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Lumber output analysis

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LUMBER OUTPUT ANALYSIS

by

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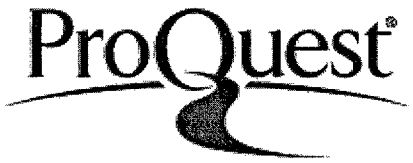

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TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

In view of the recent nationwide concern with environmental quality, interest has been cultivated in the more efficient utilization of our natural resources. One specific focus of such interest is the utilization of raw material in the wood products industry. Progress toward the industry's goal - full utilization of the raw material, that is logs, can be observed in areas such as pulping, particle board, hard board, flake board and similar products.

Specifically, this study has focussed on the efficient utilization of sawlogs in lumber production. This entailed determining the amount, type and quality of lumber obtained from logs in various sizes and grades in an attempt to determine a significant correlation between the test logs and the lumber obtained from them. Hopefully, information of this type will be of use to sawmill managers, because it will enable them to predict with some level of confidence not only the amount of lumber to be produced from any log, but also the type and quality of that lumber. If further studies of this type conclusively prove that this method is feasible, the sawmills will be able to reduce their finished lumber inventory and carry on production in accordance with current orders. This would require log yards to be arranged in a manner similar to that of warehouses. In other words, every log of a certain species, size and grade would be located in a particular place

within the log yard. When an order arrives for a specific type, size and grade of lumber, the mill can request those logs from the log yard that will produce the higher percentage of desired lumber. The use of this procedure will eliminate, to a great extent, the use of low grade logs for high grade lumber production and will therefore reduce operational costs. The opposite is also true for many cases in which a high grade log may be sawn so as to produce only a portion of its potential high quality lumber.

Lumber is broken into two major categories, boards (under 2" nominal thickness) and dimension (2" to 4" nominal thickness). The first category, boards, contains grades 1 through 5; whereas dimension contains only grades 1 through 4. Dimension is further broken down into size classes, ranging from 2x4 to 2x12 each containing four grades. The original intention of this paper was to draw significant relationships between logs and percent output within each grade of the board category and each grade within the size classes represented by the dimension category. It soon became evident that these groupings were much too small to analyse the desired data. Upon construction of a 95% confidence interval around the volume outputs of each grade within the size classes of the dimension category, the interval size was so large that they became insignificant. The grouping method finally chosen is that used by the wood products industry for the sale of both boards and dimension lumber. Within the category of boards the grouping consists of number 3 common and better; while structural dimension contains number 2 and better.

CHAPTER II

DISCUSSION OF TABLES 1 - 31

In the process of conducting this study, five tests were run; each consisting initially of 10 logs. Each one of the five tests was comprised of different size logs ranging in grade from number 1 to number 3. All test logs were Douglas fir (pseudotsuga mensiesii). All lumber measured was rough cut and green. Test number 1 was composed of 12-inch diameter logs, 16 feet long; test 2, 12-inch diameter, 20 feet long; test 3, 14-inch diameter, 16 feet long; test 4, 12-inch diameter, 12 feet long; test 5, 17-inch diameter, 16 feet long. Tests 1, 3 and 5 were used to plot the desired information via simple regression. It was therefore hoped that output trends within previously established groupings could be located. The results from tests 2 and 4 were also plotted, merely to see where they would be in relation to the 16-foot logs used in tests 1, 3 and 5. The only control over the head sawyers during this study were orders to cut for grade and not volume.

The basic information gathered and computed during this study is presented in a series of six tables for each test run. The first series for all tests is the nominal table. Every nominal table displays the log diameter and length for that particular test, as well as the log grades. The type of lumber output is divided into two major categories, boards and dimensions. Boards are subdivided only by the board grades, number 1 through number 5; whereas dimension is divided into size classes, each class being further subdivided into four grades.

The second series of tables is identical to the first in layout. The data displayed is actual volume vice nominal as in series one. In comparing the figures in these two series a noticeable feature, although quite understandable, is present in all five tests. The nominal board foot volume of boards is always less than the actual volume, while the actual board foot volume of dimension is less than the nominal. This is due to the fact that a nominal 1-inch board is usually more than 1-inch thick; thus, actual volume is greater, The reverse is true in dimension lumber. A 2-inch nominal in dimension stock is almost always less than two inches thick. Since dimension lumber comprises the greatest portion of the total lumber in each test, there is decrease in total volume when going from nominal to actual board feet.

The third series is simply a consolidation of the second series. Specifically, the size classes within the dimension category have been eliminated. Dimension is now, subdivided only into grades 1 through 4. This consolidation was necessitated by the changes in grouping requirements.

Series four contains the data from series three presented in percent of total lumber volume.

The fifth series is similar to that of the third with the exception that the data presented represents the upgraded lumber.

The term upgrading as used in this paper simply refers to the trimming process during lumber production. For example, a sixteen foot board, eight inches wide maybe a number 4 common board but if a defect at one end is removed by trimming the board to fourteen feet, the results is a shorter board of a higher grade.

It will be noticed that along with the increases in grade quality, simultaneous decreases in total volume occur due to trimming loss.

The sixth series has the same relationship to series five as does series four to series three. The data is expressed in percent of upgraded total lumber volume. It is the series of tables that will be used to make a regression analysis between log and lumber output.

Table 31 portrays the relationship between log volume measures, Scribner Decimal "C" and volumetric volume. The volumetric volume was determined through the use of a modified smalian's formula

$$\frac{\frac{Ds^2 + Db^2}{2}\ (.7854)\ x(n)}{144}.$$

A third relationshp is shown, the two log volumes and the actual lumber tally after upgrading. The fourth column is percent overrun calculated by dividing the Scribner Decimal "C" values into the actual lumber tally and subtracting 100.

