COMPENDIUM OF CABLE YARDING PRODUCTION EQUATIONS

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ABSTRACT

This paper is a compilation of most of the recent cable yarding production equations generated by the Forest Engineering Department at Oregon State University. Additional production equations found in the literature review have also been included. Background information for each of the studies involved has been summarized.

Data is basically organized into a set of tables for small, medium, and large sized yarders. Each sheet in a set of tables contains a particular type of information, such as production data, equipment information, crew information, and physical characteristics of the sale area.

Guidelines on the potential use of the compendium and a discussion of equations as predictive tools is provided. A graphical summary was developed to assist the reader in locating an equation representing a particular set of conditions.

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INTRODUCTION

BACKGROUND

Numerous production equations have been generated from recent cable yarding time studies. Such equations can be quite useful in arriving at production rate estimates. Although many of these papers may be readily available, the effort required in developing a good familiarity with the conditions of each study can be another matter. A review of the literature did not disclose any summaries of recent production equations and their study conditions. Digests are available of production studies listing background information and production rates, but equations are not included (Yancy, 1980). There are examples of "in-house" compilations of equations with a limited amount of background data attached, but these are not immediately available to the public.

In 1972, the Forest Engineering Department at Oregon State University began a small wood harvesting research program. Research projects have included both clearcut and partial cut prescriptions; uphill and downhill logging; live, standing, and running skylines; a number of different carriage models and slackpulling options; and both full cycle yarding as well as prebunch and swing operations. In addition, other research papers written in the department during this period have been concerned with medium and large yarders in a number of different cutting regimes and yarding configurations. This paper is a compilation of the production equations generated by most of these projects. Additional equations obtained in the literature are also listed. Background information for each equation is included.

OBJECTIVES

The intent of this paper is to provide a compendium of cable yarding regression equations to assist forest managers and others in estimating yarding production rates. Specific objectives are:

1. Summarize the production equations and background information of cable yarding research projects conducted at Oregon State University in the Forest Engineering Department.
2. Summarize any other recent (1974 to the present) cable yarding studies found during the literature review which resulted in production equations and contained background information about study conditions.
3. List suggestions for improving future research papers in this area with the intention to make these papers more understandable and useful to the reader.

SCOPE

The paper is intended to aid the forest manager in arriving at estimated production rates. The equations listed were developed under a particular set of circumstances and study conditions. Differences between the project area and the forest manager's site, as well as discrepancies among the parameters of each logging "show," may result in large disparities between production rates predicted by the equation and actual rates of production realized on the ground. The summary of study conditions will provide some idea of how closely the two "logging shows" match. The equations can be quite useful to the forest manager if their limitations are kept in mind, but strict reliance on equations alone could result in unreliable production estimates.

ORGANIZATION OF THE DATA

BASIC APPROACH

The production studies and equations presented in this paper have been summarized in a set of tables organized by type of information. Equations were initially segregated on the basis of yarder size: small, medium, or large. Small yarders have maximum mainline pulls less than 25,000 pounds. Medium yarders have maximum mainline pulls equal to or greater than 25,000 pounds and less than 71,000 pounds. Large yarders have maximum mainline pulls of 71,000 pounds and greater. A particular set of tables (e.g., small yarders) contains individual sheets summarizing the production equations; variables measured during the study, but not used in the equations; machine data of the yarding equipment used; rigging and yarding configuration; crew information; physical data of the sale area (e.g., topography, age and size of timber, species, density, etc.); and time study information (e.g., values of parameters commonly included in production equations). The tabular summaries are intended to provide the background information necessary for the reader to compare study conditions of a particular equation with the site conditions and circumstances of their own area.

INFORMATION LISTED

Only information presented in a reference was included in the summaries. Assumptions concerning equipment specifications, crew data, or any other study conditions were avoided. Although specification sheets for many of the yarders used are available, information about line size, pull, drum capacity, etc., was not listed unless specifically mentioned in the paper. This same approach was used in filling out all the tables. The possibility of error by assuming normal or expected conditions precluded the use of any information sources other than the research paper itself. If the reference does not indicate a certain piece of information, that block is left blank in the table. Items which have a value of "0" or "none" in the study are listed that way in the tables.

Many of the tabular variables were subject to different interpretations by various authors. Definitions were not constant. Methods of measuring particular parameters differed. When additional explanation about a particular value was needed or more information was available than could be accommodated by the table, footnotes were employed. The footnotes for a particular table immediately follow that sheet. The tabular summaries and their footnotes appear in Appendix A.

TABULAR HEADINGS

Most of the column headings for each of the tables is self-explanatory. Units of measure are also included in the headings. Any abbreviations or symbols used in the tables are defined in Appendix C. In most instances, if there is some discrepancy between the entry value and the column definition, a footnote clarifies the point. There are, however, a few columns which require some discussion. Each table with column headings subject to interpretation will be discussed separately.

Production Data

The majority of regression equations are for turn time in minutes, and this is the indicated unit of measure in the column heading. In addition, there are some equations which result in a logs/hour value rather than minutes/turn. When this occurs, the row entry for that particular equation begins with "logs/hr = ."

The variables listed in each production equation are defined in Appendix B.

Rigging and Yarding Configuration Data

Entries under the "yarding system used" column assume full cycle yarding. If the equation is for a pre-bunching or swinging operation, this will be specified.

Crew Data

Quite often crew experience was not discussed in the reference. A distinction was made between regular logging crews and crews composed of researchers and graduate students. Given no additional information on crew experience, regular logging crews were entered under the "Experience" column as "commercial logging crews," whether they were working on normal logging production sides or were involved in specific logging research projects. Crews composed of researchers and graduate students were described as such.

Time Study Data 1/3

Chordslope values are taken from the landing. Therefore, chordslopes for uphill yarding will be negative, while they'll be positive for downhill yarding. Groundslope values are taken along the inhaul direction. Therefore, groundslopes for uphill yarding will be positive. Downhill yarding will result in negative groundslopes.

Time Study Data 3/3

Values entered under the "carriage height" column indicate the height of the carriage in feet above the ground at the hook point or position of lateral yarding. Deck height is defined as the height of the log deck at the landing. Any values entered in this column having a different definition are footnoted. The pre-bunched column indicates whether pre-bunched logs were being "swung" or not. This column does not indicate the pre-bunching of logs. The value entered under the "total number of turns" column is the number of observations used to generate that particular regression equation. Any deviation from this definition is indicated by a footnote.

COMMENTS ON USING THE COMPENDIUM

This paper is a summary of recent production studies. It can serve as a central source of information on all the included research projects. However, if more detail is needed, the original article should be reviewed.

EQUATIONS AS PREDICTIVE TOOLS

Each of these equations were developed under a particular set of circumstances. For those specific conditions during that study, the equation may be a good estimate of production. However, when the equation is applied to another area, its ability to predict reliably should be viewed with caution. Circumstances cannot be identical. Physical parameters of the site will differ. Production can be affected dramatically by changes in crew size and personnel (McIntire, 1981; Zielinsky, 1980). Differences will occur; and estimated production rates based entirely on a particular regression equation, even when conditions seem to be matched closely, may not reflect actual production with any degree of accuracy. These equations can be useful if they are treated as yet one more source of information available to the land manager. They can be used as an aid in comparing different alternatives. Too much reliance upon them in estimating production rates can lead to serious errors.

Most of the production studies listed in this paper have used a detailed time study procedure. During these studies, subcycle data are usually recorded to some fraction of a minute. The duration of detailed time studies is short when compared to gross (shift-level) time studies. Detailed time studies tend to miss seasonal influences and lengthy downtimes because of their small time frame (Linjala, 1979). Dykstra (1976) has suggested that gross time studies may be more appropriate in appraisal work since the data may more accurately reflect total downtime. Curtis (1978) compared production rates determined from both detailed and gross time studies: both studies had analyzed the same systems (running skyline, inverted skyline balloon, highlead balloon, and heavy helicopter). The rates measured by the gross time study were consistently lower. Curtis concluded that the gross time study more accurately reflected total downtime and, therefore, was better suited for developing information useful for appraisal purposes.

Another point that should be remembered when using these equations is the fact that most of them have been developed for a particular yarder model. Attempts to "fit" such an equation to a similar model may prove unsatisfactory. Mann (1979) used a regression equation developed for the Washington Iron Works 108 Skylok Yarding Crane in a running skyline configuration to predict turn times for a Madill 044 running skyline system. The equation overestimated actual turn times by an average of 33%. Mann concluded that the use of one regression model as a predictive tool for a wide-range of running skyline yarders operating under different conditions is questionable.

The "limits" of the study should always be kept in mind while using these equations. Attempts to extrapolate the equation beyond those limits can yield unpredictable results. Little confidence should be placed in such production estimates. Applying a shortspan equation to a logging show requiring long horizontal spans is a futile exercise. Before using any of the regressions, compare the range of values of the study parameters with those of the proposed logging operation.

INTERPRETING PARTICULAR TABLES

Some of the information listed on two of the tabular summaries need additional explanation. Each table will be discussed separately.

Production Data

The "% delay" column on this sheet is heavily footnoted because of the numerous methods and interpretations used by authors in calculating this value. There were basically two types of variations involved: 1. differing total time bases on which delay percentages were calculated, and 2. differing interpretations of what should be considered a delay or how a delay should be categorized (e.g., operational or non-operational). When information about calculating % delays was listed in the reference, it was included as a footnote appended to the entry in the % delay column.

Many authors used as a total time base the combined totals of productive time and operational delay time. Operational delay time was then divided by this total time base for a percent delay figure. Non-operational delays (many authors considered major mechanical repairs to fall in this category) and skyline corridor and landing changes where excluded from the calculations. Other authors chose to include both operational and non-operational delays in their total time base while excluding corridor and landing changes. They would then divide either total delays or only operational delays by their total time base to arrive at % delay. Some authors made no distinction between operational and non-operational delays. Still others added an additional category called experimental delays. The possible combination of these different delay categories when determining a total time base makes the delay % figure anything but straightforward.

To further compound the matter, there were several interpretations on what constituted delay time as opposed to productive time. For example, resetting the chokers was sometimes considered part of the yarding cycle (productive time) and in other studies was categorized as a delay. Even when there was agreement about a particular item being a delay, the manner in which it was categorized and that category's inclusion or exclusion in the % delay calculations further clouded the issue. It is hoped that the footnotes will provide enough background for the reader to correctly interpret these figures. Unfortunately, some authors did not provide many details concerning their delay % calculations.

While a reader may be interested in the procedure a particular study used to calculate % delay, he should not assume the percentages will apply to his own situation. Delays are not consistent, even for a specific yarding system, and a better approach at estimating nonproductive time is to use local experience (Dykstra, 1976).

Variables Measured But Not Used In Regression Equations

Most of the entries listed on this table are given in descriptive terms rather than the variable form used in the regression equations. This approach was used to make the table more accessible to the reader and eliminate the need to refer to regression variable definitions. On occasion, the description of a variable was so involved that the regression variable had to be used instead. Definitions of all regression variables appear in Appendix B.

There were a number of reasons why variables in a study were not included in the regression equation. In some instances they did not meet the study's statistical criteria for inclusion. This may be the result of the variable's limited range of values, rather than its inherent ability to influence production rates. Also, human error in measurement or faulty sampling procedures could bias the variable against inclusion (Dykstra, 1975). At times a variable did meet the statistical criteria, but was eliminated from the equation since it could not be easily measured and used for predictive purposes (e.g., a measure of the percent defect, Curtis, 1978; volumn per turn, Linjala, 1979).

"COMBINED" EQUATIONS VERSUS "INDIVIDUAL" EQUATIONS

Some of the equations listed use the combined data base of a number of different yarders. Sometimes the combined equations are segregated by yarding direction (uphill versus downhill) or system used (e.g., highlead versus grabinski) (Linjala, 1979). Equations may also be grouped by yarder size or some physical parameter of the sale area (e.g., external yarding distance) (Gorsh, 1982). Estimating production rates using either "combined" equations or equations developed for a particular machine represent two distinct approaches.

Quite often the appraiser does not know which yarder model will be used to yard a sale area (Linjala, 1979). A combined yarder equation may be the solution. Also, combined equations may be preferred when specific equations do not react well to those variables causing the greatest amount of variation in production rates (e.g., crew performance) (Gorsh, 1982). The potential problem of estimating production rates of one yarder model with a regression developed for a different yarder has already been discussed (Mann, 1979). Faced with this situation, a combined equation may, again, be preferred.

Curtis (1978) and Linjala (1979) tested the hypothesis that combined equations in their studies could describe the data as well as their respective set of individual equations. Curtis could not reject the hypothesis at α = .95 for any of the combined equations. Linjala rejected the hypothesis at the .005 probability level for all his combined equations and concluded that there is a statistical difference between the individual equations and their respective combined equation. The combined equation did not explain the data as well as the individual equation.

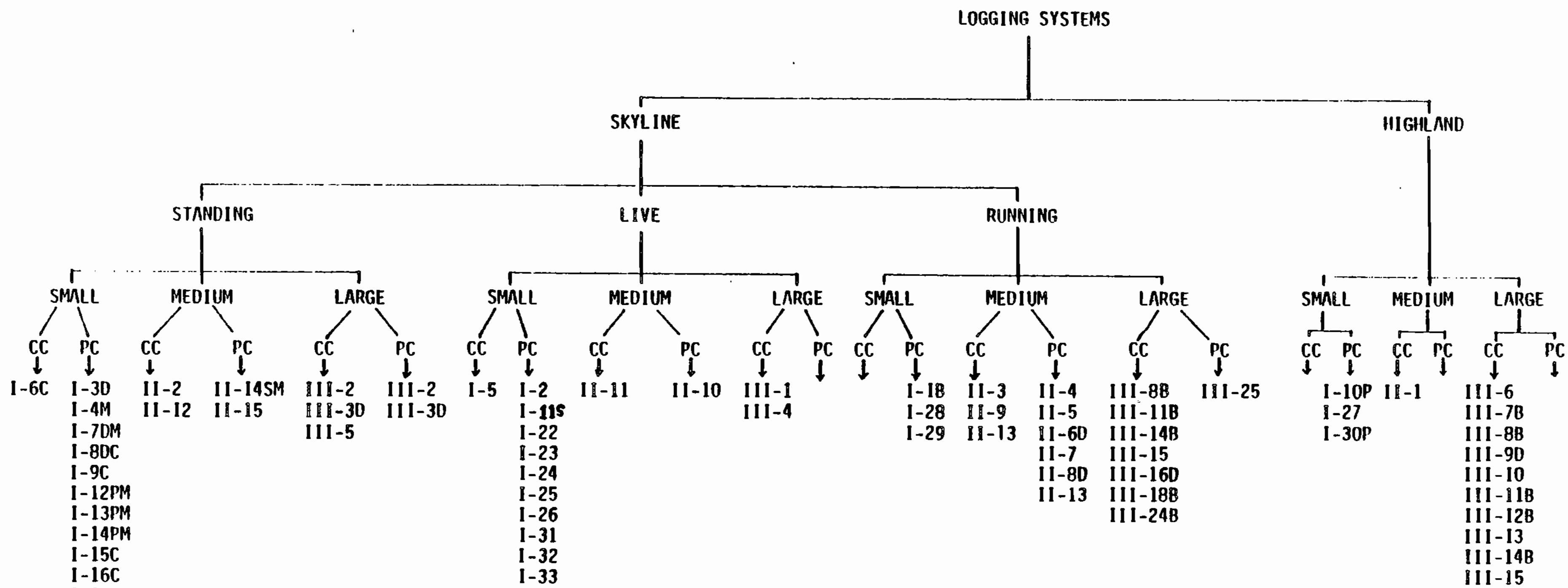
Depending upon the circumstances of a particular sale, appraisers may find either approach (combined versus individual equations) appropriate. They should keep in mind the respective advantages and limitations of each method when making their selection.

REFERENCE KEY

To assist the reader in locating equations of interest, a graphical summary has been provided (Figure 1). Equations were first separated by yarding system; either skyline or highlead. Skyline yarding was subdivided into standing, live, or running skyline systems. Equations for each of these yarding systems were then segregated on the basis of yarder model size: small, medium, or large. A final subdivision was made according to the type of cut: either clearcut or partial cut.

A code was used to designate each equation and provide a link between the graphical summary and the tables in Appendix A. Small, medium and large yarders were represented by the Roman numerals I, II, and III, respectively. The Roman numeral is followed by a dashed line and the arabic number assigned to the equation as it is listed in the tables. Single spans, uphill yarding, and full cycle yarding are assumed for all equations in the chart. Deviation from these assumptions are indicated by one or more letters following the arabic number. Pre-bunch or swing yarding operations are designated by P or S, respectively. Downhill yarding or both downhill and uphill yarding are denoted with the letters D and B, respectively. Multispans or a combination of multispans and single spans are assigned the letters M and C, respectively. A legend with these designations is included on the chart. In instances where equations involved more than one category on the chart (e.g., both clearcut and partial cut, or both highlead and live skyline), the equation was listed under both designations.

FIGURE 1



LEGEND:

CC = Clearcut
PC = Partial Cut
I = Small yarder (Mainline pull < 25000 lbs)
II = Medium yarder (25000 lbs ≤ mainline pull < 71000 lbs)
III = Large yarder (mainline pull ≥ 71000 lbs)
Arabic Number (e.g., 1,2,3 etc.) = Number of the regression equation

P = Pre-bunch Operation
S = Swing Operation
D = Downhill Yarding
B = Both Uphill & Downhill Yarding
M = Multispan (Intermediate support used)
C = Logging operation involved a combination of Multispan and Singlespan Yarding

NOTE: Unless indicated otherwise, all equations are for full cycle yarding with singlespans and in an uphill configuration.

Following is an example of how the chart could be used. If the reader was interested in equations for standing skylines operating in partial cuts and he believed that a medium sized yarder was adequate, there would be two equations available: II-14SM and II-15. The letters included in the first code would indicate that this was a swinging operation and it utilized one or more intermediate supports. Yarding would be uphill. The other equation (II-15), since no letters were included in the code, would be for an uphill yarding operation with no intermediate supports. The logging show would be full cycle yarding, rather than a pre-bunch or swing operation. By reviewing data listed for equations 14 and 15 in the medium-sized yarder tables in Appendix A, the reader should have a good idea of how well these equations fit his or her situation.

SUGGESTED IMPROVEMENTS IN FUTURE RESEARCH PAPERS

In reviewing the studies presented in this paper, there were a number of occasions where additional information or clarification would have made the equations more useful. If one of the objectives of the study is to provide the forest manager some means of estimating production rates, the following points should be considered.

BACKGROUND

Enough background information should be included in the study report so that an individual can determine how closely the production equation matches his or her circumstances. Study dates, site location, sale area information, weather conditions, crew and machine data, yarding system information, as well as the range of parameters involved in the time study should all be included in the report.

VARIABLES

The variables included in the regression equation should be easily measured and applicable to most situations. Variables such as percent defect and volume per turn are difficult, if not impossible, to measure prior to actually yarding the area. These variables may be significant in explaining production variation, but their usefulness in an equation utilized for estimating production is questionable.

Variables should be defined precisely. Their units should be specified and the manner in which they are measured should be described. This also applies to background data listed in the text. Some reports described stand composition in percentages of different species. However, the reader did not know if these values were in terms of stand volume or total stems per acre, or determined in some other manner. Volumes were often given, but the procedure or log rule with which they were calculated was not mentioned.

Standardizing the definition and manner of measuring commonly used variables would eliminate a good deal of confusion. Based upon the literature review, the worst examples of common variables having numerous definitions and disparate schemes of measurement are those listed below.

Lateral Distance

Lateral distance has been defined as the slope distance perpendicular to the corridor from the first log hooked or the last log hooked. In some studies, lateral distance meant the actual slope distance the log traveled from hook point to corridor. The length of skidding line from hook point to corridor was another definition. Lateral distances were both estimated by eye and measured. Pacing was also used. In a few studies, a log lead angle and the log's perpendicular distance to the corridor were manipulated to give an "actual lateral yarding distance."

Volume

Volumes were recorded in board feet, cubic feet, and cunits. A number of different log rules were used to calculate volumes.

Groundslope

Groundslope was always given in percent. However, authors used different sign conventions. A positive groundslope in one study would be recorded as a negative value in another study. Groundslope was also recorded as an absolute value.

Chordslope

Different sign conventions were also used when reporting chordslopes. The unit used was always percent. For those equations which used a percent value of any parameter, no instruction was given concerning the form of the value to be entered in the equation. The reader did not know if a percentage should be entered as a decimal or a whole number.

Lead Angle

Definitions for lead angles considered either a single log or the average value for a turn of logs. In some cases it was a deflection angle from the corridor, but depending upon the author, the angle could be turned either uphill or downhill to the log. Another definition of lead angle was the angle formed by the winch line and a projected line travelling along the length of and through the center of the log. For one author, turning the angle in a counter-clockwise direction resulted in a negative value. In that study, the range of lead angle values was +90° to -90°. For all the papers reviewed, lead angles were reported in degrees.

With so many different definitions for common variables, there is a very real possibility that equations can be misinterpreted. A mistake made about the sign convention is just one example. By standardizing the definitions of common variables and agreeing upon one method of measuring them, mistakes of this kind can be avoided.

PRODUCTION EQUATIONS

Most of the studies reviewed were detailed time studies. In some instances regression equations were developed for each of the defined cycle elements (e.g., outhaul, lateral outhaul, hook, lateral inhaul, inhaul, and unhook). The total production time equation (full cycle yarding) would then be obtained by summing the elemental equations. For other studies, a total production time equation was developed separately. The study should specify which type of total time equation was developed.

Although none appear in this paper, some production equations created by combining elemental equations include cycle elements which do not always occur. The reader should be aware of this possibility and modify his or her approach because of this non-constant cycle element.

All production equations should have their cycle elements well defined. There should be complete understanding of exactly what the author considers to be productive time. Among the papers reviewed, an activity such as resetting chokers was sometimes included in a cycle element and in other studies it was considered a delay.

Exactly how an activity will be categorized should be evident to the reader.

DELAYS

The discussion on delays is similar to the comments about cycle elements. If delays are to be separated into different classes (operational, non-operational, experimental, etc.), the classes should be defined precisely. Examples for the different classes or categories of delay should be given. Exactly how are skyline corridor changes, landing changes, pre-rigging time, and major mechanical repairs handled? Are these items considered separately, or are they included in one of the standard delay categories? The reader should have no doubts.

The procedure by which delays and productive time are represented as percentages of total time should be thoroughly explained. Total time was defined in a number of ways among the studies summarized in this paper. For example, one definition of total time was the summation of productive time, operating delays, non-operating delays, and skyline corridor changes. Most studies excluded corridor changes. A common definition of total time was the combination of productive time and operating delays alone.

