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L-O-S-T: *L*ogging *O*ptimization *S*election *T*echnique

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SUMMARY

L-O-S-T is a FORTRAN computer program that can be used to quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. Nonlinear harvesting relationships, irregular boundary shapes, nonuniform timber densities, unequal distances between multiple landings, variations in road construction conditions, changes in trucking speeds, and harvesting restrictions (environmental, physical, and time) can be analyzed. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

ACKNOWLEDGMENTS

The linear programming algorithm used in L-O-S-T is a modification of one developed by Dr. A. Ravindran, Chairman and Professor, Department of Industrial Engineering, University of Oklahoma, Norman, Oklahoma. The input-output format modifications to Dr. Ravindran's program were made by E. Wade Culver, a computer engineer employed by the U. S. Forest Service at Auburn, Alabama, at the time of this study.

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INTRODUCTION

An age-old problem for timber harvesters is that of selecting the location for roads and landings that will maximize profits. This complex problem is partially due to: 1) nonlinear harvesting relationships, 2) nonuniform terrain and timber characteristics, 3) irregular tract boundaries with interior obstacles, and 4) the lack of a *general* mathematical expression describing total costs as a function of road densities, landing spacings, skidding distances, and equipment mixes.

Existing Solution Techniques

One of the earliest mathematical attempts to minimize harvesting costs was by Matthews (1942). To simplify the problem, he assumed: 1) the forest boundary could be approximated by simple geometric shapes, 2) linear cost relationships, 3) equal spacings between multiple landings, and 4) uniform slopes and timber densities. Using an indirect method, Matthews determined the optimum location of roads and landings by using calculus to obtain the minimum of unconstrained equations. Peters (1978) extended this approach by developing a direct method to determine optimum location of roads and landings. Although Peters used most of Matthews' assumptions, he included landing costs and used a mathematically accurate method developed by Suddarth (1952) for determining average skidding distance. Corcoran and Sammis (1975) developed a computer program to solve the road and landing spacing equations developed by Matthews. Their computer program solves two equations in two unknowns through a heuristically iterative procedure.

Operations research techniques were used very early by Lussier (1960, 1961) to minimize harvesting costs. He developed equations useful in determining the optimum number of landings, the distance between skid roads, and optimum skid road standards. Lussier also discussed several limitations on using a strictly mathematical approach and in making simplified assumptions in solving harvesting problems.

Gibson and Egging (1973) developed a location-allocation model for determining the optimal number and location of landings when using rubber-tired skidders. A truncated enumeration algorithm was used in the allocation phase to search systematically for a local optimum solution. Dynamic programming and a branch and bound methodology were used to find the global optimal solution.

Dykstra (1976) used mathematical and heuristic programming to determine the design of individual cutting units and the assignment of specific logging equipment to each cutting unit. He assumed that timber within each "type island" was homogenous and uniformly distributed and that only cable systems would be used to harvest timber on clearcuts. He also developed a digital model to portray topography, timber conditions, and harvest restrictions.

Carter et al. (1973) developed a computer model to determine the optimum spacings of roads and landings. Their work involved minimizing harvesting costs in the Rocky Mountain area where timber was accessible either by contour work-roads or switchbacks. An iteration solution technique was used to find simultaneous zero points of the partial derivatives of the road and landing spacing equations.

Several simulation models have been developed to analyze timber harvesting problems. However, most simulation models consider only a single landing and are not specifically developed to determine the optimum location of roads and landings. Several simulation models [Forest Harvesting Simulation Model (FHSM), Harvesting System Simulator (HSS), Simulation Applied to Logging Systems (SAPLOS), and Timber Harvesting and Transport Simulator (THATS)] were evaluated by Goulet et al. (1980).

Weintraub and Navon (1976) developed a mixed integer linear programming model to maximize dis-

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counted revenues from timber sales. Road construction and maintenance, timber management, and transportation were considered. The model was developed as a tool for decision in long range forest planning. Constraints were allowed on available capital, quantity of timber harvested, haul capacity of each road, and stand access. Kirby (1974) and Newnham (1975) also developed mathematical programming models useful in the long-range planning of harvesting operations.

Objectives

Existing techniques have provided useful insights into optimum timber harvesting strategies. For harvesting specific tracts of timber by ground-based skidding systems, these models are limited. Realistic harvesting costs often are not computed because overly simplified assumptions are made concerning stand boundary shapes, slopes, timber characteristics, and harvesting methods. The objectives of this study were to: 1) develop a computer program capable of determining realistic harvesting times and costs for highly individualistic conditions, and 2) utilize these harvesting times and costs, as well as harvesting constraints, in a unique linear programming formulation to obtain maximum profits. This FORTRAN computer model is titled L-O-S-T, an acronym for *l*ogging *o*ptimization *s*election *t*echnique.

HARVESTING FUNCTIONS OPTIMIZED

Although the methodology used to compute harvesting times and the linear programming formulation are *general*, the equations used to compute harvesting times are based on data collected in the Tennessee Valley Region (fig. 1). Harvesting times and costs are only calculated for road construction, landing construction, system move between landings, skidding, and trucking (fig. 2). Their relationships to selecting harvesting methods and the linear programming formulation are discussed in later sections. Costs are not calculated for felling, bucking, and loading (figs. 3 and 4) because those costs are not *assumed* to be significantly affected by the locations of roads and landings. The assumed general relationships among various harvesting activities and harvesting costs optimizations are shown in figure 5.

Road Construction

Construction of truck roads within the harvest boundary reduces skidding costs, but increases road construction, landing construction, system move, and trucking costs. In L-O-S-T, a road is considered as a low volume, temporary structure constructed solely for removing trees. If a high volume road is constructed with a design standard or life expectancy greater than that needed for timber harvesting, then the cost of the road must be adjusted to reflect only timber harvesting. The equation (A1, appendix 1) used to compute road construction times was developed by Koger (1978) from data collected in the Tennessee Valley Region.

Due to irregular terrain, construction conditions are seldom uniform over the entire road network. In order to determine more accurately construction costs, the road can be divided into short segments. These segments reflect differences in bank cubic yards, road slope (grade), or construction problems caused by rock or dense timber.

Although the number of bank cubic yards removed for making the roadbed is a variable, it does not have to be computed by the user. However, the user must supply roadbed width, side-hill slope, cut-slope ratio, and fill-slope ratio. This information is used in an equation reported by Bowman et al. (1975) to calculate bank cubic yards. Another variable, the number of acres in the road right-of-way, is also calculated for the user.

The construction of skid trails or skid roads for use by rubber-tired skidders is not computed in L-O-S-T. Skid road costs are assumed to be independent of the locations of truck roads and landings.

Landing Construction and System Move

Landings are usually constructed in conjunction with the road system, primarily as storage and loading areas for the skidded trees. Increasing landings decreases skidding costs, but increases system move, landing construction, and trucking costs. The equation used to compute landing construction times is a modification of the road construction equation (A1, appendix 1). The landing size in acres is converted to an "equivalent" road length based on an assumed cleared road width of 26.7 feet. An average cleared road width of 26.7 feet was observed in a study of logging roads in the Tennessee Valley Region (Koger 1978). A road construction condition factor of 3,000 is used (variable X6). In addition, the depth of the cut to level the landing site is assumed to be uniform across the landing area.

System move costs are those involved in moving equipment such as loaders, crawler tractors used for decking or landing maintenance, and shop trucks to the next landing. These costs are related to the distance and road condition between landings, the amount and type of equipment, and the hourly cost of the equipment and associated labor. Skidders may be included if they travel unloaded to the next landing site. Haul trucks are not included. If only one landing is used, system move costs are assumed to be zero. Move-in costs are not considered because they are

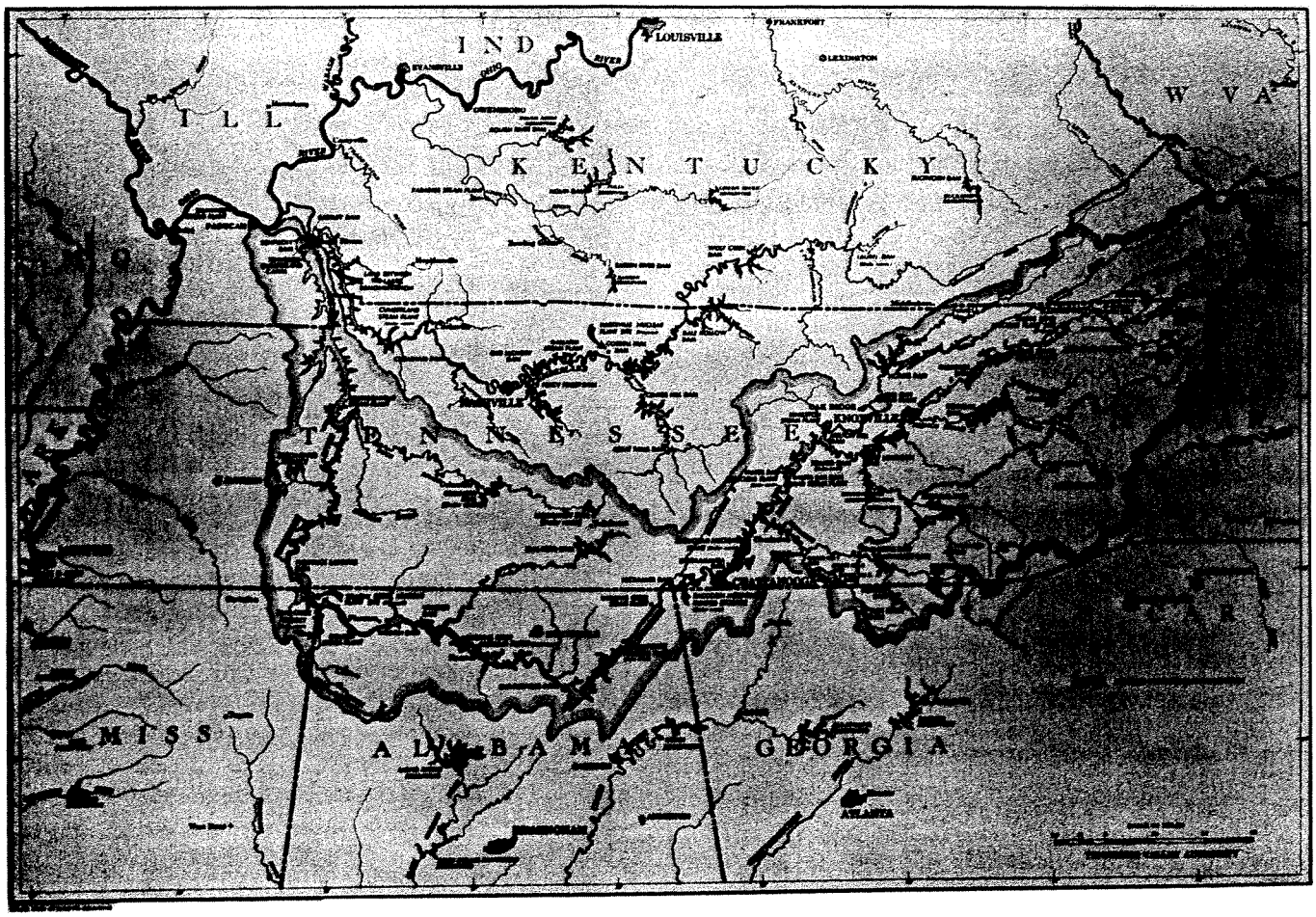

Figure 1.—*The Tennessee Valley Region (Tennessee, Kentucky, Virginia, North Carolina, Georgia, Alabama,* & Mississippi).

assumed to be approximately constant with whatever the locations of roads and landings.

In the linear programming formulation, landing construction and system move times are considered together. Since a relationship exists between these two costs, it is perhaps easier to think of them jointly rather than separately. Equation A5 (appendix 1) is used to compute a weighted time for landing construction and system move between landings.

Skidding

Skidding costs depend largely on skidding distance, which can be controlled through the locations of roads and landings. Skidding costs decrease as the density of roads and landings increases. The equation (A3, appendix 1) used to compute skidding times was developed by Koger (1976) for articulated, four-wheel drive, rubber-tired skidders operating in the Tennessee Valley Region. The range of observed volumes skidded in this region is shown in table 1 (appendix 1). Techniques available to compute average skidding distance are described in appendix 2. The differences among average skidding distance, the distance actually traveled by the skidder, and fixed skidding distance are also discussed.

Trucking

Trucking over roads within the harvest boundary reduces skidding costs but increases trucking, road construction, landing construction, and system move costs. The trucking speeds and load volumes shown in tables 2 – 4 (appendix 1) are based on data collected in the Tennessee Valley Region by Koger (1981). With respect to the optimum location of roads and landings, it is not necessary to compute trucking costs from the mill to the edge of the harvest boundary. This distance remains constant and is not affected by the road density or trucking pattern inside the harvest boundary. However, trucking costs are computed from each landing to the mill or delivery point because calculating these costs: 1) does not change the optimum location of roads and landings, 2) may alert the user to consider other routes from the mill to the harvest boundary, and 3) provides the user with an estimate of total trucking costs.

Figure 2.—*Truck road construction, system move between landings, skidding, trucking, and landing construction times are computed in L-O-S-T.*

SELECTING HARVESTING METHODS

Method Selection

The user must determine either two, three, or four different—but realistic—harvesting methods. These different methods can be viewed as harvesting or transportation plans. As a rule this requires drawing the boundary, stand densities, harvesting restrictions, road and landing locations, and skidding patterns on a topographic map. The methods should be selected so that road density (or road length) is at a minimum for the first method and at a maximum for the last method. Intermediate methods should be between these limits. Truck roads can be divided into segments to reflect differences in sidehill slope, road slope (grade), road width, or other construction factors. The size, construction condition, and distance from the harvest boundary is needed for each landing. The skidding pattern must be determined for each area and all landings. An area is a subdivision of a stand and its boundary is used in determining average skidding distance. Areas should be numbered consecutively within a stand and numbered so that no two areas have the same area number. An area can be subdivided into two or more new areas to reflect changes in skidding patterns among landings for different methods. The complexity of harvesting problems and the level of detail or realism required by the user is reflected in the number of areas selected.

Types of Harvesting Plans

L-O-S-T is capable of analyzing most ground-based plans including: 1) single road extension, 2) variable landing spacings along a fixed road length, 3) parallel roads, 4) multiple contour roads, 5) spur road extensions from major roads, and 6) climbing roads with switchbacks. The only requirement for analyzing any harvesting plan is that some relationship of road

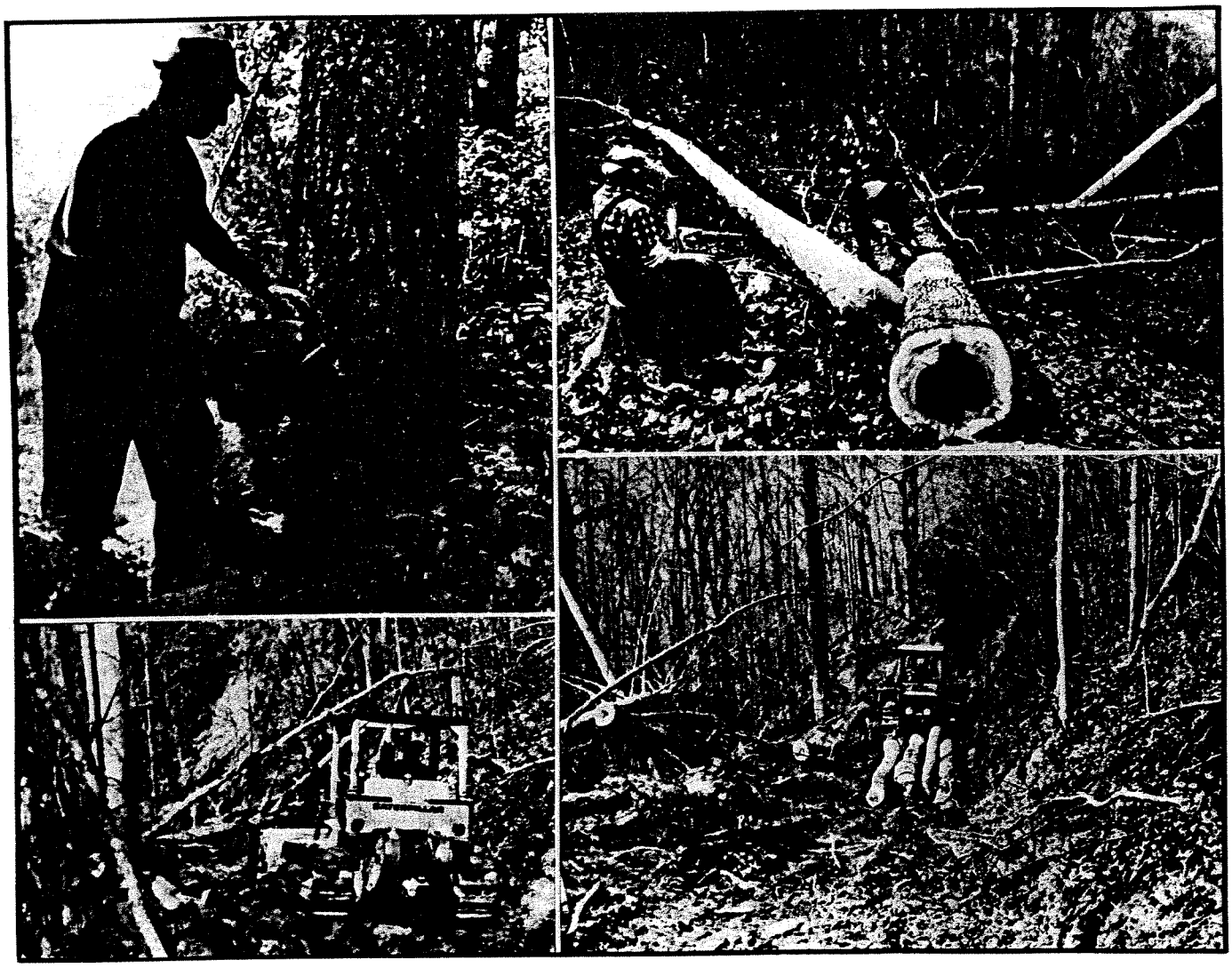

Figure 3.—*Felling, bucking, skid road construction, and bunching times are not computed in L-O-S-T.*

length and skidding exists between adjacent harvesting methods. From a silviculture perspective these harvesting plans could be for individual tree selection, group selection, diameter limit, financial maturity, or clear cuts. Once a cutting practice has been selected for an area in one method, it must remain the same in all the remaining methods. More than one different cutting practice may be used within a stand or harvest boundary.

OPTIMIZATION METHODOLOGY

Linear Programming Formulation

After the hours required for road construction, landing construction, system move between landings, skidding, and trucking have been calculated for each method, they are utilized in a linear programming formulation (equations 1 – 6). The formulation determines the proportion (λ) of each method that should be used. The formulation used in L-O-S-T is a slight modification of McCarl's (1979) and is also very similar to those developed by Allen (1956) and Chiang (1974).

$$\text{Maximize:} \quad Z = PQ_o - \Sigma C_i H_i \tag{1}$$

$$\text{Subject to:} \quad Q_o - \Sigma Q_m \lambda_m \leq 0 \tag{2}$$

$$\Sigma X_{im} \lambda_m - H_i \leq 0 \tag{3}$$

$$Q_o = Q_m \tag{4}$$

$$\Sigma \lambda_m = 1 \tag{5}$$

$$H_i \leq b_i \tag{6}$$

$$Q_o, Q_m, \lambda_m, H_i \geq 0$$

where: Z = objective function

P = delivered price of the harvested timber (ie. $/1,000 board feet)

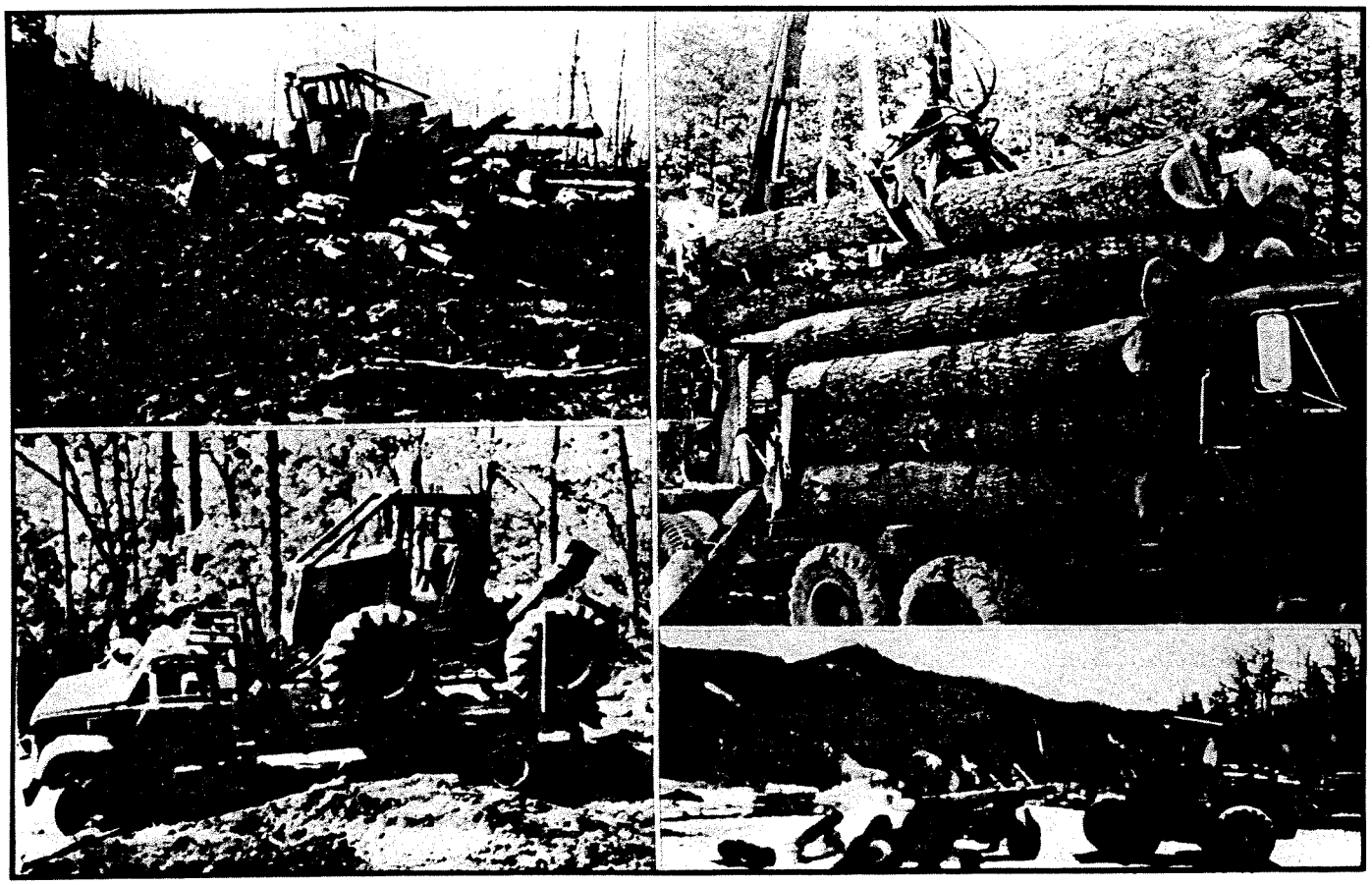

Figure 4.—*Decking, loading, move-in, and unloading times are not computed in L-O-S-T.*

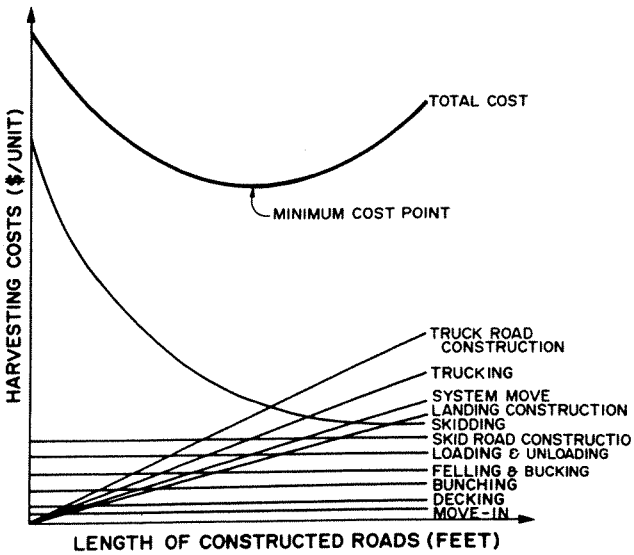

Figure 5.—*Assumed harvest cost relationships with respect to the optimum location of roads and landings (Note: fixed costs lines are in an arbitrary order).*

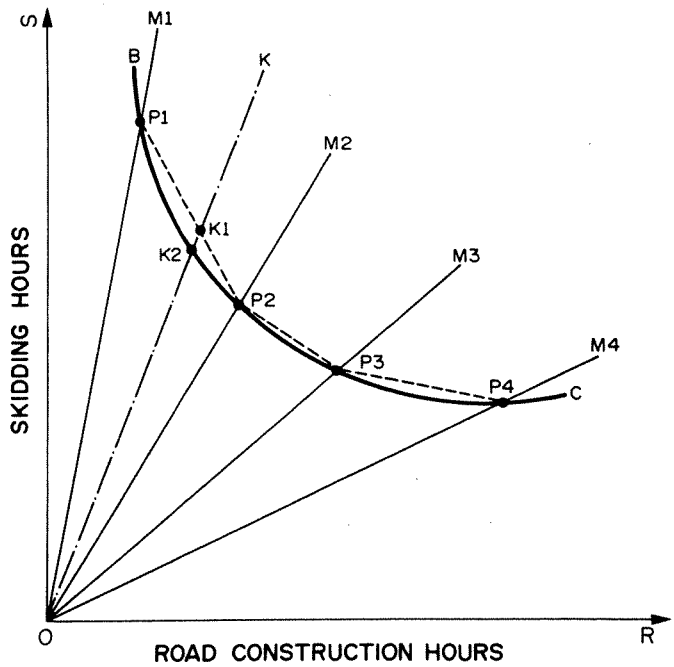

Figure 6.—*Relationships among isoquants, activity rays, and harvesting functions.*

Q_o = volume of timber harvested (ie. board feet)

C_i = hourly equipment and labor cost for the i th activity (i = 1 for road construction, i = 2 for landing construction and system move, i = 3 for skidding, and i = 4 for trucking

H_i = the total number of hours of the i th activity used by all harvesting methods

λ_m = the proportion of the m th method used to harvest the total volume of timber (a decision variable)

X_{im} = the number of hours for the i th harvesting activity of the m th method

b_i = maximum number of hours allowed for the i th harvesting activity

Formulation Explanation

The relationships among the formulation (equations 1 – 6), harvesting times, and harvesting methods are shown in figure 6. Assume that a boundary of timber can be harvested by one of four methods (M1, M2, M3, or M4). For simplicity in graphing, only the harvesting activities of skidding (the hours required are mapped on the OS axis) and road construction (the hours required are mapped on the OR axis) will be considered. The volume of timber harvested is constant and represented by the isoquant BC. Fewer hours of skidding are required as the hours of road construction increases. The harvesting methods can be considered as activity rays (OM1, OM2, OM3, & OM4) with four activity vectors:

$$P1 = \begin{bmatrix} S1 \\ R1 \end{bmatrix} \quad P2 = \begin{bmatrix} S2 \\ R2 \end{bmatrix} \quad P3 = \begin{bmatrix} S3 \\ R3 \end{bmatrix} \quad P4 = \begin{bmatrix} S4 \\ R4 \end{bmatrix}.$$

Each activity vector shows a distinct input ratio capable of yielding a constant volume of harvested timber (isoquant BC). Thus, P1 indicates that method 1 (M1) is used to harvest all of the timber. This formulation assumes that it is also possible to harvest timber in various convex combinations such as: (¼P1 + ¾P2).

This means that a new method can be determined which uses ¼ of the skidding hours of method 1, plus ¾ of the skidding hours of method 2, plus ¼ of the road construction hours of method 1, plus ¾ of the road construction hours for method 2. Graphically, this means that the ratios for the combined processes must lie on the dashed line segments (P1P2, P2P3, P3P4). Assume that the optimum combination of skidding and road construction hours is at point K1 on activity ray OK. Due to the convex nature of the production function represented by the isoquant BC, point K1 is not on BC. The difference between K1 and K2 on the activity ray OK represents the error involved in attempting to solve a nonlinear convex production function with a linear approximation.

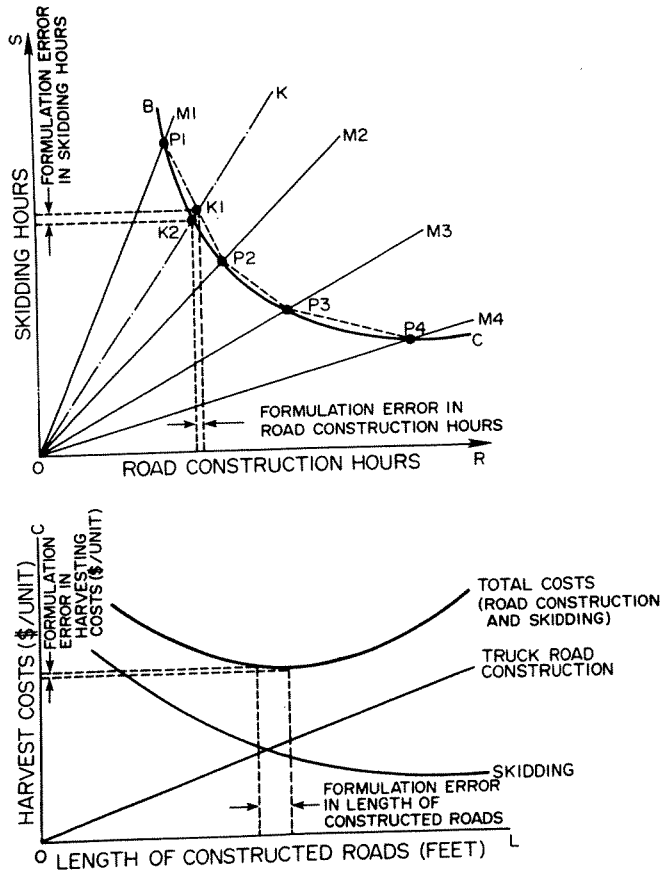

Figure 7.—*Error relationships involved in using the formulation.*

This error is not considered to be significant; its relationships to the formulation, harvesting methods, and harvesting costs are shown in figure 7. The formulation will pick only one method or a linear convex combination of adjacent methods (Allen 1956; Chiang 1974).

The assumptions of linear programming (additivity, linearity, divisibility, finiteness, and single-value expectations) are basically those used in the traditional marginal analysis of the firm. For timber harvesting, a specific method has a constant and linear proportionality between hours worked and volume harvested. Fractional hours worked can result in a fractional volume harvested. Finiteness means there are limits to the number of hours permitted to harvest a boundary of timber. The single-value expectation assumption assumes realistically that the quantity of timber harvested and its selling price is known. Another basic assumption is that the volume of timber harvested is not dependent on the harvesting method. This results in a fixed output independent of the number of hours required for road construction, landing construction, system move, skidding, and trucking.

HARVESTING EXAMPLE PROBLEM

Problem Description

An example problem has been developed to help illustrate the procedures used to select different harvesting methods, data input requirements, linear programming formulation, and program output. Specifically, the problem is to maximize profit by determining the least cost harvesting method for the boundary of timber shown in figure 8. The timber is to be harvested by a crawler tractor, two rubber-tired, cable skidders, and two trucks (table 5, appendix 3). Selected equipment weight and horsepower characteristics are given in appendix 4. The problem is sufficiently realistic to be interesting and complex enough to prevent the formulation of a *general* mathematical expression that could be differentiated to obtain minimum costs. The complexity of the problem is increased by: 1) an irregular boundary, 2) nonuniform timber densities or timber stands (fig. 9), 3) elevation changes, 4) restrictions on streambed crossings, 5) unequal costs for different road segments and landings, 6) unequal distances between landings, 7) nonlinear skidding costs, 8) decreases in truck travel speeds as the length of the road constructed inside the harvest boundary increases, and 9) restrictions on the time permitted for road construction (120 hours) and skidding (600 hours).

