19:372-376.

Stewart, R.A., 1986. An Economic Model of Soil Compaction in Forestry. Master's paper, College of Forestry, Oregon State University.

U.S.D.A. Forest Service Manual - Chapter 2500 - Watershed and Air Management, 1987

Webster, Meredith, 1986. Unpublished report on soil compaction monitoring with shovel logging. Olympic NF, Olympia, Wa.

Wert, S. and B.R. Thomas, 1981. Effects of Skid Roads on Diameter, Height and Volume Growth of Douglas Fir. Soil Sci. Soc. Am. J., 45:629-632.

Wooldridge, Daniel D., 1960. Watershed Disturbance from Tractor and Skyline Logging. J. F., 58:369-372.

Youngberg, C.T. 1959. The Influence of Soil Conditions, Following Tractor logging, on the Growth of Planted Douglas-fir Seedlings. Soil Sci. Am. J. 23:76-78.

APPENDIX A

TIME/ACTIVITY REPORT FORM SAMPLE

BACKSTRETCH TIMBER SALE COMPACTION STUDY
TIME STUDY DATA FORM

****
DATE__________ SLOPE__________ MACHINE__________
LOCATION ON UNIT__________
ACRES YARDED THIS TIME PERIOD________ NUMBER OF PIECES YARDED________
SITE CONDITIONS__________
REMARKS__________
****
ACTIVITY OPTIONS: <u>MOVING</u> <u>SWINGING</u> <u>LOADING</u> <u>TRAIL PREP</u> <u>DELAYS</u>
****
START TIME _______ (HRS:MIN:SEC)

ACTIVITY	ENDING TIME	DURATION	PIECE COUNT	REMARKS

APPENDIX B

EMPIRICAL APPRAISAL DATA

Summary

*** CAT 235 SHOVEL WITH HYDRAULIC BOOM AND GRAPPLE ***

Ownership			
Depreciable value:	$	179,000.00	
Equipment depreciation:	$	25,571.43	/ Year
Interest expense:	$	27,100.00	/ Year
Taxes, license, insurance and storage:	$	3,871.43	/ Year
Annual ownership cost:	$	56,542.86	/ Year
Ownership cost (Subtotal):	$	35.34	/ Hour
Machine operating			
Repairs and maintenance:	$	12.79	/ Hour
Fuel and oil:	$	10.40	/ Hour
Lines and rigging:	$	0.00	/ Hour
Tires or tracks:	$	1.72	/ Hour
Equipment operating cost (Subtotal):	$	24.90	/ Hour
Labor			
Direct labor cost:	$	25.43	/ Hour
Supervision and overhead:	$	2.19	/ Hour
Labor cost (Subtotal):	$	27.61	/ Hour
OWNERSHIP COST	$	35.34	/ Hour
OPERATING COST	$	24.90	/ Hour
LABOR COST	$	27.61	/ Hour
Machine rate (Ownership + Operating + Labor)	$	87.86	/ Hour

*** Press [RETURN] for the menu ***

Equipment Ownership Costs

-›Delivered equipment cost	$	275,000.00
Minus line and rigging cost	$	0.00
Minus tire or track replacement cost	$	11,000.00
Minus residual (salvage) value	$	85,000.00
Life of equipment (Years)	#	7.00
Number of days worked per year	#	160.00
Number of hours worked per day	#	10.00
Interest Expense	%	14.00
Percent of average annual investment for:		
Taxes, License, Insurance, and Storage	%	2.00
Depreciable value:	$	179,000.00
Equipment depreciation:	$	25,571.43
Average annual investment:	$	193,571.44
Interest expense:	$	27,100.00
Taxes, license, insurance and storage:	$	3,871.43
Annual ownership cost:	$	56,542.86
Annual utilization (Hours per year):	#	1,600.00
Ownership cost (Dollars per hour):	$	35.34

