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Linden, D. S.

Barrett, J. P.

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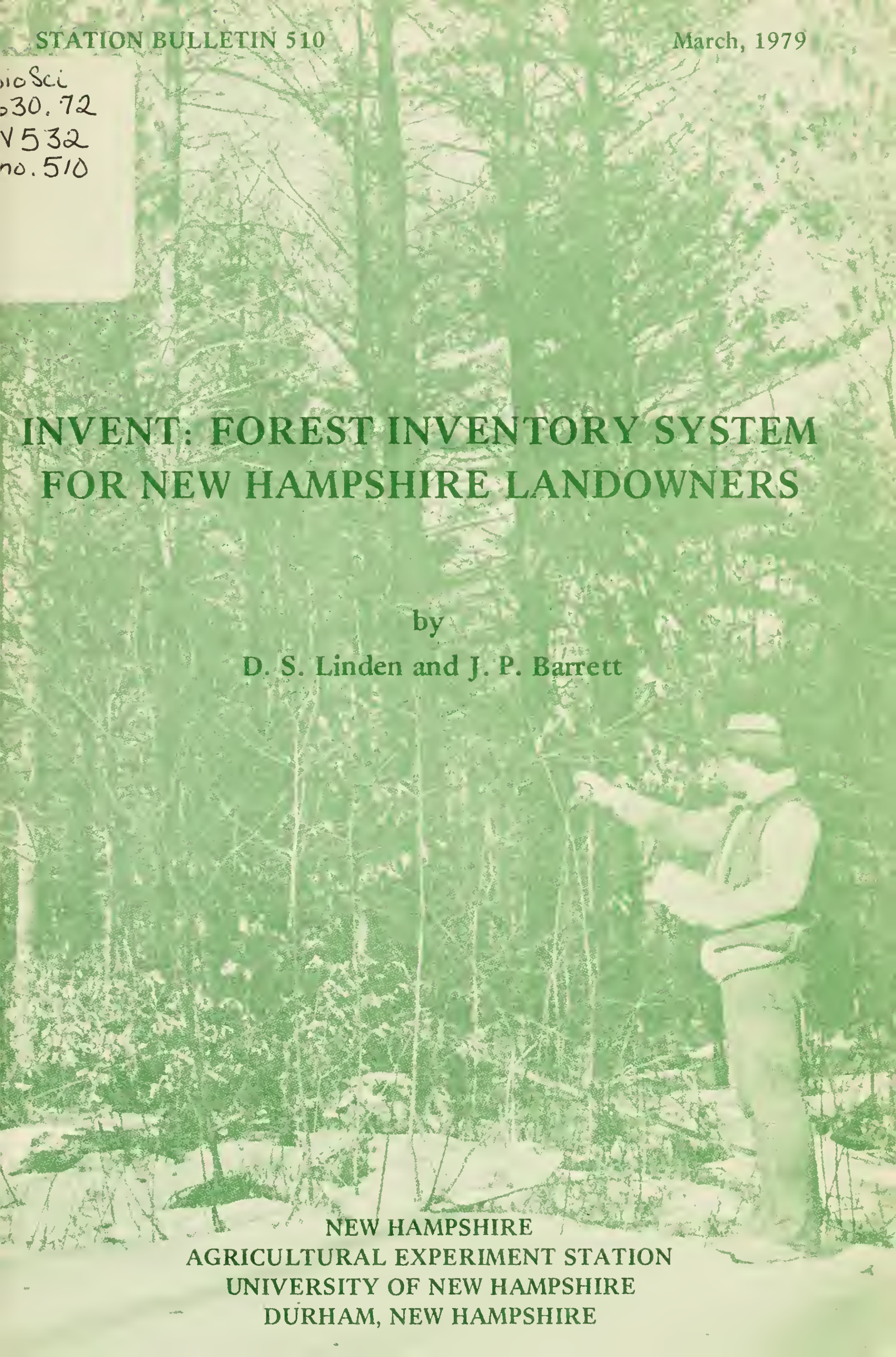

INVENT: FOREST INVENTORY SYSTEM FOR NEW HAMPSHIRE LANDOWNERS

by

D. S. Linden and J. P. Barrett

NEW HAMPSHIRE
AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

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The program was written in FORTRAN-10 on the DECsystem-10 Model 1090 Computer at the University of New Hampshire. A card deck of the program may be obtained by contacting:

Dr. James P. Barrett
Institute of Natural and Environmental Resources
University of New Hampshire
Durham, New Hampshire 03824

ABSTRACT

A computerized forest inventory system has been developed to meet the needs of New Hampshire landowners and foresters. The system will analyse all sampling designs currently in wide use throughout the State producing tables easily understood by landowners. The system includes a rigorous statistical analysis of volume standard errors as well as a newly developed height double sampling technique. The system is available through the Institute of Natural and Environmental Resources.

KEY WORDS: Forest inventory. Computer inventory. Sampling. Double sampling.

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INVENT:

FOREST INVENTORY SYSTEM FOR NEW HAMPSHIRE LANDOWNERS

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INTRODUCTION

INVENT is a computerized forest inventory processing system designed for New Hampshire landowners. INVENT was designed with the following five goals in mind:

1. Produce a system that will analyse all sampling designs and methods presently in wide use throughout the State.

2. Produce output tables easily understood by foresters and landowners--output tables that look as if they were designed by a forester, not a computer.

3. Find and implement volume equations that are well adapted to the New Hampshire species--calculate both board-foot and cubic-foot volumes.

4. Indicate the reliability of volume estimates.

5. Produce a system that any forester can use and understand--a system available to all foresters at low cost.

The realization of these goals is the result of two years work in close cooperation with consulting foresters, county foresters, and forest industry. As a result, New Hampshire foresters have "been emancipated from the drudgery and limitations of computation and can concentrate on forest data needs." (Davis 1966, p. 282).

The use of INVENT is made available by the Institute of Natural and Environmental Resources at the University of New Hampshire. Institute personnel will process data from tally sheets submitted by subscribing foresters. Persons interested in using the system should contact Professor James Barrett at I.N.E.R., University of New Hampshire.

This publication is written in four separate sections. Section 1 contains all the information a field forester needs to know to utilize the service. Section 2 describes how the data is computer coded and how the program is run. Section 3 documents the computer program itself with subroutine descriptions

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*Graduate Research Assistant and Professor of Forest Resources, Institute of Natural and Environmental Resources, respectively.

and variable dictionaries. Section 4 discusses the statistical techniques used within the program. The appendices include tally forms, species code list, volume equations, a guide to sample size determination, a program listing and other supportive material.

SECTION 1. FIELD FORESTER INFORMATION

The first step in a forest inventory is to systematically arrange the forest into groups or categories based upon some definite scheme. We shall refer to these groups as either compartments or strata, using these terms interchangeably. The boundaries of these compartments may be determined by forest type, stocking level, merchantability class or administrative convenience. Whatever the criteria actually used, INVENT will assume that each compartment should be processed individually and will produce a complete set of summary tables for each compartment. Furthermore, INVENT will produce a set of summary tables for all compartments combined assuming stratified random sampling (Cf. Freese 1962). INVENT will handle up to 999 compartments although in practice one would seldom have more than 20 compartments within any forest.

For each forest to be processed, the forester must supply the information requested on the INVENT Processing Request Form (Appendix A, page 48). This information includes:

1. Name and address of forester making request.
2. Number of compartments in the forest.
3. Alternate form class specification.
4. Diameter class size.
5. Confidence level.
6. Tract description.

Alternate Form Class Specification. If heights are measured to the merchantable top, form class equations are used to determine board foot volume. INVENT uses the following form classes as a default:

Hemlock 70 All other softwoods 76 All hardwoods 74

Alternate form classes may be specified using the space provided on the INVENT Processing Request Form. These form classes will be used for all compartments in the forest.

Diameter Class Size. INVENT assumes that trees will be grouped into diameter classes. The size of the class is up to the user within the following limitations. The class size must be a whole number. The smallest diameter class allowable is the class size; i.e., if the class size is 2 in. then the first class must be 2 inches. All other diameter classes must be integer multiples of the class size. The maximum diameter class must be less than or equal to 40 inches.

Confidence Level. INVENT uses the 95 percent confidence level as a default. Using this level, there is only a one in twenty chance that the true volume will be outside the confidence interval computed by INVENT (Cf. Freese 1967, p. 11). This is the most common confidence level used in forestry in the Northeast. If the user wishes to use a different level, he may specify that level as long as it is in the range from 65 percent to 99 percent.

Tract Description. A tract description of up to 70 characters should be specified for the forest. This description will be printed at the top of each page of the combined compartment summaries.

For each compartment within the forest, the forester must supply the information requested on the INVENT Compartment Information Form (Appendix A, page 49). This information includes:

1. Compartment name and/or description.
2. Sampling method and sample unit size.
3. Tree height measurement units.
4. Tree top specification.
5. Whether or not the heights of all volume trees were measured.
6. Size of compartment in acres.

Compartment Name. A compartment name and/or description should be specified for each compartment. The description may be up to 70 characters in length and is printed at the top of each page of the compartment output tables.

Sampling Method. INVENT will process point cruises (variable plot), plot cruises (fixed radius plot), strip cruises, and 100 percent tallies. The sampling method need not be the same for each compartment. When using point or plot sampling, a complete statistical analysis of the reliability of the volume estimates will be calculated only if the data for each point or plot is tallied separately. If only summary data is available, no such statistical analysis can be made. When point sampling, the BAF of the angle used must be specified. When plot sampling, the plot size in acres must be specified. Strip cruises are analysed as a plot cruise where only one large plot is sampled. In this case, the plot size is the total acreage of all strips. There is no statistical analysis of reliability on strip cruises. One hundred percent tallies require no statistical analysis of reliability since all trees in the population have been measured. One hundred percent tallies are also treated as a plot cruise where only one large plot is sampled. Here, however, the plot size is equal to the total acreage of the compartment.

Tree Height Measurement. Tree height may be measured in feet or sixteen foot logs to the nearest half-log.

Tree Top Specification. Trees may be measured to a merchantable top or measured by total height. There is also a mixed option where softwoods are measured by total height and hardwoods by merchantable height. As mentioned earlier, form class volume equations for board foot volume are used when merchantable height is specified.

Were Heights of All Volume Trees Measured? INVENT allows double sampling for height (Cf. Freese 1962, p. 43). Using this technique, the forester only measures height on a subsample of the trees. INVENT develops a height-dbh relationship from the height trees sampled and uses this relationship to estimate height for the remaining trees. This method must be used with some caution. On at least one-third of the trees in every species, the height should be measured. At least three height trees must be measured for every species within each compartment. An analysis table of the height-dbh relationship is printed for each compartment using the option. A warning message is printed if an insufficient number of trees within any species was sampled. (See table 17).

Size of Compartment. The size of each compartment in acres must be specified. If not known exactly it must at least be estimated.

Tally Forms and Product Specification

Tally forms are available for use with INVENT (see Appendix A, page 46). Trees are tallied using a two letter species code (Appendix A, page 45), diameter class, height and product. The product column is used as follows: INVENT allows trees to be graded as sawlog or pulpwood. If you do not wish to grade trees simply ignore the product column and all trees will be assumed sawlog. If you do wish to grade trees there are two methods available. You can grade the entire tree as sawlog or pulpwood by entering an S in the product column for sawlog, or entering a P for pulpwood. Alternatively, you may specify the percent sawlog in the tree. If you put 60 in the product column, 60 percent of the volume will go into sawlog and 40 percent will go into pulpwood.

The column marked # is used if two or more trees of the same species, size and product are tallied on a given plot.

Output Tables

Seventeen tables are presented as an example of INVENT's output. Tables 1-16 are part of a 59 page inventory report based on a 3 compartment cruise of Whitaker Woods in North Conway, N.H. Tables 1-9 are for compartment 1 while tables 10-16 are for all 3 compartments combined. Table 17 is taken from another cruise where the height double sampling option was used. This table is a summary of that relationship. The output tables are further discussed in section 3 on page 34. However, the tables should be self-explanatory to most foresters.

TABLE 1. JOB CONTROL INFORMATION (INDIVIDUAL STRATUM)

INVENT VER. 3 11/1/78 I.N.E.R. U.H.H.

DATE OF RUN: 7-Dec-78

B.A.F. = 10.00

DIAMETER CLASS SIZE = 2

HEIGHTS OF ALL VOLUME TREES MEASURED

INPUT FILE NAME: CONWIT.C1

CONFIDENCE LEVEL = .95

NUMBER OF POINTS SAMPLED = 20

HEIGHTS MEASURED BY MERCH HEIGHT IN LOGS

STRATUM # 1

ACREAGE OF TRACT = 47.0

TABLE 2. SPECIES STAND AND STOCK TABLE

WHITE PINE   FC = 76

DIAMETER CLASS	BASAL AREA PER ACRE	TREES PER ACRE	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
8	1.5	4.3	0.0	0.0	30.7
10	1.0	1.8	16.8	82.8	0.0
12	4.5	5.7	91.1	535.4	0.0
14	5.0	4.7	109.9	705.8	0.0
16	7.5	5.4	168.7	1115.0	16.4
18	9.0	5.1	221.1	1545.0	9.6
20	7.0	3.2	196.5	1405.3	0.0
22	3.5	1.3	101.6	747.0	0.0
24	2.5	0.8	70.3	538.0	0.0
26	4.5	1.2	134.1	1035.6	0.0
28	1.0	0.2	33.7	258.3	0.0
30	1.0	0.2	28.4	233.1	0.0
32	2.0	0.4	58.4	483.9	0.0
TOTAL	50.0	34.3	1230.6 ± 35%	8685.2 ± 35%	56.7 ± 83%

MEAN STAND DIAMETER = 16.3

MERCHANTABLE M.S.D. = 16.3

PERCENT CRUISE = 6.2%

BOARD FOOT COEFFICIENT OF VARIATION = 78%

PULP-WOOD COEFFICIENT OF VARIATION = 183%

TABLE 3. SPECIES STAND AND STOCK TABLE

RED OAK FC = 74

DIAMETER CLASS	BASAL AREA PER ACRE	TREES PER ACRE	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
6	1.0	5.1	0.0	0.0	19.4
8	1.5	4.3	6.1	26.3	16.7
10	4.5	8.3	54.1	273.4	13.2
12	5.5	7.0	72.4	417.1	0.0
14	2.0	1.9	30.9	183.9	0.0
16	2.0	1.4	28.2	179.2	0.0
18	3.0	1.7	41.8	277.1	0.0
20	1.5	0.7	25.1	165.4	0.0
22	0.5	0.2	4.6	35.6	0.0
TOTAL	21.5	30.5	263.3 ± 58%	1557.9 ± 56%	49.3 ±151%

MEAN STAND DIAMETER = 11.4 BOARD FOOT COEFFICIENT OF VARIATION = 122%

MERCHANTABLE M.S.D. = 12.2 PULP-WOOD COEFFICIENT OF VARIATION = 327%

PERCENT CRUISE = 3.0%

TABLE 4. SOFTWOOD SUMMARY STAND AND STOCK TABLE

AIL SCFTWOODS

DIAMETER CLASS	BASAL AREA PER ACRE	TREES PER ACRE	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
6	0.5	2.5	0.0	0.0	8.1
8	3.5	10.0	0.0	0.0	57.3
10	7.0	12.8	86.1	392.6	4.0
12	10.5	13.4	169.7	956.7	0.0
14	9.0	8.4	183.7	1147.4	0.0
16	11.5	8.2	238.4	1574.8	16.4
18	13.5	7.6	307.3	2079.7	9.6
20	8.5	3.9	226.6	1593.2	0.0
22	4.5	1.7	125.5	915.2	0.0
24	2.5	0.8	70.3	538.0	0.0
26	4.5	1.2	134.1	1035.6	0.0
28	1.0	0.2	33.7	258.3	0.0
30	1.0	0.2	28.4	233.1	0.0
32	2.0	0.4	58.4	483.9	0.0
TOTAL	79.5	71.5	1662.2 ± 29%	11208.3 ± 30%	95.4 ± 63%

MEAN STAND DIAMETER = 14.3 BOARD FOOT COEFFICIENT OF VARIATION = 65%

MERCHANTABLE M.S.D. = 14.5 PULP-WOOD COEFFICIENT OF VARIATION = 138%

PERCENT CRUISE = 4.7%

TABLE 5. HARDWOOD SUMMARY STAND AND STOCK TABLE

ALL HARDWOODS

DIAMETER CLASS	BASAL AREA PER ACRE	TREES PER ACRE	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
6	3.0	15.3	0.0	0.0	48.6
8	3.5	10.0	6.1	26.3	47.8
10	6.0	11.0	60.0	302.8	25.2
12	7.5	9.5	77.3	448.5	14.4
14	3.0	2.8	43.8	260.4	0.0
16	2.5	1.8	35.8	224.4	0.0
18	3.0	1.7	41.8	277.1	0.0
20	1.5	0.7	25.1	165.4	0.0
22	0.5	0.2	4.6	35.6	0.0
TOTAL	30.5	53.0	294.7 ± 52%	1740.5 ± 51%	136.0 ± 72%

MEAN STAND DIAMETER = 10.3 BOARD FOOT COEFFICIENT OF VARIATION = 109%

MERCHANTABLE M.S.D. = 11.6 PULP-WOOD COEFFICIENT OF VARIATION = 157%

PERCENT CRUISE = 2.4%

TABLE 6. ALL SPECIES SUMMARY STAND AND STOCK TABLE

ALL SPECIES

DIAMETER CLASS	BASAL AREA PER ACRE	TREES PER ACRE	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
6	3.5	17.8	0.0	0.0	56.7
8	7.0	20.1	6.1	26.3	105.1
10	13.0	23.8	146.1	695.4	29.2
12	18.0	22.9	246.9	1405.2	14.4
14	12.0	11.2	227.6	1407.8	0.0
16	14.0	10.0	274.3	1799.2	16.4
18	16.5	9.3	349.1	2356.7	9.6
20	10.0	4.6	251.7	1758.6	0.0
22	5.0	1.9	130.1	950.8	0.0
24	2.5	0.8	70.3	538.0	0.0
26	4.5	1.2	134.1	1035.6	0.0
28	1.0	0.2	33.7	258.3	0.0
30	1.0	0.2	28.4	233.1	0.0
32	2.0	0.4	58.4	483.9	0.0
TOTAL	110.0	124.5	1956.8 ± 21%	12948.9 ± 22%	231.4 ± 50%

MEAN STAND DIAMETER = 12.7 BOARD FOOT COEFFICIENT OF VARIATION = 48%

MERCHANTABLE M.S.D. = 13.5 PULP-WOOD COEFFICIENT OF VARIATION = 109%

PERCENT CRUISE = 3.8%

Table 7. Species Composition Table

SPECIES COMPOSITION BY PERCENT

SPECIES	BASAL AREA	TREES	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
WHITE PINE	45.45	27.59	62.89	67.07	24.50
RED PINE	5.91	5.15	6.90	6.76	0.00
HEMLOCK	20.91	24.67	15.15	12.72	16.75
SUGAR MAPLE	0.91	3.20	0.00	0.00	6.82
RED MAPLE	0.91	1.53	0.26	0.25	3.68
WHITE BIRCH	0.91	2.56	0.25	0.24	3.92
BEECH	5.45	10.80	1.09	0.91	23.03
RED OAK	19.55	24.51	13.46	12.03	21.31
ALL SOFTWOODS	72.27	57.41	84.94	86.56	41.25
ALL HARDWOODS	27.73	42.59	15.06	13.44	58.75

Table 8. Volume Summary for All Species

VOLUME TOTALS FOR ALL SPECIES

SPECIES	SAWLOG CUBIC FOOT VOLUME PER ACRE	SAWLOG BOARD FOOT VOLUME PER ACRE	PULPWOOD CUBIC FOOT VOLUME PER ACRE
WHITE PINE	1230.6	8685.2	56.7
RED PINE	135.0	876.0	0.0
HEMLOCK	296.5	1647.2	38.8
SUGAR MAPLE	0.0	0.0	15.8
RED MAPLE	5.1	32.8	8.5
WHITE BIRCH	4.8	31.4	9.1
BEECH	21.4	118.4	53.3
RED OAK	263.3	1557.9	49.3
ALL SOFTWOODS	1662.2	11208.3	95.4
ALL HARDWOODS	294.7	1740.5	136.0
ALL SPECIES	1956.8	12948.9	231.4

TABLE 9. VOLUME SUMMARY FOR ALL SPECIES EXPANDED BY ACREAGE

VOLUME TOTALS EXPANDED BY ACREAGE

SPECIES	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
WHITE PINE	57838	408202	2664
RED PINE	6347	41170	0
HEMLOCK	13936	77419	1822
SUGAR MAPLE	0	0	742
RED MAPLE	240	1542	400
WHITE BIRCH	228	1478	426
BEECH	1004	5563	2505
RED OAK	12377	73222	2317
ALL SOFTWOODS	78122	526792	4486
ALL HARDWOODS	13849	81805	6390
ALL SPECIES	91971	608597	10876

TABLE 10. JOB CONTROL INFORMATION (STRATIFIED TOTAL)

INVENT VER. 3 11/1/78 I.N.E.R. U.N.H.

