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Determining Average Yarding Distance

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Average

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ABSTRACT

Emphasis on environmental and esthetic quality in timber harvesting has brought about increased use of complex boundaries of cutting units and a consequent need for a rapid and accurate method of determining the average yarding distance and area of these units. These values, needed for evaluation of road and landing locations in planning timber harvests, are easily and accurately determined by a desk-top computer and digitizer system programed in BASIC language. This paper presents two programs designed for that purpose.

KEYWORDS: Logging operations analysis/design, computer programs/programing, computers (desk-top).

METRIC EQUIVALENTS

1 foot = 0.3048 meter

1 acre = 0.4047 hectare

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Introduction

Judicious planning is essential for arriving at the best means of meeting environmental and visual standards. Because of these standards, timber harvest unit boundaries have become more complex and often utilize streamside and visual buffer (leave) zones, multiple landings, and irregular shapes. These characteristics make it difficult to calculate one of the key elements affecting cost of harvesting--the average yarding distance (AYD). Calculating this variable by standard manual methods, such as combining regular geometric shapes with known AYD values or analyzing irregular shapes by numerical integration, usually becomes too laborious a procedure for practical use. Programable desk-top calculator-digitizer systems, however, provide a means for rapid and accurate determination of AYD values.

This report presents two desk-top calculator programs for obtaining unit area and average yarding distance. The first is formulated to determine the AYD for irregular harvest units under the classic assumption that logs are yarded from their location in a straight line to the landing. The desk-top calculator approach to this problem was initially described by Peters and Burke (1972). We update their document by providing a program written in the American Standard Code for Information Interchange (ASCII) BASIC language, which is common to many present-day computer systems. The second program determines AYD under the condition that logs are moved laterally to a yarding corridor and then longitudinally up the straight corridor to a landing, as with skyline systems.

Applications

Procedures were developed for determining the area and average and maximum yarding distances of timber harvest units. This information is needed for determining yarding system feasibility and cost. Good planning requires that yarding cost be combined with construction costs of access roads and landings so that the logging plan that best meets overall economic and environmental objectives can be determined.

PROGRAM 1 (AYD: NONSLACKPULLING SYSTEMS)

Program 1 applies to irregular-shaped units where the logs are yarded from their location straight to a landing. Examples of this would be cable systems not utilizing slackpulling capability (i.e., not moving logs laterally prior to moving them longitudinally to the landing), such as any high-lead system, and grapple or shotgun skyline systems operating in clearcuts.

PROGRAM 2 (AYD: SLACKPULLING SYSTEMS)

Program 2 applies to units where skyline systems with slackpulling (i.e., lateral yarding) capability operate in either parallel or fan-shaped settings. These systems would generally be required for skyline yarding of harvest cuts where residual timber is to be protected. The more versatile slackpulling systems are also used in clearcuts and, indeed, may be required if tailholds are widely spaced or if economic analysis shows that increasing the lateral yarding distance is less costly than making more frequent rigging changes. Program 2 can accommodate one or two leave strips (unharvested areas) between the unit's rear boundary and the landing.

Program 2 could also be used for a more detailed breakdown of ground skidding where lateral yarding to the skid road is done by pulling out the winch line. The program could be manipulated to stage process all the approximately straight skid road tangents in progression to the landing. Some hand calculations would be required, but most of the lengthy numerical processing would be performed within the program. This high a degree of analysis, however, is seldom practical or justified for ground skidding, and use of program 1 would generally be faster.

Problem Formulation

Matthews (1942) calculated AYD by the method of equal areas. Although this method had been used for many years, Lysons and Mann (1965) showed that it gave incorrect results for circular cutting units or segments thereof. Their analysis showed that AYD is given by:

$$\text{AYD} = \frac{\int y\,dA}{\int dA} = \frac{\text{First moment of area}}{\text{Area}} \qquad (1)$$

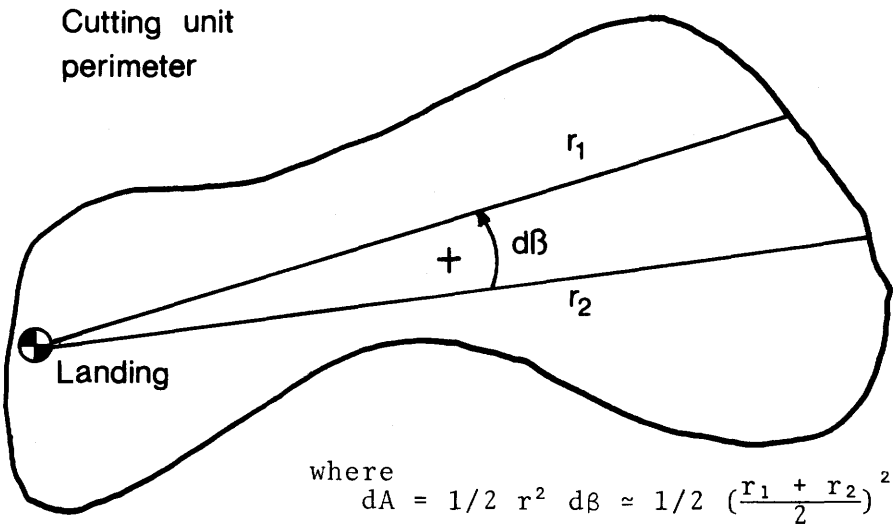
Suddarth and Herrick (1964) also derived equation 1 and developed algebraic formulas to solve AYD for the special cases of right triangles, rectangles, and circular arcs. They also derived the equation for AYD of a composite area of simple shapes, for which the respective AYD's are known. Suddarth and Herrick recommended numerical integration for complex areas.

Formulation of BASIC language programs for desk-top calculators, using the appropriate combination of these methods, provides a fast and accurate means of solving the maximum and average yarding distances and the area of a harvest unit of any shape with the landing at any location.

PROGRAM 1 (AYD: NONSLACKPULLING SYSTEMS)

Two assumptions relate to program 1: The timber is uniformly distributed over the harvest unit, and the yarding distance of each turn is equal to the shortest distance from the pickup point to the landing. These assumptions present obvious limitations when the logs are yarded over indirect routes or when there is great imbalance in timber density. For a discussion of assumptions, see Suddarth and Herrick (1964).

The programed algorithm, based on equation 1, sums the areas and moments of areas of the aggregate number of small circular arcs constituting a cutting unit:



where

$$dA = 1/2\ r^2\ d\beta \simeq 1/2\ \left(\frac{r_1 + r_2}{2}\right)^2\ d\beta;$$

$$dM = (2/3\ r)\ dA = 1/3\ r^3\ d\beta \simeq 1/3\ \left(\frac{r_1 + r_2}{2}\right)^3\ d\beta;$$

$$M = \Sigma_A\ dM;$$

$$A = \Sigma_A\ dA;$$

and

$$AYD = \frac{M}{A}.$$

PROGRAM 2 (AYD: SLACKPULLING SYSTEMS)

Operational features and assumptions relating to program 2 can be more easily understood after figure 1 is studied. They are: (1) the timber is uniformly distributed over the harvest unit; (2) a line (which passes through the midpoint between adjacent landings and the midpoint between the ends of adjacent skyline corridors) divides the yarding area tributary to each skyline corridor; (3) the front and rear boundaries of any area tributary to a skyline corridor consist of lines perpendicular to the corridor which intersect the dividing lines; (4) the unbounded exterior sides of the first and the last skyline corridor are symmetrical to the bounded interior sides of these corridors; and (5) the timber is laterally yarded in a route perpendicular to the skyline corridor and longitudinally yarded along the corridor to the landing.

Figure 1 also illustrates how the boundary of an actual cutting unit may vary from the programed assumptions. The net error caused by this variation would normally be small because calculated excesses on one side of the corridor tend to cancel deficits on the opposite side. A larger error is possible if the user is careless in laying out the first or the last corridor. If these corridors are positioned one third of the distance between the lateral unit boundary and the first interior corridor, this error is minimized. Good layout would tend toward this positioning anyway, as it balances the required lateral yarding.