Harvesting Methods for the Example Problem

For the first method, a woods road was constructed 350 feet inside the harvest boundary and one landing constructed at location A (fig. 10). All the areas were skidded to this landing. Compared to the other methods, this method minimizes costs for road construction, landing construction, trucking, and system move, but maximizes skidding costs. For the second method, a woods road was constructed 2,525 feet inside the harvest boundary and landings constructed at locations A and B (fig. 11). Areas 1, 3, and 4 were skidded to landing A and the remaining areas skidded to landing B. It is important to recognize that areas can be subdivided to reflect changes in skidding patterns for different methods. For example, area 2 used in method 1 was subdivided into areas 3 and 6 for method 2. Area 3 was skidded to landing A, but area 6 was skidded to landing B. For the third method, a woods road was constructed 3,875 feet inside the harvest boundary and landings constructed at locations A, B, and C (fig. 12). Areas 1, 3, and 4 were skidded to landing A and areas 5, 6, 7, 8, and 9 skidded to landing B. The remaining areas were skidded to landing C. For the fourth method, a woods road was constructed 6,775 feet inside the harvest boundary and landings constructed at locations A, B, C, and D (fig. 13). Areas 1, 3, and 4 were skidded to landing A; areas 5, 6, 7, 8, and 9 to landing B; areas 10, 11, 15, and 19 to landing C; and areas 16, 17, 20, 21, 22, and 23 to landing D. Area 18 in methods 1 – 3 was subdivided into areas 19 and 20 to reflect changes in skidding patterns for method 4. Compared to other methods, this method minimizes skidding costs, but maximizes road construction, landing construction, system move, and trucking costs. A summary of several calculated and assumed values for each of these methods is given in appendix 3 (tables 6 – 11).

Data Input

For each method selected, specific input information is required on road construction, landing construction, system move between landings, skidding, trucking, and equipment costs. Sixteen data "card

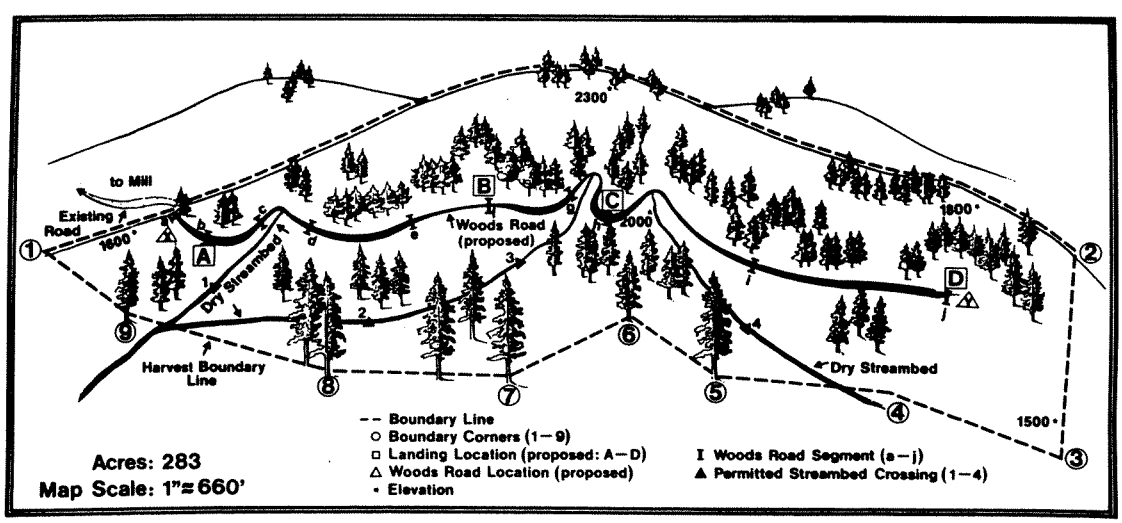

Figure 8.—*Harvesting example problem.*

types" are required for each analysis of a boundary of timber to be harvested. An additional card type is required if constraints are placed on the number of hours allowed for any of the pertinent harvesting activities. These different card types are described in detail in appendix 5. The complete input data used to analyze the hypothetical example is shown in appendix 6. The values shown for average skidding distance were based on the harvest patterns for the different areas and landing locations in figures 10 – 13. Average skidding distances were determined using a BASIC program written for use on an HP 9830A[1] calculator and HP 9864A digitizer.

Output Analysis

The computer output for the harvesting example problem is shown in appendix 7. The output consists of: 1) an echo check of the input data, 2) harvesting times and costs, and 3) the linear programming solution and sensivity analysis.

Road construction times and costs, the number of bank cubic yards, and acres cleared for the road-right-of-way are given for each segment. Road construction costs are: $170 for method 1 ($2,565 per mile); $1,061 for method 2 ($2,219 per mile); $1,625 for method 3 ($2,214 per mile); and $2,910 for method 4 ($2,268 per mile). The easiest way to modify road construction costs without changing the road design or road construction equipment characteristics is through the input variable ROADTY (card type 10, appendix 5). Although guidelines are provided for estimating ROADTY, a value should be selected that gives reasonable cost estimates based on the user's experience or modeling needs.

Landing construction and system move times and costs are computed for each landing. Landing construction costs are: $56.27 for method 1; $89.64 for method 2; $118.73 for method 3; and $150.83 for method 4. The simplest way to influence landing construction costs without changing the landing design or landing construction equipment characteristics is through the input variable EFFL (card type 12, appendix 5). System move costs are: $0.0 for method 1; $101.26 for method 2; $192.39 for method 3; and $303.78 for method 4.

Skidding times and costs are computed for each skidder on each area and summarized by area, landing, and method. The number of cycles and average cycle time are also given. The skidding costs are: $28,769.13 for method 1; $18,076.16 for method 2; $15,471.31 for method 3; and $10,950.56 for method 4. The easiest way to modify skidding times without changing skidder characteristics, skid load volumes, or skidding distances is through the input variable, AD (card type 13, appendix 5).

In addition to skidding times and costs, average skidding distance, fixed skidding distance, and weighted actual travel skidding distances are summarized by landing and method. In most cases the greatest potential for reducing skidding times is through a reduction of average *fixed* skidding distance. In the harvesting example problem, average skidding distance only decreased from 686 feet for method 1 to 550 feet for method 4. However, average fixed skidding distance decreased form 4,296 feet for method 1 to 759 feet for method 4. This drastic reduction in average fixed skidding distance was largely responsible for skidding times decreasing from 659.75 hours for method 1 to 264.83 hours for method 4. Weighted average travel skidding distance is computed by mul-

[1]The use of trade or corporate names is for reader association and convenience. Such does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval of any product or service to the exclusion of others which may be suitable.

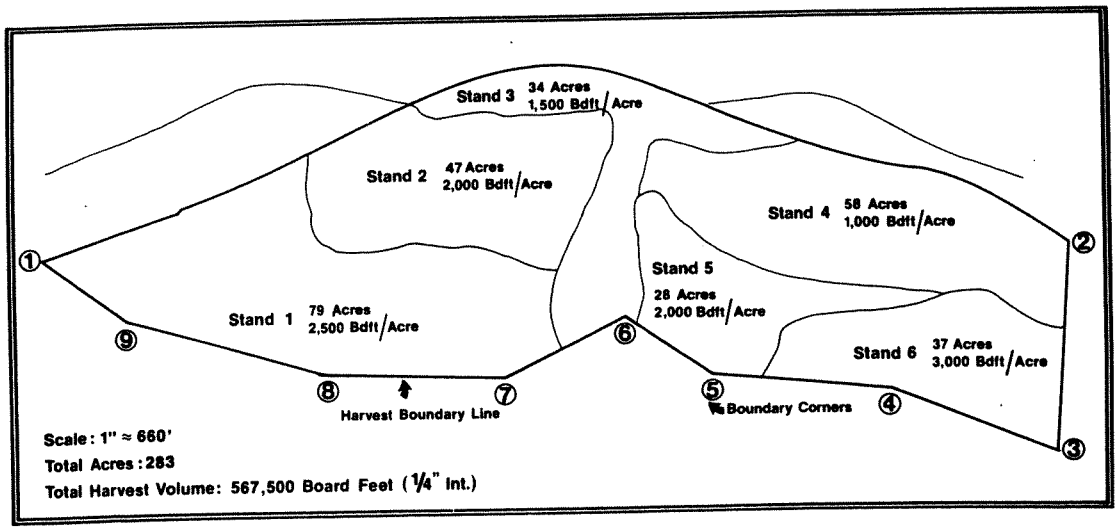

Figure 9.—*Stand densities and acres for the harvesting problem.*

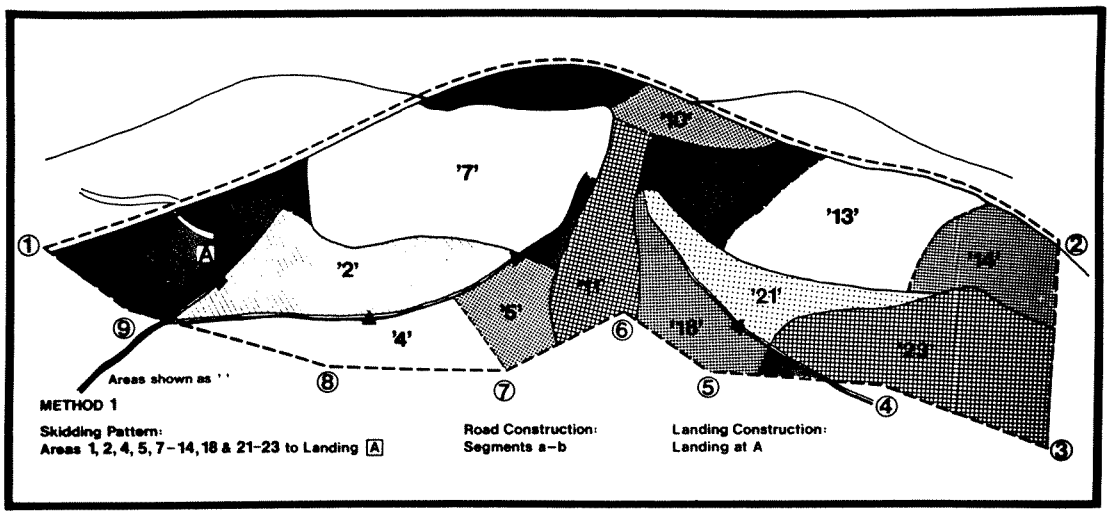

Figure 10.—*Road, landing, and area locations used in method 1.*

tiplying average skidding distance by the skidding correction factor for each area. This product is added to to the fixed skidding distance on each area and then multiplied by the volume for that area in order to obtain a weighted value.

The number of acres and volume of timber harvested for each method are provided as information and as checks on the accuracy of data input. The number of acres for each method must be the same and the volume harvested for each method must be the same. In this example, 283 acres and 567,500 board feet (¼" Int.) were harvested for each method. The linear programming formulation requires that an equal volume of timber be harvested in each method.

Trucking times and costs are shown for each truck and are summarized by landing and method. In addition, cycle times and number of loads required for each truck are given. Trucking costs for each method are: $17,182.48 for method 1; $17,913.40 for method 2; $18,277.16 for method 3; and $18,774.91 for method 4. In this case the construction of four landings and 6,775 feet of woods roads only increased trucking costs by $1,592.43.

A method summary giving the hours, costs per harvesting unit for each function, total costs, and total costs per harvesting unit is provided in the output. The total harvesting costs per thousand board feet (¼" Int.) for road construction, landing construction and system move, skidding, and trucking are: $81.37 for method 1; $65.62 for method 2; $62.79 for method 3; and $58.31 for method 4. The hours required for each harvest function considered in L-O-S-T are shown in table I and are used to illustrate a numerical example of the linear programming formulation (equations 7 – 16). The formulation can also be seen in the output (appendix 7) as the first iteration of the linear programming tableaus.

Table I.—*Harvest hours for the four methods*

Harvest Function	Method 1 (hours)	Method 2 (hours)	Method 3 (hours)	Method 4 (hours)
Road construction	7.86	49.07	75.12	134.55
Landing construction & system move	0.78	2.64	4.31	6.29
Skidding	695.75	437.15	374.16	264.83
Trucking	429.56	447.83	455.68	469.37

After 18 iterations the optimum linear programming solution consisted of 24% of method 3 and 76% of method 4. The optimum method (not a global optimum) used 120 hours of road construction, 5.8 hours of landing construction and system move, 292 hours of skidding, and 466 hours of trucking. The linear programming solution does not give the exact physical location of the roads, landings, and skidding patterns. However, the output can be used to help locate the road, landings, and skidding patterns for a new method consisting of 24% of method 3 and 76% of method 4. Since 102.2 hours were required to construct the road to the end of segment h-i, then 17.8 hours (120.0-102.2) or 909 feet of segment i-j can be constructed. The road should be constructed 2,159 feet beyond landing C. Landing D would be located 6,034 feet from the harvest boundary; whereas it was originally located 6,775 feet. The skidding patterns would stay the same for landings A and B, and probably C. However, the skidding patterns would change for landing D. If another computer analysis were made in order to obtain a better estimate, then meth-

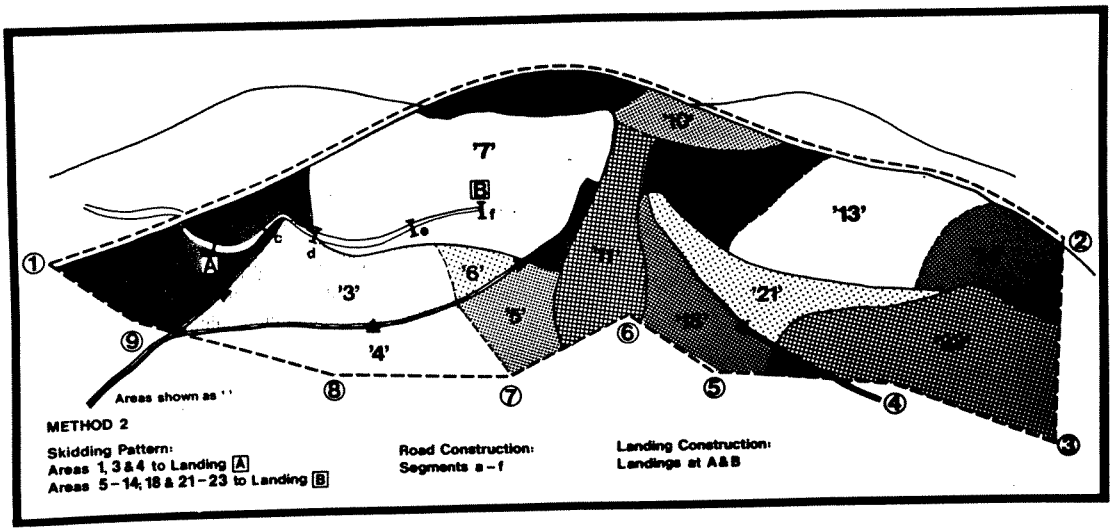

Figure 11.—*Road, landing, and area locations used in method 2.*

Linear programming equations for the harvesting example problem:

$$\text{Maximize } Z: \quad \$95.00\ Q_0 - \$21.63\ H_1 - \$72.26\ H_2 - \$41.35\ H_3 - \$40.00\ H_4 \qquad (7)$$

$$1.00\ Q_0 - 567.50\ \lambda_1 - 567.50\ \lambda_2 - 567.50\ \lambda_3 - 567.50\ \lambda_4 \leq 0.00 \qquad (8)$$

$$7.86\ \lambda_1 + 49.07\ \lambda_2 + 75.12\ \lambda_3 + 134.55\ \lambda_4 - 1.00\ H_1 \leq 0.00 \qquad (9)$$

$$0.78\ \lambda_1 + 2.64\ \lambda_2 + 4.31\ \lambda_3 + 6.29\ \lambda_4 - 1.00\ H_2 \leq 0.00 \qquad (10)$$

$$695.75\ \lambda_1 + 437.15\ \lambda_2 + 374.16\ \lambda_3 + 264.83\ \lambda_4 - 1.00\ H_3 \leq 0.00 \qquad (11)$$

$$429.56\ \lambda_1 + 447.83\ \lambda_2 + 455.68\ \lambda_3 + 469.37\ \lambda_4 - 1.00\ H_4 \leq 0.00 \qquad (12)$$

$$1.00\ Q_0 + 0.00\ \lambda_1 + 0.00\ \lambda_2 + 0.00\ \lambda_3 + 0.00\ \lambda_4 \leq 567.50 \text{ (volume)} \qquad (13)$$

$$1.00\ \lambda_1 + 1.00\ \lambda_2 + 1.00\ \lambda_3 + 1.00\ \lambda_4 \leq 1.00 \text{ (methods)} \qquad (14)$$

$$1.00\ H_1 \leq 120.00 \text{ (road construction)} \qquad (15)$$

$$1.00\ H_3 \leq 600.00 \text{ (skidding)} \qquad (16)$$

where: $Q_0, \lambda_m, H_i \geq 0$

ods 1 and 2 should be eliminated. Two new methods should be selected between the original methods 3 and 4. The original method 3 would become the new method 1. By keeping two of the original methods, the amount of new input data needed is reduced and the search area can be systematically analyzed.

Harvesting costs for the optimum method were $59.41 per thousand board feet (¼" Int.). If the constraint on road construction (120 hours) were not binding, then all of method 4 could have been used and harvesting costs would have been $58.31 per thousand board feet. Binding constraints always cause an increase in costs. However, the optimum method selected by the linear program (24% of method 3 and 76% of method 4) is still better than the method 1 ($81.37), method 2 ($65.62), or method 3 ($62.79).

The sensivity analysis in L-O-S-T consists of penalty costs, shadow prices, and ranges on all the cost coefficients and constraints. The formulation used in L-O-S-T and the original input format of the linear program algorithm make it difficult to correlate the variable codes in the sensivity analysis with the correct harvesting costs and constraints. However, users familiar with sensivity analysis should be able to interpret these results in L-O-S-T. In this formulation shadow prices are always zero because all the timber can be harvested by the number of hours computed for each method. The hourly costs of the harvesting functions are always non-basic. In this example, the hourly cost of road construction can increase from $21.63 to $64.43 without changing the optimum solution. This implies that the same road could have been constructed to a higher standard or that more roads should be constructed. The method summary costs also indicated that more roads and landings should be constructed.

LIMITATIONS

The linear programming solution calculated in L-O-S-T is not a global optimum or the absolute best of all possible harvesting methods. The program determines the "best" method based on the methods supplied by the user. Equipment interactions resulting in production delays are not calculated by the program. The effects of equipment interactions must be supplied indirectly by the user through equipment efficiency and area difficulty factors. Harvesting costs are calculated only for road construction, landing construction, system move between landings, skidding, and trucking. While this does not limit the optimization process, an estimate of total harvesting costs is not provided.

EXECUTING L-O-S-T

L-O-S-T is written in FORTRAN IV and is being run under WATFIV on an IBM 3031 at Auburn University. With a modest amount of additional effort, the program could be converted for use on similar computer systems. The example problem described in this report required 264K of storage, used 3.38 seconds of CPU time, and cost about one dollar to run. The FORTRAN source statements used in L-O-S-T are shown in appendix 8. A punched and interpreted source deck (1,914 cards) can be obtained from: Engineering Research Unit, G. W. Andrews Forestry Sciences Laboratory, U. S. Forest Service, Devall Street, Auburn University, Alabama 36849. Phone (205) 887-7542, (FTS) 534-4518.

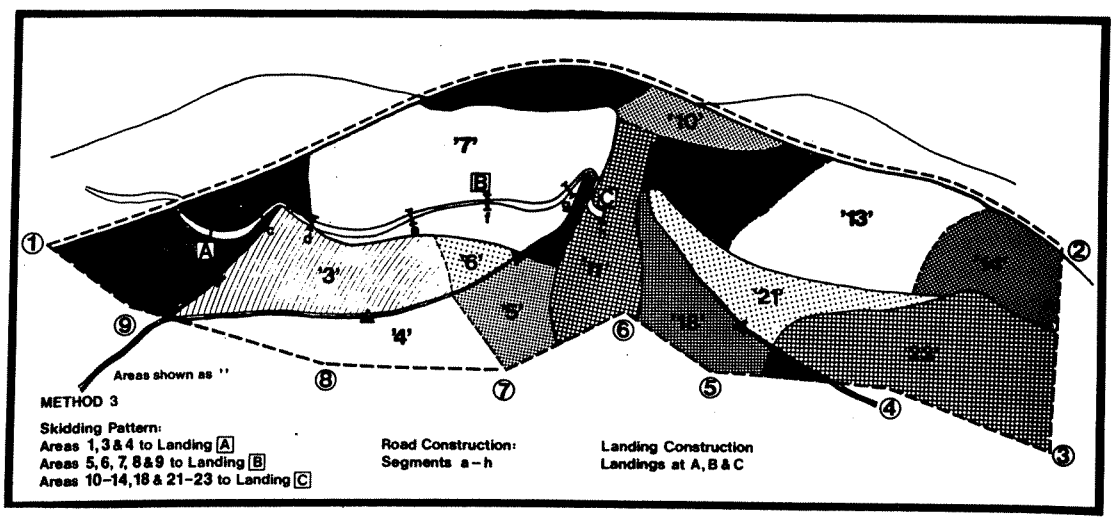

Figure 12.—*Road, landing, and area locations used in method 3.*

RESULTS AND DISCUSSION

A two-part methodology has been developed to analyze user selected harvesting methods. The first part of this methodology considers very specific and realistic harvesting conditions: terrain features, boundary shapes, roads, landings, skidding patterns, and environmental restrictions. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. The second part of the methodology uses these harvesting times in a linear programming formulation. The formulation utilizes the relationships among the harvesting methods to estimate and select the harvesting procedure having maximum profits.

Since the analysis performed by L-O-S-T depends on the harvesting methods selected by the users, it is important that users have some knowledge and experience in developing harvesting plans. Time and effort spent in selecting realistic harvesting plans will enable the output from L-O-S-T to be used with greater confidence by managers of harvesting operations.

L-O-S-T does not provide a global optimum with each computer analysis. Theoretically, the procedures used would, through repeated computer runs, find the ultimate harvesting method having maximum profits. L-O-S-T does provide a local optimum and a wealth of information for selecting a better harvesting method. Searching for the elusive global optimum has some academic merit; however, selecting feasible harvesting plans and then systematically quantifying, analyzing, and improving them has greater practical applications.

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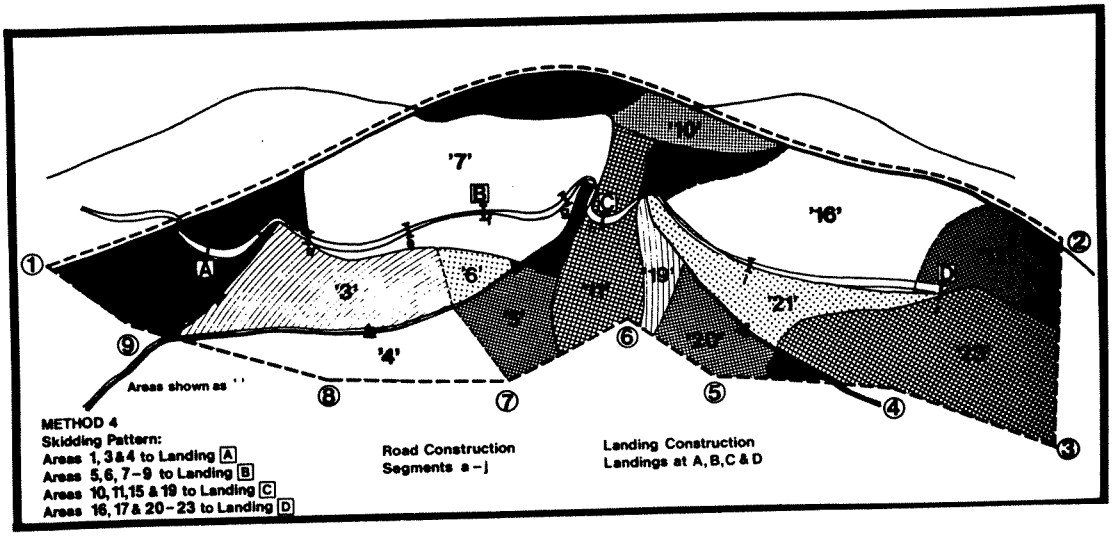

Figure 13.—*Road, landing, and area locations used in method 4.*

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Appendix 1—Harvesting Equations, Data, and Cost Relationships

HARVESTING EQUATIONS AND DATA

road construction equation: (Koger, equation 3, pg 30, 1978)

$$T = \frac{\frac{X1}{X6}\left[0.524\left[X2/(X3X4)\right]^{0.5} + 12.668\left[X5/(X3X4)\right]^{0.5}\right]}{X7} \qquad \text{(A1)}$$

where: T = predicted road constructed time in hours
X1 = road length in feet
X2 = number of bank cubic yards per 1,000 feet of road length
X3 = slope correction factor estimated by:

$$1.000 - (\%\ \text{road slope}/100) - 0.0001952\ (\%\ \text{road slope}/100)^2$$

note: % road slope (+, -) is in direction of road construction

X4 = net horsepower of crawler tractor (Table 12, Appendix 4)
X5 = number of acres of cleared road width per 1,000 feet of road length
X6 = road construction difficulty factor with suggested values of:

10	for high volume truck road or low volume road constructed adverse conditions
500	for low volume truck road constructed under average conditions
1,000	for low volume skid road constructed under average conditions
2,000	for upgrading existing low volume skid road under average conditions
3,000	for low volume landing constructed under average conditions

note: intermediate values (ie. 520, 750) can be used

X7 = (equipment availability)(equipment utilization), with suggested values of:

0.50	for low availability and utilization
0.85	for average availability and utilization
0.95	for high availability and utilization

note: only the variables X1, X4, X6, and X7 are required as user supplied inputs. The variables X2, X3, and X5 are calculated by the program.

rubber-tired skidder equation (Koger, equation 2, pg 31, 1976)

T = (travel empty + travel loaded + fixed cycle time)/efficency (A2)

$$T = \left[\frac{0.0584037\, A^{a}\, B^{b}\, C^{c}\, (1+D)^{d}\, E^{e}\, (1+\sin(F))^{f}\, G^{g}}{H^{h}\, I^{i}} + \frac{0.00005166\, J^{j}\, A^{k}\, B^{l}\, (1+D)^{m}\, E^{n}\, [1+\sin(-F)]^{o}\, G^{p}}{H^{q}\, C^{r}\, I^{s}} + K \right] \frac{1}{L} \qquad \text{(A3)}$$

where: T = cycle time in minutes
A = one-way skidding distance in feet
B = radius of curvature in feet (used average study value of 483.99)
C = net skidder horsepower (Table 13, Appendix 4)
D = rut depth in inches (used average study value of 6.26)
E = harvest elevation in feet (used average study value of 1,547.13)
F = trail slope in degrees(measured in travel loaded direction)
G = empty skidder weight in pounds (use constant of 20,400)
H = cone index of soil (used average study value of 192.23
I = arc length in feet (used average study value of 131.59)
J = board feet per cycle (1/4 " Int.)
K = fixed time per cycle in minutes for hooking, decking, etc.
L = (equipment availability)(equipment utilization), or equipment efficiency

exponents a through s:
a=1.022449; b=3.549048; c=1.317563; d=0.223969; e=0.180727
f=2.156775; g=0.177384; h=0.183381; i=6.943695; j=0.110305
k=1.098034; l=3.472234; m=0.116935; n=0.098604; o=0.681159
p=3.234567; q=0.067053; r=3.157504; s=7.456998

note: Variables B, D, E, G, H, and I remain constant in the program and do not have to be supplied as inputs by the user.

Table 1.--Observed skidding volumes by horsepower*

	VOLUME PER CYCLE WHEN MEASURED AS:											
	Pounds			Board Feet:¼" Int.			Cubic Feet			Cords		
Horsepower	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
70	2,205	7,080	5,266	87	617	410	29	117	83	0.38	1.21	0.90
80	3,141	7,129	5,278	233	741	471	43	120	81	0.54	1.21	0.90
92	4,032	6,921	4,987	350	666	464	67	108	82	0.69	1.18	0.85
94	815	19,188	8,124	23	2,403	861	14	294	119	0.14	3.28	1.39
112	2,983	25,450	8,416	141	2,260	715	51	361	128	0.50	4.35	1.44
120	5,005	20,226	12,822	503	2,142	1,334	81	310	199	0.86	3.46	2.19
147**	4,120	7,095	5,468	419	776	575	71	122	94	0.70	1.21	0.93
165**	4,808	5,503	5,155	445	522	484	83	95	89	0.82	0.94	0.88

* (Koger, Table 6, pg 22, 1976)

** Did not observe when stand conditions permitted high volume skidding.

trucking equation

The following equation is used to calculate truck cycle time from landings to the delivery point (mill).

$$Y_{ij} = \frac{O}{S_j} + \frac{O}{F_j} + \frac{X_i}{(E_j(1+C_i))/2} + \frac{X_i}{(L_j(1+C_i))/2} + K_j \qquad (A4)$$

where: Y_{ij} = round trip truck time in hours from the i th landing for the j th truck

O = one-way distance in miles over roads outside the harvest boundary

S_j = average empty travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)

F_j = average loaded travel speed in miles per hour for the j th truck over sections outside the harvest boundary (woods to mill)

X_i = distance in miles from beginning of harvest boundary to the i th landing

E_j = empty travel speed in miles per hour over the woods road for the j th truck

C_i = ratio of ending travel speed to beginning travel speed as measured from beginning of harvest boundary to the i th landing

L_j = loaded travel speed in miles per hour over the woods road for the j th truck

K_j = fixed time per cycle in hours for the j th truck

trucking data

Table 2.-- Average truck speed versus road type*

Type of Road	Average Empty Speed (mph)	Average Loaded Speed (mph)
Woods	8.34	5.35
Gravel	16.23	13.89
Two-lane blacktop	38.76	33.78
Interstate	55.00	45.82
City	23.97	21.44

* (Koger, Table 1, pg 5, 1981)

Table 3.--Load characteristic for trucks hauling logs (or tree-length stems)*

Truck Description	Average Number of logs	Average Length (feet)	Average Volume (Doyle)	Average Volume (1/4" Int.)
Single-Axle (1.5-ton)	18	13.6	1,313	1,752
Tandem-Axle (1 drag)	30	12.9	1,937	2,584
Tandem-Axle (2-ton)	25	13.0	2,018	2,693
Tri-Axle (1 drag)	35	15.2	2,643	3,526
Four-Axle (2-drag)	46	11.7	3,276	4,370
Tractor-Trailer (logs)	43	14.5	3,868	5,160
Tractor-Trailer (stems)	35	36.9	4,222	5,632

* (Koger, Table 2, pg 6, 1981)

Table 4.--Load characteristics for trucks hauling pulpwood (bolts, 21-foot stems, or tree-length stems)*

Truck Description	Type of Load	Average Volume (cords)
Single-Axle (0.75-ton)	Pulpwood bolts (5' 3")	1.5
Single-Axle (1-ton)	Pulpwood bolts	2.1
Single-Axle (1.5 ton)	Pulpwood bolts	4.6
Tandem-Axle (1 drag)	Pulpwood bolts	5.3
Tractor-Trailer	Tree-length	8.7
Tandem-Axle (2-ton)	21-foot stems	9.0
Tri-Axle (1 drag)	21-foot stems	9.3
Tractor-Trailer	Pulpwood bolts	9.8

* (Koger, Table 3, pg 6, 1981)

HARVESTING COST RELATIONSHIPS

Landing Construction and System Move

In the linear programming formulation, landing construction and system move times and costs are considered together. The following equation is used to compute a weighted time for landing construction and system moving.

$$WH = (SL + SM)/(HL + HM) \qquad (A5)$$

Where: WH = weighted number of hours for landing construction and system move
SL = sum of landing construction costs for this method
SM = sum of system move costs for this method
HL = hourly landing construction costs
HM = hourly system move costs

Multiple Equipment

In many cases multiple crawler tractors, skidders, or trucks may be used. For example, two rubber-tired cable skidders may be used on the same boundary to skid trees to the landings. Equation A6 is used to compute total time under these conditions. This equation is used for multiple equipment involved in road construction, skidding, or trucking, but not for landing construction. Only one crawler tractor is allowed to construct landings, although two or more are involved in road construction.

$$T = \frac{1}{\frac{1}{H_1} + \frac{1}{H_2} + \cdots + \frac{1}{H_n}} \qquad \text{(A6)}$$

where: T = hours required if all equipment (ie. skidders) worked together
H_1 = hours required if this harvesting activity were done entirely by the first machine
H_2 = hours required if this harvesting activity were done entirely by the second machine
H_n = hours required if this harvesting activity were done entirely by the last machine

Equipment Interactions and Efficiency

Equipment interactions resulting in production delays are not directly considered. However, an equipment efficiency factor which considers utilization is available and can be used to model indirectly the effects of delays caused by equipment interactions. Equipment efficiency can be estimated or calculated by the following equation.

$$E = AU \qquad \text{(A7)}$$

where: E = equipment efficiency (decimal value greater than 0)
A = equipment availability (decimal)
U = equipment utilization (decimal)

Labor and Equipment Costs

Harvesting costs computed in L-O-S-T are based on only the harvesting functions considered in the optimization analysis (road construction, landing construction, system move between landings, skidding, and trucking). Hourly labor cost includes the base wage rate plus social security and workmen's compensation. Hourly equipment costs include fixed and operating costs based on a scheduled hour. Miyata (1980) discusses fixed and operating costs for timber harvesting equipment and provides several examples of the different methods available. The following equation reported by Nichols (1962) is a simple rule-of-thumb method that can be used to determine the approximate scheduled hourly cost of timber harvesting equipment used in L-O-S-T.

$$C = 0.0003(P) \tag{A8}$$

where: C = hourly equipment costs (excluding labor)
P = purchase price of equipment or purchase price of an equivalent piece of new equipment

Appendix 2—Determining and Using Skidding Distances

Determining Skidding Distance

In L-O-S-T, a distinction is made between average skidding distance (ASD), average travel distance (ATD), and fixed skidding distance (Figure I). The equations developed by Suddarth (1952) for average skidding distance on simple geometric shapes are shown in Figure II. Greulich (1980) extended this and included the influence of slope on the equations he developed for average skidding distance on areas with simple geometric shapes. For irregular shaped areas, average skidding distance can be accurately computed using a desk-top programmable calculator and digitizer (Peters and Burke 1972).