DATE OF RUN: 7-Dec-78

DIAMETER CLASS SIZE = 2

NUMBER OF STRATA SAMPLED = 3

TOTAL ACREAGE SAMPLED = 105.0

TOTAL POINTS SAMPLED = 56

CONFIDENCE LEVEL = .95

TABLE 11. SPECIES VOLUME TABLE (STRATIFIED TOTAL)

WHITE PINE — FC = 76

DIAMETER CLASS	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
6	0	0	914
8	823	2718	1716
10	1499	7465	0
12	5111	30058	0
14	5550	35604	0
16	9600	63484	769
18	14541	100826	453
20	14468	103635	0
22	10177	75100	0
24	7902	60263	0
26	9247	71309	0
28	2506	19544	0
30	2074	16148	0
32	4228	34874	0
34	568	4555	0
36	455	3920	0
TOTAL	88750 ± 26%	629503 ± 26%	3853 ± 73%

TABLE 12. SPECIES VOLUME TABLE (STRATIFIED TOTAL)

RED OAK — FC = 74

DIAMETER CLASS	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
6	0	0	1635
8	288	1234	2981
10	4574	23270	622
12	7579	42632	310
14	2901	16995	0
16	4710	29345	0
18	3005	19598	664
20	1403	9308	294
22	218	1674	0
24	0	0	291
28	290	2035	0
TOTAL	24968 ± 37%	146091 ± 36%	6799 ± 61%

TABLE 13. SOFTWOOD SUMMARY VOLUME TABLE (STRATIFIED TOTAL)

AIL SCFTWOODS

DIAMETER CLASS	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
6	0	0	1874
8	1053	3451	4161
10	6105	28274	320
12	10944	61345	107
14	12957	79177	0
16	22644	141792	769
18	26139	172099	591
20	18292	127282	0
22	13103	95876	0
24	9151	68560	0
26	10723	81395	0
28	2799	21620	0
30	3291	24339	0
32	4407	36297	0
34	915	7039	0
36	455	3920	0
40	459	3204	0
TOTAL	143437 ± 19%	955670 ± 19%	7822 ± 50%

TABLE 14. HARDWOOD SUMMARY VOLUME TABLE (STRATIFIED TOTAL)

AIL BARDWOODS

DIAMETER CLASS	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
6	366	607	7887
8	288	1234	11231
10	9417	48605	2785
12	10012	56781	2805
14	4167	24463	826
16	5472	34023	488
18	3005	19598	1212
20	1403	9308	458
22	381	2825	610
24	0	0	607
26	315	2009	237
28	290	2035	0
TOTAL	35115 ± 26%	201490 ± 26%	29146 ± 27%

Table 15. All Species Summary Volume Table (Stratified Total)

ALL SPECIES

DIAMETER CLASS	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
6	366	607	9760
8	1341	4685	15393
10	15522	76879	3104
12	20955	118127	2912
14	17124	103641	826
16	28116	175815	1257
18	29144	191697	1803
20	19695	136589	458
22	13484	98701	610
24	9151	68560	607
26	11038	83404	237
28	3089	23655	0
30	3291	24339	0
32	4407	36297	0
34	915	7039	0
36	455	3920	0
40	459	3204	0
TOTAL	178552 ± 14%	1157160 ± 14%	36968 ± 22%

Table 16. Volume Summary for All Species (Stratified Total)

VOLUME TOTALS FOR ALL SPECIES

SPECIES	SAWLOG CUBIC FOOT VOLUME	SAWLOG BOARD FOOT VOLUME	PULPWOOD CUBIC FOOT VOLUME
WHITE PINE	88750	629503	3853
RED PINE	10094	65651	0
HEMLOCK	44593	260516	3746
RD-BL-WH SPRUCE	0	0	224
SUGAR MAPLE	0	0	742
RED MAPLE	1072	6271	6150
WHITE BIRCH	4474	25213	3255
YELLOW BIRCH	89	649	0
BEECH	4513	23266	12200
RED OAK	24968	146091	6799
ALL SOFTWOODS	143437	955670	7822
ALL HARDWOODS	35115	201490	29146
ALL SPECIES	178552	1157160	36968

Table 17. Regression Summary (If Option Used)

ANALYSIS OF THE HEIGHT - DBH RELATIONSHIP

MODEL: HEIGHT = B0 + B1/DBH

SPECIES	B0 INTERCEPT	B1 SLOPE	R SQUARED	STANDARD ERROR %	AVERAGE HEIGHT	VOLUME TREES	HEIGHT TREES
WHITE PINE	3.296	-21.321	54.0	5.1	1.5	92	40
HEMLOCK	1.799	-8.528	16.2	9.6	1.1	48	23
RED MAPLE	3.106	-29.436	62.1	13.5	0.9	39	11
BLACK CHERRY		*** WARNING ***		0.0	0.0	3	0
SWEET BIRCH		*** WARNING ***		0.0	0.0	1	0
BASSWOOD				0.0	2.0	2	2
RED OAK	1.140	-5.471	30.1	19.7	0.8	5	4
WHITE OAK		*** WARNING ***		0.0	0.0	3	0
BLACK OAK		*** WARNING ***		0.0	0.0	2	0
ELM	1.157	-4.992	18.7	15.0	0.8	9	6
HICKORY	2.865	-23.076	73.0	9.2	1.3	6	3
ALL SOFTWOODS				4.6	1.4	140	63
ALL HARDWOODS				8.1	1.0	70	26
ALL SPECIES				4.1	1.3	210	89

*** WARNING *** INSUFFICIENT NUMBER OF HEIGHT TREES MEASURED FOR THIS SPECIES!

SECTION 2. DATA CODING AND PROGRAM EXECUTION

Program Operating Environment

INVENT was developed on the DEC-10 system at the University of New Hampshire. INVENT is an interactive system acquiring all of its job control related information from the user through a dialogue. Unit 5 (TTY on DEC-10) is used as the input and output device for all of INVENT's interactive dialogue.

For each stratum the plot and tree data must reside on a disk file with a unique name. The name of the file is specified by the user at execution time as INVENT processes each stratum. Unit 21 is used to input each disk file. The file uses a fixed format as described below.

If the user wishes to use alternate form classes, these must reside on a disk file also. The user specifies the name of this file at execution time and unit 1 is used to input this file. The file uses a fixed format as described on page 18.

All output is written to unit 3 (LPT on DEC-10) to a file named INVENT.LPT.

Data File Format and Coding

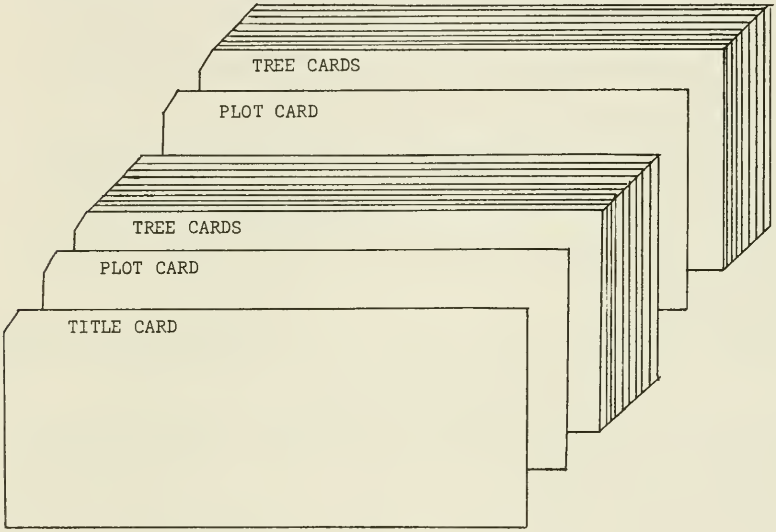
An individual data file must exist for each stratum. The file consists of card images coded as follows:

Card Type	Columns	Format	Variable	Description
Title	1-70	12A5	TITLE	Stratum title
Plot	1-2	I2	POINT	Plot number (1)
	3-5	I3	TREES	Number of trees on plot (1)
Tree	1-2	A2	SPEC	Species code
	4-5	I2	DBH	Diameter at breast height
	6	A1	PROD	Product code (2)
	7-9	F3.0	HEIGHT	Tree height
	10-11	I2	IREP	Number of trees of this description (3)
	12-14	F3.2	PCTSAW	Percent sawlog (4)

(1) When using the summary option where trees are not tallied by individual plots, only one plot card is used and it is coded as follows: POINT = -9, TREES = number of plots sampled.
(2) Product codes: Sawlog (S or blank); Pulpwood (P); Percent Sawlog (%).
(3) If IREP is coded as 0 or blank, the program assumes IREP = 1.
(4) PCTSAW is ignored unless PROD = %. PCTSAW is coded as a percent (0-100) and the F3.2 format reads it as a decimal (0-1.00).

Examples of various tree card codings may be found in Appendix A, page 44. The species code list is found in Appendix A, page 45.

The data file is constructed by combining the title, plot, and tree cards as follows. The first card in the file is the title card. This is followed by the plot card for plot number 1. The plot card is then followed by all the tree cards for that plot. Next, the plot card for plot number 2 is included followed by its tree cards; and so on for the remaining plots. The actual value of POINT (plot number) need not be consecutive.



An example of an INVENT tally sheet and the resulting data file listing may be found in Appendix A, pages 46 and 47.

Alternate Form Class File Coding

The user has the option to specify a set of alternate form classes. Form class only affects volume when tree heights are measured to a merchantable top (see page 3). A file containing these alternate form classes must reside on a disk file. This file consists of four rows and eight columns organized as follows:

Row 1:	Form classes for species 1-8	(see species list in
Row 2:	" " " " 9-16	Appendix A, page 45)
Row 3:	" " " " 17-24	
Row 4:	" " " " 25-32	

Each row is formatted 8(I2,X).

As an example, assume the following form classes were desired:

All pines	80
Hemlock, Spruces, Ash, Black Cherry	78
Balsam Fir, Tamarack, Cedar Other Softwoods, Sugar Maple White Birch, Yellow Birch	76
All other species	75

The data file that would implement these form classes is:

```
80 80 80 78 76 76 78 78
80 76 76 76 75 78 75 75
75 78 76 76 75 75 75 75
75 75 75 75 75 75 75 75
```

Running the Program

Running INVENT consists of interactively supplying the program all job control information. This information includes: alternate form class specification (if desired), diameter class size, number of strata, confidence level, input file name for each strata, sampling method (point or plot), basal area factor or plot size, method of height measurement, acreage of each stratum, and title of combined strata output (if more than one stratum sampled).

This interactive portion of the program is self-explanatory. The program asks the user certain questions while listing the possible answers. The number of questions asked depends on the options used and the number of strata sampled. The questions are asked as each data file is read and processed. Under conditions of heavy computer usage there may be a time lapse of as much as two minutes between certain questions. This process is best explained by example.

Tables 1-16 are part of a 59 page inventory report based on a 3 compartment cruise of Whitaker Woods in North Conway, N.H. Listed below is the entire user-program dialogue that produced that output. Each of the questions asked has been numbered for reference and user responses are underlined. Most questions are totally self-explanatory and therefore only a few will be discussed.

```
.RUN INVENT

1.   DO YOU WANT TO READ IN ALTERNATE FORM CLASSES FROM DISK?
     NO

2.   ENTER DIAMETER CLASS SIZE
     2

3.   ENTER NUMBER OF STRATA
     3

4.   INVENT USES THE 95% CONFIDENCE LEVEL AS A DEFAULT.
     DO YOU WISH TO USE A DIFFERENT LEVEL?
     NO

5.   ENTER INPUT FILE NAME FOR STRATUM #    1
     CONWIT.C1

     WHITAKER WOODS  1978   COMP. 1

6.   SPECIFY SAMPLING METHOD
       TYPE POINT OR PLOT
     POINT

7.   ENTER B.A.F.
     10

8.   ARE HEIGHTS IN FEET OR SIXTEEN FT. LOGS?
         TYPE FEET OR LOGS
     LOGS

9.   ARE HEIGHTS TOTAL OR MERCHANTABLE?
         TYPE TOTAL, MERCH, OR MIXED
     MERCH

10.  WERE THE HEIGHTS OF ALL VOLUME TREES MEASURED?
     YES

11.  ENTER ACREAGE OF TRACT.
     47

12.  ENTER INPUT FILE NAME FOR STRATUM #    2
     CONWIT.C2

     WHITAKER WOODS  1978   COMP. 2
```

```
13.     SPECIFY SAMPLING METHOD
          TYPE POINT OR PLOT OR SAME
        SAME

14.     ENTER ACREAGE OF TRACT.
        42

15.     ENTER INPUT FILE NAME FOR STRATUM #   3
        CONWIT.C3

        WHITAKER WOODS  1978   COMP. 3

16.     SPECIFY SAMPLING METHOD
          TYPE POINT OR PLOT OR SAME
        SAME

17.     ENTER ACREAGE OF TRACT.
        16

18.     WHAT DO YOU WANT TO TITLE THE COMBINED STRATA OUTPUT?
        WHITAKER WOODS  1978   STRATIFIED TOTAL   COMPS. 1 - 3

        END OF EXECUTION
        CPU TIME: 4.32  ELAPSED TIME: 5:31.23
        EXIT
```

Answering NO to questions 1 and 4 indicates the user will use the default form classes and the default confidence level of 95 percent.

Question 9 asks the user if heights are total or merchantable and offers three responses: TOTAL, MERCH, or MIXED. The response MIXED would have indicated that softwoods were measured by total height while hardwoods were measured by merchantable height. In this case, however, MERCH was answered indicating merchantable height was used on all trees.

There would be a pause of about thirty seconds between questions 11 and 12 as the program processes stratum 1.

Question 13 asks the user to specify the sampling method as did question 6. However, question 13 offers an additional response: SAME. Answering SAME indicates that in stratum 2 the sampling method, basal area factor, and method of height measurement are identical to those in the previous stratum. Therefore questions 7-10 are not repeated.

Once again there would be a pause of about thirty seconds between questions 14 and 15 and between questions 16 and 17.

Question 18 asks for a title for the combined strata output. This title may be up to 70 characters in length and is printed at the top of each table in the combined strata output section.

After an additional pause of about thirty seconds the end of execution message appears and the output is sent to the line printer queue.

The following example is included to illustrate the alternate form class option and the alternate confidence level option.

```
        .RUN INVENT

1.      DO YOU WANT TO READ IN ALTERNATE FORM CLASSES FROM DISK?
        YES

1A.     ENTER FORM CLASS FILE NAME
        WHIT.FRM

1B.     DO YOU WANT A LIST OF THE FORM CLASSES JUST READ?
        YES


        WP = 80      RP = 80      PP = 80      HM = 78
        BF = 76      TA = 76      SP = 78      NS = 78
        SC = 80      CE = 76      OS = 76      SM = 76
        RM = 75      WA = 78      WI = 75      AS = 75
        YP = 75      BC = 78      WB = 76      YB = 76
        SB = 75      GB = 75      BE = 75      BW = 75
        RO = 75      WO = 75      BO = 75      EL = 75
        GU = 75      HI = 75      HH = 75      OH = 75

2.      ENTER DIAMETER CLASS SIZE
        2

3.      ENTER NUMBER OF STRATA
        3

4.      INVENT USES THE 95% CONFIDENCE LEVEL AS A DEFAULT.
        DO YOU WISH TO USE A DIFFERENT LEVEL?
        YES
4A.     ENTER CONFIDENCE LEVEL AS A DECIMAL IN THE RANGE .65 TO .99
        .90
```

Answering YES to question 1 envokes the alternate form class option. Question 1a asks for the file name while question 1b gives the user the option to list the new form classes. These form classes are the ones described on page 19. Answering YES to question 4 allows the user to specify an alternate confidence level.

SECTION 3. PROGRAM DOCUMENTATION

The FORTRAN program consists of the main program: INVENT; nine subprograms: FRMCLS, LINREG, GUTS, VOLMER, VOLTOT, STRAT, OUTP1, MDSTI, and MDNRIS; and five named common storage areas: COMUNE, FORMCL, REG, OUT1, and STOUT. A description of each along with a variable dictionary are presented below. The program listings are found in Appendix E.

Common Area COMUNE

COMUNE transfers job control information from the main program to the subroutines.

Variable	Type	Dimension	Description
ACRES	Real	-	Acreage of compartment
BAF	Real	-	Prism factor or plot size
CLASIZ	Int	-	Diameter class size
FRAME	Real(C*5)[1]	-	Sampling method
IFILE	D.P.(C*10)	-	Input file name
LOGANS	Int (C*4)	-	Height measurement length technique
MULT	Int	-	Conversion factor to transform logs to feet
PROBLV	Real	-	Two-tailed area under t-curve
REGANS	Int (C*3)	-	Regression option indicator
SAMMTD	D.P.(C*8)	-	Output title indicating sampling method used
TITLE	Int (C*5)	14	Compartment title
TOPANS	Int (C*5	-	Height measurement top technique

Common Area FORMCL

FORMCL transfers the form class array.

Variable	Type	Dimension	Description
FC	Int	32	Form class array

Common Area REG

REG transfers information to and from the regression subroutine.

Variable	Type	Dimension	Description
MEANY	Real	35	Average height
MINDBH	Int	32	Minimum diameter sampled for height
NTR	Int	35	Number of height trees sampled
REGCOF	Real	33	Regression slope
REGINT	Real	33	Regression intercept
RSQR	Real	33	Coefficient of determination
SEREG	Real	35	Standard error of the regression
SPECIE	Int (C*2)	32	Species code
TOTNTR	Int	35	Number of non-cull trees above minimum d.b.h. sampled

[1] (C*5) indicates the variable is used to store 5 characters.

Common Area OUT1

OUT1 transfers processed data to the output subroutine.

Variable	Type	Dimension	Description
BASPAC	Real	40,35	Basal area/acre by d.b.h.
BASTOT	Real	35	Basal area/acre
BDTOT	Real	35	Sawlog bd.ft. volume
BDVLSM	Real	40,35	Sawlog bd.ft. volume by d.b.h.
CBTOT	Real	35	Sawlog cub.ft. volume
CBVLSM	Real	40,35	Sawlog cub.ft. volume by d.b.h.
FINPOP	Real	--	Finite population correction
NPNTS	Int	--	Number of sample units sampled
PLTOT	Real	35	Pulpwood cub.ft. volume
PLVLSM	Real	35	Pulpwood cub.ft. volume by d.b.h.
SEBRD	Real	35	Sawlog bd.ft. volume standard error
SECUB	Real	35	Sawlog cub. ft. volume standard error
SEPUL	Real	35	Pulpwood cub.ft. volume standard error
TREPAC	Real	40,35	Trees/acre by d.b.h.
TRETOT	Real	35	Trees/acre
VARBRD	Real	35	Sawlog bd.ft. volume variance
VARPUL	Real	35	Pulpwood cub.ft. volume variance

Note: All volumes are per acre

Common Area STOUT

STOUT transfers combined strata information to the output subroutine.

Variable	Type	Dimension	Description
BDTST	Real	35	Sawlog bd.ft. volume
BDVLST	Real	40,35	Sawlog bd.ft. volume by d.b.h.
CBTST	Real	35	Sawlog cub.ft. volume
CBVLST	Real	40,35	Sawlog cub.ft. volume by d.b.h.
EFDFBD	Real	35	Sawlog bd.ft. volume effective d.f.
EFDFCB	Real	35	Sawlog cub.ft. volume effective d.f.
EFDFPL	Real	35	Pulpwood cub.ft. volume effective d.f.
PLTST	Real	35	Pulpwood cub.ft. volume
PLVLST	Real	40,35	Pulpwood cub.ft. volume by d.b.h.
STSEBD	Real	35	Sawlog bd.ft. volume standard error
STSECB	Real	35	Sawlog cub.ft. volume standard error
STSEPL	Real	35	Pulpwood cub.ft. volume standard error
TACRES	Real	--	Total acres sampled

Note: All volumes are total

Main Program INVENT

INVENT provides interactive user communication and subroutine control. Input and output are to unit 5 which is the user's TTY on the DEC-10. The following job control information is acquired interactively from the user:

(1) Alternate form class specification.

(2) Diameter class size.

(3) Number of strata.

(4) Confidence level.

(5) Input file name.

(6) Sampling method and sampling frame.

(7) Method of height measurement.

(8) Acreage of strata.

(9) Title of combined strata output (if more than one strata).

INVENT opens the output file on unit 3 (LPT on DEC-10) naming it INVENT.LPT. INVENT also sets the default confidence level to 95 percent.

The following subroutine calls are made in INVENT: FRMCLS, LINREG, GUTS, OUTP1, OUTP2, STRAT, and STRAT2.

Common Area Used: COMUNE.

Other Variables	Type	Dimension	Description
ALPHA	Real	--	Confidence level as a decimal
ALPHCH	Real(C*3)	--	Confidence level change flag
FRMANS	Real(C*3)	--	Form class change flag
III	Int	--	Loop counter for strata number
ISTRAT	Int	--	Number of strata
REPEAT	D.P.(C*8)	--	User message
SVFRAM	Real(C*5)	--	Saves the contents of FRAME

Subroutine FRMCLS

FRMCLS is called by INVENT if the user specifies that he wishes to use alternate form classes. FRMCLS interactively asks the user to specify the name of the file where the alternate form classes are stored. This file is read from unit 1 (disk on DEC-10). As in INVENT, unit 5 is used to communicate with the user. The user is given the option to list the new form classes after they are read from the file.

Common Areas Used: FORMCL and REG.