The dividing line feature of this program implies that logs are to be laterally yarded to the nearest corridor. In portions of some units, however, this is not the practice. Where steep slopes perpen-

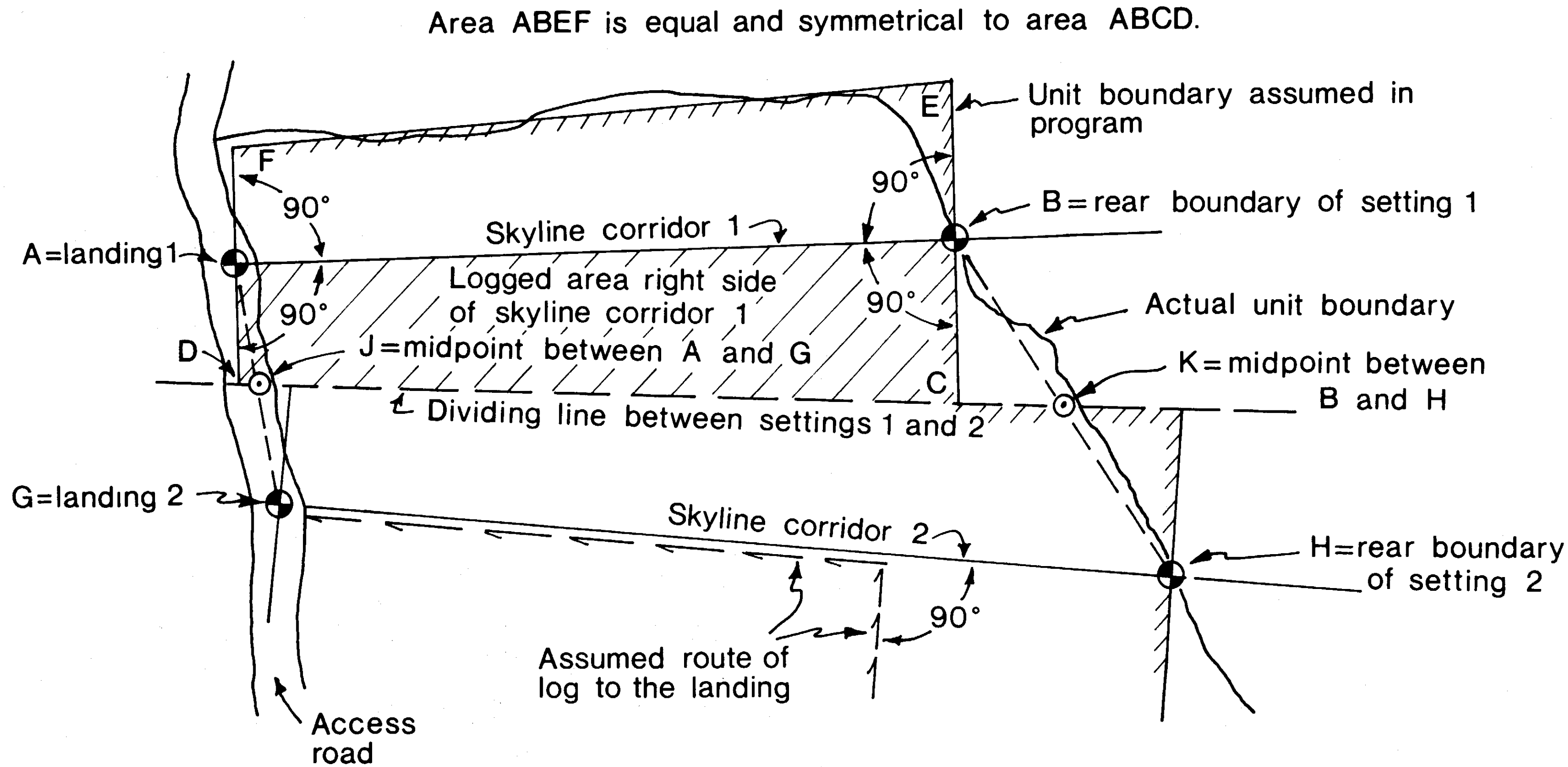


Figure 1.--Geometric assumptions of program 2.

dicular to the skyline exist, the lateral yarding may extend only in the downhill direction and all the way to the next corridor. Calculating a more accurate lateral yarding distance in these situations can be managed by analyzing the portions of the unit where transverse slopes prevail on a separate basis and *doubling* the lateral yarding distance output from the program. Some additional hand calculations are needed to arrive at the correct weighted averages for the setting and unit summaries.

The method described in this paper uses the algorithm depicted by figure 2.

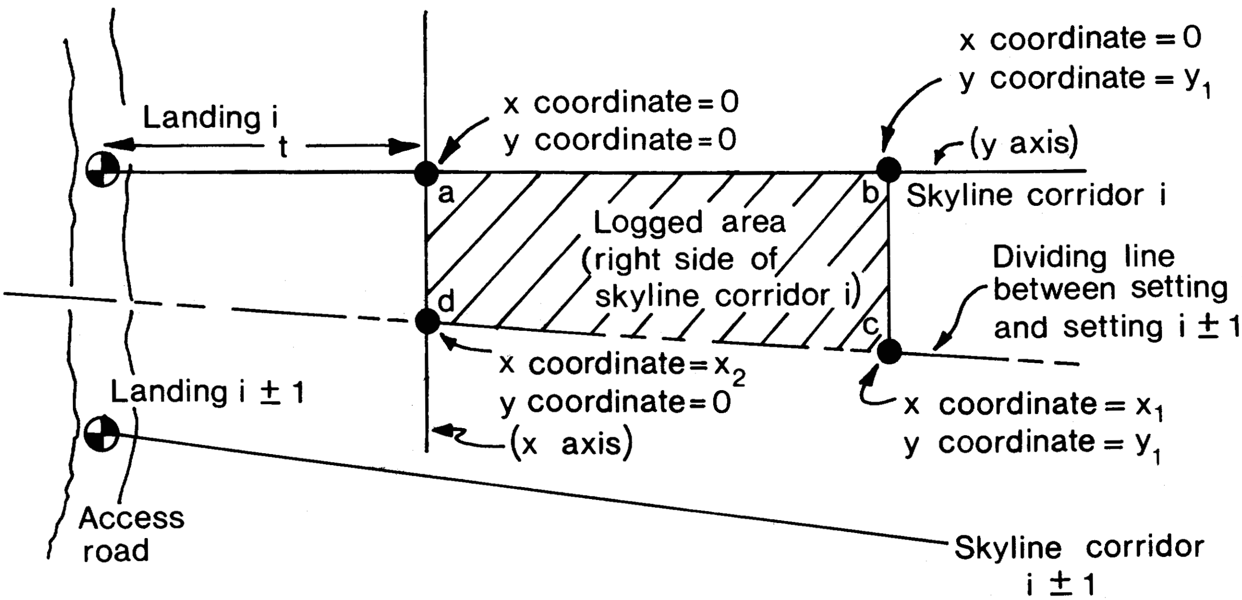


Figure 2.--Geometric basis of program 2.

For polygon abcd, lateral AYD is solved as follows:

$$A = y_1 \frac{(x_1 + x_2)}{2};$$

$$M_{lat} = y_1/6 \ (x_1^2 + x_1x_2 + x_2^2);$$

and

$$AYD_{lat} = \frac{\Sigma M_{lat}}{\Sigma A} .$$

Longitudinal AYD is solved as follows:

$$M_{long} = y_1^2/6 \ (2x_1 + x_2) + At;$$

and

$$AYD_{long} = \frac{\Sigma M_{long}}{\Sigma A} .$$

User's Guide

Detailed operating instructions and the program listings are given for computer systems programable in the ASCII BASIC language. They were developed on a Hewlett-Packard 9830A desk-top calculator/plotter/digitizer system but can be executed on equivalent hardware.[1]

The minimum Hewlett-Packard calculator system configurations needed to run these programs are:

1. Model 9830A calculator with 7,904 words of read/write memory.

2. Additional read-only memories; extended input/output and string variables.

3. Digitizer (9864A).

4. Thermal page printer (9866A).

OPERATING PROCEDURE FOR PROGRAM 1

The following procedures presume a knowledge of the Hewlett-Packard Model 9830A system procedures. Only supplemental instructions pertaining to this program will be detailed.

This program can be put on a magnetic tape cassette and executed as follows:

1. Press LOAD, 1, EXECUTE.

   This loads the program.