In most cases there is very little difference between the values obtained for average skidding distance using the mathematical equations derived by Suddarth (1952) and those obtained by determining the straight line distance from the landing to the centroid of the area. For example, if the landing is located at the corner of a mile square area, then the average skidding distance computed by Suddarth's equation is 4,040.23 feet. The straight line distance from the landing to the centroid (2640,2640) of the area is 3,733.52 feet. A simple graphical method for estimating average skidding distance on irregular shaped areas is shown in Figure III.

While average skidding distance has an exact mathematical definition (Suddarth 1952), its use, nevertheless, represents a simplification of the skidding process. If average skidding distance is used, then all the trees on the area are essentially assumed to be located an equal distance (average skidding distance) from the landing. However, trees are scattered over the area and skidding usually starts near the landing and proceeds to the farthest boun-

dary of the harvest area. A more accurate estimate of skidding cycle time can be obtained by integrating the skidding equation (A3) over the range of skidding distances. Similarly, using an average skidding cycle volume rather than the range of cycle volumes causes equation A3 to underestimate skidding times. In L-O-S-T, users have the options of using average values for skidding distance and volume or their ranges. For simplicity reasons, the simplifed version (A10) of the skidding equation will be used to illustrate the integration procedures (A11) available in L-O-S-T, given below.

$$Y = \text{travel empty time} + \text{travel loaded time} + \text{fixed time} \tag{A9}$$

$$Y = 0.0027(X)^{1.022} + 0.00088(X)^{1.098}(V)^{0.11} + K \tag{A10}$$

where: Y = cycle time in minutes for articulated, four-wheel drive, rubber-tired skidders in the 70 to 130 horsepower range
X = one-way skidding distance in feet
V = cycle volume in board feet (1/4 Int.); must be reasonable for skidder size and skid trail conditions (Table 1, Appendix 1)
K = assumed fixed time (minutes) per cycle for hooking, decking, etc.

$$Y = \frac{0.0027}{b-a}\int_a^b (X)^{1.022}\,dx + \frac{0.00088}{(b-a)(d-c)}\int_a^b\int_c^d (X)^{1.098}(V)^{0.11}\,dx\,dv + K \tag{A11}$$

where: Y = skidding cycle time in minutes
a = lower limit on skidding distance in feet
b = upper limit on skidding distance in feet
c = lower limit on skidding volume in board feet (1/4" Int.)
d = upper limit on skidding volume in board feet (1/4" Int.)
X = skidding distance, feet
V = skidding volume, board feet (1/4" Int.)
dx = derivative of Y with respect to X
dv = derivative of Y with respect to V
K = fixed time per cycle in minutes for hooking, decking, etc.

Actual Travel Distance

Due to terrain features (steep slopes, streams, rocks, soft ground) and to stand characteristics (large stumps, dead snags), the distance actually traveled by the skidder from the landing to the woods is rarely ever equal to the

straight-line value computed for average skidding distance. Koger (1976) found that a correction factor of 1.86 was needed to adjust average skidding distance to the actual travel distance. The user can supply this correction factor (1.86) or one pertinent to area conditions through the input variable, AC (card type 13, Appendix 5). In most cases, if some correction factor is not used, skidding costs will be significantly underestimated.

Fixed Skidding Distance

In most cases an area (Figures 10-13) will not be adjacent to a landing. The distance traveled by the skidder from the landing to reach the area boundary is referred to as the fixed skidding distance. This value must be calculated or estimated by the user and coded in the input data (variabale AF, card type 13, Appendix 5).

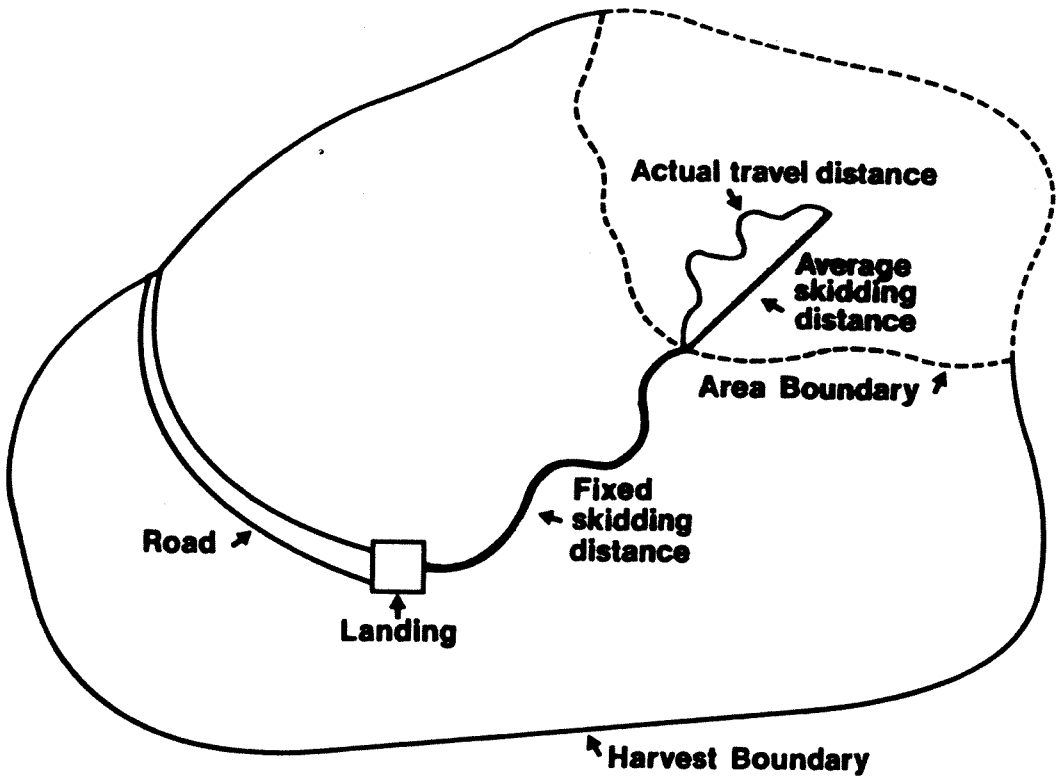
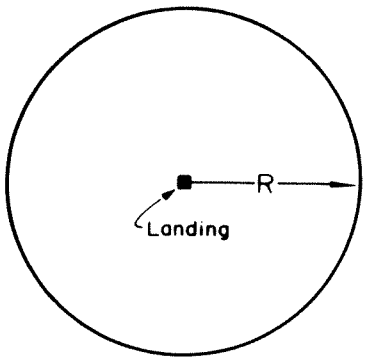


Figure I.--Relationship among average skidding distance, actual travel distance, and fixed skidding distance

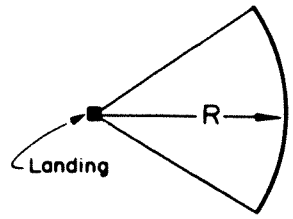
AVERAGE SKIDDING DISTANCE (ASD) FOR SIMPLE GEOMETRIC SHAPES

CIRCLE (Suddarth 1952)



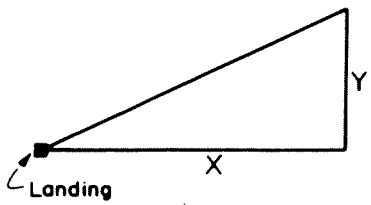
$$ASD = (2/3)\,R$$

CIRCULAR SEGMENT (Suddarth 1952)



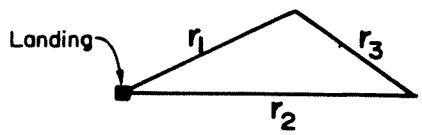
$$ASD = (2/3)\,R$$

RIGHT TRIANGLE (Suddarth 1952)



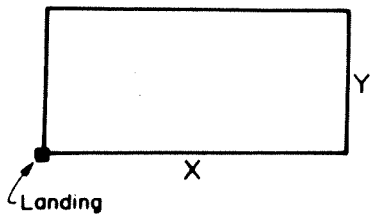
$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left[\frac{x^2}{3y}\right] \ln\left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]$$

ANY TRIANGLE (Peters 1978)



$$ASD = \frac{r_1+r_2}{6r_3^2}\left[r_3^2+(r_1-r_2)^2\right] + \frac{\left[r_3^2-(r_1-r_2)^2\right]\left[(r_1+r_2)^2-r_3^2\right]}{12r_3^3} \ln\left[\frac{r_1+r_2+r_3}{r_1+r_2-r_3}\right]$$

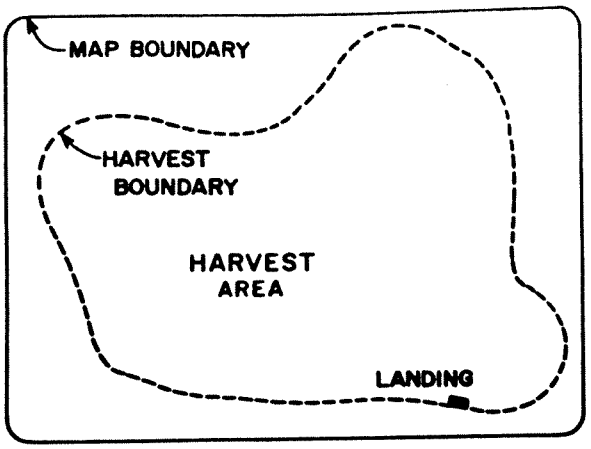
RECTANGLE (Suddarth 1952)



$$ASD = \sqrt{\frac{x^2+y^2}{3}} - \left(\left[\frac{y^2}{6x}\right] \ln\left[\tan\left\{\frac{\arctan\left(\frac{y}{x}\right)}{2}\right\}\right]\right) - \left(\left[\frac{x^2}{6y}\right] \ln\left[\tan\left\{\frac{\arctan\left(\frac{x}{y}\right)}{2}\right\}\right]\right)$$

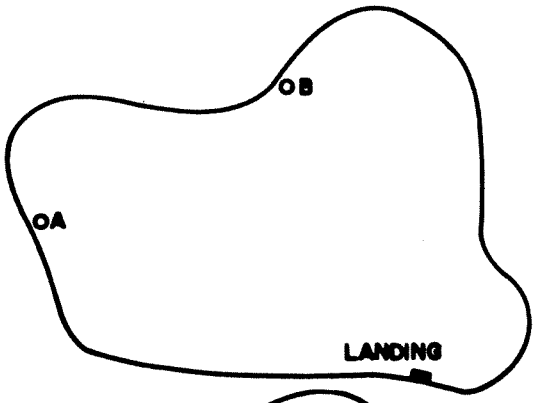
Where: ln = natural log, base e ; tan = tangent ; arctan = arctangent

Figure II.--Average skidding distance equations for areas with simple geometric shapes

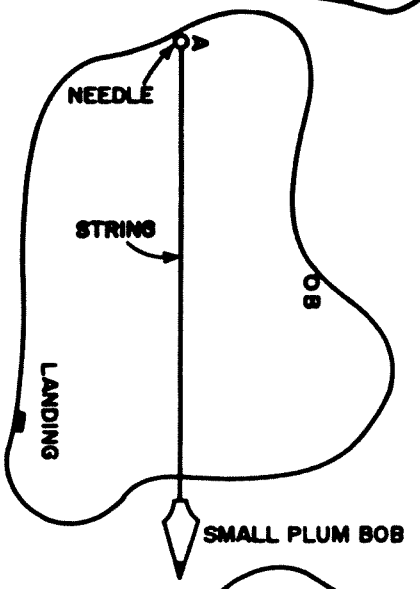


STEP 1: DETERMINE HARVEST BOUNDARY AND LANDING LOCATION.

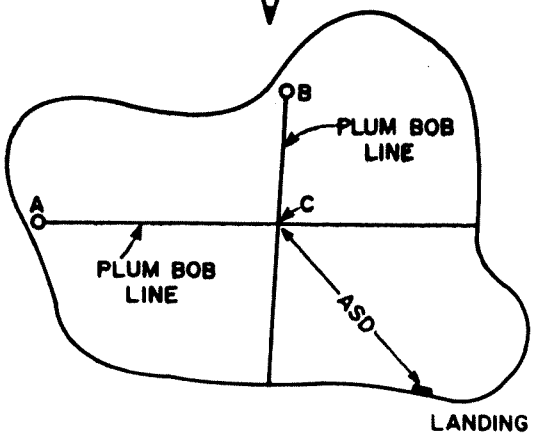
STEP 2: SEPARATE HARVEST AREA FROM MAP BY CUTTING ALONG HARVEST BOUNDARY LINE.



STEP 3: MAKE TWO SMALL HOLES NEAR MARGIN OF HARVEST BOUNDARY (A & B). SEPARATE FROM LANDING BY ABOUT 1/3 BOUNDARY CIRCUMFERENCE.



STEP 4: PLACE A NEEDLE IN HOLE AT LOCATION (A) AND MAKE SURE THAT HARVEST AREA CUTOUT ROTATES FREELY ABOUT THE NEEDLE AXIS. ATTACH A SMALL PLUM BOB TO NEEDLE AND MARK PLUM LINE ON CUTOUT. REPEAT THIS PROCESS AT LOCATION (B).



STEP 5: THE CENTROID OF THE HARVEST AREA WILL BE AT THE INTERSECTION OF THE TWO PLUM BOB LINES (C). MEASURE THE DISTANCE FROM POINT C TO THE LANDING WITH A RULER. THIS DISTANCE MULTIPLIED BY THE MAP SCALE WILL GIVE A CLOSE APPROXIMATION OF AVERAGE SKIDDING DISTANCE(ASD).

Figure III.--Graphic method for determining average skidding distance when landing is on boundary edge

Appendix 3—Harvesting Example Problem Method Assumptions

Table 5.--Harvesting equipment assumptions

Equipment Description	Equipment Efficiency Factor	Cycle Volume (1/4" Int. Bdft)	Scheduled Hourly Costs ($) +
crawler tractor (72 hp)*	0.70	NA	$21.63
rubber-tired skidder (70 hp)*	0.80	400 - 510	19.05
rubber-tired skidder (90 hp)*	0.85	420 - 550	22.30
tandem-axle truck (2 ton)	0.80	1,800	19.50
tandem-axle truck (2 ton)	0.80	2,000	20.50
knuckleboom loader*	NA	NA	13.00
repair truck*	NA	NA	8.50

\+ includes $5.50 per scheduled hour for labor costs
* equipment involved in system move between landings

Table 6.--Road segment data

Road Section	Road Length (feet)	Road Width (feet)	Constructed Slope (%)	Sidehill Slope (%)	Cut Ratio (feet)	Fill Ratio (feet)	Building Difficulty
a - b	350	15	-10	10	1.5	1.5	100
b - c	450	15	-8	15	1.5	1.5	150
c - d	325	15	-10	12	1.5	1.5	100
d - e	800	15	-10	12	1.5	1.5	150
e - f	600	14	-8	10	1.5	1.5	100
f - g	700	14	-10	8	1.5	1.5	150
g - h	650	13	-15	20	1.5	1.5	100
h - i	1,250	12	-12	15	1.5	1.5	100
i - j	1,650	12	-6	10	1.5	1.5	100

Table 7.--Landing construction data

Method Number	Landing Code Letter	Distance From Harvest Boundary (feet)	Landing Size (acres)	Average Depth of Cut (feet)	Construction Difficulty Factor	Equipment System Move Time (hours)
1	A	350	1.5	0.3	1.00	0.0
2	A	350	0.6	0.3	1.00	0.0
2	B	2,525	1.5	0.4	0.90	2.0
3	A	350	0.6	0.3	1.00	0.0
3	B	2,525	0.8	0.4	0.90	2.0
3	C	3,875	1.5	0.4	1.00	1.8
4	A	350	0.6	0.3	1.00	0.0
4	B	2,525	0.8	0.4	0.90	2.0
4	C	3,875	0.9	0.4	1.00	1.8
4	D	6,775	1.2	0.3	0.80	2.2

Table 8.--Skidding data for method 1

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	2	70,000	28	1,005	265	-2	7
A	4	40,000	16	525	2,080	-3	7
A	5	22,500	9	415	3,700	-5	7
A	7	90,000	45	1,180	1,200	-10	9
A	8	4,000	2	275	4,000	-8	9
A	9	15,000	10	840	3,000	-10	11
A	10	12,000	8	285	4,950	-2	11
A	11	24,000	16	1,095	4,550	5	11
A	12	16,000	16	625	5,050	10	13
A	13	27,000	27	990	6,230	10	13
A	14	15,000	15	570	8,000	5	13
A	18	26,000	13	520	5,740	15	9
A	21	30,000	15	1,095	5,050	12	9
A	22	6,000	2	170	7,700	10	5
A	23	105,000	35	900	7,225	10	5

Table 9.--Skidding data for method 2

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
B	10	12,000	8	285	1,680	-10	11
B	11	24,000	16	1,095	1,290	-2	11
B	12	16,000	16	625	1,780	5	13
B	13	27,000	27	990	2,670	10	13
B	14	15,000	15	570	5,050	10	13
B	18	26,000	13	520	2,080	5	9
B	21	30,000	15	1,095	1,880	15	9
B	22	6,000	2	170	3,660	12	5
B	23	105,000	35	900	4,260	10	5

Table 10.--Skidding data for method 3

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
C	10	12,000	8	285	790	-10	11
C	11	24,000	16	1,095	0	-2	11
C	12	16,000	16	625	300	5	13
C	13	27,000	27	990	1,390	10	13
C	14	15,000	15	570	3,660	10	13
C	18	26,000	13	520	790	5	9
C	21	30,000	15	1,095	300	15	9
C	22	6,000	2	170	2,480	12	5
C	23	105,000	35	900	2,870	10	5

Table 11.--Skidding data for method 4

Landing Code	Area Code	Area Volume (1/4"Int)	Area Size (acres)	Average Skidding Distance (feet)	Fixed Skidding Distance (feet)	Trail Slope (%)	Fixed Cycle Time (min)
A	1	65,000	26	485	0	5	7
A	3	57,500	23	820	265	5	7
A	4	40,000	16	525	2,080	-3	7
B	5	22,500	9	415	990	10	7
B	6	12,500	5	190	600	12	7
B	7	90,000	45	630	0	-2	9
B	8	4,000	2	275	1,300	-8	9
B	9	15,000	10	445	990	-10	11
C	10	12,000	8	285	790	-10	11
C	11	24,000	16	1,095	0	-2	11
C	15	6,000	6	490	300	-5	13
C	19	10,000	5	270	790	-5	9
D	16	37,000	37	900	500	-4	13
D	17	15,000	15	450	0	-5	13
D	20	16,000	8	335	2,370	3	9
D	21	30,000	15	1,170	200	4	9
D	22	6,000	2	170	2,820	4	5
D	23	105,000	35	720	150	6	5

Appendix 4—Equipment Specifications

Table 12.--Equipment horsepower and weight characteristics for selected crawler tractors

Equipment Make & Model		Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Case	350	39	5,905
	450	51	8,850
	850	72	13,000
	1450	130	23,800
Caterpillar	D3-PS	62	10,300
	D4-DD	75	13,990
	D5-DD	105	19,200
	D6-DD	140	24,000
John Deere	JD350-C	42	8,160
	JD450-C	65	11,600
	JD550	72	12,300
International	TD-7E-PS	65	10,459
	TD-8E-PS	78	13,834
	TD-15C-PS	140	24,153
Komatsu	D45A-1	90	18,340
	D53A-15	110	22,200
	D60A-6	140	28,220
Massey-Ferguson	MF300	65	14,700
	MF400	85	20,585
	MF5WB	136	25,800

Table 13.--Equipment horsepower and weight characteristics for selected rubber-tired skidders

Equipment Make & Model	Equipment Horsepower (net engine)	Equipment Weight (bare, pounds)
Athey S-97D	97	16,250
Caterpillar 518	120	20,400
528	175	28,300
Clark Ranger 664B	82	15,890
666B	112	17,855
668B	166	24,480
Franklin 531	70	12,000
132	80	17,840
170	112	18,740
185	175	24,140
International S8	86	13,100
John Deere JD440-B	70	12,250
JD540-A	94	16,150
JD640	110	19,900
JD740	145	26,700
Pettibone 100	93	14,950
Timber Jack 208D	67	12,300
225	92	12,784
Tree Farmer C5D	90	15,890
C6D	120	18,180

Appendix 5—Data Card Types

The following 17 data card types are used in L-O-S-T to describe organized input data for the harvesting methods, areas, road segments, landings, and equipment. Unless otherwise stated, all input data is to be right justified. Input variable names beginning with INTEGER letters (I,J,K,L,M, or N) do not require decimal points. Input variable names beginning with REAL letters (A-H, & O-Z) do require a decimal point in the input field location shown. Although harvest volume units of pounds, 1/4" Int. board feet, cubic feet, or cords may be used, once a unit has been selected it must be used throughout the analysis. The input data for the harvesting example shown in Appendix 6 should be used to supplement the data card type descriptions given below.

Card Type 1: (required; one card)

1 /_/_/_ _ _ _ _	64 cc /_/	ATITLE()	harvesting problem title

Card Type 2: (required; one card)

2 cc /_/	NMETH	number of methods analyzed (minimum of 2 and a maximum of 4)
5 cc /_/	NDZR	number of crawler tractors (1-5)
7 8 cc /_/_/	NSKD	number of rubber-tired, cable skidders (1-10)
10 11 cc /_/_/	NTRK	number of trucks (1-10)
13 cc /_/	ICTRAT	number of user supplied constraints (0-4); allows limits on number of hours permitted for harvesting functions considered
15 cc /_/	ILPANA	linear programming option code: = 0 if linear programming analysis is performed = 1 if linear programming analysis is not performed
17 cc /_/	LPCDE	= 0 if no intermediate matrices are printed; the normal case = 1 if intermediate matrices are printed; is helpful in understanding sensivity analysis

Card Type 3: (required; one card)

```
  1 cc
/_/                          IUNIT     unit code for volume;
                                       = 1 for pounds
                                       = 2 for 1/4" Int. board feet
                                       = 3 for cubic feet
                                       = 4 for cords

 3                  12 cc
/_/_/_/_/_/_/_/_/_/./        HARVOL    total volume of harvested timber
                                       in same units as coded for IUNIT

14        18  20 cc
/_/_/_/_/./_/_/              PRODPC    selling or delivered price in normal
                                       selling units (ie. $/1,000 board feet)

 22       26  28 cc
/_/_/_/_/./_/_/              SYSMHC    hourly cost ($/hr) to move pertinent
                                       equipment to the next landing; not an
                                       hourly  move-in cost

 30       35 cc
/_/_/_/./_/                  DFTBTM    distance in miles from mill to harvest
                                       boundary or start of constructed woods
                                       roads (can be zero if analyzing trucking
                                       within harvest boundary)
```

Card Type 4: (required; one card for each crawler tractor building roads ; NDZR cards required; cards adjacent)

```
 1     4 cc
/_/_/_/./                    DZRHP()   net horsepower of crawler tractor;
                                       (Table 12, Appendix 4)

 6     9 cc
/_/./_/_/                    DZREF()   crawler tractor efficiency (ie. 0.80)

 11    14  16 cc
/_/_/_/./_/_/                DZRHC()   hourly crawler tractor and operator
                                       cost ($/hr)
```

Card Type 5: (required; one card for each skidder; NSKD cards required; cards adjacent)

```
 1     4 cc
/_/_/_/./                    SKDHP()   net skidder horsepower;
                                       (Table 13, Appendix 4)

 6         11 cc
/_/_/_/_/_/./                SKDWT()   weight of unloaded skidder in pounds;
                                       (Table 13, Appendix 4)

 13    16 cc
/_/./_/_/                    SKDEF()   skidder efficiency (ie. 0.75)
```

```
 18    21  23 cc
/_/_/_/./_/_/                    SKDHC()   hourly skidder and operator cost ($/hr)
```

Card Type 6: (required; one card for each truck; NTRK cards required; cards adjacent); note: travel speeds must be > 0.

```
 1      4 cc
/_/_/./_/                        TKTENW()  empty truck travel speed in mph over
                                           non-woods road (Table 2, Appendix 1)

 6      9 cc
/_/_/./_/                        TKTLNW()  loaded truck travel speed in mph over
                                           non-woods road (Table 2, Appendix 1)

 11     14 cc
/_/_/./_/                        TKTEWD()  empty truck travel speed in mph over
                                           woods road (Table 2, Appendix 1)
 16    19 cc
/_/_/./_/                        TKTLWD()  loaded truck travel speed in mph over
                                           woods road (Table 2, Appendix 1)
 21    24 cc
/_/_/./_/                        TKFTPC()  fixed time per cycle in minutes; can
                                           include delays, stops for fuel, etc.

 26    29 cc
/_/./_/_/                        TKEF()    truck efficiency (ie. 0.80)

 31           38   40 cc
/_/_/_/_/_/_/_/./_/_/            TKVOL()   average truck volume (Tables 3 & 4,
                                           Appendix 1); same units as IUNIT in
                                           card type 3
 42    45  47 cc
/_/_/_/./_/_/                    TKHC()    hourly truck and operator cost ($/hr)
```

Card Type 7: (required; one card for each method; NMETH cards required; cards adjacent)

```
 1 cc
/_/                              IMETH()   method number (1-4)

    4 cc
/_/_/                            IRDSEG()  number of road segments for this method
                                           (0-20)

  7 cc
/_/                              ILANDN()  number of landings for this method
                                           (1-8)
```

Card Type 8: (required; one card for each landing for each method; cards adjacent)

```
  1 cc
/_/                              JMN       method number--not number of methods
                                           (1-4)
```

4 cc /_/	JLN	landing number--not number of landings (1-8)
7 cc /_/_/	JNA	number of areas for this landing (1-25); not area code number
10 cc /_/_/	JMAN	maximum value of any area code number for this landing; is equal to JNA only if areas are numbered consecutively

Card Type 9: (required; one card)

1 cc /_/	JMN	control card which follows the last card type 8 and must have a 0 (zero) coded in card column 1

Card Type 10: (required; one card for each road segment for each method; cards adjacent)

1 7 cc /_/_/_/_/_/_/./	ROADSL	length of road segment in feet; if there are no road segments code a 0 (zero) in card column 6 and then skip other variables on this card type
9 12 cc /_/_/./_/	ROADSW	segment road width in feet
14 18 cc /_/_/_/_/./	ROADSP	percent slope (+,-) or road segment in direction of construction
20 24 cc /_/_/_/_/./	ROADSS	percent slope (+ only) of side-hill adjacent road
26 28 30 cc /_/_/./_/_/	ROADCR	cut ratio; rise in cut per 1 foot of base (ie. 1.50)
32 34 36 cc /_/_/./_/_/	ROADFR	fill ratio; drop in fill per 1 foot of base (ie. 1.50)
38 42 cc /_/_/_/_/./	ROADTY	road construction difficulty code; = 10 for road constructed under adverse conditions or for high volume truck traffic = 500 for road constructed under average conditions = 1000 for road constructed under favorable conditions

= 2000 for road constructed under very favorable conditions, or the up-grading of an existing road
= 3000 for landing constructed under average conditions

note: intermediate values (ie. 520, 760) can be used; trial and error techniques may be required to obtain desired or expected times and costs

Card Type 11: (required; one card)

1 cc /_/	ILDZR	input order number of crawler tractor in card type 4 that will be used to construct all landings (ie. if the second crawler tractor in card type 4 is used, then code a 2 in card column 1); only one crawler tractor is permitted to construct landings

Card Type 12: (required; one card for each landing for each method; cards adjacent; input all landings for first method, then all landings for second method, etc.)

1 8 cc /_/_/_/_/_/_/_/_/./	DSFTB()	distance in feet this landing is from harvest boundary as measured along woods road
10 13 cc /_/_/./_/	ACRESL	landing size in acres
15 18 cc /_/_/./_/	CUTL	average depth in feet of earth removed in constructing this landing
20 23 cc /_/./_/_/	EFFL	landing construction difficulty factor; must be greater than 0.0; suggest: = less than 1.00 for difficult sites = 1.0 for average sites = greater than 1.0 for favorable sites
25 29 cc /_/_/_/./_/	SYSMHR	number of hours required to move equipment to this landing; not a move-in time, but a system move between landing time; should be 0 (zero) for the first landing

Card Type 13: (required; one card for each area for each method; cards adjacent)

1 cc /_/	IMN	method number

3 cc /_/	ILN	landing number
5 cc /_/_/	IAN	area code number
6 14 cc /_/_/_/_/_/_/_/_/./	AV	area volume in same units used for variable IUNIT in card type 3
15 20 cc /_/_/_/_/_/./	AA	area acres
21 28 cc /_/_/_/_/_/_/_/./	AN	average or minimum skidding distance in feet for this area; if AN=AX (next variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
29 36 cc /_/_/_/_/_/_/_/./	AX	average or maximum skidding distance in feet for this area; if AX=AN (last variable) average skidding distance option is assumed and skidding time is not based on integration (dx)
37 44 cc /_/_/_/_/_/_/_/./	AF	fixed skidding distance in feet from landing to start of harvest area; is 0 (zero) if landing is located on edge or inside of harvest area; this is actual travel distance and not straight line distance (Figure I, Appendix 2)
46 48 50 cc /_/_/./_/_/	AC	correction factor adjusting straight line skidding distance to actual distance traveled by skidder inside an area; suggest 1.86; use 1.00 for no correction
52 56 cc /_/_/_/_/./	AS	slope of skid trail (+,-) in percent, measured in travel loaded direction
58 61 cc /_/./_/_/	AD	difficulty factor code used to provide more sensitivity for actual skidding conditions on each area; can be used to model increased skidder interactions, multiple skidders on small areas, or adverse skidding conditions; = less than 1.00 for adverse skidding conditions or high skidder interaction = 1.00 for average skidding conditions and no significant skidder interaction = greater than 1.00 for very favorable skidding conditions and no skidder interactions

63 66 cc
/_/_/_/_/ AT average fixed skidding time per cycle in minutes (ie. hooking, unhooking, decking)

Card Type 14: (required; one card)

1 cc
/_/ IMN control card which follows the last card type 13; must have a 0 (zero) coded in card column 1

Card Type 15: (required; one card for each method, for each landing, for each area, for each skidder; cards adjacent)

1 cc
/_/ KM method number(1-4)

4 cc
/_/ KL landing number (1-8)

7 cc
/_/_/ KA area code number; same as IAN in card type 13

10 cc
/_/_/ KS skidder input order number; must be in same sequence as coded in card type 5.