TABLE 1

NOMINAL BD FT
LUMBER VOLUME BY DIAMETER CLASS,
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

Particular		12 Ft.		
Board Grades			Log Grade	
		#1	#2	#3
#1				
#2			26.68	6.68
#3			28.68	4.02
#4			14.00	4.98
#5			4.00	
Total Board Grade	89.04		73.36	15.68
Dimension Grades				
2x4 Const.			8.00	8.00
Standard				8.00
Utility			8.00	
Economy			24.00	
Total	56.00		40.00	16.00
2x6 #1			60.00	12.00
#2			12.00	
#3			12.00	
#4				
	96.00		84.00	12.00
2x8 #1			160.00	48.00
#2			32.00	29.28
#3			42.72	48.00
#4			16.00	
Total	376.00		250.72	125.28
2x10 #1			60.00	
#2			20.00	
#3			100.00	
#4				
Total	180.00		180.00	
Dimension Total	708.00		554.72	153.28
GRAND TOTAL	797.04		608.08	168.96

TABLE 2

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

		12 Ft.		
Board Grades			Log Grade	
		#1	#2	#3
#1				
#2			25.12	7.09
#3			25.46	4.73
#4			21.91	5.35
#5			8.26	
Total Board Grade	97.92		80.75	17.17
Dimension Grades				
2x4 Const.			7.34	7.00
Standard				6.66
Utility			7.07	
Economy			22.38	
Total	50.45		36.79	13.66
2x6 #1			57.08	12.36
#2			11.46	
#3			10.68	
#4				
Total	91.58		79.22	12.36
2x8 #1			148.09	42.56
#2			28.33	
#3			40.36	45.74
#4			14.77	27.40
Total	347.25		231.55	115.70
2x10 #1			56.24	
#2			17.88	
#3			89.71	
#4				
Total	163.83		163.83	
2x12 #1				
#2				
#3				
#4				
Total				
Dimension Total	653.11		511.39	141.72
GRAND TOTAL	751.03		592.14	158.89

TABLE 3

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			25.12	7.09	32.21
#3			25.46	4.73	30.19
#4			21.91	5.35	27.26
#5			8.26		8.26
Total Board Grade	97.92		80.75	17.17	97.92
Dimension Grades					
#1			268.75	61.92	330.67
#2			57.67	6.66	64.33
#3			147.82	45.74	193.56
#4			37.15	27.40	64.55
Total Dimension Grade	653.11		511.39	141.72	653.11
TOTAL BD. FT.	751.03		592.14	158.89	751.03

TABLE 4

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
BEFORE UPGRADING

12-INCH DIAMETER

12 Ft.

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			4.24	4.46	4.29
#3			4.30	2.98	4.02
#4			3.70	3.37	3.63
#5			1.39		1.10
Total Board Grade	13.04%		13.64%	10.81%	13.04%
Dimension Grades					
#1			45.39	38.97	44.03
#2			9.74	4.19	8.57
#3			24.96	28.79	25.77
#4			6.27	17.24	8.59
Total Dimension	86.96%		86.36%	89.19%	86.96%
TOTAL BOARD FEET	100.00%		100.00%	100.00%	100.00%

TABLE 5

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

12 Ft.

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			2.89		2.89
#2			25.12	7.09	32.21
#3			25.46	4.73	30.19
#4			17.60	5.35	22.95
#5			8.26		8.26
Total Board Grades	96.50		79.33	17.17	96.50
Dimension Grades					
#1			268.75	61.92	330.67
#2			62.50	6.66	69.16
#3			159.16	45.74	204.90
#4			14.77	27.40	42.17
Total Dimension	646.90		505.18	141.72	646.90
TOTAL BOARD FEET	743.40		584.51	158.89	743.40

TABLE 6

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

12 Ft.

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			.49		.39
#2			4.30	4.46	4.33
#3			4.36	2.98	4.06
#4			3.01	3.37	3.09
#5			1.41		1.11
Total Board Grades	12.98%		13.57%	10.81%	12.98%
Dimension Grades					
#1			45.98	38.97	44.48
#2			10.69	4.19	9.30
#3			27.23	28.74	27.56
#4			2.53	17.24	5.67
Total Dimension	87.02%		86.43%	89.19%	87.02%
TOTAL BOARD FEET	100.00%		100.00%	100.00%	100.00%

TABLE 7

NOMINAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

		20 Feet Log Grades		
Board Grades		#1	#2	#3
#1				
#2			30.01	
#3			67.00	28.67
#4			25.68	
#5			19.34	6.67
Total Board Grade	177.37		142.03	35.34
Dimension Grades				
2x4 Const.			75.98	
Standard			26.66	13.33
Utility			26.66	
Economy			26.66	13.33
Total	182.62		155.96	26.66
2x6 #1			94.00	40.00
#2			20.00	20.00
#3				20.00
#4				
Total	194.00		114.00	80.00
2x8 #1			354.70	
#2			234.69	26.67
#3			106.68	53.34
#4			26.67	
Total	802.75		722.74	80.01
2x10 #1				66.66
#2				33.33
#3				
#4				
Total	99.99		0.00	99.99
Dimension Total	1,279.36		992.70	286.66
GRAND TOTAL	1,456.73		1134.73	322.00

TABLE 8

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

		20 Feet		
Board Grades			Log Grade	
		#1	#2	#3
#1				
#2			32.04	
#3			71.47	28.95
#4			28.02	
#5			21.19	7.41
Total Board Grade	184.08		152.72	36.36
Dimension Grades				
2x4 Const.			69.25	
Standard			25.19	12.29
Utility			23.86	
Economy			24.22	12.29
Total	167.10		142.52	24.58
2x6 #1			88.10	36.22
#2			19.76	18.82
#3				18.02
#4				
Total	180.92		107.86	73.06
2x8 #1			331.02	
#2			212.10	26.04
#3			93.50	48.25
#4			26.07	
Total	736.98		662.69	74.29
2x10 #1				63.52
#2				29.53
#3				
#4				
Total	93.05			93.05
2x12 #1				
#2				
#3				
#4				
Total				
Total Dimension	1,178.05		913.07	264.98
GRAND TOTAL	1,367.13		1065.79	301.34

TABLE 9

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER

20 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			32.04		32.04
#3			71.47	28.95	100.42
#4			28.02		28.02
#5			21.19	7.14	28.60
Total Board Grade	189.08		152.72	36.36	189.08
Dimension Grades					
#1			488.37	99.74	588.11
#2			257.05	86.68	343.73
#3			117.36	66.27	183.63
#4			50.29	12.29	62.58
Total Dimension	1,178.05		913.07	264.98	1178.05
TOTAL BOARD FEET	1,367.13		1065.74	301.34	1367.13

TABLE 10

ACTUAL BD. FT.
LUMBER VOLUME % BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
BEFORE UPGRADING

12-INCH DIAMETER

		20 Feet		
Board Grades		Log Grade		Total Grade
	#1	#2	#3	
#1				
#2		3.01%		2.34%
#3		6.71	4.61%	7.35
#4		2.63		2.05
#5		1.99	2.46	2.09
Total Board Grade	13.03%	14.33%	12.07%	13.83%
Dimension Grades				
#1		45.82%	33.10%	43.02%
#2		24.12	28.76	25.14
#3		11.01	21.99	13.43
#4		4.72	4.08	4.58
Total Dimension	86.17%	85.67%	87.93%	86.17%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%