Current value = 275,000.00

[ESC]=Menu (Highlight value to change and press return)

```
IMMMMMMMMMMMMMMMMMMMMMMMMM5 Equipment Operating Costs FMMMMMMMMMMMMMMMMMMMMMMMMMMM:
:                                                                                 :
:->Percent of equipment depreciation for repairs    %          80.00             :
:  Fuel amount  (Gallons per hour)                  #           8.00             :
:  Fuel cost  (Per gallon)                          $           1.00             :
:  Percent of fuel consumption for lubricants       %          12.00             :
:  Cost of oil and lubricants  (Per gallon)         $           2.50             :
:  Cost of lines                                    $           0.00             :
:  Estimated life of lines  (Hours)                 #           0.00             :
:  Cost of rigging                                  $           0.00             :
:  Estimated life of rigging  (Hours)               #           0.00             :
:  Cost of tires or tracks                          $      11,000.00             :
:  Estimated life of tires or tracks  (Hours)       #       6,400.00             :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDE
:  Repairs and maintenance:                         $          12.79             :
:  Fuel:                                            $           8.00             :
:  Oil and lubricants:                              $           2.40             :
:  Lines:                                           $           0.00             :
:  Rigging:                                         $           0.00             :
:  Tires or tracks:                                 $           1.72             :
:  Equipment operating cost  (Subtotal):            $          24.90             :
:                                                                                 :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<
                        Current value =        80.00
[ESC]=Menu       (Highlight value to change and press return)
```

```
IMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM5 Labor Costs FMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM:
:                                                                                 :
:->Base wage for 1st crew position  (Per hour)     $           21.19             :
:  Base wage for 2nd crew position  (Per hour)     $            0.00             :
:  Base wage for 3rd crew position  (Per hour)     $            0.00             :
:  Base wage for 4th crew position  (Per hour)     $            0.00             :
:  Base wage for 5th crew position  (Per hour)     $            0.00             :
:  Base wage for 6th crew position  (Per hour)     $            0.00             :
:  Fringe benefits                                 %            0.00             :
:  Travel time per day (Hours)                     #            2.00             :
:  Operating time per day (Hours)                  #           10.00             :
:  Percent of direct labor cost for supervision    %            8.60             :
:                                                                                 :
GDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDE
:                                                                                 :
:  Total number of workers:                        #            1.00             :
:  Total crew wage (Per hour):                     $           21.19             :
:  Direct labor cost:                              $           25.43             :
:  Supervision and overhead:                       $            2.19             :
:  Labor cost (Subtotal):                          $           27.61             :
:  Total operating cost (Operating+Labor):         $           52.52             :
:                                                                                 :
HMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM<
                        Current value =        21.19
[ESC]=Menu       (Highlight value to change and press return)
```

Summary

*** WASHINGTON 208 SLACKLINE YARDER ***

Ownership		
Depreciable value:	$	508,716.00
Equipment depreciation:	$	63,589.50 / Year
Interest expense:	$	60.970.00 / Year
Taxes. license. insurance and storage:	$	8,710.00 / Year
Annual ownership cost:	$	133.269.50 / Year
Ownership cost (Subtotal):	$	83.29 / Hour
Machine operating		
Repairs and maintenance:	$	25.83 / Hour
Fuel and oil:	$	19.98 / Hour
Lines and rigging:	$	2.79 / Hour
Tires or tracks:	$	0.00 / Hour
Equipment operating cost (Subtotal):	$	48.60 / Hour
Labor		
Direct labor cost:	$	127.46 / Hour
Supervision and overhead:	$	10.96 / Hour
Labor cost (Subtotal):	$	138.43 / Hour
OWNERSHIP COST	$	83.29 / Hour
OPERATING COST	$	48.60 / Hour
LABOR COST	$	138.43 / Hour
Machine rate (Ownership + Operating + Labor)	$	270.32 / Hour

*** Press [RETURN] for the menu ***

Equipment Ownership Costs

Delivered equipment cost	$	670,000.00
Minus line and rigging cost	$	27,284.00
Minus tire or track replacement cost	$	0.00
Minus residual (salvage) value	$	134,000.00
Life of equipment (Years)	#	8.00
Number of days worked per year	#	160.00
Number of hours worked per day	#	10.00
Interest Expense	%	14.00
Percent of average annual investment for:		
Taxes. License. Insurance, and Storage	%	2.00
Depreciable value:	$	508,716.00
Equipment depreciation:	$	63,589.50
Average annual investment:	$	435,500.00
Interest expense:	$	60.970.00
Taxes. license. insurance and storage:	$	8,710.00
Annual ownership cost:	$	133.269.50
Annual utilization (Hours per year):	#	1,600.00
Ownership cost (Dollars per hour):	$	83.29

