ESTIMATION OF COSTS AND DESIGN OF LOGGING SYSTEMS FOR THE NORTHERN HARDWOODS

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The use of unit costs to secure the most successful operating results has been recognized for some time by timber operators. These costs have been generally based on the sale unit of the timber removed and expressed as so much per cord or so much per Mbm. Occasionally, road construction costs are recorded at a certain cost per mile or per station. These costs have been used in the most part for comparing the results of one year's operation with the next, or, at the best, in the comparing of one month's operation with that of the previous month. They have also been used to estimate future costs and to compute rates for jobbers. It often happens, however, that these costs are used with insufficient regard for the operating conditions that made them as they are, as, for example, deep snow, a wet season, distance of haul, etc.

This paper is an attempt to apply unit costs to the estimation of the cost of logging an actual timber tract to determine how the transportation system might be designed most economically, and determine what machines under a given set of conditions will give the most economic operation. Economy in operation is the one way the manager of a lumber company can show a profit. The price structure is beyond his reach and his only recourse is to operate within the limits of that price structure as set.

Economy, as defined by Grant, is "getting the most for your money in the long run." What are the factors that will prevent the operator from getting this? They are listed by Gillette and Dana as follows:

1. Excessive use of materials
2. Excessive use of supplies
3. Inefficiency of workmen
4. Inefficiency of foremen
5. Padded payrolls
6. Excessive lost time
7. Improper design of plant.

The logging operation not being primarily a user of materials is not concerned with the first item as much as it is with several of the others. The main application of this point is in the building of camps and, perhaps, roads.

The excessive use of supplies would result from improper management in the cookhouse, from careless use of logging equipment, and from equipment being stolen.

Inefficiency of workmen is a common complaint. Lazy workmen under the protection of a union will not give an "honest day's labor" if they can help it. On the other hand, they may not be properly supervised, the pay rate may lack incentive as in the use of hourly wages, and the men may not have been taught the proper way to go about their work.

Padded payrolls and other such practices can be prevented by careful clerical check and are out of the scope of this paper.

The last two items are mainly responsible for high costs in logging operation -- excessive lost time, and improper design of plant. The first of these two factors is not dealt with in this paper since it is a matter of careful planning on the job. The matter of proper design of plant, however, is one which should be carefully decided before actual operation is ever started. With the plant improperly designed, even the most efficient foreman has one strike against him when he starts. The "plant" in a logging operation consists of the roads, railroads, teams, tractors, loaders, etc. The various elements of this plant must be so designed and so coordinated as to give minimum cost and this aim has been approached in this paper through the use of unit costs.

The most expensive part of a logging operation and, therefore, where the greatest saving can be effected is in the transportation system. When skidding, hauling, loading, road construction, and road maintenance are considered as transportation, these items make up about 70% of the total cost of logging. Logging, therefore, consists in the last analysis of moving a heavy, bulky, low value product to a processing plant.

In the calculations presented, the most used method of obtaining minimum cost has been through the use of the "break - even point" concept. This is described by Grant as follows:

"Often total cost consists of several variables, some increasing and others decreasing with a change in one of the characteristics of design. In this type of situation the problem is that of finding the point at which the sum of the several variable elements becomes a minimum........Often we have a choice between two alternatives where one of them may be more economical under one set of conditions and the other may be more economical under another set of conditions. The point at which the two are equally economical has been called the 'break - even point'."

Cost data for minimum cost calculations may be collected in two ways: Either by a system of continuous records, or by occasional fact-finding studies. The continuous records as those obtained from a cost accounting system are the most commonly used and are usually recorded as has been mentioned before in a board-foot basis. They are not, however, and cannot usually be used as measures of performance because they are not recorded in the right unit basis.

Skidding costs are best recorded as the cost of hauling per M per 100 ft. of distance; road maintenance and construction costs are of little value for plant design unless expressed as costs per station. Sleigh haul and truck haul costs are useless unless expressed in terms of the cost of hauling per M per 100 ft. or per mile. Such costs must also be accompanied by explanations of the type of road hauled over, the amount of snow skidded in, ground conditions, etc. Camp costs are of more value if the cost of erecting is recorded as a cost per Mbm of the lumber being used in the construction.

The other method of obtaining costs is that obtained by time and motion studies. This type of analysis is carried on with a stop watch and the time required to do each operation is determined. An example of this is the tractor skidding data presented in this paper. What this type of study really amounts to is time keeping on a very refined basis so that all extraneous factors may be omitted and it can be known what the possible performance can be. Then allowance can be made for delays and other factors which are apt to raise the cost.

Such figures of near top efficiency can be used by the operator and compared with his results. Such <u>standards of performance</u> enable him to readily determine if the work is going poorly so that some effort can be made to correct it. This procedure is more useful than a comparison with previous costs which themselves may have been too high.

The time and motion study is the only way in which unit costs properly broken down can be obtained. Such costs can be used to best advantage in plant design and estimating future costs and can then be checked against the costs recorded in the continuous cost accounting records which are invaluable as a base for the entire procedure.

As a practical application of the proper use of unit costs as set forth, an actual timber holding has been studied and an effort made to select the best logging methods, to design the best transportation system, and to estimate the cost of logging using several different methods. The effect of selective cutting on costs where only one-half of the total volume of the stand is removed has been compared with the operation where 100% of the stand is removed.

A rather intensive cost analysis has been made of one logging plan, that of summer logging with trucks when 100% of the stand is cut. Because of the limitations of the map used which showed no topography, it was felt that it would be rather repetitious to work out plans for the other methods and cases to the degree that the one plan was. The other plans have been worked out assuming a solid stand of timber with an average stand per acre of 7M. Allowances for deadline roads, scattered ownership, and so forth, have been made in some cases by a flat percentage rise in costs as indicated by the more carefully worked out example.

The area under consideration is located in the Upper Peninsula of Michigan in Gogebic County. The total area of approximately 26,600 acres composes part of four townships and includes land in the following descriptions:

T 47 R 41 -- Sections 7, 8, 16, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36.

T 46 R 41 -- Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18.

T 47 R 42 -- Sections 2, 11, 12, 13, 14, 23, 24, 25, 26, 35, 36.

T 46 R 42 -- Sections 1, 2, 11, 12, 13, 14.

The land may be divided into the following types:

Hardwood Type:	11,500 acres	(60% or more hardwood in stand)
Hemlock Type:	6,300 acres	(60% or more hemlock in stand)
Swamp Type:	6,400 acres	
Cut - Over:	2,400 acres	
Total	26,600 acres.	

The estimated volume of timber on the area is:

Hemlock	62,276 Mbm
Hardwood	66,218
Total	128,494 Mbm.

On the basis of cruise figures from portions of this area, stand and stock tables have been built up. These indicate a volume per acre of approximately 10 Mbm per acre. However, on the basis of estimates made on other parts of the area since, the average figure has been tentatively set at 7 Mbm per acre.

The map used for guidance in this problem is one made by the Government for its acquisition work, which has been revised and brought up to date for use here. The area is tapped, as shown by the map, by a branch line of the Chicago and North Western Railroad, and, also, by a county road. The county road runs west two miles where it connects with a state highway which runs directly to the mill site, 8 miles farther. The proposed road shown running through the area from the county road to Camp #6 has been surveyed by the owner and partially constructed by the C.C.C.

Stand and Stock Tables

Hardwood Type:

	Maple			Birch			Hemlock			Basswood		
DBH	No. Trees	Gross Vol	Net Vol	No. Trees	Gross Vol	Net Vol	No. Trees	Gross Vol	Net Vol	No. Trees	Gross Vol	Net Vol
10	2.8	135	129	1.5	54	49	7.2	407	370	.7	22	20
12	4.6	247	222	2.2	105	93	7.3	496	435	.7	31	28
14	5.3	489	440	1.9	172	148	5.2	603	530	.7	73	66
16	4.7	813	715	2.2	359	304	3.4	826	725	.4	66	59
18	3.2	662	550	2.1	476	390	2.4	621	531	.5	106	93
20	1.9	565	452	1.8	507	400	1.5	506	412	.3	106	91
22	1.2	392	301	1.0	365	274	1.3	544	424	.3	121	102
24	.3	125	91	.3	150	108	.7	346	248	.1	50	41
26+	.1	48	33	.2	91	64	.4	468	304	.2	80	61
		3476	2933		2279	1830		4817	3979		655	561

	Elm		
10	.1	4	4
12	.2	8	8
14	.3	25	23
16	.2	30	27
18	.2	66	59
20	.2	51	45
22	.2	94	81
24	.2	80	67
26+	.1	21	17
		379	331

Total Stand Hardwood Type:

DBH	No. Trees	Net Vol.	Basal Area
10	12.3	572	6.8 sq.ft.
12	15.0	786	11.8
14	13.4	1207	14.3
16	10.9	1830	15.2
18	8.4	1623	14.8
20	5.7	1400	12.4
22	4.0	1182	10.6
24	1.6	555	5.0
26+	1.0	479	4.0
	72.3	9634	94.9 Tot B.A. entire stand

46.8 Tot B.A. cut when cutting to 18" diam. limit only.
16" = Ave.DBH of entire stand.
20" = Ave.DBH of trees cut when cutting to 18" diam. limit.
5,239 = Cut per Acre when cutting to 18" diameter limit.