Other Variables	Type	Dimension	Description
FCFILE	D.P.(C*10)	--	Input file name
I	Int	--	Implied do loop index
LSTANS	Int	--	Form class list option flag

Subroutine LINREG

LINREG is called by INVENT if the user specifies that only the heights of a subsample of the volume trees were measured. LINREG then reads through the data file specified by the variable IFILE and located on unit 21 (disk on DEC-10). For every species with three or more height trees measured, LINREG fits the following regression model: HEIGHT = $B_0 + B_1 * 1/DBH$. The following statistics are calculated and stored in common area REG:

(1) Regression intercept.

(2) Regression slope.

(3) Standard error of the regression.

(4) Number of height trees measured.

(5) Total number of merchantable trees sampled.

(6) Average height.

(7) Coefficient of determination (R^2).

(8) Minimum diameter of all height trees sampled if less than 8 inches.

LINREG ignores cull trees (HEIGHT = 999). It also checks that input parameters are within the following ranges:

$1 \leq$ DBH ≤ 40 $0 \leq$ HEIGHT ≤ 7 if height measured by logs.

$0 \leq$ HEIGHT ≤ 200 if height measured in feet.

If data is found outside these ranges, the value is set to the minimum or maximum of the range. If an illegal species code appears, the tree is ignored and an error message is written to unit 5.

LINREG also calculates certain statistics for the Softwood, Hardwood and All Species accumulations. These statistics include (3), (4), (5) and (6) above.

Common Area Used: REG.

Other Variables	Type	Dimension	Description
CORMNY	Real	--	Corrected mean height for species
CORNTR	Real	--	Corrected number of trees sampled
COVXY	Real	33	Covariance of X and Y
DBH	Int	--	Diameter at breast height
HEIGHT	Real	--	Tree height
IDUMMY	Int	--	DO loop index for reps on input
IREP	Int	--	Number of reps on input
ISPEC	Int	--	Species loop counter
ITYPE	Int	--	Forest type code
JTYPE	Int	--	Forest type code
LOOP	Int	--	Loop counter
MEANX	Real	35	Mean of X
MEANY	Real	35	Mean of Y
MNYCOR	Real	3	Corrected mean height for forest types

Other Variables	Type	Dimension	Description
MSE	Real	--	Mean square error
NTRCOR	Int	3	Corrected number of trees for forest type
NUMREG	Int	3	Number of regressions run
POINT	Int	--	Point number
SPEC	Int(C*2)	--	Species input code
SSE	Real	--	Sum of the squares of error
TREES	Int	--	Number of trees on a sample unit
TYPSSE	Real	3	Forest type error sum of squares
VARX	Real	33	Variance of X
VARY	Real	33	Variance of Y
X	Real	33	1/D.B.H.
XSUM	Real	33	Sum of X
XSUMSQ	Real	33	Sum of X^2
Y	Real	33	Height
YSUM	Real	35	Sum of Y
YSUMSQ	Real	33	Sum of Y^2

Subroutine GUTS

GUTS is called by INVENT to read the input data and calculate the basal area per acre, trees per acre, and all of the volumes along with their standard errors. GUTS also calculates the number of units sampled and the percent cruise. Either subroutine VOLMER or VOLTOT is called by GUTS repeatedly to calculate tree volume.

GUTS reads the input file specified by the variable IFILE and located on unit 21 (disk on DEC-10). It checks the range of input data in the same way LINREG does except that the minimum allowed DBH is set at the value of CLASIZ instead of 1.

GUTS checks the value of POINT on the first plot to see if POINT = -9. Such a value indicates the data is presented in summary mode (not tallied by individual plot) and therefore no statistical analysis of the sampling error can be made. It also indicates that the value of TREES is the number of plots sampled.

GUTS reads all the data accumulating sums of basal areas, number of trees, sawlog board foot volume, sawlog cubic foot volume, and pulpwood cubic foot volume. After all the data is read, the accumulated sums are expanded into per acre estimates based on the sampling technique used (point or plot). The variances and standard errors of these volumes are also calculated. Before attempting to calculate variances, GUTS checks to see if more than one plot has been sampled. If not, GUTS sets itself into summary mode and does not attempt to calculate any variances or standard errors.

Common Areas Used: COMUNE, REG, and OUT1.

Other Variables	Type	Dimension	Description
DBVOL	Real	--	Board foot volume of a tree
BRDPT	Real	35	Sawlog bd.ft. volume of a sample unit
BRDSQ	Real	35	Sum of $BRDPT^2$
CUBPT	Real	35	Sawlog cub.ft. volume of a sample unit
CUBSQ	Real	35	Sum of $CUBPT^2$
CUBVOL	Real	--	Cubic foot volume of a tree
DBH	Int	--	Diameter at breast height
FACTOR	Real	--	Sample method expansion factor
HEIGHT	Real	--	Tree height
I	Int	--	DO loop index
IREP	Int	--	Number of reps on input
ISPEC	Int	--	Species loop counter
ISTART	Int	2	First of a forest type
ISTOP	Int	2	Last of a forest type
LOOP	Int	--	Loop counter
NPLOTS	Int	--	Number of plots sampled
PCTCRZ	Real	--	Percent cruise
PCTSAW	Real	--	Percent sawlog
PLTSIZ	Real	--	Fixed radius plot size
POINT	Int	--	Point number
PROD	Real(C*1)	--	Product code
PULPT	Real	35	Pulpwood cub.ft. volume of a sample unit
PULSQ	Real	35	Sum of $PULPT^2$
PULVOL	Real	--	Pulpwood cub.ft. volume of a tree
REGWGT	Real	--	Weight for regression standard error
SPEC	Int(C*2)	--	Species input code
TRECNT	Int	40,32	Number of trees tallied by d.b.h.
TREES	Int	--	Number of trees on a sample unit
VARCUB	Real	--	Sawlog cub.ft. volume variance

Subroutine VOLMER

VOLMER is called by GUTS to calculate the merchantable cubic and board foot volume of individual trees when tree height is specified to a merchantable top. The input parameters are d.b.h., merchantable height, and species.

The cubic foot volume equations are from Barnard et al. (1969). To use these equations all species must be placed in one of seventeen groups. The species grouping is as follows:

Species Group Number	Species in Group
1	WP, RP, OH
2	SP
3	BF
4	HM
5	PP, TA, NS, SC
6	CE
7	SM
8	RM, YP
9	WA, AS
10	BC
11	WB, YB, SB, GB
12	BE
13	B
14	RO, BO, GU
15	WO, EL
16	HI
17	WI, HH, OH

The board foot volume equation is from Wiant and Castenada (1977). This equation is a formulation of the Mesavage and Girard (1946) form class tables. A form class must be specified for each of the 32 species. VOLMER sets the form classes to the following defaults:

Hemlock	70
All other softwoods	76
All hardwoods	74

The user can specify alternate form classes at execution time.

The cubic foot equations are based on a 4" merchantable top while the board foot equations are based on a 10" merchantable top. The equations are presented in full in Appendix C, pages 56 and 57.

Common Area Used: FORMCL.

Other Variables	Type	Dimension	Description
BDHT	Real	--	Board ft. merchantable height in logs
BDVOL	Real	--	Board ft. volume of tree
CBHT	Real	--	Cubic ft. merchantable height in feet
CUBINT	Real	17	Cubic ft. volume equation intercept
CUBSLP	Real	17	Cubic ft. volume equation slope
CUBVOL	Real	--	Cubic ft. volume of tree
DBH	Int	--	Diameter at breast height
GRP	Int	32	Species group for cub.ft. volume equation
HEIGHT	Real	--	Tree height
I	Int	--	Implied DO loop index for data statements
ISPEC	Int	--	Species loop counter
WIANT	Real Function		Computes board foot volume

Subroutine VOLTOT

VOLTOT is called by GUTS to calculate the merchantable cubic and board foot volume of individual trees when total tree height is measured. The input parameters are d.b.h., total height, and species.

Both the cubic and board foot equations are from Honer (1967). In applying these formulas, the gross cubic foot volume of the tree is first calculated. The merchantable cubic and board foot volumes are then derived from the gross volume. To use these equations it is necessary to place all species into one of 16 groups. The species grouping is as follows:

Species Group Number	Species in Group
1	WP
2	RP, PP, TA, SC, OS
3	SP, NS
4	BF
5	CE
6	HM
7	AS
8	WB, SB, GB
9	YB
10	SM, RM, YP
11	BW
12	BE
13	BC
14	EL
15	WI, HH, OH
16	RO, WO, BO GU, HI, WA

Stump height and merchantable top are variables in the equations. VOLTOT sets these to the following defaults:

Stump Height	0.5 ft.
Cubic Foot Top	4 in.
Softwood Board Foot Top	6 in.
Hardwood Board Foot Top	8 in.

The equations are presented in full in Appendix C, page 58.

No common area used.

Variables	Type	Dimension	Description
ASDRBF	Real	3	Board foot volume equation coefficients
ASDRCF	Real	3	Cubic foot volume equation coefficients
BDVOL	Real	--	Sawlog bd.ft. volume of tree
BRDTOP	Real	2	Bd.ft. merchantable top diameter
CUBINT	Real	16	Cub.ft. volume equation intercept
CUBSLP	Real	16	Cub.ft. volume equation slope
CUBTOP	Real	2	Cub.ft. merchantable top diameter
CUBVOL	Real	--	Cubic ft. volume of tree
DBH	Int	--	Diameter at breast height
GRP	Int	32	Species group for volume equations
HEIGHT	Real	--	Tree Height
I	Int	--	Implied DO loop index for data statements
ISPEC	Int	--	Species loop counter
ITYPE	Int	--	Forest type indicator
STUMP	Real	--	Stump height
TCBVOL	Real	--	Total cubic foot volume
XBRD	Real	--	Intermediate step in bd.ft. volume calculation
XCUB	Real	--	Intermediate step in cub.ft. volume calculation

Subroutine STRAT

STRAT is called by INVENT if more than one stratum are being processed. STRAT calculates combined strata statistics for sawlog cubic foot volumes, sawlog board foot volumes and pulpwood cubic foot volumes. These statistics include total volume over all strata along with their standard error and effective degrees of freedom. STRAT also calculates the total acreage of all the strata combined.

STRAT has two entry points, STRAT and STRAT2. STRAT is used as an entry point after each individual stratum is processed. Sums are accumulated for volumes, variances, and squared variances. STRAT2 is called after all of the strata have been processed. The previously accumulated sums are used to calculate total volumes, standard errors, and effective degrees of freedom.

Common Areas Used: OUT1 and STOUT.

Other Variables	Type	Dimension	Description
ACRES	Real	--	Acreage of compartment
CLASIZ	Int	--	Diameter class size
DBH	Int	--	Diameter at breast height
DFBD2	Real	32	Intermediate calculation in EFDFBD
DFCB2	Real	32	Intermediate calculation in EFDFCB
DFPL2	Real	32	Intermediate calculation in EFDFPL
ISPEC	Int	--	Species loop counter
STVMBD	Real	35	Sawlog bd.ft. variance
STVMCB	Real	35	Sawlog cub.ft. variance
STVMPL	Real	35	Pulpwood cub.ft. variance
I	Int	--	Implied DO loop index
J	Int	--	Implied DO loop index

Subroutine OUTP1

OUTP1 is called by INVENT to produce all of the program's output. The subroutine has two entry points, OUTP1 and OUTP2. OUTP1 is used to produce the individual stratum output while OUTP2 is used to produce the stratified total output. All output is written to unit 3 (LPT on DEC-10) creating a file named INVENT.LPT.

OUTP1 produces the following output tables for each stratum:

1. Summary of job control related information (Table 1).
2. Analysis of the height-dbh relationship if regression option used (Table 17).
3. Individual stand and stock table for each species sampled (Tables 2, 3).
4. Stand and stock tables for Softwood summary, Hardwood summary, and All Species summary (Tables 4, 5, 6).
5. Table of species composition by percent (Table 7).
6. Table of volume totals for all species (Table 8).
7. Table of volume totals for all species expanded by acreage (Table 9).

The stand and stock tables include basal area/acre, trees/acre, sawlog cubic and board foot volumes per acre, and pulpwood cubic foot volume per acre, all presented by diameter class as well as a total over all diameters. A confidence interval expressed as a percent is given for each volume total. Also listed are mean stand diameter, merchantable m.s.d. (mean stand diameter of trees with dbh greater than or equal to 8 inches), percent cruise, sawlog board foot coefficient of variation, and pulpwood cubic foot coefficient of variation. Furthermore, the title of each compartment is printed on the top of each page and the pages are consecutively numbered.

OUTP2 is used as an entry point to produce the following stratified total output if more than one stratum were sampled:

1. Summary of job control related information (Table 10).
2. Volume tables for each species sampled (Table 11, 12).
3. Volume tables for Softwood summary, Hardwood summary, and All Species summary (Tables 13-15).
4. Table of volume totals for all species (Table 16).

All volume figures from OUTP2 are total volumes expanded over the entire acreage of all the strata combined. The individual species tables and the three summary tables list volumes by diameter class as well as giving a total over all diameters. A confidence interval expressed as a percent is given for each volume total. Each page of the output is consecutively numbered and a specified title is printed at the top of each page.

Both OUTP1 and OUTP2, when producing individual species tables, will print the form class used to calculate board foot volume next to the species title if the trees were measured to a merchantable top. Otherwise, no form class information is printed.

Common Areas Used: COMUNE, FORMCL, OUT1, REG, and STOUT.

Other Variables	Type	Dimension	Description
AFCNUM	Real(C*2)	--	Form class number as a literal
AFCTIT	Real(C*5)	--	Output title
ALPHA	Real	--	Confidence level as a decimal
BASCOM	Real	--	Percentage of basal area
BDCOM	Real	--	Percentage of sawlog bd.ft. volume
CUBCOM	Real	--	Percentage of sawlog cub.ft. volume
DBH	Int	--	Diameter at breast height
DF	Real	--	Degrees of freedom
I	Int	--	Implied DO loop index for data statements
IBDCV	Int	--	Board ft. coefficient of variation
IBDTST	Int	--	Total sawlog bd.ft. volume all strata
IBDVST	Int	--	Total sawlog bd.ft. volume all strata by dbh
ICBTST	Int	--	Total sawlog cb.ft. volume all strata
ICBVST	Int	--	Total sawlog bd.ft. volume all strata by dbh
IDATE	Int(C*5)	2	Date
IERBRD	Int	--	Percent error in sawlog bd.ft. volume
IERCUB	Int	--	Percent error in sawlog cb.ft. volume
IERPUL	Int	--	Percent error in pulpwood cb.ft. volume
IFLAG	Int	--	Warning message flag
IPAGE	Int	--	Page number
IPLCV	Int	--	Pulpwood coefficient of variation
IPLTST	Int	--	Total pulpwood cb.ft. volume all strata
IPLVST	Int	--	Total pulpwood cb.ft. volume all strata by dbh
ISPEC	Int	--	Species loop counter
ISTRA	Int	--	Number of strata sampled
J	Int	--	Implied DO loop index
MSD	Real	--	Mean stand diameter
OFRAME	Real(C*5)	--	Saves the contents of FRAME
PCTCRZ	Real	--	Estimated percent cruise for point sampling
PULCOM	Real	--	Percentage of pulpwood volume
RBSTOT	Real	--	Basal area of trees with dbh $\leq$ 8"
REGUSE	Real(C*4)	--	Output message
RMSD	Real	--	Merchantable mean stand diameter
RTRTOT	Real	--	Trees/acre of trees with dbh $\leq$ 8"
SPETIT	Int(C*5)	35,3	Species titles for output

Other Variables	Type	Dimension	Description
TOTABD	Int	--	Total sawlog bd.ft. volume
TOTACB	Int	--	Total sawlog cb.ft. volume
TOTAPL	Int	--	Total pulpwood volume
TOTPTS	Int	--	Total number of sample units
TRECOM	Real	--	Percentage of trees/acre
TVAL	Real	--	t-value

Subroutines MDSTI and MDNRIS

MDSTI and MDNRIS are adapted from the International Mathematical and Statistical Libraries, Inc. (IMSL). Both subroutines have been edited removing capabilities not needed in this application. The remaining code is reproduced in Appendix E in accordance with the IMSL policy on research work as stated on page INTRO-22 of the July, 1977 IMSL library manual.

MDSTI is called by OUTP1 to calculate the percentage point of the Student's t distribution. MDNRIS is called by MDSTI and is used to evaluate the inverse normal probability distribution function. MDSTI gives 5 significant digit accuracy (IMSL 1977). Furthermore, table 26.10, p. 999 of the Handbook of Mathematical Functions edited by Abramowitz and Stegun was duplicated by MDSTI (IMSL 1977).

No variable dictionary is presented. The interested reader may refer to pages MDSTI-1, MERFI/MERFCI/MDNRIS-1, and MERFI/MERFCI/MDNRIS-2 of the 1977 IMSL Library manual.

SECTION 4. STATISTICAL ANALYSIS

Overview

The purpose of INVENT's statistical analysis is to indicate the reliability of the volume estimates. This is accomplished by computing a confidence interval for all volume estimates that are summed across the diameter classes. This confidence interval is specified as a percent of the respective volume estimate. The user specifies the confidence level as a decimal in the range .65 to .99. All statistical analysis assumes a stratified random sample where each sample unit is a cluster. There is an option to double sample for height within the clusters.

INVENT calculates confidence intervals for sawlog cubic foot volume, sawlog board foot volume, and pulpwood cubic foot volume. The analysis for each volume is carried out independently of the other volumes. Since the method is exactly the same for each volume, the calculation of error for an arbitrary volume V is presented. Throughout the discussion we will assume the reader is familiar with the techniques for calculating the mean volume per acre when the heights of all volume trees are measured. (Cf. Barrett and Nutt, 1975; Avery, 1975; Husch, Miller, and Beers, 1972; Dillworth and Bell, 1976.)

The statistical analysis is presented in the same sequence as the program performs it. For each individual stratum the standard error of the volume must be calculated. If the height subsampling option is used, the program first calculates the standard error due to height estimation. Next the percent cruise of the stratum is calculated. This is used to refine the standard error due to the variation between clusters which is calculated next. This standard error is then combined with the height estimation standard error to give the volume standard error of the stratum. Finally, the volume standard errors of all the strata are combined to yield the standard error of the stratified volume estimate along with the effective degrees of freedom of that estimate.

Standard Error of Height Estimation

INVENT allows the user to double sample within each cluster for tree height. For each species where three or more height trees are measured within the stratum, a regression relationship between height and the inverse of d.b.h. is analysed. When calculating volume for a tree whose height was not measured, the regression equation is used to generate a height for that tree. If the user were required to measure the heights of all trees on some of the clusters while measuring no heights on the remaining clusters, the volume standard error could be calculated using techniques developed by Donald Bruce (1961) and Floyd A. Johnson (1958). Bruce's method is outlined in Appendix B, page 53. Johnson's method is an application of double sampling with ratio of means estimation and this method is presented in Appendix B, page 52. Neither method is applicable if the user is free to subsample a portion of the trees within each cluster. A new statistical technique was developed to approximate the standard error of the resulting volume estimate.

The authors believe that this new technique is far more efficient in field application. It allows the user to sample heights more intensely on the more valuable species. It provides far more flexibility than the traditional approach.

H = height   D = d.b.h.   T = # trees sampled   t = # height trees sampled

Regression Model: $H = B_0 + B_1 \left(\frac{1}{D}\right) + \varepsilon$

$$\text{Variance (H)} = S_H^2 = \frac{MSE}{t}$$

where MSE = mean square error of the regression (for computational formula see Neter and Wasserman, 1974, p. 45).

$$\text{Standard Error (H)} = SE_H = \frac{S_H}{\bar{H}} (100)$$

SE_H is calculated for every species where three or more height trees are measured. It is also necessary to calculate SE_H for the Softwood, Hardwood and All Species summary volumes. The method used is from Neter and

Wasserman pp. 163-4 (1974). It is equivalent to fitting a regression for each of the three groups using pooled data from each species in the group. However the method used is far more efficient. We simply define T^*, t^*, and MSE^* for each summary group as a function of T, t, and MSE for every species in that group. For instance, suppose we want SE_H for hardwoods where the hardwood group in this stratum consists of three species. Then,

$$T^* = T_1 + T_2 + T_3$$

$$t^* = t_1 + t_2 + t_3$$

$$MSE^* = \frac{MSE_1(t_1-2) + MSE_2(t_2-2) + MSE_3(t_3-2)}{(t_1-2) + (t_2-2) + (t_3-2)}$$

Using these new values, SE_H is calculated as before.

Percent Cruise

Percent cruise is simply the percent of the population actually sampled. When sampling with fixed-radius plots, percent cruise is easily calculated as follows:

Let P = percent cruise

PLT = plot size in acres

n = number of plots sampled

AC = tract size in acres

Then, $P = \frac{n \cdot PLT}{AC} (100)$

When sampling with variable-radius plots (point sampling) the true value of P is unknown. However, based on our sample estimate of MSD we can estimate the value of P (Cunia, 1959).

Let P = percent cruise

n = number of sample points

AC = tract size in acres

BAF - basal area factor of angle used

B = total basal area of all trees on tract

T = total number of trees on tract

MSD = mean stand diameter (quadratic mean)

Then, $P = \frac{100 \cdot n \cdot B}{T \cdot AC \cdot BAF} = \frac{0.5454 \cdot n \cdot MSD^2}{AC \cdot BAF}$

It should be noted that in a variable-radius cruise, the percent cruise may be different for each species. See tables 2 and 3.