2. Secure unit·map to digitizer surface.

   Map must contain the needed input data:

   --*proposed cutting unit(s) outlined;*
   --*landing location(s) marked.*

3. Press RUN, EXECUTE.

   --*At this point the program assists the user by requesting input through visual prompters in the display.*
   --*Continue through entries in table 1 which relate the keyboard and digitizer inputs to the visual prompters on the computer display.*

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[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader and does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

Table 1--Input explanation for average yarding distance, program 1

Visual prompter on display	Sample keyboard response	Explanation
NEED INSTRUCTIONS (YES/NO)	YES	Prints operating instructions in response to "YES" input (fig. 3).
MAP SCALE (FEET/INCH)	400	Enters scale of map being used.
NUMBER OF SETTINGS	3	Enters the number of settings required to yard the unit.
AVERAGE PERCENT SLOPE	45	Enters the average ground slope of the setting; if the unit is to be yarded with skylines, enters the average skyline chord slope.
SETTING DESIGNATION	1	1. Sequentially enters the unit that will be digitized next. 2. When the last setting has been digitized, prints the final output.
DIGITIZE SETTING		DIGITIZER RESPONSE 1. Follow instructions printed and shown in figure 3. 2. See figure 4 for additional information on digitizing technique for complicated units.

```
AVERAGE YARDING DISTANCE (AYD) FOR IRREGULAR-SHAPED HARVEST SETTINGS

OPERATING INSTRUCTIONS:
  (1) MAKE INPUTS AS REQUIRED BY SUBSEQUENT DISPLAY STATEMENTS
  (2) ESTABLISH AN ORIGIN (PRESS 0 ON DIGITIZER CURSOR)
  (3) DIGITIZE SETTING:
     A) MOVE CURSOR TO LANDING
     B) PRESS C
     C) TRACE BOUNDARY OF SETTING IN COUNTERCLOCKWISE DIRECTION
     D) AUDIBLE SIGNAL INDICATES TRAVERSE IS CLOSED
     E) PRESS C AFTER CLOSURE
  (4) INPUT NEW SLOPE AND SETTING NO.; REPEAT (3) FOR ALL SETTINGS
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Figure 3.--Operating instructions for AYD Program 1.

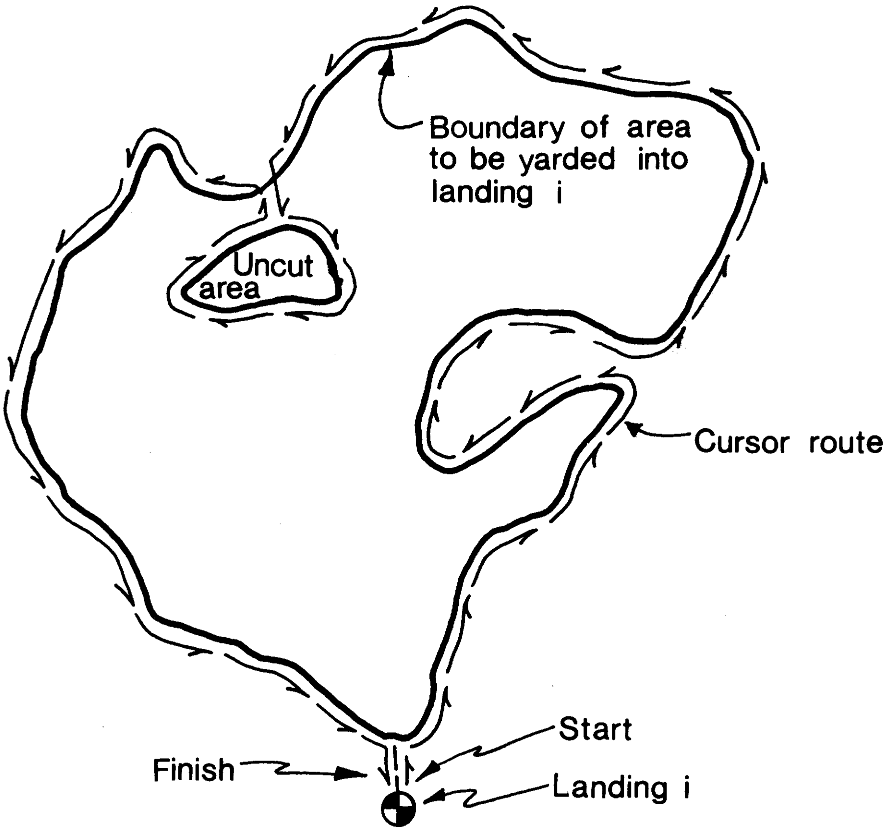


Figure 4.--Sample of acceptable cursor route for digitizing complex settings.

EXAMPLE DATA FOR PROGRAM 1

Figures 5 and 7 illustrate timber harvest units which have been digitized with the corresponding printed output from the programed calculator shown by figures 6 and 8. The average time to set up, digitize, and analyze each unit is about 1 minute.

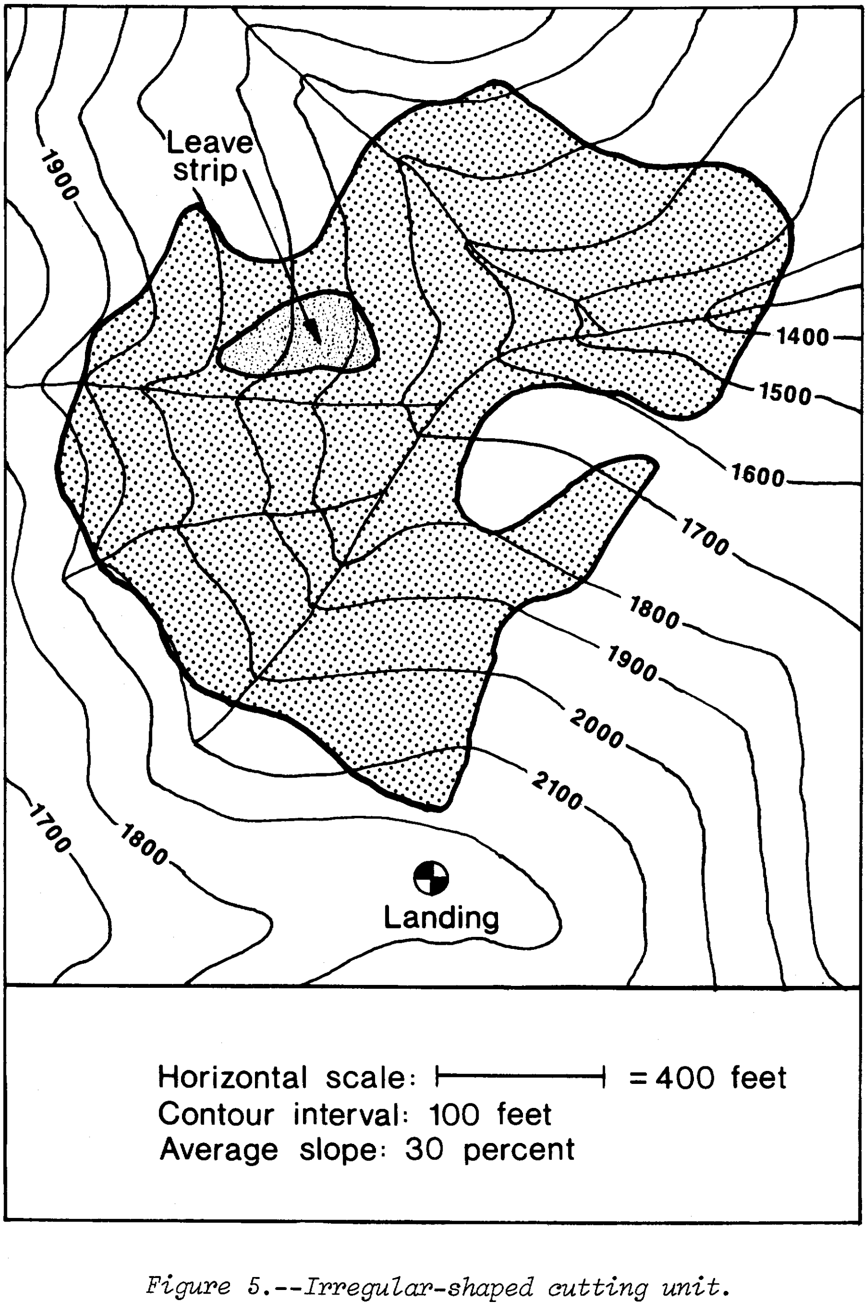


Figure 5.--Irregular-shaped cutting unit.

MAP SCALE: 1 INCH = 400 FEET

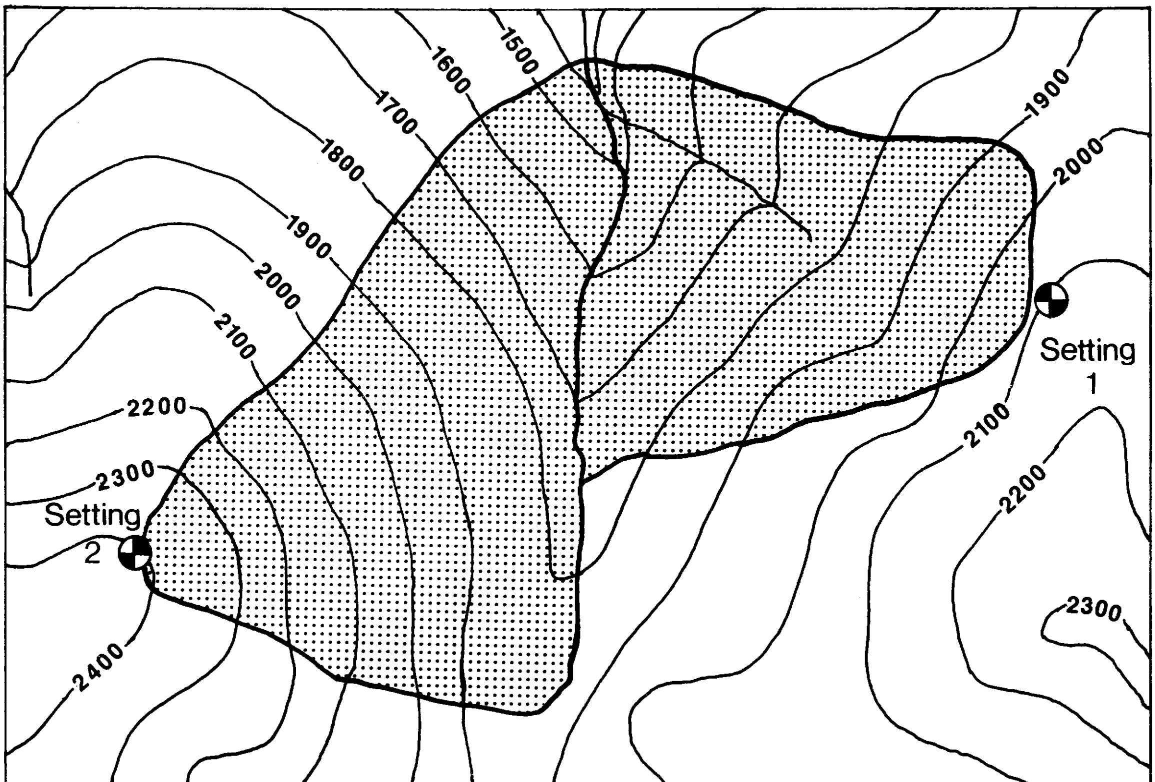
SETTING	AVERAGE SLOPE (%)	AREA (ACRES)	MAXIMUM HORIZONTAL DISTANCE (FT)	AYD (FT)	SLOPE AYD (FT)
1	30	34.11	1841	1133	1183

TOTAL FOR 1 SETTINGS

AREA= 34.11 ACRES
AYD= 1133 FEET (NO SLOPE CORRECTION)
AYD= 1183 FEET (WITH SLOPE CORRECTION)

Figure 6.--Printed output from example (fig. 5).

Figure 7.--Large unit yarded from two settings.



Horizontal scale: ├────┤ = 400 feet
Contour interval: 100 feet
Average slope = 50 percent

MAP SCALE: 1 INCH = 400 FEET

SETTING	AVERAGE SLOPE (%)	AREA (ACRES)	MAXIMUM HORIZONTAL DISTANCE (FT)	AYD (FT)	SLOPE AYD (FT)
1	50	16.44	1213	669	748
2	50	21.99	1544	794	888

TOTAL FOR 2 SETTINGS

AREA= 38.43 ACRES
AYD= 741 FEET (NO SLOPE CORRECTION)
AYD= 828 FEET (WITH SLOPE CORRECTION)

Figure 8.--Printed output from example (fig. 7).

OPERATING PROCEDURE FOR PROGRAM 2

This program can be stored on the magnetic tape cassette containing program 1 and executed as follows:

1. Press LOAD, 2, EXECUTE.

   This loads the program.

2. Secure unit map to digitizer surface.

   Map must contain the needed input data:

   --proposed cutting unit outlined;
   --landing location(s) marked;
   --rear boundary of the skyline corridors marked.

3. Press RUN, EXECUTE.

   --The program's title and the definition of unit types are printed (fig. 9).
   --Next, the program assists the user by requesting input through visual prompters in the display.
   --Continue through entries in table 2 which relate the keyboard and digitizer inputs to the visual prompters on the computer display.

EXAMPLE DATA FOR PROGRAM 2

Figures 10 and 12 illustrate timber harvest units which have been digitized with the corresponding printed output from the programed calculator shown by figures 11 and 13. The average time to set up, digitize, and analyze each unit is about 4 minutes.

AVERAGE YARDING DISTANCE (AYD) FOR LATERAL AND LONGITUDINAL YARDING

UNIT TYPES:

1--NO LEAVE STRIP OR DEAD GROUND
2--WITH DEAD GROUND
3--WITH LEAVE STRIP
4--WITH DEAD GROUND AND LEAVE STRIP