Stand and Stock Tables

Hemlock Type:

DBH	Maple No. Trees	Maple Gross Vol	Maple Net Vol	Birch No. Trees	Birch Gross Vol	Birch Net Vol	Hemlock No. Trees	Hemlock Gross Vol	Hemlock Net Vol
10	1.6	58	53	1.3	53	48	9.9	556	506
12	1.5	75	67	2.2	104	92	10.1	700	615
14	1.5	143	129	2.6	221	190	6.3	785	690
16	1.3	226	199	2.2	401	340	6.4	1220	1070
18	1.5	356	295	1.4	310	254	5.3	1378	1180
20	.7	189	151	1.2	344	272	3.6	1201	982
22	.2	135	104	.4	144	108	2.6	1146	893
24				-	39	28	1.7	727	523
26+				.1	59	41	1.8	815	530
		1182	998		1675	1373		8528	6989

Total Stand Hemlock Type:

DBH	No. Trees	Net Vol.	Basal Area
10	12.8	607	7.0 sq.ft.
12	13.8	774	10.9
14	10.4	1009	11.1
16	9.9	1669	13.9
18	8.2	1729	14.5
20	5.5	1443	12.0
22	3.2	1105	8.5
24	3.3	551	10.4
26+	2.9	571	11.5
		9458	99.8 Total basal area stand
			56.9 Total basal area cut when cutting to an 18" DBH.

Ave.DBH of entire stand = 16"
Ave.DBH of stand cut when cutting to 18" DBH = 20"
Vol.cut under partial cut = 5,399 b.m.per acre

Log Making

Log making is the first step in the delivery of logs from stump to mill. It consists of felling the tree, cleaning the bole of branches, and then bucking the bole into logs. The felling crews in the northern hardwoods consist of two men working with double-bitted axes and 5-foot long, 2-handled, cross-cut saws. Other equipment includes a measuring pole usually 8 feet long, a bottle of kerosene with which to oil the saw, and wedges generally cut from maple or birch by the sawyers themselves.

This process usually costs about one-fifth of the total cost of logging in this region and it is, therefore, of great importance to the operator to see that this cost is kept at a minimum. Aside from the cost factor, the way in which the logs are bucked determines to a large extent the quality lumber which may be obtained from them in the mill. A skillful crew will "saw out" crooks, cut off rotten portions of the bole, and obtain from the tree the highest quality of logs, as well as the greatest utilization. A poor crew will leave valuable material in the tops of the tree, will cut crooked logs, and will either "butt" the logs too much or too little. The question of butting is always a sore spot in logging this type of timber. The cutter dislikes doing more work than he absolutely has to do and may neglect to butt a rotten log, that is, cut the rotten part not worth hauling to the mill from the rest of the log; or he may carelessly cut off the butt too high up the bole and thus waste a large portion of valuable timber. Of course, it is not always possible to determine how far up the bole this cut should be made but experience will enable a sawyer to make a fairly accurate guess at this. Proper butting preventing the handling of waste material in skidding and hauling operations will be a cost factor to reckon with when considering these operations.

The length that the logs are cut to is also of great importance. While it can probably be safely held that logs should be cut to the length that will insure the highest quality lumber, it must be remembered that short logs raise future handling costs. It takes as much time to skid and load a 12 or 14-foot log as it does a 16-foot log with a higher cost per Mbm as a result of lower volume per log. When cutting the bole into logs the proper trimming allowance must be made. It has been the custom to allow 4" over the specified length for this purpose. In case of carelessness on the part of the sawyers, resulting in careless measuring or in the cutting off of the end of the measuring stick, logs slightly under the specified lengths are cut with the result that the lumber from these boards must be cut down 2 feet to the next recognized length with a great resulting waste. The log lengths generally recognized are 16 feet, 14 feet, 12 feet, and 8 feet, and occasionally special lengths are cut for special orders, such as, switch ties, timbers, and so forth.

Another factor to be watched is the stump height. Often sawyers will try to avoid butting a log that appears to them rotten by sawing a high stump. They are often mistaken with a resulting waste of timber, so it is always required that a low stump be cut -- generally from 1½ - 2 feet. High stumps are also frequently cut when the snow is deep because of the inconvenience of removing the snow. Cutting gangs should be provided with shovels and requiredto cut low stumps regardless of how deep the snow is.

Log making is paid for according to two general systems, namely, by an hourly wage or by a piece rate. Originally, all woods work was done in Northern Michigan under a monthly, or hourly, rate until the World War broke out. Then the piece rate was introduced into the woods and used very widely but, also, very unwisely. Pressed by labor shortage at that time employers raised piece rates beyond all reason until common labor was making up to $20 - $25 per day cutting logs and making roads. The labor which received this bonanza was mainly immigrant and, not being forced into the army, was able to remain and work under these conditions. After conditions had come back closer to normal it was found difficult to make men, accustomed to extra-ordinarily high piece rates, accept rates commensurate with business conditions, so the piece system was, in general, abandoned.
The evils of the system had been that the operators set the rates with too little thought. If the rates were found to be too high they were promptly reduced until the men came to realize that if they worked hard and made good earnings the rate would soon be cut and they would find themselves working a lot harder for a lot less. Naturally, under these

conditions, the men became suspicious of the piece rate system and generally it is found that unions oppose it very strenuously.

Basically, the piece rate is the only sound method of paying for work. The operator is not concerned with how much time the employee puts in, but in how much work he does in that time. The operator thus pays for work and not for time. If it is possible to measure the amount of work done with reasonable accuracy, payment should be made according to the amount of work accomplished. In regard to log making the piece rate is sound and equitable and every effort should be made to do all of this type of work under a piece system. According to every sound bit of thinking there can be no excuse for cutting logs under an hourly rate but when this is proposed those in charge will find hundreds of excuses for not doing so. The first is that the men object and will not saw under this system of payment. It has been found in the past that they will saw this way if really encouraged to do so by the management. There should never be, as is so often the case, a choice between sawing according to a piece rate or an hourly rate. Men cutting on the piece system should be treated as all other employees are treated as regards their status as employees. They should never be made to appear independent contractors and as such not subject to Workmen's Compensation, for such a policy is nothing but discrimination against this class of workmen and a very real impediment in trying to make them accept piece work. It will be held by some that under a piece rate the quality of logs drops through more hurried work. This may be so, but in the writer's experience of directing both kinds of work, he has never observed any difference in this respect. There are good sawyers and bad sawyers and they will continue to be so regardless of how they are paid.

A stumbling block which perhaps has some basis is the problem of unfinished "strips". A crew will quit in the middle of a strip and it is found difficult to make a new crew start on this strip. In the past it was the policy to deduct a certain amount from the wages of the men for every tree left, a procedure which led to much trouble with the men and usually could not be enforced anyhow. It would be much wiser to bonus the men for finishing the strip. The original piece rate might have to be lower to pay this bonus but the idea of a bonus is much less apt to have a troublesome effect than the idea of a penalty. In the past the sawyers would escape, if possible, the cutting of all large trees and it would be necessary to send around hourly men later to cut them with a great increase in cost. The reason for the leaving of those trees was twofold: First, the larger trees are apt to be rotten and since cull logs were not paid for the men would never take a chance on cutting a rotten tree. Secondly, the rate of sawing a log 20 inches through was the same as that obtained from cutting a log 12 inches through. The piece rates were set on the idea of the big and small logs averaging up to give a fair wage but labor was not apt to see it that way. To get away from this the rates should be so set that the amount paid and the amount of work to be done are more equitable. More should be paid for big logs and less for small logs. As to the cull logs a more difficult problem is involved. It is not the workmen's fault that the trees are rotten, but if the rate were so set as to pay for rotten logs along with the rest it would be so low as to not be accepted by the men. At this point the importance of good supervision enters in. The "saw boss" should be able to judge with fair accuracy if the tree should be cut and then should see that it is cut or refuse to pay the bonus for finishing the strip.