In forest sampling, we deal with finite populations. The formula we use to estimate the variance of the mean volume per acre for each stratum includes a term known as the finite population correction (FPC). The FPC reduces the variance of the mean when a significant (usually > 5 percent) portion of the population has been sampled.

Let N = number of sample units in population

n = number of units actually sampled

Then, $FPC = \frac{N - n}{N}$

In plot sampling $N = \frac{AC}{PLT}$ and n = number of plots sampled. However, in point sampling there is no easy was to calculate N. Therefore, mensurationists have traditionally ignored the FPC when analysing point cruises. This can be quite inefficient when tract sizes are small as is often the case in New Hampshire. This problem can be easily overcome using the previous result permitting the calculation of percent cruise when point sampling. It can easily be shown that the FPC is simply a function of P (percent cruise).

$$FPC = \frac{N - n}{N} = \frac{N}{N} - \frac{n}{N} = 1 - \frac{n}{N} = 1 - \frac{P}{100}$$

INVENT uses this relationship to refine the variance estimates when point sampling as well as plot sampling. INVENT calculates FPC as $1 - \frac{P}{100}$.

The standard error due to the variation in volume between clusters, $SE_{\overline{Y}}$, is calculated as follows:

$\overline{Y}$ = mean volume/acre of stratum

S^2 = sample variance of volume

n = number of sample units

then, $SE_{\overline{Y}} = \sqrt{\frac{S^2}{n}} \left[\frac{1}{\overline{Y}} \right] (100) \quad (FPC)$

If the height of all volume trees was measured, then $SE_{\overline{Y}}$ is the standard error of the volume estimate for the stratum, SE_{VOL}. If, however, the height double sampling option was used, SE_{VOL} must reflect both $SE_{\bar{Y}}$ and SE_H, the standard error due to height estimation. In this case, SE_{VOL} is calculated as follows:

$$SE_{VOL} = \sqrt{SE_{\bar{Y}}^2 + \frac{(T - t)}{T} (SE_H^2)}$$

Combined Strata Statistics

We have seen how INVENT calculates the mean volume/acre with its standard error for each stratum in the sample. The final step in the statistical analysis is to use the individual stratum statistics to calculate the total volume across all strata along with the standard error.

Let L = number of strata sampled

AC_i = size of stratum i in acres

N_i = number of sample units in stratum i

n_i = number of units sampled in stratum i

$\bar{Y}_i$ = mean volume per acre of stratum i

VOL_i = total volume of stratum i = $AC_i \cdot \bar{Y}_i$

SE_{VOL_i} = volume standard error of stratum i as a percent

$S_{VOL_i}^2$ = $(SE_{VOL_i}^2 \cdot VOL_i^2) / 100^2$ = variance of total volume

then we calculate the stratified total statistics as follows:

$$AC = \sum_{i=1}^{L} AC_i = \text{total acreage sampled}$$

$$VOL = \sum_{i=1}^{L} VOL_i = \text{stratified total volume}$$

$$SE_{VOL} = \frac{\sqrt{\sum_{i=1}^{L} S_{VOL_i}^2}}{VOL} (100)$$

Having calculated VOL and SE_{VOL}, all that remains in calculating the confidence interval is determining the appropriate percentage point of the Student's t distribution. In order to do this we must calculate the degrees of freedom associated with S_{VOL}^2. Satterthwaite (1946) states that the exact distribution of the complex estimate S_{VOL}^2 is too involved for everyday use. He suggests approximating the true distribution with a Chi-square distribution of equal variance. Cochran (1977 p. 96) uses this approach and defines the degrees of freedom of the approximating Chi-square as:

$$DF_{eff} = \frac{\left[\sum_{i=1}^{L} g_i s_i^2\right]^2}{\sum_{i=1}^{L} \frac{g_i^2 s_i^4}{n_i - 1}} \qquad \text{where} \quad g_i = \frac{N_i\,(N_i - n_i)}{n_i}$$

$$s_i^2 = \text{sample variance}$$

A more appropriate form for our purposes is given by

$$DF_{eff} = \frac{\left[\sum_{i=1}^{L} s^2_{VOL_i}\right]^2}{\sum_{i=1}^{L} \frac{s^4_{VOL_i}}{n_i - 1}}$$

The equivalence of the two formulas is shown in Appendix B, page 54.

Using this result the appropriate value t is derived from the Student's t distribution and the confidence interval is given by:

$$VOL \pm t \cdot SE_{VOL}$$

APPENDIX A

DATA CODING INFORMATION

EXAMPLES OF TREE CODING OPTIONS

	Specie Code			Diameter		Product Code	Height				Replications		Percent Sawlog	
COLUMN:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sawlog only Height in logs	W	P		1	6	S	2	.	0		2			
Sawlog only Height in feet	R	P		1	8	S		4	8		1			
Pulpwood only Height in feet	B	E		1	0	P		2	0		1			
Mixed product Height in logs	R	O		1	6	%	2	.	0		3		5	0
Mixed product Height in feet	S	P		2	2	%		6	4		1		6	0
Sawlog only Height in logs Default specif-ication of reps and product.	H	M		1	2		1	.	0					

INVENT Species List

White Pine	WP
Red Pine	RP
Pitch Pine	PP
Hemlock	HM
Balsam Fir	BF
Tamarack	TA
Spruce	SP
Norway Spruce	NS
Scotch Pine	SC
Cedar	CE
Other Softwoods	OS
Sugar Maple	SM
Red Maple	RM
Ash	WA
Willow	WI
Aspen	AS
Yellow Poplar	YP
Black Cherry	BC
White Birch	WB
Yellow Birch	YB
Sweet Birch	SB
Grey Birch	GB
Beech	BE
Basswood	BW
Red Oak	RO
White Oak	WO
Black Oak	BO
Elm	EL
Gum	GU
Hickory	HI
Hophornbeam	HH
Other Hardwoods	OH

INVENT TALLY SHEET

COMP. 1

POINT 1 # TREES 11

SPECIES	DBH	HEIGHT	PRODUCT	#
RP	14	3.0		
WP	20	4.0		
RP	14	3.5		
WP	18	4.0		
WP	12	3.0		
WP	18	3.5		
WP	16	3.0		
WP	20	4.0		
WP	22	4.5		
WP	22	4.5		
RP	16	3.0		

COMP. 1

POINT 2 # TREES 12

SPECIES	DBH	HEIGHT	PRODUCT	#
WP	12	2.5		
WP	20	3.5		
WP	32	4.0		
RP	16	3.0		
BE	10	1.0		
BE	06	.5	P	2
WP	16	3.5		
WP	16	4.0		
WP	12	2.0		
RP	16	3.0		
WP	26	4.0		

COMP. 1

POINT 3 # TREES 9

SPECIES	DBH	HEIGHT	PRODUCT	#
WP	26	4.0		
WP	32	4.5		
RP	22	3.5		
RP	18	3.5		
RO	14	1.0		
RO	22	1.0		
RO	18	1.0		
WP	26	5.0		2

COMP. 1

POINT 4 # TREES 14

SPECIES	DBH	HEIGHT	PRODUCT	#
WP	22	4.0		
WP	30	4.0		
WP	30	4.0		
WP	20	3.5		
WP	20	4.0		2
WP	26	4.5		
WP	16	4.0		
WP	18	4.5		
WP	18	3.0		
WP	20	4.5		
WP	28	4.5		
WP	32	4.0		
WP	20	4.5		

INVENT DATA FILE

```
WHITAKER WOODS  1978   COMP. 1
01 11
RP 14 3.0
WP 20 4.0
RP 14 3.5
WP 18 4.0
WP 12 3.0
WP 18 3.5
WP 16 3.0
WP 20 4.0
WP 22 4.5
WP 22 4.5
RP 16 3.0
02 12
WP 12 2.5
WP 20 3.5
WP 32 4.0
RP 16 3.0
BE 10 1.0
BE 06P0.5 2
WP 16 3.5
WP 16 4.0
WP 12 2.0
RP 16 3.0
WP 26 4.0
03 09
WP 26 4.0
WP 32 4.5
RP 22 3.5
RP 18 3.5
RO 14 1.0
RO 22 1.0
RO 18 1.0
WP 26 5.0 2
04 14
WP 22 4.0
WP 30 4.0
WP 30 4.0
WP 20 3.5
WP 20 4.0 2
WP 26 4.5
WP 16 4.0
WP 18 4.5
WP 18 3.0
WP 20 4.5
WP 28 4.5
WP 32 4.0
WP 20 4.5
05 13
WP 24 3.0
RP 16 2.0
WP 32 4.0
WP 26 3.5
RO 12 1.0
HM 18 1.5
HM 16 1.0
RP 12 1.0
RP 10 1.0
RO 16 1.0 2
WP 14 2.5
HM 18 2.0
```

INVENT Processing Request Form

Forester Information:

Name: ____

Firm Name: ____

Address: ____

____

Tract Information:

Number of compartments: ____________

Do you wish to use alternate form classes? ________ (yes or no)

If yes enter form classes below.

WP____	RP____	PP____	HM____	BF____	TA____	SP____	NS____
SC____	CE____	OS____	SM____	RM____	WA____	WI____	AS____
YP____	BC____	WB____	YB____	SB____	GB____	BE____	BW____
RO____	WO____	BO____	EL____	GU____	HI____	HH____	OH____

Diameter class size ________

INVENT uses the 95% confidence level as a default. If you wish to use a different level, please specify ________ (65 - 99)

Tract Description (up to 70 characters)

: ____

INVENT Compartment Information Form

Compartment Name and/or Description (up to 70 characters)

: ____

Sampling Method ____________ (Point, Plot, Strip, or 100%)

If Point: BAF = _______

If Plot : Plot size = _________ acres

If Strip: Total acreage of all strips = _________ acres

Tree Height Measurement Units _______________ (16 ft. logs or feet)

Tree top specification _____________ (merchantable, total, or mixed)

Were the heights of all volume trees measured? _________ (yes or no)

Acreage of compartment: _______________ acres

APPENDIX B

STATISTICAL FORMULAS AND DERIVATIONS

DOUBLE SAMPLING WITH RATIO OF MEANS EXPANSION

X_i = Basal area per acre at cluster i

Y_i = Volume per acre at cluster i_j

N = Number of possible sample units

n = Total number of units sampled

n_o = Number of volume units sampled

$\overline{X}$ = Average basal area of all units sampled

$\overline{X}_o$ = Average basal area of the volume units sampled

$\overline{Y}_o$ = Average volume of the volume units sampled

$\overline{Y}_r$ = Ratio estimate of the mean volume per acre

$$B = \frac{\overline{Y}_o}{\overline{X}_o}$$

$$\overline{Y}_r = B \cdot \overline{X}$$

$$S^2_{\overline{Y}_r} = \left(\frac{n_o - n}{n_o}\right)\left(\frac{\overline{X}_o}{\overline{X}}\right)^2 \left(\frac{S_Y^2 + B^2 S_X^2 - 2BS_{XY}}{n}\right) + \frac{S_Y^2}{n_o}\left(\frac{N - n_o}{N}\right)$$

STATISTICAL ANALYSIS OF A VARIABLE PLOT CRUISE USING BRUCE'S METHOD

(Bruce 1961)

Notation

γ	-	volume points
α	-	all points
n	-	number of points
TC	-	tree count
VBAR	-	volume to basal area ratio
VOL	-	volume per acre
SE	-	standard error expressed as a percent
CF	-	correction factor

Example of Notation:

SE_{TC_α} - standard error of the tree count on all points expressed as a percent

$$\text{Estimated volume} = VOL_\gamma \cdot \left[\frac{TC_\alpha/n_\alpha}{TC_\gamma/n_\gamma}\right] = (VOL_\gamma \cdot TC_\alpha \cdot n_\gamma)/(TC_\gamma \cdot n_\alpha)$$

$$\text{Uncorrected standard error} = \sqrt{SE^2_{VBAR_\gamma} + SE^2_{TC_\alpha}}$$

$$\text{Corrected standard error} = CF \cdot (\text{uncorrected standard error})$$

$$\text{where } CF = \frac{SE_{VOL_\gamma}}{\sqrt{SE^2_{VBAR_\gamma} + SE^2_{TC_\gamma}}}$$

FORMULA FOR EFFECTIVE DEGREES OF FREEDOM

$$DF_{eff} = \frac{\left(\sum_{i=1}^{L} g_i S_i^2\right)^2}{\sum_{i=1}^{L} \frac{g_i^2 S_i^4}{n_i - 1}} \qquad \text{where} \quad g_i = \frac{N_i \, (N_i - n_i)}{n_i}$$

$$= \frac{\left(\sum_{i=1}^{L} \frac{N_i \, (N_i - n_i)}{n_i} \; S_i^2\right)^2}{\sum_{i=1}^{L} \frac{\left(\frac{N_i \, (N_i - n_i)}{n_i}\right)^2 S_i^4}{n_i - 1}}$$

$$= \frac{\left(\sum_{i=1}^{L} \frac{S_i^2}{n_i} \cdot \frac{(N_i - n_i)}{N_i} \; N_i^2\right)^2}{\sum_{i=1}^{L} \frac{\left(\frac{S_i^2}{n_i} \cdot \frac{(N_i - n_i)}{N_i}\right)^2 N_i^4}{n_i - 1}}$$

$$= \frac{\left(\sum_{i=1}^{L} S_{\bar{Y}_i}^2 \cdot N_i^2\right)^2}{\sum_{i=1}^{L} \frac{S_{\bar{Y}_i}^4 \cdot N_i^4}{n_i - 1}} = \frac{\left(\sum_{i=1}^{L} S_{VOL}^2\right)^2}{\sum_{i=1}^{L} \frac{S_{VOL}^4}{n_i - 1}}$$

APPENDIX C

VOLUME FORMULAS

CUBIC FOOT VOLUME EQUATIONS
BASED ON MERCHANTABLE HEIGHT
(Barnard et al. 1973)

General form of equation: $VOLUME = a + b\ (DBH^2 \cdot HEIGHT)$

where height is measured to a 4" top in ft.

Species Group	a	b
1	3.5142	0.00236
2	2.1998	.00257
3	1.4793	.00272
4	2.4784	.00242
5	-0.0496	.00303
6	1.5817	.00259
7	1.6823	.00310
8	1.1763	.00310
9	1.0067	.00293
10	1.1809	.00292
11	1.1339	.00281
12	1.2851	.00326
13	0.8976	.00349
14	1.2027	.00301
15	1.0009	.00300
16	1.4438	.00316
17	0.8591	.00309

For the species composition of each group see page 31.

BOARD FOOT VOLUME EQUATION

BASED ON MERCHANTABLE HEIGHT

(Wiant and Castenada 1978)

(INT. 1/4-inch Rule)

D = diameter at breast height

H = merchantable height to a 10" top in 16 foot logs

FC = Girard form class

$$\text{VOLUME} = [(a_0+a_1H+a_2H^2) + (b_0+b_1H+b_2H^2)D + (c_0+c_1H+c_2H^2)D^2] \; [(FC-78)(.03)+1]$$

where

a_0 = -13.35212

a_1 = 9.58615

a_2 = 1.52968

b_0 = 1.79620

b_1 = -2.59995

b_2 = -0.27465

c_0 = 0.04482

c_1 = 0.45997

c_2 = -0.00961

CUBIC AND BOARD FOOT VOLUME EQUATIONS

BASED ON TOTAL HEIGHT

(Honer 1967)

(INT. 1/4-inch Rule)

D = diameter at breast height
H = total height in feet
GCVL = gross cubic foot volume
MCVL = merchantable cubic foot volume
MBVL = merchantable board foot volume
STH = stump height
CTOP = cubic foot merchantable top diameter
BTOP = board foot merchantable top diameter

Equations:

$$GCVL = \frac{D^2}{a_0 + \frac{a_1}{H}}$$

$$X = \left[\frac{CTOP^2}{D^2}\right] \left[\frac{H + STH}{H}\right]$$

$$MCVL = [b_o + b_1 X + b_2 X^2] \cdot GCVL$$

$$Y = \left[\frac{BTOP^2}{D^2}\right] \left[\frac{H + STH}{H}\right]$$

$$MBVL = [c_o + c_1 Y + c_2 Y^2] \cdot GCVL$$

where

STH = 0.5 ft.
CTOP = 4.0 in. for all species
BTOP = 6.0 in. for softwoods
8.0 in. for hardwoods
b_0 = 0.9604
b_1 = -0.1660
b_2 = -0.7868
c_0 = 5.4332
c_1 = -1.6281
c_2 = -4.4710

Species Group	a_0	a_1
1	0.691	363.676
2	0.710	355.623
3	1.226	315.832
4	2.139	301.634
5	4.167	244.906
6	1.112	350.092
7	-0.312	436.683
8	2.222	300.373
9	1.449	344.754
10	1.046	383.972
11	0.948	401.456
12	0.959	334.829
13	0.033	393.336
14	0.634	440.496
15	1.877	332.585
16	1.512	336.509

For the species composition of each group see page 32.

APPENDIX D

INVENTORY DESIGN AND SAMPLE SIZE ESTIMATION

Inventory Design

INVENT analyzes data based on two sampling designs:

(1) simple random sampling,

(2) stratified random sampling with simple random sampling within each stratum.

Sampling is assumed without replacement--that is, sample units (plots or points) are far enough apart so that a tree is sampled on only one sample unit.[1]

INVENT allows for the possibility of double sampling regression estimation of volume. The error associated with regression estimation is small relative to the error among sample units. Thus, it is ignored in the discussion given below on sample size approximation.

Foresters commonly use systematic sampling rather than simple random sampling. Generally, estimates from systematic sampling are somewhat more precise than from simple random sampling provided the systematic sample units are spread well over the tract sampled. Therefore, confidence intervals based on simple random equations provide somewhat conservative estimates for well-representative systematically collected data. For the same reason, sample size is usually overestimated.

Sample Size

Sample size is treated briefly. More detailed explanations are given in Barrett and Nutt (1975), Cochran (1977), Freese (1962), and Dilworth and Bell (1976).

---

[1]If a tree is sampled on more than one sample unit, the estimated means are still unbiased but the variance is underestimated.

Simple Random Sample

Sample size from simple random sampling is estimated by the following equation:[2]

$$n = \left[\frac{t\ CV}{E}\right]^2 \qquad \text{Equation 1}$$

where t is a t-value, CV is the coefficient of variation, and E is the allowable error in percent.

The t-value depends on the confidence level desired. The approximate t-values for the most widely used confidence levels are:

Confidence level (percent)	t-value
80	1.3
90	1.7
95	2.0
99	2.7

The coefficient of variation is a measure of the variability among volume estimates in a forest based on a particular technique of sampling.

Assume that from past experience a forester estimates that the coefficient of variation is 50 percent when he samples with a 10 B.A.F. prism. He wants to estimate the volume on a tract with an allowable error of 10 percent at the 95 percent confidence level. That is, he wants the chances to be 95 in 100 that his estimate after completing the inventory is within 10 percent of the actual volume.[3]

The sample size by Equation 1 is estimated as follows:

$$n = \left[\frac{t\ CV}{E}\right]^2 = \left[\frac{2\ (50)}{10}\right]^2 = 100 \text{ points}$$

Thus, the forester must select 100 points.

---

[2] The estimate of sample size using simple random and the subsequent estimates using stratified random sampling can be adjusted by the equation

$$n_a = \frac{n}{1 + P/100}$$

where P is the percent cruise. This additional refinement in estimating sample size is generally not necessary except on small tracts.

[3] To be within 10 percent of the actual volume implies that errors such as tree measurement errors, errors in estimating form class, and errors in volume equations are negligible.

Stratified Random Sampling

Often a forester divides the area into compartments or stands before beginning the inventory. In other words he stratifies the area.

If the forester's primary interest is in the estimates within each stratum, then he can specify the allowable error for each stratum and apply Equation 1 to estimate sample size.

If his primary interest is in the mean volume per acre or total volume over all strata, then he can estimate sample size by one of two techniques. Each technique depends on how sample units are allocated to strata. The two techniques will be illustrated with an example.

First consider proportional allocation. By proportional allocation, the forester determines sample size and allocates sample units to strata in proportion to the acreage of each stratum. The equation for sample size is

$$n = \left[\frac{t}{E}\right]^2 \sum_{i=1}^{L} W_i CV_i^2 \qquad \text{Equation 2}$$

where t is the t-value, E is the allowable error, W_i is the proportion of acreage in stratum i, CV_i is the coefficient of variation in stratum i, and L is the total number of strata.

Assume a forester has the following information on an 80-acre tract he wishes to sample with a 10-B.A.F. prism.