```
+-------------------#X#-------------------+
 L///////////////////!///////////////////S
  A////////////YARDING UNIT/////////////T
   T/////////////////!/////////////////I
    E---------------#X#---------------M
     R               !               I
      A         LEAVE STRIP         L
       L             !             .
        +-----------#X#-----------L
         L///////////!///////////A
          I////YARDING UNIT/////R
           M/////////!/////////E
            I-------#X#-------T
             T       !       A
              S DEAD GROUND L
               .     !     .
                .    !    .
                 +--#X#--+
                  LANDING
```

'LEAVE STRIP'=UNLOGGED AREA WITHIN UNIT
'DEAD GROUND'=UNLOGGED AREA BETWEEN LANDING AND UNIT

OPERATING INSTRUCTIONS*

1. INPUT DATA AS REQUIRED BY DISPLAY.
2. ESTABLISH AN ORIGIN (O ON CURSOR).
3. DIGITIZE EACH SETTING (PRESS S AT EACH #X# LOCATION) IN THE FOLLOWING SEQUENCE:
   - #X# LANDING;
   - #X# DEAD GROUND BOUNDARY (IF ANY);
   - #X# NEAR BOUNDARY OF LEAVE STRIP (IF ANY);
   - #X# FAR BOUNDARY OF LEAVE STRIP (IF ANY);
   - #X# REAR BOUNDARY OF YARDING UNIT.
     DIGITIZE THIS LAST POINT TWICE UNLESS SETTING CONTAINS BOTH DEAD GROUND AND A LEAVE STRIP; IN THAT CASE DIGITIZE THIS POINT JUST ONCE.
4. DON'T DIGITIZE TOO FAST. WAIT FOR THE AUDIBLE 'BEEP' AND DISPLAY BEFORE DIGITIZING SUBSEQUENT POINTS.
5. TO SIGNAL FOR UNIT SUMMATION OF A GROUP OF ADJACENT SETTINGS ENTER A 1% CHORD SLOPE FOR THE SETTING FOLLOWING THE FINAL SETTING.
6. UNIT SUMMATION MUST BE PERFORMED WHENEVER THE AREA BETWEEN SETTINGS IS NOT TO BE YARDED.
7. THE SETTINGS MUST BE DIGITIZED IN A SEQUENTIAL ORDER, BEGINNING AT THE LEFT (OR RIGHT) BOUNDARY AND PROCEEDING TO THE OPPOSITE BOUNDARY.

Figure 9.--Operating instructions for AYD program 2.

Table 2--Input explanation for average yarding distance, program 2

Visual prompter on display	Sample keyboard response	Explanation
NEED INSTRUCTIONS (YES/NO)	YES	Prints operating instructions in response to "YES" input (fig. 9).
MAP SCALE (FEET/INCH)	400	Enters scale of map being used.
SKYLINE CHORD SLOPE %; SETTING *i*	30	1. Uses this value to calculate the relationship between horizontal and actual yarding distance.
	1	2. After the last setting in the unit is digitized, enter a value of 1 to signal for printed unit summary.
DIGITIZE LANDING *i*		DIGITIZER RESPONSE (fig. 9).
NEXT POINT, SETTING *i*		DIGITIZER RESPONSE (fig. 9).

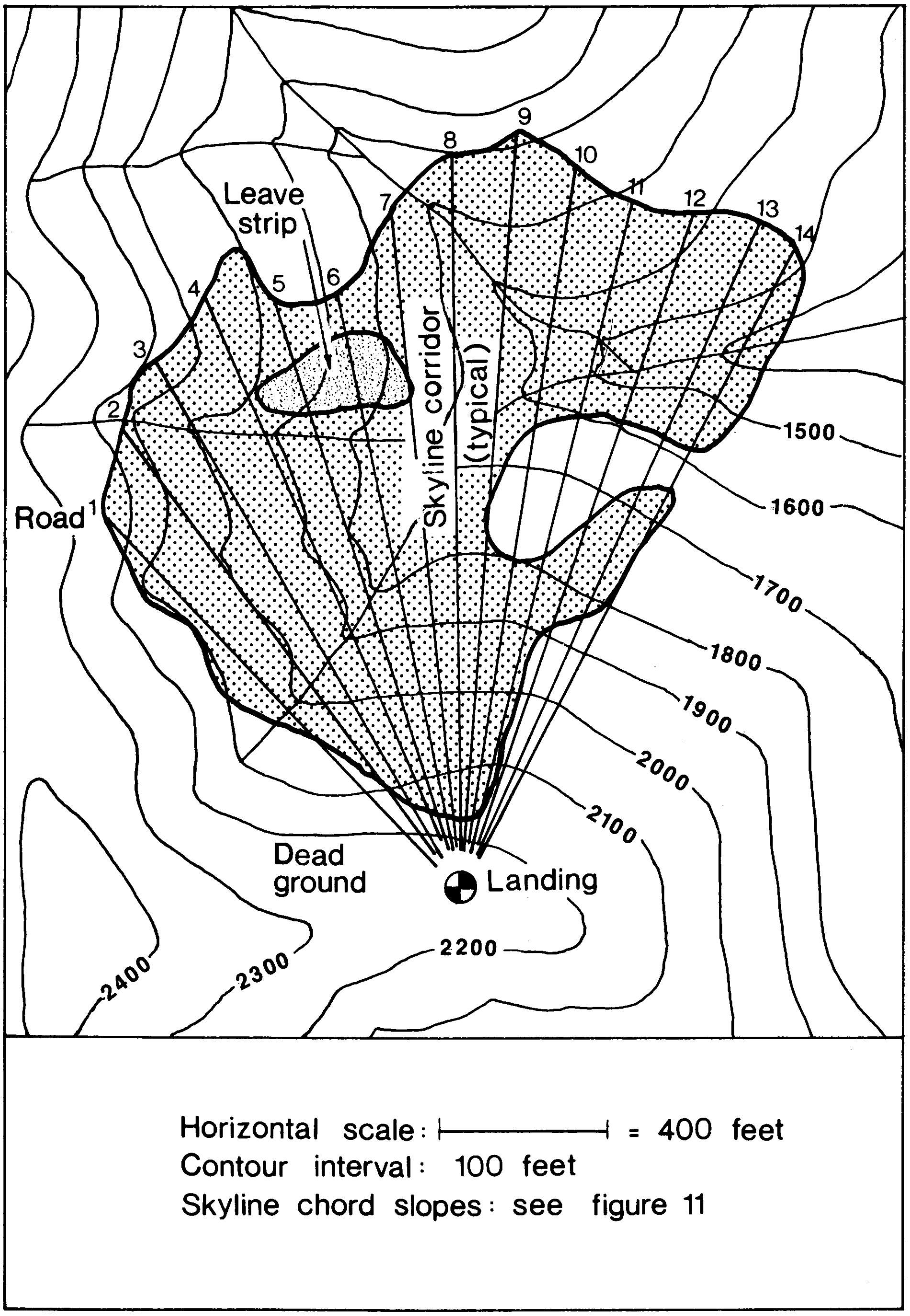


Figure 10.--Irregular unit yarded in fan-shaped pattern.

AVERAGE YARDING DISTANCE (AYD) FOR LATERAL AND LONGITUDINAL YARDING

UNIT TYPES:
1--NO LEAVE STRIP OR DEAD GROUND
2--WITH DEAD GROUND
3--WITH LEAVE STRIP
4--WITH DEAD GROUND AND LEAVE STRIP

MAP SCALE: 1 INCH= 400 FEET

SETTING OR ROAD NO.	TYPE	AVERAGE SLOPE (%)	AREA (ACRES)	LAT. AYD (FT)	LONG. SLOPE AYD (FT)	COMB. AYD (FT)	MAX. LONG. SLOPE DIST. (FT)	MAX. LAT. DIST. (FT)
1	2	4	1.99	31	922	953	1242	83
2	2	13	2.43	28	962	990	1386	83
3	2	9	2.79	29	1006	1034	1483	89
4	2	16	2.91	28	1066	1094	1577	89
5	4	32	2.26	25	1026	1051	1587	79
6	4	30	2.06	24	959	983	1538	79
7	2	34	2.96	26	1177	1203	1752	79
8	2	29	3.19	26	1233	1259	1848	79
9	2	26	3.25	26	1264	1290	1891	78
10	4	32	2.49	27	1302	1329	1865	78
11	4	36	2.29	26	1270	1296	1829	75
12	4	40	2.03	30	1438	1468	1861	78
13	4	43	2.00	26	1463	1489	1933	78
14	4	46	1.44	21	1515	1537	1915	53

TOTAL FOR 14 SETTINGS

AREA= 34.10 ACRES
LATERAL AYD= 27 FEET
LONGITUDINAL AYD= 1125 FEET (NO SLOPE CORRECTION)
LONGITUDINAL AYD= 1176 FEET (WITH SLOPE CORRECTION
TOTAL AYD= 1202 FEET (WITH SLOPE CORRECTION)
SLOPE CORRECTION = 50 FEET
(AYD'S ARE AREA WEIGHTED MEANS)

Figure 11.-- Printed output from example (fig. 10).

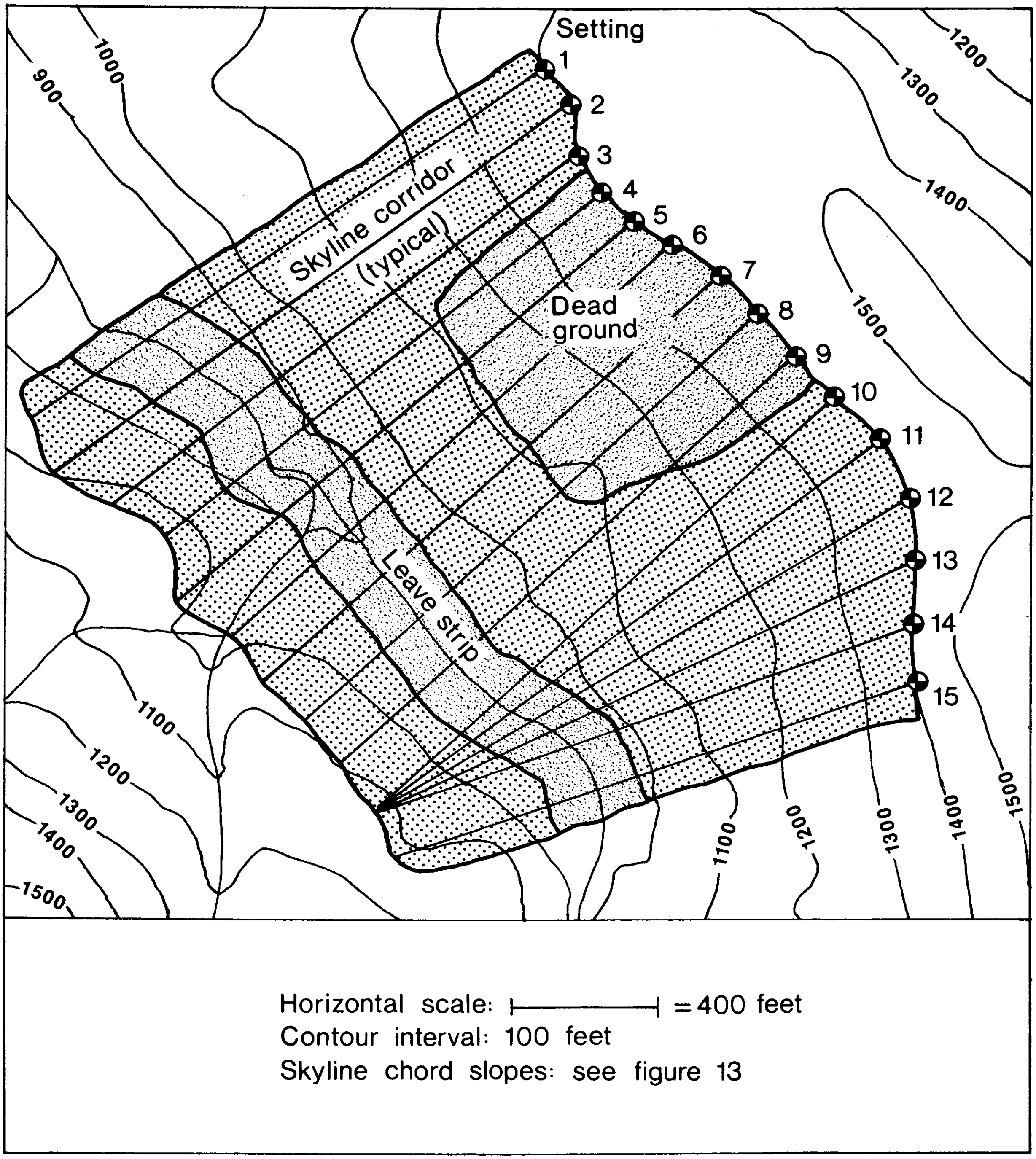


Figure 12.--Unit yarded with a combination of parallel and fan-shaped settings

AVERAGE YARDING DISTANCE (AYD) FOR LATERAL AND LONGITUDINAL YARDING

UNIT TYPES:
1--NO LEAVE STRIP OR DEAD GROUND
2--WITH DEAD GROUND
3--WITH LEAVE STRIP
4--WITH DEAD GROUND AND LEAVE STRIP

MAP SCALE; 1 INCH= 400 FEET

SETTING OR ROAD NO.	TYPE	AVERAGE SLOPE (%)	AREA (ACRES)	LAT. AYD (FT)	LONG. SLOPE AYD (FT)	COMB. AYD (FT)	MAX. LONG. SLOPE DIST. (FT)	MAX. LAT. DIST. (FT)
1	3	30	4.19	33	821	854	1778	78
2	3	26	4.68	35	867	902	1803	84
3	3	27	4.32	35	799	835	1662	84
4	4	29	2.27	36	1046	1081	1578	79
5	4	27	2.67	37	1176	1213	1694	85
6	4	29	2.43	38	1176	1215	1687	85
7	4	24	2.47	38	1212	1250	1729	77
8	4	22	2.39	38	1211	1249	1717	77
9	4	21	3.35	39	1058	1097	1720	79
10	3	20	4.15	36	692	728	1735	85
11	3	19	3.16	30	534	564	1760	88
12	3	20	2.98	30	514	544	1735	89
13	3	20	2.70	29	486	515	1674	82
14	3	21	3.46	35	628	663	1601	83
15	3	22	4.30	37	721	759	1546	78

TOTAL FOR 15 SETTINGS

AREA= 49.54 ACRES
LATERAL AYD= 35 FEET
LONGITUDINAL AYD= 812 FEET (NO SLOPE CORRECTION)
LONGITUDINAL AYD= 837 FEET (WITH SLOPE CORRECTION
TOTAL AYD= 872 FEET (WITH SLOPE CORRECTION)
SLOPE CORRECTION = 24 FEET
(AYD'S ARE AREA WEIGHTED MEANS)

Figure 13.--Printed output from example (fig. 12).

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Appendix

Program Listings

PROGRAM 1