Equipment Operating Costs

Percent of equipment depreciation for repairs	%	65.00
Fuel amount (Gallons per hour)	#	17.00
Fuel cost (Per gallon)	$	1.00
Percent of fuel consumption for lubricants	%	7.00
Cost of oil and lubricants (Per gallon)	$	2.50
Cost of lines	$	27,284.00
Estimated life of lines (Hours)	#	12,000.00
Cost of rigging	$	4,950.00
Estimated life of rigging (Hours)	#	9,600.00
Cost of tires or tracks	$	0.00
Estimated life of tires or tracks (Hours)	#	0.00
Repairs and maintenance:	$	25.83
Fuel:	$	17.00
Oil and lubricants:	$	2.97
Lines:	$	2.27
Rigging:	$	0.52
Tires or tracks:	$	0.00
Equipment operating cost (Subtotal):	$	48.60

Labor Costs

Base wage for 1st crew position (Per hour)	$	18.91
Base wage for 2nd crew position (Per hour)	$	16.02
Base wage for 3rd crew position (Per hour)	$	17.84
Base wage for 4th crew position (Per hour)	$	16.54
Base wage for 5th crew position (Per hour)	$	16.54
Base wage for 6th crew position (Per hour)	$	20.37
Fringe benefits	%	0.00
Travel time per day (Hours)	#	2.00
Operating time per day (Hours)	#	10.00
Percent of direct labor cost for supervision	%	8.60
Total number of workers:	#	6.00
Total crew wage (Per hour):	$	106.22
Direct labor cost:	$	127.46
Supervision and overhead:	$	10.96
Labor cost (Subtotal):	$	138.43
Total operating cost (Operating+Labor):	$	187.02

Summary

*** CAT 235 SHOVEL WITH HYDRAULIC GRAPPLE - LOADING ONLY ***

Ownership			
Depreciable value:	$	179,000.00	
Equipment depreciation:	$	19,888.89	/ Year
Interest expense:	$	26,677.78	/ Year
Taxes, license, insurance and storage:	$	3,811.11	/ Year
Annual ownership cost:	$	50,377.78	/ Year
Ownership cost (Subtotal):	$	31.49	/ Hour
Machine operating			
Repairs and maintenance:	$	8.08	/ Hour
Fuel and oil:	$	7.35	/ Hour
Lines and rigging:	$	0.00	/ Hour
Tires or tracks:	$	1.38	/ Hour
Equipment operating cost (Subtotal):	$	16.80	/ Hour
Labor			
Direct labor cost:	$	25.43	/ Hour
Supervision and overhead:	$	2.19	/ Hour
Labor cost (Subtotal):	$	27.61	/ Hour
OWNERSHIP COST	$	31.49	/ Hour
OPERATING COST	$	16.80	/ Hour
LABOR COST	$	27.61	/ Hour
Machine rate (Ownership + Operating + Labor)	$	75.91	/ Hour

Equipment Ownership Costs

Delivered equipment cost	$	275,000.00
Minus line and rigging cost	$	0.00
Minus tire or track replacement cost	$	11,000.00
Minus residual (salvage) value	$	85,000.00
Life of equipment (Years)	#	9.00
Number of days worked per year	#	160.00
Number of hours worked per day	#	10.00
Interest Expense	%	14.00
Percent of average annual investment for:		
Taxes, License, Insurance, and Storage	%	2.00
Depreciable value:	$	179,000.00
Equipment depreciation:	$	19,888.89
Average annual investment:	$	190,555.56
Interest expense:	$	26,677.78
Taxes, license, insurance and storage:	$	3,811.11
Annual ownership cost:	$	50,377.78
Annual utilization (Hours per year):	#	1,600.00
Ownership cost (Dollars per hour):	$	31.49

Equipment Operating Costs

->Percent of equipment depreciation for repairs	%	65.00
Fuel amount (Gallons per hour)	#	6.00
Fuel cost (Per gallon)	$	1.00
Percent of fuel consumption for lubricants	%	9.00
Cost of oil and lubricants (Per gallon)	$	2.50
Cost of lines	$	0.00
Estimated life of lines (Hours)	#	0.00
Cost of rigging	$	0.00
Estimated life of rigging (Hours)	#	0.00
Cost of tires or tracks	$	11,000.00
Estimated life of tires or tracks (Hours)	#	8,000.00
Repairs and maintenance:	$	8.08
Fuel:	$	6.00
Oil and lubricants:	$	1.35
Lines:	$	0.00
Rigging:	$	0.00
Tires or tracks:	$	1.38
Equipment operating cost (Subtotal):	$	16.80