Because of the different definitions of delays, delay categories and total time; it is difficult to compare percentage values among studies. Interpreting these values can also be a problem. If a set of standards could be agreed upon by researchers, the information about delays would be much more useful. Set categories and definitions of delays, as well as one specific procedure to calculate percentages for productive time and delay time, would improve this section of the time study tremendously. The following are references that may be useful in standardizing terms and procedures: 1. Mifflin and Lysons, 1978; 2. Berrard, Dibblee, and Horncastle, Undated; and 3. Haarlaa, 1981.

COMMENTS ON THE STUDY

A section should be reserved in the research paper to comment on any complications or pecularities about the study that could influence the interpretation of results. Changes in equipment, personnel, or procedures during the project should be noted. Assumptions made by the authors should be specified. If necessary, a guide should be provided on how to interpret information contained in charts, graphs, tables, or any other summaries of data.

COMMON ERRORS WHEN USING MID-RANGE VALUES

When mid-range values of independent variables are assumed to be the average values, and these values are used in the regression equation to estimate an average production rate, errors will result if either of two common conditions exist:

1. The regression has nonlinear terms, or
2. The independent variable has a nonsymmetrical (skewed) distribution (Olsen, unpublished).

If either of these two conditions are present, a weighted average of each independent variable should be used instead of its mid-range.

Olsen (unpublished) has developed a method, using integral calculus, to determine the correct weighted average. A table listing his formulas for computing weighted averages of common nonlinear regression terms for two types of distributions (uniform and triangular) appears in Appendix D. The uniform and triangular distributions represent the extremes normally encountered in logging applications. The uniform distribution (symmetrical) would be appropriate for a slope yarding distance variable on a long, narrow corridor, since equal numbers of turns would be expected throughout the length. An example of the triangular (nonsymmetrical) distribution would be slope yarding distance on a circular setting where more turns will come from farther distances as the area yarded increases in proportion to distance from the landing. Variable distributions can be identified by analyzing production studies or they may be determined on the basis of logging engineering principles or past experience

(Olsen, unpublished). Given uphill yarding on a steep, clearcut slope, a nonsymmetrical distribution of slope yarding distances would be expected because of the tendency for logs to roll downhill after cutting, thus increasing the number of turns farther from the landing.

When the mid-range value is incorrectly applied, the resulting estimate can be as much as 50% in error. In most cases, the error is an underestimation (Olsen, unpublished).

If a regression equation is to be used for predicting an average production rate, the terms of the regression and the distribution of the independent variables must be assessed. Given the proper formula for computing a weighted average and the end points of a variable's range, estimates can be correctly calculated.

A complete numerical example using one of the regression's listed in this paper and considering the need for weighted averages of independent variables, appears below:

Numerical Example:

GIVEN: $y = 5.102 + 0.970\ (LOGS) + 0.00000172(SYDIST)^2 + 0.031\ (LDIST) - 0.194\ (CREW)$ (Hensel et. al., 1979)

where:

y = delay-free turn time estimate (minutes)

LOGS = number of pieces yarded per turn

SYDIST = the slope yarding distance (feet)

LDIST = lateral yarding distance (feet). Actual slope distance the log travels from hook point to corridor.

CREW = the number of persons in the yarding crew.

Range of variables and actual average values (Hensel, 1977)

LOGS = 3.50 - 6.00, $\overline{4.87}$

SYDIST = 1000 - 3000, $\overline{1990}$

LDIST = 50 - 150, $\overline{97}$

CREW = 4 - 5, $\overline{4.25}$

Yarding Conditions: Uphill logging with a Wyssen system - Slopes range from 45% to 75%

Variable Distribution Assumptions	Formula
"LOGS" - UNIFORM	$\frac{b(X_1+X_0)}{2}$
("SYDIST")^2 - UNIFORM	$\frac{b(X_1^3-X_0^3)}{3(X_1-X_0)}$
"LDIST" - UNIFORM	$\frac{b(X_1+X_0)}{2}$

where:

b = coefficient

X_1 = maximum value

X_0 = minimum value

Comparing the true averages of "LOGS," "SYDIST," and "LDIST" to their respective range of values indicated that a uniform distribution was the most likely. Given a triangular distribution, the true average for each variable would not have approximated its mid-range figure so closely. Normally, variable distributions will have to be determined based on logging engineering principles and past experience. The distribution of the variable "CREW" was not considered. A whole number will be used rather than a weighted average since fractional loggers are hard to find these days.

This example will compare the actual average cycle time of the study to two estimates from the regression equation. The first calculation will use the true averages of the independent variables. The second estimation will use weighted averages computed from the formulas in Appendix D with the exception of the variable "CREW."

In most cases, the second approach will be more appropriate when using an equation to predict cycle time for a proposed logging operation. The true average of the independent variables will not be known until logging has been completed. However, the appraiser will have a good idea of the range of values for each variable on the proposed sale area. The formulas in Appendix D utilize this range to determine weighted averages.

The actual average cycle time in the study was 19.292 minutes (Hensel, et. al., 1979). Using the true variable averages, the predicted average cycle time [E(Y)] is:

$$E(Y) = 5.102 + 0.970(4.87) + 0.00000172(1990)^2 + 0.031(97) - 0.194(4.25)$$

$$= 18.820 \text{ minutes}$$

Using the formulas in Appendix D and setting "CREW" equal to 4 (average number in the study was 4.25), the predicted average cycle time is:

$$E(Y) = 5.102 + \frac{0.970(6.00 + 3.50)}{2} + \frac{0.00000172(3000^3 - 1000^3)}{3(3000-1000)} + \frac{0.031(150 + 50)}{2} - 0.194(4)$$

$$= 19.487 \text{ minutes.}$$

If "CREW" had been set equal to 5, E(Y) would equal 19.293 minutes.

OBTAINING INPUT DATA

Caution should be used when estimating or calculating values of independent variables. A clear understanding of the variable's definition will help eliminate potential errors. Special attention should be given to the sign conventions and units associated with each variable. Time spent in accurately estimating slope yarding distance will be wasted if input is made in feet while the equation requires distances in stations. Groundslopes entered with the wrong sign convention will nullify any potential usefulness of the equation. One common error involves estimating yarding distances from topographic maps. Keep in mind that measuring distances on such maps will only account for the horizontal component. If the input desired is slope distance, the average slopes over the area will have to be incorporated into the calculations to account for the vertical component.

SUMMARY

A number of production equations have been developed in recent years by researchers in the Forest Engineering Department at Oregon State University. This paper is a summary of most of those equations. Background information about the study conditions for each of the listed projects has also been included. Besides studies conducted at Oregon State University, any recent production equations found during the literature review were also included.

Data from the production studies was basically organized into a set of tables. Each table dealt with a particular type of information: production data (regression equations and delay percentages), independent variables measured but not used in the equation, machine data, rigging and yarding configuration information, crew data, physical data of the sale area, and time study data.

A section of the paper was devoted to guidelines on using the compendium. Equations as predictive tools was discussed. Comments were made on interpreting information listed in two of the summary tables: "production data" and "variables measured but not used." The relative merits of using "combined" equations or "individual" equations were listed.

A graphical summary was developed as a quick reference for the reader and an example was provided on how it might be used and interpreted. The chart can easily be used in conjunction with the tabular summaries.

In reviewing the studies listed in this paper, there appeared to be a number of opportunities for improving the organization and conduct of future studies. Background information was sometimes insufficient. Commonly used variables had many different definitions and methods of measurement. Activities involved in the logging operation were considered either a delay or productive time, depending upon the study. Different approaches were used in calculating delay percentages. Standardization would remedy much of the confusion. A section reserved in each study to discuss complications or peculiarities of the project and comment on interpretation of data would also help.

If an individual assumes the mid-range value of a variable is the average value and he uses this figure in the regression equation to arrive at an average production rate, he or she may be in error. Nonlinear terms in the equation or a nonsymmetrical (skewed) distribution of the independent variable will normally cause an underestimation of turn time. A method to compensate for this by using weighted averages is provided in the paper. The equations can also be incorrectly used if there are errors in calculating or estimating values of the independent variables. Inputing data with the wrong sign convention or units of measure will nullify any potential benefit of the equation.

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APPENDIX A

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs

PRODUCTION DATA

	REFERENCE	REGRESSION EQUATION - TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME ?	DELAY %	COMMENTS
1.	Pursell, 1979	$.6144 + .00475\,(SYDIST) + .00053\,(LDIST)^2 + .28694(LOGS) + .00563\,(LEADTURN)$	.61567	Yes	17.0 ①	
2.	Fisher, et al, 1980	$2.374 + .00841141\,(SYDIST) + .72548570\,(LOGS)$	.40	Yes	②	Moving the carriage stop was considered a delay
3.	Hensel, et al, 1979	$12.304 + 0.385\,(LOGS) + 0.00000062\,(SYDIST)^2 + 0.0096\,(LDIST) - 0.945\,(CREW)$	.254	Yes	31.4 ③	
4.	Hensel, et al, 1979	$5.102 + 0.970\,(LOGS) + 0.00000172\,(SYDIST)^2 + 0.031\,(LDIST) - 0.194\,(CREW)$	.670	Yes	20.5 ③	
5.	Kramer, 1978	$0.68620 + 0.00525\,(SYDIST) + 0.01243\,(LDIST) + 0.27960\,(LOGS) + 0.01759\,(CH) + 0.02521\,(CHORDSLOPE)$	.28	Yes	19.9 ④	Includes a "RESET" element and "MOVING SKYLINE STOP CLAMP" element in the yarding cycle
6.	Kramer, 1978	$1.62970 + 0.32467\,(DKHT) + 0.00219\,(SYDIST) + 0.00320\,(VOLUME) - 0.02040\,(CH) + 0.00624\,(LDIST)$	.39	Yes	17.1 ④	Includes a "RESET" element in the yarding cycle
7.	Kellogg, 1978 Unpublished	$1.66608 + .989382\,(LOGS) + .0217172\,(VOLUME) - 1.10751\,(CHOKERS) + .00367794\,(SYDIST) + .0460988\,(LATDIST)$	.37	Yes	③⑤	Time spent untangling chokers or lines or repositioning a turn on the deck considered delays
8.	Kellogg, 1978 Unpublished	$1.27545 + 1.36991\,(LOGS) - 1.10802\,(CHOKERS) + .0483455\,(CH) + .0023582\,(SYDIST) + .0111352\,(LDIST)$	.34	Yes	③ ⑥	Time spent untangling chokers or lines or repositioning a turn on the deck considered delays
9.	Neilson, 1977	$1.6932 + 0.005119\,(SYDIST) + 0.025653\,(LDIST) + 0.2783\,(LOGS)$	.29	Yes	③ 26.1 ⑦	⑧

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

PRODUCTION DATA

REFERENCE	REGRESSION EQUATION - TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME ?	DELAY%	COMMENTS
10. Kellogg, 1976	-2.8897 + .028864 (SYDIST) + .010653 (LANGLE) + .036543 (VOLUME) + 2.1101 (CHOKERS)	.39	Yes	(9) 34.2	"RESET" considered part of the yarding cycle
11. Kellogg, 1976	1.0935 + .0040312 (SYDIST) + .00519 (ZONE) + .0092485 (VOLUME)	.34	Yes	(3) 18.6	"RESET" considered part of the yarding cycle. Moving the carriage stop was considered a delay
12. Keller, 1979	.907 + .00837 (VOLUME) + .0119 (LATDIST) - .0142 (VOLUME)/(LOGS) + (.218 x 10^{-5}) $(SYDIST)^2$ + .00341 (LDIST) + .458 (BLOCK)	.415	Yes	(3) 43.2	(10)
13. Keller, 1979	1.493 + .0288 (VOLUME) + .00734 (LATDIST) - .0328 (VOLUME)/(LOG) + (.177 x 10^{-5}) $(SYDIST)^2$ + .00491 (LDIST) - .0957 (BLOCK)	.346	Yes	(3) 43.8	(10)
14. Keller, 1979	.951 + .00877 (VOLUME) + .324 (LOGS) + (.578 x 10^{-4}) $(LATDIST)^2$ + .0117 (SIDIST) + .014 (CH)	.185	Yes	(3) 52.2	(10) (14)
15. McIntire, 1981 (13)	.584083 + .0034641 (SYDIST) + .0152292 (LATDIST) + .427251 (HOOKLOG) + .0665714 (DKHT) + .0178205 (VOLUME)	.4284	Yes	(12) 50.0	"RESET" considered part of delay time. "REPOSITION" was part of yarding cycle time
16. McIntire, 1981 (13)	.4502091 + .00282149 (SYDIST) + .0176626 (LATDIST) + .529121 (HOOKLOG) + .0564319 (DKHT) + .00736944 (VOLUME)	.4476	"	"	" " "
17. McIntire, 1981 (13)	.037302 + .0027979 (SYDIST) + .0182247 (LATDIST) + .509236 (HOOKLOG) + .0911757 (DKHT) + .00796932 (VOLUME)	.5212	"	"	" " "
18. McIntire, 1981 (13)	.922269 + .00275107 (SYDIST) + .011785 (LATDIST) + .449032 (HOOKLOG) + .0256433 (VOLUME)	.4697			
19. McIntire, 1981 (13)	.612107 + .00296974 (SYDIST) + .0173265 (LATDIST) + .499394 (HOOKLOG) + .00788264 (VOLUME)	.4526	"	"	" " "
20. McIntire, 1981 (13)	.0741916 + .00466162 (SYDIST) + .0245706 (LATDIST) + .293742 (HOOKLOG) + .00759683 (VOLUME)	.6675	"	"	" " "
21. McIntire, 1981 (13)	1.3969 + .00391347 (SYDIST) + .0178717 (LATDIST) + .429317 (HOOKLOG) + .0151707 (VOLUME) - .381483 (RIGGERS) - .0941052 (LOGCREW) - .307468 (DMYSKID)	.5369 (11)	"	"	" " "

FOOTNOTES:

(1) Excludes yarding road changes, computed as $\frac{\text{TOTAL DELAY TIME}}{\text{TOTAL PRODUCTIVE TIME + TOTAL DELAY TIME}}$, total turn time (excluding yarding road changes) =

$$\frac{\text{DELAY FREE TIME (REGRESSION EQUATION)}}{\frac{(100 - \text{Delay }\%)}{100}}$$

e.g., D.F.T. = 6 minutes

Delay % = 6.2%

$$\text{T.T.} = \frac{6}{\frac{100 - 6.2}{100}} = 6.397 \text{ minutes}$$

(2) Average production time per cycle was 7.13 minutes. With delays average cycle time was 9.20 minutes.

(3) Excludes yarding road changes

(4) Excludes yarding road changes and delay times the author attributed to the experimental nature of the study. All delays considered to be associated with normal yarding operations were included.

(5) Average delay free turn time was 5.03 minutes. With delays, average turn time was 6.85 minutes.

(6) Average delay free turn time was 4.37 minutes. With delays, average turn time was 5.73 minutes.

(7) Value based on a total study time of 8700 minutes which includes both thinning (this study) and some clear felling operations (not in this study). Total study time composed of cycle time (average 4.48 minutes for 549 observations), operational delay time, experimental delay time and road change time.

(8) Cycle time elements: 1 outhaul 2 sort rigging-choker setter (untangling chokers 32% of turns), 3 lateral out, 4 hook, 5 lateral in, 6 reset - 23% of turns, 7 inhaul, 8 position (occurred when a turn had to be positioned on the deck before it could be unhooked - 16% of turns), 9 unhook, 10 sort rigging - operator (7% of turns), 11 sort deck (involved the operator flattening down the deck or moving logs to enable landing additional logs safely - 21% of turns).

(9) Excluded time spent in moving single drum winch to a new location.

(10) Included in delay time were resets, sorting chokers or rigging, transit delays when a choker setter wasn't in position to execute a basic element of the yarding cycle when the element is scheduled to begin, repositioning a turn of logs on the deck for unhooking and side blocking a turn to either free or avoid a hang-up during inhaul.

(11) Author presents production equations for different crew sizes with and without swing skidder. He refers to this equation as the "combined" equation using the combined data base of all his other equations.

FOOTNOTES (continued)

(12) Excludes yarding road and landing changes and pre-rigging.

(13) Separate regressions were made for two portions of the cycle and added together.

One portion: inhaul, reposition, unhook

Other portion: outhaul, lateral outhaul, hook, lateral inhaul

(14) Author states that this model is sufficient for either carriage type used in this study: Igland-Jones multispan carriage or Christy gravity outhaul. The model is for a haulback assisted prebunch yarding cycle.

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

PRODUCTION DATA

REFERENCE	REGRESSION EQUATION - TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME ?	DELAY %	COMMENTS
22. Aulerich, 1975	0.826 + 0.006 (SYDIST) + 0.032 (LDIST) + 0.897 (LOGS)	.56	Yes		
23. Aulerich, 1975	1.925 + 0.002 (SYDIST) + 0.017 (LDIST) + 0.909 (LOGS)	.45	Yes		
24. Aulerich, 1975	1.210 + 0.009 (SYDIST) + 0.015 (LDIST) + 0.253 (LOGS)	.32	Yes	3.1 (1)(2)	"RESET" not considered a delay
25. Aulerich, et al, 1974	6.3210 - 0.6972 (CREW) + 0.0062 (SYDIST) + 0.0320 (LDIST) + .7603 (LOGS) + 0.0095 (SLOPE) - 0.0522 (TI)	.58	Yes	9.0 (1)	"RESET" considered part of the yarding cycle
26. IFF, 1982	1.054 + 0.00234 (SYDIST) + 0.01180 (LDIST) + 0.980 (LOGS) + 0.00069 (WEIGHT)	.127 to .760 (4)	Yes	56.15 (5)	"RESET" and "MOVING STOP" considered delays, untangling chain chokers considered cycle time (3)
27. IFF, 1982	1.751 + 0.00358 (SYDIST) + 0.01257 (LDIST) + 0.00024 (WEIGHT)	.140 to .344 (4)	Yes	56.31 (5)	"RESETS" considered delays (3)
28. IFF, 1982	1.311 + 0.00439 (SYDIST) + 0.01257 (LDIST) + 0.00035 (WEIGHT)	.141 to .533 (4)	Yes	41.33 (5)	"RESETS" considered delays (3)
29. IFF, 1982	1.090 + 0.00530 (SYDIST) + 0.01257 (LDIST) + 0.00037 (WEIGHT)	.140 to .533 (4)	Yes	26.03 (5)	"RESETS" considered delays (3)
30. Zielinsky, 1980	1.2142 + 0.0154 (LATSD) + 0.00157 (SDIST) + 0.9976 (CREW1)	.4332	Yes	(6)	
31. Gabrielli, 1980	2.1832 + .00248 (SYDIST) + 0.00662 (SINANG) (LATDIST) + .32165 (LOGS)	.3566	Yes	20.8 (8)(1)	(10)
32. Gabrielli, 1980	2.2838 + .00304 (SYDIST) + .00526 (SINANG) (LATDIST) + .13111 (LOGS) + .01263 (VOLUME) (7)	.4378	Yes	21.4 (8)(1)	(10)
33. Gabrielli, 1980	4.4305 + .00267 (SYDIST) + .03435 (VOLUME) (7)	.2094	Yes	22.0 (9)(8)(1)	(10)

FOOTNOTES

(1) Excludes landing and road changes.

(2) Moving the carriage stop was excluded from delay time and yarding time in this study. Moving the carriage stop accounted for 9.7% of total time.

(3) Total cycle time equation determined by summing individual cycle element equations.

(4) Range of R^2 for individual cycle element equations which were added to form total cycle time equation.

(5) Value is total delay percentage based on total scheduled operations time which includes total cycle element time, operating delays, maintenance and repair delays, planning delays and personnel delays, but excludes yarding road change times.

(6) Percentages listed below are based on total yarding time which is the sum of total productive time, total operating delay time and total non-operating delay time. Examples of operating delays are: resets, repositioning logs, yarding road changes, changing pre-bunch spars, block changes, and repositioning drum set to facilitate line spooling. Examples of non-operating delays are breaking line, line fouled on the drum, personal delays and mechanical failures. Total productive time = 53%. Operating delays = 32%. Non-Operating delays = 15%.

(7) Volume calculated by Smalian's formula: $V = (\frac{b + t}{2})\, L$

where:
- v = cubic foot volume inside bark
- b = basal area in square feet at the large end of the log
- t = basal area in square feet at the small end of the log
- L = length of the log in feet

(8) Value is total delay percentage based on total turn time. Total turn time is the sum of all operational delay time and yarding cycle time. Road changes, landing changes and experimental delays are excluded. Operational delay categories are: moving the carriage stop, resets, sort rigging, transit time for a choker setter out of position to move to the correct position, landing delays, repositioning a turn on the log deck, mechanical (carriage), mechanical (yarder-lines), personal, and other. Experimental delays were defined as the time required due to the researchers or the study that normally would not occur had not an experimental study been in progress.

(9) An additional operational delay besides those listed in footnote #8 was "bunch". "Bunch" is defined as any time required over and above one cycle of lateral outhaul, hook, and inhaul to build up a turn of logs.

(10) Operational delay time was recorded for moving the carriage stop only if no other activity, typically unhooking, was occurring.

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs

VARIABLES MEASURED BUT NOT USED IN REGRESSION EQUATIONS:

REFERENCE	
1. Pursell, 1979	Weight per turn, chordslope, volume per turn, logs per acre by thinning block.
2. Fisher et al, 1980	Lateral yarding distance.
3. Hensel et al, 1979	①
4. Hensel et al, 1979	①
5. Kramer, 1978	Distance skyline stop moved, accumulated sum of logs per turn on a deck, volume of logs per turn, number of choker setters per turn.
6. Kramer, 1978	Number of pieces per turn, chordslope, number of choker setters per turn.
7. Kellogg, 1978, unpub.	Lead angle (angle between skyline and log path during lateral inhaul), carriage height, log deck height.
8. Kellogg, 1978, unpub.	Volume/turn, lead angle (angle between skyline and log path during lateral inhaul), log deck height.
9. Neilson, 1977	Carriage height, ground slope %, number of intermediate supports, number of choker setters used, volume, number of pre-set logs, number of chokers used, log deck height.
10. Kellogg, 1976	--
11. Kellogg, 1976	Number of choker setters, number of chokers used.
12. Keller, 1979	Carriage height above the ground, SIDIST, groundslope %, slope direction with respect to outhaul direction, lead angle.
13. Keller, 1979	Carriage height above the ground, SIDIST, groundslope %, slope direction with respect to outhaul direction, lead angle.
14. Keller, 1979	Actual lateral yarding distance, lead angle, groundslope %, slope direction with respect to outhaul direction, slope yarding distance, BLOCK, lead angle.
15. McIntire, 1981	Lead angle.