Stratum	Acreage	W_i	CV_i	$W_i CV_i^2$
1. small pines	36	.450	30	405.00
2. large pines	18	.225	50	562.50
3. mixed pine-hardwood	26	.325	80	2080.00
Totals	80	1.000	--	3047.50

Suppose he wants to estimate the mean volume per acre within 10 percent with 95 percent confidence. Then, by applying equation 2, he estimates the number of points required.

$$n = \left[\frac{t}{E}\right]^2 \sum_{i=1}^{L} W_i CV_i^2 = \left[\frac{2}{10}\right]^2 (3047.50) = 122 \text{ points}$$

He would allocate points to strata as follows:

Stratum	W_i	$n \cdot W_i$
1	.450	55
2	.225	27
3	.325	40
Totals	1.000	122

By the second technique of allocation, called Neyman allocation, the forester takes into account the coefficient of variation as well as the relative acreage in each stratum in assigning sample units to strata. Neyman allocation minimized the number of sample units required to achieve a specified precision. The equation for sample size is

$$n = [\frac{t}{E}]^2 \cdot \left[\sum_{i=1}^{L} W_i CV_i \right]^2 \qquad \text{Equation 3}$$

To apply this equation to the data given above we require the following computations:

Stratum	W_i	CV_i	$W_i CV_i$
1	.450	30	13.50
2	.225	50	11.25
3	.325	80	26.00
Totals	1.000	--	50.75

Assuming an allowable error of 10 percent with 95 percent confidence, the forester estimates the number of points required.

$$n = [\frac{t}{E}]^2 \left[\sum_{i=1}^{L} W_i CV_i \right]^2 = [\frac{2}{10}]^2 \, (50.75)^2 = 103 \text{ points}$$

The points are allocated to strata as follows:

Stratum	$W_i CV_i$	$n \cdot W_i CV_i / \sum_{i=1}^{L} W_i CV_i$
1	13.50	27
2	11.25	23
3	26.00	53
Totals	50.75	103

Proportional and Neyman allocation are two of the most common allocations. Other techniques of allocation are given in the references cited.