Labor Costs

->Base wage for 1st crew position (Per hour)	$	21.19
Base wage for 2nd crew position (Per hour)	$	0.00
Base wage for 3rd crew position (Per hour)	$	0.00
Base wage for 4th crew position (Per hour)	$	0.00
Base wage for 5th crew position (Per hour)	$	0.00
Base wage for 6th crew position (Per hour)	$	0.00
Fringe benefits	%	0.00
Travel time per day (Hours)	#	2.00
Operating time per day (Hours)	#	10.00
Percent of direct labor cost for supervision	%	8.60
Total number of workers:	#	1.00
Total crew wage (Per hour):	$	21.19
Direct labor cost:	$	25.43
Supervision and overhead:	$	2.19
Labor cost (Subtotal):	$	27.61
Total operating cost (Operating+Labor):	$	44.42

APPENDIX C

NATURAL RESOURCE EVALUATION

> "You speak without sufficient thought; you see without observing. In short, you go through life as if the world were your own private playground, taking this and that at will, at your own pleasure, as if there were no consequences involved."
>
> Shi Silin,
> a character from the book "Shan",
> by Eric Van Lustbader.

1.) INTRODUCTION

Several months before coming to Oregon State University, I had the opportunity to work on the preparation of an environmental impact statement. This particular project proposed and analyzed several different alternatives for managing an unroaded area classified as general forest. Part of the analyses involved comparing alternatives that ranged from a no-action alternative to an alternative that emphasized intensive management exclusively for timber production.

In trying to compare this wide range of alternatives, it was critical that the different activites within each alternative be fairly evaluated using some kind of common basis. Dollar value, a common means of evaluating commodities, was selected as the common basis. At first, it was fairly easy to place a dollar value on activities such as building roads and harvesting timber. However, I soon discovered that trying to calculate the value of hiking and camping in a roadless area, or the value of sitting on a mountain top, breathing clean, fresh air and watching the sun set over an undisturbed valley, was a whole different problem - one that I did not find an adequate solution to.

Thus, in coming to Oregon State University, I saw an excellent opportunity to learn more about the problems surrounding the issue of evaluating both the non-market resources and the activities associated with their use. Besides the required engineering classes, I took additional classes in forest economics, recreation economics, environmental law and forest management and did a considerable amount of additional outside reading to try and learn more about this subject.

What follows, then, is a discussion and summary of some of the things I discovered. Because it is not an analytically based discussion, I do not consider it part of this study. However, because I believe it relates directly to the problem of evaluating soil compaction, I have included it as an appendix.

2.) SOCIETY'S VIEW OF NATURE

During my first economics class, at the beginning of the discussion on evaluating "non-timber forest outputs", the professor opened with the question, "How much money is the view of Mary's Peak from Corvallis worth?" (Mary's Peak is the highest point in the Coast Range in Oregon and can easily be seen from Corvallis - if it isn't raining.) While there wasn't any one right or wrong answer, he concluded the discussion by saying that it is possible to put a dollar value on anything. He also went on to say that if it feels uncomfortable or wrong to be doing it, it is because we just aren't used to thinking about some things in terms of dollar. At the time, this seemed reasonable. Much later, it occurred to me that two things might be wrong with what he said.

First of all, if it feels uncomfortable or wrong to be putting a dollar value on things because we are just not used to doing it, then doesn't it follow that if we do it enough times, we will start to get used to doing it and it won't feel wrong any more. The problem here, is, that doing something until we get used to doing it, like cheating on tests (or allowing soil to be compacted to some acceptable level), doesn't necessarily make it right.

Secondly, when the professor asked what the dollar value of the view was worth, he had already decided that putting a value on it was acceptable. Thus, students were not given an opportunity to think about this more fundamental question, "Should we really even be putting a value on a view?" (This research project does the same thing. It evaluates soil compaction several different ways, but never once addresses the more fundamental question, "Should soil compaction even be allowed to occur?")