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

VARIABLES MEASURED BUT NOT USED IN REGRESSION EQUATIONS:

16. McIntire, 1981	Lead angle.
17. McIntire, 1981	Lead angle.
18. McIntire, 1981	Lead angle.
19. McIntire, 1981	Lead angle.
20. McIntire, 1981	Lead angle.
21. McIntire, 1981	Lead angle, deck height.
22. Aulerich, 1975	--
23. Aulerich, 1975	--
24. Aulerich, 1975	--
25. Aulerich, et al, 1974	--
26. IFF, 1982	Groundslope %, slope from top of tower to carriage, slope along lateral yarding direction, DBH.
27. IFF, 1982	Groundslope %, slope from top of tower to carriage, slope along lateral yarding direction, DBH, pieces per turn.
28. IFF, 1982	Groundslope %, slope from top of tower to carriage, slope along lateral yarding direction, DBH, pieces per turn.
29. IFF, 1982	Groundslope %, slope from top of tower to carriage, slope along lateral yarding direction, DBH, pieces per turn.
30. Zielinsky, 1980	Height of block on pre-bunching spar, LANGLE, number of chokers used, pieces per turn, volume per turn, log deck height.
31. Gabrielli, 1980	Cubic foot volume per turn, log lead angle, carriage height above the ground.
32. Gabrielli, 1980	Log lead angle, carriage height above the ground.
33. Gabrielli, 1980	Lateral yarding distance, pieces per turn, log lead angle, carriage height above the ground.

FOOTNOTE

(1) Authors mention that other variables were considered but not included because of their small effect on R^2. The other variables are not specified.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (1 of 2)

	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS: DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT) SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
1.	Pursell, 1979	Peewee (12)	--	PeeWee	--	6.0/750/2600 (1)	4.5/750/2600 (1)	9.0/759/2600 (1)	-/½/½/½
2.	Fisher, et al 1980	Ecologger (2)	Maki	Ecologger	23.4/750/-	8.5 (3) /950/1540	--	--	$\frac{9}{16}$/$\frac{9}{16}$/-/-
3.	Hensel, et al 1979	Wyssen W-90 (4)	Wyssen Automatic Standard	--	--	--	--	--	-/⅝/-/-
4.	Hensel, et al 1979	Wyssen W-90 (5)	" "	--	--	--	--	--	-/⅝/-/-
5.	Kramer, 1978	Igland-Jones (9) Trailer Alp	Christy	Igland-Jones	-/400-1000/3300	-/400-1000/1800	--	-/400-1000/1800	⅞/⅞/-/⅞
6.	Kramer, 1978	" "	Igland-Jones (6)	Igland-Jones	-/400-1000/3300	-/400-1000/1800	--	-/400-1000/1800	¾/¾/-/¾
7.	Kellogg, 1978 Unpublished	" "	Igland-Jones Alp Cat	Igland-Jones	--	--	--	--	--
8.	Kellogg, 1978 Unpublished	" "	" "	" "	--	--	--	--	--
9.	Neilson, 1977	" "	Igland-Jones (6)	" "	-/400-1000/2600	-/400-1000/1800	--	-/400-1000/1800	⅝/⅝/-/⅝
10.	Kellogg, 1976	Mini-Yarder (10)	None	None	--	9/120/316	--	--	-/⅝/-/-
11.	Kellogg, 1976	Schield-Bantam T-350	Maki	--	-/-/1000	-/-/900	--	-/-/1600	⅜/⅝/-/$\frac{9}{16}$

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (1 of 2)

	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS — DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT): SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
12.	Keller, 1979	Igland-Jones (9) Trailer Alp	Igland-Jones	Igland-Jones	-/-/2000-3000	-/400-1000/1800	--	-/400-1000/1800	5/8 / 3/8 / - / 3/8
13.	Keller, 1979	" "	Christy	" "	-/-/2000-3000	-/400-1000/1800	--	-/400-1000/1800	5/8 / 3/8 / - / 3/8
14.	Keller, 1979	" "	Igland-Jones & Christy	" "	-/-/2000-3000	-/400-1000/1800	--	-/400-1000/1800	5/8 / 3/8 / - / 3/8
15.	McIntire, 1981	Koller K-300 (13)	Koller SKA 1	Koller	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
16.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
17.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
18.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
19.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
20.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -
21.	McIntire, 1981	" "	" "	" "	-/-/1100	-/-/1100	--	--	5/8 / 5/16 / - / -

1. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (2 of 2)

	YARDER SPECIFICATIONS			CARRIAGE SPECIFICATIONS							
					LATERAL CAPABILITY			POSITION HOLDING			
REFERENCE	INTERLOCK	TOWER HEIGHT (FT)	WEIGHT(lbs.)	MAN	LINES	CARR.	OPER. LINES	CLAMP	STOP	CAPACITY
1. Pursell, 1979	Hydraulic	37.0	600		x		--	--	--	--
2. Fisher, et al 1980	None	42.0	---	x					x	--
3. Hensel, et al 1979	None	--	---	x					x	11000 lbs (8)
4. Hensel, et al 1979	None	--	---	x					x	11000 lbs (8)
5. Kramer, 1978	None	23.7	158	x					x	--
6. Kramer, 1978	None	23.7	35/80 (7)	x			x			--
7. Kellogg, 1978 Unpublished	None	23.7	---		x		x			--
8. Kellogg, 1978 Unpublished	None	23.7	---		x		x			--
9. Neilson, 1977	None	23.7	35/80 (7)	x			x			--
10. Kellogg, 1976	None	None	---	-	-	-	-	-	-	--
11. Kellogg, 1976	None	--	---	x					x	--
12. Keller, 1979	None	23.7	---	x			x			--
13. Keller, 1979	None	23.7	---	x					x	--
14. Keller, 1979	None	23.7	---		(11)		Igland-Jones		Christy	--

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (2 of 2)

	YARDER SPECIFICATIONS			CARRIAGE SPECIFICATIONS							
					LATERAL CAPABILITY			POSITION HOLDING			
	REFERENCE	INTERLOCK	TOWER HEIGHT (FT)	WEIGHT(lbs.)	MAN	LINES	CARR.	OPER. LINES	CLAMP	STOP	CAPACITY
15.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
16.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
17.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
18.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
19.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
20.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)
21.	McIntire, 1981	None	22.97	330	x				x		1 Ton (8)

FOOTNOTES

(1) Drum half full.

(2) Mounted on 130-horsepower tree farmer C6D skidder, yarder equiped with remote electronic controls.

(3) Base of Drum.

(4) Rated at 80 horsepower.

(5) Rated at 66 horsepower.

(6) Two Igland-Jones carriages used, one for singlespan and one for multispan.

(7) Singlespan carriage/multispan carriage.

(8) Load capacity.

(9) Power unit was John Deere 2640 70 horsepower farm tractor.

(10) Radio controlled single drum winch contained on a sled and powered by a 47 horsepower Volkswagen industrial engine (machine weight - 1600 lbs.) Manufactured by Modern Logging Equipment, Inc.

(11) Haulback line was rigged laterally to pull the mainline out from the carriage ("squirrel" block attached to the end of the haulback and the mainline was pulled through the "squirrel" block.).

(12) Peewee yarder prototype mounted on John Deere JD 640 cable skidder (110 horsepower at 2200 RPM).

(13) Power source is a 60 horsepower gasoline engine.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (1 of 2)

	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT) SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
22.	Aulerich, 1975	Schield-Bantam T-350	Ross	--	--	--	None	--	--
23.	Aulerich, 1975	" "	"	--	--	--	None	--	--
24.	Aulerich, 1975	" "	Maki Log Carriage	--	--	--	None	--	3/4 / 5/8 / - / -
25.	Aulerich et al, 1974	" "	Ross	--	-/-/1000	-/-/900	None	-/-/1600	3/4 / 5/8 / - / 7/16
26.	IFF, 1982	①	Christy	--	None	-/492/600	None	-/-/1300	- / 1/2 / - / 5/16
27.	IFF, 1982	①	Single Block Used	--	None	-/492/600	None	-/-/1300	- / 1/2 / - / 5/16
28.	IFF, 1982	①	Igland Double Block Carriage	--	None	-/492/600	None	-/-/1300	- / 1/2 / - / 5/16
29.	IFF, 1982	①	" "	--	None	-/492/600	None	-/-/1300	- / 1/2 / - / 5/16
30.	Zielinsky, 1980	②	None	None	None	③	None	④	- / 7/16 / - / ④
31.	Gabrielli, 1980	Skagit SJ2-R Mobil Thinning Yarder	Christy	--	--	--	None	--	5/8 / 7/16 / - / -
32.	Gabrielli, 1980	" "	Christy	--	--	--	None	--	5/8 / 7/16 / - / -
33.	Gabrielli, 1980	" "	Christy	--	--	--	None	--	5/8 / 7/16 / - / -

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

MACHINE DATA (2 of 2)

	YARDER SPECIFICATIONS			CARRIAGE SPECIFICATIONS							
					LATERAL CAPABILITY			POSITION HOLDING			
	REFERENCE	INTERLOCK	TOWER HEIGHT (FT)	WEIGHT(lbs.)	MAN	LINES	CARR.	OPER. LINES	CLAMP	STOP	CAPACITY
22.	Aulerich, 1975	None	---	---	x			x			--
23.	Aulerich, 1975	None	---	---	x			x			--
24.	Aulerich, 1975	None	---	---	x					x	--
25.	Aulerich et al., 1974	None	---	---	x			x			--
26.	IFF, 1982	None	12	170	x					x	--
27.	IFF, 1982	None	12	---	x			x			--
28.	IFF, 1982	None	12	---	x			x			--
29.	IFF, 1982	None	12	---	x			x			--
30.	Zielinsky, 1980	None	None	No Carriage Involved.							
31.	Gabrielli, 1980	--	40	600 (5)	x					x	--
32.	Gabrielli, 1980	--	40	600 (5)	x					x	--
33.	Gabrielli, 1980	--	40	600 (5)	x					x	--

FOOTNOTES

(1) Igland 4000/2 winch mounted on a Holder A55-F rubber tired, articulated logging tractor with a 12 foot tower. 2 drum yarder.

(2) Two-speed Skagit GU-10 drum set powered by a 350 cubic inch Chevrolet V-8 engine. (Capable of delivering 175 horsepower). The entire unit was mounted on the back of a dump truck. Only one of the two drums was required for pre-bunching.

(3) Mid-drum, low gear: 23.8 KIPS/245 F.P.M./1100 feet
High gear: 11.75 KIPS/500 F.P.M./1100 feet

(4) Only one of two drums used in this pre-bunching operation. No information given on second drum.

(5) 300 pound Christy carriage had 3/4" steel plates added to increase weight to 600 pounds (aided gravity outhaul on relatively flat chordslopes).

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

RIGGING AND YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/ DOWNHILL	SINGLESPAN/ MULTISPAN	CHOKERS/ GRAPPLE	YARDER HAS SWINGING BOOM? Yes	No	COMMENTS
1.	Pursell, 1979	Running Skyline	Generally (14) Uphill	Singlespan	Chokers		X	(11)
2.	Fisher, et al, 1980	Live-Gravity Outhaul	Uphill	Singlespan	Chokers		X	
3.	Hensel, et al, 1979	Standing-Wyssen	Downhill (1)	Singlespan	Chokers		X	
4.	Hensel, et al, 1979	Standing-Wyssen	Uphill	Multispan	Chokers		X	
5.	Kramer, 1978	Live-Gravity Outhaul	Uphill	Singlespan	Chokers		X	(12)
6.	Kramer, 1978	Standing-Haulback Line Required	Uphill	Both (2)	Chokers		X	
7.	Kellogg, 1978 Unpublished	Standing-Haulback Pulls Slack	Downhill	Multispan (9)	Chokers		X	
8.	Kellogg, 1978 Unpublished	Standing-Haulback Pulls Slack	Downhill	Both (10)	Chokers		X	
9.	Neilson, 1977	Standing-Haulback Line Required	Uphill	Both (3)	Chokers		X	
10.	Kellogg, 1976	Single Drum Winch-Radio Controlled, Pre-Bunching to the Corridor	Uphill	Not applicable	Chokers	Not applicable		
11.	Kellogg, 1976	Live-Gravity Outhaul, Swinging from the Corridor	Uphill	Singlespan	Chokers	X		
12.	Keller, 1979	Standing – Pre-bunch (4) to Corridor	Uphill	Multispan	Chokers		X	(13)
13.	Keller, 1979	Standing – Pre-Bunch (5) to Corridor	Uphill	Multispan	Chokers		X	(13)

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

RIGGING AND YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/ DOWNHILL	SINGLESPAN/ MULTISPAN	CHOKERS/ GRAPPLE	YARDER HAS SWINGING BOOM? YES	NO	COMMENTS
14.	Keller, 1979	Standing Pre-Bunch to Corridor (6)	Uphill	Multispan	Chokers		X	(13)
15.	McIntire, 1981	Standing Skyline - Gravity Outhaul (15)	Uphill	Both (7)	Chokers		X	
16.	McIntire, 1981	Standing Skyline - Gravity Outhaul (16)	Uphill	Both (7)	Chokers		X	
17.	McIntire, 1981	Standing Skyline - Gravity Outhaul (17)	Uphill	Both (7)	Chokers		X	
18.	McIntire, 1981	Standing Skyline - Gravity Outhaul (18)	Uphill	Both (7)	Chokers		X	
19.	McIntire, 1981	Standing Skyline - Gravity Outhaul (19)	Uphill	Both (7)	Chokers		X	
20.	McIntire, 1981	Standing Skyline - Gravity Outhaul (20)	Uphill	Multispan	Chokers		X	
21.	McIntire, 1981	Standing Skyline - Gravity Outhaul (21)	Uphill	Both (8)	Chokers		X	
22.	Aulerich, 1975	Live Skyline with Haulback-Manual Slackpull	Uphill	Singlespan	Chokers	X		
23.	Aulerich, 1975	Live Skyline with Haulback-Manual Slackpull	Uphill	Singlespan	Chokers	X		
24.	Aulerich, 1975	Live Skyline - No Haulback, Manual Slackpull, Self-Locking Carriage	Uphill	Singlespan	Chokers	X		
25.	Aulerich, et al, 1974	Live Skyline with Haulback-Manual Slackpulling	Uphill	Singlespan	Chokers	X		

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

RIGGING AND YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/ DOWNHILL	SINGLESPAN/ MULTISPAN	CHOKERS/ GRAPPLE	YARDER HAS SWINGING BOOM? YES	NO	COMMENTS
26.	IFF, 1982	Live Skyline – Gravity Outhaul Carriage, Chain Chokers, Manual Slackpull, No Haulback	Uphill	Singlespan	Chain Chokers		X	
27.	IFF, 1982	Highlead – Lateral Capability using Block Instead of Butt Rigging, Manual Slackpull, Cable Chokers	Uphill	Singlespan	Chokers		X	
28.	IFF, 1982	Running Skyline - Double Block Carriage, Manual Slackpull, Tow Grapple	Uphill	Singlespan	Tow Grapple		X	
29.	IFF, 1982	Running Skyline - Double Block Carriage, Manual Slackpull, Cable Chokers	Uphill	Singlespan	Chokers		X	

FOOTNOTES

① Yarder is uphill. Gravity, with yarder acting as a brake, is used to lower logs downhill to the landing.

② 2 skyline roads - multispan, 1 skyline road - singlespan.

③ 4 skyline roads - multispan, 3 skyline roads - single span.

④ An Igland-Jones multispan carriage was used and manual slackpulling was required in this pre-bunching operation. Since inhaul and outhaul to the landing was not required, the haulback wasn't used. A tie-back line was substituted for the haulback to maintain the carriage position during lateral outhaul and lateral inhaul.

⑤ Christy gravity outhaul carriage was used and manual slackpulling required in this pre-bunching operation. Inhaul and outhaul not required since logs were being pre-bunched at the corridor. Carriage was locked to the skyline "stop" ("stop" attached to skyline by means of a mechanical clamp). The skyline had to be lowered to release the clamp each time the carriage was moved to a new pre-bunching position. The intermediate supports had to be lowered in order to move the carriage past the supports.

⑥ This pre-bunching operation used both the Igland-Jones multispan carriage and the Christy gravity outhaul carriage. The haulback line was used to assist slackpulling. The haulback was rigged laterally to pull the mainline out from the carriage. A "squirrel" block was attached to the end of the haulback and the mainline was pulled through the squirrel block. Except for manual slackpulling, the comments in ④ and ⑤ regarding these two carriages apply here as well.

⑦ 2 skyline roads - singlespan, 1 skyline road - multispan.

⑧ 10 skyline roads - singlespan, 6 skyline roads - multispan.

⑨ 3 skyline roads - 2 intermediate supports, 2 skyline roads - 1 intermediate support.

⑩ 2 skyline roads - 1 intermediate support, 1 skyline road - 2 intermediate supports, 1 skyline road - singlespan.

⑪ Minimum landing width was 115 feet. Maximum landing width was 190 feet. Minimum length of span (horizontal) was 432 feet. Maximum length of span (horizontal) was 1044 feet.

⑫ 4 tailholds outside the unit boundaries, 2 tailholds inside the unit boundaries.

⑬ Tailholds are inside the unit boundaries.

FOOTNOTES (continued)

(14) In terms of cordslope, 13 of the corridors were downhill and 5 corridors were essentially flat. Slopes ranged from 22% downhill to 3% uphill.

(15) 2 man crew: yarder operator and choker setter, no swing skidder.

(16) 3 man crew: yarder operator and 2 choker setters, no swing skidder.

(17) 4 man crew: yarder operator, chaser and 2 choker setters, no swing skidder.

(18) 3 man crew: yarder operator, choker setter and skidder operator to swing and sort logs away from the yarding area.

(19) 4 man crew: yarder operator, 2 choker setters, and skidder operator to swing and sort logs away from the yarding area.

(20) 5 man crew: yarder operator, chaser, 2 choker setters and skidder operator to swing and sort logs away from the yarding area.

(21) Author's "combined" equation: independent variables include the number of choker setters, landing crew size (yarder operator with or without a chaser) and a variable which indicates the presence or absence of a "swing" skidder on the landing.

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

RIGGING AND YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/ DOWNHILL	SINGLESPAN/ MULTISPAN	CHOKERS/ GRAPPLE	YARDER HAS SWINGING BOOM? YES	NO	COMMENTS
30.	Zielinsky, 1980	2-Speed Drum Set Mounted on Back of Dump Truck Used to Pre-Bunch Logs to the Skyline Corridor, Manual Slackpulling. ②	Uphill	Singelspan	Chokers		X	① ⑦
31.	Gabrielli, 1980	Live Skyline-Gravity⑥ Outhaul ③, Self-Clamping Carriage.	Uphill	Singlespan	Chokers③	X		
32.	Gabrielli, 1980	Live Skyline-Gravity⑥ Outhaul ④, Self-Clamping Carriage.	Uphill	Singlespan	Chokers④	X		
33.	Gabrielli, 1980	Live Skyline-Gravity⑥ Outhaul ⑤, Self-Clamping Carriage.	Uphill	Singlespan	Chokers⑤	X		

FOOTNOTES

① Two landings in this study: Landing 1 was 0.1 acres.
Landing 2 was 0.08 acres.

② This pre-bunching yarder was positioned on the landing approximately where the swing yarder would later be located. The pre-bunching line was strung down the corridor and through a block attached to a choker or strap hung in the pre-bunching spar which was situated along the corridor edge. Line was manually pulled out to a turn of logs and the turn was then yarded into a deck at the pre-bunching spar. This procedure was repeated until all logs that were to be bunched to the spar were yarded. The rigging was then moved down the corridor to the next pre-bunching spar.

③ Three chokers and sliders were used.

④ Three preset ring chokers and a toggle hook were used.

⑤ Six ring chokers and a toggle hook were used.

⑥ Logs were cold decked and loading occurred after the yarder moved out. Using the yarder's swing capability, a deck was first built on the road behind the yarder. When there were more logs than a deck on the road could hold, the remaining logs were decked in front of the yarder in the corridor.

⑦ Length of spans (horizontal) ranged from 620 feet to 930 feet, the average span was 802 feet.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

CREW DATA

		CREW SIZE BY POSITION							
	REFERENCE SOURCE	HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	SKIDDER OPERATOR (6)	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
1.	Pursell, 1979	1	1	-	1 (8)	1	-	4 (1)	--
2.	Fisher, et al, 1980	-	1	-	-	2	-	3	None
3.	Hensel, et al, 1979	-	-	-	-	-	-	$\overline{4.5}$	--
4.	Hensel, et al, 1979	-	-	-	-	-	-	$\overline{4.25}$	--
5.	Kramer, 1978	-	-	-	-	Min. 1 Max. 2 Avg. 1.47	-	-	Crew unfamiliar with new machine
6.	Kramer, 1978	-	-	-	-	Min. 1 Max. 2 Avg. 1.31	-	-	Crew unfamiliar with new machine
7.	Kellogg, 1978 Unpublished	-	-	-	-	-	-	-	Crew unfamiliar with new carriage. Never worked "downhill" before.
8.	Kellogg, 1978 Unpublished	-	-	-	-	-	-	-	Crew unfamiliar with new carriage. Never worked "downhill" before.
9.	Neilson, 1977	-	1	-	-	Min. 1 (2) Max. 2	-	2 or 3 (2)	Crew unfamiliar with new machine. (3)
10.	Kellogg, 1976	-	-	-	-	-	-	1 (4)	Unfamiliar with new machine.
11.	Kellogg, 1976	0	1	0	0	Min. 1 Max. 2 Avg. 1.2	1	3 or 4	--

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

CREW DATA

		CREW SIZE BY POSITION							
	REFERENCE SOURCE	HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	SKIDDER OPERATOR (6)	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
12.	Keller, 1979	0	1	0	0	2 (5)	0	3	Yarding technique was new to the crew.
13.	Keller, 1979	0	1	0	0	2 (5)	0	3	Yarding technique was new to the crew.
14.	Keller, 1979	0	1	0	0	2 (5)	0	3	Yarding technique was new to the crew.
15.	McIntire, 1981	0	1	0	0	1	0	2	Crew unfamiliar with new yarder and carriage.
16.	McIntire, 1981	0	1	0	0	2	0	3	Crew unfamiliar with new yarder and carriage.
17.	McIntire, 1981	0	1	0	0	2	1	4	Crew unfamiliar with new yarder and carriage.
18.	McIntire, 1981	0	1	0	1	1	0	3	Crew unfamiliar with new yarder and carriage.
19.	McIntire, 1981	0	1	0	1	2	0	4	Crew unfamiliar with new yarder and carriage.
20.	McIntire, 1981	0	1	0	1	2	1	5	Crew unfamiliar with new yarder and carriage.
21.	McIntire, 1981	0	1	0	0 or 1	1 or 2	0 or 1	(7)	Crew unfamiliar with new yarder and carriage.