APPENDIX E

PROGRAM LISTING

```
C
      PROGRAM INVENT
C
C***********************************************************************
C
C   INVENT   VER. 3    1/1/79   DAVID S. LINDEN  I.N.E.R.  U.N.H.
C
C
C   THIS IS THE MAIN PROGRAM OF INVENT
C   IT PROVIDES TWO WAY USER COMMUNICATION AND SUBROUTINE CONTROL
C
C***********************************************************************
      DOUBLE PRECISION IFILE,SAMMTD,REPEAT
      INTEGER LOGANS,TOPANS,CLASIZ,REGANS,TITLE(14)
      COMMON/COMONE/CLASIZ,TITLE,MULT,PROBLV,BAF,TOPANS,REGANS,ACRES
     1,FRAME,SAMMTD,LOGANS,IFILE
      DATA PROBLV/.05/
C OPEN OUTPUT FILE
      OPEN(UNIT=3,ACCESS='SEQOUT',FILE='INVENT.LPT')
C
C *********************************
C USER COMMUNICATION PORTION
C *********************************
C
C ASK USER IF HE WANTS TO USE ALTERNATE F.C.'S
   10 WRITE(5,20)
   20 FORMAT('0DO YOU WANT TO READ IN ALTERNATE FORM CLASSES ',
     1'FROM DISK?')
      READ(5,270) FRMANS
      IF(FRMANS.EQ.'YES')  CALL FRMCLS
      IF(FRMANS.NE.'NO'.AND.FRMANS.NE.'YES')  GOTO 10
C HAVE USER SPECIFY DBH CLASS SIZE
      WRITE(5,30)
   30 FORMAT('0ENTER DIAMETER CLASS SIZE')
      READ(5,*) CLASIZ
C HAVE USER SPECIFY NUMBER OF STRATA
      WRITE(5,40)
   40 FORMAT('0ENTER NUMBER OF STRATA')
      READ(5,*) ISTRAT
C ASK USER FOR NEW VALUE OF ALPHA IF DESIRED
   50 WRITE(5,60)
   60 FORMAT('0INVENT USES THE 95% CONFIDENCE LEVEL AS A DEFAULT.'/
     1' DO YOU WISH TO USE A DIFFERENT LEVEL?')
      READ(5,270) ALPHCH
      IF(ALPHCH.NE.'YES'.AND.ALPHCH.NE.'NO')  GOTO 50
      IF(ALPHCH.EQ.'NO')  GOTO 90
   70 WRITE(5,80)
   80 FORMAT(' ENTER CONFIDENCE LEVEL AS A DECIMAL IN THE RANGE ',
     1'.65 TO .99')
      READ(5,*) ALPHA
      IF(ALPHA.GT.0.99.OR.ALPHA.LT.0.65)  GOTO 70
      PROBLV=1.0-ALPHA
   90 CONTINUE
C
C--------------BEGIN PROGRAM CONTROL LOOP------------------------
C
      DO 310 III=1,ISTRAT
C
C HAVE USER SPECIFY INPUT FILE
      WRITE(5,100) III
  100 FORMAT('0ENTER INPUT FILE NAME FOR STRATUM # ',I3)
      READ(5,110) IFILE
  110 FORMAT(A10)
C OPEN INPUT FILE
      OPEN(UNIT=21,ACCESS='SEQIN',FILE=IFILE)
C READ INVENTORY TITLE FROM FILE
      READ(21,120) TITLE
  120 FORMAT(14A5)
C WRITE TITLE ON TERMINAL
      WRITE(5,130) TITLE
  130 FORMAT('0',14A5/)
      SVFRAM=FRAME
C HAVE USER SPECIFY SAMPLING METHOD
      IF(III.GT.1)  REPEAT=' OR SAME'
  140 WRITE(5,150) REPEAT
  150 FORMAT('0SPECIFY SAMPLING METHOD'/'   TYPE POINT OR PLOT',A8)
      READ(5,240) FRAME
      IF(FRAME.EQ.'SAME'.AND.III.GT.1)    160 , 170
```

```
  160 FRAME=SVFRAM
      GOTO 280
  170 IF(FRAME.NE.'POINT'.AND.FRAME.NE.'PLOT')  GOTO 140
      IF(FRAME.EQ.'POINT')  SAMMTD='B.A.F.'
      IF(FRAME.EQ.'PLOT')  SAMMTD='PLOT SIZE'
C HAVE USER SPECIFY BAF OR PLOT SIZE
      WRITE(5,180) SAMMTD
  180 FORMAT('0ENTER ',A9)
      READ(5,*) BAF
C ASK USER IF HEIGHTS ARE IN LOGS
  190 WRITE(5,200)
  200 FORMAT('0ARE HEIGHTS IN FEET OR SIXTEEN FT. LOGS?'/
     1'      TYPE FEET OR LOGS')
      READ(5,210) LOGANS
  210 FORMAT(A4)
      IF(LOGANS.NE.'FEET'.AND.LOGANS.NE.'LOGS')  GOTO 190
C ASK USER IF HEIGHTS ARE MERCHANTABLE OR TOTAL
  220 WRITE(5,230)
  230 FORMAT('0ARE HEIGHTS TOTAL OR MERCHANTABLE?'/
     1'      TYPE TOTAL, MERCH, OR MIXED')
      READ(5,240)TOPANS
  240 FORMAT(A5)
      IF(LOGANS.EQ.'FEET')  MULT=1
      IF(LOGANS.EQ.'LOGS')  MULT=16
      IF(TOPANS.NE.'TOTAL'.AND.TOPANS.NE.'MERCH'.AND.TOPANS.NE.'MIXED')
     1  GOTO 220
C ASK USER IF REGRESSION ROUTINE IS NEEDED
  250 WRITE(5,260)
  260 FORMAT('0WERE THE HEIGHTS OF ALL VOLUME TREES MEASURED?')
      READ(5,270) REGANS
  270 FORMAT(A3)
      IF(REGANS.NE.'YES'.AND.REGANS.NE.'NO')  GOTO 250
C ASK USER FOR ACREAGE
  280 WRITE(5,290)
  290 FORMAT('0ENTER ACREAGE OF TRACT.')
      READ(5,*) ACRES
C
C ************************************************************
C IF NEEDED RUN THE HEIGHT REGRESSION ROUTINE
C ************************************************************
C
      IF(REGANS.EQ.'NO')  CALL LINREG(IFILE,TOPANS)
C
C ******************************************
C  READ IN TREE DATA AND PROCESS
C ******************************************
  300 CALL GUTS
C
C **********************************
C CALL THE OUTPUT ROUTINE
C **********************************
C
      CALL OUTP1
C
C ****************************************
C ACCUMULATE TOTALS FROM EACH STRATA
C ****************************************
C
      IF(ISTRAT.GT.1)  CALL STRAT(ACRES,CLASIZ)
C
  310 CONTINUE
C
C----------------END PROGRAM CONTROL LOOP------------------------
C
C *************************************
C CALCULATE COMBINED STRATA STATISTICS
C *************************************
C
      IF(ISTRAT.GT.1)  CALL STRAT2
C
C
C ********************************
C OUTPUT STRATA COMBINED TOTALS
C ********************************
C
      IF(ISTRAT.GT.1)  CALL OUTP2
C
      END
```

```
C
      SUBROUTINE FRMCLS
C
C***********************************************************************
C
C   THIS SUBPROGRAM READS IN AN ARRAY OF FORM CLASSES FROM A
C   USER SPECIFIED DISK FILE.  THIS DISK FILE IS FREE FORMATTED
C   USING LIST DIRECTED INPUT.  THE USER IS GIVEN THE OPTION
C   TO LIST THE FORM CLASSES AFTER THEY ARE READ.
C
C***********************************************************************
C
      INTEGER FC(32),SPECIE(32)
      DOUBLE PRECISION FCFILE
      REAL REGCOF(33),REGINT(33),SEREG(35),RSQR(33),MEANY(35)
      INTEGER MINDBH(32),NTR(35),TOTNTR(35)
      COMMON/REG/REGCOF,REGINT,SPECIE,MINDBH,SEREG,NTR,RSQR,MEANY
     1,TOTNTR
      COMMON/FORMCL/FC
C HAVE USER SPECIFY FORM CLASS FILE NAME
      WRITE(5,10)
   10 FORMAT('0ENTER FORM CLASS FILE NAME')
C READ FORM CLASSES FROM FILE
      READ(5,20) FCFILE
   20 FORMAT(A10)
      OPEN(FILE=FCFILE,ACCESS='SEQIN',UNIT=1)
      READ(1,30) FC
   30 FORMAT(8(I2,X))
C ASK USER IF HE WANTS TO LIST FORM CLASSES JUST READ
   40 WRITE(5,50)
   50 FORMAT('0DO YOU WANT A LIST OF THE FORM CLASSES JUST READ?')
      READ(5,60) LSTANS
   60 FORMAT(A3)
      IF(LSTANS.NE.'YES'.AND.LSTANS.NE.'NO')     GOTO 40
      IF(LSTANS.EQ.'NO')     RETURN
      WRITE(5,70) (SPECIE(I),FC(I),I=1,32)
   70 FORMAT('0',8(/' ',4(A2,' = ',I2,5X)))
      RETURN
      END
```

```
C
      SUBROUTINE LINREG(IFILE,TOPANS)
C
C***********************************************************************
C
C   THIS SUBPROGRAM READS IN DATA FROM ALL THE SAMPLE TREES
C   IT FINDS THE TREES WITH HEIGHT MEASUREMENTS
C   IT THEN FITS A REGRESSION MODEL FOR EACH SPECIE SAMPLED
C
C        MODEL:  HEIGHT = B0 + B1 * 1/DBH
C
C***********************************************************************
      DOUBLE PRECISION IFILE
      REAL SEREG(35),RSQR(33),MSE,TYPSSE(3)
      REAL VARX(33),VARY(33),COVXY(33),REGCOF(33),REGINT(33)
      REAL X(33),Y(33),XSUM(33),YSUM(35),XSUMSQ(33),YSUMSQ(33)
      REAL XYSUM(33),MEANX(33),MEANY(35),HEIGHT,MNYCOR(3)
      INTEGER SPECIE(32),NTR(35),POINT,TREES,DBH,SPEC,MINDBH(32)
      INTEGER TOTNTR(35),NUMREG(3),NTRCOR(3),TOPANS
      COMMON/REG/REGCOF,REGINT,SPECIE,MINDBH,SEREG,NTR,RSQR,MEANY
     1,TOTNTR
C SET MINIMUM DBH'S TO 8
      DO 10 ISPEC=1,32
   10   MINDBH(ISPEC)=8
C
C ZERO ALL ACCUMULATORS
C
      DO 20 JTYPE=1,3
        NTRCOR(JTYPE)=0
        MNYCOR(JTYPE)=0
        NUMREG(JTYPE)=0
   20   TYPSSE(JTYPE)=0
      DO 30 ISPEC=1,35
        NTR(ISPEC)=0;YSUM(ISPEC)=0
        SEREG(ISPEC)=0;MEANY(ISPEC)=0
        IF(ISPEC.GT.32)  GOTO 30
        XSUM(ISPEC)=0;XSUMSQ(ISPEC)=0
        YSUMSQ(ISPEC)=0;XYSUM(ISPEC)=0
        REGCOF(ISPEC)=0;REGINT(ISPEC)=0;RSQR(ISPEC)=0
   30 CONTINUE
C
C INPUT POINT INFORMATION
C
   40 READ(21,50,END=130) POINT,TREES
   50 FORMAT(I2,X,I2)
C CHECK TO SEE IF DATA IS IN SUMMARY FORM
      IF(POINT.NE.-9)  GOTO 60
      TREES=1000000
C INPUT INDIVIDUAL TREE DATA
   60 LOOP=0
   70 IF(LOOP.GE.TREES)  GOTO 40
      READ(21,80,END=40) SPEC,DBH,HEIGHT,IREP
   80 FORMAT(A2,X,I2,1X,F3.0,I2)
      IF(IREP.EQ.0)  IREP=1
      LOOP=LOOP+IREP
C CHECK TO SEE IF TREE IS A CULL
      IF(HEIGHT.EQ.999)  GOTO 70
C CHECK DBH
      IF(DBH.LT.1)  DBH=1
      IF(DBH.GT.40)  DBH=40
C CHECK HEIGHT
      IF(HEIGHT.LT.0.)  HEIGHT=0.
      IF(TOPANS.EQ.'FEET'.AND.HEIGHT.GT.200.)  HEIGHT=200.
      IF(TOPANS.EQ.'LOGS'.AND.HEIGHT.GT.7.)  HEIGHT=7.
C CHECK TO SEE IF HEIGHT OF THIS TREE WAS MEASURED
      IF(HEIGHT.EQ.0)  GOTO 70
C DECODE SPECIE CODES
      DO 90 ISPEC=1,32
   90   IF(SPEC.EQ.SPECIE(ISPEC))  GOTO 110
C PRINT ERROR MESSAGE
      WRITE(5,100) SPEC,POINT
  100 FORMAT('0***ERROR*** ILLEGAL SPECIE CODE: ',A2,' AT POINT: ',I2,
     1/'0DATA FOR THIS TREE IGNORED! EXECUTION CONTINUES.')
      GOTO 70
C DETERMINE MINIMUM MERCHANTABLE DBH
  110 IF(DBH.LT.MINDBH(ISPEC))  MINDBH(ISPEC)=DBH
```

```
C COMPUTE ACCUMULATED SUMS FOR INDIVIDUAL SPECIE
      ITYPE=33
      IF(ISPEC.GE.12)  ITYPE=34
      DO 120 IDUMMY=1,IREP
        X(ISPEC)=1.0/DBH
        Y(ISPEC)=HEIGHT
        NTR(ISPEC)=NTR(ISPEC)+1
        NTR(ITYPE)=NTR(ITYPE)+1
        NTR( 35  )=NTR( 35  )+1
        XSUM(ISPEC)=XSUM(ISPEC)+X(ISPEC)
        YSUM(ISPEC)=YSUM(ISPEC)+Y(ISPEC)
        YSUM(ITYPE)=YSUM(ITYPE)+Y(ISPEC)
        YSUM( 35  )=YSUM( 35  )+Y(ISPEC)
        XSUMSQ(ISPEC)=XSUMSQ(ISPEC)+X(ISPEC)**2
        YSUMSQ(ISPEC)=YSUMSQ(ISPEC)+Y(ISPEC)**2
        XYSUM(ISPEC)=XYSUM(ISPEC)+X(ISPEC)*Y(ISPEC)
  120 CONTINUE
      GOTO 70
  130 CONTINUE
C
C COMPUTE REGRESSION PARAMETERS FOR ALL SPECIES
C
      DO 170 ISPEC=1,32
        JTYPE=1
        IF(ISPEC.GE.12)  JTYPE=2
        IF(NTR(ISPEC).LT.1)  GOTO 170
        MEANY(ISPEC)=YSUM(ISPEC)/NTR(ISPEC)
C CHECK TO SEE IF ENOUGH TREES EXIST FOR REGRESSION
        IF(NTR(ISPEC).GE.3)  GOTO 140
C CALULATE CORRECTION SUMS FOR SPECIES WHERE NO REGRESSION WAS RUN
        MNYCOR(JTYPE)=MNYCOR(JTYPE)+YSUM(ISPEC)
        NTRCOR(JTYPE)=NTRCOR(JTYPE)+NTR(ISPEC)
        GOTO 170
  140   NUMREG(JTYPE)=NUMREG(JTYPE)+1
        MEANX(ISPEC)=XSUM(ISPEC)/NTR(ISPEC)
        VARX(ISPEC)=(XSUMSQ(ISPEC)-
     1     (XSUM(ISPEC)**2/NTR(ISPEC)))/(NTR(ISPEC)-1)
        VARY(ISPEC)=(YSUMSQ(ISPEC)-
     1     (YSUM(ISPEC)**2/NTR(ISPEC)))/(NTR(ISPEC)-1)
        COVXY(ISPEC)=(XYSUM(ISPEC)-
     1    XSUM(ISPEC)*YSUM(ISPEC)/NTR(ISPEC))/(NTR(ISPEC)-1)
C CHECK TO SEE IF VARIANCE IS ZERO
        IF(VARX(ISPEC).GT.0.000001.AND.  VARY(ISPEC).GT.0.000001)
     1  GOTO 150
        REGINT(ISPEC)=MEANY(ISPEC)
        GOTO 160
  150   REGCOF(ISPEC)=COVXY(ISPEC)/VARX(ISPEC)
        REGINT(ISPEC)=MEANY(ISPEC)-REGCOF(ISPEC)*MEANX(ISPEC)
  160   IF(VARY(ISPEC).LT.0.0000001)  GOTO 170
        SSE=YSUMSQ(ISPEC)-REGINT(ISPEC)*YSUM(ISPEC)-
     1  REGCOF(ISPEC)*XYSUM(ISPEC)
        TYPSSE(JTYPE)=TYPSSE(JTYPE)+SSE
        MSE=SSE/(NTR(ISPEC)-2)
        SEREG(ISPEC)=SQRT(MSE/NTR(ISPEC))*100/MEANY(ISPEC)
        RSQR(ISPEC)=100*(COVXY(ISPEC)**2)/(VARX(ISPEC)*VARY(ISPEC))
  170 CONTINUE
C
C COMPUTE STANDARD ERROR FOR SOFTWOOD,HARDWOOD, ALL SPECIES
C
      NTRCOR(3)=NTRCOR(1)+NTRCOR(2)
      MNYCOR(3)=MNYCOR(1)+MNYCOR(2)
      TYPSSE(3)=TYPSSE(1)+TYPSSE(2)
      NUMREG(3)=NUMREG(1)+NUMREG(2)
      DO 180 JTYPE=1,3
        ISPEC=JTYPE+32
        IF(NTR(ISPEC).LE.0)  GOTO 180
        MEANY(ISPEC)=YSUM(ISPEC)/NTR(ISPEC)
        CORNTR=NTR(ISPEC)-NTRCOR(JTYPE)
        IF(CORNTR.LE.0)  GOTO 180
        CORMNY=(YSUM(ISPEC)-MNYCOR(JTYPE))/CORNTR
        MSE=TYPSSE(JTYPE)/(CORNTR-2*NUMREG(JTYPE))
        SEREG(ISPEC)=SQRT(MSE/CORNTR)*100/CORMNY
  180 CONTINUE
      CLOSE(UNIT=21)
      OPEN(UNIT=21,ACCESS='SEQIN',FILE=IFILE)
      SKIP RECORD 21
      RETURN
      END
```

```
C
      SUBROUTINE GUTS
C
C***********************************************************************
C
C   THIS SUBPROGRAM IS THE 'GUTS' OF INVENT.
C
C   GUTS PERFORMS THE FOLLOWING:
C
C      1.  INPUTS PLOT AND TREE DATA
C      2.  CALCULATES BASAL AREA, TREES PER ACRE AND ALL VOLUMES
C      3.  CALCULATES VARIANCES AND STANDARD ERRORS
C
C***********************************************************************
      DOUBLE PRECISION SAMMTD,IFILE
      INTEGER REGANS,ISTART(2),ISTOP(2),DBH,SPEC,TOTNTR(35)
      INTEGER SPECIE(32),POINT,TREES,TRECNT(40,32)
      INTEGER CLASIZ,TITLE(14),MULT,TOPANS,MINDBH(32),NTR(35)
      REAL VARBRD(35),VARPUL(35),SEREG(35),RSQR(33),MEANY(35)
      REAL REGINT(33),REGCOF(33),SECUB(35),SEBRD(35)
      REAL CUBPT(35),BRDPT(35),PULPT(35),CUBSQ(35),BRDSQ(35)
      REAL BASPAC(40,35),BASTOT(35),TREPAC(40,35),TRETOT(35)
      REAL CBVLSM(40,35),CBTOT(35),BDVLSM(40,35),BDTOT(35),HEIGHT
      REAL SEPUL(35),PULSQ(35),PLVLSM(40,35),PLTOT(35)
      COMMON/COMUNE/CLASIZ,TITLE,MULT,PROBLV,BAF,TOPANS,REGANS,ACRES
     1,FRAME,SAMMTD,LOGANS,IFILE
      COMMON/REG/REGCOF,REGINT,SPECIE,MINDBH,SEREG,NTR,RSQR,MEANY
     1,TOTNTR
      COMMON/OUT1/BASPAC,BASTOT,BDTOT,BDVLSM,CBTOT,CBVLSM,TREPAC,TRETOT
     1,SECUB,SEBRD,NPNTS,PLVLSM,PLTOT,SEPUL,FINPOP,VARBRD,VARPUL
      DATA (SPECIE(I),I=1,32)/'WP','RP','PP','HM','BF','TA','SP','NS'
     1,'SC','CE','OS','SM','RM','WA','WI','AS','YP','BC','WB'
     2,'YB','SB','GB','BE','BW','RO','WO','BO','EL','GU'
     3,'HI','BH','OH'/
      DATA ISTART(1)/1/,ISTART(2)/12/,ISTOP(1)/11/,ISTOP(2)/32/
C
C ZERO ALL ACCUMULATORS
C
      DO 10 ISPEC=1,35
        BASTOT(ISPEC)=0;TRETOT(ISPEC)=0;CBTOT(ISPEC)=0;BDTOT(ISPEC)=0
        PLTOT(ISPEC)=0;TOTNTR(ISPEC)=0
        CUBSQ(ISPEC)=0 ; BRDSQ(ISPEC)=0 ; PULSQ(ISPEC)=0
        SECUB(ISPEC)=0;SEBRD(ISPEC)=0;SEPUL(ISPEC)=0
        DO 10 DBH=CLASIZ,40,CLASIZ
          TREPAC(DBH,ISPEC)=0;BASPAC(DBH,ISPEC)=0
          CBVLSM(DBH,ISPEC)=0;BDVLSM(DBH,ISPEC)=0
          PLVLSM(DBH,ISPEC)=0
          IF(ISPEC.LT.33)  TRECNT(DBH,ISPEC)=0
   10 CONTINUE
      NPNTS=0
C
C *********************************************
C READ IN ALL TREE DATA AND ACCUMULATE SUMS
C *********************************************
C
C INPUT POINT OR PLOT INFORMATION
C
   20 READ(21,30,END=140) POINT,TREES
   30 FORMAT(I2,I3)
C CHECK TO SEE IF DATA IS IN SUMMARY FORM
      IF(POINT.NE.-9)  GOTO 40
      NPNTS=TREES
      TREES=1000000
C INPUT INDIVIDUAL TREE DATA
   40 LOOP=0
   50 IF(LOOP.GE.TREES)  GOTO 120
        READ(21,60,END=120) SPEC,DBH,PROD,HEIGHT,IREP,PCTSAW
   60   FORMAT(A2,X,I2,A1,F3.0,I2,F3.2)
        IF(IREP.EQ.0)  IREP=1
        LOOP=LOOP+IREP
C DECODE SPECIE CODES
        DO 70 I=1,32
   70     IF(SPEC.EQ.SPECIE(I))  GOTO 90
C PRINT ERROR MESSAGE
        WRITE(5,80) SPEC,POINT
   80 FORMAT('0***ERROR*** ILLEGAL SPECIE CODE: ',A2,' AT POINT: ',I2,
     1/'ODATA FOR THIS TREE IGNORED! EXECUTION CONTINUES.')
        GOTO 50
```

```
C CHECK DBH TO SEE IF WITHIN LEGAL LIMITS
   90 IF(DBH.LT.CLASIZ)  DBH=CLASIZ
      IF(DBH.GT.40)  DBH=40
C TALLY TREES FOR EACH SPECIES
      ISPEC=I
      TRECNT(DBH,ISPEC)=TRECNT(DBH,ISPEC) +IREP
C CHECK TO SEE IF DIAMETER IS ABOVE MINIMUM LIMIT
      IF(DBH.LT.MINDBH(ISPEC).AND.REGANS.EQ.'NO')  GOTO 50
C ACCUMULATE NUMBER OF NON-CULL TREES ABOVE MIN DBH SAMPLED
      TOTNTR(ISPEC)=TOTNTR(ISPEC)+IREP
      IF(ISPEC.LE.11)  TOTNTR(33)=TOTNTR(33)+IREP
      IF(ISPEC.GE.12)  TOTNTR(34)=TOTNTR(34)+IREP
      TOTNTR(35)=TOTNTR(35)+IREP
C IF HEIGHT WAS NOT MEASURED GENERATE HEIGHT FROM REGRESSION
      IF(HEIGHT.EQ.0.AND.REGANS.EQ.'NO')  HEIGHT=REGINT(I)+REGCOF(I)/DBH
      IF(HEIGHT.EQ.0)  GOTO 50
C COMPUTE VOLUMES
C CHECK TO SEE IF TREE A CULL
      IF(HEIGHT.EQ.999)  GOTO 50
      HEIGHT=HEIGHT*MULT
C CHECK HEIGHT TO SEE IF WITHIN LEGAL LIMITS
      IF(HEIGHT.LT.0)  HEIGHT=0
      IF(MULT.EQ.1.AND.HEIGHT.GT.200)  HEIGHT=200.
      IF(MULT.EQ.16.AND.HEIGHT.GT.128)  HEIGHT=128
      IF(TOPANS.EQ.'TOTAL')  CALL VOLTOT(DBH,HEIGHT,ISPEC,CUBVOL,BDVOL)
      IF(TOPANS.EQ.'MERCH')  CALL VOLMER(DBH,HEIGHT,ISPEC,CUBVOL,BDVOL)
      IF(TOPANS.EQ.'MIXED'.AND.ISPEC.GT.11)      CALL VOLMER(DBH,HEIGHT,
     1ISPEC,CUBVOL,BDVOL)
      IF(TOPANS.EQ.'MIXED'.AND.ISPEC.LE.11)      CALL VOLTOT(DBH,HEIGHT,
     1ISPEC,CUBVOL,BDVOL)
      PULVOL=0
C CHECK TO SEE IF % SAWLOG OPTION USED
      IF(PROD.NE.'%')  GOTO 100
C CHECK PCTSAW TO SEE IF WITHIN LEGAL LIMITS
      IF(PCTSAW.LT.0)  PCTSAW=0.0
      IF(PCTSAW.GT.1.0)  PCTSAW=1.0
      BDVOL =PCTSAW*BDVOL
      PULVOL=(1.-PCTSAW)*CUBVOL
      CUBVOL=PCTSAW*CUBVOL
      GOTO 110
C CHECK TO SEE IF TREE IS PULPWOOD
  100 IF(PROD.NE.'P')  GOTO 110
      PULVOL=CUBVOL;CUBVOL=0;BDVOL=0
  110 CBVLSM(DBH,ISPEC)=CBVLSM(DBH,ISPEC)+CUBVOL*IREP
      BDVLSM(DBH,ISPEC)=BDVLSM(DBH,ISPEC)+BDVOL*IREP
      PLVLSM(DBH,ISPEC)=PLVLSM(DBH,ISPEC)+PULVOL*IREP
C
C    ACCUMULATE SUMS FOR VOLUME STANDARD ERRORS
C
C      CHECK TO SEE IF DATA IS IN SUMMARY FORM
      IF(POINT.EQ.-9)  GOTO 50
C
      IF(FRAME.EQ.'PLOT')  FACTOR=1.0/BAF
      IF(FRAME.EQ.'POINT')  FACTOR=BAF/(.005454*DBH**2)
      CUBPT(ISPEC)=CUBPT(ISPEC)+CUBVOL*IREP*FACTOR
      BRDPT(ISPEC)=BRDPT(ISPEC)+BDVOL*IREP*FACTOR
      PULPT(ISPEC)=PULPT(ISPEC)+PULVOL*IREP*FACTOR
      IF(ISPEC.LE.11)  ITYPE=33
      IF(ISPEC.GT.11)  ITYPE=34
      CUBPT(ITYPE)=CUBPT(ITYPE)+CUBVOL*IREP*FACTOR
      BRDPT(ITYPE)=BRDPT(ITYPE)+BDVOL*IREP*FACTOR
      PULPT(ITYPE)=PULPT(ITYPE)+PULVOL*IREP*FACTOR
      CUBPT(35)=CUBPT(35)+CUBVOL*IREP*FACTOR
      BRDPT(35)=BRDPT(35)+BDVOL*IREP*FACTOR
      PULPT(35)=PULPT(35)+PULVOL*IREP*FACTOR
C
      GOTO 50
  120 CONTINUE
C IF IN SUMMARY MODE DON'T ACCUMULATE VOLUMES OR INCREMENT NPNTS