It bothered me that these more fundamental questions weren't being asked in my class, either by the professor or the students. Was it because the answers were too trivial, or too hard? Or was it that the questions really have never been asked? To find the answer, I approached the problem in typical fashion - I reviewed the literature. The first subject I researched was the subject of how our society views the value of nature. For me, it turned out that that was as far as I needed to go.

"In the White Male System, power is conceived of in a zero-sum fashion.....if one has, say, 20 units of power and gives 12 of them away, he only has 8 units left...power is conceived of to exert domination and control over others."

"In the Female System, power is....limitless, and when it is shared, it regenerates and expands....power is conceived of as 'personal' power which has nothing to do with power or control over another."

Anne Wilson Schaef
from "Women's Reality", (1981)

A.) The White Male System

A good place to start in trying to understand how our society views the value of Nature is with a book written by Anne Wilson Schaef titled "Women's Reality." Schaef, an internationally know psychotherapist, lecturer and writer who has a doctorate in clinical psychology, puts forth an interesting theory defining the society in which we live.

In this, her first book, she describes three systems:

<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>>

SYSTEM #1 - THE WHITE MALE SYSTEM

This, the system she believes we are now living in, she calls the White Male System because the power and influence in it are held by white males and it is perpetuated by white males with the help of all of us.

She believes this system is supported by four myths:

Myth #1. THE WHITE MALE SYSTEM IS THE ONLY THING THAT EXISTS.

(The beliefs and perceptions of other systems, especially the female system which is defined in a moment, are thus seen as irrelevant, sick, bad, stupid and incompetent.)

Myth #2. THE WHITE MALE SYSTEM IS INNATELY SUPERIOR.

(Thus, anyone who does not belong to this system is innately inferior.)

Myth #3. THE WHITE MALE SYSTEM KNOWS AND UNDERSTANDS EVERYTHING.

(Anything that is not known and understood by the methods and technology of the White Male System therefore does not exist.)

Myth #4. IT IS POSSIBLE TO BE TOTALLY LOGICAL, RATIONAL AND OBJECTIVE.

(This system ignores the existence of and devalues other thinking processes, such as intuition, and multivariate nonlinear thinking.)

Finally, Schaef summarizes these four myths into one, never spoken but nevertheless present and real myth:

"IT IS POSSIBLE TO BE GOD"

at least as God is defined by the system - totally rational, logical and objective; innately superior; knows and understands all things; and finally, is the only system that exists.

<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>

SYSTEM #2 - THE REACTIONARY FEMALE SYSTEM

For women, the White Male System surrounds and envelopes them. To survive in it, they have had to give up their own personal power and adjust their language, values, thinking and even the way they view the world. In doing this, a complimentary system has evolved - a stereotypic, externally defined system that tells women what they should think, feel and do. It defines women in such a way that they will consciously and unconsciously support the White Male System and its myths. This system Schaef calls the Reactionary Female System and it revolves around the concept of the "Original Sin of Being Born Female."

In this system, women are taught that they are innately inferior by birth and that there is no absolution except by attaching themselves to a male and by obtaining male validation and approval. Unfortunately, this never quite works so that women are always trying to make themselves acceptable by being fair, following the rules, hiding their feelings and becoming incredibly understanding.

<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>

SYSTEM #3 - THE EMERGING FEMALE SYSTEM

This system Schaef defines as a variable and changing open system in process and of process. Much of the book is devoted to describing this system, particularly as it compares to the White Male System.

<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>>

Toward the end of her book, Schaef devotes a chapter to what she calls Female Theology. Within this chapter, she writes about how our society views God, men and women. She concludes that when humans are compared to God, humans fall into categories that include such things as sinful, weak, stupid and mortal. When men are compared to women, men fall into godlike categories such as intelligent, powerful, brave, good and strong. Women fall into the weak and sinful categories, however. This, then sets up the basic mythology of the White Male System - men believe they can become God, strive to achieve godhood, and die in the process. Women have no chance of ever becoming God and try to relate to these mortal gods - men - in an acceptable way.