FOOTNOTES

(1) Crew paid hourly.

(2) A single choker setter operated for 75% of the turns observed.

(3) Study conducted two weeks after machine was delivered to yarding crew.

(4) One man performed all yarding functions.

(5) Pre-bunching operation-choker setters performed both hook and unhook tasks.

(6) Used to keep landing clear by sorting and decking logs along the road.

(7) Independent variables in production equation include: a) number of choker setters (1 or 2), b) presence or absence of chaser (landing crew = 1 (yarder operator) or 2 (yarder operator and chaser)), and c) presence or absence of swing skidder.

(8) Skidder operator "chased" at the landing when he was free of his other duties.

I. SMALL YARDER: MAXIMUM MAINLINE PULL < 25000 lbs.

CREW DATA

	REFERENCE SOURCE	CREW SIZE BY POSITION							
		HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	SKIDDER OPERATOR	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
22.	Aulerich, 1975	-	-	-	-	-	-	-	--
23.	Aulerich, 1975	-	-	-	-	-	-	-	--
24.	Aulerich, 1975	-	-	-	-	-	-	4	Crew consisted of personnel of the Forest Engineering Department, O.S.U.
25.	Aulerich, et al, 1974	-	1	-	-	2	1 (1)	4	Commercial logging crew.
26.	IFF, 1982	0	1 (2)	0	0	1	0	2	Inexperienced.
27.	IFF, 1982	0	1 (2)	0	0	1	0	2	Inexperienced.
28.	IFF, 1982	0	1 (2)	0	0	1	0	2	Inexperienced.
29.	IFF, 1982	0	1 (2)	0	0	1	0	2	Inexperienced.
30.	Zielinsky, 1980	0	1	0	0	2	0	3	Commercial logging crew. (3)
31.	Gabrielli, 1980	0	1	1	0	1 (4)	1 (4)	4	Commercial logging crew. (4)
32.	Gabrielli, 1980	0	1	1	0	1 (4)	1 (4)	4	Commercial logging crew. (4)
33.	Gabrielli, 1980	0	1	1	0	1 (4)	1 (4)	4	Commercial logging crew. (4)

FOOTNOTES

(1) Chaser doubled as a skidder operator to swing logs from the landing to the loading deck.

(2) Doubled as chaser.

(3) One choker setter had two years woods experience. The other choker setter alternated between the owner (good experience) and a man with six months rigging experience.

(4) Yarder operator and rigging slinger were part owners with about 10 years logging experience, the last couple of years with the SJ-2. A third crew member was the same throughout the study, working either as the choker setter or chaser. Three different people worked as the fourth crew member. All of the crew had at least a few years of logging experience.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs

PHYSICAL DATA OF SALE AREA

	REFERENCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ACRE (MBF)	DENSITY STEMS/ACRE	COMMENTS	LOCATION OF STUDY
1.	Pursell, 1979	44.7	Retangular	Terraces and Steep Slopes	Height = 50' DBH = 10"	Age= 38	⑱	2300(ft^3)	200	⑯	Pack Forest, Pierce County, Western WA
2.	Fisher, et al 1980	62.0	Retangular	--	15 inches①	--	②	--	--	--	Jefferson N.F. near Marion, Virginia
3.	Hensel, et al 1979	--	--	--	--	--	--	③	--	--	Washington/Idaho Area
4.	Hensel, et al 1979	--	--	--	--	--	--	③	--	--	Washington/Idaho Area
5.	Kramer, 1978	4.64	Irregular	Small Draw Near Ridge Top	④	35-40	Red Alder, Big Leaf Maple	2343⑤	--	⑦	Spaulding Tract, Benton Co., OR
6.	Kramer, 1978	1.32	Irregular	Pronounced Convex Break	⑥	35-40	" "	2590⑤	--	⑦	Blodgett Tract Forest Columbia Co., OR
7.	Kellogg, 1978 Unpublished	15	Rectangular⑧	Groundslope=40% Constant Slope	--	--	--	--	--	--	McDonald Forest Corvallis, OR
8.	Kellogg, 1978 Unpublished	15	Rectangular⑧	" " "	--	--	--	--	--	--	McDonald Forest Corvallis, OR
9.	Neilson, 1977	--	Irregular	Pronounced Convex Break	Height = 85' DBH = 14.1"	35-40	Douglas-fir	5060(ft^3)	226	⑦	Blodgett Tract Forest Columbia Co., OR
10.	Kellogg, 1976	2.76	--	--	--	35-40	" "	4824(ft^3)	221.4	--	McDonald Forest, Corvallis, OR
11.	Kellogg, 1976	2.76	--	--	--	35-40	" "	" "	" "	--	" "

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

PHYSICAL DATA OF SALE AREA

	REFERENCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
12.	Keller, 1979	58.24 (9)	Rectangular Corridors 250' wide	(10)	(11)	27-53	(12)	6601(ft^3)	195	--	Blodgett Tract Forest, Columbia County, OR
13.	Keller, 1979	58.24 (9)	" "	(10)	(11)	27-53	(12)	" "	195	--	" "
14.	Keller, 1979	58.24 (9)	" "	(10)	(11)	27-53	(12)	" "	195	--	" "
15.	McIntire, 1981	65 (13)	--	Slopes Gentle 10-20%	$\overline{DBH}$= 11 (14)	20-40	(15)	5000(ft^3)	245 (14)	(17)	Paul Dunn Forest Benton Co., OR
16.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "
17.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "
18.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "
19.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "
20.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "
21.	McIntire, 1981	" "	--	" "	" "	20-40	(15)	" "	""	(17)	" "

FOOTNOTES

(1) The average diameter (average of small and large ends) of the harvested logs with a minimum top diameter of 8 inches. Average length was 34 feet.

(2) Primarily basswood, black and yellow birch, red and white oak and sugar maple. Smaller amounts of ash, hard maple and cherry.

(3) Timber harvested was purchased as fire salvage. Cutting prescription called for a selection cut.

(4) Average log length = 26.4'.
Average scaling diameter inside bark = 10.1"

(5) Average log volume per acre in cubic feet.

(6) Average log length = 22.0'.
Average scaling diameter inside bark = 9.6".

(7) Formula used to calculate volume was: $V = (0.001818)\,(L)[D_1^2 + D_2^2 + (D_1)\,(D_2)]$

where: V = log volume in FT^3
L = log length in feet
D_1 = large end d.i.b. in inches
D_2 = small end d.i.b. in inches

(8) Seven corridors fanshaped from one landing. Remaining two corridors parallel the last corridor in the fan-shaped set.

(9) Total area of study. Area divided into 5 different yarding techniques plus an uncut treatment for a total of six different treatments.
Uncut treatment covers approximately 50% of the total area. Area specific to this production equation is a portion of the remaining acreage.

(10) Topography required intermediate supports. Logging corridors had northeast or southwest aspects.

(11) $\overline{DBH}$ (Douglas-fir) = 16.7" $\overline{HEIGHT}$ (Douglas-fir) = 88.4'
$\overline{DBH}$ (Western Hemlock) = 12.0" $\overline{HEIGHT}$ (Western Hemlock) = 79.1'
$\overline{DBH}$ (total merchantable conifer) = 13.8"

FOOTNOTES (continued)

(12) Approximately 38% Douglas-fir and 62% Western Hemlock by volume, some Red Alder.

(13) Total area of study - only a portion used for this production equation.

(14) Value is for fir component only.

(15) Approximately 80% fir and 20% hardwoods by volume. Species were: Douglas-fir, Grand fir, Bigleaf Maple and Pacific Madrone.

(16) Understory vegetation was a salal - swordfern association.

(17) Smalian rule was used to calculate volumes.

(18) Based on number of stems; 95% Douglas-fir, 3% Red Alder, .015% Bigleaf Maple and .005% Western Red Cedar.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25,000 lbs.

PHYSICAL DATA OF SALE AREA

	REFERENCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
22.	Aulerich, 1975	--	--	--	$\overline{DBH}$ = 10"	35	Douglas-fir	--	--	--	Western Oregon
23.	Aulerich, 1975	--	--	--	" "	35	" "	--	--	--	Western Oregon
24.	Aulerich, 1975	--	--	30% to 50% Slopes	" "	35 to 40	" "	10.5 (12)	--	--	McDonald Forest Corvallis, OR
25.	Aulerich et al., 1974	95	--	(1)	" "	35	" "	" "	--	--	" "
26.	IFF, 1982	--	--	15% to 30% Slopes Terraces Cross Slopes	DBH = 6"-20" $\overline{DBH}$ = 8"	--	Slash Pine Shortleaf Pine	15 (2)	150	--	Waverly, Alabama
27.	IFF, 1982	--	--	" "	" " "	--	" "	"	"	--	" "
28.	IFF, 1982	--	--	" "	" " "	--	" "	"	"	--	" "
29.	IFF, 1982	--	--	" "	" " "	--	" "	"	"	--	" "
30.	Zielinsky, 1980	26.6	Fanshaped Settings	(3)	$\overline{DBH}$ = 17"	60 to 90	(4)	93.75 (2)	70	(11)	Linn County, OR
31.	Gabrielli, 1980	13.58	--	(6)	$\overline{DBH}$= 8.3" (7)	$\overline{Age}$ = 33 (8)	(9)	5250 (10)	483 (5)	(13)	Grande Ronde, OR
32.	Gabrielli, 1980	13.58	--	(6)	" " "	"	(9)	" "	"	(13)	" "
33.	Gabrielli, 1980	13.58	--	(6)	" " "	"	(9)	" "	"	(13)	" "

FOOTNOTES

(1) Data was segregated by slope classes of 20% and 40%.

(2) C units/acre

(3) Two units in the study. Both have northeast to northwest aspects. In both units skyline corridor profiles are characterized by slopes in excess of 60% immediately below the landings, flattening out to less than 25% about one third of the way down the slope.

(4) Main merchantable species is Douglas-fir. Western Hemlock accounted for 0.4% by volume.

(5) Merchantable stems (over 6" dbh). Total number of trees (over 1.5" dbh) per acre was 1091 .

(6) Average elevation is 2000 feet above mean sea level. East aspect. Slope averages 40%.

(7) Mean dbh of merchantable stems (over 6" dbh). Mean dbh of the total stand (over 1.5") was 5.7".

(8) Average of dominant trees in this uneven aged stand.

(9) Species mix was 48% Western Hemlock, 45% Douglas-fir and 7% White fir.

(10) Cubic feet/acre. Board feet/acre = 17850 (based on conversion factor of 3.42 board feet per cubic foot).

(11) Understory consisted of vine maple and scattered Pacific yew. Soil was a Holocomb silty clay loam.

(12) Scribner.

(13) Soil is from the Tyee sandstone formation.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 1/3

	REFERENCE	TYPE OF CUT [c.c., partial, thinning below/above, wholetree tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET) MIN	MAX	AVG	LATERAL YARDING DISTANCE (FEET) MIN	MAX	AVG	CHORDSLOPE % MIN	MAX	AVG	GROUNDSLOPE % MIN	MAX	AVG
1.	Pursell, 1979	Thinning - Log Length	Summer 1978	---	1072	486	---	---	22	-29	+2	---	-3	+22	---
2.	Fisher, et al 1980	Clearcut - Generally Tree Length	1977	---	700	369	---	---	---	---	---	---	---	---	---
3.	Hensel, et al 1979	Fire Salvage-Selection	(2)	---	---	1468	---	---	80	---	---	---	---	---	-50
4.	Hensel, et al 1979	Fire Salvage-Selection	(2)	---	---	1990	---	---	97	---	---	---	---	---	54
5.	Kramer, 1978	Clearcut	Summer 1977	0	365	148	0	160	33.8	-16.4	-36.0	-26.4	---	---	---
6.	Kramer, 1978	Clearcut	Summer 1977	200	520	367	0	110	41	---	---	---	---	---	---
7.	Kellogg, 1978 Unpublished	Thinning-Tree Length	Sept 1978 (8) to June 1979	10	950	448	0	345	57.9	---	---	---	---	---	---
8.	Kellogg, 1978 Unpublished	Thinning-Log Length	Sept1978 (8) to June 1979	60	970	492	0	170 (3)	28 (3)	---	---	---	---	---	---
9.	Neilson, 1977	Thinning-Log Length	Summer 1977	0	650	224	0	140	41	---	---	---	10	70	---
10.	Kellogg, 1976	Thinning-Log Length	Winter 1976	---	---	76	---	---	(4)	---	---	---	---	---	---
11.	Kellogg, 1976	Thinning-Log Length	Winter 1976	---	---	178	---	---	(5)	---	---	---	---	---	25
12.	Keller, 1979	Thinning-Log Length	Summer 1978	20	900	365.6	15 (3)	135 (3)	63.8 (3)	---	---	---	0	31	12.3
13.	Keller, 1979	Thinning-Log Length	Summer 1978	10	807	319.3	15 (3)	130 (3)	55.3 (3)	---	---	---	0	32	13.0
14.	Keller, 1979	Thinning-Log Length	Summer 1978	25	880	379.1	10 (3)	140 (3)	64.0 (3)	---	---	---	0	44	10.6

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA [1/3]

REFERENCE	TYPE OF CUT [c.c., partial, thinning below/ above, wholetree tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET) MIN	MAX	AVG	LATERAL YARDING DISTANCE (FEET) MIN	MAX	AVG	CHORDSLOPE % MIN	MAX	AVG	GROUNDSLOPE % MIN	MAX	AVG
15. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
16. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
17. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
18. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
19. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
20. McIntire, 1981	Thinning-Log Length	Summer 1980	---	---	---	---	---	---	---	---	---	---	---	---
21. McIntire, 1981	Thinning-Log Length	Summer 1980	0	790	314.3	0	200	36.6 [3]	---	---	---	---	---	---

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 2/3

REFERENCE	PIECES/TURN MIN	PIECES/TURN MAX	PIECES/TURN AVG	GROSS VOLUME PER PIECE (Bd Ft) MIN	GROSS VOLUME PER PIECE (Bd Ft) MAX	GROSS VOLUME PER PIECE (Bd Ft) AVG	GROSS VOLUME PER TURN (Bd Ft) MIN	GROSS VOLUME PER TURN (Bd Ft) MAX	GROSS VOLUME PER TURN (Bd Ft) AVG	THINNING INTENSITY (BEFORE/AFTER)
1. Pursell, 1979	---	---	2.6	---	---	9.3 (1)	---	---	24.3 (1)	200/163 (Stems/acre)
2. Fisher, et al 1980	---	---	1.35	---	---	---	---	---	52.8 (1)	---
3. Hensel, et al 1979	---	---	2.82	---	---	---	---	---	768	---
4. Hensel, et al 1979	---	---	4.87	---	---	---	---	---	853	---
5. Kramer, 1978	1	4	1.46	---	---	16.5 (1)	1.0 (1)	76.4 (1)	24.06 (1)	---
6. Kramer, 1978	1	3	1.44	---	---	15.83 (1)	3.6 (1)	54.9 (1)	22.8 (1)	---
7. Kellogg, 1978 Unpublished	1	4	1.76	---	---	---	2.98 (1)	108.5 (1)	30.07 (1)	Approximately 50% Stem Removal
8. Kellogg, 1978 Unpublished	1	4	1.92	---	---	---	4.64 (1)	77.69 (1)	24.64 (1)	Approximately 50% Stem Removal
9. Neilson, 1977	1	4	1.62	---	---	---	2.1 (1)	60.0 (1)	21.0 (1)	42% Stems Removed 37% Volume Removed
10. Kellogg, 1976	---	---	1.3	---	---	---	---	---	20.69 (1)	39% Stems Removed 36% Volume Removed
11. Kellogg, 1976	---	---	2.8	---	---	---	---	---	42.31 (1)	39% Stems Removed 36% Volume Removed
12. Keller, 1979	1	4	1.8	3.0	44.4	12.4	3.0 (1)	69.0 (1)	21.3 (1)	(6)
13. Keller, 1979	1	3	1.6	2.0	63.8	13.2	2.0 (1)	72.0 (1)	19.8 (1)	(6)
14. Keller, 1979	1	3	1.4	2.7	86.8	13.4	3.0 (1)	87.0 (1)	17.9 (1)	(6)

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 2/3

REFERENCE	PIECES/TURN MIN	PIECES/TURN MAX	PIECES/TURN AVG	GROSS VOLUME PER PIECE (Bd Ft) MIN	GROSS VOLUME PER PIECE (Bd Ft) MAX	GROSS VOLUME PER PIECE (Bd Ft) AVG	GROSS VOLUME PER TURN (Bd Ft) MIN	GROSS VOLUME PER TURN (Bd Ft) MAX	GROSS VOLUME PER TURN (Bd Ft) AVG	THINNING INTENSITY
15. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
16. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
17. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
18. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
19. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
20. McIntire, 1981	---	---	---	---	---	---	---	---	---	(7) c.36% Stem Removal
21. McIntire, 1981	0	5	1.87	---	---	---	1.7 (1)	77.9 (1)	23.2 (1)	

FOOTNOTES

(1) Volume given in cubic feet.

(2) Study dates not given in article, article submitted for publication 1978.

(3) Perpendicular distance to skyline corridor NOT the actual lateral yarding distance.

(4) Single drum winch pre-bunching logs into skyline corridor.

(5) Yarder swinging pre-bunched logs in the skyline corridor up to the landing.

(6) From cruise data: 33% of stems removed, 23% of volume removed. Using data from the logging study, volume removed was estimated at 18%. These are general values for the entire study area. Data used to generate this particular production equation came from only a portion of the study area.

(7) Figure applies to the fir stems only.

(8) Logging crew consisted of O.S.U. students that worked on weekends and during school breaks.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 1/3

REFERENCE	TYPE OF CUT [c.c., partial, thinning below/ above, wholetree tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET)			LATERAL YARDING DISTANCE (FEET)			CHORDSLOPE %			GROUNDSLOPE %		
			MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
22. Aulerich, 1975	Thinning	---	---	---	---	---	---	---	---	---	---	---	---	---
23. Aulerich, 1975	Thinning	---	---	---	---	---	---	---	---	---	---	---	---	---
24. Aulerich, 1975	Thinning	Dec. 1974 to Jan. 1975	---	290	95	---	120	31	---	---	---	---	---	---
25. Aulerich, et al 1974	Thinning	Summer 1972	---	---	310.7	---	---	49.2	---	---	---	---	---	---
26. IFF, 1982	Thinning	Spring 1979	10	154	98.9	5	73	32.6	---	---	---	11	54	19.6
27. IFF, 1982	Thinning	Spring 1979	40	168	95.2	3	59	25.8	---	---	---	2	14	5.8
28. IFF, 1982	Thinning	Spring 1979	22	220	127.2	3	107	28.5	---	---	---	8	21	16.2
29. IFF, 1982	Thinning	Spring 1979	34	184	120.4	5	117	42.3	---	---	---	4	21	10.2
30. Zielinsky, 1980	Thinning	Aug. 9 - Sept. 30, 1979	190	890	575.9	10	214	92.75	---	---	---	---	70+	---
31. Garbrielli, 1980	Thinning	Late Summer 1979	0	750	379.3	0	150	39.2	---	---	---	---	---	---
32. Gabrielli, 1980	Thinning	Late Summer 1979	10	675	345.9	0	127.3	54.7	---	---	---	---	---	---
33. Gabrielli, 1980	Thinning	Late Summer 1979	25	700	376.3	0	193.2	49.0	---	---	---	---	---	---

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 2/3

REFERENCE	PIECES/TURN MIN	MAX	AVG	GROSS VOLUME PER PIECE (Bd Ft) MIN	MAX	AVG	GROSS VOLUME PER TURN (Bd Ft) MIN	MAX	AVG	THINNING INTENSITY
22. Aulerich, 1975	---	---	---	---	---	---	---	---	---	---
23. Aulerich, 1975	---	---	---	---	---	---	---	---	---	---
24. Aulerich, 1975	---	---	2.3	---	---	---	---	---	---	Approximately 50% Stem Removal
25. Aulerich, et al 1974	---	---	2.53	---	---	51 (1)	---	---	---	(2)
26. IFF, 1982	1	3	1.64	---	---	---	97 (3)	2293 (3)	809 (3)	(4)
27. IFF, 1982	1	2	1.08	---	---	---	97 (3)	2109 (3)	717 (3)	(4)
28. IFF, 1982	1	1	1	---	---	---	97 (3)	3000 (3)	720 (3)	(4)
29. IFF, 1982	1	2	1.04	---	---	---	97 (3)	3203 (3)	522 (3)	(4)
30. Zielinsky, 1980	1	5	2.14	---	---	---	0.04 (5)	1.38 (5)	0.54 (5)	37% Stems Removed 19% Volume Removed
31. Gabrielli, 1980	1	6	3.0	---	---	---	2.41 (6)	71.08 (6)	21.28 (6)	40% of Merchantable Stems Removed
32. Gabrielli, 1980	1	7	3.23	---	---	---	2.41 (6)	88.99 (6)	23.68 (6)	40% of Merchantable Stems Removed
33. Gabrielli, 1980	2	9	5.3	---	---	---	6.86 (6)	80.13 (6)	40.13 (6)	40% of Merchantable Stems Removed

FOOTNOTES

① Cubic foot volume was 12.3. No "yum" yarding included.

② Thinning intensity ranged from 35% to 55% of the merchantable stems (8" - 12" DBH).

③ Value is turn weight estimated from volume equations.

④ Before thinning, the stand averaged 15 cunits/acre.
After thinning, the stand averaged approximately 7 cunits/acre.

⑤ Value given in cunits.