The question of butting also causes some trouble. In order to induce the men to butt where necessary some operators pay 5 - 10¢ per butt for so doing. This apt to lead, however, to too much butting and raises the cost unnecessarily high. Usually if butting is insisted on, the men will do it through long habit in doing so. Another job often insisted on when men are working by piece work is to swamp all the logs clear and have them lying so that a team can come right in and skid them out. It is really too much to expect a sawyer to do under the piece rates usually set and as a result he will not do a good swamping job and the saw boss is put in the position of having to bring about performance of an unreasonable task. Swamping usually costs about 75¢ per M and to try and make a sawyer do this work and also saw logs for about $2.00 per M is not conducive to good results. However, to prevent a sloppy job of felling and to prevent tops being thrown in all directions and on top of logs already cut, it should be demanded that the logs be fairly clear of brush and in a position where they can later be swamped out without too much trouble. This amount of work can only be brought about through good supervision. Swamping itself is not an easily measurable task and is probably best paid for on an hourly wage.

Good supervision, as has been said previously, is absolutely necessary for good results. The saw boss must check carefully for proper length, bucking, and butting; and in the case of daily work must see that enough work is done. He must see that the strips are cut clean if the job is a clear-cut operation, or that the marked trees and only marked trees are cut under a selective job. In the case of a piece cutting job he needs be absolutely honest and not too friendly with the men and should not be made to live with them.

In the following tables and computations comparison of the various methods of payment are made. It cannot be assumed that the costs obtained in the field will be exactly those given below but the divergence should not be too wide. In the case of the linear foot computations it has been assumed that the per cent of the various log lengths remains the same in each diameter class, which may or may not be true but is assumed for lack of more accurate data. The very important question of rot as cull factor has not been determined accurately. It has been assumed here to be 10% on logs accepted. In the computations involving the payment of a daily rate it has been assumed that the average log has a net volume of 72 board feet.

The following system is that of payment of daily wage without bonus:

Hourly wage = $.38 per hour per man
Daily wage per 2-man crew = $6.08.

A crew can easily saw 40 logs of average size per day.

40 x 72 bm = 2,900 bm $\quad \frac{\$6.08}{2.9} = \$2.10$ per M

A saw boss is ordinarily paid $75 per month and a filer $65 per month. Assuming 26 working days in a month and a daily cut of 50 M, the cost per M of these two men becomes 11¢ per M. Saws, axes, kerosene, and so forth, come to about 6¢ per M. The cost per M then, when 40 logs per day are sawn per crew, is $2.27.

The cost reported from one camp on the operation in question was $2.54. This would mean that the men averaged about 36 logs per day.

A system which the men and unions would not object to as much as a piece rate would be a bonus system with a fixed daily wage. In the following table 40 logs has been set up as the standard production which should be obtained per crew per day. While there is no data to work with to show just what the effect would be, two tie cuts should be considered the equivalent of one log in getting this count of 40. This number is not unreasonable since men cutting on a piece system often cut 50 - 60 logs without too much effort. This would be necessary, also, to prevent men from cutting up good 16-foot logs to increase the number of logs produced and thus obtain the bonus with less effort. It is seen that if a bonus of 10¢ per log is paid that the cost per M gradually decreases the more logs are cut and that if a 15¢ per log bonus is paid the cost per M remains stationary. The main purpose of the bonus is to get the production per day per crew up to the 40-log standard and after that the company should be satisfied and pass along the maximum bonus possible to the men. Probably at first, however, the 10¢ bonus would be safer until it has been determined definitely just what the costs under the plan will be.

Logging Costs When Sawing Under an Hourly Wage With and Without Bonuses

No. Logs Sawed	Cost 38¢ per Hr. Ave Log 72 bm No Bonus	Volume Sawed bm	Cost per M 10¢ Bonus per Log Paid for Logs Cut in Excess of 40	Amount Paid To Crew Per Day	Cost per M 15¢ per Log Bonus Paid for Every Log in Excess of 40	Amount Paid To Crew Per Day
30	$ 2.78	2,180	$ 2.78	$ 6.08	$ 2.78	$ 6.08
31	2.70	2,252	2.70	6.08	2.70	6.08
32	2.62	2,324	2.62	6.08	2.62	6.08
33	2.54	2,396	2.54	6.08	2.54	6.08
34	2.46	2,468	2.46	6.08	2.46	6.08
35	2.39	2,540	2.39	6.08	2.39	6.08
36	2.33	2,612	2.33	6.08	2.33	6.08
37	2.27	2,684	2.27	6.08	2.27	6.08
38	2.21	2,756	2.21	6.08	2.21	6.08
39	2.15	2,828	2.15	6.08	2.15	6.08
40	2.10	2,900	2.10	6.08	2.10	6.08
41	2.05	2,972	2.08	6.18	2.10	6.23
42	2.00	3,044	2.06	6.28	2.10	6.38
43	1.95	3,116	2.05	6.38	2.10	6.53
44	1.91	3,188	2.03	6.48	2.10	6.68
45	1.87	3,260	2.02	6.58	2.10	6.83
46	1.83	3,332	2.01	6.68	2.10	6.98
47	1.79	3,404	1.99	6.78	2.10	7.13
48	1.75	3,476	1.98	6.88	2.10	7.28
49	1.71	3,548	1.97	6.98	2.10	7.43
50	1.68	3,620	1.96	7.08	2.10	7.58
51	1.65	3,692	1.95	7.18	2.10	7.73
52	1.62	3,764	1.94	7.28	2.10	7.89
53	1.59	3,836	1.93	7.38	2.10	8.03
54	1.56	3,908	1.92	7.48	2.10	8.18
55	1.53	3,980	1.91	7.58	2.10	8.33

The following table has been worked up from data given in "Timber Management and Financial Plans for the Goodman Working Circle" and roughly checked against data collected for volume table check on the operation in question. While this data is probably approximately correct for the trees on the land in question, there is some doubt if it quite coincides with the utilization practiced since all logs of every length have averaged about 72 bm. net or about 14 logs per M in stands having an average d.b.h. of about 16 inches. According to this data 16-foot logs would have an average of less than 70 gross volume. While this discrepancy has not been accounted for, this data has been used for lack of anything better and so the log making costs computed using it as a base should not be followed without further consideration.

Maple:

DBH	Used Length Tree	Bd Ft Vol Gross Tree	No.16' Logs per Tree	Volume Per Log Gross	Ave Top Diameter of Logs
10	15 Ft	25 bm	1	25 bm	7 In
12	24	60	1.5	40	9
14	32	110	2	55	10
16	40	178	2.5	71	11
18	46	267	2.9	92	13
20	48	360	3.0	120	14
22	50	453	3.1	146	15
24	51	540	3.2	169	16
26	53	649	3.3	196	17
28	54	758	3.4	222	18
30	55	896	3.4	263	20

Birch:

10	15	22	1	22	7
12	22	45	1.4	32	8
14	27	90	1.7	53	10
16	32	140	2.0	70	11
18	35	200	2.2	91	13
20	38	275	2.4	115	14
22	40	380	2.5	152	16
24	43	490	2.7	180	17
26	44	610	2.8	220	18
28	45	730	2.8	260	19
30	45	852	2.8	304	21

Hemlock:

10	13	22	.8	25	7
12	20	51	1.3	39	9
14	30	100	1.9	52	10
16	37	150	2.3	65	11
18	46	230	2.9	79	12
20	53	325	3.3	99	13
22	58	425	3.6	118	14
24	61	562	3.8	148	15
26	65	722	4.0	180	17
28	69	892	4.3	207	18
30	71	1104	4.4	250	19

The log lengths cut in the past have run as follows:

8'	-- 7%
12'	-- 25
14'	-- 7
16'	-- 61.

In the following table the above percentages have been used to pro-rate the volumes in each log diameter class into the various length classes, which are then expressed percentically to compute a weighted cost for each diameter class.

The following table uses the linear foot as a measure of payment. This is the most commonly used method of measurement for piece cutting in this area although logs are often paid for by the log instead with a differential for different lengths, which is, in fact, about the same thing as the linear-foot measurement. As has been suggested before the method of payment, regardless of the amount that can be earned under it, effects the quality of work performed. Thus, if the payment is strictly on a linear foot or per Mbm basis the logs are apt to be cut into the 16-foot length regardless of crook or quality. On the other hand, if the payment is on a set amount per log with no differential for length the operator is apt to find himself the owner of a large number of tie cuts. If the piece rate does not take into account the diameter of the log there is trouble in getting the larger trees cut. While it is impossible to set any piece rate which will make dishonest workmen become models of perfection over night the following piece rate suggested would help in some respects to improve matters. Instead of paying on a straight 1¢ per linear foot it is suggested that the rate be cut on the small logs and increased with larger logs. For example, it is shown below that a rate of as high as 2¢ per linear foot can be paid for logs with a top diameter of 17 inches and over without materially raising the sawing cost. This high rate of payment, amounting to 32¢ a log in the case of a 16-foot length, would be a good talking point in convincing the men to accept it. While there might be some difficulty in getting the small trees cut if the rate were too low the difficulty should not be insuperable. Also, from a forestry standpoint, it is just as well not to cut the small unprofitable trees which can be the only result when a straight linear-foot basis of payment is used. As for the small logs at the top of the larger trees it would be a foolish crew, indeed, which would leave a log unbucked when it had gone to all the effort of felling the tree.