This all leads up to what Schaef calls the basic hierarchical structure of our society:

GOD
MEN
WOMEN
CHILDREN
ANIMALS
EARTH

God is dominant over men, women, children, animals and the earth. Men are dominant over women, children, animals and the earth. Women are dominant over children, animals and the earth and finally, <u>the earth is at the bottom of the hierarchy; it is powerless and submissive.</u>

Interestingly enough, throughout the book, Schaef makes the statement that she does not consider the White Male System all bad or the Female System all good. Each has its positive and negative points and each is only a system. What makes this interesting is that in her second book, written just six years later, she makes an abrupt turnabout. In this second book, titled "When Society Becomes An Addict", she writes:

> "In that book (Women's Reality), as I was comparing the Emerging Female System with the White Male system, I kept stressing that neither is right or wrong, good or bad - they are just different. That period was my "fair" phase. I really believed then that neither was right or wrong, and I wanted to be fair. I no longer believe that. The two systems are not "just different". Instead, what I called the Emerging Female System is life-supporting and life-producing and what I called the White Male System is nonliving-oriented and entropic. The White Male System is not only destructive to women; it is destructive to men, animals, plants and our planet and it is threatening to spread its destructiveness into space. The White Male System has a nonliving orientation. The Emerging Female System is proliving. It embodies the state of being fully alive in the broadest possible sense of the word."

Between her first book and this one, she was involved with addiction - alcoholism in her immediate family. Being involved, she decided to learn all she could about addiction - all kinds of addiction. The more she learned about the addictive system and its characteristics, the more she found herself saying, "Gee, that is just like the White Male System." Finally, she comes to the conclusion that what she calls the addictive system and the White Male System are exactly the same. As she states:

> "There is no question that what I called the White Male System is the Addictive System. If we love this society in which we live, we must be willing to confront the reality that it is a disease. Like an alcoholic, it is not bad and trying to get good. It is sick and trying to get well."

B.) Ecofeminism

Another interesting and similar perspective of how our society views the importance of our natural resources comes from the "Ecofeminists". Ecofeminism is a word first used by Franscoise De'Eaubonne in her book "Le' Feminisme ou la mort," where, "She maintains that the fate of the human race and of the planet is at stake and that no male-led "revolution" will counteract the horrors of overpopulation and destruction of natural resources" (Daly, 1978).

Ecofeminism deals with the concept that just as men have always oppressed and dominated women, men also oppress and dominate nature. As Lansing Scott writes in the July, 1987 issue of "Alliance":

> "Ecofeminists have discovered that women and the earth both have a common enemy: the mentality and social structure of partriarchal domination and exploitation. It is a mentality that sees both women and nature as Other, an Other to be conquered, controlled and used as a means to personal gratification. It's a mentality that measures the value of a forest in board feet and the value of a woman in breast size. Ecofeminists reclaim history and transform it into herstory, which tells of the transition into and development of patriarchy, and its oppression of women through the ages. Just as both ecology and feminism have long stressed the inter-relatedness of things, ecofeminism re-evaluates and reclaims all aspects of life; spirituality, consciousness, personal relationships, social institutions, work, community and political action."

Several books have been written that deal with ecofeminists themes including Susan Griffin's "Women and Nature"' Carolyn Merchant's "The Death of Nature," and Mary Daly's "Gyn/ecology - The Metaethics of Radical Feminism." In addition to ecofeminism, these books all deal with the concept of patriarchy - a social organization marked by the supremacy of the father in the family, the legal dependence of wives and children and the reckoning of descent and inheritance in the male line.

"Patriarchy is itself the prevailing religion of the entire planet and its essential message is necrophilia. All of the so-called religions legitimating patriarchy are mere sects subserved under its vast umbrella/canopy. They are essentially similar, despite the variations. All - from buddhism and hinduism to islam, judaism, christianity, to secular derivatives such as freudianism, jungianism, marxism and maoism - are infrastructures of the edifice of patriarchy."

Mary Daly *

* (from her book, "Gyn/Ecology: The Metaethics of Radical Feminism", 1978 - '..an extremist book, written in a situation of extremity, written on the edge of a culture that is killing itself and all of sentient life.'"

C.) Patriarchy

Mary Daly researches this subject most thoroughly, not only in "Gyn/ecology" but in her other three books; "The Church and The Second Sex", "Beyond God the Father", and "Pure Lust - Elemental Feminist Philosophy."

An associate professor of theology at Boston College with doctorates in theology and philosophy, Daly deals mostly with the patriarchical nature of the Catholic Church in her first book, "The Church and the Second Sex". Drawing from a considerable historical research, she describes the patriarchal nature of the biblical tradition within the Catholic Church and points out the obvious contradiction of Christian religion where women have been both symbolically glorified and, at the same time, socially oppressed throughout history. Interestingly enough, she, too, follows the same pattern as Anne Wilson Schaef. Toward the end of her first book, she offers some "modest proposals" as to how women can gain equality within the Church. However, by the time she writes her second book, "Beyond God the Father," she, like Schaef, completely reverses her way of thinking.