TABLE 11

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

20 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			32.04		32.04
#3			90.90	28.95	119.85
#4			21.75		21.75
#5				7.41	7.41
Total Board Grade	181.05		144.69	36.36	181.05
Dimension Grades					
#1			581.02	99.74	680.76
#2			244.46	97.72	342.18
#3			70.78	66.27	137.05
#4					
Total Dimension	1,159.99		896.26	263.73	1159.99
TOTAL BOARD FEET	1,341.04		1040.95	300.09	1341.04

TABLE 12

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

		20 Feet			
Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			3.08%		2.39%
#3			8.73	9.65%	8.94
#4			2.09		1.62
#5				2.47	.55
Total Board Grade	13.50%		13.90%	12.12%	13.50%
Dimension Grades					
#1			55.82%	33.24%	50.76%
#2			23.48	32.56	25.52
#3			6.80	22.08	10.22
#4					
Total Dimension	86.50%		86.10%	87.88%	86.50%
TOTAL BOARD FEET	100.00%		100.00%	100.00%	100.00%

TABLE 13

NOMINAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS,
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

		16 Feet		
Board Grades		Log Grade		
		#1	#2	#3
#1				
#2			32.67	
#3		14.66	24.33	2.67
#4		21.33	59.98	15.33
#5		8.00	12.33	
Total Board Grade	191.30	43.99	129.31	18.00
Dimension Grades				
2x4 Const.			21.34	10.67
Standard			9.33	
Utility			10.67	
Economy			9.33	
Total	61.34	0.00	50.67	10.67
2x6 #1			48.00	
#2				
#3				
#4				
Total	48.00	0.00	48.00	0.00
2x8 #1		63.99	229.30	21.33
#2		42.66	63.99	42.66
#3			106.65	21.33
#4		21.33		21.33
Total	634.57	127.98	399.94	106.65
2x10 #1		80.01	186.69	
#2				
#3			26.67	
#4			26.67	
Total	320.04	80.01	240.03	0.00
Dimension Total	1,063.95	207.99	738.64	117.32
GRAND TOTAL	1,255.25	251.98	867.95	135.32

TABLE 14

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER CLASS

16 Feet

Board Grades		Log Grade		
		#1	#2	#3
#1				
#2			34.40	
#3		15.72	28.72	2.79
#4		20.24	63.16	15.51
#5		7.50	12.97	
Total Board Grade	206.01	43.46	139.25	18.30
Dimension Grades				
2x4 Const.			20.22	
Standard				8.87
Utility			9.68	
Economy			15.60	
Total	54.37		45.50	8.87
2x6 #1			44.78	
#2				
#3				
#4				
Total	44.78		44.78	
2x8 #1		58.77	223.43	19.78
#2		40.01	41.14	40.95
#3			74.81	18.66
#4		17.16	18.77	19.75
Total	573.23	115.94	358.15	99.14
2x10 #1		71.58	142.11	
#2				
#3			49.52	
#4			23.30	
Total	286.51	71.58	214.93	
2 2x12 #1				
#2				
#3				
#4				
Total				
Dimension Total	958.89	187.52	663.36	108.01
GRAND TOTAL	1,159.90	230.98	802.61	126.31

TABLE 15

ACTUAL BD. FT.
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

12-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			34.40		34.40
#3		15.72	28.72	2.79	47.23
#4		20.24	63.16	15.51	98.91
#5		7.50	12.97		20.47
Total Board Grade	201.01	43.46	139.25	18.30	201.01
Dimension Grades					
#1		130.35	451.45	19.78	601.58
#2		40.01	20.23	49.82	110.06
#3			134.01	18.66	152.67
#4		17.16	57.67	19.75	94.58
Total Dimension	958.89	187.52	663.36	108.01	958.89
TOTAL BOARD FEET	1,159.90	230.98	802.61	126.31	1159.90

TABLE 16

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
BEFORE UPGRADING

12-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2			4.29%		2.97%
#3		6.81%	3.58	2.21	4.07
#4		8.76	7.87	12.28	8.53
#5		3.25	1.62		1.76
% Total Board Grades	17.33%	18.82%	17.35%	14.49%	17.33%
Dimension Grades					
#1		56.43%	56.25%	15.66%	51.86%
#2		17.32	2.50	39.44	9.49
#3			16.70	14.77	13.16
#4		7.43	7.19	15.64	8.15
% Total Dimension	82.67%	81.18%	82.65%	85.51%	82.67%
% TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 17

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			4.13		4.13
#2		31.97	34.40		34.40
#3		31.97	57.85	2.79	92.61
#4		7.08	33.88	15.51	56.47
#5					
Total Board Grade	187.61	39.05	130.26	18.30	187.61
Dimension Grades					
#1		143.25	546.85	34.63	724.73
#2		40.01	66.48	66.24	172.73
#3			9.68		9.68
#4			15.60		15.60
Total Dimension	922.74	183.26	638.61	100.87	922.74
TOTAL BOARD FEET	1,110.35	22.31	768.87	119.17	1110.35

TABLE 18

ACTUAL BOARD FEET
LUMBER VOLUME % BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

12-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			.54%		.37%
#2			4.47		3.10
#3		14.38%	7.52	2.34	8.34
#4		3.18	4.41	13.02	5.09
#5					
Total Board Grade	16.90%	17.57%	16.94%	15.36%	16.90%
Dimension Grades					
#1		64.44%	71.12%	29.06%	65.27%
#2		18.00	8.65	55.58	15.56
#3			1.26		.87
#4			2.03		
Total Dimension	83.10%	82.43%	83.06%	84.64%	83.10%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 19

NOMINAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

14-INCH DIAMETER CLASS

16 Feet

Board Grades		Log Grades		
		#1	#2	#3
#1			2.67	
#2		14.34		
#3		4.67	32.66	6.67
#4		5.33	28.67	
#5			29.98	3.00
Total Board Grade	127.99	24.34	93.98	9.67
Dimension Grades				
2x4 Const.			21.34	
Standard			21.33	10.67
Utility				
Economy				
Total	53.34	0.00	42.67	10.67
2x6 #1		32.00	64.00	12.00
#2			14.00	
#3				
#4				
Total	122.00	32.00	78.00	12.00
2x8 #1		58.66	40.00	
#2			61.33	18.67
#3				
#4				
Total	178.66	58.66	101.33	18.67
2x10 #1		26.67	183.35	143.34
#2		26.67	310.02	
#3		53.34	106.68	
#4				
Total	850.07	106.68	600.05	143.34
2x12 #1		156.00		
#2				
#3			120.00	
#4				
Total	276.00	156.00	120.00	0.00
Dimension Total	1,480.07	353.34	943.37	184.68
GRAND TOTAL	1,608.06	377.68	1036.03	194.35