⑥ Value given in cubic feet. No "yum" yarding involved.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 3/3

REFERENCE	CUTTING PATTERN	LOG LEAD ANGLE (°) MIN	MAX	AVG	CARRIAGE HEIGHT (FT) MIN	MAX	AVG	DECK HEIGHT (FT) MIN	MAX	AVG	SKIDDER PRESENT TO CLEAR DECK?	LOADER PRESENT YES	NO	# OF CHOKERS FLOWN	PRE-BUNCHED YES	NO	PRESET CHOKERS YES	NO	TOTAL # TURNS	TOTAL YARDING ROADS
1. Pursell, 1979	Herringbone	---	---	34 (7)	---	---	---	---	---	---	Yes		x	3		x		x	196	18
2. Fisher, et al 1980	--	---	---	---	---	---	---	---	---	---	No	Sometimes		-		x		x	95 (1)	--
3. Hensel, et al 1979	--	---	---	---	---	---	---	---	---	---	--	--		-		x		x	120	--
4. Hensel, et al 1979	--	---	---	---	---	---	---	---	---	---	--	--		-		x		x	110	--
5. Kramer, 1978	--	---	---	---	---	---	---	---	---	---	No	--		-		x		x	451	6
6. Kramer, 1978	--	---	---	---	6.0	42.0	27.0	0	14	5.6	No	--		-		x		x	150	3
7. Kellogg, 1978 Unpublished	Herringbone	(6)(2) 0	(6)(2) 135	---	10 (2)	30 (2)	---	2 (2)	12 (2)	---	--	--		3		x		x	311	5
8. Kellogg, 1978 Unpublished	Herringbone	30 (6)	180 (6)	147 (6)	10	35	21	2 (2)	12 (2)	---	--	--		3		x		x	250	4
9. Neilson, 1977	--	---	---	---	6	48	17.5	---	---	---	No		x	(3)		x	(4)		549	7
10. Kellogg, 1976	--	---	---	28.3 (5)	---	---	---	---	---	---	N/A	N/A		(8)		x		x	207	10 (11)
11. Kellogg, 1976	--	---	---	110.8 (6)	---	---	---	---	---	---	--	--		(9)	x			x	113	1
12. Keller, 1979	45° Lead to Skyline Corridor	12 (10)	80 (10)	45.8 (10)	12	39	21.2	---	---	---	--	--		2		x		x	198	2 (12)
13. Keller, 1979	45° Lead to Skyline Corridor	20 (10)	95 (10)	44.6 (10)	12	40	21.6	---	---	---	--	--		2		x		x	170	2 (12)
14. Keller, 1979	45° Lead to Skyline Corridor	20 (10)	99 (10)	52.5 (10)	10	47	20.8	---	---	---	--	--		2		x		x	468	3 (12)

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 3/3

REFERENCE	CUTTING PATTERN	LOG LEAD ANGLE (°) MIN	MAX	AVG	CARRIAGE HEIGHT (FT) MIN	MAX	AVG	DECK HEIGHT (FT) MIN	MAX	AVG	SKIDDER PRESENT TO CLEAR DECK?	LOADER PRESENT YES NO	# OF CHOKERS FLOWN	PRE-BUNCHED YES NO	PRESET CHOKERS YES NO	TOTAL # TURNS	TOTAL YARDING ROADS
15. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	No	(14)	--	--	--	--	3
16. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	No	(14)	--	--	--	--	3
17. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	No	(14)	--	--	--	--	3
18. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	Yes	(14)	--	--	--	--	3
19. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	Yes	(14)	--	--	--	--	3
20. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	Yes	(14)	--	--	--	--	1
21. McIntire, 1981	45° Lead to Skyline Corridor When Possible	---	---	---	---	---	---	---	---	---	(13)	(14)	--	--	--	1485	16

FOOTNOTES

(1) Number of cycles upon which average times of phases and delays in the yarding cycle were based.

(2) Expected range of values at beginning of study.

(3) Number of chokes per cycle ranged from 1 to 2, with an average of 1.58.

(4) Logs preset per cycle ranged from 0 to 1, with an average of 0.14.

(5) Variable measured is the angle formed by the winch line and a projected line travelling along the length of and through the center of the log, (e.g., a 90° lead angle implies that the log is at a right angle to the winch line.).

(6) Angle the turn of logs forms with the skyline. 0° indicates the turn is parallel to the skyline. At 90°, the turn is perpendicular to the skyline. Angles measured from the skyline and rotate in the downhill direction toward the log turn.

(7) Angles measured with reference to a line parallel to the corridor. Sighting was made down the log and always pointing toward the landing. Angles formed by the line of sight and line parallel to the corridor. Possible range of angles is +90° to -90°. If the line of sight must be rotated toward the corridor in a counterclockwise direction, a negative angle results.

(8) Number of chokers used averaged 1.4.

(9) Number of chokers used averaged 2.0.

(10) Variable measured is the number of "settings". A setting refers to a spar tree and all the material yarded to that tree. In this study there were 5 machine locations and 10 "settings".

(11) Value is the lead angle at which a turn of logs is yarded. Angle is measured as a deflection angle from the direction of the skyline corridor.

(12) Value is the number of skyline corridors on which this system was used to pre-bunch logs.

(13) Presence or absence of skidder is one of the independent variables in the production equation.

(14) Self-loading log trucks with Crown Super 3000 self-loaders were used.

I. SMALL YARDERS: MAXIMUM MAINLINE PULL < 25000 lbs.

TIME STUDY DATA 3/3

REFERENCE	CUTTING PATTERN	LOG LEAD ANGLE (°) MIN	MAX	AVG	CARRIAGE HEIGHT (FT) MIN	MAX	AVG	DECK HEIGHT (FT) MIN	MAX	AVG	SKIDDER PRESENT TO CLEAR DECK?	LOADER PRESENT YES	NO	# OF CHOKERS FLOWN	PRE-BUNCHED YES	NO	PRESET CHOKERS YES	NO	TOTAL # TURNS	TOTAL YARDING ROADS
22. Aulerich, 1975	Random Thin	---	---	---	---	---	---	---	---	---	--	--		--	--			x	--	--
23. Aulerich, 1975	Herringbone	---	---	---	---	---	---	---	---	---	--	--		--	--			x	--	--
24. Aulerich, 1975	Random Thinning	---	---	---	---	---	---	---	---	---	--	--		--	--			x	83	--
25. Aulerich, et al 1974	--	---	---	---	---	---	---	---	---	---	Yes	--		--	--		--		685	--
26. IFF, 1982	--	---	---	---	---	---	---	---	---	---	--	--		--		x	x (2)		33 (3)	8 (4)
27. IFF, 1982	--	---	---	---	---	---	---	---	---	---	--	--		--		x		x	24 (3)	8 (4)
28. IFF, 1982	--	---	---	---	---	---	---	---	---	---	--	--		(1)		x		x	54 (3)	8 (4)
29. IFF, 1982	--	---	---	---	---	---	---	---	---	---	--	--		--		x		x	53 (3)	8 (4)
30. Zielinsky, 1980	Random	0	140	55.7 (5)	---	---	---	0	10	.57 (6)	No		x	2		x (7)		x	151	8 (4)
31. Gabrielli, 1980	Herringbone – c.45° Angle From the Corridor	0	105 (8)	41.3 (8)	20	40	35.2	---	---	---	No		x	3		x		x	160	1
32. Gabrielli, 1980	Herringbone – c.45° Angle From the Corridor	0	105 (8)	51.9 (8)	10	35	29.1	---	---	---	No		x	3		x	x		197	1
33. Gabrielli, 1980	Herringbone – c.45° Angle From the Corridor	0	90 (8)	35.1 (8)	15	50	28.2	---	---	---	No		x	6		x (9)		x	87	1

FOOTNOTES

(1) Single-log, 3-pronged tow-grapple used instead of chokers.

(2) Author states that adjustable chain chokers, with rings attached to the hook end, were used in an attempt to preset chokers.

(3) Number of turns used to calculate delay percentages.

(4) Total yarding roads for the study area. Author does not mention the number of roads involved in this equation.

(5) These values were measured as the angle between a line formed by the prolongation of a line through the axis of the log and the lead of the skidding line measured to the nearest 5 degrees in the horizontal plane.

(6) This is a pre-bunch deck along the skyline corridor.

(7) This equation is for pre-bunching logs to the corridor. Operation did not involve yarding any pre-bunched logs themselves.

(8) Angle is measured as a deflection angle from the skyline corridor to the inhaul path of the logs. Angle is turned looking toward the landing.

(9) Six chokers were used in this system. If there was a turn that had empty chokers and a few logs situated so they would not make a full turn by themselves, these logs would be bunched into the same full turn. This occurred on 14% of the turns. Time required over and above one cycle of lateral outhaul, hook and lateral inhaul to build a turn was classified as "bunch delay". The average time for the second lateral and hooking cycle was 1.38 minutes.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

PRODUCTION DATA

REFERENCE	REGRESSION EQUATION - TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME?	DELAY %	COMMENTS
1. Dykstra, 1975	3.69533 + 0.00287968 (BFVOL)[1] - 0.0040344 (BFVOL)[1]/(LOGS) + 0.00169959 (SYDIST)	R=.169 to .279[7]	Yes	15.5[3]	Total time equation obtained by summing outhaul, hook, inhaul and unhook equations—any "lateral" movement of chokers was included in these 4 elemental equations
2. Dykstra, 1975	3.86101 + 0.001693482 (BFVOL)[1] - 0.0021163 (BFVOL)[1]/(LOGS) + 0.00214649 (SYDIST)	R=.214 to .338[7]	Yes	15.5[3]	" " "
3. Dykstra, 1975	3.08932 + 0.00091426 (BFVOL)[1] - 0.0010625 (BFVOL)[1]/(LOGS) + 0.00184237 (SYDIST)	R=.101 to .303[7]	Yes	6.6[3]	" " "
4. Dykstra, 1975	2.39219 + 0.0019426 (CHORDSLOPE) - 0.11478 (RIGGERS)[1] + 0.00211976 (SYDIST). +[1] 0.0118565 (LDIST) + 0.030463 (LOGS) + 0.000863135 (BFVOL)[1] - 0.000397724 (BFVOL)[1]/(LOGS)	R=.151 to[1] .588[7]	Yes	27.6[3]	Total time equation obtained by summing outhaul, lateral outhaul, hook, lateral inhaul, inhaul and unhook equations. [1]
5. Gardner, 1980[2]	LN(TT) = 1.458050 + (.001)(0.486540)(SYDIST) + .001145 (LDIST) + (.001)(0.00896) (WEIGHT)	.34	Yes	14.4[4]	Material removed: Green and recent dead logs to 5½" top, 1/3 or more sound.
6. Gardner, 1980[2]	LN(TT) = 0.676830 + .000240 (LOGS)(LDIST) + .132343 LN(SYDIST) - 0.000032 (SLOPE) (VOL)	.44	Yes	23.7[4]	" " "
7. Gardner, 1980[2]	LN(TT) = 0.580136 - .003076 (SLOPE) + .001928 (LDIST) + 0.191832 LN(SYDIST) + (.00001)(0.400174) (LOGS)(WEIGHT)	.68	Yes	26.3[4]	" " "
8. Gardner, 1980[2]	LN(TT) = 0.689134 + .002647 (LDIST) + .337807 LN(SYDIST) + (.353655)(0.00001)(LOGS)(WEIGHT)	.32	Yes	6.4[4]	" " "
9. Gardner, 1980[2]	LN(TT) = 1.089454 + .019567 (LOGS) + 0.001065 (SYDIST) + .000617 (VOL)-(0.001)(0.000545)(SYDIST)^2 + .000043 (LDIST)(SLOPE)	.48	Yes	8.2[4]	" " "

11. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

PRODUCTION DATA

REFERENCES	REGRESSION EQUATION - TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME?	DELAY %	COMMENTS
10. Gardner, 1980 (2)	LN(TT) = 1.812551 + .000940 (SYDIST) -.00950(SLOPE) + 0.001721 (LDIST) + (.00001)(0.277323)(LOGS) (WEIGHT)	.42	Yes	27.8 (4)	Material removed: Green and recent dead logs to 5½" top, 1/3 or more sound.
11. Gardner, 1980 (2)	LN(TT) = 1.910023 + .000545 (SYDIST) - .006795 (SLOPE) + 0.002118 (LDIST) - .4162 $(LOGS)^{-1}$	.41	Yes	10.8 (4)	" " "
12. Curtis, 1978 (6)	LOGS/HR = -5.5364 + 17.981 (LOGS) - 0.77521 (AYD)	.43	Yes	29.0 (5)	(12)
13. Curtis, 1978 (6)	LOGS/HR = 10.283 + 15.157 (LOGS) - 2.5147 (AYD) + 0.18561 (CHORDSLOPE)	.67	Yes	28.1 (5)	(12)
14. Keller, 1979	2.164 + .147 (LANDLOG) + .00281 (SYDIST) + .213 (CHOKERS)	.266	Yes	25.4 (5)	(8)
15. Keller, 1979	2.77 + .0222 (VOLUME) - .0492 (VOLUME)/(LOGS) - .634 (HOOKLOG)/(CHOKERS) + .463 (SINANG) + .000144 $(LATDIST^2)$ + $(.243 \times 10^{-5})$ $(SYDIST^2)$ + .0364 (CH)	.565	Yes	25.2 (5)	(9)

FOOTNOTES

(1) The constant for this equation includes the average of several "events" that were isolated by the study crew but are not considered normally as separate yarding events. This includes the time for the rigging crew to approach and move away from the hook point and the time required to raise and lower the skyline.

(2) LN = Natural Log   TT = Turn Time (minutes)

(3) Excludes yarding road changes, computed as $\frac{\text{Total Delay Time}}{\text{Total Productive Time + Total Delay Time}}$; total turn time (excluding yarding road changes) = $\frac{\text{Delay Free Turn Time (Regression Equation)}}{\frac{(100 - \text{Delay }\%)}{100}}$

e.g.; D.F.T. = 6 minutes, Delay % = 6.2%, Total Time = $\frac{6}{\frac{(100 - 6.2)}{100}}$ = 6.397 minutes

(4) Average foreign element time for all turns in percent. Foreign elements are delays attributed to machines, manpower, material, and environmental factors occurring within a turn cycle - does not include rest breaks, repairs, rerigging, etc. Total turn time = turn time (regression equation) x (1 + percent foreign element time).

TT (Regression) = 6 minutes, percent foreign element time = 14.4%; 6 x (1.144) = 6.864 minutes for total turn time.

(5) Excludes landing and yarding road changes.

(6) Regression equation results in number of logs yarded per productive hour (no delays, yarding or road changes).

(7) Range of "R" values for elemental equations. Total time equation obtained by summing elemental equations of the system (e.g., outhaul, hook, etc.).

(8) Included in delays were resets, sorting chokers or rigging, and repositioning a turn of logs on the deck for unhooking.

(9) Included in delays were resets and sorting chokers or rigging. Repositioning a turn of logs on the deck for unhooking was included in the unhook element of the yarding cycle and was not treated as a delay.

FOOTNOTES (continued)

(10) Where chokers are preset, only the number of choker setters actually participating in the hooking operation *is* used.

(11) Scribner volume was approximated with Knouf's rule: $V = [(D_s^2 - 3D_s)/10]\,[L/2]$

where: D_s = small end diameter in inches
L = length in feet
V = board feet volume

Logs over 40 feet long were scaled as two logs, one 40 feet long and the other L-40 feet long.

(12) Source of data used to generate these equations were gross (shift-level) time study records which the timber purchasers were required to keep.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

VARIABLES MEASURED BUT NOT USED IN REGRESSION EQUATIONS:

	REFERENCE	
1.	Dykstra, 1975	Chordslope %, Groundslope %, Soil Index, Brush Index, Choker Setters, Chasers
2.	Dykstra, 1975	Chordslope %, Groundslope %, Soil Index, Brush Index, Choker Setters, Chasers
3.	Dykstra, 1975	Chordslope %, Groundslope %, Soil Index, Brush Index, Choker Setters, Chasers
4.	Dykstra, 1976	Groundslope %, Soil Index, Brush Index, Chasers, Chokers
5.	Gardner, 1980	Groundslope %, Number of Logs Per Turn, Gross Board Foot Volume Per Turn
6.	Gardner, 1980	Weight of Load in Pounds
7.	Gardner, 1980	Gross Board Foot Volume Per turn
8.	Gardner, 1980	Gross Board Foot Volume Per Turn, Groundslope %
9.	Gardner, 1980	Weight of Load in Pounds
10.	Gardner, 1980	Gross Board Foot Volume Per Turn
11.	Gardner, 1980	Gross Board Foot Volume Per Turn, Weight of Load in Pounds
12.	Curtis, 1978	Number of cable road changes/day, average groundslope %, landing size, number of cable roads used at a landing, ground profile index, total number of men working on yarding operation, type of cut, index combining the aspect of the work site with the season of work, initial number of trees per acre, number of trees cut per acre, chordslope, dummy variable relating requirements for yarding "yum" ≥ 50 Bd. ft/piece, variable corresponding to Forest Service landscape management classes (0=preservation to 4 = maximum modification), "ratio" (total # of mechantable logs yarded for the day divided by total logs yarded that day).
13.	Curtis, 1978	Same as regression equation above (regression #12) with the exception of chordslope.
14.	Keller, 1979	Carriage height, groundslope %, number of logs hooked in a turn, deck height, perpendicular lateral distance of turn from corridor, slope direction with respect to outhaul direction.
15.	Keller, 1979	Groundslope %, lead angle, actual lateral yarding distance, slope direction with respect to outhaul direction.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25000 < 71000 lbs.

MACHINE DATA (1 of 2)

REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT) SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
1. Dykstra, 1975	West Coast Falcon	--	--	-/-/2000	67(1)/2120(2)/1200	--	-/-/2700	1/¾/-/1
2. Dykstra, 1975	West Coast Falcon	--	--	-/-/2000	67(1)/2120(2)/1200	--	-/-/2700	1/¾/-/1
3. Dykstra, 1975	Smith-Berger Planet-Lok L-1	--	Marc I Self-Propelled	--	62(3)/425(3)/2200	-/-/2300	29(4)/1800(4)/4400	-/⅞/⅝/⅞
4. Dykstra, 1976	Skagit GT-3(7)	--	--	--	67.6(5)/1460(6)/1200	67.6(5)/1460(6)/1200	41.3(5)/2275(6)/2200	-/⅝/⅝/¾
5. Gardner, 1980	Skagit GT-3	--	--	--	$-/-/\frac{1700}{1100}$	$-/-/\frac{1700}{1100}$	$-/-/\frac{2600}{2400}$	$-/\frac{5/8}{3/4}/\frac{5/8}{3/4}/\frac{3/8}{3/4}$
6. Gardner, 1980	Skagit GT-3	--	--	--	$-/-/\frac{1700}{1100}$	$-/-/\frac{1700}{1100}$	$-/-/\frac{2600}{2400}$	$-/\frac{5/8}{3/4}/\frac{5/8}{3/4}/\frac{3/8}{3/4}$
7. Gardner, 1980	Skagit GT-3	--	--	--	$-/-/\frac{1700}{1100}$	$-/-/\frac{1700}{1100}$	$-/-/\frac{2600}{2400}$	$-/\frac{5/8}{3/4}/\frac{5/8}{3/4}/\frac{3/8}{3/4}$
8. Gardner, 1980	Skagit GT-3	--	--	--	$-/-/\frac{1700}{1100}$	$-/-/\frac{1700}{1100}$	$-/-/\frac{2600}{2400}$	$-/\frac{5/8}{3/4}/\frac{5/8}{3/4}/\frac{3/8}{3/4}$
9. Gardner, 1980	Skagit GT-3	--	--	--	$-/-/\frac{1700}{1100}$	$-/-/\frac{1700}{1100}$	$-/-/\frac{2600}{2400}$	$-/\frac{5/8}{3/4}/\frac{5/8}{3/4}/\frac{3/8}{3/4}$
10. Gardner, 1980	Link Belt HC-78B	--	--	-/-/1100	-/-/1300	--	--	⅝/½/-/-
11. Gardner, 1980	Link Belt HC-78B	--	--	-/-/1100	-/-/1300	--	--	⅝/½/-/-

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

MACHINE DATA (1 of 2)

	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS: DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT) — SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
12.	Curtis, 1978	West Coast Falcon	--	--	-/-/2000	67(1)/2120(2)/1200	--	-/-/2700	1/3/4/--/1
13.	Curtis, 1978	Skagit GT-3	--	--	--	67.6(5)/1460(6)/1200	67.6(5)/1460(6)/1200	41.3(5)/2275(6)/2200	-/5/8/5/8/3/4
14.	Keller, 1979	West Coast Falcon	Koller (Multispan)(8)	--	-/-/1600	67(1)/2120(2)/1200	-/-/1600	-/-/2200	1 1/8/3/4/7/16/9/16
15.	Keller, 1979	West Coast Falcon	West Coast (Slackpulling)	--	-/-/1600	67(1)/2120(2)/1200	-/-/1600	-/-/2200	1 1/8/3/4/7/16/9/16

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs

MACHINE DATA (2 of 2)

	YARDER SPECIFICATIONS			CARRIAGE SPECIFICATIONS							
					LATERAL CAPABILITY			POSITION HOLDING			
REFERENCES	INTERLOCK	TOWER HEIGHT (FT)	WEIGHT (lbs)	MAN	LINES	CARR.	OPER. LINES	CLAMP	STOP	CAPACITY
1. Dykstra, 1975	None	49'	--	--	--	--	--	--	--	--
2. Dykstra, 1975	None	49'	--	--	--	--	--	--	--	--
3. Dykstra, 1975	Planetary	50'	--	--	--	--	--	--	--	--
4. Dykstra, 1976	Mechanical	44'6"	--		X		--	--	--	--
5. Gardner, 1980	Mechanical	44'	--		X		--	--	--	--
6. Gardner, 1980	Mechanical	44'	--		X		--	--	--	--
7. Gardner, 1980	Mechanical	44'	--		X		--	--	--	--
8. Gardner, 1980	Mechanical	44'	--		X		--	--	--	--
9. Gardner, 1980	Mechanical	44'	--		X		--	--	--	--
10. Gardner, 1980	None	41'6"	--	--	--	--	--	--	--	--
11. Gardner, 1980	None	41'6"	--	--	--	--	--	--	--	--
12. Curtis, 1978	None	49'	--	--	--	--	--	--	--	--
13. Curtis, 1978	Mechanical	44'6"	--	--	--	--	--	--	--	--
14. Keller, 1979	None	--	--	X				X		--
15. Keller, 1979	None	--	--		X		X			200' 5/8" dropline

FOOTNOTES

① Bare drum, third gear.

② Full drum, third gear.

③ Half full drum, low gear.

④ Half full drum, high gear.

⑤ Empty drum.

⑥ Full drum.

⑦ New machine.

⑧ Carriage design required the yarder's mainline be rigged as the skyline and the haulback be used for the skidding line.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL $\geq$ 25,000 < 71,000 lbs.