She realizes that equality for women in the Catholic Church would only mean that women would be getting their share of the partriarchal pie. This, in itself, is a contradiction because the very definition of patriarchy requires inequality between men and women. As she explains:

> "...a woman's asking for equality in the church would be comparable to a black person's demanding equality in the Ku Klux Klan."

She sees clearly that mere reform and modernization cannot counter the Church's view of women's divinely ordained inferiority anymore than removing symptoms can cure a disease. In this second book, she moves beyond patriarchy in the Catholic Church to describing at length, the subtle and not-so-subtle sexist nature of patriarchy in our world. At the same time, she offers a feministic viewpoint of how things could be as a comparison. With respect to the environment, two sentences she concludes with may best sum up the feminist viewpoint:

> "We will look upon the earth and her sister planets as being with us, not for us. One does not rape a sister."

Her final two books show a Daly who has completely given up trying to deal with our society's patriarchal nature. She sees now that if women are ever to recapture their own energy, their own lives, they must do it by themselves, completely removed from the polluting effects of partriarchy. It is difficult for men to understand this kind of reasoning. Even the idea of patriarchy, from a woman's point of view, is difficult for men to understand. As Anne Wilson Schaef explains (Women's Reality, pg. 32):

> "If one stands under, one had better understand that those who stand over have the power and the influence. If one over-stands, then one does not <u>have</u> to understand. Understanding is for the under-standers. Over-standing is a secure position."

An interesting example (Statesman-Journal, March 2, 1988, Salem, Oregon) that shows the insideous and subtle nature of patriarchy involved an Oregon jury that recently gave a life sentence instead of the death sentence to a man convicted of torturing and killing a

21 year old woman. In Oregon, the answer "yes" is required to three particular questions before the death sentence can be given. The question of particular importance was, "Is the man likely to commit violent crimes in the future." His lawyer argued that although his client may be a sexual monster, he should be sentenced to life in prison. He went on to say that all of the man's victims had been women and therefore, he represents no threat to men, and would thus, not be a threat to society in prison with other men. While the logic of this may seem believeable, it also implies that all <u>men</u> would be immune to the death penalty in Oregon as long as the victims were only women and children. Certainly there is truth to Schaef's claim that the White Male System is destructive to women and children.

D.) Deep Ecology

> "..a term coined by Norwegian philosopher Arne Naess that distinguishes itself from 'shallow' environmentalism by emphasizing the intrinsic value of all life on earth, whereas 'shallow' environmentalists are more concerned with preserving the earth for human benefit through environmental management. Deep ecologists assert that we need to reclaim our place in the earth community as a more equal participant rather than as masters. Deep ecology also emphasizes developing an emotional or spiritual connection with wild nature."
>
> Lansing Scott
> from an article in "The Alliance,"
> July, 1987.

One final book that rounds out this brief look at how our society views nature is titled "Deep Ecology." It was written by two men - Bill Duvall, a professor at Humbolt State University and George Sessions, a professor at Sierra College, California.

In Chapter 3 of their book, Duvall and Sessions write about the "Dominant, Modern Worldview." Drawing from several references, they list the following four assumptions that summarize this worldview:

-1. People are fundamentally different from all other creatures on Earth, over which they have dominion (defined as domination).

-2. People are masters of their own destiny; they can choose their goals and learn to do whatever is necessary to achieve them.

-3. The world is vast, and thus provides unlimited opportunities for humans.

-4. The history of humanity is one of progress; for every problem, there is a solution, and thus, progress need never cease.

This worldview of nature from a human-centered perspective involves the belief that humans will continue to dominate and control nature because they are superior to or above the rest of nature. Thus, men conquer, dominate and remold natural resources into an artificial environment based on men's specifications and managed for and by men. Progress is merely further development and expansion of this artificial environment. Resources are developed as quickly as is technically possible with the available capital to serve human "needs." As Duvall and Sessions state:

> "The whole of Nature and nonhuman species are not seen as having value in themselves and the right to follow their own evolutionary destinys......humans are not understood or experienced to be an integral part of natural processes, but rather as rightfully dominating and controlling the rest of Nature based on principles of scientific management. This means altering Nature to produce more or better commodities for human consumption and directing Nature to do the bidding of humans on the utilitarian principle of the 'greatest good for the greatest number' of humans".