TABLE 20

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

14-INCH DIAMETER CLASS

16 Feet

Board Grades		Log Grade #1	Log Grade #2	Log Grade #3
#1			2.83	
#2		15.41		
#3		5.02	33.49	7.46
#4		5.81	29.46	
#5			32.22	3.14
Total Board Grade	134.84	26.24	98.00	10.60
Dimension Grades				
2x4 Const.				
Standard			19.03	
Utility			19.24	9.51
Economy				
Total	47.78		38.27	9.51
2x6 #1		29.85	29.80	11.70
#2			41.92	
#3				
#4				
Total	113.27	29.85	71.72	11.70
2x8 #1		54.58	36.09	
#2			57.11	17.28
#3				
#4				
Total	165.06	54.48	93.20	17.28
2x10 #1		23.99	168.08	133.89
#2		24.33	300.60	
#3		51.51	97.93	
#4				
Total	800.33	99.83	566.61	133.89
2x12 #1		142.33		
#2				
#3			113.67	
#4				
Total	256.00	142.33	113.67	
Dimension Total	1,389.44	326.59	883.47	172.38
GRAND TOTAL	1,517.28	352.83	981.47	182.98

TABLE 21

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

14-INCH DIAMETER CLASS

Board Grades		16 Feet Log Grade			Total Grade
		#1	#2	#3	
#1			2.83		2.83
#2		15.41			15.41
#3		5.02	33.49	7.46	45.97
#4		5.81	29.46		35.27
#5			32.22	3.14	35.36
Total Board Grade	134.84	26.24	98.00	10.60	134.84
Dimension Grades					
#1		250.75	253.00	145.59	649.34
#2		24.33	418.87	26.79	469.99
#3		51.51	211.60		263.11
#4					
Total Dimension	1,382.44	326.59	883.47	172.38	1382.44
TOTAL BOARD FEET	1,517.28	352.83	981.47	182.98	1517.28

TABLE 22

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
BEFORE UPGRADING

14-INCH DIAMETER

Board Grades		16 Feet Log Grade			Total Grade
		#1	#2	#3	
#1			.29%		.19%
#2		4.37%			1.02
#3		1.42	3.41	4.08	3.03
#4		1.65	3.00	1.72	2.32
#5			3.28		2.33
Total Board Grade	8.89%	7.44%	9.99%	5.79%	8.89%
Dimension Grades					
#1		71.07%	25.78%	79.57%	42.80%
#2		6.80	42.68	14.64	30.98
#3		14.60	21.56		17.34
#4					
Total Dimension	91.11%	92.56%	90.01%	94.21%	91.11%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 23

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

14-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			2.83		2.83
#2		15.41	4.83		20.24
#3		5.02	37.66	7.46	50.14
#4		5.81	29.46		35.27
#5			18.93	3.14	22.07
Total Board Grade	130.55	26.24	93.71	10.60	130.55
Dimension Grades					
#1		250.75	253.00	145.59	649.34
#2		24.33	418.87	26.79	469.99
#3		51.51	211.60		263.11
#4					
Total Dimension	1,382.44	326.59	883.47	172.38	1382.44
TOTAL BOARD FEET	1,512.99	352.83	977.18	182.98	1512.99

TABLE 24

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

14-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1			.29%		.19%
#2		4.37%	.49		1.34
#3		1.42	3.85	4.08%	3.31
#4		1.65	3.02		2.33
#5			1.94	1.72	1.46
Total Board Grade	8.63%	7.44%	9.59%	5.79%	8.63%
Dimension Grades					
#1		71.07%	25.89%	79.57%	42.92%
#2		6.90	42.87	14.64	31.06
#3		14.60	21.65		17.39
#4					
Total Dimension	91.37%	92.56%	90.41%	94.21%	91.37%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 25

NOMINAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE AND LUMBER GRADE
PRIOR TO UPGRADING

17-INCH DIAMETER CLASS

16 Feet

Board Grades		Log Grades		
		#1	#2	#3
#1				
#2				
#3		10.66	73.00	8.00
#4			26.33	3.33
#5			5.33	8.00
Total Board Grade	134.65	10.66	104.66	19.33
Dimension Grades				
2x4 Const.		10.67	10.67	10.67
Standard			26.67	10.67
Utility				
Economy			21.34	18.67
Total	109.36	10.67	58.68	40.01
2x6 #1			32.00	16.00
#2				16.00
#3			16.00	48.00
#4				
Total	128.00		48.00	80.00
2x8 #1			234.63	21.33
#2		16.00	56.00	21.33
#3			18.67	40.00
#4				
Total	407.96	16.00	309.30	82.66
2x10 #1			26.67	26.67
#2				20.00
#3				
#4				
Total	73.34		26.67	46.67
2x12 #1		64.00	482.67	96.00
#2		56.00	224.00	96.00
#3		96.00	224.00	96.00
#4		32.00	64.00	
Total	1,530.67	248.00	994.67	288.00
Dimension Total	2,249.33	274.67	1437.32	537.34
GRAND TOTAL	2,383.98	285.33	1541.98	556.67

TABLE 26

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

17-INCH DIAMETER CLASS
16 Feet

Board Grades		Log Grade		
		#1	#2	#3
#1				
#2				
#3		11.67	79.97	9.23
#4			29.50	3.71
#5			5.69	8.91
Total Board Grade	148.68	11.67	115.16	21.85
Dimension Grades				
2x4 Const.		10.04	10.08	9.32
Standard			27.21	9.78
Utility				
Economy			19.15	13.78
Total	99.36	10.04	56.44	32.88
2x6 #1			29.73	13.53
#2				14.36
#3			15.15	42.00
#4				
Total	114.77		44.88	69.89
2x8 #1			220.09	19.90
#2		15.96	53.56	18.58
#3			16.82	38.72
#4				
Total	383.63	15.96	190.47	77.20
2x10 #1			23.86	24.30
#2				19.00
#3				
#4				
Total	67.16		23.86	43.30
2x12 #1		58.33	446.96	87.39
#2		50.71	203.24	87.82
#3		87.18	206.91	91.66
#4		28.98	57.19	
Total	1,406.37	225.20	914.30	266.87
Total Dimension	2,071.29	251.20	1329.95	490.14
GRAND TOTAL	2,219.97	262.87	1445.11	511.99