In the following, three variations of the linear-foot method of payment have been presented. The first is the cost under a straight linear-foot basis, the second shows a differential for increases in diameter, and the third shows the same thing with an added increase in the piece payment for the logs 17 inches and over.

The Cost of Cutting Various Lengths and Diameters of Logs
at
Specified Payments per Linear Foot

Top Diam Log IB	Log Length Ft.	Gross Vol per Log b.m.	Cost Per Lin.Ft. ¢	Cost Per Log ¢	Cost Per Mbm $	% Vol In Ea Diam Class	Weighted Cost Per M $	Ave Cost Per M $
8	8	10	1	8	8.00	3	.21	
	12	20	1	12	6.00	20	1.20	
	14	20	1	14	7.00	5	.35	
	16	30	1	16	5.32	72	3.82	5.61
9	8	20	1	8	4.00	4	.16	
	12	30	1	12	4.00	21	.84	
	14	30	1	14	4.67	6	.28	
	16	40	1	16	4.00	69	2.75	4.03
10	8	30	1	8	2.66	4	.11	
	12	30	1	12	4.00	15	.60	
	14	40	1	14	3.50	6	.21	
	16	60	1	16	2.67	75	2.00	2.92
11	8	30	1	8	2.65	4	.11	
	12	40	1	12	3.00	17	.51	
	14	50	1	14	2.80	6	.17	
	16	70	1	16	2.29	73	1.68	2.47
12	8	40	1	8	2.00			
	12	60	1	12	2.00			
	14	70	1	14	2.00			
	16	80	1	16	2.00			2.00
13	8	50	1	8	1.60	4	.06	
	12	70	1	12	1.71	20	.34	
	14	80	1	14	1.75	6	.11	
	16	100	1	16	1.60	70	1.12	1.63
14	8	60	1	8	1.33	4	.05	
	12	90	1	12	1.33	22	.29	
	14	100	1	14	1.40	7	.10	
	16	110	1	16	1.45	67	.97	1.41
15	8	70	1	8	1.14	4	.05	
	12	110	1	12	1.09	22	.22	
	14	120	1	14	1.16	7	.08	
	16	140	1	16	1.14	67	.76	1.11
16	8	80	1	8	1.00			
	12	120	1	12	1.00			
	14	140	1	14	1.00			
	16	160	1	16	1.00			1.00
17	8	90	1	8	.89	4	.04	
	12	140	1	12	.86	22	.19	
	14	160	1	14	.88	7	.06	
	16	180	1	16	.89	67	.60	.89
18	8	110	1	8	.73	4	.03	
	12	160	1	12	.75	21	.16	
	14	190	1	14	.74	7	.05	
	16	210	1	16	.76	68	.52	.76

Top Diam Log IB	Log Length Ft.	Gross Vol per Log b.m.	Cost Per Lin.Ft. ¢	Cost Per Log ¢	Cost Per Mbm $	% Vol In Ea Diam Class	Weighted Cost Per M $	Ave Cost Per M $
8	8	10	.5	4	4.00	3	.12	
	12	20	.5	6	3.00	20	.60	
	14	20	.5	7	3.50	5	.18	
	16	30	.5	8	2.67	72	1.93	2.83
9	8	20	.5	4	2.00	4	.08	
	12	30	.5	6	2.00	21	.42	
	14	30	.5	7	2.33	6	.14	
	16	40	.5	8	2.00	69	1.38	2.02
10	8	30	.5	4	1.33	4	.05	
	12	30	.5	6	2.00	15	.30	
	14	40	.5	7	1.75	6	.11	
	16	60	.5	8	1.33	75	1.00	1.46
15	8	70	1.5	12	1.72	4	.07	
	12	110	1.5	18	1.64	22	.36	
	14	120	1.5	21	1.75	7	.12	
	16	140	1.5	16	1.71	67	1.15	1.70
16	8	80	1.5	12	1.50			
	12	120	1.5	18	1.50			
	14	140	1.5	21	1.50			
	16	160	1.5	24	1.50			1.50
17	8	90	1.5	12	1.33	4	.05	
	12	140	1.5	18	1.28	22	.28	
	14	160	1.5	21	1.31	7	.09	
	16	180	1.5	24	1.33	67	.89	1.31
18	8	110	1.5	12	1.10	4	.04	
	12	160	1.5	18	1.12	21	.24	
	14	190	1.5	21	1.10	7	.08	
	16	210	1.5	24	1.14	68	.77	1.13
17	8	90	2	16	1.78	4	.07	
	12	140	2	24	1.72	22	.38	
	14	160	2	28	1.75	7	.12	
	16	180	2	32	1.78	67	1.19	1.76
18	8	110	2	16	1.45	4	.06	
	12	160	2	24	1.50	21	.31	
	14	190	2	28	1.48	7	.10	
	16	210	2	32	1.53	68	1.04	1.51

- Cost of Sawing at 1¢ per Linear Foot -- Hardwood Type -

Maple:

DBH	% of Vol per Diameter Class	Cost per M $	Weighted Cost $
10	3.9	5.61	.22
12	7.1	4.03	.28
14	14.0	2.92	.41
16	23.4	2.47	.58
18	19.0	1.63	.31
20	16.3	1.41	.23
22	11.3	1.11	.13
24	3.6	1.00	.04
26	1.4	.89	.01
			2.21

Birch:

DBH	% of Vol per Diameter Class	Cost per M $	Weighted Cost $
10	2.4	5.61	.14
12	4.6	5.61	.26
14	7.6	2.92	.22
16	15.7	2.47	.39
18	20.9	1.63	.34
20	22.2	1.41	.31
22	16.0	1.00	.16
24	6.6	.89	.06
26	4.0	.76	.03
			1.91

Hemlock:

DBH	% of Vol per Diameter Class	Cost per M $	Weighted Cost $
10	8.5	5.61	.47
12	10.3	4.03	.42
14	12.5	2.92	.36
16	17.1	2.47	.42
18	12.9	2.00	.26
20	10.5	1.63	.17
22	11.3	1.41	.16
24	7.2	1.11	.08
26	9.7	.89	.09
			2.43

% of Species in Stand of Hardwood Type:

Hemlock:	41%
Maple:	34
Birch:	41
	100%.

Weighted Cost of Production:

2.21 x 34% = $ .75
1.91 x 25% = .48
2.43 x 41% = 1.00

$2.23 = Cost of logs based on gross volume.

2.23 + 10% = $2.46 Cost of logs based on net volume.
.16 Cost of filer, sawboss, tools

$2.62 Total cost of sawing at 1¢ per linear foot.

This cost is 8¢ per M higher than that obtained when sawing by present hourly wages.

The cost when computed according to the species and volume distributions of the Hemlock type works out to:

Hemlock	$2.23	per M -- Gross
Maple	2.24	
Birch	2.24.	

Thus, the cost as computed above would amount to $2.62 for this type, also.

Cost of Log Making Using the Following Differential Rate:

8" - 10"	logs inclusive	- .5¢	per linear foot
11 - 14	" "	- 1¢	" " "
15 - 18 +	" "	- 1.5¢	" " " .

Hardwood Type:

	Maple:			Birch:			Hemlock:		
DBH	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol Per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $
10	3.9	2.83	.11	2.4	2.83	.07	8.5	2.83	.24
12	7.1	2.02	.14	4.6	2.83	.13	10.3	2.02	.21
14	14.0	1.46	.20	7.6	1.46	.11	12.5	1.46	.18
16	23.4	2.47	.58	15.7	2.47	.39	17.1	2.47	.42
18	19.0	1.63	.31	20.9	1.63	.34	12.9	2.00	.26
20	16.3	1.41	.23	22.2	1.41	.31	10.5	1.63	.17
22	11.3	1.70	.19	16.0	1.50	.24	11.3	1.41	.16
24	3.6	1.50	.05	6.6	1.31	.09	7.2	1.70	.12
26	1.4	1.31	.02	4.0	1.13	.05	9.7	1.31	.13
	100.0		1.83	100.0		1.83	100.0		1.89

Hemlock Type:

	Maple:			Birch:			Hemlock:		
DBH	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $
10	4.9	2.83	.14	3.2	2.83	.09	6.5	2.83	.18
12	6.4	2.02	.13	6.2	2.83	.18	8.2	2.02	.17
14	12.1	1.46	.18	13.2	1.46	.19	9.2	1.46	.14
16	19.1	2.47	.47	24.0	2.47	.59	14.3	2.47	.35
18	30.1	1.63	.49	18.6	1.63	.30	16.2	2.00	.32
20	16.0	1.41	.23	20.5	1.41	.29	14.1	1.63	.23
22	11.4	1.70	.19	8.6	1.50	.13	13.3	1.41	.19
24				2.3	1.31	.03	8.5	1.71	.14
26				3.5	1.13	.04	9.6	1.31	.13
	100.0		1.83	100.0		1.84	100.0		1.85

Cost Sawing Log Run all Species Hardwood

Type: 1.83 x 34% = $ .62
1.73 x 25 = .43
1.89 x 41 = .77

$1.82.