```
10 REM****PIAYD-AYD OF IRREGULAR UNITS WITH LARGE CENTRAL LANDING
20 DIM A$[100],F$[10]
30 PRINT "AVERAGE YARDING DISTANCE (AYD) FOR IRREGULAR-SHAPED HARVEST SETTINGS"
40 PRINT
50 PRINT
60 DISP "NEED INSTRUCTIONS (YES/NO)";
70 INPUT F$
80 IF F$="NO" THEN 200
90 PRINT "OPERATING INSTRUCTIONS:"
100 PRINT "  (1) MAKE INPUTS AS REQUIRED BY SUBSEQUENT DISPLAY STATEMENTS"
110 PRINT "  (2) ESTABLISH AN ORIGIN (PRESS O ON DIGITIZER CURSOR)"
120 PRINT "  (3) DIGITIZE SETTING:"
130 PRINT "      A) MOVE CURSOR TO LANDING"
140 PRINT "      B) PRESS C"
150 PRINT "      C) TRACE BOUNDARY OF SETTING IN COUNTERCLOCKWISE DIRECTION"
160 PRINT "      D) AUDIBLE SIGNAL INDICATES TRAVERSE IS CLOSED"
170 PRINT "      E) PRESS C AFTER CLOSURE"
180 PRINT "  (4) INPUT NEW SLOPE AND SETTING NO.; REPEAT (3) FOR ALL SETTINGS"
190 PRINT
200 A1=M1=D1=A6=P=M4=D4=0
210 DISP "MAP SCALE (FEET/INCH)";
220 INPUT S
230 PRINT "MAP SCALE: 1 INCH = "S"FEET"
240 DISP "NUMBER OF SETTINGS";
250 INPUT N
260 PRINT
270 PRINT
280 PRINT "   SETTING    AVERAGE        AREA       MAXIMUM        AYD         ";
290 PRINT "SLOPE"
300 PRINT "               SLOPE      (ACRES)    HORIZONTAL      (FT)   ";
310 PRINT "      AYD"
320 PRINT TAB16"(%)"TAB38"DISTANCE"TAB63" (FT)"
330 PRINT TAB39" (FT)"
340 FOR J=1 TO 5
350 PRINT "     ----     ";
360 NEXT J
370 PRINT "    ----     "
380 DISP "AVERAGE PERCENT SLOPE";
390 INPUT S2
400 DISP "SETTING DESIGNATION";
410 INPUT A$
420 S1=S2/100
430 C=R9=A3=M3=0
440 DISP "DIGITIZE SETTING";
450 WAIT 2000
460 WRITE (9,*)
470 REM*****DIGITIZE BOUNDARY COORDINATES
480 ENTER (9,*)X,Y
490 ENTER (9,*)X1,Y1
500 ENTER (9,*)X2,Y2
```