TABLE 27

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
PRIOR TO UPGRADING

17-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2					
#3		11.67	79.97	9.23	100.87
#4			29.50	3.71	33.21
#5			5.64	8.91	14.60
Total Board Grade	148.68	11.67	115.16	21.85	148.68
Dimension Grades					
#1		68.37	730.72	154.44	953.53
#2		66.67	284.01	149.54	500.22
#3		87.18	238.88	172.38	498.44
#4		28.98	76.34	13.78	119.10
Total Dimension	2,071.19	251.20	1329.95	490.14	2071.29
TOTAL BOARD FEET	2,219.97	262.87	1445.11	511.99	2219.97

TABLE 28

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
BEFORE UPGRADING

17-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2					
#3		4.44%	5.53%	1.80%	4.54%
#4			2.04	.72	1.50
#5			.39	1.74	.66
Total Board Grade	6.70%	4.44%	7.97%	4.27%	6.70%
Dimension Grades					
#1		26.01%	50.57%	30.16%	42.95%
#2		25.36	19.65	29.21	22.53
#3		33.16	16.53	33.67	22.45
#4		11.02	5.28	2.69	5.36
Total Dimension	93.30%	95.56%	92.03%	95.73%	93.30%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 29

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

17-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2					
#3		11.67	79.97	9.23	100.87
#4			33.78	11.48	45.26
#5					
Total Board Grade	146.13	11.67	113.75	20.71	146.13
Dimension Grades					
#1		97.61	808.92	154.44	1060.97
#2		88.58	168.97	149.54	507.09
#3			223.73	172.38	396.11
#4		28.98	9.83	13.78	52.59
Total Dimension	2,016.76	215.17	1311.45	490.14	2016.76
TOTAL BOARD FEET	2,162.89	226.84	1425.20	510.85	2162.89

TABLE 30

ACTUAL BOARD FEET
LUMBER VOLUME BY DIAMETER CLASS
LENGTH, LOG GRADE, AND LUMBER GRADE
AFTER UPGRADING

17-INCH DIAMETER

16 Feet

Board Grades		Log Grade			Total Grade
		#1	#2	#3	
#1					
#2					
#3		5.14%	5.61%	1.81%	4.66%
#4			2.37	2.25	2.09
#5					
Total Board Grade	6.76%	5.14%	7.98%	4.05%	6.76%
Dimension Grades					
#1		43.03%	56.76%	30.23%	49.05%
#2		39.05	18.87	29.27	23.45
#3			15.70	33.74	18.31
#4		12.78	.69	2.70	2.43
Total Dimension	93.24%	94.86%	92.02%	95.95%	93.24%
TOTAL BOARD FEET	100.00%	100.00%	100.00%	100.00%	100.00%

TABLE 31

VOLUME COMPARISONS IN BOARD FEET
AFTER UPGRADING

Log No.	Test Dia. in.	Lgth. ft.	Log Gd. Gd. #	No. Logs	Scribner Decimal "C"	Volumetric Volume	Actual Lumber Volume	Percent Overrun
4	12	12	1	0	0	0	0	0
			2	7	420	944.07	584.51	39.17%
			3	2	120	276.27	158.89	32.41%
			Total		540	1220.34	743.40	37.67%
2	12	20	1	0	0	0	0	0
			2	8	800	1798.70	1040.95	30.12%
			3	2	200	508.88	300.09	50.05%
			Total		1000	2307.58	1341.04	34.41%
1	12	16	1	2	160	336.41	22.31	38.94%
			2	7	560	1211.68	768.87	37.30%
			3	1	80	191.16	119.17	48.96%
			Total		800	1739.25	1110.35	38.79%
3	14	16	1	2	220	539.08	352.83	60.38%
			2	6	660	1415.54	977.18	48.06%
			3	2	110	275.30	182.98	66.26%
			Total		990	2229.92	1512.99	52.83%
5	17	16	1	1	180	335.36	226.84	26.02
			2	6	1080	2083.60	1425.20	31.96%
			3	3	360	777.85	510.85	41.90%
			Total		1620	3196.81	2161.89	33.51%

CHAPTER III

STATISTICAL DATA

In constructing the graphs presented on pages 40, 41 and 42 in this paper, the data from series six was consolidated and arranged according to the desired groupings previously mentioned. This data is shown in Tables 32 and 33, pages 38 and 39.

The information plotted on the graphs represents 16-foot, grade 2 logs in the 12, 14 and 17 inch diameter classes. This data is from tests 1, 3 and 5 respectively. The information on the grade 2 logs from tests 2 and 4 is plotted to see where they fall in relation to the regressed line in their diameter class.

A mill manager now has the idea that mill production can adequately be determined merely by sorting logs into three grades. By sorting the logs in such a manner, the manager is still unable to determine the effectiveness of log grading; in other words, the relationship between log grades and the final lumber output. What is needed is a regression analysis to determine if a relationship between log grades and lumber output exists and, if so, what is the relationship?

The following is an attempt at such an analysis. The first step was to plot the percentages of the two major categories, percent boards of total lumber volume and percent dimension of total lumber volume. The lines shown on Graphs 1 and 2 are the regressed lines for that data. In both cases, a statistically significant correlation exists

TABLE 32

PERCENT LUMBER BY GRADE AFTER UPGRADING

Log Test			Log Grade		Percent of Total Log Volume		
No.	Diameter Inch	Length Feet	Grade Number	No. Logs	Board	Dimension	Total
4	12	12	1	0			
			2	7	13.57	86.43	100%
			3	2	10.81	89.19	100%
2	12	20	1	0			
			2	8	13.90	86.10	100%
			3	2	12.12	87.88	100%
1	12	16	1	2	17.57	82.43	100%
			2	7	16.94	83.06	100%
			3	1	15.36	84.64	100%
3	14	16	1	2	7.44	92.56	100%
			2	6	9.59	90.41	100%
			3	2	5.79	94.21	100%
5	17	16	1	1	4.44	95.56	100%
			2	6	7.97	92.03	100%
			3	3	4.27	95.73	100%