11 20 cc
/_/_/_/_/_/_/_/_/_/_/ SKVMN average or minimum volume skidded per cycle; if SKVMN=SKVMX (next variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3

21 30 cc
/_/_/_/_/_/_/_/_/_/_/ SKVMX average or maximum volume skidded per cycle; if SKVMX=SKVMN (last variable) average skid volume is assumed and skidding time is not based on integration (dv); volume ranges (Table 1, Appendix 1); volume must be in same units as used for variable IUNIT in card type 3

Card Type 16: (required; one card for each landing for each method; cards adjacent)

1 cc
/_/ ITMN method number (1-4)

4 cc
/_/ ITLN landing number(1-8)

6 9 cc
/_/_/_/_/ TKTVCF truck speed correction factor; reflects change in truck travel speed as a function of distance traveled over woods road; ratio of ending travel speed on woods road to beginning travel speed on woods road; a value of 1.00 would indicate the use of average travel speed

Card Type 17: (optional; use only if adding constraints for number of hours; use only if value of ICTRAT in card type 2 is greater than zero; one card required for each constraint; cards adjacent; most often used after one computer analysis has been made without upper bound constraints; upper bound values are usually not know in advance of an initial unconstrained analysis

1 cc
/_/ ICSTFO constraint code:
= 1 if supplying upper bound on road construction hours
= 2 if supplying upper bound on landing construction and system move hours
= 3 if supplying upper bound on skiding hours
= 4 if supplying upper bound on trucking hours

3 10 cc
/_/_/_/_/_/_/_/_/_/ upper bound value of constraint in hours

Appendix 6—Harvesting Example Problem Input Data

```
HYPOTHETICAL HARVESTING EXAMPLE: 4 METHODS
 4  1  2  2 2 0 1
2    567500.   95.00   50.63  30.5
 72. 0.70  21.63
 70. 14175. 0.80  19.05
 90. 16675. 0.85  22.30
34.0 28.0  8.3  5.3 15.0 0.80    1800.00  19.50
34.0 26.0  8.3  5.0 15.0 0.80    2000.00  20.50
1  1  1
2  5  2
3  7  3
4  9  4
1  1 16 23
2  1  3  4
2  2 14 23
3  1  3  4
3  2  5  9
3  3  9 23
4  1  3  4
4  2  5  9
4  3  4 19
4  4  6 23
0
   350. 15.0  -10.   10.  1.50  1.50  100.
   350. 15.0  -10.   10.  1.50  1.50  100.
   450. 15.0   -8.   15.  1.50  1.50  150.
   325. 15.0  -10.   12.  1.50  1.50  100.
   800. 15.0  -10.   12.  1.50  1.50  150.
   600. 14.0   -8.   10.  1.50  1.50  100.
   350. 15.0  -10.   10.  1.50  1.50  100.
   450. 15.0   -8.   15.  1.50  1.50  150.
   325. 15.0  -10.   12.  1.50  1.50  100.
   800. 15.0  -10.   12.  1.50  1.50  150.
   600. 14.0   -8.   10.  1.50  1.50  100.
   700. 14.0  -10.    8.  1.50  1.50  150.
   650. 13.0  -15.   20.  1.50  1.50  100.
   350. 15.0  -10.   10.  1.50  1.50  100.
   450. 15.0   -8.   15.  1.50  1.50  150.
   325. 15.0  -10.   12.  1.50  1.50  100.
   800. 15.0  -10.   12.  1.50  1.50  150.
   600. 14.0   -8.   10.  1.50  1.50  100.
   700. 14.0  -10.    8.  1.50  1.50  150.
   650. 13.0  -15.   20.  1.50  1.50  100.
  1250. 12.0  -12.   15.  1.50  1.50  100.
  1650. 12.0   -6.   10.  1.50  1.50  100.
1
    350.  1.5  0.3 1.00   0.0
    350.  0.6  0.3 1.00   0.0
   2525.  1.5  0.4 0.90   2.0
```

350.	0.6	0.3	1.00	0.0
2525.	0.8	0.4	0.90	2.0
3875.	1.5	0.4	1.00	1.8
350.	0.6	0.3	1.00	0.0
2525.	0.8	0.4	0.90	2.0
3875.	0.9	0.4	1.00	1.8
6775.	1.2	0.3	0.80	2.2

1 1 1	65000.	26.	485.	485.	0.	1.9	5.	1.00	7.0
1 1 2	70000.	28.	1005.	1005.	265.	1.9	-2.	1.00	7.0
1 1 4	40000.	16.	525.	525.	2080.	1.9	-3.	1.00	7.0
1 1 5	22500.	9.	415.	415.	3700.	1.9	-5.	1.00	7.0
1 1 7	90000.	45.	1180.	1180.	1200.	1.4	-10.	1.00	9.0
1 1 8	4000.	2.	275.	275.	4000.	1.4	-8.	0.90	9.0
1 1 9	15000.	10.	840.	840.	3000.	1.4	-10.	1.00	11.0
1 110	12000.	8.	285.	285.	4950.	1.4	-2.	1.00	11.0
1 111	24000.	16.	1095.	1095.	4550.	1.4	+5.	0.95	11.0
1 112	16000.	16.	625.	625.	5050.	1.5	+10.	0.85	13.0
1 113	27000.	27.	990.	990.	6230.	1.5	+10.	0.90	13.0
1 114	15000.	15.	570.	570.	8000.	1.5	+5.	0.90	13.0
1 118	26000.	13.	520.	520.	5740.	1.5	+15.	0.80	9.0
1 121	30000.	15.	1095.	1095.	5050.	1.7	+12.	0.90	9.0
1 122	6000.	2.	170.	170.	7700.	1.7	+10.	1.00	5.0
1 123	105000.	35.	900.	900.	7225.	1.7	+10.	1.00	5.0
2 1 1	65000.	26.	485.	485.	0.	1.6	5.	1.00	7.0
2 1 3	57500.	23.	820.	820.	265.	1.6	5.	1.00	7.0
2 1 4	40000.	16.	525.	525.	2080.	1.6	-3.	1.00	7.0
2 2 5	22500.	9.	415.	415.	990.	1.6	10.	1.00	7.0
2 2 6	12500.	5.	190.	190.	600.	1.6	12.	1.00	7.0
2 2 7	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
2 2 8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
2 2 9	15000.	10.	445.	445.	990.	1.6	-10.	1.00	11.0
2 210	12000.	8.	285.	285.	1680.	1.4	-10.	1.00	11.0
2 211	24000.	16.	1095.	1095.	1290.	1.4	-2.	1.00	11.0
2 212	16000.	16.	625.	625.	1780.	1.4	5.	0.95	13.0
2 213	27000.	27.	990.	990.	2670.	1.4	10.	0.85	13.0
2 214	15000.	15.	570.	570.	5050.	1.9	10.	0.90	13.0
2 218	26000.	13.	520.	520.	2080.	1.5	5.	0.90	9.0
2 221	30000.	15.	1095.	1095.	1880.	1.5	15.	0.80	9.0
2 222	6000.	2.	170.	170.	3660.	1.5	12.	1.00	5.0
2 223	105000.	35.	900.	900.	4260.	1.5	10.	1.00	5.0
3 1 1	65000.	26.	485.	485.	0.	1.9	5.	1.00	7.0
3 1 3	57500.	23.	820.	820.	265.	1.9	5.	1.00	7.0
3 1 4	40000.	16.	525.	525.	2080.	1.9	-3.	1.00	7.0
3 2 5	22500.	9.	415.	415.	990.	1.6	10.	1.00	7.0
3 2 6	12500.	5.	190.	600.	600.	1.6	12.	1.00	7.0
3 2 7	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
3 2 8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
3 2 9	15000.	10.	445.	445.	990.	1.6	-10.	1.00	11.0
3 310	12000.	8.	285.	285.	790.	1.7	-10.	1.00	11.0
3 311	24000.	16.	1095.	1095.	0.	1.7	-2.	1.00	11.0
3 312	16000.	16.	625.	625.	300.	1.7	5.	0.95	13.0
3 313	27000.	27.	990.	990.	1390.	1.7	10.	0.85	13.0
3 314	15000.	15.	570.	570.	3660.	1.8	10.	0.90	13.0
3 318	26000.	13.	520.	520.	790.	1.8	5.	0.90	9.0
3 321	30000.	15.	1095.	1095.	300.	1.8	15.	0.80	9.0
3 322	6000.	2.	170.	170.	2480.	1.8	12.	1.00	5.0
3 323	105000.	35.	900.	900.	2870.	1.8	10.	1.00	5.0

4	1	1	65000.	26.	485.	485.	0.	1.9	5.	1.00	7.0
4	1	3	57500.	23.	820.	820.	265.	1.9	5.	1.00	7.0
4	1	4	40000.	16.	525.	525.	2080.	1.9	-3.	1.00	7.0
4	2	5	22500.	9.	415.	415.	990.	1.6	10.	1.00	7.0
4	2	6	12500.	5.	190.	600.	600.	1.6	12.	1.00	7.0
4	2	7	90000.	45.	630.	630.	0.	1.6	-2.	1.00	9.0
4	2	8	4000.	2.	275.	275.	1300.	1.6	-8.	1.00	9.0
4	2	9	15000.	10.	445.	445.	990.	1.6	-10.	1.00	11.0
4	310		12000.	8.	285.	285.	790.	1.7	-10.	1.00	11.0
4	311		24000.	16.	1095.	1095.	0.	1.7	-2.	1.00	11.0
4	315		6000.	6.	490.	490.	300.	1.7	-5.	0.95	13.0
4	319		10000.	5.	270.	270.	790.	1.7	-5.	0.90	9.0
4	416		37000.	37.	900.	900.	500.	1.5	-4.	0.90	13.0
4	417		15000.	15.	450.	450.	0.	1.5	-5.	0.90	13.0
4	420		16000.	8.	335.	335.	2370.	1.5	3.	0.80	9.0
4	421		30000.	15.	1170.	1170.	200.	1.5	4.	0.80	9.0
4	422		6000.	2.	170.	170.	2820.	1.5	4.	1.00	5.0
4	423		105000.	35.	720.	720.	150.	1.5	6.	1.00	5.0
0											
1	1	1	1	400.	400.						
1	1	1	2	460.	460.						
1	1	2	1	450.	450.						
1	1	2	2	470.	470.						
1	1	4	1	450.	450.						
1	1	4	2	470.	470.						
1	1	5	1	450.	450.						
1	1	5	2	470.	470.						
1	1	7	1	460.	460.						
1	1	7	2	500.	500.						
1	1	8	1	400.	400.						
1	1	8	2	420.	420.						
1	1	9	1	510.	510.						
1	1	9	2	550.	550.						
1	1	10	1	460.	460.						
1	1	10	2	490.	490.						
1	1	11	1	500.	500.						
1	1	11	2	520.	520.						
1	1	12	1	450.	450.						
1	1	12	2	490.	490.						
1	1	13	1	450.	450.						
1	1	13	2	490.	490.						
1	1	14	1	450.	450.						
1	1	14	2	490.	490.						
1	1	18	1	450.	450.						
1	1	18	2	490.	490.						
1	1	21	1	450.	450.						
1	1	21	2	490.	490.						
1	1	22	1	450.	450.						
1	1	22	2	490.	490.						
1	1	23	1	450.	450.						
1	1	23	2	490.	490.						
2	1	1	1	400.	400.						
2	1	1	2	460.	460.						
2	1	3	1	450.	450.						
2	1	3	2	470.	470.						
2	1	4	1	450.	450.						
2	1	4	2	470.	470.						

2	2	5	1	400.	400.
2	2	5	2	420.	420.
2	2	6	1	400.	400.
2	2	6	2	420.	420.
2	2	7	1	460.	460.
2	2	7	2	500.	500.
2	2	8	1	400.	400.
2	2	8	2	420.	420.
2	2	9	1	510.	510.
2	2	9	2	550.	550.
2	2	10	1	460.	460.
2	2	10	2	490.	490.
2	2	11	1	500.	500.
2	2	11	2	520.	520.
2	2	12	1	450.	450.
2	2	12	2	490.	490.
2	2	13	1	450.	450.
2	2	13	2	490.	490.
2	2	14	1	450.	450.
2	2	14	2	490.	490.
2	2	18	1	450.	450.
2	2	18	2	490.	490.
2	2	21	1	450.	450.
2	2	21	2	490.	490.
2	2	22	1	450.	450.
2	2	22	2	490.	490.
2	2	23	1	450.	450.
2	2	23	2	450.	450.
3	1	1	1	400.	400.
3	1	1	2	460.	460.
3	1	3	1	450.	450.
3	1	3	2	470.	470.
3	1	4	1	450.	450.
3	1	4	2	470.	470.
3	2	5	1	400.	400.
3	2	5	2	420.	420.
3	2	6	1	400.	400.
3	2	6	2	420.	420.
3	2	7	1	460.	460.
3	2	7	2	500.	500.
3	2	8	1	400.	400.
3	2	8	2	420.	420.
3	2	9	1	510.	510.
3	2	9	2	550.	550.
3	3	10	1	460.	460.
3	3	10	2	490.	490.
3	3	11	1	500.	500.
3	3	11	2	520.	520.
3	3	12	1	450.	450.
3	3	12	2	490.	490.
3	3	13	1	450.	450.
3	3	13	2	490.	490.
3	3	14	1	450.	450.
3	3	14	2	490.	490.
3	3	18	1	450.	450.
3	3	18	2	490.	490.
3	3	21	1	450.	450.

```
3   3 21   2      490.       490.
3   3 22   1      450.       450.
3   3 22   2      490.       490.
3   3 23   1      450.       450.
3   3 23   2      450.       450.
4   1   1   1      400.       400.
4   1   1   2      460.       460.
4   1   3   1      450.       450.
4   1   3   2      470.       470.
4   1   4   1      450.       450.
4   1   4   2      470.       470.
4   2   5   1      400.       400.
4   2   5   2      420.       420.
4   2   6   1      400.       400.
4   2   6   2      420.       420.
4   2   7   1      460.       460.
4   2   7   2      500.       500.
4   2   8   1      400.       400.
4   2   8   2      420.       420.
4   2   9   1      510.       510.
4   2   9   2      550.       550.
4   3  10   1      460.       460.
4   3  10   2      490.       490.
4   3  11   1      500.       500.
4   3  11   2      520.       520.
4   3  15   1      450.       450.
4   3  15   2      490.       490.
4   3  19   1      420.       420.
4   3  19   2      470.       470.
4   4  16   1      430.       430.
4   4  16   2      460.       460.
4   4  17   1      440.       440.
4   4  17   2      480.       480.
4   4  20   1      450.       450.
4   4  20   2      490.       490.
4   4  21   1      490.       490.
4   4  21   2      520.       520.
4   4  22   1      450.       450.
4   4  22   2      500.       500.
4   4  23   1      470.       470.
4   4  23   2      510.       510.
1   1 0.95
2   1 0.95
2   2 0.90
3   1 0.95
3   2 0.90
3   3 0.85
4   1 0.95
4   2 0.90
4   3 0.85
4   4 0.80
1       120.0
3       600.0
//
```

Appendix 7—Harvesting Example Problem Output Data

```
TITLE L-O-S-T  RUN=     HYPOTHETICAL HARVESTING EXAMPLE: 4 METHODS
 NUMBER OF METHODS=     4
  NUMBER OF DOZERS=     1
NUMBER OF SKIDDERS=     2
  NUMBER OF TRUCKS=     2
  LP ANALYSIS CODE=     0
    LP OUTPUT CODE=     0
# USER CONSTRAINTS=     2
HARVEST VOLUME=                                  567500.  INT. BOARD FEET
PRICE IN SELLING UNITS ($)=                          95.00
HOURLY LANDING MOVE COST ($)=                        50.63
DISTANCE FROM WOODS EDGE TO MILL (MILES)=            30.5

******************************
DOZER   DOZER    DOZER    HOURLY
NUMBER     HP    EFFIC      COST

    1    72.     0.70     21.63

******************************
                          21.63


*****************************************************
                                                SKIDDER
SKIDDER       SKIDDER    SKIDDER   SKIDDER       HOURLY
 NUMBER    HORSEPOWER     WEIGHT     EFFIC         COST

       1          70.     14175.     0.80        19.05
       2          90.     16675.     0.85        22.30

*****************************************************
                                                 41.35


*****************************************************************************
        ** NON-WOODS **   ***** WOODS ****
        TRAVEL    TRAVEL    TRAVEL    TRAVEL    FIXED
         EMPTY    LOADED     EMPTY    LOADED     TIME                CYCLE    TRUCK
TRUCK    SPEED     SPEED     SPEED     SPEED      PER    TRUCK       TRUCK   HOURLY
NUMBER     MPH       MPH       MPH       MPH     LOAD    EFFIC      VOLUME     COST

   1    34.00     28.00      8.30      5.30    15.00     0.80     1800.00    19.50
   2    34.00     26.00      8.30      5.00    15.00     0.80     2000.00    20.50

*****************************************************************************
                                                                         40.00
```

METHOD NUMBER	NUMBER ROAD SEGMENTS	NUMBER OF LANDINGS
1	1	1
2	5	2
3	7	3
4	9	4

METHOD NUMBER	LANDING NUMBER	NUMBER OF AREAS	MAXIMUM AREA CODE NUMBER
1	1	16	23
2	1	3	4
2	2	14	23
3	1	3	4
3	2	5	9
3	3	9	23
4	1	3	4
4	2	5	9
4	3	4	19
4	4	6	23

METHOD NUMBER	SEGMENT NUMBER	DOZER NUMBER	ROAD LENGTH	ROAD WIDTH	ROAD SLOPE	SIDE SLOPE	CUT SLOPE RATIO	FILL SLOPE RATIO	ROAD TYPE CODE	CUBIC YARDS	ACRES CLEARED	SEGMENT HOURS	SEGMENT COST	METHOD HOURS	METHOD COST
1	1	1	350.	15.0	-10.	10.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
1			350.							46.9	0.1			7.9	170.
2	1	1	350.	15.0	-10.	10.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
2	2	1	450.	15.0	-8.	15.	1.50	1.50	150.	99.2	0.2	7.8	169.00		
2	3	1	325.	15.0	-10.	12.	1.50	1.50	100.	54.2	0.1	7.7	167.38		
2	4	1	800.	15.0	-10.	12.	1.50	1.50	150.	133.3	0.3	12.7	274.67		
2	5	1	600.	14.0	-8.	10.	1.50	1.50	100.	70.0	0.2	13.0	280.23		
2			2525.							403.6	1.0			49.1	1061.
3	1	1	350.	15.0	-10.	10.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
3	2	1	450.	15.0	-8.	15.	1.50	1.50	150.	99.2	0.2	7.8	169.00		
3	3	1	325.	15.0	-10.	12.	1.50	1.50	100.	54.2	0.1	7.7	167.38		
3	4	1	800.	15.0	-10.	12.	1.50	1.50	150.	133.3	0.3	12.7	274.67		
3	5	1	600.	14.0	-8.	10.	1.50	1.50	100.	70.0	0.2	13.0	280.23		
3	6	1	700.	14.0	-10.	8.	1.50	1.50	150.	63.1	0.3	9.4	202.75		
3	7	1	650.	13.0	-15.	20.	1.50	1.50	100.	158.8	0.3	16.7	360.69		
3			3875.							625.5	1.6			75.1	1625.
4	1	1	350.	15.0	-10.	10.	1.50	1.50	100.	46.9	0.1	7.9	170.07		
4	2	1	450.	15.0	-8.	15.	1.50	1.50	150.	99.2	0.2	7.8	169.00		
4	3	1	325.	15.0	-10.	12.	1.50	1.50	100.	54.2	0.1	7.7	167.38		
4	4	1	800.	15.0	-10.	12.	1.50	1.50	150.	133.3	0.3	12.7	274.67		
4	5	1	600.	14.0	-8.	10.	1.50	1.50	100.	70.0	0.2	13.0	280.23		
4	6	1	700.	14.0	-10.	8.	1.50	1.50	150.	63.1	0.3	9.4	202.75		
4	7	1	650.	13.0	-15.	20.	1.50	1.50	100.	158.8	0.3	16.7	360.69		
4	8	1	1250.	12.0	-12.	15.	1.50	1.50	100.	176.3	0.4	27.1	587.16		
4	9	1	1650.	12.0	-6.	10.	1.50	1.50	100.	141.5	0.5	32.3	698.43		
4			6775.							943.3	2.6			134.6	2910.

METHOD NUMBER	LANDING NUMBER	DISTANCE FROM BOUNDARY	LANDING SIZE ACRES	AVERAGE CUT DEPTH	DOZER HP	HOURLY DOZER COST	EFFIC CODE	LANDING BUILDING HOURS	LANDING BUILDING COST	SYSTEM MOVE HOURS	SYSTEM MOVE COST	WEIGHTED BUILDING & MOVING HOURS	METHOD MOVE & LANDING COST
1	1	350.	1.5	0.3	72.	21.63	1.00	2.60	56.27	0.0	0.00		
1												0.78	56.27
2	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
2	2	2525.	1.5	0.4	72.	21.63	0.90	3.10	67.13	2.0	101.26		
2												2.64	190.90
3	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
3	2	2525.	0.8	0.4	72.	21.63	0.90	1.66	35.80	2.0	101.26		
3	3	3875.	1.5	0.4	72.	21.63	1.00	2.79	60.42	1.8	91.13		
3												4.31	311.13
4	1	350.	0.6	0.3	72.	21.63	1.00	1.04	22.51	0.0	0.00		
4	2	2525.	0.8	0.4	72.	21.63	0.90	1.66	35.80	2.0	101.26		
4	3	3875.	0.9	0.4	72.	21.63	1.00	1.68	36.25	1.8	91.13		
4	4	6775.	1.2	0.3	72.	21.63	0.80	2.60	56.27	2.2	111.39		
4												6.29	454.62

METHOD NUMBER	LANDING NUMBER	AREA NUMBER	AREA VOLUME	AREA ACRES	MINIMUM SKIDDING DISTANCE	MAXIMUM SKIDDING DISTANCE	FIXED SKIDDING DISTANCE	SKIDDING CORRECTION FACTOR	TRAIL TRAVEL DIRECTION	SLOPE LOADED (%)	AREA DIFFICULTY FACTOR	FIXED TIME CYCLE
1	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
1	1	2	70000.	28.	1005.	1005.	265.	1.90		-2.	1.00	7.0
1	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
1	1	5	22500.	9.	415.	415.	3700.	1.90		-5.	1.00	7.0
1	1	7	90000.	45.	1180.	1180.	1200.	1.40		-10.	1.00	9.0
1	1	8	4000.	2.	275.	275.	4000.	1.40		-8.	0.90	9.0
1	1	9	15000.	10.	840.	840.	3000.	1.40		-10.	1.00	11.0
1	1	10	12000.	8.	285.	285.	4950.	1.40		-2.	1.00	11.0
1	1	11	24000.	16.	1095.	1095.	4550.	1.40		5.	0.90	11.0
1	1	12	16000.	16.	625.	625.	5050.	1.50		10.	0.80	13.0
1	1	13	27000.	27.	990.	990.	6230.	1.50		10.	0.90	13.0
1	1	14	15000.	15.	570.	570.	8000.	1.50		5.	0.90	13.0
1	1	18	26000.	13.	520.	520.	5740.	1.50		15.	0.80	9.0
1	1	21	30000.	15.	1095.	1095.	5050.	1.70		12.	0.90	9.0
1	1	22	6000.	2.	170.	170.	7700.	1.70		10.	1.00	5.0
1	1	23	105000.	35.	900.	900.	7225.	1.70		10.	1.00	5.0
2	1	1	65000.	26.	485.	485.	0.	1.60		5.	1.00	7.0
2	1	3	57500.	23.	820.	820.	265.	1.60		5.	1.00	7.0
2	1	4	40000.	16.	525.	525.	2080.	1.60		-3.	1.00	7.0
2	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
2	2	6	12500.	5.	190.	190.	600.	1.60		12.	1.00	7.0
2	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
2	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
2	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
2	2	10	12000.	8.	285.	285.	1680.	1.40		-10.	1.00	11.0
2	2	11	24000.	16.	1095.	1095.	1290.	1.40		-2.	1.00	11.0
2	2	12	16000.	16.	625.	625.	1780.	1.40		5.	0.90	13.0
2	2	13	27000.	27.	990.	990.	2670.	1.40		10.	0.80	13.0
2	2	14	15000.	15.	570.	570.	5050.	1.90		10.	0.90	13.0
2	2	18	26000.	13.	520.	520.	2080.	1.50		5.	0.90	9.0
2	2	21	30000.	15.	1095.	1095.	1880.	1.50		15.	0.80	9.0
2	2	22	6000.	2.	170.	170.	3660.	1.50		12.	1.00	5.0
2	2	23	105000.	35.	900.	900.	4260.	1.50		10.	1.00	5.0
3	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
3	1	3	57500.	23.	820.	820.	265.	1.90		5.	1.00	7.0
3	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
3	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
3	2	6	12500.	5.	190.	600.	600.	1.60		12.	1.00	7.0
3	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
3	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
3	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
3	3	10	12000.	8.	285.	285.	790.	1.70		-10.	1.00	11.0
3	3	11	24000.	16.	1095.	1095.	0.	1.70		-2.	1.00	11.0
3	3	12	16000.	16.	625.	625.	300.	1.70		5.	0.90	13.0
3	3	13	27000.	27.	990.	990.	1390.	1.70		10.	0.80	13.0
3	3	14	15000.	15.	570.	570.	3660.	1.80		10.	0.90	13.0
3	3	18	26000.	13.	520.	520.	790.	1.80		5.	0.90	9.0
3	3	21	30000.	15.	1095.	1095.	300.	1.80		15.	0.80	9.0
3	3	22	6000.	2.	170.	170.	2480.	1.80		12.	1.00	5.0
3	3	23	105000.	35.	900.	900.	2870.	1.80		10.	1.00	5.0
4	1	1	65000.	26.	485.	485.	0.	1.90		5.	1.00	7.0
4	1	3	57500.	23.	820.	820.	265.	1.90		5.	1.00	7.0
4	1	4	40000.	16.	525.	525.	2080.	1.90		-3.	1.00	7.0
4	2	5	22500.	9.	415.	415.	990.	1.60		10.	1.00	7.0
4	2	6	12500.	5.	190.	600.	600.	1.60		12.	1.00	7.0
4	2	7	90000.	45.	630.	630.	0.	1.60		-2.	1.00	9.0
4	2	8	4000.	2.	275.	275.	1300.	1.60		-8.	1.00	9.0
4	2	9	15000.	10.	445.	445.	990.	1.60		-10.	1.00	11.0
4	3	10	12000.	8.	285.	285.	790.	1.70		-10.	1.00	11.0
4	3	11	24000.	16.	1095.	1095.	0.	1.70		-2.	1.00	11.0
4	3	15	6000.	6.	490.	490.	300.	1.70		-5.	0.90	13.0
4	3	19	10000.	5.	270.	270.	790.	1.70		-5.	0.90	9.0
4	4	16	37000.	37.	900.	900.	500.	1.50		-4.	0.90	13.0
4	4	17	15000.	15.	450.	450.	0.	1.50		-5.	0.90	13.0
4	4	20	16000.	8.	335.	335.	2370.	1.50		3.	0.80	9.0
4	4	21	30000.	15.	1170.	1170.	200.	1.50		4.	0.80	9.0
4	4	22	6000.	2.	170.	170.	2820.	1.50		4.	1.00	5.0
4	4	23	105000.	35.	720.	720.	150.	1.50		6.	1.00	5.0

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	********** ALL SKIDDERS WORKING TOGETHER ********** AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
1	1	1	1	400.0	400.0	18.91	163.	51.21					
1	1	1	2	460.0	460.0	16.51	141.	38.89					
1	1	1							22.10				
1	1	2	1	450.0	450.0	32.45	156.	84.13					
1	1	2	2	470.0	470.0	27.21	149.	67.54					
1	1	2							37.46				
1	1	4	1	450.0	450.0	42.81	89.	63.42					
1	1	4	2	470.0	470.0	35.43	85.	50.25					
1	1	4							28.04				
1	1	5	1	450.0	450.0	58.71	50.	48.93					
1	1	5	2	470.0	470.0	47.57	48.	38.27					
1	1	5							21.47				
1	1	7	1	460.0	460.0	40.05	196.	130.59					
1	1	7	2	500.0	500.0	33.49	180.	100.48					
1	1	7							56.79				
1	1	8	1	400.0	400.0	64.21	10.	10.70					
1	1	8	2	420.0	420.0	52.82	10.	8.38					
1	1	8							4.70				
1	1	9	1	510.0	510.0	57.60	29.	28.23					
1	1	9	2	550.0	550.0	47.71	27.	21.69					
1	1	9							12.27				
1	1	10	1	460.0	460.0	76.48	26.	33.25					
1	1	10	2	490.0	490.0	62.58	24.	25.71					
1	1	10							14.50				
1	1	11	1	500.0	500.0	102.74	48.	82.19					
1	1	11	2	520.0	520.0	84.38	46.	64.91					
1	1	11							36.27				
1	1	12	1	450.0	450.0	121.88	36.	72.23					
1	1	12	2	490.0	490.0	101.06	33.	55.00					
1	1	12							31.22				
1	1	13	1	450.0	450.0	136.69	60.	136.69					
1	1	13	2	490.0	490.0	112.57	55.	103.38					
1	1	13							58.86				
1	1	14	1	450.0	450.0	148.22	33.	82.34					
1	1	14	2	490.0	490.0	121.35	31.	61.91					
1	1	14							35.34				
1	1	18	1	450.0	450.0	131.56	58.	126.69					
1	1	18	2	490.0	490.0	108.37	53.	95.84					
1	1	18							54.56				
1	1	21	1	450.0	450.0	120.20	67.	133.56					
1	1	21	2	490.0	490.0	98.73	61.	100.75					
1	1	21							57.43				
1	1	22	1	450.0	450.0	117.11	13.	26.03					
1	1	22	2	490.0	490.0	95.19	12.	19.43					
1	1	22							11.12				
1	1	23	1	450.0	450.0	128.61	233.	500.16					
1	1	23	2	490.0	490.0	104.40	214.	372.85					
1	1	23							213.61				
1	1									695.75	28769.13		
1												695.75	28769.13