$1.82 + 10% = $2.00 Net cost labor
Cull logs not paid for but mill cull deducted
.16 Supervision and filing, etc.

$2.16

Cost Sawing Log Run all Species Hemlock

Type: $1.84.

$1.84 + 10% = $2.03 Net cost of logs when mill cull deducted but not cull logs of merchantable trees.
.16 Supervision, filing, etc.

$2.19

It is to be noted from the above that while the composition of the Hemlock and Hardwood types differs both as to species and diameter distributions, the cost of sawing averages out to approximately the same figure.

In order to show the effect of raising the price paid for linear foot in the higher diameters of logs, the following table is presented. In the case below, the rates for logs 17 inches and over top diameter were raised to 2¢ per foot. The rates paid are then:

8" - 10"	logs	inclusive	-- .5¢	per linear foot
11 - 14	"	"	-- 1¢	" " "
15 - 16	"	"	-- 1.5¢	" " "
17 - 18 +	"	"	-- 2.0¢	" " " .

Hardwood Type:

	Maple:			Birch:			Hemlock:		
DBH	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost Per M $	Wghtd. Cost per M $
10	3.9	2.83	.11	2.4	2.83	.07	8.5	2.83	.24
12	7.1	2.02	.14	4.6	2.83	.13	10.3	2.02	.21
14	14.0	1.46	.20	7.6	1.46	.11	12.5	1.46	.18
16	23.4	2.47	.58	15.7	2.47	.39	17.1	2.47	.42
18	19.0	1.63	.31	20.9	1.63	.34	12.9	2.00	.26
20	16.3	1.41	.23	22.2	1.41	.31	10.5	1.63	.17
22	11.3	1.70	.19	16.0	1.50	.24	11.3	1.41	.16
24	3.6	1.50	.05	6.6	1.76	.12	7.2	1.70	.12
26	1.4	1.76	.03	4.0	1.51	.06	9.7	1.76	.17
	100.0		1.84	100.0		1.77	100.0		1.93

Average = $1.86 + 10% = $2.05.

Hemlock Type:

Maple:

DBH	% Vol per Diam. Class	Cost per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost per M $	Wghtd. Cost per M $	% Vol per Diam. Class	Cost per M $	Wghtd. Cost per M $
10	4.9	2.83	.14	3.2	2.83	.09	6.5	2.83	.18
12	6.4	2.02	.13	6.2	2.83	.18	8.2	2.02	.17
14	12.1	1.46	.18	13.2	1.46	.19	9.2	1.46	.14
16	19.1	2.47	.47	24.0	2.47	.59	14.3	2.47	.35
18	30.1	1.63	.49	18.6	1.63	.30	16.2	2.00	.32
20	16.0	1.41	.23	20.5	1.41	.29	14.1	1.63	.23
22	11.4	1.70	.19	8.6	1.50	.13	13.3	1.41	.19
24				2.3	1.76	.04	8.5	1.70	.14
26				3.5	1.51	.05	9.6	1.76	.17
	100.0		1.83	100.0		1.86	100.0		1.89

Average = \$1.88 + 10% = \$2.07.

Average Cost Logs Hardwood Type:

\$2.05 Cost of labor based on net vol. of logs cut but not paying for cull logs of merchantable trees
.16 Supervision, filing, etc.

\$2.21

Average Cost Logs Hemlock Type:

\$2.07 Cost labor based on net vol. of logs
.16 Supervision, filing, etc.

\$2.23

Thus, it can be seen the effect of raising the piece rate $\frac{1}{2}$¢ in the diameter classes 17 inches and above only raised the average cost of log making

Top Diameter of Log	% of Logs in each Diam. Class	Rate per Lin. Ft.	Cost per M	Weighted Cost per M
6"	8.1%	.5¢	$4.00	$ .32
8"	16.3	.5¢	2.83	.46
10	16.4	.5¢	1.46	.24
12	17.4	1 ¢	2.00	.35
14	14.8	1 ¢	1.41	.21
16	10.1	1.5¢	1.50	.15
18	7.2	2 ¢	1.51	.11
20	5.1	2 ¢	1.15	.06
22 +	4.6	2 ¢	.97	.04
				$1.94

1.94 + 10% = $2.13
.16 Filer, Sawboss, Tools
$2.29

The cost of sawing in the hemlock type with the same piece rate amounts to $2.23, so it is probable that the rate set will give the costs indicated.

3¢ per M in the case of the hardwood type and 4¢ in the case of the hemlock type. This fact, while generally realized by most operators, is not generally made use of. In bargaining with unions over wage payments apparently large concessions can be made in the upper diameter sizes which do not affect the costs appreciably.

In order to secure some check on the accuracy of the rates set, the piece rate indicated was applied to 6,517 hemlock logs measured in 1937 on logging operations taking place on the area being considered in this paper. The top diameters of these logs were all measured and from this data it was possible to get some idea of what per cent of the logs fell into the various diameter classes. Unfortunately, only hemlock logs were measured and the data does not apply to hardwoods.

Skidding

This operation which consists of moving the logs from the stump to the spur roads is one of the most expensive operations in logging and the speed with which this operation is carried on to a great extent controls the production of the entire operation. Skidding has often been referred to as the "bottle neck" of the logging operation. In order to carry on this operation economically, it becomes necessary to know what skidding device is best suited to the logging conditions and once a skidding device has been selected it is necessary to know how to use it most efficiently. In the Northern Hardwoods the skidding methods and machines now in use are:

1. Animal skidding--Teams.
2. Light tractors--Caterpillar RD-2 and Allis Chalmers M. Sometimes equipped with towing winches.
3. Medium-sized tractors--Caterpillar RD-4. Sometimes equipped with towing winch.

Each of the above skidding devices has a fixed and a variable cost. By variable cost is meant the cost of hauling 1 Mbm. 100 feet. Thus, this cost varies with the distance skidded, becoming higher as the skidding distance increases. By fixed cost is meant that portion of the skidding cost which is independent of the distance skidded and consists of the hook-on and unhook time.

In order to obtain information as to what the fixed and variable costs are for the various skidding devices, a timing study was carried out on the only operation available at the time of this writing. This operation was logging a pure stand of White Pine where the logs ran considerably larger than on a hardwood operation with the result that skidding costs were considerably lower. Skidding was done in trails plowed out by a bulldozer mounted on a model M. These trails were built in three feet of snow at the rate of 2,400 feet per day and put in about 2 or 3 to the skidway. The tractors had to leave this trail for hooking on to the logs but otherwise the bulk of the hauling was on the trail. These trails were put in before the sawyers felled the trees to avoid obstructions from logs and also as a guide to the sawyers on to which way to drop the trees. The cost of these trails was estimated at 62¢ per 100 feet. Model M tractors were used both with and without towing winches and from what could be seen, the towing winch did not seem to increase production. This, however, was due to rather abnormal conditions since the tractor with the winch had the wrong kind of track for operating in snow and also because tongs were used for hooking on to the logs instead of chokers. The tongs had to be used to take the logs to the skidways each trip and the chainer or hooker could not have tongs set for the tractor when it came back. Also, in order to hook on to a load the chainer had to make three trips through the deep snow to the log, one trip with each pair of tongs and one trip to pull out the cable. If a set of chokers had been used only one trip to pull out the cable would have been necessary. In the following data no distinction is made between tractors with or without towing winches since the results were about the same. This statement is not meant to minimize the advantages of the winch, however, since if properly used, it should effectuate considerable saving.

Data Collected for Skidding
with
Model M Tractors

Conditions: Snow 3 feet deep.
Skidding trails put in 2-3 per skidway by bulldozer.
Tongs and occasionally chains used to hook on to logs.
One chainer, logs swamped out in advance.
Time consumed by tractor when yarding load considered as hook-on time, i.e., that time elapsed from the moment the tractor leaves the skidding trail until it is back on it with a load ready to go.
Stand: White Pine--100%.