```
510 R2=SQR((X2-X)↑2+(Y2-Y)↑2)
520 REM*****TEST:HAS CURSOR LEFT LANDING ?
530 IF R2<0.05 THEN 550
540 C=1
550 R1=SQR((X1-X)↑2+(Y1-Y)↑2)
560 REM*****TEST:MAX HORIZONTAL DISTANCE
570 IF R2<R9 THEN 590
580 R9=R2
590 A2=(X1-X)*(Y2-Y)/2-(Y1-Y)*(X2-X)/2
600 A3=A3+A2
610 M2=(R1+R2)/3*A2
620 M3=M3+M2
630 X1=X2
640 Y1=Y2
650 REM*****TEST:HAS CURSOR LEFT LANDING ?
660 IF C#1 THEN 500
670 REM*****TEST CLOSURE
680 IF R2>0.05 THEN 500
690 R=R9*S
700 A=A3*S↑2
710 M=M3*S↑3
720 D=M/A
730 A5=A/43560
740 D5=D*SQR(1+S1↑2)
750 REM*****SIGNAL CLOSURE
760 FOR I=1 TO 3
770 WRITE (9,*)
780 WAIT 300
790 NEXT I
800 A1=A1+A
810 M1=M1+M
820 M4=M4+(D5*A5)
830 A6=A6+A5
840 PRINT TAB5,A$;
850 PRINT TAB12;
860 FORMAT F7.0,4X,F9.2,3X,F8.0,4X,F8.0,3X,F8.0
870 WRITE (15,860)S2,A5,R,D,D5
880 P=P+1
890 IF P=N THEN 910
900 GO TO 380
910 D1=M1/A1
920 D4=M4/A6
930 PRINT
940 PRINT "TOTAL FOR "N" SETTINGS"
950 FIXED 2
960 PRINT
970 PRINT TAB20"AREA="A6"ACRES"
980 FIXED 0
990 PRINT TAB20"AYD="D1"FEET (NO SLOPE CORRECTION)"
1000 PRINT TAB20"AYD="D4"FEET (WITH SLOPE CORRECTION)"
1010 PRINT
1020 PRINT
1030 GOTO 200
1040 END
```

PROGRAM 2

```
10 REM****PROGRAM"PAYD2"
20 PRINT
30 PRINT
40 PRINT "AVERAGE YARDING DISTANCE (AYD) FOR LATERAL AND LONGITUDINAL YARDING"
50 PRINT
60 PRINT "UNIT TYPES:"
70 PRINT TAB10"1--NO LEAVE STRIP OR DEAD GROUND"
80 PRINT TAB10"2--DEAD GROUND"
90 PRINT TAB10"3--LEAVE STRIP"
100 PRINT TAB10"4--DEAD GROUND AND LEAVE STRIP"
110 PRINT
120 PRINT
130 DISP "NEED INSTRUCTIONS (YES/NO)";
140 INPUT A$
150 IF A$="YES" THEN 3430
160 DIM A5[70,13],A$[10]
170 MAT A=ZER[70,13]
180 N=H5=L5=L6=0
190 DISP "MAP SCALE (FEET/INCH)";
200 INPUT S
210 N=N+1
220 P=1
230 DISP "SKYLINE CHORD SLOPE%-SETTING "N"";
240 INPUT S1
250 IF S1=1 THEN 590
260 DISP "DIGITIZE LANDING "N"";
270 WAIT 1000
280 WRITE (9,*)
290 ENTER (9,*)X,Y
300 P=P+1
310 A[N,P]=X
320 P=P+1
330 A[N,P]=Y
340 DISP "NEXT POINT, SETTING "N"";
350 WAIT 1000
360 WRITE (9,*)
370 ENTER (9,*)X,Y
380 Z9=SQR((X-A[N,P-1])↑2+(Y-A[N,P])↑2)
390 IF Z9<0.04 THEN 460
400 P=P+1
410 A[N,P]=X
420 P=P+1
430 A[N,P]=Y
440 IF P=11 THEN 550
450 GO TO 340
460 IF P=5 THEN 490
470 IF P=7 THEN 510
480 IF P=9 THEN 530
490 A[N,13]=1
500 GO TO 560
```