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	********** ALL SKIDDERS WORKING TOGETHER ********** AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
2	1	1	1	400.0	400.0	17.19	163.	46.57					
2	1	1	2	460.0	460.0	15.12	141.	35.62					
2	1	1							20.18				
2	1	3	1	450.0	450.0	27.00	128.	57.49					
2	1	3	2	470.0	470.0	22.96	122.	46.82					
2	1	3							25.80				
2	1	4	1	450.0	450.0	40.93	89.	60.64					
2	1	4	2	470.0	470.0	33.93	85.	48.13					
2	1	4							26.83				
2	1									72.82	3011.06		
2	2	5	1	400.0	400.0	28.95	56.	27.14					
2	2	5	2	420.0	420.0	24.62	54.	21.99					
2	2	5							12.15				
2	2	6	1	400.0	400.0	19.55	31.	10.18					
2	2	6	2	420.0	420.0	17.05	30.	8.46					
2	2	6							4.62				
2	2	7	1	460.0	460.0	21.61	196.	70.47					
2	2	7	2	500.0	500.0	18.94	180.	56.82					
2	2	7							31.46				
2	2	8	1	400.0	400.0	28.39	10.	4.73					
2	2	8	2	420.0	420.0	24.26	10.	3.85					
2	2	8							2.12				
2	2	9	1	510.0	510.0	30.36	29.	14.88					
2	2	9	2	550.0	550.0	26.17	27.	11.89					
2	2	9							6.61				
2	2	10	1	460.0	460.0	34.21	26.	14.87					
2	2	10	2	490.0	490.0	29.22	24.	11.93					
2	2	10							6.62				
2	2	11	1	500.0	500.0	45.40	48.	36.22					
2	2	11	2	520.0	520.0	38.22	46.	29.40					
2	2	11							16.25				
2	2	12	1	450.0	450.0	53.58	36.	31.75					
2	2	12	2	490.0	490.0	45.66	33.	24.85					
2	2	12							13.94				
2	2	13	1	450.0	450.0	87.09	60.	87.09					
2	2	13	2	490.0	490.0	73.10	55.	67.14					
2	2	13							37.91				
2	2	14	1	450.0	450.0	110.70	33.	61.50					
2	2	14	2	490.0	490.0	91.73	31.	46.60					
2	2	14							26.58				
2	2	18	1	450.0	450.0	50.98	58.	49.10					
2	2	18	2	490.0	490.0	42.81	53.	37.86					
2	2	18							21.37				
2	2	21	1	450.0	450.0	74.66	67.	82.96					
2	2	21	2	490.0	490.0	62.47	61.	63.74					
2	2	21							36.05				
2	2	22	1	450.0	450.0	58.82	13.	13.07					
2	2	22	2	490.0	490.0	48.47	12.	9.89					
2	2	22							5.63				
2	2	23	1	450.0	450.0	82.00	233.	318.99					
2	2	23	2	450.0	450.0	66.70	233.	259.37					
2	2	23							143.03				
2	2									364.33	15065.10		
2												437.15	18076.16
3	1	1	1	400.0	400.0	18.51	163.	51.21					
3	1	1	2	460.0	460.0	16.51	141.	38.89					

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
									********** ALL SKIDDERS WORKING TOGETHER **********				
3	1	1							22.10				
3	1	3	1	450.0	450.0	30.08	128.	64.05					
3	1	3	2	470.0	470.0	25.44	122.	51.36	28.66				
3	1	3											
3	1	4	1	450.0	450.0	42.81	89.	63.42					
3	1	4	2	470.0	470.0	35.43	85.	50.25	28.04				
3	1	4								78.80	3258.22		
3	1												
3	2	5	1	400.0	400.0	28.55	56.	27.14					
3	2	5	2	420.0	420.0	24.62	54.	21.99	12.15				
3	2	5											
3	2	6	1	400.0	400.0	23.09	31.	12.03					
3	2	6	2	420.0	420.0	19.96	30.	9.90	5.43				
3	2	6											
3	2	7	1	460.0	460.0	21.61	196.	70.47					
3	2	7	2	500.0	500.0	18.54	180.	56.82	31.46				
3	2	7											
3	2	8	1	400.0	400.0	28.39	10.	4.73					
3	2	8	2	420.0	420.0	24.26	10.	3.85	2.12				
3	2	8											
3	2	9	1	510.0	510.0	30.36	25.	14.88					
3	2	9	2	550.0	550.0	26.17	27.	11.89	6.61				
3	2	9								57.77	2388.61		
3	2												
3	3	10	1	460.0	460.0	25.81	26.	11.22					
3	3	10	2	490.0	490.0	22.56	24.	9.21	5.06				
3	3	10											
3	3	11	1	500.0	500.0	33.54	48.	27.15					
3	3	11	2	520.0	520.0	29.11	46.	22.39	12.27				
3	3	11											
3	3	12	1	450.0	450.0	35.33	36.	20.46					
3	3	12	2	490.0	490.0	31.02	33.	16.88	9.35				
3	3	12											
3	3	13	1	450.0	450.0	69.85	60.	69.85					
3	3	13	2	490.0	490.0	59.23	55.	54.39	30.58				
3	3	13											
3	3	14	1	450.0	450.0	87.39	33.	48.55					
3	3	14	2	490.0	490.0	73.01	31.	37.25	21.08				
3	3	14											
3	3	18	1	450.0	450.0	34.84	58.	33.55					
3	3	18	2	490.0	490.0	29.83	53.	26.38	14.77				
3	3	18											
3	3	21	1	450.0	450.0	51.88	67.	57.64					
3	3	21	2	490.0	490.0	44.03	61.	44.93	25.25				
3	3	21											
3	3	22	1	450.0	450.0	42.71	13.	9.49					
3	3	22	2	490.0	490.0	35.47	12.	7.24	4.11				
3	3	22											
3	3	23	1	450.0	450.0	65.85	233.	256.08					
3	3	23	2	450.0	450.0	53.79	233.	209.18	115.13				
3	3	23								237.59	5824.48		
3	3											374.16	15471.31
3													
4	1	1	1	400.0	400.0	18.51	163.	51.21					
4	1	1	2	460.0	460.0	16.51	141.	38.89	22.10				
4	1	1											
4	1	3	1	450.0	450.0	30.08	128.	64.05					

METHOD NO	LAND NO	AREA NO	SKID NO	MINIMUM VOLUME SKIDDED	MAXIMUM VOLUME SKIDDED	CYCLE TIME MINUTES	NUMBER OF CYCLES	AREA SKID TIME HOURS	AREA SKIDDING HOURS	LANDING SKIDDING HOURS	LANDING SKIDDING COSTS	METHOD SKIDDING HOURS	METHOD SKIDDING COSTS
									********** ALL SKIDDERS WORKING TOGETHER **********				
4	1	3	2	470.0	470.0	25.44	122.	51.86					
4	1	3							28.66				
4	1	4	1	450.0	450.0	42.81	89.	63.42					
4	1	4	2	470.0	470.0	35.43	85.	50.25	28.04				
4	1	4								78.80	3258.22		
4	1												
4	2	5	1	400.0	400.0	28.55	56.	27.14					
4	2	5	2	420.0	420.0	24.62	54.	21.99	12.15				
4	2	5											
4	2	6	1	400.0	400.0	23.09	31.	12.03					
4	2	6	2	420.0	420.0	19.96	30.	9.90	5.43				
4	2	6											
4	2	7	1	460.0	460.0	21.61	196.	70.47					
4	2	7	2	500.0	500.0	18.54	180.	56.82	31.46				
4	2	7											
4	2	8	1	400.0	400.0	28.39	10.	4.73					
4	2	8	2	420.0	420.0	24.26	10.	3.85	2.12				
4	2	8											
4	2	9	1	510.0	510.0	30.36	29.	14.88					
4	2	9	2	550.0	550.0	26.17	27.	11.89	6.61				
4	2	9								57.77	2388.61		
4	2												
4	3	10	1	440.0	460.0	25.81	26.	11.22					
4	3	10	2	490.0	490.0	22.56	24.	9.21	5.06				
4	3	10											
4	3	11	1	500.0	500.0	33.54	48.	27.15					
4	3	11	2	520.0	520.0	29.11	46.	22.39	12.27				
4	3	11											
4	3	15	1	450.0	450.0	30.61	13.	6.80					
4	3	15	2	490.0	490.0	27.09	12.	5.53	3.05				
4	3	15											
4	3	19	1	420.0	420.0	26.38	24.	10.47					
4	3	19	2	470.0	470.0	22.93	21.	8.13	4.58				
4	3	19								24.95	1031.86		
4	3												
4	4	16	1	430.0	430.0	39.56	96.	56.74					
4	4	16	2	460.0	460.0	34.23	80.	45.89	25.37				
4	4	16											
4	4	17	1	440.0	440.0	25.23	34.	14.33					
4	4	17	2	480.0	480.0	22.77	31.	11.84	6.49				
4	4	17											
4	4	20	1	450.0	450.0	54.55	36.	33.51					
4	4	20	2	490.0	490.0	47.44	33.	25.82	14.58				
4	4	20											
4	4	21	1	490.0	490.0	42.63	61.	43.50					
4	4	21	2	520.0	520.0	36.26	58.	34.86	19.35				
4	4	21											
4	4	22	1	450.0	450.0	43.26	13.	9.61					
4	4	22	2	500.0	500.0	35.74	12.	7.15	4.10				
4	4	22											
4	4	23	1	470.0	470.0	20.42	223.	76.04					
4	4	23	2	510.0	510.0	17.37	206.	59.61	33.41				
4	4	23								103.31	4271.88		
4	4											264.83	10950.56
4													

METHOD NUMBER	LANDING NUMBER	LANDING VOLUME	LANDING ACRES	METHOD VOLUME	METHOD ACRES	PER LANDING: AVERAGE SKIDDING DISTANCE	PER LANDING: AVERAGE FIXED SKIDDING DISTANCE	PER LANDING: WEIGHTED AVERAGE TRAVEL SKIDDING DISTANCE	PER METHOD: AVERAGE SKIDDING DISTANCE	PER METHOD: AVERAGE FIXED SKIDDING DISTANCE	PER METHOD: WEIGHTED AVERAGE TRAVEL SKIDDING DISTANCE
1	1	567500.	283.			686.	4296.	4871.			
1				567500.	283.				686.	4296.	4871.
2	1	162500.	65.			610.	792.	1587.			
2	2	405000.	218.			586.	2016.	3212.			
2				567500.	283.				598.	1399.	2747.
3	1	162500.	65.			610.	782.	1771.			
3	2	144000.	71.			432.	776.	1221.			
3	3	261000.	147.			694.	1356.	3204.			
3				567500.	283.				579.	985.	2290.
4	1	162500.	65.			610.	782.	1771.			
4	2	144000.	71.			432.	776.	1221.			
4	3	52500.	35.			535.	470.	1524.			
4	4	209000.	112.			624.	1007.	1583.			
4				567500.	283.				550.	759.	1540.

METHOD NUMBER	LANDING NUMBER	TRUCK TRAVEL CORRECTION FACTOR
1	1	0.95
2	1	0.95
2	2	0.90
3	1	0.95
3	2	0.90
3	3	0.85
4	1	0.95
4	2	0.90
4	3	0.85
4	4	0.80

METHOD NUMBER	LANDING NUMBER	TRUCK NUMBER	CYCLE TIME HOURS	NUMBER OF LOADS	TRUCK TIME HOURS	ALL TRUCKS WORKING TOGETHER: LANDING TRUCKING HOURS	LANDING TRUCKING COST	METHOD TRUCKING HOURS	METHOD TRUCKING COST
1	1	1	2.82	315.3	889.62				
1	1	2	2.93	283.8	830.65				
1	1					429.56	17182.48		
1								429.56	17182.48
2	1	1	2.82	90.3	254.74				
2	1	2	2.93	81.3	237.85				
2	1					123.00	4920.10		
2	2	1	2.99	225.0	672.74				
2	2	2	3.10	202.5	628.12				
2	2					324.83	12993.30		
2								447.83	17913.40
3	1	1	2.82	90.3	254.74				
3	1	2	2.93	81.3	237.85				
3	1					123.00	4920.10		
3	2	1	2.99	80.0	239.20				
3	2	2	3.10	72.0	223.33				
3	2					115.50	4619.84		
3	3	1	3.10	145.0	449.80				
3	3	2	3.22	130.5	419.55				
3	3					217.18	8687.21		
3								455.68	18227.16
4	1	1	2.82	90.3	254.74				
4	1	2	2.93	81.3	237.85				
4	1					123.00	4920.10		
4	2	1	2.99	80.0	239.20				
4	2	2	3.10	72.0	223.33				
4	2					115.50	4619.84		
4	3	1	3.10	28.9	89.61				
4	3	2	3.22	26.0	83.67				
4	3					43.27	1730.79		
4	4	1	3.35	116.1	388.55				
4	4	2	3.47	104.5	362.75				
4	4					187.60	7504.20		
4								469.37	18774.91

CONSTRAINT CODE	UPPER BOUND VALUE
1= ROAD HR	
2= LAND HR	
3= SKID HR	
4= TRUK HR	
1	120.
3	600.

METHOD SUMMARY

METH NO	ROAD CONSTRUCTION HOURS	ROAD CONSTRUCTION $$$	ROAD CONSTRUCTION $/VOL	LANDING CONSTRUCTION AND SYSTEM MOVING HOURS	LANDING CONSTRUCTION AND SYSTEM MOVING $$$	LANDING CONSTRUCTION AND SYSTEM MOVING $/VOL	SKIDDING HOURS	SKIDDING $$$	SKIDDING $/VOL	TRUCKING HOURS	TRUCKING $$$	TRUCKING $/VOL	TOTAL METHOD HARVESTING COSTS	METHOD HARVESTING UNIT COSTS
1	9.	170.	0.	1.	56.	0.	696.	28769.	51.	430.	17182.	30.	46177.95	61.37
2	49.	1061.	2.	3.	191.	0.	437.	18076.	32.	448.	17913.	32.	37241.81	65.62
3	75.	1625.	3.	4.	311.	1.	374.	15471.	27.	456.	18227.	32.	35634.38	62.79
4	135.	2910.	5.	6.	455.	1.	265.	10951.	19.	469.	16775.	33.	33090.45	58.31

ITERATION NO= 1

CB	I	S	SELLING PRICE $ (Y0)	METHOD 1 (M1)	METHOD 2 (M2)	METHOD 3 (M3)	METHOD 4 (M4)	$/HR ROADS (Z1)	$/HR LAND (Z2)	$/HR SKID (Z3)	$/HR TRUCK (Z4)	RIGHT HAND CONSTANTS
	CJ		95.00					-21.63	-72.26	-41.35	-40.00	
95.00	X10		1.00	-567.50	-567.50	-567.50	-567.50	0.00	0.00	0.00	0.00	0.00
0.00	X11		0.00	7.86	49.07	75.12	134.55	-1.00	0.00	0.00	0.00	0.00
0.00	X12		0.00	0.78	2.64	4.31	6.29	0.00	-1.00	0.00	0.00	0.00
0.00	X13		0.00	695.75	437.15	274.16	264.83	0.00	0.00	-1.00	0.00	0.00
0.00	X14		0.00	429.55	447.83	455.68	469.27	0.00	0.00	0.00	-1.00	0.00
-21.63	X15		1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	567.50
-72.26	X16		0.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	1.00
-41.35	X17		0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	120.00
-40.00	X18		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	600.00
												Z =
C-BAR ROW			95.00	0.00	0.00	0.00	0.00	-21.63	-72.26	-41.35	-40.00	0.

AFTER 18 ITERATIONS THE OPTIMUM SOLUTION CONSISTED OF:

METHOD #	METHOD PROPORTION	ROAD CONST HOURS	ROAD CONST COSTS	LANDING CONST AND SYSTEM HOURS	LANDING CONST AND SYSTEM COSTS	SKIDDING HOURS	SKIDDING COSTS	TRUCKING HOURS	TRUCKING COSTS	TOTAL METHOD COSTS
4	0.76	101.6	2198.	4.8	343.	200.	8269.	354.5	14178.	24989.
3	0.24	18.4	398.	1.1	76.	92.	3788.	111.6	4463.	8725.
TOTALS:	1.00	120.0	2596.	5.8	419.	292.	12057.	466.0	18641.	33713.

(A) TOTAL DELIVERD PRICE OF HARVESTED TIMBER:	53913.	UNIT PRICE:	95.00
(B) TOTAL HARVESTING COSTS (THOSE CONSIDERED):	33713.	UNIT COSTS:	59.41
DIFFERENCE: (A)-(B):	20199.		35.59

ITERATION NO= 18

CB	I	S	SELLING PRICE $ (Y0)	METHOD 1 (M1)	METHOD 2 (M2)	METHOD 3 (M3)	METHOD 4 (M4)	$/HR ROADS (Z1)	$/HR LAND (Z2)	$/HR SKID (Z3)	$/HR TRUCK (Z4)	RIGHT HAND CONSTANTS
	CJ		95.00					-21.63	-72.26	-41.35	-40.00	
0.00	X 1		1.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	567.50
0.00	Y 7		-0.00	1.28	0.79	0.00	-0.00	-0.00	1.00	-0.00	-0.00	5.81
0.00	X 8		-0.00	-197.89	-15.09	0.00	-0.00	-0.00	-0.00	1.00	-0.00	291.59
0.00	X 9		-0.00	10.62	1.84	0.00	-0.00	-0.00	-0.00	-0.00	1.00	466.02
-40.00	X19		-0.00	197.88	15.08	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	308.40
0.00	X 5		-0.00	-1.13	-0.44	0.00	1.00	-0.00	-0.00	-0.00	-0.00	0.76
0.00	X 4		0.00	2.13	1.44	1.00	0.00	0.00	0.00	0.00	0.00	0.24
-72.26	X16		-0.00	-0.00	0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00
0.00	X 6		-0.00	0.00	-0.00	0.00	-0.00	1.00	-0.00	-0.00	-0.00	120.00
												Z =
C-BAR ROW			0.00	-7665.56	-492.68	0.00	0.00	0.00	0.00	0.00	0.00	20199.

ABOVE VALUES IN C-BAR ROW ARE PENALTY COSTS

ABOVE VALUES IN C-BAR ROW ARE SHADOW PRICES

SENSITIVITY ANALYSIS

NOTE: VARIABLE CODE NUMBERS USED IN SENSITIVITY ANALYSIS ARE NOT EASY TO CORRELATE WITH OUTPUT COLUMNS AND ROWS FROM LP MATRIX

USERS FAMILIAR WITH LP SHOULD MAKE CHANGES IN INPUT COSTS (CJ) AND RESOURCE LIMITS (EJ) TO BECOME FAMILIAR WITH THE SENSITIVITY ANALYSIS AS IT APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION USED IN L-O-S-T

SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT CHANGE IN RIGHT HAND SIDE CONSTRAINTS.

PENALTY COSTS ARE CHANGE IN OBJECTIVE FUNCTION VALUE PER UNIT INCREASE IN NON-BASIC VARIABLES.

RANGES ON C(J) REPRESENT LIMITING VALUES OF COST COEFFICIENTS THAT WILL NOT CHANGE THE OPTIMUM SOLUTION

RANGES ON B(I) REPRESENT LIMITING VALUES OF RIGHT HAND SIDE CONSTRAINTS THAT WILL NOT CHANGE OPTIMUM BASIC VARIABLES.

NON-BASIC VARIABLES	PENALTY COST
10	-67.947
11	-64.426
12	-72.260
13	-41.350
14	-40.000
15	-27.053
17	-42.756
2	-7665.563
3	-492.884

ROW NUMBER	SHADOW PRICES
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.000
7	0.000
8	0.000
9	0.000

RANGES ON NON-BASIC C(J)

VARIABLE	LOWER LIMIT
10	67.947
11	64.426
12	72.260
13	41.350
14	40.000
15	27.053
17	42.756
2	7665.563
3	492.884

RANGES ON BASIC C(J)

VARIABLE	LOWER LIMIT	UPPER LIMIT
16	-38559.850	15352.200
18	-23.267	30.446
1	67.947	999999.000
4	-342.694	2543.590
5	-2543.590	1124.623
6	-64.426	17372.890
7	-693.435	0.000
8	-71.932	-18.083
9	-74.861	0.000

RANGES ON B(I)

I	LOWER LIMIT	UPPER LIMIT
1	567.500	567.500
2	274.124	132.501
3	-999999.000	1.923
4	504.219	501.998
5	-999999.000	440.392
6	-0.000	-0.000
7	1.000	999999.000
8	274.124	132.501
9	504.219	999999.000