Load No. Logs	Load B.M.	Distance	Hook-On Time	In & Out Time	Unhook Time
3	160	450	7	4	3
1	100	450	4	4	½
2	90	50	4½	1	½
1	30	50	2	1	½
2	520	50	4½	1½	1
2	360	500	6	4	1
2	170	550	3	2	3
2	140	500	4	2	1
2	270	500	5	1½	½
2	220	500	4	3½	½
2	220	500	5	2½	½
2	170	500	3	2½	½
2	190	600	7	3½	½
2	130	600	3	2½	½
2	130	600	2	4½	½
2	290	600	3	3½	½
2	230	600	4	2½	½
2	170	600	4	3½	½
2	200	600	3	3½	½
2	160	600	4	2½	½
2	210	600	3	5½	½
2	150	600	3	3½	½
2	150	600	4	3½	½
2	80	600	6	3½	½
2	120	600	4	2½	½
2	280	600	4	4½	½
1	160	50	½	1	½
2	70	50	1	1	½

Load No. Logs	B.M.	Distance	Hook-On Time	In & Out Time	Unhook Time
2	130	50	3	1	½
2	200	100	1	2	½
2	210	100	1	1	1
2	290	100	1½	1	1½
2	220	100	2½	1½	½
2	110	100	½	1½	½
2	230	100	½	1	2
2	170	100	2	1½	½
2	170	200	2½	2	½
2	170	200	1½	2	½
2	150	150	1½	1½	½
2	140	150	1	2	½
2	130	200	1	2	½
2	100	200	2½	1½	½
2	150	200	2½	1½	½
2	190	200	2	1½	½
2	250	200	4	2	1
2	380	200	6	2	½
2	380	100	2½	2	½
2	150	150	4	2	1
1	180	300	5	1½	1½
2	340	300	3	2	½
2	200	300	2	2	½
2	240	300	2	3	½
2	170	500	5	3½	½
2	280	500	4	3½	½
2	300	200	4	2	½
3	250	200	4½	1½	½
3	380	200	4½	3	½
3	360	200	5½	2½	½
3	380	200	5½	2½	½
3	410	200	5	2	½
3	240	200	3½	2½	½
2	300	500	4	6	1
3	290	500	12	4	1
2	430	500	7	5	1
2	380	500	7	8	9
2	310	500	7	4	1
3	220	300	7	3	3
2	210	500	5	2	3
3	290	500	9	5	1
3	270	500	10	5	1
147	15,520	23,900	272	186	63

On the basis of the data collected, information from various operators, and data collected in other parts of the country, the following tables are built up. The data given for pine logging with the light tractor is, ofcourse, all on the basis of actual observation by the writer.

Caterpillar RD-2 or Allis Chalmers Model M:

Based on Cost of	$ 1.40	per hour	for	tractor and driver
	.16	"	"	towing winch
	.40	"	"	hooker
	.35	"	"	1 swamper
	$ 2.31	per hour		Total Cost
	3.85¢ per minute.			

Ave DBH Stand In.	Load B.M. Gross	Hook & Unhook Min.	Fix. Cost per Load ¢	Fix. Cost per M ¢	Min. per 100' Distance Rd.Trip	Var. Cost per Load ¢	Var. Cost per M ¢	Var. Cost + 10% ¢	Min. Fix.	per M Var. + 10%
Pine:	220	4.7	18.1	82	.8	3.1	14	15.4	21.4	4
Hardwoods:										
16	160	4.7	18.1	113	.8	3.1	19.4	21.4	29.4	5.5
20	200	4.7	18.1	90	.8	3.1	15.5	17.0	23.5	4.4

Caterpillar RD-4:

Based on Cost of	$ 1.67	per hour	for	tractor and driver
	.22	"	"	towing winch
	.70	"	"	2 swampers
	.40	"	"	1 hooker
	$ 2.99	"	"	Total Cost
	5.0¢ per minute.			

Ave DBH Stand In.	Load B.M. Gross	Hook & Unhook Min.	Fix. Cost per Load ¢	Fix. Cost per M ¢	Min. per 100' Distance Rd.Trip	Var. Cost per Load ¢	Var. Cost per M ¢	Var. Cost + 10% ¢	Min. per M Fix.	Min. per M Var. + 10%
16	280	7	35	125	.9	4.5	16.0	17.6	23.3	3.6
20	340	7	35	103	.9	4.5	13.2	14.5	20.6	2.9

Teams:

Based on Cost of $ .32 per hour for team
.40 per hour for teamster
.35 per hour for swamper

$ 1.07 Total Cost per hour.
1.78¢ per minute.

16	90	4	7.1	80	2	3.6	39	43	45	24
20	110	4	7.1	65	2.4	4.3	39	43	36	24

In estimating the variable skidding cost, this cost was increased by 10% in order to make an allowance for crooked skidding trails. After examination of many of these trails it was estimated that in order to move a log 100 feet in a straight line, it would be necessary to skid it 110 feet.

The application of this data is twofold: first, it can be used to design an economical transportation system; and second, it can be used to set up standards of performance for setting piece rate and for determining if the work is being performed efficiently.

The first application is to determine the spacing of spur roads. Two formulae have been developed for this purpose by Matthews, the first of which assumes that skidding is done at right angles to the spur road direction, the logs being dropped by the skidding crews along the road and not in specially built skidways. The other assumes that skidding is done to skidways which are spaced at the same distance along the spurs as the spurs are spaced apart. The first formula would only be applicable in the event some mobile loading unit were used, the second is applicable to the system of skidding and loading with jammer now in most general use.

Skidding direct to road:

$$S = \sqrt{\frac{.33 \times R}{V\ C}}$$

Where: R = The cost of road construction per mile in cents.

S = The road spacing in hundreds of feet.

C = The variable cost of skidding in cents.

SKIDDING LOGS

Skidding with A.C. Mod. M tractor

Unhooking logs from tractor at skidway

Skidding logs with team.

Skidding to skidways:

$$S = \sqrt{\frac{10.22 \times r}{V\ C}}$$

Where: S = The road spacing in hundreds of feet.

r = The cost of road construction per station in cents.

V = The volume per acre cut.

C = The variable cost of skidding.

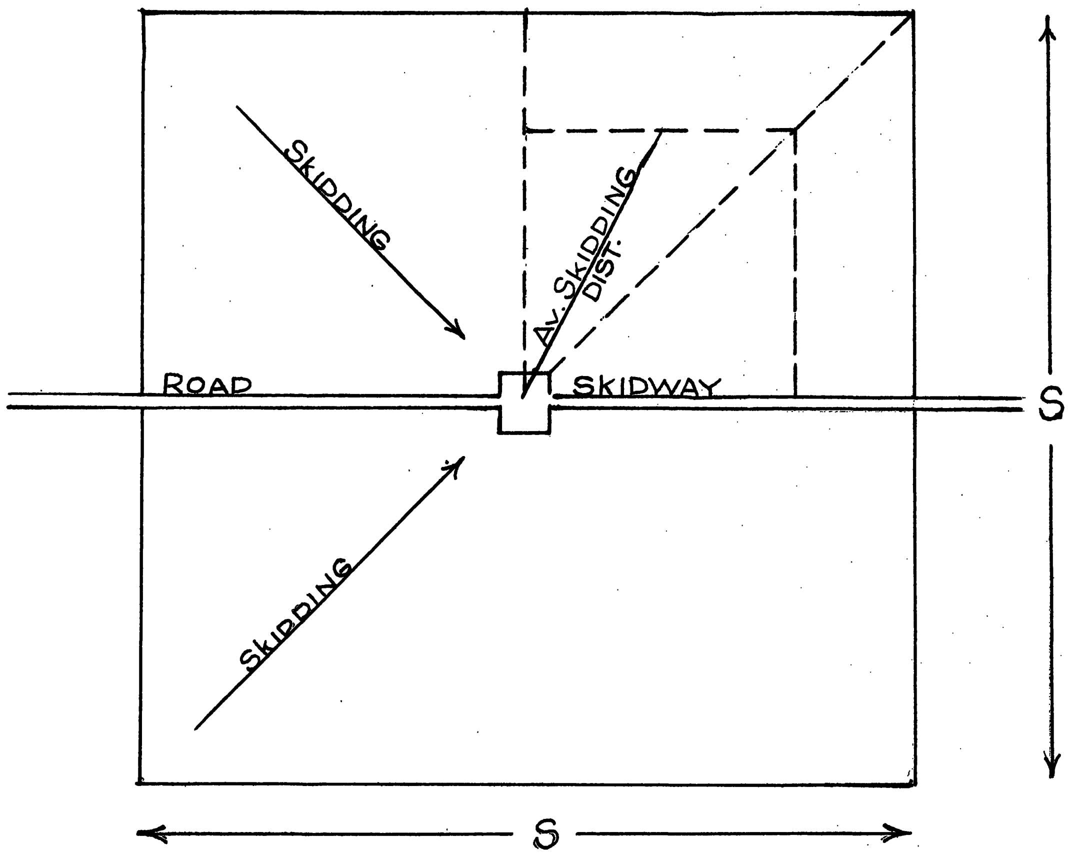
Two types of road are commonly used in logging operations in the Lake States. A graded earth road which can be a snow road in the winter costs on the average $400.00 per mile to construct, or $7.60 per station. A road with two plank tracks made of hemlock lumber sawn on the operation costs approximately $800.00 per mile for planking and $400.00 per mile for grade, or a total cost of $1,200.00 per mile or $22.80 per station.