```
510 A[N,13]=2
520 GO TO 560
530 A[N,13]=3
540 GO TO 560
550 A[N,13]=4
560 A[N,12]=S1
570 A[N,1]=N
580 GO TO 210
590 REM***REORGANIZE DIGITIZED POINTS
600 N=0
610 N=N+1
620 IF A[N,1]=0 THEN 830
630 IF A[N,13]=1 THEN 670
640 IF A[N,13]=2 THEN 710
650 IF A[N,13]=3 THEN 750
660 IF A[N,13]=4 THEN 610
670 A[N,10]=A[N,4]
680 A[N,11]=A[N,5]
690 A[N,5]=A[N,4]=0
700 GO TO 610
710 A[N,10]=A[N,6]
720 A[N,11]=A[N,7]
730 A[N,6]=A[N,7]=0
740 GO TO 610
750 A[N,10]=A[N,8]
760 A[N,11]=A[N,9]
770 A[N,8]=A[N,6]
780 A[N,9]=A[N,7]
790 A[N,6]=A[N,4]
800 A[N,7]=A[N,5]
810 A[N,4]=A[N,5]=0
820 GO TO 610
830 REM****CALCULATE YARDING DISTANCES
840 PRINT "MAP SCALE; 1 INCH="S" FEET"
850 PRINT
860 PRINT
870 PRINT "SETTING  TYPE  AVERAGE     AREA     LAT.     LONG.   ";
880 PRINT " COMB.   MAX.     MAX."
890 PRINT "  OR            SLOPE      (ACRES)   AYD      SLOPE     AYD    LONG.";
900 PRINT "   LAT."
910 PRINT " ROAD"TAB17"(%)"TAB36"(FT)"TAB44"AYD"TAB53"(FT)"TAB60"SLOPE  DIST."
920 PRINT "  NO."TAB44"(FT)"TAB60"DIST.    (FT)"
930 PRINT TAB60"(FT)"
940 PRINT "  ---      ---    ---        ---      ---      ---     ---      ---";
950 PRINT "    ---"
960 DEG
970 N=L3=L4=H5=H2=C3=C4=C7=0
980 N=N+1
990 IF A[N,2]#A[N,10] THEN 1010
1000 A[N,10]=A[N,10]+0.001
```

```
1010 A=ATN((A[N,3]-A[N,11])/(A[N,2]-A[N,10]))
1020 D=SQR((A[N,2]-A[N,10])↑2+(A[N,3]-A[N,11])↑2)
1030 IF A[N,13]=2 THEN 1350
1040 IF A[N,13]=3 THEN 1860
1050 IF A[N,13]=4 THEN 2150
1060 IF A[N+1,1]=0 THEN 1150
1070 T=N+1
1080 GOSUB 2460
1090 GOSUB 2690
1100 IF I4 >= I3 THEN 1130
1110 I8=I3
1120 GO TO 1140
1130 I8=I4
1140 IF N=1 THEN 1220
1150 T=N-1
1160 GOSUB 2460
1170 GOSUB 2690
1180 IF I4 >= I3 THEN 1210
1190 I9=I3
1200 GO TO 1220
1210 I9=I4
1220 IF A[N+1,1]#0 AND N#1 THEN 1300
1230 L3=L3*2
1240 L4=L4*2
1250 H2=H2*2
1260 IF N=1 THEN 1290
1270 I8=I9
1280 GO TO 1300
1290 I9=I8
1300 C1=L3*S/H2
1310 C2=L4*S/H2
1320 H3=H2*S↑2/43560
1330 GOSUB 2770
1340 GO TO 980
1350 REM***CASE 2
1360 IF A[N+1,1]=0 THEN 1450
1370 T=N+1
1380 GOSUB 2460
1390 GOSUB 2950
1400 IF I4 >= I5 THEN 1430
1410 I8=I5
1420 GO TO 1440
1430 I8=I4
1440 IF N=1 THEN 1520
1450 T=N-1
1460 GOSUB 2460
1470 GOSUB 2950
1480 IF I4 >= I5 THEN 1510
1490 I9=I5
1500 GO TO 1520
```

```
1510 I9=I4
1520 IF A[N+1,1]#0 AND N#1 THEN 1600
1530 L3=L3*2
1540 L4=L4*2
1550 H2=H2*2
1560 IF N=1 THEN 1590
1570 I8=I9
1580 GO TO 1600
1590 I9=I8
1600 C1=L3*S/H2
1610 C2=((L4/H2)+D3)*S
1620 H3=H2*S↑2/43560
1630 GOSUB 2770
1640 GO TO 980
1650 C5=C3/H5
1660 C6=C4/H5
1670 C8=C7/H5
1680 PRINT
1690 PRINT
1700 PRINT "TOTAL FOR "N"SETTINGS"
1710 PRINT
1720 FIXED 2
1730 PRINT TAB10"AREA="H5"ACRES"
1740 FIXED 0
1750 PRINT TAB10"LATERAL AYD="C5"FEET"
1760 PRINT TAB10"LONGITUDINAL AYD="C8"FEET (NO SLOPE CORRECTION)"
1770 PRINT TAB10"LONGITUDINAL AYD="C6"FEET (WITH SLOPE CORRECTION"
1780 G2=C5+C6
1790 PRINT TAB10"TOTAL AYD="G2"FEET (WITH SLOPE CORRECTION)"
1800 PRINT TAB10"SLOPE CORRECTION ="C6-C8"FEET"
1810 PRINT TAB12"(AYD'S ARE AREA WEIGHTED MEANS)"
1820 PRINT
1830 PRINT
1840 GO TO 160
1850 REM***CASE 3
1860 IF A[N+1,1]=0 THEN 1950
1870 T=N+1
1880 GOSUB 2460
1890 GOSUB 3050
1900 IF I4 >= I3 THEN 1930
1910 I8=I3
1920 GO TO 1940
1930 I8=I4
1940 IF N=1 THEN 2020
1950 T=N-1
1960 GOSUB 2460
1970 GOSUB 3050
1980 IF I4 >= I3 THEN 2010
1990 I9=I3
2000 GO TO 2020
```

```
2010 I9=I4
2020 IF A[N+1,1]#0 AND N#1 THEN 2100
2030 L3=L3*2
2040 L4=L4*2
2050 H2=H2*2
2060 IF N=1 THEN 2090
2070 I8=I9
2080 GO TO 2100
2090 I9=I8
2100 C1=L3*S/H2
2110 C2=L4*S/H2
2120 H3=H2*S↑2/43560
2130 GOSUB 2770
2140 GO TO 980
2150 REM****CASE 4
2160 IF A[N+1,1]=0 THEN 2250
2170 T=N+1
2180 GOSUB 2460
2190 GOSUB 3230
2200 IF I4 >= I5 THEN 2230
2210 I8=I5
2220 GO TO 2240
2230 I8=I4
2240 IF N=1 THEN 2320
2250 T=N-1
2260 GOSUB 2460
2270 GOSUB 3230
2280 IF I4 >= I5 THEN 2310
2290 I9=I5
2300 GO TO 2320
2310 I9=I4
2320 IF A[N+1,1]#0 AND N#1 THEN 2400
2330 L3=L3*2
2340 L4=L4*2
2350 H2=H2*2
2360 IF N=1 THEN 2390
2370 I8=I9
2380 GO TO 2400
2390 I9=I8
2400 C1=L3*S/H2
2410 C2=L4*S/H2
2420 H3=H2*S↑2/43560
2430 GOSUB 2770
2440 GO TO 980
2450 STOP
2460 REM*****DIVISION LINE SUBROUTINE
2470 R1=(A[N,2]+A[T,2])/2
2480 Y1=(A[N,3]+A[T,3])/2
2490 R5=(A[N,10]+A[T,10])/2
2500 Y5=(A[N,11]+A[T,11])/2
```