RIGGING & YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/ DOWNHILL	SINGLESPAN/ MULTISPAN	CHOKERS/ GRAPPLE	YARDING HAS SWINGING BOOM YES	NO	N/A	LANDING SIZE (LENGTH/WIDTH)
1.	Dykstra, 1975	Highlead	Uphill	Not Applicable	Chokers		x		①
2.	Dykstra, 1975	North Bend	Uphill	Singlespan	Chokers		x		①
3.	Dykstra, 1975	Grabinski	Uphill	Singlespan	Chokers		x		①
4.	Dykstra, 1976	Running Skyline	Uphill	Singlespan	Chokers	x			①
5.	Gardner, 1980	Running Skyline	Uphill	Singlespan	Chokers	x			-
6.	Gardner, 1980	Running Skyline	Downhill	Singlespan	Chokers	x			-
7.	Gardner, 1980	Running Skyline	Uphill	Singlespan	Chokers	x			-
8.	Gardner, 1980	Running Skyline	Downhill	Singlespan	Chokers	x			-
9.	Gardner, 1980	Running Skyline	Uphill	Singlespan	Chokers	x			-
10.	Gardner, 1980	Live-Gravity Outhaul	Uphill	Singlespan	Chokers	x			-
11.	Gardner, 1980	Live-Gravity Outhaul	Uphill	Singlespan	Chokers	x			-
12.	Curtis, 1978	North Bend	Uphill	Singlespan	Chokers		x		-
13.	Curtis, 1978	Running Skyline	Uphill	Singlespan	Chokers	x			-
14.	Keller, 1979	Standing-Gravity Outhaul, Swinging ②	Uphill	Multispan	Chokers		x		④
15.	Keller, 1979	Standing-Haulback ③ Required	Uphill	Singlespan	Chokers		x		④

FOOTNOTES

① Tailholds were generally outside the unit boundaries.

② Logs swung from corridor to landing, Koller carriage with hydraulic clamp used.

③ Haulback holds carriage in position during lateral yarding. West Coast mechanical slackpulling carriage used. Guinea line pulls slack. Mainline takes up slack.

④ Tailholds were inside the unit boundaries.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

CREW DATA

		CREW SIZE BY POSITION							
	REFERENCE SOURCE	HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	SIDE FOREMAN	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
1.	Dykstra, 1975	-	-	-	-	Min 2, Avg 2.8 Max 3	Min 1, Avg 1.0 Max 2	-	Commercial Logging Crew
2.	Dykstra, 1975	-	-	-	-	Min 2, Avg 2.8 Max 3	Min 1, Avg 1.2 Max 2	-	Commercial Logging Crew
3.	Dykstra, 1975	-	-	-	-	Min 2, Avg 3.0 Max 4	Min 1, Avg 1.0 Max 1	-	Commercial Logging Crew
4.	Dykstra, 1976	-	-	-	-	Min 1, Avg 2.0 Max 3	Min 1, Avg 1.0 Max 2	-	Commercial Logging Crew (1)
5.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
6.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
7.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
8.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
9.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
10.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
11.	Gardner, 1980	-	1	-	1	2	1	5	Commercial Logging Crew
12.	Curtis, 1978	-	-	-	-	-	-	Min 5, Avg 6.0 Max 6	Commercial Logging Crew
13.	Curtis, 1978	-	-	-	-	-	-	Min 4, Avg 5.7 Max 8	Commercial Logging Crew (1)
14.	Keller, 1979	0	1	1	0	0	1	3	Yarding technique was new to the crew
15.	Keller, 1979	0	1	1	0	1	1	4	Yarding technique and machinery familiar to crew

FOOTNOTE

① New machine and crew inexperienced with its operation.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

PHYSICAL DATA OF SALE AREA

	REFERENCE SOURCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
1.	Dykstra, 1975	0.55	Triangular to Rectangular	Gentle and Uniform	Largely Old-Growth	Ave: 150-250	(3)	40-85		Min 0, Avg .9 (1)(2) Max 1 (1)(2)	Mt. Hood National Forest, Oregon
2.	Dykstra, 1975	0.79	Triangular to Rectangular	Gentle and Uniform	Largely Old-Growth	Ave: 150-250	(3)	40-85		Min 0, Avg. 0 Max 0 (1)(2)	Mt. Hood National Forest, Oregon
3.	Dykstra, 1975	2.6	Triangular to Rectangular	Gentle and Uniform	Largely Old-Growth	Ave: 150-250	(3)	40-85		Min 0, Avg 0 Max 0 (2)(1)(1)	Mt. Hood National Forest, Oregon
4.	Dykstra, 1976	9.8	Irregular	Primarily Steep & Broken	Largely Old-Growth	Ave: >200	(4)	65 (net)		Min 0, Avg 1 Max 2	Mt. Hood National Forest, Oregon
5.	Gardner, 1980	-	--	Generally Uniform, 45-60%	--	--	Larch-Fir Stand	50-106 (4)		--	Coram Experimental Forest - Montana
6.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana
7.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana
8.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana
9.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana
10.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana
11.	Gardner, 1980	-	--	" "	--	--	" "	50-106 (4)		--	Coram Experimental Forest - Montana

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs

PHYSICAL DATA OF SALE AREA

	REFERENCE SOURCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
12.	Curtis, 1978	22.0	--	Min 0, Avg 0.8 (5) Max 2	Largely Old-Growth	--	(6)	--	--	Min 0.5, Avg 0.8 (7) Max 1.0	Mt. Hood N.F. Oregon
13.	Curtis, 1978	64	--	Min 0, Avg 0.9 (5) Max 2	Largely Old-Growth	--	(6)	--	--	Min 0.3, Avg 0.7 (7) Max 1.0	Mt. Hood N.F. Oregon
14.	Keller, 1979	20.61	Rectangular Corridors 250' Wide	(8) (9)	(10)	27-53	(11)	6601(ft^3)	195	--	Blodgett Tract Forest, Columbia County, Oregon
15.	Keller, 1979	10.06	Rectangular Corridors 250' Wide	(9)	(10)	27-53	(11)	6601(ft^3)	195	--	Blodgett Tract Forest, Columbia County, Oregon

FOOTNOTES

① Ground surface conditions ranged from firm, even footing with solid and dry soil to rocky, gravel-strewn, or otherwise hazardous footing. Average ground surface conditions provided firm, even footing.

② Brush and slash conditions at the hook point described as follows:

0 = light or nonexistent, does not restrict movement.

1 = medium, causes some difficulty in movement.

2 = heavy, hampers movement considerably.

Also, volume estimates were based on Scribner long-log scale.

③ By volume: 60-75% Douglas-fir. Other species: Western Hemlock, Western Red Cedar, Western White Pine, Western Larch, and Noble fir.

④ Range in 100's of FT^3 for the entire study area. 7 regression equations were generated from this area. Density of the area used to generate a particular regression equation falls within this range.

⑤ Values are an index describing shape of ground profile along the cable road based on the logger's map:

0 = concave
1 = constant
2 = convex

⑥ General timber type was old-growth Douglas-fir with mixed hemlock, Western Red Cedar and associated subalpine fir species.

⑦ Values are a ratio of the total number of merchantable logs yarded for the day divided by the total number of logs yarded for the day.

⑧ Topography required intermediate supports.

⑨ Logging corridors had northeast or southwest aspects.

⑩ $\overline{DBH}$ (Douglas-fir) = 16.7" $\overline{HEIGHT}$ (Douglas-fir) = 88.4' $\overline{DBH}$ (Western Hemlock) = 12.0" $\overline{HEIGHT}$ (Western Hemlock) = 79.1'

$\overline{DBH}$ (Total merchantable conifer) = 13.8"

FOOTNOTES (continued)

(11) Approximately 38% Douglas-fir and 62% Western Hemlock by volume, some Red Alder.

(12) A net volume to gross volume ratio was 80%.

(13) Ground surface conditions at the hook point provided firm, even footing. Soil was solid and dry.

(14) By volume: approximately 80% Douglas-fir. Other species: Western Hemlock, Western Red Cedar and Noble Fir.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

TIME STUDY DATA [1/3]

	REFERENCE	TYPE OF CUT [c.c., partial, thinning below/above, wholetree, tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET) MIN	SLOPE YARDING DISTANCE (FEET) MAX	SLOPE YARDING DISTANCE (FEET) AVG	LATERAL YARDING DISTANCE (FEET) MIN	LATERAL YARDING DISTANCE (FEET) MAX	LATERAL YARDING DISTANCE (FEET) AVG	CHORDSLOPE % MIN	CHORDSLOPE % MAX	CHORDSLOPE % AVG	GROUNDSLOPE % MIN	GROUNDSLOPE % MAX	GROUNDSLOPE % AVG
1.	Dykstra, 1975	Clearcut	July 23-26, 1973	100	525	299.6	---	---	---	-9	-10	-9.9	10	20	10.9
2.	Dykstra, 1975	Clearcut	July 10-13, 19, 26, 1973	50	400	188.3	---	---	---	-10	-25	-19.8	10	50	27.2
3.	Dykstra, 1975	Clearcut	July 9, 18-26, 1973	75	850	427.6	---	---	---	-34	-38	-34.4	15	50	29.7
4.	Dykstra, 1976	Partial Cut	Summer, 1974	35	610	273.0	0	85	20.3	-7	-38	-16.0	0	90	18.9
5.	Gardner, 1980[1]	Shelterwood	--	25[2]	1125[2]	---	0[2]	100[2]	---	---	---	---	---	---	---
6.	Gardner, 1980[1]	Shelterwood	--	25[2]	825[2]	---	0[2]	100[2]	---	---	---	---	-30[2]	20[2]	---
7.	Gardner, 1980[1]	Group Selection	---	50[2]	1250[2]	---	0[2]	100[2]	---	---	---	---	22[2]	72[2]	---
8.	Gardner, 1980[1]	Group Selection	---	180[2]	780[2]	---	10[2]	100[2]	---	---	---	---	---	---	---
9.	Gardner, 1980[1]	Clearcut	---	60[2]	910[2]	---	0[2]	100[2]	---	---	---	---	20[2]	60[2]	---
10.	Gardner, 1980[1]	Group Selection	---	50[2]	800[2]	---	0[2]	100[2]	---	---	---	---	40[2]	70[2]	---
11.	Gardner, 1980[1]	Clearcut	---	10[2]	970[2]	---	0[2]	100[2]	---	---	---	---	45[2]	70[2]	---
12.	Curtis, 1978	Clearcut	Sept-Nov 1973	2[4]	7[4]	3.2[4]	---	---	---	-10	-47	-26.9	1[5]	2[5]	1.4[5]
13.	Curtis, 1978	Shelterwood, Clearcut [3]	Jun-Nov 1974, Aug-Sep 1975	2[4]	9[4]	5[4]	---	---	---	-14	-50	-26.7	1[5]	2[5]	1.2[5]
14.	Keller, 1979	Thinning, Log Length	Summer, 1978	48	1000	469	0[9]	25[9]	0.9[9]	---	---	---	1.0	44.0	15.1
15.	Keller, 1979	Thinning, Log Length	Summer, 1978	15	1085	459	0[9]	150[9]	59[9]	---	---	---	0.0	48.0	14.2

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

TIME STUDY DATA [1]/3

	REFERENCE	TYPE OF CUT [c.c., partial, thinning below/ above, wholetree, tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET)			LATERAL YARDING DISTANCE (FEET)			CHORDSLOPE %			GROUNDSLOPE %		
				MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1.	Dykstra, 1975	Clearcut	July 23-26, 1973	100	525	299.6	---	---	---	-9	-10	-9.9	10	20	10.9
2.	Dykstra, 1975	Clearcut	July 10-13, 19, 26, 1973	50	400	188.3	---	---	---	-10	-25	-19.8	10	50	27.2
3.	Dykstra, 1975	Clearcut	July 9, 18-26, 1973	75	850	427.6	---	---	---	-34	-38	-34.4	15	50	29.7
4.	Dykstra, 1976	Partial Cut	Summer, 1974	35	610	273.0	0	85	20.3	-7	-38	-16.0	0	90	18.9
5.	Gardner, 1980[1]	Shelterwood	--	25[2]	1125[2]	---	0[2]	100[2]	---	---	---	---	---	---	---
6.	Gardner, 1980[1]	Shelterwood	--	25[2]	825[2]	---	0[2]	100[2]	---	---	---	---	-30[2]	20[2]	---
7.	Gardner, 1980[1]	Group Selection	---	50[2]	1250[2]	---	0[2]	100[2]	---	---	---	---	22[2]	72[2]	---
8.	Gardner, 1980[1]	Group Selection	---	180[2]	780[2]	---	10[2]	100[2]	---	---	---	---	---	---	---
9.	Gardner, 1980[1]	Clearcut	---	60[2]	910[2]	---	0[2]	100[2]	---	---	---	---	20[2]	60[2]	---
10.	Gardner, 1980[1]	Group Selection	---	50[2]	800[2]	---	0[2]	100[2]	---	---	---	---	40[2]	70[2]	---
11.	Gardner, 1980[1]	Clearcut	---	10[2]	970[2]	---	0[2]	100[2]	---	---	---	---	45[2]	70[2]	---
12.	Curtis, 1978	Clearcut	Sept-Nov 1973	2[4]	7[4]	3.2[4]	---	---	---	-10	-47	-26.9	1[5]	2[5]	1.4[5]
13.	Curtis, 1978	Shelterwood, Clearcut [3]	Jun-Nov 1974, Aug-Sep 1975	2[4]	9[4]	5[4]	---	---	---	-14	-50	-26.7	1[5]	2[5]	1.2[5]
14.	Keller, 1979	Thinning, Log Length	Summer, 1978	48	1000	469	0[9]	25[9]	0.9[9]	---	---	---	1.0	44.0	15.1
15.	Keller, 1979	Thinning, Log Length	Summer, 1978	15	1085	459	0[9]	150[9]	59[9]	---	---	---	0.0	48.0	14.2

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 <71,000 lbs.

TIME STUDY DATA 2/3

	REFERENCE	PIECES/TURN MIN	MAX	AVG	GROSS VOLUME PER PIECE (Bd Ft) MIN	MAX	AVG	GROSS VOLUME PER TURN (Bd. Ft.) MIN	MAX	AVG	WEIGHT PER TURN (LBS) MIN	MAX	AVG	THINNING INTENSITY %
1.	Dykstra, 1975	1	7	2.4	0	564	102.6	0 (12)	1125 (12)	246.1 (12)	---	---	---	--
2.	Dykstra, 1975	1	4	2.1	15	1474	301.3	15 (12)	2745 (12)	586.2 (12)	---	---	---	--
3.	Dykstra, 1975	1	5	2.2	0	2084	223.4	0 (12)	4165 (12)	493.3 (12)	---	---	---	--
4.	Dykstra, 1976	1	6	2.3	0	2820	168.8	0 (12)	2820 (12)	329.5 (12)	---	---	---	--
5.	Gardner, 1980	---	---	---	---	---	---	---	---	---	30 (2)	14830 (2)	---	--
6.	Gardner, 1980	1 (2)	10 (2)	---	---	---	---	5 (2)	255 (2)	---	---	---	---	--
7.	Gardner, 1980	1 (2)	10 (2)	---	---	---	---	---	---	---	200 (2)	10200 (2)	---	--
8.	Gardner, 1980	2 (2)	11 (2)	---	---	---	---	---	---	---	250 (2)	9250 (2)	---	--
9.	Gardner, 1980	1 (2)	10 (2)	---	---	---	---	5 (2)	205 (2)	---	---	---	---	--
10.	Gardner, 1980	1 (2)	12 (2)	---	---	---	---	---	---	---	75 (2)	8075 (2)	---	--
11.	Gardner, 1980	1 (2)	10 (2)	---	---	---	---	---	---	---	---	---	---	--
12.	Curtis, 1978	1.5 (6)	2.7 (6)	1.9 (6)	---	---	(7)	---	---	---	---	---	---	--
13.	Curtis, 1978	1.3 (6)	3.1 (6)	2.0 (6)	---	---	(7)	---	---	---	---	---	---	(3)
14.	Keller, 1979	1 (10)	13 (10)	5.1 (10)	---	---	---	---	---	---	---	---	---	(8)
15.	Keller, 1979	1 (10)	8 (10)	3.8 (10)	---	---	---	7.2 (11)	150.3 (11)	47.4 (11)	---	---	---	(8)

FOOTNOTES

(1) Most time study data in this paper were not presented in a form where ranges and averages could be segregated according to particular aggression equations. The reference does provide a general idea of the range and averages of many parameters listed on this sheet.

(2) This is a range of values used by the author in conjunction with this particular regression equation. Seven equations are presented in the paper and actual averages and ranges of values observed during the study were not listed by specific regression equations.

(3) Eighteen acres clearcut, 46 acres shelterwood cut. Author states that shelterwood cut prescriptions were so heavy, they created a near-clearcut condition.

(4) Value is average yarding distance for the day recorded in 100's of feet.

(5) Value is an estimate of the average ground slope for the area yarded each day, measured perpendicular to the contours and recorded in the following classes: 1 = 0 to 30%; 2 = 30% to 60%; 3 > 60%.

(6) Value is the total number of logs yarded during the day divided by the total number of turns yarded for the day.

(7) Average gross volume per log for running skyline, northbend systems and longspan systems (uphill and downhill) combined = .269 MBF, Net = .229 MBF/log.

(8) From cruise data: 33% of stems removed, 23% of volume removed. Using data from the logging study, volume removed was estimated at 18%. These are general values for the entire study area. Data used to generate this particular production equation came from only a portion of the study area.

(9) Perpendicular distance to skyline corridor. Not the actual lateral yarding distance.

(10) Value is the number of logs choked at the beginning of a turn. Occasionally "bonus" logs were lost during inhaul.

(11) Volume given in cubic feet

(12) Unmerchantable pieces included.

II. MEDIUM YARDERS: MAXIMUM MAINLINE PULL ≥ 25,000 < 71,000 lbs.

TIME STUDY DATA 3/3

	REFERENCE	CUTTING PATTERN	LOG LEAD ANGLE (°) MIN	MAX	AVG	CARRIAGE HEIGHT (FEET) MIN	MAX	AVG	DECK HEIGHT (FEET) MIN	MAX	AVG	SKIDDER PRESENT TO CLEAR DECK?	LOADER PRESENT YES	NO	# OF CHOKERS FLOWN	PRE-BUNCHED YES	NO	PRESET CHOKERS YES	NO	TOTAL # OF TURNS	TOTAL YARDING ROADS
1.	Dykstra, 1975	--	---	---	---	---	---	---	---	---	---	--	--	--	--		x		x	133	5
2.	Dykstra, 1975	--	---	---	---	---	---	---	---	---	---	--	--	--	--		x		x	158	8
3.	Dykstra, 1975	--	---	---	---	---	---	---	---	---	---	--	--	--	--		x		x	427	11
4.	Dykstra, 1976	--	---	---	---	---	---	---	---	---	---	--	--	--	Min 1, Avg 2 Max 2		x	Some-times		833	22
5.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	10+
6.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	18
7.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	--
8.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	5
9.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	6
10.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	6+
11.	Gardner, 1980	--	---	---	---	---	---	---	---	---	---	No	x		--		x	---		---	8
12.	Curtis, 1978	--	---	---	---	---	---	---	---	---	---	--	--	--	--	--	--	---		26	--
13.	Curtis, 1978	--	---	---	---	---	---	---	---	---	---	--	--	--	--	--	--	---		91	--
14.	Keller, 1979	45° Lead to Skyline Corridor	---	---	---	6.0	55.0	21.3	1	10	3.1	--	--	--	5	x			x	291	4
15.	Keller, 1979	45° Lead to Skyline Corridor	0	130	49.9 (1)	8.0	46.0	23.1	---	---	---	--	--	--	4		x		x	242	2

FOOTNOTE

① Value is the lead angle at which a turn of logs is yarded. Angle is measured as a deflection angle from the direction of the skyline corridor.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

PRODUCTION DATA

	REFERENCES	REGRESSION EQUATION—TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME?	DELAY %	COMMENTS
1.	Dykstra, 1975	4.67769 + 0.00051987 (BFVOL) (10) + 0.00146182 (SYDIST)	R=.126 to .633 (4)	Yes	9.2 (1)	Total time equation obtained by summing outhaul, hook, inhaul and unhook equations. Any "lateral" movement of chokers was included in these four elemental equations.
2.	Curtis, 1978 (2)	LOGS/HR = 23.755 +2.7776 (LOGS) - 0.63694 (AYD)	.13	Yes	14.0 (3)	(11)
3.	Curtis, 1978 (2)	LOGS/HR = 11.138 + 7.1774 (LOGS) - 0.59976 (AYD)	.29	Yes	12.0 (3)	(11)
4.	Sherar, 1978	1.924 + 0.1927 (SYD) + 0.3717(LOGS) + 0.35 (V)	.262	Yes	3.9 (3)	--
5.	Sherar, 1978	3.496 + 0.1014 (SYD) + 0.437 (V)	.162	Yes	5.3 (3)	--
6.	Sherar, 1978	2.284 + 0.4943 (SYD) + 0.328 (V)	.402	Yes	23.0 (3)	--
7.	Linjala, 1979 (2)	LOGS/HR = 5.78983 + 11.3255 (CHOK) - 0.0128329 (SYDIST)	.2805	Yes	8.4 (5)	(7)
8.	Linjala, 1979 (2)	LOGS/HR = 38.4141 - 0.0211831 (SYDIST) - 0.172377 (SLOPE1)	.3589	Yes	8.4 (5)	(7)
9.	Linjala, 1979 (2)	LOGS/HR = 36.7246 + 5.54309 (SETTERS) - 0.0567812 (SYDIST)	.2798	Yes	12.3 (5)	(7)
10.	Linjala, 1979 (2)	LOGS/HR = 24.1770 + 8.34334 (CHOK) - 0.03117 (SYDIST)	.4054	Yes	6.9 (5)	(7)
11.	Linjala, 1979 (2)	LOGS/HR = 44.9807 - 0.0329644 (SYDIST) + 0.446165 (SLOPE1)	.3662	Yes	2.2 (5)	(7)
12.	Linjala, 1979 (2)	LOGS/HR = 65.4010 - 0.0435101 (SYDIST) - 4.62756 (CHOK) (12)	.2618	Yes	6.0 (5)	(7)
13.	Linjala, 1979 (2)	LOGS/HR = 54.6604 - 0.0331774 (SYDIST) + 0.382246 (SLOPE1)	.1827	Yes	5.9 (5)	(7)
14.	Linjala, 1979 (2) LOGS/HR =	22.5023 + 7.51109 (CHOK) - 0.0207704 (SYDIST) - 0.0912802 (SLOPE1)	.272	Yes	8.2 (5)	(7) See Footnotes on Machine Data Table for this Equation
15.	Linjala, 1979 (2)	LOGS/HR = 41.9492 - 3.30186 (CREW) + 10.1666 (CHOK) - 0.025554 (SYDIST)	.3180	Yes	7.5 (5)	(7) " "

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

PRODUCTION DATA

	REFERENCE	REGRESSION EQUATION–TOTAL TURN TIME (MINUTES)	R^2	BASED ON DELAY FREE TIME?	DELAY %	COMMENTS
16.	Linjala, 1979 (2)	LOGS/HR = 16.9881 + 2.28639 (SETTERS) + 5.65854 (CHOK) - 0.0183524 (SYDIST)	.2781	Yes	8.6 (5)	(7) See Footnotes on Machine Data Table for this equation
17.	Linjala, 1979 (2)	LOGS/HR = 23.1470 + 7.41064 (CHOK) - 0.0211132 (SYDIST) - 0.0816038 (SLOPEI)	.2558	Yes	8.3 (5)	(7) " "
18.	Linjala, 1979 (2)	LOGS/HR = 32.2253 - 0.567472 (SLOPEI)	.2204	Yes	7.2 (5)	(7) " "
19.	Linjala, 1979 (2)	LOGS/HR = 69.2603 - 5.26513 (CREW) - 0.0353321 (SYDIST)	.2523	Yes	1.90,5.80 (6)	(7)
20.	Linjala, 1979 (2)	LOGS/HR = 84.7407 - 7.6587 (CREW) - 0.0181058 (SYDIST)	.1885	Yes	1.38, 5.66 (6)	(7) " "
21.	Linjala, 1979 (2)	LOGS/HR = 51.6547 - 0.04839 (SYDIST) + 0.598041 (SLOPEI)	.2696	Yes	0.84,3.74 (6)	(7) " "
22.	Linjala, 1979 (2)	LOGS/HR = -42.2686 + 12.9092 (CREW) - 0.0329641 (SYDIST) + 0.311246 (SLOPEI) (12)	.2734	Yes	1.58,3.93 (6)	(7) " "
23.	Linjala, 1979 (2)	LOGS/HR = 65.1014 - 9.26667 (CREW) + 14.2265 (SETTERS) - 5.31694 (CHOK) - 0.0258301 (SYDIST)	.2659	Yes	8.0 (5)	(7) " "
24.	Linjala, 1979 (2)	LOGS/HR = 44.4590 - 3.40943 (CREW) + 5.43716 (SETTERS) - 0.0236702 (SYDIST)	.2442	Yes	8.1 (5)	(7) " "
25.	Mann, 1979	0.61040 + 0.00317 (SYDIST) + 0.01958 (LATDIST) + 0.33913 (LOGS) + 0.00167 (VOLUME) (8) + 0.33088 (RIGGERS)	.4727	Yes	32.0 (3)(9)	"Reposition" and "Reset" considered part of delay free time (not delays)

FOOTNOTES

(1) Excludes yarding road changes. Computed as $\frac{\text{Total Delay Time}}{\text{Total Productive Time + Total Delay Time}}$

Total turn time (excluding yarding road changes) = $\frac{\text{Delay Free Turn Time (Regression Equation)}}{\frac{100 - \text{Delay \%}}{100}}$

e.g., D.F.T. = 6 minutes, Delay % = 6.2%, Total time = $\frac{6}{\frac{(100 - 6.2)}{100}}$ = 6.397 minutes

(2) Regression equation results in number of logs yarded per productive hour (no delays, yarding or road changes).