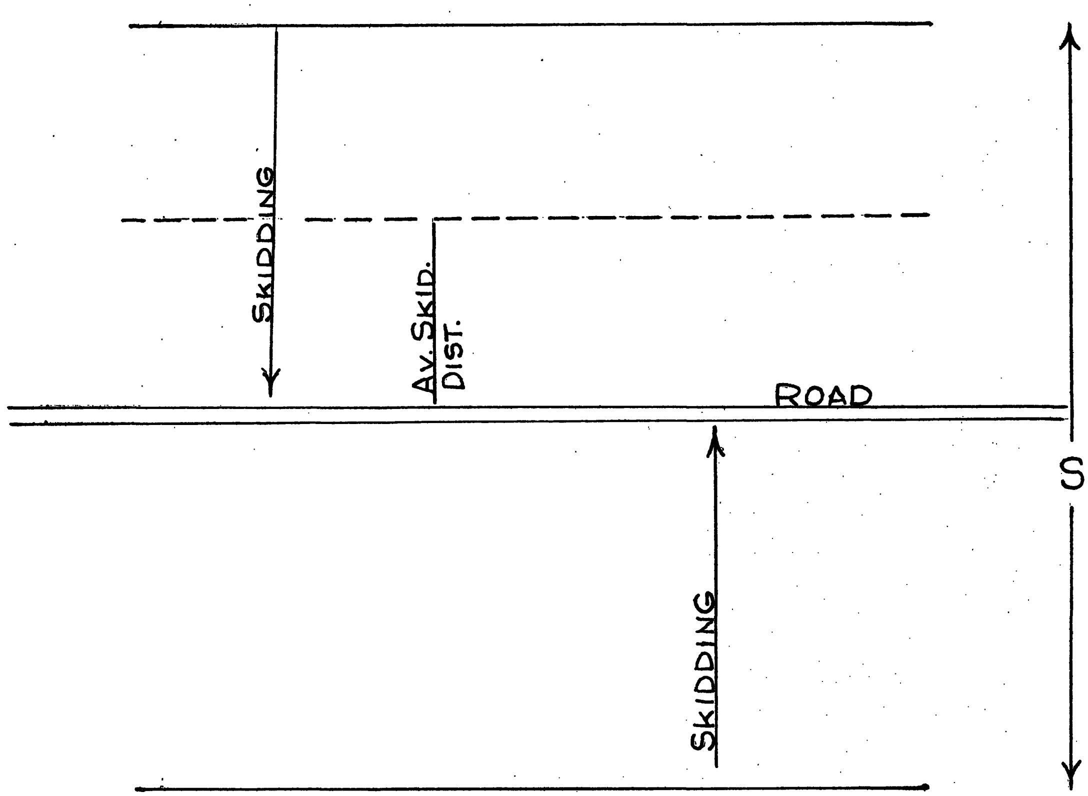
To determine the costs of skidding and road construction most economical with the various skidding devices, the above formulae are used:

RD-2 -- Skidding directly to an earth road:

$$S = \sqrt{\frac{.33 \times 40000}{7 \times 21.4}} = 9.4 \text{ stations.}$$

SKIDDING DESIGN





Skidding:

Variable Cost = $\frac{9.4}{4} \times 21.4 =$ .50¢

Fixed Cost = 1.13

Total Cost: 1.63

Roads:

$$\frac{40000}{9.4 \times 12.1 \times 7} = .50$$

$2.13.

RD-2 -- Skidding to earth road -- Skidways used.

$$S = \sqrt{\frac{10.22 \times 760}{7 \times 21.4}} = 7.2 \text{ stations.}$$

Skidding: Variable Cost = .427 x 7.2 x 21.4 = $ .66

Fixed Cost = 1.13

Total Cost $ 1.79

Roads: $\frac{40000}{12.1 \times 7.2 \times 7}$ = .66

$ 2.45.

RD-4 -- Skidding directly to earth road.

$$S = \sqrt{\frac{.33 \times 40000}{7 \times 17.6}} = 10.3 \text{ stations.}$$

Skidding: Variable Cost = $\frac{10.3}{4} \times 17.6$ = $ .45

Fixed Cost = 1.25

Total Cost $ 1.70

Roads: $\frac{40000}{12.1 \times 7 \times 8}$ = .46

$ 2.16.

RD-4 -- Skidding to skidways on earth roads.

$$S = \sqrt{\frac{10.22 \times 760}{17.6 \times 7}} = 8 \text{ stations.}$$

Skidding:	Variable Cost = .427 x 17.6 x 8	=	$ .60
	Fixed Cost	=	1.25
	Total Cost		$ 1.85
Roads:	$\frac{40000}{12.1 \times 7 \times 8}$	=	.59
			$ 2.44.

Teams -- Skidding to earth road -- direct.

$$S = \sqrt{\frac{.33 \times 40000}{43 \times 7}} = 6.6 \text{ stations.}$$

Skidding:	Variable Cost = $\frac{6.6}{4} \times 43$	=	$ .71
	Fixed Cost	=	.80
	Total Cost		$ 1.51
Roads:	$\frac{40000}{6.6 \times 7 \times 12.1}$	=	.72
			$ 2.23.

Teams -- Skidding to skidways on earth road.

$$S = \sqrt{\frac{10.22 \times 760}{43 \times 7}} = 5.1 \text{ stations.}$$

Skidding:	Variable Cost = .427 x 5.1 x 43	=	$ .94
	Fixed Cost	=	.80
	Total Cost		$ 1.74
Roads:	$\frac{40000}{12.1 \times 5.1 \times 7}$	=	.93
			$ 2.67.

Matthews has developed the following formula for use when two types of skidding devices are used on the same skidding job, as, for example, horses and tractors. This formula applies to direct skidding to the road.

$$S = \sqrt{\frac{.33R}{VC} - \frac{4C'D^2}{C} - 4D^2}$$

Where: S = Proper road spacing in hundreds of feet

R = Cost of road construction per mile

C = Variable cost of skidding of that skidding device having the lowest variable cost and highest fixed cost.

C = Variable cost of skidding of that skidding device having the highest variable cost and the lowest fixed cost.

V = The volume cut per acre

D = The point at which both skidding devices are equally efficient.

To determine the point at which two skidding devices are equally efficient, the following formula is used:

$$D = \frac{F - F'}{C' - C}$$

Where: F = The fixed cost of the high fixed cost machine

F'= The fixed cost of the low fixed cost machine

C = The variable cost of the high fixed cost machine

C'= The variable cost of the low fixed cost machine.

To determine D for a team and RD-2 tractor in which the tractor is the high fixed cost machine:

$$D = \frac{113 - 80}{43 - 21} = 1.5 \text{ stations.}$$

This means that if teams and RD-2 tractors are used in combination, the teams should skid everything within 150 feet of the road and the remainder should be skidded with tractors. This "break - even" point need not be adhered to rigidly in order to maintain the lowest possible cost. The nature of the formula is such that any slight variation in costs of skidding with either machine can move this break-even point to a considerable extent. Its use is that it is some guide as to what portion of the timber should be skidded with either machine.

To determine what spacing should be used when teams and RD-2 tractors are used in combination the proper values are substituted in the previously given formula:

$$S = \sqrt{\frac{.33 \times 40000}{7 \times 21.4} - \frac{4 \times 43 \times 1.5^2}{21.4} + 4 \times 1.5^2} = 8.9 \text{ stations}$$

Skidding: Team variable cost = $\frac{1.5}{2} \times 43$ = \$ .32

Fixed Cost = .80

\$1.12 x 34% =\$ .38

$\left(\frac{1.5 \times 2}{8.9} = 34\%\right)$

Tractor variable cost =

$$\left(\frac{\frac{8.9}{2} - 1.5}{2}\right) 21.4 = \$ .64$$

Fixed Cost = 1.13

\$1.77 x 66% = 1.17

Total Skidding Cost \$1.55

Roads: $\frac{40000}{12.1 \times 7 \times 8.9}$ = .53

\$2.08.

This cost figure of \$2.08 is to be compared with the cost of roads and skidding of \$2.16 when the RD-2 tractor is used alone and the cost of \$2.23 when the team is used alone. When skidding to skidways, however, the proportion of timber within @ 1.5 stations becomes a smaller proportion of the total timber to be skidded and as a result the saving would be less from using the two machines in combination. No formula has been developed to show this exactly.