```
2510 D6=SQR((A[N,2]-R1)↑2+(A[N,3]-Y1)↑2)
2520 D7=SQR((A[N,2]-R5)↑2+(A[N,3]-Y5)↑2)
2530 IF A[N,2]#R1 THEN 2550
2540 R1=R1+0.001
2550 A1=ATN((A[N,3]-Y1)/(A[N,2]-R1))
2560 IF A[N,2]#R5 THEN 2580
2570 R5=R5+0.001
2580 A5=ATN((A[N,3]-Y5)/(A[N,2]-R5))
2590 Z1=90-ABS(A-A1)
2600 Z5=90-ABS(A-A5)
2610 R6=D6*COS(Z1)
2620 Y6=D6*SIN(Z1)
2630 R7=D7*COS(Z5)
2640 Y7=D7*SIN(Z5)
2650 I2=(R7-R6)/(Y7-Y6)
2660 I3=R6-(Y6*(R7-R6)/(Y7-Y6))
2670 I4=D*I2+I3
2680 RETURN
2690 REM*****CASE 1 SUBROUTINE
2700 H1=ABS(D*(I3+I4)/2)
2710 L1=ABS((D/6)*(I3↑2+(I3*I4)+I4↑2))
2720 L2=ABS(D↑2*(2*I4+I3)/6)
2730 L3=L3+L1
2740 L4=L4+L2
2750 H2=H2+H1
2760 RETURN
2770 REM*******PRINTING SUB ROUTINE
2780 F2=C2*SQR((A[N,12]/100)↑2+1)
2790 F3=C1+F2
2800 F4=D*S*SQR((A[N,12]/100)↑2+1)
2810 IF I8 >= I9 THEN 2840
2820 G7=I9
2830 GO TO 2850
2840 G7=I8
2850 G8=G7*S
2860 FORMAT F4.0,F8.0,F8.0,F11.2,F8.0,F9.0,2F8.0,F7.0
2870 WRITE (15,2860)N,A[N,13],A[N,12],H3,C1,F2,F3,F4,G8
2880 C3=C3+(C1*H3)
2890 C4=C4+(F2*H3)
2900 C7=C7+(C2*H3)
2910 H5=H5+H3
2920 L3=L4=H2=0
2930 IF A[N+1,1]=0 THEN 1650
2940 RETURN
2950 REM******CASE 2 SUB ROUTINE
2960 D3=SQR((A[N,2]-A[N,4])↑2+(A[N,3]-A[N,5])↑2)
2970 I5=D3*I2+I3
2980 H1=ABS((D-D3)*(I4+I5)/2)
2990 L1=ABS((D-D3)/6*(I5↑2+(I4*I5)+I4↑2))
3000 L2=ABS((D-D3)↑2*(2*I4+I5)/6)
```

```
3010 L3=L3+L1
3020 L4=L4+L2
3030 H2=H2+H1
3040 RETURN
3050 REM****CASE 3 SUBROUTINE
3060 D2=SQR((A[N,2]-A[N,6])↑2+(A[N,3]-A[N,7])↑2)
3070 D1=SQR((A[N,2]-A[N,8])↑2+(A[N,3]-A[N,9])↑2)
3080 I6=D2*I2+I3
3090 I7=D1*I2+I3
3100 H6=ABS(D2*(I3+I6)/2)
3110 H7=ABS((D-D1)*(I4+I7)/2)
3120 L1=ABS((D2/6)*(I3↑2+(I3*I6)+I6↑2))
3130 L2=ABS(D2↑2*(2*I6+I3)/6)
3140 L5=ABS((D-D1)/6*(I7↑2+(I7*I4)+I4↑2))
3150 L6=ABS((D-D1)↑2*(2*I4+I7)/6)
3160 L1=L1+L5
3170 L8=L2+L6+H7*D1
3180 H1=H6+H7
3190 L3=L3+L1
3200 L4=L4+L8
3210 H2=H2+H1
3220 RETURN
3230 REM****CASE 4 SUBROUTINE
3240 D2=SQR((A[N,2]-A[N,6])↑2+(A[N,3]-A[N,7])↑2)
3250 D1=SQR((A[N,2]-A[N,8])↑2+(A[N,3]-A[N,9])↑2)
3260 D3=SQR((A[N,2]-A[N,4])↑2+(A[N,3]-A[N,5])↑2)
3270 I5=D3*I2+I3
3280 I6=D2*I2+I3
3290 I7=D1*I2+I3
3300 H6=ABS((D2-D3)*(I5+I6)/2)
3310 H7=ABS((D-D1)*(I4+I7)/2)
3320 L1=ABS((D2-D3)/6*(I6↑2+(I6*I5)+I5↑2))
3330 L2=ABS((D2-D3)↑2*(2*I6+I5)/6)
3340 L5=ABS((D-D1)/6*(I7↑2+(I7*I4)+I4↑2))
3350 L6=ABS((D-D1)↑2*(2*I4+I7)/6)
3360 L1=L1+L5
3370 L8=L2+L6+(H7*D1)+(H6*D3)
3380 H1=H6+H7
3390 L3=L3+L1
3400 L4=L4+L8
3410 H2=H2+H1
3420 RETURN
3430 PRINT
3440 PRINT
3450 PRINT TAB20"+-------------------#X#-------------------+"
3460 PRINT TAB21"L///////////////////!///////////////////S"
3470 PRINT TAB22"A////////////YARDING UNIT/////////////T"
3480 PRINT TAB23"T/////////////////!/////////////////I"
3490 PRINT TAB24"E---------------#X#---------------M"
3500 PRINT TAB25"R               !               I"
3510 PRINT TAB26"A         LEAVE STRIP         L"
3520 PRINT TAB27"|             |              "
```

```
3530 PRINT TAB28"+---------------#X#---------------|"
3540 PRINT TAB29"L////////////!////////////A"
3550 PRINT TAB30"I////YARDING UNIT/////R"
3560 PRINT TAB31"M//////////!//////////E"
3570 PRINT TAB32"I--------#X#--------T"
3580 PRINT TAB33"T        !        A"
3590 PRINT TAB34"S DEAD GROUND L"
3600 PRINT TAB35".      !      ."
3610 PRINT TAB36".     !     ."
3620 PRINT TAB37"+--#X#--+"
3630 PRINT TAB38"LANDING"
3640 PRINT
3650 PRINT
3660 PRINT "'LEAVE STRIP'=UNLOGGED AREA WITHIN UNIT"
3670 PRINT "'DEAD GROUND'=UNLOGGED AREA BETWEEN LANDING AND UNIT"
3680 PRINT
3690 PRINT "OPERATING INSTRUCTIONS*"
3700 PRINT TAB5"1.INPUT DATA AS REQUIRED BY DISPLAY."
3710 PRINT TAB5"2.ESTABLISH AN ORIGIN (O ON CURSOR)."
3720 PRINT TAB5"3.DIGITIZE EACH SETTING (PRESS S AT EACH #X# LOCATION)"
3730 PRINT TAB8"IN THE FOLLOWING SEQUENCE:"
3740 PRINT TAB10"#X# LANDING;"
3750 PRINT TAB10"#X# DEAD GROUND BOUNDARY (IF ANY);"
3760 PRINT TAB10"#X# NEAR BOUNDARY OF LEAVE STRIP (IF ANY);"
3770 PRINT TAB10"#X# FAR BOUNDARY OF LEAVE STRIP (IF ANY);"
3780 PRINT TAB10"#X# REAR BOUNDARY OF YARDING UNIT."
3790 PRINT TAB13"DIGITIZE THIS LAST POINT TWICE UNLESS SETTING"
3800 PRINT TAB13"CONTAINS BOTH DEAD GROUND AND A LEAVE STRIP;"
3810 PRINT TAB13"IN THAT CASE DIGITIZE THIS POINT JUST ONCE."
3820 PRINT TAB5"4.DON'T DIGITIZE TOO FAST. WAIT FOR THE AUDIBLE 'BEEP' AND"
3830 PRINT TAB8"DISPLAY BEFORE DIGITIZING SUBSEQUENT POINTS."
3840 PRINT TAB5"5.TO SIGNAL FOR UNIT SUMMATION OF A GROUP OF ADJACENT SETTINGS"
3850 PRINT TAB8"ENTER A 1% CHORD SLOPE FOR THE SETTING FOLLOWING THE FINAL"
3860 PRINT TAB8"SETTING."
3870 PRINT TAB5"6.UNIT SUMMATION MUST BE PERFORMED WHENEVER THE AREA BETWEEN"
3880 PRINT TAB8"SETTINGS IS NOT TO BE YARDED."
3890 PRINT TAB5"7.THE SETTINGS MUST BE DIGITIZED IN A SEQUENTIAL ORDER,"
3900 PRINT TAB8"BEGINNING AT THE LEFT (OR RIGHT) BOUNDARY AND PROCEEDING"
3910 PRINT TAB8"TO THE OPPOSITE BOUNDARY."
3920 PRINT
3930 PRINT
3940 GO TO 160
```

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.

2. Developing and evaluating alternative methods and levels of resource management.

3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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