Appendix 8—L-O-S-T Program Listing

```
00100 //LOST     JOB (UFS26JK,153),'KOGER',NOTIFY=UFS26JK,MSGCLASS=A,
00200 //         MSGLEVEL=(1,1)
00300 /*ROUTE PRINT LOCAL
00400 /*JOBPARM T=21,L=40K
00500 //  EXEC WATFIV
00600 //WATFIV.SYSIN DD *
00700 /JOB KOGER,PAGES=60,S=1000000,TIME=25
00800       DIMENSION DZRHP(5),DZREF(5),DZRHC(5),SKDHP(10),SKDWT(10),
00900      1SKDEF(10),SKDHC(10),TKTENW(10),TKTLNW(10),
01000      2TKTEWD(10),TKTLWD(10),TKFTPC(10),TKEF(10),TKVOL(10),
01100      3TKHC(10),ILAND(10),ATITLE(16),
01200      4INRSBM(20),JNAREA(4,10),DSFTB(4,10)
01300       DIMENSION AREAV(4,8,25),AREAA(4,8,25),AREAMN(4,8,25),
01400      1AREAMX(4,8,25),AREAFD(4,8,25),AREACF(4,8,25),
01500      2AREATS(4,8,25),AREADI(4,8,25),AREAFT(4,8,25),
01600      3VOLML(4,10),VOLBM(4),TKTCF(4,10)
01700      4,AREA(4,8,25),VOLMA(4,10),ACRBM(4)
01800      5,ASKDBL(4,8),FSKDBL(4,8),WSKDBL(4,8),ASKDBM(4),
01900      6FSKDBM(4),WSKDBM(4)
02000       DIMENSION LOGMET(11,20),SUM(10,10,14),SUMMET(2,50),CI(25)
02100       COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
02200      1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
02300      2,B(25),CC(25),JVAR(25),IARR(4),PROP(4),RC(4),LD(4),SK(4),
02400      3TK(4)
02500       REAL LOGMET,LD,LAMOMC
02600 CJK
02700 CJK  CJK COMMENT CARDS BY JERRY KOGER
02800 CJK  CWC COMMENT CARDS BY WADE CULVER
02900 CJK  C   COMMENT CARDS BY RAVINDRAN, ETC.
03000 CJK
03100 CJK
03200 CJK
03300 CJK      L-O-S-T IS DIVIDED INTO 2 SECTIONS; THE FIRST SECTION
03400 CJK      CALCULATES LOGGING COSTS AND THE SECOND SECTION USES
03500 CJK      THESE COSTS AS INPUT FOR THE LINEAR PROGRAM
03600 CJK
03700 CJK
03800 CJK
03900 CJK       ########  SECTION 1  ######################
04000 CJK
04100 CJK
04200 CJK
04300 CJK  CTRAD CONVERTS DEGREES TO RADIANS; CTDEG CONVERTS RADIANS
04400 CJK  TO DEGREES;  KR=5 FOR READ
04500 CJK  READ(KR,YY); KW=6 FOR WRITE  WRITE(KW,ZZ)
04600 CJK
04700       CTRAD = 0.01745329
04800       CTDEG = 57.29578
04900       KR=5
05000       KW = 6
05100 CJK
05200 CJK
05300 CJK CONPTB=CONVERSION POUNDS TO BOARD FEET,VALUE OF 0.11951
05400 CJK TAKEN FROM TVA TECHNICAL NOTE 846, 1982 BY JERRY KOGER
05500 CJK "LOG LOADING METHODS AND COSTS IN THE TENNESSEE VALLEY
05600 CJK  REGION   PAGE 20
05700 CJK  CONBTB=CONVERSION FROM BOARD FEET TO BOARD FEET 1/4 INT
05800 CJK  CONCTB=CONVERSION FROM CORDS TO BOARD FEET
05900 CJK  CONUTB= CONVERSION FROM CUBIC FEET TO BOARD FEET
06000 CJK   THESE CONVERSIONS ARE ONLY USED IN SKIDDING TIME EQUATIONS
06100 CJK
06200       CONPTB=0.11951
06300       CONBTB=1.0
06400       CONCTB=687.2746
06500       CONUTB=6.7947
06600 CJK
06700 CJK
06800 CJK  **************** CARD TYPE 1 ****************************
06900 CJK
07000 CJK
07100       READ(KR,70) (ATITLE(ITR),ITR=1,16)
07200    70 FORMAT(16A4)
07300       WRITE(KW,80) (ATITLE(ITW),ITW=1,16)
07400    80 FORMAT(1H1,/,2X,'TITLE L-O-S-T  RUN=',4X,16A4)
07500 CJK

07600 CJK
07700 CJK  **************** CARD TYPE 2 ******************************
07800 CJK
07900 CJK
08000 CJK  NMETH=# OF METHODS; NDZR=#OF DOZERS; NSKD=# OF SKIDDERS;
08100 CJK  NTRK= # OF TRUCKS;  ICTRAT=# OF USER SUPPLIED CONSTRAINTS
08200 CJK  FOR LP ANALYSIS;  LPCDE=LP OUTPUT MATRIX DEBUG CODE
08300 CJK
08400       READ(KR,90)NMETH,NDZR,NSKD,NTRK,ICTRAT,ILPANA,LPCDE
08500    90 FORMAT(I2,1X,I2,1X,I2,1X,I2,1X,I1,1X,I1,1X,I1)
08600       WRITE(KW,100)NMETH,NDZR,NSKD,NTRK
08700   100 FORMAT(3X,'NUMBER OF METHODS=',2X,I3,/,4X,'NUMBER OF',
08800      11X,'DOZERS=',2X,I3,/,2X,'NUMBER OF SKIDDERS=',2X,I3,/,
08900      24X,'NUMBER OF TRUCKS=',2X,I3)
09000       WRITE(KW,125)ILPANA,LPCDE,ICTRAT
09100   125 FORMAT(4X,'LP ANALYSIS CODE=',3X,I2,/,6X,'LP OUTPUT CODE=',
09200      13X,I2,/,2X,'# USER CONSTRAINTS=',3X,I2)
09300       M=ICTRAT+5
09400       M2=NMETH+ICTRAT+10
09500 CJK
09600 CJK
09700 CJK  ZERO OUT AREA VOLUME ARRAY
09800 CJK
09900 CJK
10000       DO 150 IZAVM=1,NMETH
10100       DO 140 IZAVL=1,8
10200       DO 130 IZAVA=1,25
10300       AREAV(IZAVM,IZAVL,IZAVA)=0.0
10400   130 CONTINUE
10500   140 CONTINUE
10600   150 CONTINUE
10700 CJK
10800 CJK
10900 CJK
11000 CJK  ZERO OUT SELECTED ARRAYS USED IN LP SECITON OF LOST
11100 CJK
11200       DO 170 IDL21=1,25
11300       DO 160 IDL22=1,25
11400       A(IDL22,IDL21)=0.0
11500   160 CONTINUE
11600   170 CONTINUE
11700       DO 185 IZOUT1=1,11
11800       DO 180 IZOUT2=1,20
11900       LOGMET(IZOUT1,IZOUT2)=0.0
12000   180 CONTINUE
12100   185 CONTINUE
12200       DO 190 IZOUT3=1,25
12300       CI(IZOUT3)=0.0
12400       C(IZOUT3)=0.0
12500       P(IZOUT3)=0.0
12600       OMZ(IZOUT3)=0.0
12700       ZJ(IZOUT3)=0.0
12800       IVAR(IZOUT3)=0.0
12900       PCOST(IZOUT3)=0.0
13000       SHADO(IZOUT3)=0.0
13100       CL(IZOUT3)=0.0
13200       CU(IZOUT3)=0.0
13300       CUP(IZOUT3)=0.0
13400       CLO(IZOUT3)=0.0
13500       BUP(IZOUT3)=0.0
13600       BLO(IZOUT3)=0.0
13700       B(IZOUT3)=0.0
13800       CC(IZOUT3)=0.0
13900       JVAR(IZOUT3)=0.0
14000   190 CONTINUE
14100 CJK
14200 CJK
14300 CJK ************** CARD TYPE 3 ********************************
14400 CJK
14500 CJK
14600 CJK  IUNIT=UNITS CODE FOR BOARD FEET CORDS, ETC; HARVOL=
14700 CJK  VOLUME HARVEST; PRODPC=PRODUCT SELLING PRICE;
14800 CJK  SYSMHC=SYSTEM MOVE HOURLY COST; DFTBTM=DISTANCE IN MILES
14900 CJK  FROM TRACT BOUNDARY TO MILL
15000 CJK
15100       READ(KR,200)IUNIT,HARVOL,PRODPC,SYSMHC,DFTBTM
15200   200 FORMAT(I1,1X,F10.0,1X,F7.2,1X,F7.2,1X,F5.1)
15300       IF(IUNIT.EQ.1)WRITE(KW,250)HARVOL
15400   250 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'POUNDS')
15500       IF(IUNIT.EQ.2)WRITE(KW,300)HARVOL
15600   300 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'INT. BOARD FEET')
15700       IF(IUNIT.EQ.3)WRITE(KW,350)HARVOL
15800   350 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CUBIC FEET')
15900       IF(IUNIT.EQ.4)WRITE(KW,360)HARVOL
16000   360 FORMAT(2X,'HARVEST VOLUME=',22X,F11.0,2X,'CORDS')
16100       WRITE(KW,400)PRODPC,SYSMHC,DFTBTM
16200   400 FORMAT(2X,'PRICE IN SELLING UNITS ($)=',15X,F8.2,/,2X,
16300      1'HOURLY LANDING MOVE COST ($)=',13X,F8.2,/,2X,
16400      2'DISTANCE FROM WOODS EDGE TO MILL (MILES)=',2X,F6.1)
16500       WRITE(KW,450)
16600   450 FORMAT(/,2X,29('*'),/,2X,'DOZER',2X,'DOZER',
16700      13X,'DOZER',3X,'HOURLY',/,1X,'NUMBER',5X,'HP',3X,'EFFIC',
16800      25X,'COST',/)
16900       DO 475 IDL00=1,NMETH
17000       IF(IUNIT.EQ.1)LOGMET(1,IDL00)=-HARVOL/2000.0
17100       IF(IUNIT.EQ.2)LOGMET(1,IDL00)=-HARVOL/1000.0
17200       IF(IUNIT.EQ.3)LOGMET(1,IDL00)=-HARVOL/100.0
17300       IF(IUNIT.EQ.4)LOGMET(1,IDL00)=-HARVOL/1.0
17400   475 CONTINUE
17500       SMDZHC=0.0
```

```
      DO 600 IDL01=1,NDZR
CJK
CJK
CJK ****************CARD TYPE 4   **********************
CJK
CJK
CJK  DZRPH()=DOZER HORSEPOWER; DZREF()=DOZER EFFICEINCY;
CJK  DZRHC()=DOZER HOURLY COST; SMDZHC=SDOZER
CJK  HOURLY COST
CJK
      READ(KR,500)DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  500 FORMAT(F4.0,1X,F4.2,1X,F6.2)
      SMDZHC=SMDZHC+DZRHC(IDL01)
      WRITE(KW,550)IDL01,DZRHP(IDL01),DZREF(IDL01),DZRHC(IDL01)
  550 FORMAT(4X,I3,2X,F5.0,3X,F5.2,2X,F7.2)
  600 CONTINUE
      WRITE(KW,650)SMDZHC
  650 FORMAT(/,2X,29('*'),/,23X,F8.2)
      WRITE(KW,700)
  700 FORMAT(2(/),2X,51('*'),/,46X,'SKIDDER',/,
     12X,'SKIDDER',6X,'SKIDDER',3X,'SKIDDER',2X,
     2'SKIDDER',6X,'HOURLY',/,3X,'NUMBER',3X,
     3'HORSEPOWER',4X,'WEIGHT',4X,'EFFIC',8X,'COST',/)
      SMSKHC=0.0
      DO 850 IDL02=1,NSKD
CJK
CJK
CJK  ************** CARD TYPE 5 **************************
CJK
CJK
CJK  SKDHP()=SKIDDER HORSEPOWER; SKDWT()=SKIDDER WEIGHT;
CJK  SKDEF()=SKIDDER EFFICIENCY; SMSKHC=SUM OF ALL SKIDDERS
CJK  HOURLY COSTS
CJK
      READ(KR,750)SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02)
     1,SKDHC(IDL02)
  750 FORMAT(F4.0,1X,F6.0,1X,F4.2,1X,F6.2)
      SMSKHC=SMSKHC+SKDHC(IDL02)
      WRITE(KW,800)IDL02,SKDHP(IDL02),SKDWT(IDL02),SKDEF(IDL02),
     1SKDHC(IDL02)
  800 FORMAT(5X,I5,7X,F6.0,2X,F8.0,1X,F7.2,5X,F7.2)
  850 CONTINUE
      WRITE(KW,900)SMSKHC
  900 FORMAT(/,2X,51('*'),/,45X,F8.2)
      WRITE(KW,950)
  950 FORMAT(2(/),2X,78('*')/,9X,'** NON-WOODS **',
     13X,'***** WOODS',
     21X,'****',/,9X,'TRAVEL',3X,'TRAVEL',3X,'TRAVEL',4X,
     3'TRAVEL',3X,'FIXED',/,10X,'EMPTY',3X,'LOADED',4X,'EMPTY',
     44X,'LOADED',4X,'TIME',14X,'CYCLE',4X,'TRUCK',/,2X,
     5'TRUCK',3X,'SPEED',4X,'SPEED',4X,'SPEED',5X,'SPEED',
     65X,'PER',3X,'TRUCK',6X,'TRUCK',3X,'HOURLY',/,1X,
     7'NUMBER',5X,'MPH',6X,'MPH',6X,'MPH',7X,'MPH',4X,'LOAD',
     83X,'EFFIC',5X,'VOLUME',5X,'COST',/)
      SMTKHC=0.0
      DO 1100 IDL03=1,NTRK
CJK
CJK
CJK  ************  CARD TYPE 6  ****************************
CJK
CJK
CJK  TKTENW()=TRUCK TRAVEL SPEED EMPTY OVER NON-WOODS ROAD
CJK  TKTLNW()=TRUCK TRAVEL SPEED LOADED OVER NON-WOODS ROAD
CJK  TKTEWD()=TRUCK TRAVEL SPEED EMPTY OVER WOODS ROAD
CJK  TKTLWD()=TRUCK TRAVEL SPEED LOADED OVER WOODS ROAD
CJK  TKFTPC()=FIXED TIME PER TRUCK CYCLE IN MINUTES
CJK  TKEF()=TRUCK EFFICIENCY (IE 0.80)
CJK  TKVOL()=TRUCK VOLUME
CJK  TRAVEL SPEEDS ARE IN MPH
CJK  SMTKHC=SUM OF ALL TRUCKS HOURLY COST
CJK
CJK
      READ(KR,1000)TKTENW(IDL03),TKTLNW(IDL03),TKTEWD(IDL03),
     1TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),TKVOL(IDL03),
     2TKHC(IDL03)
 1000 FORMAT(5(F4.1,1X),F4.2,1X,F10.2,1X,F6.2)
      SMTKHC=SMTKHC+TKHC(IDL03)
      WRITE(KW,1050)IDL03,TKTENW(IDL03),TKTLNW(IDL03),
     1TKTEWD(IDL03),TKTLWD(IDL03),TKFTPC(IDL03),TKEF(IDL03),
     2TKVOL(IDL03),TKHC(IDL03)
 1050 FORMAT(2X,I4,3X,F6.2,3X,F6.2,3X,F6.2,4X,F6.2,2X,F6.2,2X,
     1F6.2,1X,F10.2,2X,F7.2)
 1100 CONTINUE
      WRITE(KW,1150)SMTKHC
 1150 FORMAT(1(/),2X,78('*'),/,71X,F8.2)
      WRITE(KW,1175)
 1175 FORMAT(1H1,/,2X,26('*'),/,12X,'NUMBER',4X,'NUMBER',/,
     12X,'METHOD',6X,'ROAD',8X,'OF',/,2X,'NUMBER',2X,
     2'SEGMENTS',2X,'LANDINGS',/)
      DO 1250 IDL04=1,NMETH
CJK
CJK
CJK  ************ CARD TYPE 7  **************************
CJK
CJK
CJK  IMETH=METHOD NUMBER; IRDSEG=NUMBER OF ROAD SEGMENTS
CJK  FOR THIS METHOD; ILAND()= NUMBER OF LANDINGS FOR THIS METHOD
CJK
      READ(KR,1200)IMETH,IRDSEG,ILAND(IDL04)
 1200 FORMAT(I1,1X,I2,1X,I2)
      INRSBM(IDL04)=IRDSEG
      WRITE(KW,1225)IMETH,IRDSEG,ILAND(IDL04)
 1225 FORMAT(4X,I4,6X,I4,6X,I4)
 1250 CONTINUE
      WRITE(KW,1275)
 1275 FORMAT(/,2X,26('*'),//)
      WRITE(KW,1300)
 1300 FORMAT(2(/),2X,43('*'),/,22X,'NUMBER',/,
     12X,'METHOD',3X,'LANDING',2X,6X,'OF',5X,'MAXIMUM AREA',/,
     22X,'NUMBER',4X,'NUMBER',5X,'AREAS',5X,'CODE  NUMBER',/)
 1325 CONTINUE
CJK
CJK
CJK  *****************  CARD TYPE 8  *******************
CJK
CJK
CJK  JMN=METHOD NUMBER; JLN=LANDING NUMBER;
CJK  JNA= NUMBER OF AREAS
CJK  JMAN=MAXIMUM VALUE OF AREA CODE NUMBER ; IS THE SAME
CJK  AS JNA ONLY IF AREAS ARE CODED IN NUMERICAL SEQUENCE
CJK
CJK
CJK
      READ(KR,1350)JMN,JLN,JNA,JMAN
 1350 FORMAT(I1,1X,I2,1X,I2,1X,I2)
      IF(JMN.EQ.0)GO TO 1400
      JNAREA(JMN,JLN)=JMAN
      WRITE(KW,1375)JMN,JLN,JNA,JMAN
 1375 FORMAT(4X,I4,6X,I4,6X,I4,14X,I3)
      GO TO 1325
 1400 WRITE(KW,1425)
 1425 FORMAT(/,2X,43('*'),2(/))
      WRITE(KW,1450)
 1450 FORMAT(2(/),2X,127('*'),/,59X,'CUT',3X,'FILL',4X,'ROAD',
     1/,2X,'METHOD',2X,'SEGMENT',3X,'DOZER',5X,'ROAD',3X,
     2'ROAD',3X,'ROAD',3X,'SIDE',2X,'SLOPE',2X,'SLOPE',4X,'TYPE',
     34X,'CUBIC',
     44X,'ACRES',2X,'SEGMENT',2X,'SEGMENT',2X,'METHOD',2X,
     5'METHOD',/,2X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,
     6'LENGTH',2X,'WIDTH',2X,'SLOPE',2X,'SLOPE',2X,'RATIO',2X,
     7'RATIO',4X,'CODE',4X,'YARDS',2X,'CLEARED',4X,'HOURS',
     85X,'COST',3X,'HOURS',4X,'COST',/)
CJK
CJK
CJK      START OF DO LOOP BY METHOD++++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1850 IDL05=1,NMETH
      SMRDSL=0.0
      SMRDCY=0.0
      SMRDNA=0.0
      SMRDHR=0.0
      SMRDHM=0.0
      IDLB01=INRSBM(IDL05)
      IDLB02=INRSBM(IDL05)
      IF(IDLB01.EQ.0)IDLB02=1
CJK
CJK
CJK      START OF DO LOOP BY ROAD SEGMENT+++ROAD CONSTRUCTION TIMES
CJK
CJK
      DO 1650 IDL06=1,IDLB02
CJK
CJK
CJK  ************** CARD TYPE 10  **************************
CJK
CJK
CJK  ROADSL=ROAD SEGMENT LENGTH IN FEET; ROADSW=ROAD
CJK  SEGMENT WIDTH ISEGMENT SLOPE IN PERCENT
CJK  OF DIRECTION BUILT; ROADSS=ROAD SEGMENT SIDE SLOPE IN
CJK  IN PERCENT; ROADCR=ROAD SEGMENT CUT RATI; ROADFR=
CJK  ROAD SEGMENT FILL RATIO; ROADTY=ROAD DIFFICULTY CODE
CJK
CJK
CJK
CJK
      READ(KR,1500)ROADSL,ROADSW,ROADSP,ROADSS,ROADCR,ROADFR,ROADTY
 1500 FORMAT(F7.0,1X,F4.1,1X,F5.0,1X,F5.0,1X,F5.2,1X,F5.2,1X,F5.0)
      IF(IDLB01.EQ.0)GO TO 1700
      IF(ROADSL.EQ.0.0)GO TO 1700
CJK  FOLLOWING EQUATIONS COMPUTE CUBIC YARDS OF EARTH REMOVED
CJK  IN ROAD BUILDING BASED ON EQUATIONS BY JOHN K. BOWMAN,
CJK  ROBERT B. MCCREA, AND CARL L. FONNESBECK "A METHOD
CJK  OF FIELDESIGN APPLIED TO FOREST ROADS" PAGE 194,
CJK  IN: LOW VOLUME ROADS, SPECIAL REPORT 160, TRANSPORTATION
CJK  RESEARCH BORAD, NATIONAL RESEARCH COUNCIL, NATIONAL
CJK  ACADEMY OF SCIENCES, WASHINGTON DC, 1975
CJK
CJK
CJK
CJK
CJK   SHRINKF HAS A VALUE OF 0.20 IN ORDER TO OBTAIN THE VALUES
CJK   FOR CUBIC YARDS AND ACRES GIVEN IN THE 4 TH EDITION OF
CJK   "ENGINEERING FIELD TABLES" USDA FOREST SERVICE AND BLM
CJK   JULY 1976,  (EM7100-10)
CJK
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37000 CJK
37100        SHRIKF=0.20
37200        ROADSD = ATAN(ROADSS/100.0)*CTDEG
37300        ROADCS = ATAN(ROADCR)*CTDEG
37400        ROADSF=1.000-(0.014*ROADSP)-(0.00019*ROADSP*ROADSP)
37500        ROADFS = ATAN(ROADFR)*CTDEG
37600        CCCC = COTAN(ROADSD*CTRAD)
37700        A0 = COTAN(ROADSD*CTRAD)-ROADCR
37800        A1 = A0*(1+SHRIKF)
37900        A2 = COTAN(ROADSD*CTRAD)-ROADFR
38000        A3 = SQRT(A1/A2)
38100        A4 = ROADSW/2.0*(A3-1.0)
38200        BK = A4/(A3+1.0)
38300        DF = ((ROADSW/2.0)-BK)/(COTAN(ROADSD*CTRAD)-ROADFR)
38400        DC = (BK+ROADSW/2.0)/(COTAN(ROADSD*CTRAD)-ROADCR)
38500        THETA = 180.0-ROADCS
38600        BASE1 = DC/TAN(ROADSD*CTRAD)
38700        THETA = 180.0-ROADFS
38800        AREAF = (1.0/2.0)*(ROADSW/2.0)*ROADFR*SIN(THETA*CTRAD)
38900        BASE2 = DF/TAN(ROADSD*CTRAD)
39000        BASE = BASE1+BASE2
39100        BASECU=DC/TAN(ROADCS*CTRAD)
39200        AREAC=(0.5*((ROADSW/2.0)+BK+BASECU)*DC)-(0.5*BASECU*DC)
39300        ROADNA = (BASE*1000.0)/43560.0
39400        ROADCY = (AREAC*1000.0)/27.0
39500        CUBEYD=(AREAC*ROADSL)/27.0
39600        ACRES=(BASE*ROADSL)/43560.0
39700        SMRDSL=SMRDSL+ROADSL
39800        SMRDCY=SMRDCY+CUBEYD
39900        SMRDNA=SMRDNA+ACRES
40000        SMRDSH=0.0
40100 CJK
40200 CJK
40300 CJK     START OF DO LOOP FOR DOZERS++++ROAD CONSTRUCTION TIMES
40400 CJK
40500 CJK
40600        DO 1600 IDL07=1,NDZR
40700 CJK
40800 CJK    SEGRDH=HOURS TO BUILD THIS ROAD SEGMENT; BASED ON EQUATION
40900 CJK    BY JERRY KOGER "FACTORS AFFECTING THE CONSTRUCTION AND
41000 CJK    COST OF LOGGING ROADS"  TVA TECHNICAL NOTE B27, TENNESSEE
41100 CJK    VALLEY AUTHORITY, NORRIS, TN, 37828  PAGE 30, 1978
41200 CJK    EQUATION MODIFIED BY LATER ANALYSIS INTO DIFFERENT ROAD
41300 CJK    TYPES... SEE FACTOR ROADTY FOR THIS ADJUSTMENT
41400 CJK    ROADCY= CUBIC YARDS OF EARTH PER 1000 FT OF ROAD;
41500 CJK    ROADNA= NUMBER OF ACRES OF CLEARED RIGHT OF WAY PER
41600 CJK    100SLOPE CORRECTION FACTOR TO
41700 CJK    PRODUCE VALUES GIVEN IN FIGURE 22 OF TVA TECH NOTE B27
41800 CJK
41900 CJK
42000        SEGRDH=(ROADSL/ROADTY)*
42100       1(0.524*SQRT(ROADCY/(ROADSF*DZRHP(IDL07)))+
42200       212.668*SQRT(ROADNA/(ROADSF*DZRHP(IDL07)))))/DZREF(IDL07)
42300        SMRDSH=SMRDSH+(1.0/SEGRDH)
42400        SEGRDC=SEGRDH*DZRHC(IDL07)
42500        WRITE(KW,1550)IDL05,IDL06,IDL07,ROADSL,ROADSW,ROADSP,
42600       1ROADSS,ROADCR,ROADFR,ROADTY,CUBEYD,ACRES,SEGRDH,SEGRDC
42700  1550 FORMAT(4X,I4,5X,I4,4X,I4,1X,F8.0,1X,F6.1,1X,F6.0,1X,
42800       1F6.0,2X,F5.2,2X,F5.2,2X,F6.0,1X,F8.1,1X,F8.1,1X,F8.1,F9.2)
42900  1600 CONTINUE
43000 CJK
43100 CJK
43200 CJK    SMRDHS=NUMBER OF HOURS TO BUILD THIS ROAD SEGMENT
43300 CJK    IF ALL DOZERS WORKED TOGETHER
43400 CJK
43500 CJK
43600        SMRDHS=1.0/SMRDSH
43700        SMRDHM=SMRDHM+SMRDHS
43800        SMRDCS=SMRDHS*SMDZHC
43900        SMRDOM=SMRDHM*SMDZHC
44000        IF(NDZR.GT.1)WRITE(KW,1625)IDL05,IDL06,SMRDHS,SMRDCS
44100  1625 FORMAT(4X,I4,5X,I4,81X,F6.1,F9.2)
44200  1650 CONTINUE
44300  1700 CONTINUE
44400        IF(IDLB01.EQ.0)SMRDHM=0.0
44500        IF(IDLB01.EQ.0)SMRDOM=0.0
44600        LOGMET(2,IDL05)=SMRDHM
44700        WRITE(KW,1800)IDL05,SMRDSL,SMRDCY,SMRDNA,
44800       1SMRDHM,SMRDOM
44900  1800 FORMAT(4X,I4,17X,F9.0,43X,F9.1,1X,F8.1,18X,F8.1,F8.0,//)
45000  1850 CONTINUE
45100        WRITE(KW,1900)
45200  1900 FORMAT(/,127('*'))
45300        WRITE(KW,1950)
45400  1950 FORMAT(1H1,//,2X,127('*'),/,110X,'WEIGHTED',5X,'METHOD',/,
45500       119X,'DISTANCE',3X,'LANDING',2X,'AVERAGE',10X,'HOURLY',
45600       211X,'LANDING',3X,'LANDING',3X,'SYSTEM',3X,'SYSTEM',
45700       32X,'BUILDING',5X,'MOVE &',/,2X,'METHOD',2X,'LANDING',6X,
45800       4'FROM',6X,'SIZE',6X,'CUT',3X,'DOZER',3X,'DOZER',3X,'EFFIC',
45900       52X,'BUILDING',2X,'BUILDING',5X,'MOVE',5X,'MOVE',2X,
46000       6'& MOVING',4X,'LANDING',
46100       6/,2X,'NUMBER',3X,'NUMBER',2X,'BOUNDARY',5X,
46200       7'ACRES',4X,'DEPTH',6X,'HP',4X,'COST',4X,'CODE',5X,
46300       8'HOURS',6X,'COST',4X,'HOURS',5X,'COST',5X,'HOURS',
46400       97X,'COST',/)
46500 CJK
46600 CJK
46700 CJK  ********** CARD TYPE 11 ****************************
46800 CJK
46900 CJK
47000 CJK   ILDZR=INPUT ORDER NUMBER OF DOZER USED TO BUILD
47100 CJK    LANDINGS... ONLY ONE DOZER IS ALLOWED TO BUILD
47200 CJK   LANDINGS
47300 CJK
47400 CJK
47500 CJK
47600        READ(KR,2000)ILDZR
47700  2000 FORMAT(I1)
47800 CJK
47900 CJK
48000 CJK     START OF DO LOOP FOR METHODS++++ LANDING CONSTRUCTION TIMES
48100 CJK
48200 CJK
48300        DO 2200 IDL08=1,NMETH
48400        SMRLA=0.0
48500        SMCBL=0.0
48600        SMSYMH=0.0
48700        SMOML=0.0
48800        IDLB03=ILAND(IDL08)
48900 CJK
49000 CJK
49100 CJK     START OF DO LOOP FOR LANDINGS+++++LANDING CONSTRUCTION TIMes
49200 CJK
49300 CJK
49400        DO 2150 IDL09=1,IDLB03
49500 CJK
49600 CJK
49700 CJK   ************* CARD TYPE 12  *************************
49800 CJK
49900 CJK
50000 CJK   DSFTB()=DISTANCE IN FEET FROM TRACT BOUNDARY TO THIS LANDIG
50100 CJK   ACRESL= ACRES IN THIS LANDING... SIZE OF LANDING
50200 CJK   CUTL=AVERAGE CUT DEPTH OF EARTH REMOVED IN BUILDING LANDING
50300 CJK   EFFL=DEFFICIENCY FACTOR FOR THIS LANDING (IE 0.80)
50400 CJK   SYSMHR=SYSTEM MOVE TIME IN HOURS TO THIS LANDING; NOT A
50500 CJK   MOVE IN TIME BUT A MOVE BETWEEN LANDING TIME
50600 CJK
50700 CJK
50800        READ(KR,2050)DSFTB(IDL08,IDL09),ACRESL,CUTL,EFFL,SYSMHR
50900  2050 FORMAT(F8.0,1X,F4.1,1X,F4.1,1X,F4.2,1X,F5.1)
51000        APPLL=(ACRESL*43560.0)/26.70
51100        APPCYL=((APPLL*CUTL*26.70)/27.0)/(APPLL/1000.0)
51200        APPACL=(((APPLL*26.70)/43560.0))/(APPLL/1000.0)
51300 CJK
51400 CJK    LOGIC WAS TO CONVERT LANDING SIZIN ACRES TO AN
51500 CJK    EQUIVALENT LENGHT OF ROAD AND THEN USE ROAD
51600 CJK    CONSTRUCTION EQUATION IN TVA TECH NOTE B27
51700 CJK    APPCYL=APPROXIMATE NUMBER OF CUBIC YARDS
51800 CJK    APPACL=APPROXIMATED NUMBER OF ACRES IF CONVERTED
51900 CJK           FROM LANDING ACRES TO ROAD LENGTH ACRES
52000 CJK    HRTBL=HOURS TO BUILD LANDING
52100 CJK
52200 CJK
52300        HRTBL=(APPLL/3000.0)*(0.524*SQRT(APPCYL/DZRHP(ILDZR))+
52400       1(12.668*SQRT(APPACL/DZRHP(ILDZR))))/(DZREF(ILDZR)*EFFL)
52500        SMHRLA=SMHRLA+HRTBL
52600        CBL=HRTBL*DZRHC(ILDZR)
52700        SMCBL=SMCBL+CBL
52800        OML=SYSMHR*SYSMHC
52900        SMOML=SMOML+OML
53000        SMSYMH=SMSYMH+SMOML
53100        WRITE(KW,2100)IDL08,IDL09,DSFTB(IDL08,IDL09),ACRESL,CUTL,
53200       1DZRHP(ILDZR),DZRHC(ILDZR),EFFL,HRTBL,CBL,SYSMHR,OML
53300  2100 FORMAT(4X,I4,5X,I4,1X,F9.0,4X,F6.1,3X,F6.1,2X,F6.0,
53400       11X,F7.2,2X,F6.2,1X,F9.2,1X,F9.2,2X,F7.1,1X,F8.2)
53500  2150 CONTINUE
53600        WLBH1=DZRHC(ILDZR)+SYSMHC
53700        WLBHRS=(SMCBL+SMOML)/WLBH1
53800 CJK
53900 CJK
54000 CJK    WLBHRS=WEIGHTED HOURS FOR BUILDING LANDING AND
54100 CJK    MOVING BETWEEN LANDINGS ** THIS VALUE IS USED
54200 CJK    IN THE LP HOURS COLUMNS BY METHOD
54300 CJK
54400 CJK
54500        SMCLMM=SMCBL+SMOML
54600        WRITE(KW,2175)IDL08,WLBHRS,SMCLMM
54700  2175 FORMAT(4X,I4,103X,F8.2,2X,F9.2)
54800        LOGMET(3,IDL08)=WLBHRS
54900  2200 CONTINUE
55000        WRITE(KW,2250)
55100  2250 FORMAT(/,2X,127('*'),//)
55200        WRITE(KW,2300)
55300  2300 FORMAT(2(/),1X,127('*'),/,49X,'MINIMUM',4X,'MAXIMUM',6X,
55400       1'FIXED',
55500       24X,'SKIDDING',3X,'TRAIL',3X,'SLOPE',9X,'AREA',2X,'FIXED',/,
55600       32X,'METHOD',2X,'LANDING',4X,'AREA',7X,'AREA',5X,'AREA',
55700       43X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',2X,'CORRECTION',
55800       53X,'TRAVEL LOADED',3X,'DIFFICULTY',2X,'TIME',/,
55900       62X,'NUMBER',3X,'NUMBER',2X,'NUMBER',5X,'VOLUME',4X,
56000       7'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',6X,
56100       8'FACTOR',3X,'DIRECTION (%)',7X,'FACTOR',2X,'CYCLE',/)
56200  2350 CONTINUE
56300 CJK
56400 CJK
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56500 CJK ************CARD TYPE 13 ******************************
56600 CJK
56700 CJK
56800 CJK    IMN=METHOD NUMBER, ILN=LANDING NUMBER,IAN=AREA NUMBER,
56900 CJK    AV=AREA VOLUME, AA=AREA ACRES, AN=MINIMUM SKIDDING
57000 CJK    DISTANCE, AX=MAXIMUM SKIDDING DISTANCE, AF=FIXED SKIDDING
57100 CJK    TO AREA WHERE AN AND AX WOULD APPLY; AC=CORRECTION FACTOR
57200 CJK    CONVERTING STRAIGHT LINE SKIDDING DISTANCE TO ACTUAL
57300 CJK    DISTANCE TRAVELED BY SKIDDER; AS=SLOPE OF SKID TRAIL IN
57400 CJK    PERCENT IN DIRECTION OF TRAVEL LOADED; AD=AREA DIFFICULTY
57500 CJK    CODE AFFECTING SKIDDING TIME SIMILAR TO SKIDDER EFFICIENCY
57600 CJK    (IE 0.80)
57700 CJK
57800 CJK
57900  2375 CONTINUE
58000       READ(KR,2400)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
58100  2400 FORMAT(I1,I2,I2,F9.0,F6.0,F8.0,
58200      1F8.0,F8.0,1X,F5.2,F5.0,1X,F4.2,1X,F4.1)
58300       IF(IMN.EQ.0)GO TO 2500
58400       AREAV(IMN,ILN,IAN)=AV
58500       AREAA(IMN,ILN,IAN)=AA
58600       AREAMN(IMN,ILN,IAN)=AN
58700       AREAMX(IMN,ILN,IAN)=AX
58800       AREAFD(IMN,ILN,IAN)=AF
58900       AREACF(IMN,ILN,IAN)=AC
59000       AREATS(IMN,ILN,IAN)=AS
59100       AREADI(IMN,ILN,IAN)=AD
59200       AREAFT(IMN,ILN,IAN)=AT
59300       WRITE(KW,2450)IMN,ILN,IAN,AV,AA,AN,AX,AF,AC,AS,AD,AT
59400  2450 FORMAT(4X,I4,5X,I4,4X,I4,1X,F10.0,2X,F7.0,2X,F9.0,
59500      12X,F9.0,2X,F9.0,5X,F7.2,10X,F6.0,6X,F7.2,1X,F6.1)
59600       GO TO 2350
59700  2500 CONTINUE
59800       WRITE(KW,2250)
59900       WRITE(KW,2550)
60000  2550 FORMAT(1H1,/,2X,126('*'),/,75X,11('*'),1X,'ALL'
60100      1,1X,'SKIDDERS WORKING TOGETHER',1X,11('*'),/,68X,
60200      2'AREA',/,28X,'MINIMUM',3X,'MAXIMUM',4X,'CYCLE',2X,
60300      3'NUMBER',6X,'SKID',10X,'AREA',4X,'LANDING ',2X,
60400      4'LANDING',5X,'METHOD',6X,'METHOD',/,2X,
60500      5'METHOD',2X,'LAND',2X,'AREA',2X,'SKID',3X,'VOLUME',
60600      64X,'VOLUME',5X,'TIME',6X,'OF',6X,'TIME',6X,
60700      7'SKIDDING',3X,'SKIDDING',2X,'SKIDDING',3X,'SKIDDING',
60800      84X,'SKIDDING')
60900       WRITE(KW,2600)
61000  2600 FORMAT(6X,'NO',4X,'NO',4X,'NO',4X,'NO',2X,
61100      1'SKIDDED',3X,'SKIDDED',2X,'MINUTES',2X,'CYCLES',