      IF(POINT.EQ.-9)  GOTO 140
C TALLY NUMBER OF POINTS SAMPLED
      NPNTS=NPNTS+1
```

```
C ACCUMULATE SUMS OF SQUARES FOR VOLUMES
      DO 130 ISPEC=1,35
        CUBSQ(ISPEC)=CUBSQ(ISPEC)+CUBPT(ISPEC)**2
        BRDSQ(ISPEC)=BRDSQ(ISPEC)+BRDPT(ISPEC)**2
        PULSQ(ISPEC)=PULSQ(ISPEC)+PULPT(ISPEC)**2
        CUBPT(ISPEC)=0
        PULPT(ISPEC)=0
  130   BRDPT(ISPEC)=0
      GOTO 20
  140 CONTINUE
C IF ONLY ONE POINT SAMPLED, SET IN SUMMARY MODE
      IF(NPNTS.EQ.1)  POINT=-9
C
C ******************************
C DETERMINE SAMPLING METHOD
C ******************************
C
      IF(FRAME.EQ.'PLOT')  GOTO  170
C
C ***************************************************
C       POINT SAMPLING
C
C CALCULATE PER ACRE ESTIMATES FOR INDIVIDUAL SPECIES
C ***************************************************
C
      DO 160 ISPEC=1,32
        DO 150 DBH=CLASIZ,40,CLASIZ
C CHECK TO SEE IF ANY TREES TALLIED
          IF(TRECNT(DBH,ISPEC).EQ.0)  GOTO 150
C BASAL AREA CALCULATIONS
          BASPAC(DBH,ISPEC)=TRECNT(DBH,ISPEC)*BAF/NPNTS
          BASTOT(ISPEC)=BASTOT(ISPEC)+BASPAC(DBH,ISPEC)
C TREES PER ACRE CALCULATIONS
          TREPAC(DBH,ISPEC)=BASPAC(DBH,ISPEC)/(.005454*DBH**2)
          TRETOT(ISPEC)=TRETOT(ISPEC)+TREPAC(DBH,ISPEC)
C CUBIC VOLUME CALCULATIONS
          CBVLSM(DBH,ISPEC)=CBVLSM(DBH,ISPEC)*BAF/
     1    (NPNTS*.005454*DBH**2)
          CBTOT(ISPEC)=CBTOT(ISPEC)+CBVLSM(DBH,ISPEC)
C BOARD FOOT VOLUME CALCULATIONS
          BDVLSM(DBH,ISPEC)=BDVLSM(DBH,ISPEC)*BAF/
     1    (NPNTS*.005454*DBH**2)
      BDTOT(ISPEC)=BDTOT(ISPEC)+BDVLSM(DBH,ISPEC)
C PULPWOOD CALCULATIONS
          PLVLSM(DBH,ISPEC)=PLVLSM(DBH,ISPEC)*BAF/
     1   (NPNTS*.005454*DBH**2)
          PLTOT(ISPEC)=PLTOT(ISPEC)+PLVLSM(DBH,ISPEC)
  150   CONTINUE
  160 CONTINUE
      GOTO 200
C
C ***************************************************
C       PLOT SAMPLING
C
C CALCULATE PER ACRE ESTIMATES FOR INDIVIDUAL SPECIES
C ***************************************************
C
  170 PLTSIZ=BAF
      NPLOTS=NPNTS
      DO 190 ISPEC=1,32
        DO 180 DBH=CLASIZ,40,CLASIZ
C CHECK TO SEE IF ANY TREES TALLIED
          IF(TRECNT(DBH,ISPEC).EQ.0)  GOTO 180
C TREES PER ACRE CALCULATIONS
          TREPAC(DBH,ISPEC)=TRECNT(DBH,ISPEC)/PLTSIZ/NPLOTS
          TRETOT(ISPEC)=TRETOT(ISPEC)+TREPAC(DBH,ISPEC)
C BASAL AREA CALCULATIONS
          BASPAC(DBH,ISPEC)=TREPAC(DBH,ISPEC)*.005454*DBH**2
          BASTOT(ISPEC)=BASTOT(ISPEC)+BASPAC(DBH,ISPEC)
C CUBIC VOLUME CALCULATIONS
          CBVLSM(DBH,ISPEC)=CBVLSM(DBH,ISPEC)/PLTSIZ/NPLOTS
          CBTOT(ISPEC)=CBTOT(ISPEC)+CBVLSM(DBH,ISPEC)
C BOARD FOOT VOLUME CALCULATIONS
          BDVLSM(DBH,ISPEC)=BDVLSM(DBH,ISPEC)/PLTSIZ/NPLOTS
          BDTOT(ISPEC)=BDTOT(ISPEC)+BDVLSM(DBH,ISPEC)
C PULPWOOD CALCULATIONS
          PLVLSM(DBH,ISPEC)=PLVLSM(DBH,ISPEC)/PLTSIZ/NPLOTS
          PLTOT(ISPEC)=PLTOT(ISPEC)+PLVLSM(DBH,ISPEC)
  180   CONTINUE
  190 CONTINUE
```

```
C
C ***********************************************
C CALCULATE TOTALS FOR SOFTWOODS AND HARDWOODS
C ***********************************************
C
  200 DO 230 ITYPE=33,34
        DO 220 DBH=CLASIZ,40,CLASIZ
          DO 210 ISPEC=ISTART(ITYPE-32),ISTOP(ITYPE-32)
            BASPAC(DBH,ITYPE)=BASPAC(DBH,ITYPE)+BASPAC(DBH,ISPEC)
            TREPAC(DBH,ITYPE)=TREPAC(DBH,ITYPE)+TREPAC(DBH,ISPEC)
            CBVLSM(DBH,ITYPE)=CBVLSM(DBH,ITYPE)+CBVLSM(DBH,ISPEC)
            BDVLSM(DBH,ITYPE)=BDVLSM(DBH,ITYPE)+BDVLSM(DBH,ISPEC)
  210       PLVLSM(DBH,ITYPE)=PLVLSM(DBH,ITYPE)+PLVLSM(DBH,ISPEC)
          BASTOT(ITYPE)=BASTOT(ITYPE)+BASPAC(DBH,ITYPE)
          TRETOT(ITYPE)=TRETOT(ITYPE)+TREPAC(DBH,ITYPE)
          CBTOT(ITYPE)=CBTOT(ITYPE)+CBVLSM(DBH,ITYPE)
          BDTOT(ITYPE)=BDTOT(ITYPE)+BDVLSM(DBH,ITYPE)
  220     PLTOT(ITYPE)=PLTOT(ITYPE)+PLVLSM(DBH,ITYPE)
  230 CONTINUE
C
C **********************************
C CALCULATE TOTALS FOR ALL SPECIES
C **********************************
C
      DO 240 DBH=CLASIZ,40,CLASIZ
        BASPAC(DBH,35)=BASPAC(DBH,33)+BASPAC(DBH,34)
        TREPAC(DBH,35)=TREPAC(DBH,33)+TREPAC(DBH,34)
        CBVLSM(DBH,35)=CBVLSM(DBH,33)+CBVLSM(DBH,34)
        BDVLSM(DBH,35)=BDVLSM(DBH,33)+BDVLSM(DBH,34)
        PLVLSM(DBH,35)=PLVLSM(DBH,33)+PLVLSM(DBH,34)
  240 CONTINUE
      BASTOT(35)=BASTOT(33)+BASTOT(34)
      TRETOT(35)=TRETOT(33)+TRETOT(34)
      CBTOT(35)=CBTOT(33)+CBTOT(34)
      BDTOT(35)=BDTOT(33)+BDTOT(34)
      PLTOT(35)=PLTOT(33)+PLTOT(34)
C
C ***************************
C CALCULATE STANDARD ERRORS
C ***************************
C
      FINPOP=1.0
      IF(FRAME.EQ.'PLOT')  FINPOP=((ACRES/BAF)-NPNTS)/(ACRES/BAF)
      IF(FINPOP.LT.0.0)  FINPOP=0.0
C CHECK TO SEE IF DATA IS IN SUMMARY FORM
      IF(POINT.EQ.-9)  GOTO 270
      DO 260 ISPEC=1,35
        IF(TRETOT(ISPEC).EQ.0)  GOTO 260
        IF(FRAME.EQ.'PLOT')  GOTO 250
        PCTCRZ=100*NPNTS*BASTOT(ISPEC)/TRETOT(ISPEC)/ACRES/BAF
        IF(PCTCRZ.GT.100.0)  PCTCRZ=100.0
        FINPOP=(100-PCTCRZ)/100
  250   VARCUB=(CUBSQ(ISPEC)-NPNTS*(CBTOT(ISPEC)**2))/(NPNTS-1)
        VARBRD(ISPEC)=(BRDSQ(ISPEC)-NPNTS*(BDTOT(ISPEC)**2))/(NPNTS-1)
        VARPUL(ISPEC)=(PULSQ(ISPEC)-NPNTS*(PLTOT(ISPEC)**2))/(NPNTS-1)
        SECUB(ISPEC)=SQRT((VARCUB/NPNTS)*FINPOP)
        SEBRD(ISPEC)=SQRT((VARBRD(ISPEC)/NPNTS)*FINPOP)
  260   SEPUL(ISPEC)=SQRT((VARPUL(ISPEC)/NPNTS)*FINPOP)
C CHECK TO SEE IF REGRESSION ROUTINE USED
  270 IF(REGANS.EQ.'YES')  RETURN
      DO 280 ISPEC=1,35
        IF(TOTNTR(ISPEC).EQ.0)  GOTO 280
        REGWGT=FLOAT(TOTNTR(ISPEC)-NTR(ISPEC))/FLOAT(TOTNTR(ISPEC))
        SECUB(ISPEC)=SQRT(SECUB(ISPEC)**2 +
     1      REGWGT*(SEREG(ISPEC)*CBTOT(ISPEC)/100.)**2)
        SEBRD(ISPEC)=SQRT(SEBRD(ISPEC)**2 +
     1      REGWGT*(SEREG(ISPEC)*BDTOT(ISPEC)/100.)**2)
        SEPUL(ISPEC)=SQRT(SEPUL(ISPEC)**2 +
     1      REGWGT*(SEREG(ISPEC)*PLTOT(ISPEC)/100.)**2)
  280 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE VOLMER(DBH,HEIGHT,ISPEC,CUBVOL,BDVOL)
C
C***********************************************************************
C
C  THIS SUBPROGRAM COMPUTES THE MERCHANTABLE CUBIC AND BOARD FOOT
C  VOLUMES OF INDIVIDUAL TREES.  THE INPUT PARAMETERS ARE DBH,
C  MERCHANTABLE HEIGHT, AND SPECIES.
C
C  THE CUBIC FOOT EQUATIONS ARE FROM BARNARD, JOSEPH E. ET AL. 1973.
C  FOREST SURVEY CUBIC-FOOT VOLUME EQUATIONS. USDA FOREST SERV.
C  NE. FOREST EXP. STA. RESEARCH NOTE NE-66.
C
C  THE BOARD FOOT EQUATIONS ARE FROM WIANT, H.V. AND CASTENADA, F. 1977
C  MESAVAGE AND GIRARD'S VOLUME TABLES FORMULATED.  RESOURCE INVENTORY
C  NOTES, USDI, BLM, DENVER, COLO.
C
C***********************************************************************
C
      REAL HEIGHT,CUBINT(17),CUBSLP(17),BDHT
      INTEGER DBH,GRP(32),D,FC(32)
      COMMON/FORMCL/FC
C
C DEFINE FORM CLASS FOR THE SPECIES
C
      DATA (FC(I),I=1,32)/3*76,70,7*76,21*74/
C
C DEFINE VOLUME EQUATION GROUPING FOR THE SPECIES
C
      DATA (GRP(I),I=1,32)/1,1,5,4,3,5,2,5,5,6,1,7,8,9,17,9,8,10
     1,4*11,12,13,14,15,14,15,14,16,2*17/
C
C DEFINE THE INTERCEPTS FOR THE CUBIC VOLUME EQUATIONS
C
      DATA (CUBINT(I),I=1,17)/3.5142,2.1998,1.4793,2.4784,-.0496,1.5817
     1,1.6823,1.1763,1.0067,1.1809,1.1339,1.2851,.8976,1.2027,1.0009
     2,1.4438,.8591/
C
C DEFINE THE SLOPES FOR THE CUBIC VOLUME EQUATIONS
C
      DATA (CUBSLP(I),I=1,17)/236,257,272,242,303,259,310,310,293,292
     1,281,326,349,301,300,316,309/
C
C FUNCTION TO COMPUTE BOARD FOOT VOLUMES FOR G.F.C. 78
C
      WIANT(DBH,BDHT)=(-13.35212+9.58615*BDHT+1.52968*BDHT**2)+
     1    (1.79620-2.59995*BDHT-.27465*BDHT**2)*DBH+
     2    (.04482+.45997*BDHT-.00961*BDHT**2)*DBH**2
C
C DETERMINE BOARD FOOT HEIGHT TO THE HALF-LOG
C
      BDHT=HEIGHT/16.0
      CBHT=HEIGHT
C
C CALCULATE CUBIC AND BOARD FOOT VOLUME
C
      CUBVOL=CUBINT(GRP(ISPEC))+.00001*CUBSLP(GRP(ISPEC))*CBHT*DBH**2
      BDVOL=WIANT(DBH,BDHT)*(((FC(ISPEC)-78)*.03)+1)
      IF(BDHT.LT.0.5)  BDVOL=0
      IF(CUBVOL.LT.0)  CUBVOL=0
      IF(BDVOL.LT.0)  BDVOL=0
      RETURN
      END
```

```
C
      SUBROUTINE VOLTOT(DBH,HEIGHT,ISPEC,CUBVOL,BDVOL)
C
C***********************************************************************
C
C  THIS SUBPROGRAM COMPUTES THE MERCHANTABLE CUBIC AND BOARD FOOT
C  VOLUMES OF INDIVIDUAL TREES.  THE INPUT PARAMETERS ARE DBH,
C  TOTAL HEIGHT, AND SPECIES.
C
C  ALL OF THE EQUATIONS USED ARE FROM HONER, T.G. 1967. STANDARD VOLUME
C  TABLES AND MERCHANTABLE CONVERSION FACTORS FOR THE COMMERCIAL TREE
C  SPECIES OF CENTRAL AND EASTERN CANADA. FMR-X-5, FMI, OTTAWA, CANADA
C
C***********************************************************************
C
      INTEGER GRP(32),DBH
      REAL CUBINT(16),CUBSLP(16),ASDRCF(3),ASDRBF(3),BRDTOP(2),CUBTOP(2)
C
C DEFINE VOLUME EQUATION GROUPING FOR THE TREE SPECIES
C
      DATA (GRP(I),I=1,32)/1,2,2,6,4,2,3,3,2,5,2,10,10,16,15,7,10,13
     1,8,9,8,8,12,11,3*16,14,16,16,15,15/
C
C DEFINE THE INTERCEPTS FOR THE TOTAL CUBIC FT VOL EQUATION
C
      DATA (CUBINT(I),I=1,16)/.691,.710,1.226,2.139,4.167,1.112,-.312
     1,2.222,1.449,1.046,.948,.959,.033,.634,1.877,1.512/
C
C DEFINE THE SLOPES FOR THE TOTAL CUBIC FT VOL EQUATION
C
      DATA (CUBSLP(I),I=1,16)/363.676,355.623,315.832,301.634,244.906
     1,350.092,436.683,300.373,344.754,383.972,401.456,334.829
     2,393.366,440.496,332.585,336.509/
C
C DEFINE STUMP HEIGHT AND MERCH TOPS
C
      DATA STUMP/0.5/
      DATA (CUBTOP(I),I=1,2)/4.0,4.0/
      DATA (BRDTOP(I),I=1,2)/6.0,8.0/
C
C DEFINE ADJUSTED SQRD DIA RATIO CUBIC FT VOL CONVERSION COEFFICIENTS
C
      DATA (ASDRCF(I),I=1,3)/.9604,-.1660,-.7868/
C
C DEFINE ADJUSTED SQRD DIA RATIO BOARD FT VOL CONVERSION COEFFICIENTS
C
      DATA (ASDRBF(I),I=1,3)/5.4332,-1.6281,-4.4710/
C
C DETERMINE SW OR HW TYPE
C
      IF(ISPEC.LE.11)  ITYPE=1
      IF(ISPEC.GE.12)  ITYPE=2
C
C COMPUTE TOTAL CUBIC FOOT VOLUME
C
      TCBVOL=DBH**2/(CUBINT(GRP(ISPEC))+CUBSLP(GRP(ISPEC))/HEIGHT)
C
C COMPUTE MERCH CUBIC AND BOARD FT VOLUMES
C
      XCUB=((CUBTOP(ITYPE)/DBH)**2)*(1.0+STUMP/HEIGHT)
      XBRD=((BRDTOP(ITYPE)/DBH)**2)*(1.0+STUMP/HEIGHT)
      CUBVOL=TCBVOL*(ASDRCF(1)+ASDRCF(2)*XCUB+ASDRCF(3)*XCUB**2)
      BDVOL =TCBVOL*(ASDRBF(1)+ASDRBF(2)*XBRD+ASDRBF(3)*XBRD**2)
      IF(CUBVOL.LT.0)  CUBVOL=0
      IF(BDVOL.LT.0)  BDVOL=0
      RETURN
      END
```

```
C
      SUBROUTINE STRAT(ACRES,CLASIZ)
C
C*************************************************************************
C
C   THIS SUBPROGRAM CALCULATES COMBINED STRATA STATISTICS
C
C*************************************************************************
C
      INTEGER CLASIZ
      REAL STSECB(35),STSEBD(35),EFDFCB(35),EFDFBD(35)
      REAL STVMCB(35),STVMBD(35),DFCB2(35),DFBD2(35)
      REAL STVMPL(35),DFPL2(35),PLTST(35),STSEPL(35),EFDFPL(35)
      REAL PLVLST(40,35)
      REAL CBTST(35),BDTST(35),CBVLST(40,35),BDVLST(40,35)
      COMMON/OUT1/BASPAC(40,35),BASTOT(35),BDTOT(35),BDVLSM(40,35),
     1CBTOT(35),CBVLSM(40,35),TREPAC(40,35),TRETOT(35)
     2,SECUB(35),SEBRD(35),NPNTS,PLVLSM(40,35),PLTOT(35),SEPUL(35)
     3,FINPOP,VARBRD(35),VARPUL(35)
      COMMON/STOUT/CBTST,BDTST,CBVLST,BDVLST,STSECB,STSEBD,EFDFCB
     1,EFDFBD,TACRES,PLTST,PLVLST,STSEPL,EFDFPL
C ZERO ACCUMULATORS AND OTHER VARIABLES
      DATA ((CBVLST(J,I),BDVLST(J,I),PLVLST(J,I) , J=1,40,1)
     1,CBTST(I),BDTST(I),PLTST(I),STVMCB(I),STVMBD(I),STVMPL(I)
     2,DFCB2(I),DFBD2(I),DFPL2(I),EFDFCB(I),EFDFBD(I),EFDFPL(I)
     3,STSECB(I),STSEBD(I),STSEPL(I) , I=1,35) / 4725*0.0 /
C
      TACRES=TACRES+ACRES
C
C ACCUMULATE SUMS FOR VOLUMES
C
      DO 20 ISPEC=1,35
        DO 10 DBH=CLASIZ,40,CLASIZ
          CBVLST(DBH,ISPEC)=CBVLST(DBH,ISPEC)+CBVLSM(DBH,ISPEC)*ACRES
          BDVLST(DBH,ISPEC)=BDVLST(DBH,ISPEC)+BDVLSM(DBH,ISPEC)*ACRES
   10     PLVLST(DBH,ISPEC)=PLVLST(DBH,ISPEC)+PLVLSM(DBH,ISPEC)*ACRES
        CBTST(ISPEC)=CBTST(ISPEC)+CBTOT(ISPEC)*ACRES
        BDTST(ISPEC)=BDTST(ISPEC)+BDTOT(ISPEC)*ACRES
        PLTST(ISPEC)=PLTST(ISPEC)+PLTOT(ISPEC)*ACRES
C
C ACCUMULATE SUMS FOR VARIANCE AND D.F.
C
        IF(NPNTS.LT.2)  GOTO 20
        STVMCB(ISPEC)=STVMCB(ISPEC)+(ACRES**2)*(SECUB(ISPEC)**2)
        STVMBD(ISPEC)=STVMBD(ISPEC)+(ACRES**2)*(SEBRD(ISPEC)**2)
        STVMPL(ISPEC)=STVMPL(ISPEC)+(ACRES**2)*(SEPUL(ISPEC)**2)
        DFCB2(ISPEC)=DFCB2(ISPEC)+ACRES**4*SECUB(ISPEC)**4/(NPNTS-1)
        DFBD2(ISPEC)=DFBD2(ISPEC)+ACRES**4*SEBRD(ISPEC)**4/(NPNTS-1)
        DFPL2(ISPEC)=DFPL2(ISPEC)+ACRES**4*SEPUL(ISPEC)**4/(NPNTS-1)
   20 CONTINUE
      RETURN
C
C*****************************************************
C CALCULATE STANDARD ERRORS AND EFFECTIVE D.F.
C  BASED ON PREVIOUSLY ACCUMULATED SUMS
C*****************************************************
C
      ENTRY STRAT2
      DO 50 ISPEC=1,35
        IF(PLTST(ISPEC).EQ.0)  GOTO 30
        STSEPL(ISPEC)=SQRT(STVMPL(ISPEC)/TACRES**2)
        IF(DFPL2(ISPEC).EQ.0)  GOTO 30
        EFDFPL(ISPEC)=STVMPL(ISPEC)**2/DFPL2(ISPEC)
   30   IF(CBTST(ISPEC).EQ.0)  GOTO 50
        STSECB(ISPEC)=SQRT(STVMCB(ISPEC)/TACRES**2)
        STSEBD(ISPEC)=SQRT(STVMBD(ISPEC)/TACRES**2)
        IF(DFCB2(ISPEC).EQ.0)  GOTO 40
        EFDFCB(ISPEC)=STVMCB(ISPEC)**2/DFCB2(ISPEC)
   40   IF(DFBD2(ISPEC).EQ.0)  GOTO 50
        EFDFBD(ISPEC)=STVMBD(ISPEC)**2/DFBD2(ISPEC)
   50 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE OUTP1
C
C**********************************************************************
C
C    THIS SUBPROGRAM PRODUCES ALL OF INVENTS TABLES AND SUMMARIES
C
C    THE SUBPROGRAM HAS TWO ENTRY POINTS:  OUTP1   AND   OUTP2
C
C       OUTP1 PRODUCES ALL OF THE INDIVIDUAL STRATA OUTPUT
C       OUTP2 PRODUCES THE STRATIFIED TOTAL OUTPUT
C
C**********************************************************************
      INTEGER TOTACB,TOTABD,TOTAPL,IDATE(2),TOTNTR(35),TOTPTS
      INTEGER DBH,TOPANS,MULT,REGANS,FC(32)
      INTEGER SPETIT(35,3),TITLE(14),CLASIZ,SPECIE(32)
      INTEGER MINDBH(32),NTR(35)
      REAL VARBRD(35),VARPUL(35),REGCOF(33),REGINT(33),SEREG(35)
      REAL RSQR(33),MEANY(35)
      REAL TREPAC(40,35),TRETOT(35),CBTOT(35),BDTOT(35),MSD
      REAL SECUB(35),SEBRD(35),SEPUL(35),PLVLSM(40,35),PLTOT(35)
      REAL CBVLSM(40,35),BDVLSM(40,35),BASPAC(40,35),BASTOT(35)
      DOUBLE PRECISION IFILE,SAMMTD
      COMMON/REG/REGCOF,REGINT,SPECIE,MINDBH,SEREG,NTR,RSQR,MEANY
     1,TOTNTR
      COMMON/FORMCL/FC
      COMMON/STOUT/CBTST(35),BDTST(35),CBVLST(40,35),BDVLST(40,35)
     1,STSECB(35),STSEBD(35),EFDFCB(35),EFDFBD(35),TACRES
     2,PLTST(35),PLVLST(40,35),STSEPL(35),EFDFPL(35)
      COMMON/COMUNE/CLASIZ,TITLE,MULT,PROBLV,BAF,TOPANS,REGANS,ACRES
     1,FRAME,SAMMTD,LOGANS,IFILE
      COMMON/OUT1/BASPAC,BASTOT,BDTOT,BDVLSM,CBTOT,CBVLSM,TREPAC,TRETOT
     1,SECUB,SEBRD,NPNTS,PLVLSM,PLTOT,SEPUL,FINPOP,VARBRD,VARPUL
      DATA ((SPETIT(I,J),J=1,3),I=1,35)/'WHITE PINE      RED PINE       ',
     1'PITCH PINE      HEMLOCK         BALSAM FIR      ',
     2'TAMARACK        ',
     3'RD-BL-WH SPRUCENORWAY SPRUCE   SCOTCH PINE     CEDAR           ',
     4'OTHER SOFTWOODSSUGAR MAPLE     RED MAPLE       WHITE ASH       ',
     5'WILLOW          ASPEN           YELLOW POPLAR   ',
     6'BLACK CHERRY    WHITE BIRCH     YELLOW BIRCH    SWEET BIRCH     ',
     7'GREY BIRCH      BEECH           BASSWOOD        ',
     8'RED OAK         WHITE OAK       BLACK OAK       ',
     9'ELM             GUM             HICKORY         HOPHORNBEAM     ',
     1'OTHER HARDWOODSALL SOFTWOODS   ',
     2'ALL HARDWOODS   ALL SPECIES    '/
C ACCUMULATE NUMBER OF STRATA SAMPLED
      ISTRA=ISTRA+1
C ACCUMULATE TOTAL NUMBER OF POINTS SAMPLED IN ALL STRATA
      TOTPTS=TOTPTS+NPNTS
C
C CALCULATE T-VALUE FOR THIS STRATA
C
      TVAL=0
      DF=NPNTS-1
      IF(DF.GE.1)  CALL MDSTI(PROBLV,DF,TVAL)
      IPAGE=IPAGE+1
C
C**********************************
C PRINT HEADING ON OUTPUT FILE
C**********************************
C
      CALL DATE(IDATE)
      REGUSE='ALL'
      IF(REGANS.EQ.'NO')  REGUSE='SOME'
      WRITE(3,100) TITLE,IPAGE
      OFRAME=FRAME
      IF(FRAME.EQ.'PLOT')  OFRAME=' PLOT'
      ALPHA=1.0-PROBLV
      WRITE(3,10) IDATE,SAMMTD,BAF,OFRAME,NPNTS,CLASIZ,TOPANS,LOGANS,
     1REGUSE,ISTRA,IFILE,ACRES,ALPHA
   10 FORMAT(//' INVENT VER. 3   11/1/78   I.N.E.R.   U.N.H.'/
     1/'0DATE OF RUN: ',2A5//'0',A9,' =',F6.2,28X,'NUMBER OF ',A5,'S ',
     2'SAMPLED =',I4/'0DIAMETER CLASS SIZE =',I3,21X
     3,'HEIGHTS MEASURED BY ',A5,' HEIGHT IN ',A4/
     4'0HEIGHTS OF ',A4,' VOLUME TREES MEASURED',8X,'STRATUM #',I3/
     5'0INPUT FILE NAME: ',A10,18X,'ACREAGE OF TRACT =',F7.1/
     6'0CONFIDENCE LEVEL = ',F3.2)
```

```
C*****************************************************
C PRINT REGRESSION ANALYSIS SUMMARY
C*****************************************************
C
      IF(REGANS.EQ.'YES')  GOTO 90
      IPAGE=IPAGE+1
      WRITE(3,100) TITLE,IPAGE
      WRITE(3,20)
   20 FORMAT('0',99('*')/' *',97X,'*'/' *',28X,'ANALYSIS OF THE HEIGHT',
     1' - DBH RELATIONSHIP',28X,'*'/' *',97X,'*'/' *',35X,'MODEL:  HEI',
     2'GHT = B0 + B1/DBH',34X,'*'/' *',97X,'*'/' ',99('*')/'0',99('-')
     3/' ',15X,':',5X,'B0',4X,':',5X,'B1',4X,':',5X,'R',5X,': STANDAR',
     4'D  :  AVERAGE  :  VOLUME   :  HEIGHT'/'     SPECIES     : INTERC',
     5'EPT :   SLOPE    :  SQUARED  :  ERROR %  :    HEIGHT   :    TREES  ',