(3) Excludes landing and yarding road changes.

(4) Range of "R" values for elemental equations. Total time equation obtained by summing elemental equations of the system (outhaul, hook, inhaul, unhook).

(5) Excludes landing and yarding road changes, major equipment repairs and general delays when the crew was at the landing and not performing productive work (e.g., crew waiting for the yarder to warm up in the morning - usually about 15 minutes).

(6) Values are respectively mean total delay time per turn and mean net productive time per turn. Total delay time includes operating, non-operating and general delays (e.g., yarding and road changes, major equipment delays, and waiting for machinery to warm up in the morning).

(7) All data recorded on a turn time or yarding cycle basis. Time spent in freeing hangups was considered part of the yarding cycle time and not a delay. Time was measured to the nearest minute.

(8) Cubic foot volume determined using two-end conic rule: $C.V. = 0.001818\ L[(D_1^2 + D_2^2) + (D_1)(D_2)]$

where: C.V. = Log volume in cubic feet
L = Log length in feet
D_1 = large end diameter inside bark in inches
D_2 = Small end diameter inside bark in inches

FOOTNOTES (continued)

(9) A skidder was required to swing logs from the landing to another area for loading to keep the haul road open. A major source of delay was stopping the yarding operation to permit log truck traffic to pass since the yarder setting was on the haul road.

(10) Scribner volume was approximated with Knouf's Rule: $[(D_s^2 - 3D_s)/10]\,[L/2]$

where: D_s = small end diameter in inches
L = length in feet
V = board foot volume

Logs over 40 feet long were scaled as two logs, one 40 feet long and the other L-40 feet long.

(11) Source of data for these equations were gross (shift-level) time study records which the timber purchasers were required to keep.

(12) The regression coefficient associated with this variable was not found to be significantly different from zero at the 0.10 probability level. However, the addition of the variable increases R^2 by more than one percent and does not increase the mean square error term.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

VARIABLES MEASURED BUT NOT USED IN REGRESSION EQUATIONS

	REFERENCES	
1.	Dykstra, 1975	Chordslope %, Groundslope %, Soil Index, Brush Index, Number of Choker Setters, Number of Chasers, Logs per turn.
2.	Curtis, 1978	Number of cable road changes/day, average ground slope %, landing size, number of cable roads used at a landing, ground profile index, total number of men working on yarding operation, type of cut, index combining the aspect of the work site with the season of work, initial number of trees per acre , number of trees cut per acre, chordslope, dummy variable relating requirements for yarding "yum" ≥ 50 Bd. Ft/piece, variable corresponding to Forest Service landscape management classes (0=preservation to 4=maximum modification), "ratio" (total number merchantable logs yarded for the day divided by total logs yarded that day).
3.	Curtis, 1978	Same as Regression #2 above.
4.	Sherar, 1978	Groundslope %, number of chokers flown, choker length
5.	Sherar, 1978	Number of logs per turn, groundslope %, number of chokers flown.
6.	Sherar, 1978	Number of logs per turn, groundslope %, number of chokers flown.
7.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method, slopel, crew size, number of chokersetters, turn volume, pieces per turn.
8.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , crew size, number of choker setters, number of chokers flown, turn volume, pieces per turn.
9.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, crew size, number of chokers flown, turn volume, pieces per turn.
10.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, crew size, number of choker setters, turn volume, pieces per turn.
11.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , crew size, number of choker setters, number of chokers flown, turn volume, pieces per turn.
12.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, crew size, number of choker setters, turn volume, pieces per turn.
13.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , crew size, number of choker setters, turn volume, pieces per turn, number of chokers flown.
14.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, crew size, number of choker setters, turn volume, pieces per turn, loading method.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL $\geq$ 71,000 lbs.

VARIABLES MEASURED BUT NOT USED IN REGRESSION EQUATIONS

	REFERENCES	
15.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, number of choker setters, turn volume, pieces per turn.
16.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, crew size, turn volume, pieces per turn.
17.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method ,crew size, number of choker setters, turn volume, pieces per turn.
18.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , yarding distance, crew size, number of chokers flown, turn volume, pieces per turn, number of choker setters.
19.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, number of choker setters, number of chokers flown, turn volume, pieces per turn.
20.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, number of choker setters, number of chokers flown, turn volume, pieces per turn.
21.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method ,crew size,number of choker setters, number of chokers flown, turn volume, pieces per turn.
22.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , number of choker setters, number of chokers flown, turn volume, pieces per turn.
23.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, turn volume, pieces per turn.
24.	Linjala, 1979	Weather, soil type, terrain conditions, landing conditions, loading method , slopel, number of chokers flown, turn volume, pieces per turn.
25.	Mann, 1979	Gross board foot volume per turn, log turn weight, average board foot volume per log for the turn, chordslope.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL $\geq$ 71,000 lbs.

MACHINE DATA (1 of 2)

	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	YARDER SPECIFICATIONS DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT): SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
1.	Dykstra, 1975	Skagit BU-90	--	Skagit T-90	-/-/1450	81.7(1)/400(2)/1250	--	-/-/3580	1 1/4/1/-/7/8
2.	Curtis, 1978	(3)	Skagit RCC-15	115' Spar Tree	-/-/4500	90(4)/1200(5)/4000	--	45(4)/1500(5)-1800/7000	1 3/4/1/-/3/4
3.	Curtis, 1978	(3)	" "	" "	" "	" "	--	" "	1 3/4/1/-/3/4
4.	Sherar, 1978	Skagit BU-94	--	Skagit T110-HD	--	--	--	--	-/1 7/8/-/7/8
5.	Sherar, 1978	" BU-98	Young HR-300	" "	-/-/2355	-/-/2000	--	-/-/5200	1 1/4/1 1/8/-/7/8
6.	Sherar, 1978	" BU-94	Buttrigging	Skagit T100-HD	--	--	--	--	-/1 3/8/-/7/8
7.	Linjala, 1979	Washington 208	Buttrigging	--	--	34.4(1)/1415(20)/1650	--	23.8(1)/2060(20)/3600	-/1 3/8/-/1
8.	Linjala, 1979	Madill	" "	--	--	84(1)/1750(22)/1130	--	78(1)/1750(22)/2300	-/1 1/4/-/7/8
9.	Linjala, 1979	Skagit M.H.S.	" "	--	--	-/-/1380	--	-/-/3100	-/1 1/8/-/3/4
10.	Linjala, 1979	Washington 157	" "	--	--	20.6(1)/930(22)/1500	--	4.15(1)/2540(22)/3400	-/1 1/4/-/7/8
11.	Linjala, 1979	Skagit	" "	--	--	--	--	--	-/1 1/4/-/-
12.	Linjala, 1979	Washington Slackline Yarder	" "	--	--	76.8(19)/1390(19)/2000	--	35.6(19)/2780(19)/6340	-/1 3/8/-/3/4
13.	Linjala, 1979	Berger	" "	--	--	--	--	--	0/1 3/8/-/-
14.	Linjala, 1979	(8)	" "	--	--	--	--	--	--

III. LARGE YARDERS: MAXIMUM MAINLINE PULL $\geq$ 71,000 lbs.

MACHINE DATA (1 of 2)

					YARDER SPECIFICATIONS DRUM PULL/SPEED/CAPACITY (KIPS/FPM/FT)				
	REFERENCE SOURCE	YARDER MODEL	CARRIAGE MODEL	TOWER MODEL	SKYLINE	MAINLINE	SLACKPULLING	HAULBACK	LINE SIZE SL/ML/SP/HB (INCHES)
15.	Linjala, 1979	(9)	Butt Rigging	--	--	--	--	--	--
16.	Linjala, 1979	(10)	" "	--	--	--	--	--	--
17.	Linjala, 1979	(11)	" "	--	--	--	--	--	--
18.	Linjala, 1979	(12)	" "	--	--	--	--	--	--
19.	Linjala, 1979	(13)	" "	--	--	--	--	--	--
20.	Linjala, 1979	(14)	" "	--	--	--	--	--	--
21.	Linjala, 1979	(15)	" "	--	--	--	--	--	--
22.	Linjala, 1979	(16)	" "	--	--	--	--	--	--
23.	Linjala, 1979	(17)	" "	--	--	--	--	--	--
24.	Linjala, 1979	(18)	" "	--	--	--	--	--	--
25.	Mann, 1979	Madill 044	Danebo MSP	--	--	84(23)/900(23)/1760	12.1(23)/1058(23)/1500	78(23)/900(23)/2300	-/1/5/8/7/8

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs

MACHINE DATA (2 of 2)

	YARDER SPECIFICATIONS			CARRIAGE SPECIFICATIONS							
					LATERAL CAPABILITY			POSITION HOLDING			
REFERENCE	INTERLOCK	TOWER HEIGHT (FT.)	WEIGHT(lbs)	MAN	LINES	CARR.	OPER. LINES	CLAMP	STOP	CAPACITY
1. Dykstra, 1975	None	90	--	--	--	--	--	--	--	--
2. Curtis, 1978	--	115' Spar Tree	6900			x		x		(6)
3. Curtis, 1978	None	115' Spar Tree	6900			x		x		(6)
4. Sherar, 1978	None	110	2500	--	--	--	--	--	--	--
5. Sherar, 1978	None	110	4700		x			x (7)		300' of 7/8" dropline
6. Sherar, 1978	None	100	--	--	--	--	--	--	--	--
7. Linjala, 1979	Yes	(21)	--	--	--	--	--	--	--	--
8. Linjala, 1979	--	90	--	--	--	--	--	--	--	--
9. Linjala, 1979	--	100	--	--	--	--	--	--	--	--
10. Linjala, 1979	--	(21)	--	--	--	--	--	--	--	--
11. Linjala, 1979	--	110	--	--	--	--	--	--	--	--
12. Linjala, 1979	--	110	--	--	--	--	--	--	--	--
13. Linjala, 1979	--	110	--	--	--	--	--	--	--	--
14. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
15. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
16. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
17. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
18. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
19. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
20. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
21. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
22. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
23. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
24. Linjala, 1979	--	--	--	--	--	--	--	--	--	--
25. Mann, 1979	None	60	--		x		x			--

FOOTNOTES

(1) Half full, low gear.

(2) Half full, fifth gear.

(3) Yarder was 3-drum, trailer mounted, logger-fabricated unit. Drumset model unknown but believed to be a Washington 303 highlead drumset built about 1940.

(4) Maximum.

(5) Average maximum.

(6) Dropline drum capacity = 440' of 7/8" line; speed = 315 F.P.M. (no load); load capacity = 44000 pounds.

(7) Radio-controlled.

(8) This equation was generated by combining the data base of the seven individual yarder equations presented in this paper.

(9) This equation was generated by combining the data base of the seven individual yarder equations presented in this paper when only in an uphill yarding configuration (6 of 8 models involved).

(10) This equation was generated by combining the data base of the seven individual yarder equations presented in this paper when only in a downhill yarding configuration (5 of 8 models involved).

(11) This equation was generated by combining the data base of the seven individual yarder equations presented in this paper when only in a highlead yarding configuration (7 of 8 models involved).

(12) This equation was generated by combining the data base of the seven individual yarder equations presented in this paper when only in a Grabinski yarding configuration (2 of 8 models involved).

(13) Three of eight yarder models involved in this study worked in windthrow areas ranging from 100% to 30% windthrow. The paper does not indicate which models, or how many, worked in areas with a particular degree of windthrow. This equation is for 100% windthrow areas.

FOOTNOTES (continued)

(14) Three of eight yarder models involved in this study worked in windthrow areas ranging from 100% to 30% windthrow. The paper does not indicate which models, or how many, worked in areas with a particular degree of windthrow. This equation is for 80% windthrow areas.

(15) Three of eight yarder models involved in this study worked in windthrow areas ranging from 100% to 30% windthrow. The paper does not indicate which models, or how many, worked in areas with a particular degree of windthrow. This equation is for 60% windthrow areas.

(16) Three of eight yarder models involved in this study worked in windthrow areas ranging from 100% to 30% windthrow. The paper does not indicate which models, or how many, worked in areas with a particular degree of windthrow. This equation is for 30% windthrow areas.

(17) Three of eight yarder models involved in this study worked in windthrow areas ranging from 100% to 30% windthrow. The paper does not indicate which models, or how many, worked in areas with a particular degree of windthrow. This equation was generated by combining the data bases of the 100%, 80%, 60% and 30% windthrow area equations.

(18) This equation was generated by combining the total data bases of all eight yarder models in this paper (all yarding configurations, working non-windthrow and windthrow areas).

(19) Full drum.

(20) Half full, fourth gear.

(21) All yarders in this study had towers 90 feet tall or greater.

(22) Half full, high gear.

(23) Low gear.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

RIGGING & YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/DOWNHILL	SINGLESPAN/MULTI	CHOKERS/GRAPPLE	YARDER HAS SWINGING BOOM YES	YARDER HAS SWINGING BOOM NO	COMMENTS
1.	Dykstra, 1975	Live Skyline-Shotgun(Flyer)	Uphill	Singlespan	Chokers		x	①
2.	Curtis, 1978	Standing Longspan, no Haulback used	Uphill	Singlespan	Chokers		x	②
3.	Curtis, 1978	Standing Longspan, Haulback Required	Downhill	Singlespan	Chokers		x	②
4.	Sherar, 1978	Live Skyline-Shotgun (Flyer)	Uphill	Singlespan	Chokers		x	③
5.	Sherar, 1978	Standing Longspan, Haulback Pulls Slack	Uphill	Singlespan	Chokers		x	③
6.	Sherar, 1978	Highlead	Uphill	Not Applicable	Chokers		x	③
7.	Linjala, 1979	Highlead, Non-Windthrow Area	Both	Not Applicable	Chokers	--	--	--
8.	Linjala, 1979	Highlead and Grabinski Non-Windthrow Area	Both	Singlespan with Grabinski	Chokers	--	--	--
9.	Linjala, 1979	Highlead-Non-Windthrow Area	Downhill	Not Applicable	Chokers	--	--	--
10.	Linjala, 1979	Highlead-Non-Windthrow Area	Uphill	Not Applicable	Chokers	--	--	--
11.	Linjala, 1979	Highlead and Grabinski — Non-Windthrow Area	Both	Singlespan with Grabinski	Chokers	--	--	--
12.	Linjala, 1979	Highlead-Non-Windthrow Area	Both	Not Applicable	Chokers	--	--	--
13.	Linjala, 1979	Highlead-Non-Windthrow Area	Uphill	Not Applicable	Chokers	--	--	--
14.	Linjala, 1979	Highlead and Grabinski – Non-Windthrow (combined data, 7 yarder models)	Both	Singlespan with Grabinski	Chokers	--	--	--
15.	Linjala, 1979	Highlead and Grabinski – Non-Windthrow (combined data, 6 yarder models)	Uphill	Singlespan with Grabinski	Chokers	--	--	--
16.	Linjala, 1979	Highlead and Grabinski – Non-Windthrow (combined, 5 yarder models)	Downhill	Singlespan with Grabinski	Chokers	--	--	--
17.	Linjala, 1979	Highlead – Non-Windthrow (combined data, 7 yarder models)	Both	Not Applicable	Chokers	--	--	--

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

RIGGING & YARDING CONFIGURATION DATA

	REFERENCE	YARDING SYSTEM USED	UPHILL/DOWNHILL	SINGLESPAN/MULTI	CHOKERS/GRAPPLE	YARDER HAS SWING BOOM YES	NO	COMMENTS
18.	Linjala, 1979	Grabinski, Non-Windthrow (combined data, 2 yarder models)	Both	Singlespan	Chokers	--	x	--
19.	Linjala, 1979	Highlead-100% Windthrow, 3 yarder models	Both	Not Applicable	Chokers	--	x	--
20.	Linjala, 1979	Highlead-80% Windthrow, 3 yarder models	Uphill	Not Applicable	Chokers	--	x	--
21.	Linjala, 1979	Highlead-60% Windthrow, 3 yarder models	Both	Not Applicable	Chokers	--	x	--
22.	Linjala, 1979	Highlead-30% Windthrow, 3 yarder models	Both	Not Applicable	Chokers	--	x	--
23.	Linjala, 1979	Highlead-All Windthrow Areas, 3 yarder models	Both	Not Applicable	Chokers	--	x	--
24.	Linjala, 1979	Highlead & Grabinski – Both Windthrow and Non-Windthrow Areas (total combined data)	Both	Singlespan with Grabinski	Chokers	--	x	--
25.	Mann, 1979	Running Skyline - Mech. Slackpulling Carriage, Skidder "Swing" Necessary to Keep Haul Road Open.	Uphill	Singlespan	Chokers	x		④

FOOTNOTES

(1) Tailholds were generally outside the unit boundaries.

(2) Landing size was 0.9 acres.

(3) Tailholds were outside of unit boundaries.

(4) Length of span (horizontal) ranged from 350 feet to 1040 feet.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs

CREW DATA

		CREW SIZE BY POSITION							
	REFERENCE SOURCE	HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	HOOKER	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
1.	Dykstra, 1975	--	--	--	--	1 to 4, $\overline{2.7}$	1 to 2, $\overline{1.3}$	--	Commercial Logging Crew
2.	Curtis, 1978	--	--	--	--	--	--	7 to 12, $\overline{9.9}$	" "
3.	Curtis, 1978	--	--	--	--	--	--	7 to 11, $\overline{8.8}$	" "
4.	Sherar, 1978	0	1	0	0	2	2	5	Commercial Logging Crew, Good familiarity with systems
5.	Sherar, 1978	--	--	--	--	--	--	--	" "
6.	Sherar, 1978	0	1	0	0	2	1	4	" "
7.	Linjala, 1979	--	--	--	--	2 to 4, $\overline{3.04}$	--	5 to 7, $\overline{6.38}$	Commercial Logging Crew
8.	Linjala, 1979	--	--	--	--	1 to 4, $\overline{2.30}$	--	4 to 7, $\overline{5.2}$	" "
9.	Linjala, 1979	--	--	--	--	2 to 3, $\overline{2.51}$	--	5 to 7, $\overline{6.31}$	" "
10.	Linjala, 1979	--	--	--	--	4	--	7	" "
11.	Linjala, 1979	--	--	--	--	2 to 4, $\overline{2.39}$	--	5	" "
12.	Linjala, 1979	--	--	--	--	4	--	7	" "
13.	Linjala, 1979	--	--	--	--	2 to 3, $\overline{2.83}$	--	5 to 6, $\overline{5.83}$	" "
14.	Linjala, 1979	--	--	--	--	1 to 4, $\overline{2.74}$	--	4 to 7, $\overline{5.84}$	" "
15.	Linjala, 1979	--	--	--	--	2 to 4, $\overline{2.94}$	--	5 to 7, $\overline{5.9}$	" "
16.	Linjala, 1979	--	--	--	--	1 to 4, $\overline{2.58}$	--	4 to 7, $\overline{5.6}$	" "
17.	Linjala, 1979	--	--	--	--	1 to 4, $\overline{2.89}$	--	4 to 7, $\overline{6.0}$	" "
18.	Linjala, 1979	--	--	--	--	1 to 4, $\overline{1.34}$	--	4 to 7, $\overline{4.34}$	" "
19.	Linjala, 1979	--	--	--	--	2 to 3, $\overline{2.73}$	--	5 to 6, $\overline{5.73}$	" "
20.	Linjala, 1979	--	--	--	--	2 to 3, $\overline{2.93}$	--	5 to 6, $\overline{5.75}$	" "

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

CREW DATA

		CREW SIZE BY POSITION							
	REFERENCE SOURCE	HOOKTENDER	YARDER OPERATOR	RIGGING SLINGER	HOOKER	CHOKER SETTER	CHASER	TOTAL	EXPERIENCE
21.	Linjala, 1979	--	--	--	--	3 to 4, $\overline{3.43}$	--	6 to 7, $\overline{6.43}$	Commercial Logging Crew
22.	Linjala, 1979	--	--	--	--	3 to 4, $\overline{3.80}$	--	6 to 7, $\overline{6.80}$	" "
23.	Linjala, 1979	--	--	--	--	2 to 4, $\overline{3.00}$	--	5 to 7, $\overline{5.97}$	" "
24.	Linjala, 1979	--	--	--	--	--	--	--	" "
25.	Mann, 1979	--	--	--	--	2 to 4, $\overline{2.98}$ (1)	--	--	Commercial Logging Crew, Some inexperienced choker setters

FOOTNOTE

(1) Includes rigging slinger.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

PHYSICAL DATA OF SALE AREA

	REFERENCE SOURCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
1.	Dykstra, 1975	10.78	Triangular to Rectangular	Rugged and Broken	Largely Old-Growth	150-250	(11)	40-85	--	(1)(2)	Mt. Hood N.F. in Oregon
2.	Curtis, 1978	211.0	--	Min 0 Max 2 Avg 0.4 (3)	Largely Old-Growth	--	(4)	--	--	Min 0.4 Max 1.0 Avg 0.8 (5)	" "
3.	Curtis, 1978	30.0	--	Min 0 Max 2 Avg 1.1 (3)	Largely Old-Growth	--	(4)	--	--	Min 0.3 Max 1.0 Avg 0.6 (5)	" "
4.	Sherar, 1978	17.8	Irregular	--	Largely Old-Growth	--	(12)	50-70	--	--	Western Oregon
5.	Sherar, 1978	44.0	Rectangular (6)	--	Second Growth	80-100	Douglas-fir	40	--	--	Western Oregon
6.	Sherar, 1978	20.0	Rectangular	2 Blind Leads	Largely Old-Growth	--	(12)	50-70	--	--	Western Oregon
7.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	Southeastern Alaska
8.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
9.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
10.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
11.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
12.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
13.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
14.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
15.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
16.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
17.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
18.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
19.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "
20.	Linjala, 1979	(7)	--	--	--	--	--	--	--	--	" "

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

PHYSICAL DATA OF SALE AREA

	REFERENCE SOURCE	SIZE OF UNIT INVOLVED IN STUDY (ACRES)	GENERAL SHAPE OF AREA	TOPOGRAPHY (SLOPE/ BROKEN OR NOT)	SIZE OF TIMBER	AGE (YEARS)	SPECIES	DENSITY VOL/ ACRE (MBF)	DENSITY STEMS/ ACRE	COMMENTS	LOCATION OF STUDY
21.	Linjala, 1979	⑦	--	--	--	--	--	--	--	--	Southeastern Alaska
22.	Linjala, 1979	⑦	--	--	--	--	--	--	--	--	" "
23.	Linjala, 1979	⑦	--	--	--	--	--	--	--	--	" "
24.	Linjala, 1979	⑦	--	--	--	--	--	--	--	--	Southeastern Alaska
25.	Mann, 1979	13.3	--	⑧	Old Growth, Mixed Conifer	--	⑨	⑩	--	--	Sierra N.F. Fresno Co., Calif.