61200      25X,'HOURS',9X,'HOURS',7X,'HOURS',5X,'COSTS',6X,
61300      3'HOURS',7X,'COSTS',/)
61400 CJK
61500 CJK
61600 CJK       START OF DO LOOP FOR METHODS++++SKIDDING TIMES
61700 CJK
61800 CJK
61900 CJK  SKIDDING AVERAGE VALUES FROM TVA TECHNICAL NOTE 818, 1976
62000 CJK  BY JERRY KOGER "FACTORS AFFECTING THE PRODUCTION OF
62100 CJK  RUBBER TIRED SKIDDERS" TVA, NORRIS, TN  37828
62200 CJK  RADCUR = RADIUS OF CURVATURE AVERAGE VALUE OF 483.99 FT
62300 CJK  RUTD=RUTD DEPTH ON SKID TRAIL; VALUE OF 2" ASSUMED
62400 CJK  CONEP= SOIL STRENGTH BY CONE PENETROMETER, ASSUMED 200
62500 CJK  ARCLG= ARC LENGTH OF SKID TRAIL, USED AVERAGE OF 132.
62600 CJK  SEE TVA TECHNOTE 818 PAGE 23 FOR THESE VALUES
62700 CJK
62800       RADCUR=483.99
62900       RUTD=6.3
63000       CONEP=192.2
63100       ARCLG=131.6
63200       ELEV=1547.1
63300       DO 3100 IDL10=1,NMETH
63400       SMVOLM=0.0
63500       SMACLM=0.0
63600       SMHMA=0.0
63700       SASKD=0.0
63800       SFSKD=0.0
63900       SWSKD=0.0
64000       IDLB04=ILAND(IDL10)
64100 CJK
64200 CJK
64300 CJK      START OF DO LOOP FOR LANDINGS++++++ SKIDDING TIMES
64400 CJK
64500 CJK
64600       DO 3000 IDL11=1,IDLB04
64700       SMHLA=0.0
64800       SMAA=0.0
64900       SMAV=0.0
65000       ASKDPL=0.0
65100       FSKDPL=0.0
65200       WSKDPL=0.0
65300       AMAXN=0.0
65400       IDLB05=JNAREA(IDL10,IDL11)
65500 CJK
65600 CJK
65700 CJK    START OF DO LOOP FOR AREA+++++SKIDDING TIMES
65800 CJK
65900 CJK
66000       DO 2900 IDL12=1,IDLB05
66100       IF(AREAV(IDL10,IDL11,IDL12).EQ.0.0)GO TO 2900
66200       SMHA=0.0
66300       AMAXN=AMAXN+1.0
66400       SMAV=SMAV+AREAV(IDL10,IDL11,IDL12)
66500       SMAA=SMAA+AREAA(IDL10,IDL11,IDL12)
66600       ASKDPL=ASKDPL+0.5*(AREAMN(IDL10,IDL11,IDL12)+
66700      1AREAMX(IDL10,IDL11,IDL12))
66800       FSKDPL=FSKDPL+AREAFD(IDL10,IDL11,IDL12)
66900       WSKDPL=WSKDPL+((((0.5*(AREAMN(IDL10,IDL11,IDL12)+
67000      1AREAMX(IDL10,IDL11,IDL12)))*AREACF(IDL10,IDL11,IDL12))+
67100      2AREAFD(IDL10,IDL11,IDL12))*AREAV(IDL10,IDL11,IDL12)
67200 CJK
67300 CJK
67400 CJK    START OF DO LOOP FOR SKIDDERS++++SKIDDING TIMES
67500 CJK
67600 CJK
67700       DO 2800 IDL13=1,NSKD
67800 CJK
67900 CJK
68000 CJK    ************** CARD TYPE 15 ***************************
68100 CJK
68200 CJK
68300 CJK   KM=MEHTOD NUMBER; KL=LANDING NUMBER;KA=AREA NUMBER;
68400 CJK   KS=SKIDDER NUMBER; SKVMN=MINIMUM VOLUME SKIDDED PER CYCLE;
68500 CJK   SKVMS=MAXIMUM VOLUME SKIDDED PER CYCLE;
68600 CJK   IF SKVMN=SKVMX THEN INTEGRATION
68700 CJK   EQUATION FOR SKIDDING TIME IS NOT USED
68800 CJK
68900 CJK
69000 CJK
69100       READ(KR,2700)KM,KL,KA,KS,SKVMN,SKVMX
69200  2700 FORMAT(I1,1X,I2,1X,I2,1X,I2,F10.1,F10.1)
69300       XN=AREAMN(KM,KL,KA)
69400       XX=AREAMX(KM,KL,KA)
69500       FX=AREAFD(KM,KL,KA)
69600       FC=AREACF(KM,KL,KA)
69700 CJK
69800 CJK
69900 CJK    CODE SYMBOLS USED FAC=FACTOR; A...=SYMBOL IN APPENDIX
70000 CJK     OF THIS REPORT FOR SKIDDING EQUATION; E=SYMBOL FOR
70100 CJK    TRAVEL EMPTY .........THIS APPLIES TO FACAE,FACBE
70200 CJK    TYPE CODEING USED BELOW
70300 CJK
70400 CJK
70500       IF(XN.EQ.XX)FACAE=(FX+(XN*FC))**1.022449
70600 CJK
70700 CJK
70800 CJK   IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
70900 CJK   VALUE OF FACAE  ++TRAVEL EMPTY
71000 CJK
71100 CJK
71200       IF(XN.NE.XX)FACAE=(FX**1.022449)+((1.0/(XX*FC-XN*FC))*
71300      1(((XX*FC)**2.022449/2.022449)-((XN*FC)**2.022449/2.022449)))
71400       FACBE=RADCUR**3.549048
71500       FACCE=(SKDHP(IDL13))**1.317563
71600       FACCE=120.0**1.317563
71700       FACDE=(1.0+RUTD)**0.223969
71800 CJK   FACEE=(AREAE(KM,KL,KA))**0.180727
71900       FACEE=ELEV**0.180727
72000       TS=ATAN(AREATS(KM,KL,KA)/100.0)*CTDEG
72100       FACFE=(1.0+SIN(TS*CTRAD))**2.156775
72200       FACHE=CONEP**0.183381
72300       FACIE=ARCLG**6.943695
72400       IF(IUNIT.EQ.1)VSN=SKVMN*CONPTB
72500       IF(IUNIT.EQ.1)VSX=SKVMX*CONPTB
72600       IF(IUNIT.EQ.2)VSN=SKVMN*CONBTB
72700       IF(IUNIT.EQ.2)VSX=SKVMX*CONBTB
72800       IF(IUNIT.EQ.3)VSN=SKVMN*CONCTB
72900       IF(IUNIT.EQ.3)VSX=SKVMX*CONCTB
73000       IF(IUNIT.EQ.4)VSN=SKVMN*CONUTB
73100       IF(IUNIT.EQ.4)VSX=SKVMX*CONUTB
73200       IF(SKVMN.EQ.SKVMX)FACJL=VSN**0.110305
73300 CJK
73400 CJK
73500 CJK   IF SKVMN.NE.SKVMX THEN INTEGRATION EQUATION IS USED
73600 CJK   TO COMPUTE VALUE OF FACJL  *** VOLUME FACTOR FOR
73700 CJK   TRAVEL LOADED
73800 CJK
73900 CJK
74000       IF(SKVMN.NE.SKVMX)FACJL=((1.0/(VSX-VSN))*
74100      1((VSX**1.110305)/1.110305)*
74200      2((VSN**1.110305)/1.110305))
74300       IF(XN.EQ.XX)FACAL=(FX+(XN*FC))**1.1098034
74400 CJK
74500 CJK
74600 CJK   IF XN.NE.XX THEN INTEGRATION EQUATION IS USED TO COMPUTE
74700 CJK   VALUE OF FACAL+++ DISTANCE FACTOR--TRAVEL LOADED
74800 CJK
74900 CJK
75000       IF(XN.NE.XX)FACAL=(FX**1.1098034)+((1.0/(XX*FC-XN*FC))*
75100      1(((XX*FC)**2.1098034/2.1098034)-((XN*FC)**2.1098034
75200      2/2.1098034)))
75300       FACBL=RADCUR**3.472234
75400       FACDL=(1.0+RUTD)**0.116935
75500 C     FACEL=(AREAE(KM,KL,KA))**0.098604
75600       FACEL=ELEV**0.098604
75700       FACFL=(1.0+SIN(TS*CTRAD))**0.681159
75800       FACGL=(SKDWT(IDL13))**3.234567
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75900        FACHL=CONEP**0.067053
76000        FACCL=(SKDHP(IDL13))**3.157504
76100        FACIL=ARCLG**7.456998
76200        TIMEE=0.3395469*((FACAE*FACBE*FACCE*FACDE*FACEE*FACFE)/
76300       1(FACHE*FACIE))
76400        TIMEL=0.00005166*((FACJL*FACAL*FACBL*FACDL*FACEL*
76500       1FACFL*FACGL)/(FACHL*FACCL*FACIL))
76600 CJK
76700 CJK
76800 CJK    T=SKIDDING CYCLE TIME IN MINUTES AS COMPUTED BY EQUATION
76900 CJK    2 PAGE 31 OF TVA TECHNICAL NOTE B18, 1976 BY JERRY KOGER
77000 CJK    "FACTORS AFFECTING THE PRODUCTION OF RUBBER TIRED SKIDDERS"
77100 CJK     TVA, NORRIS, TN, 37828
77200 CJK
77300 CJK     TIMEE=TRAVEL TIME EMPTY; TIMEL=TRAVEL TIME LOADED;
77400 CJK     AREAFT()=FIXED CYCLE TIME; SKEF=SKIDDER EFFICIENCY;
77500 CJK     AREADI(,) =AREA DIFFICULTY FACTOR FOR SKIDDING
77600 CJK
77700 CJK
77800        T=((TIMEE+TIMEL+AREAFT(KM,KL,KA))/SKDEF(KS))/AREADI(KM,KL,KA)
77900        SKSFE=(FACBE*FACCE*FACDE*FACEE)/(FACHE*FACIE)
78000        SKSFL=(FACBL*FACDL*FACEL)/(FACHL*FACIL)
78100        CYCLEN=(AREAV(KM,KL,KA))/((SKVMN+SKVMX)/2.0)
78200        ATH=(T*CYCLEN)/60.0
78300        WRITE(KW,2750)KM,KL,KA,KS,SKVMN,SKVMX,T,CYCLEN,ATH
78400  2750 FORMAT(4X,I4,2X,I4,2X,I4,2X,I4,F9.1,1X,F9.1,1X,
78500       1F8.2,1X,F7.0,F10.2)
78600        SMHA=SMHA+(1.0/ATH)
78700  2800 CONTINUE
78800 CJK
78900 CJK
79000 CJK     SMHAA= THE TIME IT WOULD TAKE ALL SKIDDERS IF THEY
79100 CJK     WORKED TOGETHER ON THIS AREA
79200 CJK
79300 CJK
79400        SMHAA=1.0/SMHA
79500        SMHLA=SMHLA+SMHAA
79600        IF(NSKD.GT.1)WRITE(KW,2850)KM,KL,KA,SMHAA
79700  2850 FORMAT(4X,I4,2X,I4,2X,I4,57X,F10.2)
79800  2900 CONTINUE
79900        VOLML(IDL10,IDL11)=SMAV
80000        VOLMA(IDL10,IDL11)=SMAA
80100        ASKDBL(IDL10,IDL11)=ASKDPL/AMAXN
80200        FSKDBL(IDL10,IDL11)=FSKDPL/AMAXN
80300        SWSKD=SWSKD+WSKDPL
80400        WSKDBL(IDL10,IDL11)=WSKDPL/SMAV
80500        SASKD=SASKD+ASKDBL(IDL10,IDL11)
80600        SFSKD=SFSKD+FSKDBL(IDL10,IDL11)
80700        SMHMA=SMHMA+SMHLA
80800        SKDLC=SMHLA*SMSKHC
80900        SMVOLM=SMVOLM+SMAV
81000        SMACLM=SMACLM+SMAA
81100        WRITE(KW,2950)KM,KL,SMHLA,SKDLC
81200  2950 FORMAT(4X,I4,2X,I4,73X,F10.2,F10.2)
81300  3000 CONTINUE
81400        VOLBM(IDL10)=SMVOLM
81500        ACRBM(IDL10)=SMACLM
81600        SKDMC=SMHMA*SMSKHC
81700        LOGMET(4,IDL10)=SMHMA
81800        ADL11=IDLB04
81900        ASKDBM(IDL10)=SASKD/ADL11
82000        FSKDBM(IDL10)=SFSKD/ADL11
82100        WSKDBM(IDL10)=SWSKD/SMVOLM
82200        WRITE(KW,3050)KM,SMHMA,SKDMC
82300  3050 FORMAT(4X,I4,99X,F11.2,1X,F11.2,//)
82400  3100 CONTINUE
82500        WRITE(KW,3125)
82600  3125 FORMAT(/,2X,126('*'))
82700        WRITE(KW,3150)
82800  3150 FORMAT(1H1,2(/),125('*'),/,62X,8('*'),' PER LANDING',1X,
82900       19('*'),5X,9('*'),' PER METHOD',1X,9('*'),/,
83000       284X,'WEIGHTED',27X,'WEIGHTED',/,74X,'AVERAGE',4X,'AVERAGE',
83100       317X,'AVERAGE ',3X,'AVERAGE',/,63X,'AVERAGE',6X,'FIXED',5X,
83200       4'TRAVEL',6X,'AVERAGE',6X,'FIXED',5X,'TRAVEL',/,2X,
83300       5'METHOD',2X,'LANDING',3X,'LANDING',3X,'LANDING',5X,
83400       6'METHOD',5X,'METHOD',3X,'SKIDDING',3X,'SKIDDING',3X,
83500       7'SKIDDING',5X,'SKIDDING',3X,'SKIDDING',3X,'SKIDDING',/,
83600       82X,'NUMBER',3X,'NUMBER',4X,'VOLUME',5X,'ACRES',5X,'VOLUME',
83700       96X,'ACRES',3X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',
83800       15X,'DISTANCE',3X,'DISTANCE',3X,'DISTANCE',/)
83900        DO 3250 IDL14=1,NMETH
84000        IDLB5A=ILAND(IDL14)
84100        DO 3230 IDL14A=1,IDLB5A
84200 CJK
84300 CJK
84400 CJK    OUTPUT LANDING AND METHOD VOLUMES AND SKIDDING INFO
84500 CJK    BY LANDING ONLY
84600 CJK
84700 CJK
84800        WRITE(KW,3220)IDL14,IDL14A,VOLML(IDL14,IDL14A),
84900       1VOLMA(IDL14,IDL14A),ASKDBL(IDL14,IDL14A),
85000       2FSKDBL(IDL14,IDL14A),WSKDBL(IDL14,IDL14A)
85100  3220 FORMAT(4X,I4,5X,I4,1X,F9.0,2X,F8.0,25X,F8.0,3X,F8.0,3X,F8.0)
85200  3230 CONTINUE
85300 CJK
85400 CJK
85500 CJK    OUTPUT LANDING AND METHOD VOLUME, ACRES AND SKIDDING
85600 CJK    DISTANCES BY METHOD ONLY
85700 CJK
85800 CJK
85900        WRITE(KW,3240)IDL14,VOLBM(IDL14),ACRBM(IDL14),
86000       1ASKDBM(IDL14),FSKDBM(IDL14),WSKDBM(IDL14)
86100  3240 FORMAT(4X,I4,30X,F10.0,1X,F10.0,37X,F9.0,2X,F9.0,2X,F9.0)
86200  3250 CONTINUE
86300        WRITE(KW,3300)
86400  3300 FORMAT(/,2X,125('*'))
86500        WRITE(KW,3350)
86600  3350 FORMAT(2(/),2X,27('*'),/,24X,'TRUCK',/,
86700       123X,'TRAVEL',/,2X,'METHOD',2X,'LANDING',2X,
86800       2'CORRECTION',/,2X,'NUMBER',3X,'NUMBER',6X,'FACTOR',/)
86900        DO 3500 IDL15=1,NMETH
87000        IDLB06=ILAND(IDL15)
87100        DO 3400 IDL16=1,IDLB06
87200 CJK
87300 CJK ************** CARD TYPE 16 **********************
87400 CJK
87500 CJK
87600 CJK     ITMN=METHOD NUMBER; ITLN=LANDING NUMBER FOR THIS METHOD
87700 CJK     TKTVCF=TRUCK SPEED CORRECTION FACTOR THAT RECOGNIZES
87800 CJK     THAT TRAVEL SPEED MAY DECREASE AS THE ROAD STANDARD
87900 CJK     DECREASES AS A FUNCTION OF ROAD LENGTH
88000 CJK     (IE 0.80 WOULD MEAN THAT TRAVEL SPEED AT THE END
88100 CJK     WAS 80 % OF BEGINNIG TRAVEL SPEED)
88200 CJK
88300 CJK
88400        READ(KR,3360)ITMN,ITLN,TKTVCF
88500  3360 FORMAT(I1,1X,I2,1X,F4.2)
88600        TKTCF(IDL15,IDL16)=TKTVCF
88700        WRITE(KW,3370)ITMN,ITLN,TKTVCF
88800  3370 FORMAT(4X,I4,5X,I4,6X,F6.2)
88900  3400 CONTINUE
89000  3500 CONTINUE
89100        WRITE(KW,3550)
89200  3550 FORMAT(/,2X,27('*'),//)
89300        WRITE(KW,3600)
89400  3600 FORMAT(1H1,/,2X,94('*'),/,57X,5('*'),1X,'ALL TRUCKS',1X,
89500       1'WORKING TOGETHER',1X,5('*'),/,
89600       228X,'CYCLE',4X,'NUMBER',5X,'TRUCK',5X,'LANDING',
89700       33X,'LANDING',5X,'METHOD',5X,'METHOD'/,
89800       42X,'METHOD',2X,'LANDING',3X,'TRUCK',4X,'TIME',8X,
89900       5'OF',6X,'TIME',4X,'TRUCKING',2X,'TRUCKING',3X,
90000       6'TRUCKING',3X,'TRUCKING',/,
90100       72X,'NUMBER',3X,'NUMBER',2X,'NUMBER',3X,'HOURS',5X,
90200       8'LOADS',5X,'HOURS',7X,'HOURS',6X,'COST',
90300       96X,'HOURS',7X,'COST',/)
90400 CJK
90500 CJK
90600 CJK    START OF DO LOOP FOR METHODS++++TRUCKING TIMES
90700 CJK
90800 CJK
90900        DO 3950 IDL16=1,NMETH
91000        SMTKMH=0.0
91100        IDLB07=ILAND(IDL16)
91200 CJK
91300 CJK
91400 CJK    START OF DO LOOP FOR LANDINGS++++TRUCKING TIMES
91500 CJK
91600 CJK
91700        DO 3850 IDL17=1,IDLB07
91800        SMTKLH=0.0
91900        SMTKH=0.0
92000        DO 3750 IDL18=1,NTRK
92100 CJK
92200 CJK
92300 CJK    START OF DO LOOP FOR TRUCKS+++TRUCKING TIMES
92400 CJK
92500 CJK
92600        TKTEWM=DFTBTM/TKTENW(IDL18)
92700        TKTLWM=DFTBTM/TKTLNW(IDL18)
92800        TKTEBR=(DSFTB(IDL16,IDL17)/5280.0)/
92900       1((TKTEWD(IDL18)*(1.0+TKTCF(IDL16,IDL17)))/2.0)
93000        TKTLBR=(DSFTB(IDL16,IDL17)/5280.0)/
93100       1((TKTLWD(IDL18)*(1.0+TKTCF(IDL16,IDL17)))/2.0)
93200 CJK
93300 CJK
93400 CJK     TKCT=TRUCK CYCLE TIME; TKTEWM=TRAEMPTY TIME
93500 CJK      OVER NON-WOODS ROAD;  TKTLWM=TRAVEL LOADED TIME
93600 CJK      OVER NON-WOODS ROAD;  TKTEBR=TRAVEL TIME EMPTY
93700 CJK      OVER WOODS OR BUILT ROAD; TKTLBR=TRAVEL TIME
93800 CJK      LOADED OVER BUILT OR WOODS ROAD
93900 CJK
94000 CJK
94100        TKCT=(TKTEWM+TKTLWM+TKTEBR+TKTLBR+(TKFTPC(IDL18)/60.0))
94200       1/TKEF(IDL18)
94300        TKCYC=VOLML(IDL16,IDL17)/TKVOL(IDL18)
94400        TKH=TKCT*TKCYC
94500        SMTKH=SMTKH+(1.0/TKH)
94600        WRITE(KW,3700)IDL16,IDL17,IDL18,TKCT,TKCYC,TKH
94700  3700 FORMAT(4X,I4,5X,I4,4X,I4,1X,F7.2,1X,F9.1,F10.2)
94800  3750 CONTINUE
94900 CJK
95000 CJK
95100 CJK     SMTKHL=THE TIME IT WOULD TAKE IF ALL TRUCKS WORKED
95200 CJK     TOGETHER
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95300 CJK
95400 CJK
95500        SMTKHL=1.0/SMTKH
95600        SMTKLH=SMTKLH+SMTKHL
95700        SMTKLC=SMTKLH*SMTKHC
95800        SMTKMH=SMTKMH+SMTKLH
95900        IF(NTRK.GT.1)WRITE(KW,3800)IDL16,IDL17,SMTKLH,SMTKLC
96000  3800 FORMAT(4X,I4,5X,I4,38X,F10.2,F9.2)
96100  3850 CONTINUE
96200        SMTKMC=SMTKMH*SMTKHC
96300        LOGMET(5,IDL16)=SMTKMH
96400        WRITE(KW,3900)IDL16,SMTKMH,SMTKMC
96500  3900 FORMAT(4X,I4,67X,F11.2,F11.2,/)
96600  3950 CONTINUE
96700        WRITE(KW,4000)
96800  4000 FORMAT(/,2X,94('*'))
96900        IF(ICTRAT.EQ.0)GO TO 4500
97000        WRITE(KW,4250)
97100  4250 FORMAT(2(/),2X,21('*'),/,
97200       12X,'CONSTRAINT',/,8X,'CODE',/,2X,'1= ROAD HR',/,
97300       22X,'2= LAND HR',6X,'UPPER',/,2X,'3= SKID HR',6X,'BOUND',/,
97400       32X,'4= TRUK HR',6X,'VALUE',/)
97500        DO 4400 IDL23=1,ICTRAT
97600        K=IDL23+7
97700        JCONSC=NMETH+ICTRAT+12
97800 CJK
97900 CJK
98000 CJK  ********** CARD TYPE 17 ****************************
98100 CJK
98200 CJK
98300 CJK      ICSTFO=CONSTRAINT CODE; CSTVAL=VALUE OF THIS
98400 CJK      CONSTRAINT
98500 CJK
98600 CJK
98700        READ(KR,4300)ICSTFO,CSTVAL
98800  4300 FORMAT(I1,1X,F9.1)
98900        MCONSC=JCONSC-(4-ICSTFO)
99000 CJK
99100 CJK UPPER BOUND ROAD CONSTRUCTION HOURS
99200 CJK
99300        IF(ICSTFO.EQ.1)P(K)=CSTVAL
99400        IF(ICSTFO.EQ.1)A(K,MCONSC)=1.0
99500        IF(ICSTFO.EQ.1)JVAR(K)=1
99600 CJK
99700 CJK UPPER BOUND FOR WEIGHTED LANDING CONST. & MOVING
99800 CJK
99900        IF(ICSTFO.EQ.2)P(K)=CSTVAL
100000       IF(ICSTFO.EQ.2)A(K,MCONSC)=1.0
100100       IF(ICSTFO.EQ.2)JVAR(K)=2
100200 CJK
100300 CJK UPPER BOUND FOR SKIDDING HOURS
100400 CJK
100500       IF(ICSTFO.EQ.3)P(K)=CSTVAL
100600       IF(ICSTFO.EQ.3)A(K,MCONSC)=1.0
100700       IF(ICSTFO.EQ.3)JVAR(K)=3
100800 CJK
100900 CJK  UPPER BOUND FOR TRUCKING HOURS
101000 CJK
101100       IF(ICSTFO.EQ.4)P(K)=CSTVAL
101200       IF(ICSTFO.EQ.4)A(K,MCONSC)=1.0
101300       IF(ICSTFO.EQ.4)JVAR(K)=4
101400       WRITE(KW,4350)ICSTFO,CSTVAL
101500  4350 FORMAT(6X,I2,7X,F8.0)
101600  4400 CONTINUE
101700       WRITE(KW,4450)
101800  4450 FORMAT(/,2X,21('*'),/)
101900  4500 CONTINUE
102000       IF(IUNIT.EQ.1)TOTLVL=HARVOL/2000.0
102100       IF(IUNIT.EQ.2)TOTLVL=HARVOL/1000.0
102200       IF(IUNIT.EQ.3)TOTLVL=HARVOL/100.0
102300       IF(IUNIT.EQ.4)TOTLVL=HARVOL/1.0
102400       WRITE(KW,4700)
102500  4700 FORMAT(1H1,/,64X,'METHOD SUMMARY',/,1X,127('*'),/,31X,
102600      1'LANDING CONSTRUCTION',58X,'TOTAL',6X,
102700      2'METHOD',/,9X,'ROAD CONSTRUCTION',5X,'AND',2X,'SYSTEM',
102800      33X,'MOVING',10X,'SKIDDING',15X,'TRUCKING',16X,'METHOD',
102900      42X,'HARVESTING',/,1X,'METH',2X,21('-'),3X,21('-'),3X,
103000      521('-'),3X,21('-'),4X,'HARVESTING',8X,'UNIT',/,
103100      63X,'NO',2X,'HOURS',6X,'$$$',2X,'$/VOL',3X,'HOURS',6X,
103200      7'$$$',2X,'$/VOL',3X,'HOURS',6X,'$$$',2X,'$/VOL',3X,
103300      8'HOURS',6X,'$$$',2X,'$/VOL',9X,'COSTS',7X,'COSTS',/)
103400       DO 4900 IDL30=1,NMETH
103500       SOUT01=LOGMET(2,IDL30)*SMDZHC
103600       SOUT02=SOUT01/TOTLVL
103700       SOUT03=LOGMET(3,IDL30)*(DZRHC(ILDZR)+SYSMHC)
103800       SOUT04=SOUT03/TOTLVL
103900       SOUT05=LOGMET(4,IDL30)*SMSKHC
104000       SOUT06=SOUT05/TOTLVL
104100       SOUT07=LOGMET(5,IDL30)*SMTKHC
104200       SOUT08=SOUT07/TOTLVL
104300       SOUT09=SOUT01+SOUT03+SOUT05+SOUT07
104400       SOUT10=SOUT09/TOTLVL
104500       WRITE(KW,4800)IDL30,LOGMET(2,IDL30),SOUT01,SOUT02,
104600      1LOGMET(3,IDL30),SOUT03,SOUT04,LOGMET(4,IDL30),
104700      2SOUT05,SOUT06,LOGMET(5,IDL30),SOUT07,SOUT08,
104800      3SOUT09,SOUT10
104900  4800 FORMAT(2X,I3,1X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
105000      1F8.0,F7.0,2X,F6.0,1X,F8.0,1X,F6.0,2X,F6.0,1X,
105100      2F8.0,1X,F6.0,2X,F12.2,2X,F10.2)
105200  4900 CONTINUE
105300       WRITE(KW,5000)
105400  5000 FORMAT(/,127('*'))
105500 CJK
105600 CJK
105700 CJK     ############## SECTION 2 ######################
105800 CJK
105900 CJK
106000 CWC
106100 CWC  FORMAT STATEMENTS USED IN RAVINDRIN'S PROGRAM
106200 CWC
106300      1 FORMAT(1H1,/,3X,'ITERATION NO=',I5)
106400 C 112 FORMAT(1X,12X,4I12/(13X,4I12)/(13X,4I12)/(13X,2I12))
106500 C 121 FORMAT(1X,I2,F8.2,3X,4F12.2/(14X,4F12.2)/(14X,4F12.2)/
106600 C     2(14X,2F12.2))
106700 C 122 FORMAT(5X,4F13.1/(5X,3F13.1))
106800 C 123 FORMAT(1X,F12.1,1X,4F12.1/(4X,4F12.1)/(4X,4F12.1)/(
106900 C     34X,2F12.1))
107000 C 325 FORMAT( 1X/ 7X,8HSOLUTION,10X,7HTABLEAU)
107100 C 326 FORMAT( 1X,14HVARIABLE COSTS,2X,3F15.4/(2X,4F15.4)/(2X
107200 C     4,4F15.4)/(2X,3F15.4))
107300    102 FORMAT(1X,5X,37HTHE OBJECTIVE FUNCTION IS NOT BOUNDED)
107400    335 FORMAT(1HA)
107500        IP1 = 1
107600        IP2 = 1
107700 CWC
107800 CWC  M = NUMBER OF COLUMNS IN BASIS
107900 CWC  N = NUMBER OF COLUMNS IN "A" MATRIX
108000 CWC
108100        M = ICTRAT+7
108200        M2 = NMETH+10
108300        N = NMETH+5+M
108400        N2 = NMETH+5
108500        M3 = M+1
108600        N9 = NMETH+M
108700 CWC
108800 CWC  IREP = 0 IF ONLY FIRST TABLEAU IS TO BE PRINTED
108900 CWC       = 1 IF ALL TABLEAUS SHOULD BE PRINTED
109000 CWC
109100        IREP = 1
109200        IT=0
109300        WRITE(KW,335)
109400        EP=.5E-6
109500 CWC
109600 CWC  "JVAR" ARRAY CONTAINS A NUMBER CORRESPONDING TO EACH COLUMN
109700 CWC  IN THE "A" MATRIX.  DUE TO THE METHOD OF INPUT INTO THE
109800 CWC  MATRIX, THE FIRST M COLUMNS (BASIS) OF THE MATRIX MUST
109900 CWC  BE NUMBERED TO REFLECT THE FACT THAT IT SHOULD APPEAR
110000 CWC  AT THE END OF THE MATRIX.
110100 CWC
110200        DO 3 I=1,M
110300        JVAR(I) = N2+I
110400      3 CONTINUE
110500 CWC
110600 CWC  NUMBER OTHER COLUMNS AS THOUGH THEY WERE AT FRONT OF MATRIX
110700 CWC
110800        DO 4 I=M3,N
110900        JVAR(I)=I-M
111000      4 CONTINUE
111100        K=M3
111200 CWC
111300 CWC  SET PRODUCT PRICE IN OBJECTIVE FUNCTION
111400 CWC
111500        C(K) = PRODPC
111600        K = NMETH+M3+1
111700 CWC
111800 CWC  SET ROAD EQUIPMENT HOURLY COST IN OBJECTIVE FUNCTION
111900 CWC
112000        C(K) = -SMDZHC
112100        K = K+1
112200 CWC
112300 CWC  SET LANDING CONSTRUCTION HOURLY COST IN OBJECTIVE FUNCTION
112400 CWC  LANDING CONSTRUCTION HOURLY COST = ROAD EQUIPMENT HOURLY
112500 CWC     COST + SYSTEM MOVE HOURLY COST
112600 CWC
112700        C(K) = -DZRHC(ILDZR)-SYSMHC
112800        K = K+1
112900 CJK
113000 CJK
113100 CJK  SMSKHC= SUM OF HOURLY SKIDDER COSTS
113200 CJK  SMTKHC= SUM OF HOURLY TRUCKING COSTS
113300 CJK
113400 CJK
113500        C(K) = -SMSKHC
113600        K = K+1
113700        C(K) = -SMTKHC
113800        K = K+1
113900 CWC
114000 CWC  SET RIGHT HAND CONSTANTS OF FIRST FIVE EQUATIONS
114100 CWC  EQUAL TO 0.0
114200 CWC
114300        DO 778 I=1,5
114400        P(I) = 0.0
114500        B(I) = 0.0
114600    778 CONTINUE
114700        A(1,M3)=1.0
114800        K9=M+NMETH+1
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114900        K8=M+2
115000 CWC
115100 CWC  STORE DATA IN "LOGMET" MATRIX IN "A" MATRIX TO BE USED
115200 CWC  IN LP
115300 CWC
115400        DO 317 I=K8,K9
115500        DO 242 J=1,M
115600        K=I-M-1
115700        A(J,I) = LOGMET(J,K)
115800    242 CONTINUE
115900    317 CONTINUE
116000 CWC
116100 CWC  STORE Z VALUES INTO "A" MATRIX
116200 CWC
116300        K9 = K9+1
116400        K8 = K9+3
116500        J=1
116600        DO 467 I=K9,K8
116700        J=J+1
116800        A(J,I)=-1.0
116900    467 CONTINUE
117000 CWC
117100 CWC  STORE CONSTRAINT RELATING TO TRACK VOLUME INTO "A" MATRIX
117200 CWC
117300        A(6,M3)=1.0
117400 CWC
117500 CWC  STORE TRACK VOLUME INTO "B" MATRIX
117600 CWC
117700        P(6)=TOTLVL
117800        B(6)=TOTLVL
117900        M4 = M3+1
118000 CWC
118100 CWC  STORE CONSTRAINT RESTRICTING SUM OF METHODS TO EQUAL ONE
118200 CWC
118300        DO 992 K=1,NMETH
118400        A(7,M4) = 1.0
118500        M4 = M4+1
118600    992 CONTINUE
118700 CWC
118800 CWC  STORE 1.0 INTO "B" MATRIX
118900 CWC
119000        P(7) = 1.0
119100        B(7) = 1.0
119200        DO 5 J=1,N
119300        JJ=JVAR(J)
119400      5 CC(JJ)=C(J)
119500        L=M+1
119600        DO 301 I=1,N
119700        CI(I)=C(I)
119800        IVAR(I)=JVAR(I)
119900    301 CONTINUE
120000 CWC
120100 CWC  STORE BASIS INTO MATRIX
120200 CWC
120300        DO 444 I=1,M
120400        A(I,I)=1.0
120500    444 CONTINUE
120600    194 OMZM=-9.E30
120700 CWC
120800 CWC  CALCULATE C-BAR ROW
120900 CWC  OUTER DO LOOP CONTROLS COLUMNS IN "A" MATRIX
121000 CWC  INNER DO LOOP CONTROLS SUMMING OF EACH ELEMENT OF COLUMN
121100 CWC
121200        DO 74 JVC=1,N
121300        Z=0.0
121400 CWC  "Z" IS PRODUCT OF "A" ARRAY COLUMN TIMES CB ELEMENTS OF MATRIX
121500 CWC
121600        DO 75 I=1,M
121700     75 Z=Z+A(I,JVC)*CI(I)
121800 CWC
121900 CWC  ENT IS C-BAR ELEMENT FOR THAT COLUMN
122000 CWC  OMZ IS ARRAY THAT HOLDS C-BAR ELEMENTS
122100 CWC
122200        ENT=C(JVC)-Z
122300        OMZ(JVC)=ENT
122400 CWC
122500 CWC  FIND LARGEST VALUE IN C-BAR ROW TO USE AS PIVOT COLUMN
122600 CWC  STORE VALUE OF LARGEST C-BAR ELEMENT IN OMZM AND STORE
122700 CWC  PIVOT COLUMN NUMBER IN KOUT
122800 CWC
122900        IF(OMZM.GT.ENT)GO TO 74
123000        OMZM=ENT
123100        KOUT=JVC
123200     74 CONTINUE
123300 CWC
123400 CWC  INCREMENT ITERATION COUNTER AND WRITE ITERATION MESSAGE
123500 CWC
123600        IT=IT+1
123700        WRITE(KW,1)IT
123800        IF(IREP.EQ.0)GO TO 25
123900 CWC
124000 CWC  CALCULATE Z VALUE AND STORE IN VARIABLE "VALUE"
124100 CWC
124200    601 VALUE=0.0
124300        DO 110 I=1,M
124400    110 VALUE=VALUE+P(I)*CI(I)
124500 CWC
124600 CWC  WRITE OUT "A" MATRIX AS INPUTTED INTO LP PROGRAM
124700 CWC
124800 CJK
124900 CJK   DEBUG FORMAT OPTION:::: THIS FORMAT IS HARD TO
125000 CJK   FOLLOW BUT SHOWS THE INPUT MATRIX IN THE FORM
125100 CJK   USED BY RAVANDRINA :: SLACKS AND SURPLUS FIRST
125200 CJK   THEN NORMAL LP VALUES
125300 CJHK
125400        IF(LPCDE.EQ.1)WRITE(KW,6001)M,N
125500   6001 FORMAT(25X,'ROWS 1 THRU ',I3,'  AND COLUMNS 1 THRU ',I3,
125600       1'  IN RAVINDRAN LP MATRIX',/)
125700        DO 2456 K=1,M
125800        IF(LPCDE.EQ.1)WRITE(KW,8456) (A(K,JHA),JHA=1,N)
125900   8456 FORMAT(13F10.2)
126000   2456 CONTINUE
126100   2457 CONTINUE
126200 CWC
126300 CWC  WRITE OUT TOP THREE OR FOUR LINES OF TABLEAU WHICH DOES
126400 CWC  NOT VARY BY NUMBER OF METHODS
126500 CWC
126600        WRITE(KW,6000)