     6' :   TREES'/' ',99('-')/' ')
      IFLAG=0
      DO 50 ISPEC=1,32
          IF(TOTNTR(ISPEC).EQ.0)  GOTO 50
          IF(NTR(ISPEC).LT.3.AND.NTR(ISPEC).LT.TOTNTR(ISPEC))  IFLAG=1
          IF(NTR(ISPEC).GE.3)  WRITE(3,30)  (SPETIT(ISPEC,J),J=1,3)
     1      ,REGINT(ISPEC),REGCOF(ISPEC),RSQR(ISPEC),SEREG(ISPEC) ,
     2      MEANY(ISPEC),TOTNTR(ISPEC),NTR(ISPEC)
   30     FORMAT(' ',3(A5),2(':',F9.3,2X),3(':',F8.1,3X),2(':',I8,3X))
          IF(NTR(ISPEC).LT.3.AND.NTR(ISPEC).EQ.TOTNTR(ISPEC))
     1      WRITE(3,60)  (SPETIT(ISPEC,J),J=1,3),SEREG(ISPEC),
     2      MEANY(ISPEC) ,TOTNTR(ISPEC),NTR(ISPEC)
          IF(NTR(ISPEC).LT.3.AND.NTR(ISPEC).LT.TOTNTR(ISPEC))
     1      WRITE(3,40)  (SPETIT(ISPEC,J),J=1,3),SEREG(ISPEC),
     2      MEANY(ISPEC),TOTNTR(ISPEC),NTR(ISPEC)
   40     FORMAT(' ',3A5,':',10X,'*** WARNING ***',10X,
     1    2(':',F8.1,3X),2(':',I8,3X))
   50 CONTINUE
      WRITE(3,250)
      DO 70 ISPEC=33,35
          WRITE(3,60)  (SPETIT(ISPEC,J),J=1,3),SEREG(ISPEC),MEANY(ISPEC)
     1      ,TOTNTR(ISPEC),NTR(ISPEC)
   60     FORMAT(' ',3A5,':',35X,2(':',F8.1,3X),2(':',I8,3X))
   70     IF(ISPEC.EQ.34.OR.ISPEC.EQ.35)  WRITE(3,250)
      IF(IFLAG.EQ.1)  WRITE(3,80)
   80 FORMAT('0'/'0*** WARNING ***    INSUFFICIENT NUMBER OF HEIGHT TR',
     1'EES MEASURED FOR THIS SPECIES!')
C
C *******************************************
C OUTPUT STAND AND STOCK TABLES
C *******************************************
C
   90 DO 210 ISPEC=1,35
        IF(TRETOT(ISPEC).EQ.0.0)  GOTO 210
        IPAGE=IPAGE+1
        WRITE(3,100) TITLE,IPAGE
  100   FORMAT('1',14A5,26X,I3/'0')
C
C THE FOLLOWING SECTION CONTROLS THE OUTPUT OF THE SPECIES FORM CLASS
C PRINTED IN THE STAND TABLE HEADING.  THE FORM CLASS IS NOT PRINTED
C UNDER THE FOLLOWING CONDITIONS:
C         1. STAND TABLES FOR SOFTWOOD,HARDWOOD, OR ALL SPECIES
C            ( ISPEC >= 33 )
C         2. TREES MEASURED BY TOTAL HEIGHT ( TOPANS = "TOTAL" )
C         3. STAND TABLES FOR SOFTWOODS WHEN "MIXED" HEIGHTS USED
C            ( TOPANS = "MIXED" AND ISPEC <= 11 )
C
        AFCTIT=' ' ; AFCNUM=' '
        IF(ISPEC.GE.33)  GOTO 120
        IF(TOPANS.EQ.'TOTAL')  GOTO 120
        IF(TOPANS.EQ.'MIXED'.AND.ISPEC.LE.11)  GOTO 120
        AFCTIT='FC = '
C ENCODE WRITES THE INTEGER VALUE OF FC INTO AFCNUM AS ASCII CHARACTERS
        ENCODE(2,110,AFCNUM) FC(ISPEC)
  110   FORMAT(I2)
  120   WRITE(3,130)  (SPETIT(ISPEC,J),J=1,3),AFCTIT,AFCNUM
  130 FORMAT('0',99('*')/' ','*',97X,'*'/
     1,' *',39X,3(A5),35X,A5,A2,X,'*'/' *',97X,'*'/
     2' ',99('*')/'0',99('-')/' ',10X,':  BASAL AREA  :',
     3'     TREES    :        SAWLOG        :        SAWLOG        :',
     4'      PULPWOOD'/'  DIAMETER :'6X,'PER',5X,':',6X,'PER',5X,':',
     5' CUBIC FOOT VOLUME : BOARD FOOT VOLUME : CUBIC FOOT VOLUME'/
     6' ',' CLASS',3X,':',5X,'ACRE',5X,
     7':',5X,'ACRE',5X,3(':',5X,'PER ACRE',6X)/' ',99('-')/' ')
```

```
      DO 150 DBH=CLASIZ,40,CLASIZ
        IF(TREPAC(DBH,ISPEC).EQ.0.0)  GOTO 150
          WRITE(3,140) DBH,BASPAC(DBH,ISPEC),TREPAC(DBH,ISPEC)
     1      ,CBVLSM(DBH,ISPEC),BDVLSM(DBH,ISPEC),PLVLSM(DBH,ISPEC)
  140     FORMAT(' ',4X,I2,4X,':',F10.1,4X,':',F10.1,4X,':',F10.1,
     1    2(9X,':',F10.1))
  150 CONTINUE
      IF(PLTOT(ISPEC).EQ.0)   IERPUL=0
      IF(PLTOT(ISPEC).NE.0) IERPUL=(SEPUL(ISPEC)*TVAL*100/PLTOT(ISPEC))+
     1.5
      IF(CBTOT(ISPEC).EQ.0)   IERCUB=0
      IF(CBTOT(ISPEC).NE.0) IERCUB=(SECUB(ISPEC)*TVAL*100/CBTOT(ISPEC))+
     1.5
      IF(BDTOT(ISPEC).EQ.0)   IERBRD=0
      IF(BDTOT(ISPEC).NE.0) IERBRD=(SEBRD(ISPEC)*TVAL*100/BDTOT(ISPEC))+
     1.5
      WRITE(3,160) BASTOT(ISPEC),TRETOT(ISPEC),CBTOT(ISPEC),IERCUB,
     1BDTOT(ISPEC),IERBRD,PLTOT(ISPEC),IERPUL
  160 FORMAT('0',99('-')/'0',3X,'TOTAL',2X,':',3X,F7.1,4X,':',3X,F7.1
     1,4X,':',F10.1,' +',I3,'%',2(3X,':',F10.1,' +',I3,'%')/
     2'+',52X,'_',2(19X,'_')/'0',99('-'))
C CALCULATE AND OUTPUT MSD AND C.V.
      MSD=SQRT(BASTOT(ISPEC)/TRETOT(ISPEC)/.005454)
      IBDCV=0 ; IPLCV=0
      IF(BDTOT(ISPEC).NE.0)   IBDCV=SQRT(VARBRD(ISPEC))*100/BDTOT(ISPEC)+
     1.5
      IF(PLTOT(ISPEC).NE.0)   IPLCV=SQRT(VARPUL(ISPEC))*100/PLTOT(ISPEC)+
     1.5
      WRITE(3,170) MSD,IBDCV
  170 FORMAT('0'/'0',5X,'MEAN STAND DIAMETER = ',F4.1
     1,9X,'BOARD FOOT COEFFICIENT OF VARIATION =',I4,'%')
C CALCULATE AND OUTPUT MERCHANTABLE MSD
      RBSTOT=BASTOT(ISPEC)
      RTRTOT=TRETOT(ISPEC)
      DO 180 DBH=CLASIZ,7,CLASIZ
        RBSTOT=RBSTOT-BASPAC(DBH,ISPEC)
  180   RTRTOT=RTRTOT-TREPAC(DBH,ISPEC)
      IF(RTRTOT.LT.0.01)  RMSD=0
      IF(RTRTOT.GE.0.01)  RMSD=SQRT(RBSTOT/RTRTOT/.005454)
      WRITE(3,190) RMSD,IPLCV
  190 FORMAT('0'/'0',5X,'MERCHANTABLE M.S.D. = ',F4.1
     1,9X,'PULP-WOOD  COEFFICIENT OF VARIATION =',I4,'%')
C
C CALCULATE AND OUTPUT (ESTIMATED) % CRUISE
      IF(FRAME.EQ.'PLOT')  PCTCRZ=100*(1.0-FINPOP)
      IF(FRAME.EQ.'POINT')  PCTCRZ=.5454*NPNTS*MSD*MSD/ACRES/BAF
      WRITE(3,200) PCTCRZ
  200 FORMAT('0'/'0',5X,'PERCENT CRUISE =',F5.1,'%')
  210 CONTINUE
C
C ****************************************************
C CALCULATE AND OUTPUT SPECIES COMPOSITION PERCENTAGES
C ****************************************************
C
      IPAGE=IPAGE+1
      WRITE(3,100) TITLE,IPAGE
      WRITE(3,220)
  220 FORMAT('0',99('*')/' *',97X,'*'/
     1,' *',30X,'SPECIES COMPOSITION BY PERCENT',37X,'*'/
     2' *',97X,'*'/' ',99('*')/'0',99('-')/
     3' ',3(15X,':'),2(5X,'SAWLOG',6X,':'),4X,'PULPWOOD'/
     4' ',3(15X,':'),3X,'CUBIC FOOT',4X,':','   BOARD FOOT'
     5,4X,':',3X,'CUBIC FOOT'/
     6' ',4X,'SPECIES',4X,':','  BASAL AREA   :',5X,'TREES
     73(':',5X,'VOLUME',6X)/' ',99('-')/' ')
      IF(CBTOT(35).EQ.0)  CBTOT(35)=-999
      IF(BDTOT(35).EQ.0)  BDTOT(35)=-999
      IF(PLTOT(35).EQ.0)  PLTOT(35)=-999
      DO 240 ISPEC=1,34
        IF(TRETOT(ISPEC).EQ.0.0)  GOTO 240
        BASCOM=BASTOT(ISPEC)*100/BASTOT(35)
        TRECOM=TRETOT(ISPEC)*100/TRETOT(35)
        CUBCOM=CBTOT(ISPEC)*100/CBTOT(35)
        BDCOM=BDTOT(ISPEC)*100/BDTOT(35)
        PULCOM=PLTOT(ISPEC)*100/PLTOT(35)
```

```
      WRITE(3,230)  (SPETIT(ISPEC,J),J=1,3),BASCOM    ,TRECOM,
     1   CUBCOM,BDCOM,PULCOM
  230   FORMAT(' ',3(A5),':',2(3X,F7.2,5X,':'),2(4X,F7.2,6X,':')
     1  ,4X,F7.2)
  240   IF(ISPEC.EQ.32)  WRITE(3,250)
      WRITE(3,250)
  250 FORMAT('0',99('-')/' ')
      IF(CBTOT(35).EQ.-999)  CBTOT(35)=0
      IF(BDTOT(35).EQ.-999)  BDTOT(35)=0
      IF(PLTOT(35).EQ.-999)  PLTOT(35)=0
C
C***********************************************************
C OUTPUT VOLUME TOTALS FOR ALL SPECIES
C***********************************************************
C
      IPAGE=IPAGE+1
      WRITE(3,100) TITLE,IPAGE
      WRITE(3,260)
  260 FORMAT('0',99('*')/' *',97X,'*'/
     1' *',30X,'VOLUME TOTALS FOR ALL SPECIES',38X,'*'/
     2' *',97X,'*'/' ',99('*')/'0',99('-')/
     3' ',15X,2(':',11X,'SAWLOG',11X),':',10X,'PULPWOOD'/
     4'     SPECIES    :',6X,'CUBIC FOOT VOLUME',5X,':',6X,'BOARD',
     5' FOOT VOLUME',5X,':',6X,'CUBIC FOOT VOLUME'/
     6' ',15X,2(':',10X,'PER ACRE',10X),':',10X,'PER ACRE'/
     7' ',99('-')/' ')
      DO 290 ISPEC=1,35
        IF (CBTOT(ISPEC).EQ.0.AND.PLTOT(ISPEC).EQ.0.AND.ISPEC.LT.33)
     1        GOTO 280
        WRITE(3,270)  (SPETIT(ISPEC,J),J=1,3),CBTOT(ISPEC),BDTOT(ISPEC),
     1    PLTOT(ISPEC)
  270 FORMAT(' ',3(A5),3(':',F17.1,11X))
  280   IF(ISPEC.EQ.32.OR.ISPEC.EQ.34.OR.ISPEC.EQ.35)  WRITE(3,250)
  290 CONTINUE
C
C *******************************************************
C OUTPUT VOLUME TOTALS EXPANDED BY ACREAGE
C *******************************************************
C
      IPAGE=IPAGE+1
      WRITE(3,100) TITLE,IPAGE
      WRITE(3,300)
  300 FORMAT('0',99('*')/' *',97X,'*'/
     1' *',30X,'VOLUME TOTALS EXPANDED BY ACREAGE',34X,'*'/
     2' *',97X,'*'/' ',99('*')/'0',99('-')/
     3' ',15X,2(':',11X,'SAWLOG',11X),':',10X,'PULPWOOD'/
     4'     SPECIES    :',6X,'CUBIC FOOT VOLUME',5X,':',6X,'BOARD',
     5' FOOT VOLUME',5X,':',6X,'CUBIC FOOT VOLUME'/
     6' ',99('-')/' ')
      DO 330 ISPEC=1,35
        IF (CBTOT(ISPEC).EQ.0.AND.PLTOT(ISPEC).EQ.0.AND.ISPEC.LT.33)
     1        GOTO 320
        TOTACB=CBTOT(ISPEC)*ACRES+.5
        TOTABD=BDTOT(ISPEC)*ACRES+.5
        TOTAPL=PLTOT(ISPEC)*ACRES+.5
        WRITE(3,310)  (SPETIT(ISPEC,J),J=1,3),TOTACB,TOTABD,TOTAPL
  310   FORMAT(' ',3(A5),3(':',I17,11X))
  320   IF(ISPEC.EQ.32.OR.ISPEC.EQ.34.OR.ISPEC.EQ.35)  WRITE(3,250)
  330 CONTINUE
      RETURN
```

```
C
C**************************************************************************
C
C   OUTPUT TABLES FOR STRATIFIED TOTAL
C
C**************************************************************************
C
      ENTRY OUTP2
      WRITE(5,340)
  340 FORMAT('OWHAT DO YOU WANT TO TITLE THE COMBINED STRATA OUTPUT?')
      READ(5,350) TITLE
  350 FORMAT(14A5)
      IPAGE=IPAGE+1
      WRITE(3,100) TITLE,IPAGE
C PRINT HEADING ON OUTPUT FILE
      OFRAME=FRAME
      IF(FRAME.EQ.'PLOT')  OFRAME=' PLOT'
      WRITE(3,360) IDATE,CLASIZ,ISTRA,TACRES,OFRAME,TOTPTS,ALPHA
  360 FORMAT(//' INVENT VER. 3    11/1/78    I.N.E.R.    U.N.H.'//
     1'ODATE OF RUN: ',2A5//
     2'ODIAMETER CLASS SIZE =',I3,21X,'NUMBER OF STRATA SAMPLED ='
     3,I3/'OTOTAL ACREAGE SAMPLED =',F9.1,13X,'TOTAL ',A5
     4,'S SAMPLED =',I5/'OCONFIDENCE LEVEL = ',F3.2)
C
C****************************************
C OUTPUT DIAMETER CLASS VOLUME TABLES
C****************************************
C
      DO 450 ISPEC=1,35
        IF(CBTST(ISPEC).EQ.0.AND.PLTST(ISPEC).EQ.0)  GOTO 450
        IPAGE=IPAGE+1
        WRITE(3,100) TITLE,IPAGE
C
C THE FOLLOWING SECTION CONTROLS FORM CLASS PRINTING AS PREVIOUSLY
C DESCRIBED.  THE INPUTS OF THE LAST STRATUM ANALYSED CONTROLS WHAT
C IS PRINTED IN THE STRATIFIED TOTAL OUTPUT.
C
        AFCTIT=' ' ; AFCNUM=' '
        IF(ISPEC.GE.33)  GOTO 370
        IF(TOPANS.EQ.'TOTAL')  GOTO 370
        IF(TOPANS.EQ.'MIXED'.AND.ISPEC.LE.11)  GOTO 370
        AFCTIT='FC = '
C ENCODE WRITES THE INTEGER VALUE OF FC INTO AFCNUM AS ASCII CHARACTERS
        ENCODE(2,110,AFCNUM) FC(ISPEC)
  370   WRITE(3,380) (SPETIT(ISPEC,J),J=1,3),AFCTIT,AFCNUM
  380   FORMAT('0',99('*')/' *',97X,'*'/
     1' *',39X,3(A5),35X,A5,A2,X,'*'/
     2' *',97X,'*'/' ',99('*')/'0',99('-')/
     3'    DIAMETER',4X,2(':',11X,'SAWLOG',11X),':',10X,'PULPWOOD'/
     4'     CLASS       :',6X,'CUBIC FOOT VOLUME',5X,':',6X,'BOARD',
     5' FOOT VOLUME',5X,':',6X,'CUBIC FOOT VOLUME'/
     6' ',99('-')/' ')
        DO 400 DBH=CLASIZ,40,CLASIZ
          IF(CBVLST(DBH,ISPEC).EQ.0.AND.PLVLST(DBH,ISPEC).EQ.0)
     1          GOTO 400
          ICBVST=CBVLST(DBH,ISPEC)+.5
          IBDVST=BDVLST(DBH,ISPEC)+.5
          IPLVST=PLVLST(DBH,ISPEC)+.5
          WRITE(3,390) DBH,ICBVST,IBDVST,IPLVST
  390     FORMAT(' ',I8,7X,3(':',I17,11X))
  400   CONTINUE
        ICBTST=CBTST(ISPEC)+.5 ; IBDTST=BDTST(ISPEC)+.5
        IPLTST=PLTST(ISPEC)+.5
C CALCULATE ERROR AS A PERCENT
        IERCUB=0;IERBBD=0;IERPUL=0;TVAL=0
        IF(CBTST(ISPEC).EQ.0)  GOTO  410
        IF(EFDFCB(ISPEC).GE.1)CALL MDSTI(PROBLV,EFDFCB(ISPEC),TVAL)
        IERCUB=(STSECB(ISPEC)*TVAL*100*TACRES/CBTST(ISPEC))+.5
  410   IF(BDTST(ISPEC).EQ.0)  GOTO 420
        TVAL=0
        IF(EFDFBD(ISPEC).GE.1)CALL MDSTI(PROBLV,EFDFBD(ISPEC),TVAL)
        IERBRD=(STSEBD(ISPEC)*TVAL*100*TACRES/BDTST(ISPEC))+.5
  420   IF(PLTST(ISPEC).EQ.0)  GOTO 430
        TVAL=0
        IF(EFDFPL(ISPEC).GE.1)CALL MDSTI(PROBLV,EFDFPL(ISPEC),TVAL)
        IERPUL=(STSEPL(ISPEC)*TVAL*100*TACRES/PLTST(ISPEC))+.5
  430   WRITE(3,440) ICBTST,IERCUB,IBDTST,IERBRD,IPLTST,IERPUL
  440   FORMAT('0',99('-')/'0',4X,'TOTAL',6X
     1  ,3(':',I17,' +',I3,'%',5X)/'+',15X,3(19X,'_',9X)/
     2  '0',99('-'))
  450 CONTINUE
```

```
C
C***********************************
C OUTPUT ALL SPECIES VOLUME TABLE
C***********************************
C
      IPAGE=IPAGE + 1
      WRITE(3,100) TITLE,IPAGE
      WRITE(3,460)
  460 FORMAT('0',99('*')/' *',97X,'*'/
     1' *',30X,'VOLUME TOTALS FOR ALL SPECIES',38X,'*'/
     2' *',97X,'*'/' ',99('*')/'0',99('-')/
     3' ',15X,2(':',11X,'SAWLOG',11X),':',10X,'PULPWOOD'/
     4'      SPECIES    :',6X,'CUBIC FOOT VOLUME',5X,':',6X,'BOARD ',
     5'FOOT VOLUME',5X,':',6X,'CUBIC FOOT VOLUME'/
     6' ',99('-')/' ')
      DO 480 ISPEC=1,35
        IF(CBTST(ISPEC).EQ.0.AND.PLTST(ISPEC).EQ.0.AND.ISPEC.LT.33)
     1        GOTO 470
        ICBTST=CBTST(ISPEC)+.5 ; IBDTST=BDTST(ISPEC)+.5
        IPLTST=PLTST(ISPEC)+.5
        WRITE(3,310) (SPETIT(ISPEC,J),J=1,3),ICBTST,IBDTST,IPLTST
  470   IF(ISPEC.EQ.32.OR.ISPEC.EQ.34.OR.ISPEC.EQ.35)  WRITE(3,250)
  480 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE MDSTI (Q,F,X)
C
C***********************************************************************
C
C    THIS SUBPROGRAM IS COMPOSED OF TWO SUBROUTINES ADAPTED FROM THE
C    INTERNATIONAL MATHEMATICAL AND STATISTICAL LIBRARIES,INC. (IMSL)
C      MDSTI  -  INVERSE STUDENT'S T DISTRIBUTION
C      MDNRIS -  INVERSE NORMAL PROBABILITY DISTRIBUTION FUNCTION
C    BOTH SUBROUTINES HAVE BEEN EDITED REMOVING CAPABILITIES NOT NEEDED
C    IN THIS APPLICATION.  THE REMAINING CODE IS REPRODUCED HERE IN
C    ACCORDANCE WITH THE IMSL POLICY ON RESEARCH WORK AS STATED ON
C    PAGE INTRO-22 OF THE JULY, 1977 LIBRARY MANUAL.
C
C***********************************************************************
C
C                                 EXACT INTEGRAL FOR 2 D.F.
      IF (ABS(F-2.0) .GT. .000001)  GO TO 10
      X = SQRT(2.0/(Q*(2.0-Q))-2.0)
      GO TO 50
   10 HPI = 1.570796
C                                 EXACT INTEGRAL FOR 1 D.F.
      IF (ABS(F-1.0) .GT. .000001)  GO TO 20
      A = Q*HPI
      X = COS(A)/SIN(A)
      GO TO 50
C                                 EXPANSION FOR N GREATER THAN 2
   20 A = 1.0/(F-0.5)
      B = 48.0/(A*A)
      C = ((20700.*A/B-98.)*A-16.)*A+96.36
      D = ((94.5/(B+C)-3.0)/B+1.0)*SQRT(A*HPI)*F
      XX = D*Q
      Y = XX**(2.0/F)
      IF (Y .GT. A+.05)  GO TO 40
      Y = ((1.0/(((F+6.0)/(F*Y)-0.089*D-0.822)*(F+2.0)*3.0)+
     1    0.5/(F+4.0))*Y-1.0)*(F+1.0)/(F+2.0)+1.0/Y
   30 X = SQRT(F*Y)
      GO TO 50
C                                 ASYMPTOTIC INVERSE EXPANSION ABOUT
C                                 NORMAL
   40 X = .5 * Q
      CALL MDNRIS(X,XX)
      Y = XX * XX
      IF (F .LT. 5.)  C = C+0.3*(F-4.5)*(XX+0.6)
      C = (((.05*D*XX-5.0)*XX-7.0)*XX-2.0)*XX+B+C
      Y = (((((0.4*Y+6.3)*Y+36.)*Y+94.5)/C-Y-3.0)/B+1.0)*XX
      Y = A*Y*Y
      D = Y
      Y = .05*Y*Y+Y
      IF (Y .GT. .002)  Y = EXP(D) - 1.0
      GO TO 30
   50 RETURN
      END
```

```
      SUBROUTINE MDNRIS(P,Y)
      DATA              SQRT2/1.4142136/
      DATA              A1,A2,A3/-.57517029,-1.8965133,-.054962605/
      DATA              B0,B1,B2,B3/-.11377303,-3.2934740,-2.3749959,
     1                              -1.1875145/
      DATA              C0,C1,C2,C3/-.11466659,-.13147744,-.23682010,
     1                              .050739749/
      DATA              D0,D1,D2/-44.279769,21.985462,-7.5861027/
      DATA              E0,E1,E2,E3/-.0566842208,.39370209,-.31665010,
     1                              .062089629/
      DATA              F0,F1,F2/-6.2667859,4.6662627,-2.9628832/
      DATA              G0,G1,G2,G3/.00018511591,-.0020281520,
     1                              -.14983844,.010786386/
      DATA              H0,H1,H2/.099529751,.52117329,-.068883009/
      GO TO 40
   10 IF (X.LT. .15)  GO TO 30
      IF (X.LT.1.85)  GO TO 20
      SIGMA = -1.
      A = 2.-X
      B = X-1.
      GO TO 50
   20 Z = 1.-X
      SIGMA = SIGN(1.,Z)
      Z = ABS(Z)
      GO TO 80
   30 SIGMA = 1.
      A = X
      B = 1.-X
      GO TO 50
C                                 INVERSE GAUSSIAN ENTRY
   40 INT = 3
      X = 2.*P
      GO TO 10
C                                 REDUCED ARGUMENT IS IN (.85,1.),
C                                    OBTAIN THE TRANSFORMED VARIABLE
   50 W = SQRT(-ALOG(A+A*B))
      IF (W.LT.2.5)  GO TO 70
      IF (W.LT.4.)  GO TO 60
C                                 W GREATER THAN 4., APPROX. F BY A
C                                    RATIONAL FUNCTION IN 1./W
      WI = 1./W
      SN = ((G3*WI+G2)*WI+G1)*WI
      SD = ((WI+H2)*WI+H1)*WI+H0
      F = W + W*(G0+SN/SD)
      GO TO 90
C                                 W BETWEEN 2.5 AND 4., APPROX. F
C                                    BY A RATIONAL FUNCTION IN W
   60 SN = ((E3*W+E2)*W+E1)*W
      SD = ((W+F2)*W+F1)*W+F0
      F = W + W*(E0+SN/SD)
      GO TO 90
C                                 W BETWEEN 1.13222 AND 2.5, APPROX.
C                                    F BY A RATIONAL FUNCTION IN W
   70 SN = ((C3*W+C2)*W+C1)*W
      SD = ((W+D2)*W+D1)*W+D0
      F = W + W*(C0+SN/SD)
      GO TO 90
C                                 Z BETWEEN 0. AND .85, APPROX. F
C                                    BY A RATIONAL FUNCTION IN Z
   80 Z2 = Z*Z
      F = Z+Z*(B0+A1*Z2/(B1+Z2+A2/(B2+Z2+A3/(B3+Z2))))
C                                 FORM THE SOLUTION BY MULT. F BY
C                                    THE PROPER SIGN
   90 Y = SIGMA*F
      IF (INT.NE.3)  GO TO 100
      Y = -Y*SQRT2
  100 RETURN
      END
```

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