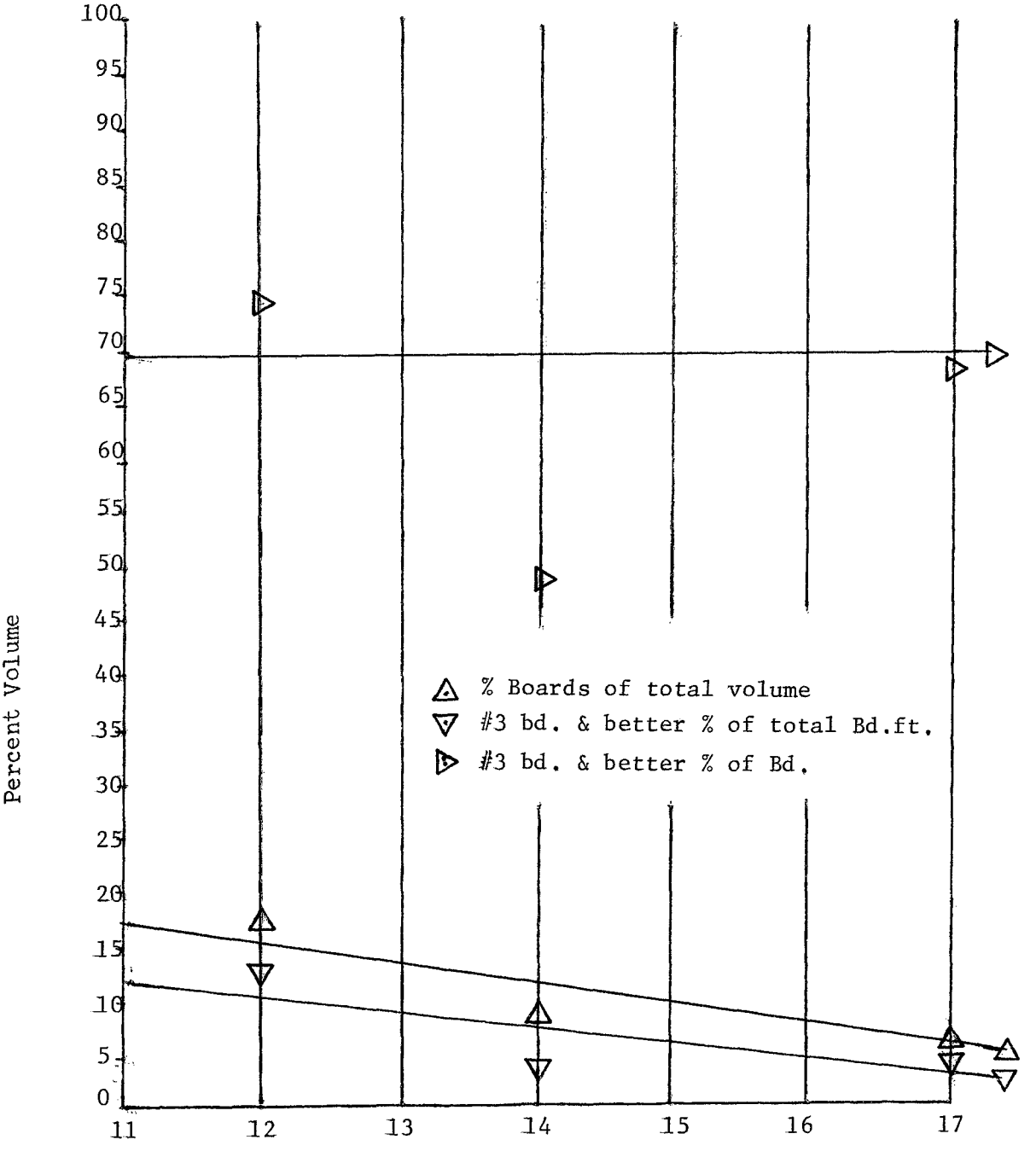
TABLE 33

PERCENT LUMBER BY GRADE AFTER UPGRADING

Log Test			Log Gd.		Type Yield w/in Class		% Lumber Grade Yield of Total Volume		
No.	Inch	Lgth. Ft.	Gd. No.	No. Logs	#3 + Bd.	#2 + Dim.	#3 + Bd.	#2 + Dim.	Per-cent
4	12	12	1	0	67.42	65.57	9.15	56.67	65.82
			2	7	67.42	65.57	9.15	56.67	65.82
			3	2	68.27	48.39	7.38	43.16	50.54
2	12	20	1	0					
			2	8	84.96	92.10	11.81	79.30	91.11
			3	2	79.62	74.87	9.65	65.80	75.45
1	12	16	1	2	81.84	100%	14.38	82.43	96.81
			2	7	73.97	96.04	12.53	79.77	92.30
			3	1	15.23	100%	2.34	84.64	86.98
3	14	16	1	2	77.82	84.24	5.79	77.97	83.76
			2	6	48.28	76.05	4.63	68.76	73.39
			3	2	70.47	100%	4.08	94.21	98.29
5	17	16	1	1	100%	53.76	4.44	51.37	55.81
			2	6	69.39	76.30	5.53	70.22	75.75
			3	3	42.15	62.02	1.80	59.37	61.17