126700   6000 FORMAT(/,1X,128('*'))
126800        WRITE(KW,6010)
126900   6010 FORMAT(1X,'*',4X,'* *',7X,'*',99X,'*',11X,'*')
127000        K2=NMETH+2
127100        K2=NMETH+M3+1
127200        WRITE(KW,6020) C(M3),(C(I),I=K2,N)
127300   6020 FORMAT(1X,'*',4X,'*  *',2X,'CJ',2X,'*',1X,F8.2,49X,4(1X,F9.2),
127400       11X,'*',3X,'RIGHT',3X,'*')
127500        WRITE(KW,6030)
127600   6030 FORMAT(1X,'*',4X,'* B *',5X,'*',99X,'*',11X,'*')
127700        WRITE(KW,6040)
127800   6040 FORMAT(1X,'*',4X,'*  A *',4X,101('*'),3X,'HAND',4X,'*')
127900        N3 = NMETH-1
128000 CWC
128100 CWC  BRANCH TO STATEMENT NUMBER AND COMPLETE OUTPUT ACCORDING
128200 CWC  TO THE NUMBER OF METHODS
128300 CWC
128400        GO TO (7000,7010,7020),N3
128500 CJK
128600 CJK
128700 CJK CONTROL GOES TO STATEMENT NUMBER 7000 IF 2 METHODS
128800 CJK CONTROL GOES TO STATEMENT NUMBER 7010 IF 3 MEHTODS
128900 CJK CONTROL GOES TO STATEMENT NUMBER 7020 IF 4 METHODS
129000 CJK
129100 CJK
129200 CWC
129300 CWC  WRITE OUT TABLEAU FOR COMPARISON OF TWO METHODS
129400 CWC
129500   7000 WRITE(KW,6060)
129600   6060 FORMAT(1X,'*',5X,'*  S *   *',9X,'* METHOD  * METHOD  *'
129700       1,29X,'*   $/HR  *   $/HR  *   $/HR  *   $/HR  *',11X,'*')
129800        WRITE(KW,6070)
129900   6070 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  *  (YO)   *',4X,'1',4X,
130000       1'*',4X,'2',4X,'*',29X,'*  ROADS  *   LAND  *   SKID  *',
130100       2'  TRUCK  * CONSTANTS *')
130200        WRITE(KW,6080)
130300   6080 FORMAT(1X,'*',7X,'*  S * *',9X,'*  (M1)   *  (M2)   *',29X,
130400       1'*   (Z1)  *   (Z2)  *   (Z3)  *   (Z4)  *',11X,'*')
130500        WRITE(KW,6050)
130600   6050 FORMAT(1X,128('*'))
130700        WRITE(KW,6115)
130800   6115 FORMAT(1X,'*',9X,'*',4X,'*',99X,'*',11X,'*')
130900 CWC
131000 CWC  DO LOOP CONTROLS PRINTING OF EACH ROW IN MATRIX
131100 CWC
131200        DO 8000 I=1,M
131300        K=IVAR(I)
131400 CWC
131500 CWC  VARIABLES USED TO CONTROL OUTPUT.  YOU HAVE TO THINK
131600 CWC  TO FIGURE OUT THE VALUES THAT NEED TO BE ASSIGNED TO
131700 CWC  THE VARIABLES
131800 CWC
131900        N5=N9+1
132000        N6=N5+1
132100        M4=M3+1
132200 CJK
132300 CJK  OUTPUT FORMAT FOR LP IN CONVEX FORM BY METHOD
132400 CJK  AND HOURS AND NEAT HEADINGS
132500 CJK
132600        WRITE(KW,6090) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
132700       1J=N6,N),P(I)
132800   6090 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',3F10.2,
132900       129X,4F10.2,'*',1X,F9.2,1X,'*')
133000   8000 CONTINUE
133100        WRITE(KW,6115)
133200        WRITE(KW,6100)
133300   6100 FORMAT(1X,128('*'))
133400        WRITE(KW,6110)
133500   6110 FORMAT(1X,'*',14X,'*',99X,'*',4X,'Z =',4X,'*')
133600 CWC
133700 CWC  WRITE C-BAR ROW OUT IN TABLEAU
133800 CWC
133900        WRITE(KW,6120) (OMZ(J),J=M3,N),VALUE
134000   6120 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',3F10.2,'*',28X,4F10.2,1X,
134100       1F11.0,'*')
134200        GO TO 7040
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134300  7010 WRITE(KW,6130)
134400 CWC
134500 CWC  WRITE OUT TABLEAU FOR COMPARISON OF THREE METHODS
134600 CWC
134700  6130 FORMAT(1X,'*',5X,'*  S *',3X,'* SELLING ',3('* METHOD  '),'*',
134800      120X,3('*   $/HR  '),'*',3X,'$/HR',1X,'*',11X,'*')
134900       WRITE(KW,6140)
135000  6140 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  * PRICE $ *',4X,'1',4X,
135100      1'*',4X,'2',4X,'*',4X,'3',4X,'*',20X,'* ROADS  *   LAND  *',
135200      2'   SKID  *  TRUCK * CONSTANTS *')
135300       WRITE(KW,6150)
135400  6150 FORMAT(1X,'*',7X,'*  S * *   (Y0)  *  (M1)   *  (M2)   *',2X,
135500      1'(M3)   *',20X,'*',3X,'(Z1)  *   (Z2)  *   (Z3)  *   (Z4) *',
135600      211X,'*',/,1X,128('*'))
135700 CWC
135800 CWC  DO LOOP CONTROLS PRINTING OF EACH ROW
135900 CWC
136000       DO 8010 I=1,M
136100       K = IVAR(I)
136200 CWC
136300 CWC  VARIABLES USED TO CONTROL OUTPUT
136400 CWC
136500       N5=N9+1
136600       N6=N5+1
136700       M4=M3+1
136800       WRITE(KW,6160) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
136900      1J=N6,N),P(I)
137000  6160 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',4F10.2,20X,4F10.2,
137100      1F10.2,1X,'*')
137200  8010 CONTINUE
137300       WRITE(KW,6115)
137400       WRITE(KW,6100)
137500       WRITE(KW,6110)
137600 CWC
137700 CWC  PRINTS OUT C-BAR ROW
137800 CWC
137900       WRITE(KW,6190) (OMZ(J),J=M3,N),VALUE
138000  6190 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',4F10.2,20X,4F10.2,
138100      1F11.0,'*')
138200       GO TO 7040
138300 CWC
138400 CWC  WRITE OUT TABLEAU FOR COMPARISON OF FOUR METHODS
138500 CWC
138600  7020 WRITE(KW,6200)
138700  6200 FORMAT(1X,'*',5X,'*  S *',3X,'* SELLING ',4('* METHOD  '),'*',
138800      19X,4('*   $/HR  '),'*',11X,'*')
138900       WRITE(KW,6210)
139000  6210 FORMAT(1X,'*',2X,'CB',2X,'*',2X,'I *  * PRICE $ *',4X,'1',4 X,
139100      1'*',4X,'2',4X,'*',4X,'3',4X,'*',4X,'4',4X,'*',9X,
139200      2'* ROADS  *   LAND  *   SKID  *  TRUCK  * CONSTANTS *')
139300       WRITE(KW,6220)
139400  6220 FORMAT(1X,'*',7X,'*  S * *   (Y0)  *  (M1)   *  (M2)   *',
139500      12X,'(M3)   *  (M4)   *',9X,'*   (Z1)  *   (Z2)  *   (Z3)  *',
139600      23X,'(Z4)  *',11X,'*',/)
139700       WRITE(KW,6100)
139800       WRITE(KW,6115)
139900       DO 8020 I=1,M
140000 CWC
140100 CWC  VARIABLES USED TO CONTROL OUTPUT
140200 CWC
140300       K = IVAR(I)
140400       N5 = N9+1
140500       N6 = N5+1
140600       M4 = M3+1
140700       WRITE(KW,6230) C(K),IVAR(I),A(I,M3),(A(I,J),J=M4,N5),(A(I,J),
140800      1J=N6,N),P(I)
140900  6230 FORMAT(1X,'*',1X,F7.2,1X,'*',1X,'X',I2,'*',5F10.2,9X,4F10.2,
141000      1'*',1X,F9.2,1X,'*')
141100  8020 CONTINUE
141200       WRITE(KW,6115)
141300       WRITE(KW,6100)
141400       WRITE(KW,6110)
141500 CWC
141600 CWC  PRINTS OUT C BAR ROW
141700 CWC
141800       WRITE(KW,6260) (OMZ(J),J=M3,N),VALUE
141900  6260 FORMAT(1X,'*',2X,'C-BAR ROW',3X,'*',5F10.2,9X,4F10.2,'*',
142000      1F11.0,'*')
142100  7040 CONTINUE
142200       WRITE(KW,6131)
142300  6131 FORMAT(1X,128('*'))
142400 CWC
142500 CWC  CHECK FOR OPTIMAL SOLUTION
142600 CWC
142700       IF(OMZM.LT.EP)GO TO 192
142800       GO TO 801
142900    25 IF(IT.EQ.1)GO TO 601
143000    26 IF(OMZM.LT.EP)GO TO 191
143100   801 THETA=9.E30
143200 CWC
143300 CWC  DETERMINE PIVOT ELEMENT IN COLUMN.
143400 CWC  DO LOOP CONTROLS SEARCH THROUGH ROWS
143500 CWC
143600       DO 812 I=1,M
143700       IF(A(I,KOUT).LE.EP)GO TO 812
143800       TH=P(I)/A(I,KOUT)
143900       IF(THETA.LT.TH)GO TO 812
144000 CWC
144100 CWC  VARIABLE THETA CONTAINS VALUE OF PIVOT ELEMENT AFTER DIVISION.
144200 CWC  IRIN CONTAINS THE NUMBER OF THE PIVOT ROW.
144300 CWC
144400       THETA=TH
144500       IRIN=I
144600   812 CONTINUE
144700 CWC
144800 CWC  CHECK FOR UNBOUNDED SOLUTION.  IF FOUND WRITE OUT MESSAGE
144900 CWC  AND END PROGRAM
145000 CWC
145100       IF(THETA.LT.9.0E20)GO TO 507
145200       WRITE(KW,102)
145300       GO TO 192
145400   191 IF(IREP.EQ.0)GO TO 601
145500 CWC
145600 CWC  VARIABLE PIVOT CONTAINS PIVOT ELEMENT
145700 CWC
145800   507 PIVOT=A(IRIN,KOUT)
145900       P(IRIN)=P(IRIN)/PIVOT
146000 CWC
146100 CWC  DIVIDE PIVOT ROW BY PIVOT ELEMENT
146200 CWC
146300       DO 521 J=1,N
146400   521 A(IRIN,J)=A(IRIN,J)/PIVOT
146500 CWC
146600 CWC  DO NECESSARY MATRIX DIVISION AFTER PIVOT ELEMENT AND ROW
146700 CWC  IS FOUND.  OUTER LOOP CONTROLS COLUMNS; INNER LOOP
146800 CWC  CONTROLS ROWS
146900 CWC
147000       DO 522 J=1,N
147100       IF(J.EQ.KOUT)GO TO 522
147200       DO 523 I=1,M
147300       IF(I.EQ.IRIN)GO TO 523
147400       A(I,J)=A(I,J)-A(I,KOUT)*A(IRIN,J)
147500   523 CONTINUE
147600   522 CONTINUE
147700       DO 529 I=1,M
147800 CWC
147900 CWC  IF STATEMENT PROTECTS PIVOT ELEMENT
148000 CWC
148100       IF(I.EQ.IRIN)GO TO 529
148200 CWC
148300 CWC  CALCULATE RIGHT-HAND CONSTANTS
148400 CWC
148500       P(I)=P(I)-P(IRIN)*A(I,KOUT)
148600 CWC
148700 CWC  ZERO OUT PIVOT COLUMN
148800 CWC
148900       A(I,KOUT)=0.0
149000   529 CONTINUE
149100       EP=EP+.5E-6
149200       CI(IRIN)=C(KOUT)
149300       IVAR(IRIN)=JVAR(KOUT)
149400 CWC
149500 CWC  SET PIVOT ELEMENT TO 1.0
149600 CWC
149700       A(IRIN,KOUT)=1.0
149800       GO TO 194
149900 CWC
150000 CWC  WRITE OUT SUMMARY OF METHODS PICKED FROM LP
150100 CWC
150200   192 CONTINUE
150300       I1=0
150400 CWC
150500 CWC  ITOT KEEPS TRACK OF NUMBER OF METHODS PICKED
150600 CWC  TSSUM IS THE SUM OF THE PROPORTION OF EACH METHOD PICKED
150700 CWC
150800       ITOT=0
150900       INMIP=0
151000       TSSUM=0.0
151100       DO 9431 IHELPM=1,25
151200  9431 CONTINUE
151300       DO 9433 IHELPY=1,4
151400       IARR(IHELPY)=0
151500       RC(IHELPY)=0.0
151600       LD(IHELPY)=0.0
151700       SK(IHELPY)=0.0
151800       TK(IHELPY)=0.0
151900  9433 CONTINUE
152000       SUMRPH=0.0
152100       SUMRPC=0.0
152200       SUMLPH=0.0
152300       SUMLPC=0.0
152400       SUMSPH=0.0
152500       SUMSPC=0.0
152600       SUMTPH=0.0
152700       SUMTPC=0.0
152800       SUMTOT=0.0
152900       WRITE(KW,6500)
153000  6500 FORMAT(1X,16('*'),57X,'***',40X,12('*'),/,1X,16('*'),
153100      157X,'***',40X,12('*'),/,1X,16('*'),9X,
153200      2'ABOVE VALUES IN C-BAR ROW',23X,'***',6X,
153300      3'ABOVE VALUES IN C-BAR ROW',9X,12('*'),/,1X,16('*'),
153400      49X,'ARE PENALTY COSTS',31X,'***',6X,
153500      5'ARE SHADOW PRICES',17X,12('*'),/,1X,16('*'),57X,'***',
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      640X,12('*'),/,1X,16('*'),57X,'***',40X,12('*'),
      7/,1X,128('*'))
       WRITE(KW,8042)IT
 8042 FORMAT(1H1,2(/),37X,'AFTER ',I3,' ITERATIONS THE OPTIMUM',
      11X,'SOLUTION CONSISTED OF:',
      1/,1X,128('*'),/,25X,'ROAD',5X,'ROAD',4X,
      2'LANDING CONST',4X,'LANDING CONST',52X,'TOTAL',/,
      31X,'METHOD',6X,'METHOD',5X,'CONST',4X,'CONST',4X,
      4'AND',4X,'SYSTEM',4X,'AND',4X,'SYSTEM',3X,'SKIDDING',
      54X,'SKIDDING',4X,'TRUCKING',4X,'TRUCKING',4X,'METHOD',
      6/,6X,'#',2X,'PROPORTION',
      15X,'HOURS',4X,'COSTS',12X,'HOURS',12X,'COSTS',
      76X,'HOURS',7X,'COSTS',7X,'HOURS',7X,'COSTS',5X,'COSTS',/)
       DO 1012 I=1,M
       DO 1012 K=1,NMETH
       K2=K+1
       IF(IVAR(I).NE.K2) GO TO 1012
       I1=I1+1
       IARR(I1)=IVAR(I)-1
       TSSUM=TSSUM+P(I)
       ITOT=ITOT+1
       PROP(I1)=P(I)
       I2P=IARR(I1)
       RC(I2P)=LOGMET(2,I2P)*PROP(I1)
       LD(I2P)=LOGMET(3,I2P)*PROP(I1)
       SK(I2P)=LOGMET(4,I2P)*PROP(I1)
       TK(I2P)=LOGMET(5,I2P)*PROP(I1)
       INMIP=INMIP+1
       ROADMC=RC(I2P)*SMDZHC
       LAMDMC=LD(I2P)*(DZRHC(ILDZR)+SYSMHC)
       SKIDMC=SK(I2P)*SMSKHC
       TRUKMC=TK(I2P)*SMTKHC
       SUMRPH=SUMRPH+RC(I2P)
       SUMRPC=SUMRPC+ROADMC
       SUMLPH=SUMLPH+LD(I2P)
       SUMLPC=SUMLPC+LAMDMC
       SUMSPH=SUMSPH+SK(I2P)
       SUMSPC=SUMSPC+SKIDMC
       SUMTPH=SUMTPH+TK(I2P)
       SUMTPC=SUMTPC+TRUKMC
       TOTHRM=ROADMC+LAMDMC+SKIDMC+TRUKMC
       SUMTOT=SUMTOT+TOTHRM
       WRITE(KW,8047)IARR(I1),PROP(I1),RC(I2P),ROADMC,LD(I2P),
      1LAMDMC,SK(I2P),SKIDMC,TK(I2P),TRUKMC,TOTHRM
 8047 FORMAT(3X,I4,6X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,F8.0,2X,
      1F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0)
 1012 CONTINUE
       WRITE(KW,8048)
 8048 FORMAT(12X,7('-'),1X,9('-'),1X,8('-'),8X,9('-'),9X,
      18('-'),2X,9('-'),4X,8('-'),3X,9('-'),4X,8('-'),1X,9('-'))
       WRITE(KW,8049)TSSUM,SUMRPH,SUMRPC,SUMLPH,SUMLPC,SUMSPH,
      1SUMSPC,SUMTPH,SUMTPC,SUMTOT
 8049 FORMAT(1X,'TOTALS:',5X,F6.2,1X,F9.1,1X,F8.0,8X,F9.1,9X,
      1F8.0,2X,F9.0,4X,F8.0,3X,F9.1,4X,F8.0,1X,F9.0,/,
      21X,128('*'))
       GROSSV=PROOPC*TOTLVL
       GRSMHC=GROSSV-VALUE
       UNITHC=VALUE/TOTLVL
       GMNHLC=PROOPC-UNITHC
       WRITE(KW,8055)GROSSV,PROOPC
 8055 FORMAT(2(/),1X,91('*'),/,1X,'(A) TOTAL DELIVERD PRICE',
      11X,'OF HARVESTED TIMBER:',2X,F13.0,7X,'UNIT PRICE:',3X,F9.2)
       WRITE(KW,8060)GRSMHC,GMNHLC
 8060 FORMAT(1X,'(B) TOTAL HARVESTING COSTS (THOSE CONSIDERED):'
      1,1X,F13.0,7X,'UNIT COSTS:',3X,F9.2,/,54X,7('-'),24X,
      27('-'))
       WRITE(KW,8070)VALUE,UNITHC
 8070 FORMAT(26X,'DIFFERENCE: (A)-(B):',2X,F13.0,21X,F9.2,/,
      191('*'))
       CALL SENS(N,M)
       STOP
       END
       SUBROUTINE SENS(N,M)
C
C*****THIS SUBROUTINE IS THE EXECUTIVE ROUTINE TO INITIALIZE THE
C      SENSITIVITY ANALYSIS.
C
       COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
      1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
      2,B(25),CC(25),JVAR(25)
      3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
C
C*****FIRST, THE LIMITS ON EACH C(J) ARE FOUND.  IF X(L) IS A BASIC
C      VARIABLE, THEN SUBROUTINE CBAS IS CALLED, OTHERWISE SUBROUTINE
C      CNONB IS USED FOR NONBASIC X(L).  IF X(L) IS BASIC, NCLE IS  SET
C      TO 1, OTHERWISE NCLE REMAINS 0.
C
       K=0
       KW=6
     5 NCLE=0
       K=K+1
       L=JVAR(K)
       IF(K.GT.N)GO TO 15
       DO 10 I=1,M
       KV=IVAR(I)
       IF(L-KV)10,20,10
    20 NCLE=1
    10 CONTINUE
       IF(NCLE-1) 25,30,25
    25 CALL CNONB(K,N,M)
       GO TO 5
    30 CALL CBAS(K,N,M)
       GO TO 5
C
C*****NOW,SUBROUTINE BRANG IS CALLED TO DETERMINE THE RANGES ON THE
C      RIGHT HAND SIDE CONSTANTS B(I).
C
    15 CALL BRANG(N,M)
C
C*****THE FINAL STEP IS TO WRITE THE REPORT.  FIRST, THE SHADOW PRICES
C      AND PENALTY COSTS ARE WRITTEN.  NEXT, THE RANGES ON THE BASIC
C      AND NONBASIC C(J) ARE WRITTEN.  THEN, THE B(I) RANGES ARE
C      DISPLAYED, AND THE SENSITIVITY ANALYSIS IS COMPLETED.  DURING THE
C      WRITE ROUTINES, THE SUBROUTINE CHECK IS CALLED, WHICH DETERMINES
C      IF X(J) IS BASIC OR NONBASIC IN THE OPTIMUM TABLEAU.
C
       WRITE(KW,100)
       WRITE(KW,1000)
       WRITE(KW,101)
       WRITE(KW,102)
       K=0
    11 K=K+1
       IF(K.GT.N) GO TO 31
       CALL CHECK(K,NQLE,N,M)
       IF(NQLE-1) 21,11,21
    21 WRITE(KW,103) JVAR(K),PCOST(K)
CJK
CJK
CJK   WRITES OUT NON-BASIC VARIABLES AND PENALTY COSTS
CJK
CJK
CJK
       GO TO 11
    31 WRITE(KW,149)
CJK
CJK
CJK    WRITES OUT ROW NUMBER AND SHADOW PRICES
CJK
CJK
       DO 22 I=1,M
    22 WRITE(KW,103) I,ZJ(I)
       WRITE(KW,104)
       WRITE(KW,105)
       K=0
    40 K=K+1
       IF(K.GT.N) GO TO 60
       CALL CHECK(K,NQLE,N,M)
       IF(NQLE-1) 50,40,50
    50 WRITE(KW,106) JVAR(K),CL(K)
CJK
CJK
CJK   WRITES OUT RANGES ON NON-BASIC C(J), VARIABLE CODE
CJK   AND ITS LOWER LIMIT
CJK
CJK
       GO TO 40
    60 WRITE(KW,107)
       WRITE(KW,108)
       K=0
    70 K=K+1
       IF(K.GT.N) GO TO 90
       CALL CHECK(K,NQLE,N,M)
       IF(NQLE) 70,70,80
    80 WRITE(KW,109)JVAR(K),CLO(K),CUP(K)
CJK
CJK
CJK  WRITES OUT RANGES ON BASIC C(J), VARIABLE LOWER LIMIT, AND
CJK  VARIABLE UPPER LIMIT
CJK
CJK
       GO TO 70
    90 WRITE(KW,110)
       WRITE(KW,111)
       DO 95 I=1,M
       WRITE(KW,112) I,BLO(I),BUP(I)
CJK
CJK
CJK  WRITES OUT VARIABLE CODE AND UPPER AND LOWER LIMIT OF B(I)
CJK
CJK
    95 CONTINUE
   100 FORMAT(1H1,25X,'SENSITIVITY ANALYSIS',2(/),
      110X,'NOTE: VARIABLE CODE NUMBERS USED IN SENSITIVITY',/,
      210X,'ANALYSIS ARE NOT EASY TO CORRELATE WITH OUTPUT',/,
      310X,'COLUMNS AND ROWS FROM LP MATRIX',//,
      410X,'USERS FAMILAR WITH LP SHOULD MAKE CHANGES IN',/,
      510X,'INPUT COSTS (CJ) AND RESOURCE LIMITS (BJ) TO',/,
      610X,'BECOME FAMILAR WITH THE SENSITIVITY ANALYSIS AS IT',/,
      710X,'APPLIES TO THE CONVEX-ISOQUANT-METHOD FORMULATION',/,
      810X,'USED IN L-O-S-T',//)
   101 FORMAT(10X,'NON-BASIC',12X,'PENALTY')
   102 FORMAT(10X,'VARIABLES',13X,'COST',/)
   103 FORMAT(13X,I2,13X,F12.3)
   104 FORMAT(4(/),3X,'RANGES ON NON-BASIC C(J)',/)
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173000  105 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT',/)
173100  106 FORMAT(13X,I2,14X,F11.3)
173200  107 FORMAT(4(/),3X,'RANGES ON BASIC C(J)',/)
173300  108 FORMAT(10X,'VARIABLE',11X,'LOWER LIMIT',11X,'UPPER LIMIT',/)
173400  109 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
173500  110 FORMAT(4(/),3X,'RANGES ON B(I)',/)
173600  111 FORMAT(14X,'I',14X,'LOWER LIMIT',11X,'UPPER LIMIT',/)
173700  112 FORMAT(13X,I2,14X,F11.3,11X,F11.3)
173800  149 FORMAT(3(/),13X,'ROW',15X,'SHADOW',/,12X,'NUMBER',13X,
173900     1'PRICES',/)
174000 1000 FORMAT(1X,'SHADOW PRICES ARE CHANGE IN OBJECTIVE FUNCTION',
174100     11X,'VALUE PER UNIT CHANGE',/,6X,'IN RIGHT HAND SIDE',
174200     21X,'CONSTRAINTS.',2(/),1X,'PENALTY COSTS ARE CHANGE',
174300     31X,'IN OBJECTIVE FUNCTION VALUE PER UNIT',/,6X,
174400     4'INCREASE IN NON-BASIC VARIABLES.',2(/),1X,
174500     5'RANGES ON C(J) REPRESENT LIMITING VALUES OF COST',
174600     61X,'COEFFICIENTS THAT',/,6X,'WILL NOT CHANGE THE OPTIMUM',
174700     71X,'SOLUTION',2(//),2X,'RANGES ON B(I) REPRESENT LIMITING',
174800     81X,'VALUES OF RIGHT HAND SIDE CONSTRAINTS',/,6X,'THAT WILL',
174900     91X,'NOT CHANGE OPTIMUM BASIC VARIABLES.',2(/))
175000      RETURN
175100      END
175200      SUBROUTINE CHECK(K,NQUE,N,M)
175300      COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
175400     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
175500     2,B(25),CC(25),JVAR(25)
175600     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
175700 C
175800 C*****THIS ROUTINE CHECKS TO SEE IF THE INDEX OF X(L) MATCHES THE
175900 C     INDEX OF ANY OF THE OPTIMUM BASIC VARIABLES.  IF THERE
176000 C     IS A MATCH, NQUE IS SET TO 1, OTHERWISE A VALUE OF ZERO IS
176100 C     RETURNED.
176200 C
176300      L=JVAR(K)
176400      NQUE=0
176500      DO 10 I=1,M
176600      KV=IVAR(I)
176700      IF(L-KV) 10,20,10
176800   20 NQUE=1
176900   10 CONTINUE
177000      RETURN
177100      END
177200      SUBROUTINE CNONB(K,N,M)
177300 C
177400 C*****THIS ROUTINE DETERMINES THE LOWER LIMIT FOR NONBASIC C(J).
177500 C     THE METHOD USED IS TO FIND THE MINIMUM VALUE OF C(J) SUCH THAT
177600 C     CBAR(J) IN THE OPTIMUM TABLEAU REMAINS NEGATIVE, THUS MAINTAINING
177700 C     OPTIMALITY OF THE CURRENT SOLUTION.
177800 C
177900      COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
178000     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
178100     2,B(25),CC(25),JVAR(25)
178200     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
178300      J=1
178400      ZZ=0.
178500   10 KV=IVAR(J)
178600      ZZ=ZZ+CC(KV)*A(J,K)
178700      J=J+1
178800      IF(J.GT.M) GO TO 20
178900      GO TO 10
179000   20 CL(K)=ZZ
179100      CU(K)=999999.
179200 C
179300 C*****INCLUDED IN THIS ROUTINE IS THE IDENTIFYING OF THE PENALTY
179400 C     COST OF THE NONBASIC VARIABLES.  IT SHOULD BE
179500 C     NOTED THAT IF THE PENALTY COST OF ANY NONBASIC X(J) IS ZERO,
179600 C     THE PROBLEM HAS AN ALTERNATIVE OPTIMUM SOLUTION USING X(J).
179700 C
179800      PCOST(K)=OMZ(K)
179900      RETURN
180000      END
180100      SUBROUTINE CBAS(K,N,M)
180200 C
180300 C     THIS SUBROUTINE DETERMINES THE RANGE ON OPTIMAL BASIC C(J)
180400 C
180500      DIMENSION ZS(60)
180600      COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
180700     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
180800     2,B(25),CC(25),JVAR(25)
180900     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
181000 C
181100 C*****FIRST, A MAXIMUM LIMIT IS SET ON THE UPPER AND LOWER BOUND
181200 C     FOR C(J).  IF THE FINAL RESULT IN THE OUTPUT IS THIS
181300 C     MAXIMUM VALUE IT CAN BE ASSUMED THAT THE LIMIT DOES NOT EXIst.
181400 C
181500      CUP(K)=999999.
181600      CLO(K)=-999999.
181700 C
181800 C*****THE LIMITS ON BASIC C(J) ARE DETERMINED BY THE VALUES OF THE
181900 C     NONBASIC C(J)'S.  EACH NONBASIC C(J) IS TREATED SEPARATELY, AND
182000 C     A LIMIT ON C(J) IS DETERMINED BY FINDING THE MAX OR MIN VALUE
182100 C     C(J) MAY HAVE IN ORDER TO MAINTAIN THAT CBAR(J) NEGATIVE.
182200 C
182300      J=0
182400   10 J=J+1
182500      IF(J.GT.N) GO TO 75
182600 C
182700 C*****ZS(J) IS THE VALUE OF THE SUM OF THE INNER PRODUCTS OF CB AND
182800 C     ABAR, EXCLUDING THE TERM INVOLVING THE BASIC C(J).
182900 C
183000      ZS(J)=0.
183100      I=0
183200   15 I=I+1
183300      IF(I.GT.M) GO TO 20
183400      IF(JVAR(J).EQ.IVAR(I)) GO TO 10
183500      GO TO 15
183600   20 L=0
183700   22 L=L+1
183800   25 IF(L.GT.M) GO TO 30
183900      LV=IVAR(L)
184000      IF(LV.EQ.JVAR(K)) GO TO 35
184100      ZS(J)=ZS(J)+CC(LV)*A(L,J)
184200      GO TO 22
184300   35 NI=L
184400      GO TO 22
184500 C
184600 C*****IF A(NI,J) IS SMALL, IT IS IGNORED BECAUSE IT APPEARS IN THE
184700 C     DENOMINATOR.  OTHERWISE, IF IT IS POSITIVE, A LOWER LIMIT IS
184800 C     FOUND, AND IF IT IS NEGATIVE, AN UPPER LIMIT IS FOUND.  THESE
184900 C     VALUES ARE THEN COMPARED TO THE PRESENT LIMITS.  IF THEY ARE MORE
185000 C     RESTRICTIVE THAN THE PRESENT LIMITS, THE PRESENT LIMITS ARE
185100 C     REVISED.
185200 C
185300   30 IF(ABS(A(NI,J)).LT.1.E-08) GO TO 10
185400      IF(A(NI,J)) 40,10,50
185500   40 TCU= (C(J)-ZS(J))/A(NI,J)
185600      IF(TCU.LT.CUP(K)) CUP(K)=TCU
185700      GO TO 10
185800   50 TCL= (C(J)-ZS(J))/A(NI,J)
185900      IF(TCL.GT.CLO(K)) CLO(K)=TCL
186000      GO TO 10
186100   75 CONTINUE
186200      RETURN
186300      END
186400      SUBROUTINE BRANG(N,M)
186500 C
186600 C*****THIS ROUTINE DETERMINES THE RANGES ON ALL B(I).
186700 C
186800      DIMENSION PPRIME(40)
186900      COMMON C(25),P(25),OMZ(25),A(25,25),ZJ(25),IVAR(25),PCOST(25)
187000     1,SHADO(25),CL(25),CU(25),CUP(25),CLO(25),BUP(25),BLO(25)
187100     2,B(25),CC(25),JVAR(25)
187200     3,IARR(4),PROP(4),RC(4),LD(4),SK(4),TK(4)
187300      K=0
187400   30 K=K+1
187500      IF(K.GT.M)GO TO 35
187600 C
187700 C*****INITIAL UPPER AND LOWER BOUNDS ON B(K) ARE SET.
187800 C
187900      BUP(K)=999999.
188000      BLO(K)=-999999.
188100      I=0
188200   20 I=I+1
188300      IF(I.GT.M) GO TO 30
188400 C
188500 C*****PPRIME IS THE VALUE OF THE SUM OF THE INNER PRODUCT B-INVERSE
188600 C     TIMES B(I), EXCLUDING THE TERM INVOLVING THE B(K) WE ARE FINDING
188700 C     LIMITS FOR.
188800 C
188900      PPRIME(I)=0.
189000      J=0
189100   10 J=J+1
189200      IF(J.GT.M) GO TO 25
189300      IF(J.EQ.K)GO TO 15
189400      PPRIME(I)=PPRIME(I)+A(I,J)*B(J)
189500      GO TO 10
189600   15 NI=J
189700      GO TO 10
189800 C
189900 C*****IF A(I,NI) IS SMALL, IT IS IGNORED.  PRESENT LIMITS ARE THEN
190000 C     REVISED IF IMPROVEMENTS ARE POSSIBLR.
190100 C
190200   25 IF(ABS(A(I,NI)).LT.1.E-8) GO TO 20
190300      IF(A(I,NI)) 26,20,27
190400   26 TBU=-PPRIME(I)/A(I,NI)
190500      IF(TBU.LT.BUP(K)) BUP(K)=TBU
190600      GO TO 20
190700   27 TBL=-PPRIME(I)/A(I,NI)
190800      IF(TBL.GT.BLO(K)) BLO(K)=TBL
190900      GO TO 20
191000   35 RETURN
191100      END
191200 /GO
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data cards go here

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L-O-S-T is a FORTRAN computer program developed to systematically quantify, analyze, and improve user selected harvesting methods. Harvesting times and costs are computed for road construction, landing construction, system move between landings, skidding, and trucking. A linear programming formulation utilizing the relationships among marginal analysis, isoquants, and the harvesting methods is used to estimate and select the harvesting procedure having maximum profits.

Additional keywords: optimization, harvesting, computer program, roadbuilding, skidders, hauling.

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