This worldview that Duvall and Sessions suggest is very similar to the Addictive System of Schaef and the patriarchal system of Daly. As with Daly and Schaef, Duvall and Sessions also conclude that the system that exists today needs to be completely replaced by something different.

3.) <u>Conclusions</u>

In summary, then, based on the several viewpoints from above, our society views nature from an anthropocentric or man-centered viewpoint. Man is not a part of nature but rather a controller of nature. Nature has no value in and of itself but only value when it can be used by man. Just as man has always dominated women, he will continue to dominate, control and manipulate nature to meet his needs. Whether this system is called the White Male System, the Addictive System, Patriarchy or just the Dominant World View, critics of this system believe it is a death-oriented system destructive to women, children, animals, nature and other men and must be replaced.

As I read more and more about the different but similar viewpoints of how we view nature, I found myself wanting not to believe what I was reading. The problem was that the more I thought about what I was reading, and the more I observed about what was happening in the news and newspapers, the more I realized that much of what I read was true. It was as Anne Wilson Schaef suggested. Our society is like pollution - if you live in it long enough, pretty soon, you don't notice it anymore. I have come to find this to be true.

For example (Corvallis Gazette-Times, Feb. 22, 1988), on January 2, 1988, an estimated 730,000 gallons of diesel oil accidently poured into the Monongahela River near Pittsburgh, Pennsylvania and then slowly flowed down river and into the Ohio River. Samples taken of the oil flow further on down the Ohio River on January 10th, showed high concentrations of chloroform and methylene chloride, cancer-causing substances, and 1,1,1-trichloroethane, a toxic substance. Apparently, one or more industries took advantage of the fuel spill to dump their toxic solvents into the river.

Two years ago, I would not have given this article much thought - just one more part of the "pollution" that I had become accustomed to. Today, however, I see it as one more example of what the authors of the books I have reported about are trying to describe.

Realizing that the present economic system we use today has been developed out of this world viewpoint, I am not surprised that trying to evaluate and measure values such as existence and option value - values associated more with intrinsic values - are difficult, and perhaps impossible to adequately measure, given the use-oriented system we have developed to evaluate them with.

While the ideas and even the term "ecofeminism" often have brought smiles and chuckles from my male peers, I believe this concept has much to offer as a way of turning our society from the destructive path it may be heading down. Concepts and ideas such as having reverence for the earth, peace-making and consciousness, spirituality, nurturing and caring, practicing land stewardship and forestry as if nature mattered, and viewing humans as part of the system taking only what is needed, not controllers consuming to the limit of economic feasibility, may be the concepts and ideas that can insure a healthy earth for future generations.

> "George Wald has pointed out that we have something to learn from the history of the dinosaurs, who had very small brains for their size. Since the proportion of brains to brawn was very low, they disappeared. Whereas within the individual human being, the proportion of brains to brawn is high, technology has inversed the proportion and we are coming again into the situation of the dinosaurs."
>
> George Wald
>
> a quote from Mary Daly's book, "Gyn/ecology," (1978).

> "A transvaluation of values can only be accomplished when there is a tension of new needs, and a new set of needy people who feel all old values as painful - although they are not conscious of what is wrong."
>
> Friedrich Nietzsche

REFERENCES FOR APPENDIX C

"Women's Reality: An Emerging Female System in a White Male Society", 1981, by Anne Wilson Schaef.

"When Society Becomes an Addict", 1987, By Anne Wilson Schaef.

"Deep Ecology", 1985, by Bill Duvall and George Sessions.

"The Church and The Second Sex", 1968, by Mary Daly.

"Beyond God the Father: Toward a Philosophy of Women's Liberation", 1973, by Mary Daly.

"Gyn/Ecology: The Metaethics of Radical Feminism", 1978, by Mary Daly.

"Pure Lust: Elemental Feminist Philosophy", 1984, by Mary Daly.

"Woman and Nature: The Roaring Inside Her.", 1978, by Susan Griffin.

"The Death of Nature: Women, Ecology and the Scientific Revolution", 1980, by Carolyn Merchant.