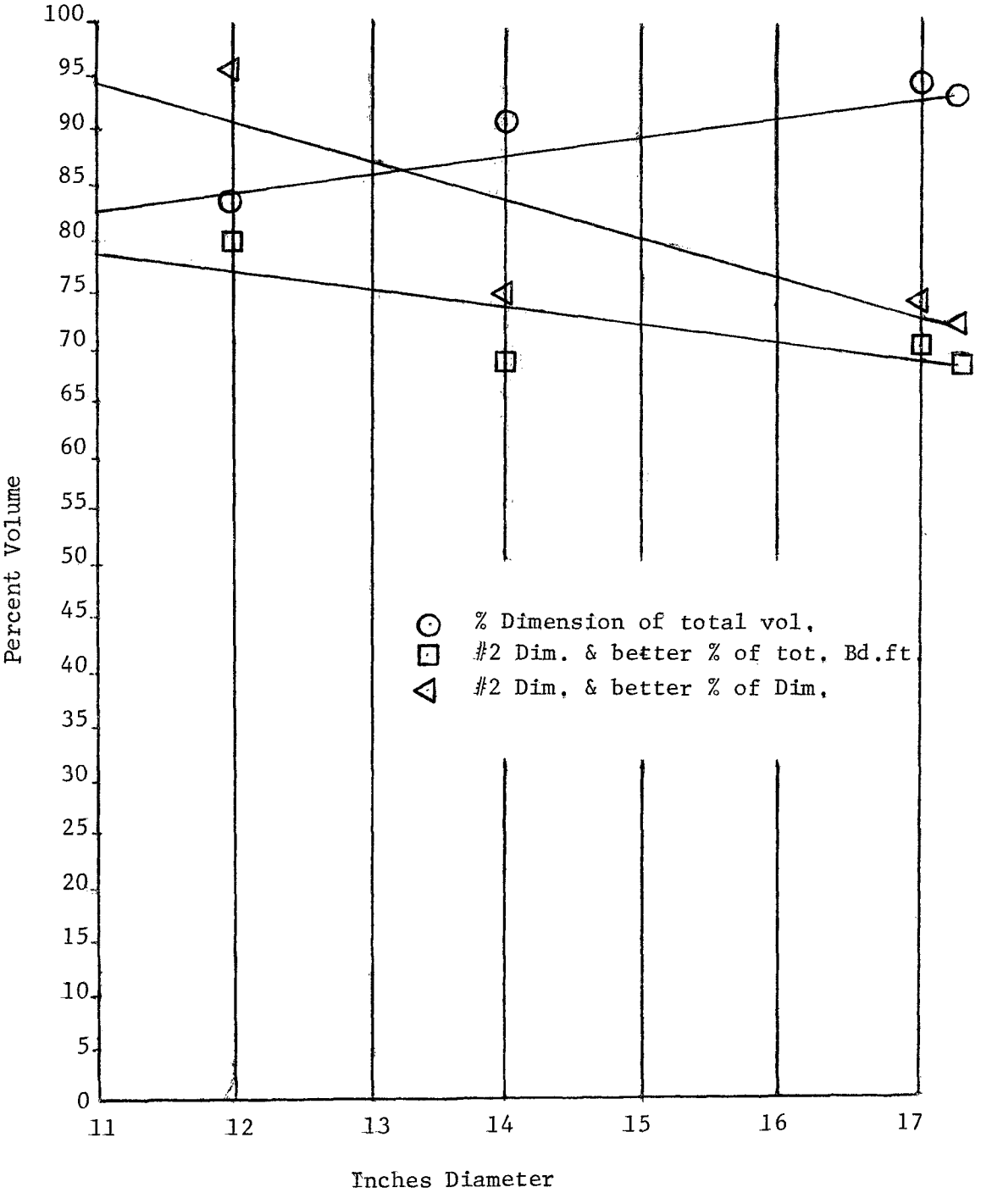
GRAPH 1

PERCENT BOARD VOLUME VERSUS DIAMETER IN 16-FOOT GRADE 2 LOGS



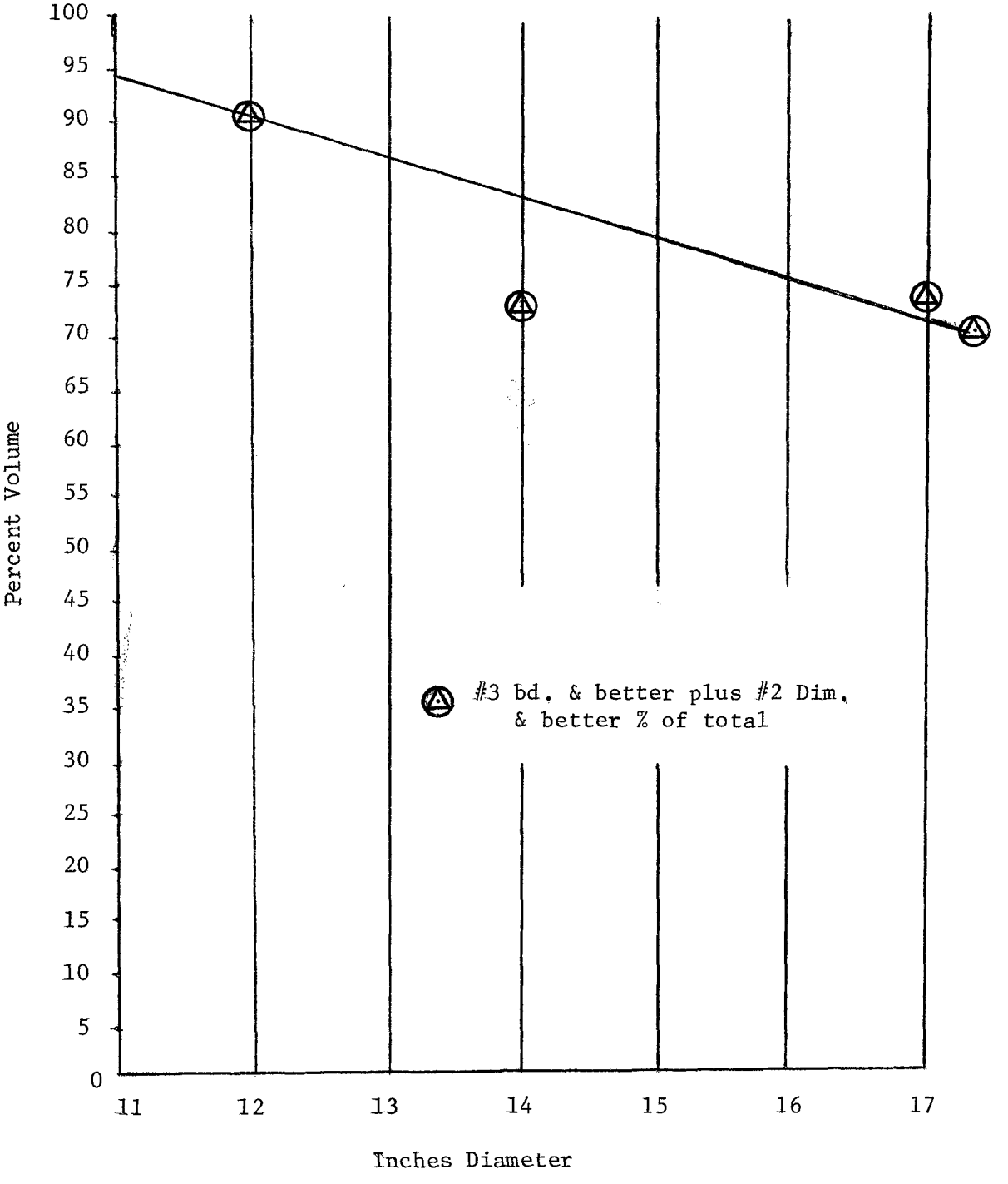
GRAPH 2

PERCENT DIMENSION VOLUME VERSUS DIAMETER IN 16-FOOT GRADE 2 LOGS



GRAPH 3

PERCENT VOLUME VERSUS DIAMETER IN 16-FOOT GRADE 2 LOGS



between the dependent variable, percent volume, and the independent variable, diameter. In the case of boards, the correlation coefficient r = -.89. The negative correlation simply means, as diameter increases, percent boards of total boardfoot volume decreases.