FOOTNOTES

(1) Ground surface conditions at the hook point provided firm, even footing. Soil was solid and dry.

(2) Brush and slash conditions at the hook point were light or nonexistent and did not restrict movement. Also, volume estimates were based on Scribner long-log scale.

(3) Values are an index describing shape of ground profile along the cable road based on logger's map: 0 = concave; 1 = constant; 2 = convex.

(4) General timber type was old-growth Douglas-fir with mixed hemlock, Western Red Cedar and associated subalpine fir species.

(5) Values are a ratio of the total number of merchantable logs yarded for the day divided by the total number of logs yarded for the day.

(6) Fanshaped settings.

(7) Data used to generate this equation were taken from a yarding time study conducted by the U.S. Forest Service in Reigon 10, Alaska. All data recorded on a turn time or yarding cycle basis. Data were obtained on twelve different models of yarders involving a number of different sale areas. In this paper, only the large yarder class (eight yarder models) was analyzed and no information was given on individual sale areas.

(8) Moderate to steep slopes often in excess of 50%, slopes long, continuous or convex.

(9) Species involved in partial cut removal were (by volume): 33% Ponderosa/Jeffrey Pine, 20% Sugar Pine, 25% White Fir (A. concolor), 22% Incense Cedar.

(10) Average volume per acre removed was 25.5 MBF.

(11) By volume: 60-70% Douglas-fir. Other Species: Western Hemlock, Western Red Cedar, Western White Pine, Western Larch and Noble Fir.

(12) 80% Douglas-fir, 20% Western Hemlock.

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

TIME STUDY 1/3

	REFERENCE	TYPE OF CUT [c.c., partial, thinning below/above, wholetree, tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET) MIN	MAX	AVG	LATERAL YARDING DISTANCE (FEET) MIN	MAX	AVG	CHORDSLOPE % MIN	MAX	AVG	GROUNDSLOPE % MIN	MAX	AVG
1.	Dykstra, 1975	Clearcut	July 31, Aug 1,3,6, 9,10,13-16,20,21, 23,28-30, 1973	50	1505	703.6	---	---	---	-24	-60	-44.3	40	80	67.2
2.	Curtis, 1978	Shelterwood(1), Clearcut(2)	Oct-Nov 1974, Jun-Oct 1975, May-Nov 1976	6(4)	20(4)	12.7(4)	---	---	---	-1	-36	-14.4	1(5)	2(5)	1.8(5)
3.	Curtis, 1978	Shelterwood(2)	Oct-Nov 1974,(3) Jun-Oct 1975, May-Nov 1976	5(4)	14(4)	8.4(4)	---	---	---	3	16	10.9	-2(5)	-1(5)	-2.0(5)
4.	Sherar, 1978	Clearcut	Summer, 1977	200	1250	789	---	---	---	---	---	---	30	100	---
5.	Sherar, 1978	Clearcut	Summer, 1977	400	1850	1486	---	---	---	---	---	-6.0	-70	60	__(8)
6.	Sherar, 1978	Clearcut	Summer, 1977	100	850	582	---	30(10)	---	---	---	---	40	60	(16)
7.	Linjala, 1979	Clearcut	Completed Fall, 1972	50	1050	539	---	---	---	---	---	---	-39	80	-14
8.	Linjala, 1979	Clearcut	""	50	1350	684	---	---	---	---	---	---	-34	46	4.6
9.	Linjala, 1979	Clearcut	""	50	500	323	---	---	---	---	---	---	-45	-9	-25.1
10.	Linjala, 1979	Clearcut	""	50	900	536	---	---	---	---	---	---	21	40	29.3
11.	Linjala, 1979	Clearcut	""	100	900	531	---	---	---	---	---	---	-19	25	5.9
12.	Linjala, 1979	Clearcut	""	30	800	341	---	---	---	---	---	---	-16	5	4.8
13.	Linjala, 1979	Clearcut	""	100	750	437	---	---	---	---	---	---	2	40	19
14.	Linjala, 1979	Clearcut	""	30	1350	579	---	---	---	---	---	---	-45	80	-1.6

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.

TIME STUDY 1/3

	REFERENCE	TYPE OF CUT [c.c., partial, thinning below/above, wholetree, tree length, etc]	DATES OF STUDY	SLOPE YARDING DISTANCE (FEET) MIN	MAX	AVG	LATERAL YARDING DISTANCE (FEET) MIN	MAX	AVG	CHORDSLOPE % MIN	MAX	AVG	GROUNDSLOPE % MIN	MAX	AVG
15.	Linjala, 1979	Clearcut	Completed Fall, 1972	30	1300	576	---	---	---	---	---	---	0	80	22
16.	Linjala, 1979	Clearcut	""	50	1350	581	---	---	---	---	---	---	-45	-1	-17.3
17.	Linjala, 1979	Clearcut	""	30	1350	566	---	---	---	---	---	---	-45	80	0.8
18.	Linjala, 1979	Clearcut	""	150	1250	697	---	---	---	---	---	---	-34	1.0	-23.4
19.	Linjala, 1979	Clearcut	""	50	950	440	---	---	---	---	---	---	-15	18	3.0
20.	Linjala, 1979	Clearcut	""	50	1050	543	---	---	---	---	---	---	9	65	21.7
21.	Linjala, 1979	Clearcut	""	30	700	395	---	---	---	---	---	---	-13	10	-2.3
22.	Linjala, 1979	Clearcut	""	30	500	318	---	---	---	---	---	---	-12	6.0	-3.4
23.	Linjala, 1979	Clearcut	""	30	1050	441	---	---	---	---	---	---	-15	65	4.8
24.	Linjala, 1979	Clearcut	""	---	---	---	---	---	---	---	---	---	---	---	---
25.	Mann, 1979	(12)	Summer, 1978	40	900	373	0	185 (13)	46.8 (13)	-31	-45	-35.4	---	---	---

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs.
TIME STUDY 2/3

	REFERENCE	PIECES/TURN MIN	MAX	AVG	GROSS VOLUME PER PIECE (Bd. Ft) MIN	MAX	AVG	GROSS VOLUME PER TURN (Bd. Ft) MIN	MAX	AVG	THINNING INTENSITY %
1.	Dykstra, 1975	1	6	2.1	22	4631	392.7	25 (15)	5400 (15)	758.8 (15)	--
2.	Curtis, 1978	1.7 (6)	6.1 (6)	4.1 (6)	---	---	(7)	---	---	---	(2)
3.	Curtis, 1978	2.1 (6)	5.2 (6)	3.8 (6)	---	---	(7)	---	---	---	(2)
4.	Sherar, 1978	1	5	2.5	---	---	---	10.2	617	219.7 (9)	--
5.	Sherar, 1978	1	5	2.8	---	---	---	21.4	312	122 (9)	--
6.	Sherar, 1978	1	2	1.71	---	---	---	27.7	528	218 (9)	--
7.	Linjala, 1979	0	6	2.18	---	---	---	0	457	84.4 (11)	--
8.	Linjala, 1979	0	4	1.83	---	---	---	0	679	86.3 (11)	--
9.	Linjala, 1979	1	4	2.15	---	---	---	2	203	65.8 (11)	--
10.	Linjala, 1979	1	4	1.99	---	---	---	3	258	64.5 (11)	--
11.	Linjala, 1979	1	5	2.33	---	---	---	12	355	88.9 (11)	--
12.	Linjala, 1979	0	7	2.44	---	---	---	0	701	175.3 (11)	--
13.	Linjala, 1979	0	4	1.96	---	---	---	0	359	80.1 (11)	--
14.	Linjala, 1979	0	7	2.01	---	---	---	0	701	86.8 (11)	--
15.	Linjala, 1979	0	5	1.96	---	---	---	0	679	97.5 (11)	--
16.	Linjala, 1979	0	7	2.05	---	---	---	0	701	78.8 (11)	--
17.	Linjala, 1979	0	7	2.04	---	---	---	0	701	89.0 (11)	--
18.	Linjala, 1979	0	4	1.75	---	---	---	0	384	66.5 (11)	--
19.	Linjala, 1979	0	5	2.0	---	---	---	0	668	108.8 (11)	--
20.	Linjala, 1979	1	6	2.69	---	---	---	8	225	67.4 (11)	--
21.	Linjala, 1979	1	4	2.09	---	---	---	5	313	79.2 (11)	--
22.	Linjala, 1979	1	4	2.16	---	---	---	3	328	88.7 (11)	--
23.	Linjala, 1979	0	6	2.16	---	---	---	0	668	92.7 (11)	--
24.	Linjala, 1979	---	---	---	---	---	---	---	---	---	--
25.	Mann, 1979	1	4	1.77	35	3564	754 (14)	35	3564	972 (14)	25.5 MBF/Acre Removed

FOOTNOTES

(1) 144 acres shelterwood, 67 acres clearcut.

(2) Author states that shelterwood cut prescriptions were so heavy, they created a near-clearcut condition.

(3) These are dates given when the longspan yarder was working either uphill or downhill (2 separate regression equations). They indicate a time frame within which the study occurred. They DO NOT indicate that data for the particular regression equation was collected throughout this time.

(4) Value is average yarding distance for the day, recorded in 100's of feet.

(5) Value is an estimate of the average groundslope for the area yarded each day, measured perpendicular to the contours and recorded in the following classes: 1 = 0 to 30%; 2 = 30 to 60%; 3 = > 60%. A negative sign indicates downhill yarding.

(6) Value is the total number of logs yarded during the day divided by the total number of turns yarded for the day.

(7) Average gross volume per log in this study for running skyline, northbend, and long-span systems (uphill and downhill) combined = .269 MBF; Net = .229 MBF/log.

(8) Creek divided unit at a distance of 1400 feet. Yarding operation essentially ridge to ridge. Both sides of a canyon being yarded.

(9) Units are in cubic feet.

(10) Choker length.

(11) Scribner D.C. scale used.

(12) Combination of seed tree cut and overstory removal cut of the shelterwood method.

(13) Perpendicular distance from the center of the skyline corridor to the near end of the log.

(14) Based on Knouf's Rule.

(15) Unmerchantable pieces included.

(16) Average groundslope was not given. Average sideslope was 20%

III. LARGE YARDERS: MAXIMUM MAINLINE PULL ≥ 71,000 lbs

TIME STUDY 3/3

	REFERENCE	CUTTING PATTERN	LOG LEAD ANGLE (°) MIN	MAX	AVG	CARRIAGE HEIGHT (FEET) MIN	MAX	AVG	DECK HEIGHT (FEET) MIN	MAX	AVG	SKIDDER PRESENT TO CLEAR DECK?	LOADER PRESENT YES	NO	# OF CHOKERS FLOWN	PRE-BUNCHED YES	NO	PRE-SET CHOKERS YES	NO	TOTAL # OF TURNS	TOTAL YARDING ROADS
1.	Dykstra, 1975	--	---	---	---	---	---	---	---	---	---	---	--	--	--		x		x	549	21
2.	Curtis, 1978	--	---	---	---	---	---	---	---	---	---	---	--	--	--	--	--	--	--	201	--
3.	Curtis, 1978	--	---	---	---	---	---	---	---	---	---	---	--	--	--	--	--	--	--	54	--
4.	Sherar, 1978	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3	--	--	--	--	115	2
5.	Sherar, 1978	--	---	---	---	---	---	---	---	---	---	---	--	--	--	--	--	x		98	1
6.	Sherar, 1978	--	---	---	---	---	---	---	---	---	---	---	--	--	2	--	--	--	--	96	2
7.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2 to 3,$\overline{2.26}$	--	--	--	--	713	--
8.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 2,$\overline{1.99}$	--	--	--	--	974	--
9.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2	--	--	--	--	124	--
10.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 2,$\overline{1.96}$	--	--	--	--	100	--
11.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2	--	--	--	--	36	--
12.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2 to 3,$\overline{2.45}$	--	--	--	--	87	--
13.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2	--	--	--	--	120	--
14.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.10}$	--	--	--	--	2154	--
15.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.02}$	--	--	--	--	927	--
16.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.15}$	--	--	--	--	1227	--
17.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.10}$	--	--	--	--	1945	--
18.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.03}$	--	--	--	--	209	--
19.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2 to 3,$\overline{2.46}$	--	--	--	--	363	--
20.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2 to 3,$\overline{2.45}$	--	--	--	--	135	--
21.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{1.87}$	--	--	--	--	174	--
22.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	2	--	--	--	--	45	--
23.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	1 to 3,$\overline{2.29}$	--	--	--	--	717	--
24.	Linjala, 1979	--	---	---	---	---	---	---	---	---	---	---	--	--	--	--	--	--	--	2872	--
25.	Mann, 1979	--	---	---	---	---	---	---	---	---	---	Yes	--	--	--	--	--	Sometimes		325	3

Appendix B. DEFINITIONS OF VARIABLES USED IN REGRESSION EQUATIONS.

ANGLE	The lead angle, in degrees, at which a turn of logs is lateral inhauled. The angle is measured as a deflection angle from the skyline corridor to the inhaul path of the logs. The angle is turned looking toward the landing.
AYD	The average slope yarding distance for the day, recorded in 100's of feet (i.e., 400 feet = 4).
BFVOL	The gross board-feet volume in the turn--includes unmerchantable pieces. Volumes given in board-feet.
BLOCK	A variable used by the author to help isolate variations which may have occurred between observations in Block I and Block II of the study area. Block equals "1" if the observation is from Block I, and equals "0" if from Block II. The author states that, for prediction purposes, "Block" can be set to zero in the equation.
CH	Height of the carriage above the ground at the position of lateral yarding in feet.
CHOK	The number of chokers flown.
CHOKERS	The number of chokers used in the turn.

CHORDSLOPE	The slope, in percent, of a line segment that connects the support points of the skyline. Chordslope inclination is taken from the landing (i.e., for uphill yarding, chordslopes were negative). Percent values given as a whole number (e.g. 30.5% ⟶ 30.5).
CREW	The number of persons in the yarding crew.
CREW1	A zero-one dummy variable: "0" when the owner/operator was a chokersetter, and "1" when he was not. (NOTE: In this study the crew with the more experienced owner/operator as a chokersetter averaged 54% more volume per hour than the crew with the less experienced alternate chokersetter).
DKHT	Height of the log deck on the landing after the turn was landed and decked in feet.
DMYSKID	A dummy variable to indicate the presence of a skidder used to keep the landing clear by sorting and decking logs along the road prior to loading by a self-loading truck. Skidder Present = 1. No Skidder Present = 0.
HOOKLOG	The number of logs hooked in a turn.
LANDLOG	The number of logs landed in a turn.

LANGLE	The angle, in degrees, formed by the winch line and a projected line travelling along the length of and through the center of the log (e.g., a 0° "LANGLE" implies the log and winch line are co-linear, a 90° "LANGLE" implies the log is at right angles to the winch line).
LATDIST	The length on the slope measured in feet from the location of the furthest log in the turn to the skyline corridor. The distance measured is perpendicular to the skyline corridor.
LATSD	The actual lateral slope distance, in feet, from the pre-bunching spar to the first log in the turn (estimated to the nearest five feet).
LDGCREW	The number of people in the landing crew (e.g., yarder operator and one chaser would result in a value of 2 for LDGCREW). The skidder operator is not considered.
LDIST	The lateral yarding distance in feet. This is the actual slope distance the log travels from hook point to corridor.
LEADTURN	The average lead angle, in degrees, of a turn. The lead angle is the angle formed between the line of sight down a log (in the direction of the

landing), and a line parallel to the skyline corridor. If the line of sight is rotated toward the corridor in a counter-clockwise direction, the angle is negative. The possible range of angles is +90° to -90°.

LOGS	The number of pieces yarded per turn.
RIGGERS	The number of chokersetters, including a rigging slinger if present.
SDIST	The slope distance down the corridor to the pre-bunching spar from the yarder measured to the nearest foot.
SETTERS	The number of chokersetters working on the yarding operation. The rigging slinger is not included.
SIDIST	The distance, in feet, a chokersetter had to reach from the lead of the mainline and haulback to the position of the farthest log when using the haulback to pull mainline out from the carriage. (A "squirrel" block was attached to the end of the haulback and the mainline was pulled through the "squirrel" block.)
SINANG	The reciprocal of the sine ($\frac{1}{\text{sine}}$) of the lead angle (ANGLE).

SLO	The groundslope at the carriage position in percent. The percentage is given as a whole number (e.g., 60.5% ⟶ 60.5).
SLOPE	The average groundslope in percent. The percentage is given as a whole number (e.g., 60.5% ⟶ 60.5). The groundslope inclination is taken looking toward the landing from the skyline road (i.e., uphill yarding - "slope" is positive, downhill yarding - "slope" is negative).
SLOPE1	The slope measured from the landing to the hook point in percent. Percentage given as a whole number (e.g., 65.5% = 65.5). For uphill yarding, the value is negative. For downhill yarding, the value is positive.
SYD	The slope yarding distance in 100-foot stations.
SYDIST	The slope yarding distance, in feet.
TI	The percentage of merchantable stems removed. Percentage given as a whole number (e.g., 35% = 35.0).
TNVOL	The gross board foot volume per turn (Scribner decimal log rule). Volume given in 10's of board feet.

V	The volume of logs per turn measured in cunits.
VOL	The gross board-foot volume in the turn. Volume given in board feet.
VOLUME	The volume of logs per turn in cubic feet.
WEIGHT	The turn weight in pounds.
ZONE	The average lead angle a turn of logs forms with the skyline. Angles are measured from the skyline and rotate in a downhill direction toward the log turn (e.g., 0° - turn is parallel to the skyline). The possible range of angles is 0° - 179°).

Appendix C. SYMBOLS AND ABBREVIATIONS.

MBF	=	Thousand Board Feet
Ac	=	Acre
KIPS	=	Thousand Pounds
lbs	=	Pounds
FPM	=	Feet per Minute
Ft	=	Foot
SL	=	Skyline
ML	=	Mainline
SP	=	Slackpulling Line
HB	=	Haulback Line
%	=	Percent
Bd. Ft.	=	Board Feet
$(Ft)^3$	=	Cubic Feet
°	=	Degree
R^2	=	Coefficient of Multiple Determination
$\overline{X}$	=	Average Value of X Variable

Appendix D. Formulas for Computing Weighted Averages of Nonlinear Terms in Regression Equations For Two Types of Distributions.

Name	Regression term ①	Formulas for Weighted Averages, by Distribution Type: Uniform		Triangular ②	
Constant	b	b	(1)	b	(8)
Linear	bx	$\frac{b(x_1 + x_0)}{2}$	(2)	$\frac{2bx_1}{3}$	(9) ③
Squared	bx^2	$\frac{b(x_1^3 - x_0^3)}{3(x_1 - x_0)}$	(3)	$\frac{2}{4}bx_1^2$	(10)
Power ④ $n \neq (-1)$	bx^n	$\frac{b(x_1^{n+1} - x_0^{n+1})}{(n+1)(x_1 - x_0)}$	(4)	$\frac{2b\ x_1^n}{(n+2)}$	(11)
Inverse $n = (-1)$	$\frac{b}{x}$	$\frac{b(\ln x_1 - \ln x_0)}{x_1 - x_0}$	(5)	$\frac{2b}{x_1}$	(12)
Natural Logarithm	$b\ln x$	$\frac{b[(x_1 \ln x_1 - x_1) - (x_0 \ln x_0 - x_0)]}{x_1 - x_0}$	(6)	$b(\ln x_1 - 1/2)$	(13)
Exponential	ae^{bx}	$\frac{a(e^{bx_1} - e^{bx_0})}{b(x_1 - x_0)}$	(7)	$\frac{2a}{x_1^2}\left[\frac{e^{bx_1}}{b}(x_1 - 1/b) + \frac{1}{b^2}\right]$	(14)

LEGEND: n = power or exponent
$\ln$ = natural logarithm
e = base of natural logarithm (approximately 2.72)
x_1 = maximum value
x_0 = minimum value

① a = coefficient of "e"
b = coefficients in regression equation

② Assuming $x_0 = 0$ simplifies the formulas.

③ Corresponds to the widely known 2/3 correction for average yarding distance on circular settings

④ Constant, linear, and squared functions are special cases of the general formula for power.