In order to determine whether or not this is a "dummy" correlation, a 0.95% confidence interval was constructed with the resulting interval of $-.95 < p < -.75$. With the value of zero not contained in the interval the -.89 correlation coefficient is significant. In squaring the r value, the result is .79 or 79%. This shows us that 79% of the movement in the dependent variable (percent volume) is explained by the dependent variable (diameter). A major portion of the remaining movement is due to the variations within log grade number 2.

The second major category, dimension, shows a very similar correlation, with the exception that it is positive. The correlation coefficient is .89. The positive correlation explains the increase in percent dimension with the increase in diameter. Once again a 95% confidence interval was constructed to insure against a "dummy" correlation. A $.75 < p < .95$ is the resulting interval. Since this interval fails to capture zero, we can safely assume that the correlation is statistically significant. The squaring of r equals .79 as in the previous case. Therefore, the independent variable (diameter) has explained 79% of the movement in the dependent variable (percent volume).

The next step was to plot the data according to the selected groupings. The first analysis was made on number 3 grade and better

boards, as a percent of the total lumber volume. As might be expected, the correlation coefficient is negative and equals -.74. A 95% confidence interval was constructed around -.74 with a resulting interval of $-.87 < p < -.35$. The first noticeable feature is the length of the interval compared with the two given previously. The larger length is due to the smaller grouping size. In this case when r is squared, only 54% of the movement in the dependent variable is explained. The smaller the grouping, the larger is the role played by the variations within the same log grade. In other words, the movement in the dependent variable depends increasingly on two or more independent variables, in this case, diameter and log grade.

The second step, once within the desired groupings, was to plot the number 2 and better structural dimension as a percent of the total boardfootage. Here a surprising situation is observed. The correlation coefficient is negative (-.72). The negative coefficient is due to the high percentage of number 2 and better structural dimension in the 12-inch diameter class. A similar regression analysis was run on the data prior to upgrading and a positive correlation coefficient was obtained. The reason for this drastic change is upgrading. In the 12-inch diameter class, the number of pieces in dimension sizes is very few, but they account for a very high percentage of the total log volume. Therefore, if only one or two pieces are upgraded, then there is a drastic change in percent by grade of dimension. For this reason, it is believed that the positive correlation is more reasonable as log diameters increase. The correlation coefficient is -.72 with a 95% confidence interval of

$-.88 < p < -.34$. This shows a significant correlation for the data gathered. If further studies of this type are conducted, eliminating the 12-inch diameter class and incorporating larger diameter classes, the correlation would probably be positive.

The third step was to plot number 3 common and better boards and number 2 and better dimension in order to produce a correlation in the higher grades of lumber. As would be expected, this correlation is also negative because of the negative coefficients of its two components. The same reasoning holds for this situation as in the previous. A study concerning larger diameters would show a positive correlation. This data gives a correlation coefficient of -.73 with a 95% confidence interval of $-.87 < p < .35$. Once again it can be seen as the groupings become more specific, the interval increases in length.

The last two regression lines pertain to the most specific of the groups. The first is the number 3 common and better boards as a percent of total boards. As might be expected with a grouping this small and this specific, the correlation coefficient is very low (-.05). When a 95% confidence interval is established, the interval contains zero ($+47 < p < +.42$), and therefore no significant correlation exists for this particular grouping based on the data correlated.

The last regression line is that of number 2 and better structural dimension as a percent of total dimension. This is where the upgrading effect in the 12-inch diameter class is very apparent. Ninety-six percent of the structural dimension lumber in the 12-inch logs is grade 2

or better. While prior to upgrading, the percent was only 78. This makes it quite clear that with a low number of pieces in the dimension class, upgrading causes a substantial change in dimension percentages by grade.

CHAPTER IV

REGRESSION ANALYSIS SUMMARY

The following is a summary of the regression analysis, presenting the equations formulated from the data collected during this study. All of the equations take the standard form for a straight line $Y = a + bx$ where a = the Y axis intercept and b = the slope of the line. Y = % volume and x = diameter class.

1. Boards as percent of total lumber.

$$Y = 35.65 - 1.69x \qquad r = -.89$$

2. Dimension as percent of total lumber.

$$Y = 63.22 + 1.76x \qquad r = .89$$

3. Number 3 boards and better as a percent of total lumber.

$$Y = 25.60 - 1.26x \qquad r = -.74$$

4. Number 2 dimension and better as a percent of total lumber.

$$Y = 96.74 - 1.66x \qquad r = -.72$$

5. Number 3 boards and better plus number 2 dimension and better as a percent of total lumber.

$$Y = 122.36 - 2.92x \qquad r = -.73$$

6. Number 3 board and better as a percent of total boards.

$$Y = 67.20 - .24x \qquad r = -.05$$

7. Number 2 dimension and better as a percent of total dimension.

$$Y = 133.68 - 3.55x \qquad r = -.79$$

The equations noted above are only applicable to diameters between 12 and 17 inches. The model was established with these ends points. The accuracy beyond these ends points is highly uncertain until samples of logs in diameter classes outside of these have been observed.

CHAPTER V

SUMMARY AND CONCLUSIONS

In summary, the problem existing is one of full utilization. At the present time most efforts have been directed toward the use of all raw material removed from the woods. This paper is an attempt to point out an associated problem in utilization. The problem concerns the efficient use of the sawlog. In other words, using the better grade logs to produce the higher grade lumber. In order to accomplish this type of utilization, a relationship between log grade and the type, quality and amount of lumber produced had to be established.

In reviewing the data presented it appears a statistically significant relationship does exist between log grade and the type, quality and amount of lumber produced. It is this researcher's opinion that further studies of this nature should be conducted on a larger scale, primarily through increased sample size, in order to determine conclusively the exact relationship between log grade and lumber output within definite limits. Conclusive relationships of this type would prove invaluable to the sawmill manager in all phases of planning from raw material procurement to finished lumber inventories.

LIST OF TABLES

LIST OF ILLUSTRATIONS

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