Should the skidding be in winter and skidding trails put in by bulldozer the cost per M would be about 38¢ per M. It is estimated these trails cost 60¢ per station or 3200¢ per mile and that they will be spaced 100 feet apart.

$$\frac{3200}{12.1 \times 7 \times 1} = 38¢.$$

RD-2--Skidding directly to plank road:

$$S = \sqrt{\frac{.33 \times 120000}{7 \times 21.4}} = 16.3 \text{ stations.}$$

Skidding:	Variable Cost = $\frac{16.3}{4} \times 21.4$	=	\$ .87 per M
	Fixed Cost	=	1.13
	Total Cost		\$ 2.00
Roads:	$\frac{120000}{12.1 \times 7 \times 16.3}$	=	.87
			\$ 2.87.

RD-2--Skidding to skidways on plank road:

$$S = \sqrt{\frac{10.22 \times 22.70}{7 \times 21.4}} = 12.5 \text{ stations.}$$

Skidding: Variable Cost = $.427 \times 12.5 \times 21.4 = \$1.14$

Fixed Cost $= 1.13$

Total Cost $\$2.27$

Road Cost: $\frac{120000}{12.1 \times 12.5 \times 7} = 1.13$

$\$3.40.$

RD-4 -- Skidding directly to plank road:

$$S = \sqrt{\frac{.33 \times 120000}{7 \times 17.6}} = 17.9 \text{ stations.}$$

Skidding: Variable Cost = $\frac{17.9}{4} \times 17.6 = \$ .79$

Fixed Cost $= 1.25$

Total Cost $\$2.04$

Road: $\frac{120,000}{12.1 \times 7 \times 17.9} = .79$

$\$2.83.$

RD-4 -- Skidding to skidways on plank road:

$$S = \sqrt{\frac{10.22 \times 22.70}{7 \times 17.6}} = 13.8 \text{ stations.}$$

Skidding: Variable Cost = $.427 \times 13.8 \times 17.6 = \$1.03$ per M

Fixed Cost $= 1.25$

Total Cost $\$2.28$

Roads: $\frac{120000}{13.8 \times 12.1 \times 7} = 1.03$

$\$3.31.$

Teams skidding directly to plank road:

$$S = \sqrt{\frac{.33 \times 120000}{7 \times 43}} = 11.5 \text{ stations.}$$

Skidding:	Variable cost = $\frac{11.5}{4} \times 43$	=$ 1.23
	Fixed Cost	= .80
	Total Cost	$ 2.03
Roads:	$\frac{120000}{12.1 \times 11.5 \times 7}$	= 1.23
		$ 3.26.

Teams skidding to skidways on plank road:

$$S = \sqrt{\frac{10.22 \times 22.80}{7 \times 43}} = 8.8 \text{ stations.}$$

Skidding:	Variable Cost = .427 x 8.8 x 43	=$ 1.62
	Fixed Xost	= .80
	Total Cost	$ 2.42
Roads:	$\frac{120000}{12.1 \times 8.8 \times 7}$	= 1.61
		$ 4.03.

Skidding Direct to road with RD-2 -- RD-4 Combination:

Break-even point = $\frac{125 - 113}{21.4 \times 17.6}$ = 3.1 stations.

$$S = \sqrt{\frac{.33 \times 120000}{7 \times 17.6} - \frac{4 \times 21.4 \times 3.1^2}{17.6} + 4 \times 3.1^2} = 17.8 \text{ stations.}$$

Skidding:

RD-2 Variable Cost = $\frac{3.1}{2} \times 21.4$ =$ .33

Fixed = 1.13

($\frac{3.1 \times 2}{17.8}$ = 35%) $ 1.46 x 35% =$ .51 /M

RD-2 Total Cost (Forwarded) $ .51/M

RD-4 Variable Cost =

$$\frac{\left(\frac{17.8}{2} + 3.1\right)}{2}\ 17.6 = \$\ 1.06$$

Fixed Cost = 1.25

$ 2.31 x 65% = $ 1.50

Total Skidding Cost $ 2.01

Roads: $\frac{120000}{12.1 \times 7 \times 17.8}$ = .80

$ 2.81.

When using plank roads for spurs, therefore, the most economical method of skidding is a combination of RD-2 tractors and RD-4 tractors, the short skidding being done by the former and the long skidding by the latter. The saving, however, is negligible so that it makes little difference which tractor is used. Teams, however, are at a greater disadvantage than ever occasioned by the wide spacing required of the expensive plank spurs.

Cost of Skidding and Road Construction

Clear-Cut Operation

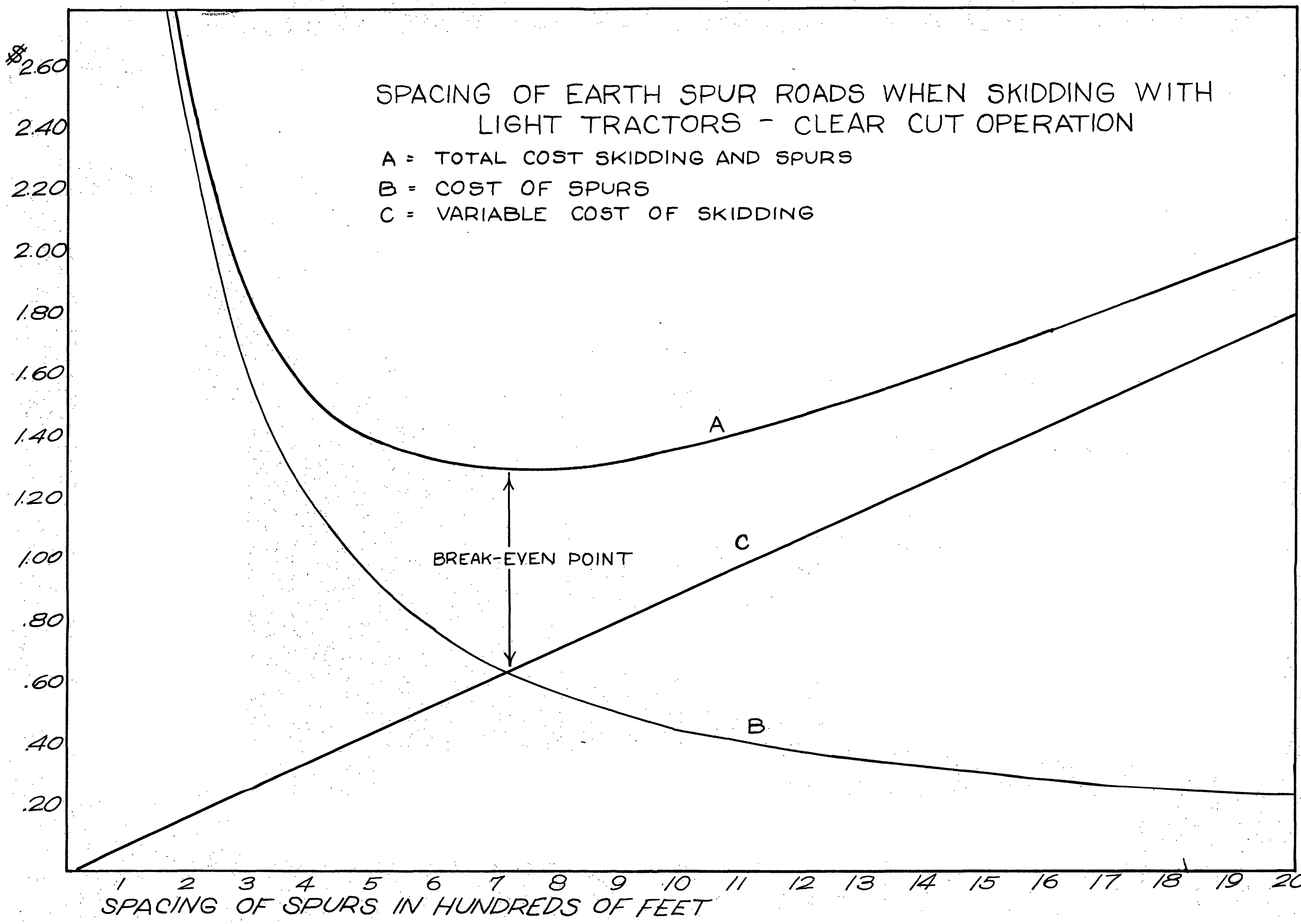
Based on formula: $S = \sqrt{\frac{10.22 \times 7.60}{7 \times 21.4}}$

Where: Cost of road per mile = $400.00.

Skidding with RD-2 tractor costs 21.4¢ per M per 100 feet of distance.

Volume cut per acre = 7 M.

Spacing	Var. Cost of Skidding	Road Cost	Total Cost
100'	$ .09	$4.72	$4.81
200	.18	2.37	2.55
300	.27	1.57	1.84
400	.36	1.18	1.52
500	.46	.95	1.41
600	.55	.79	1.34
700	.64	.68	1.32
800	.73	.59	1.32
900	.82	.52	1.34
1,000	.91	.47	1.38
1,100	1.00	.43	1.43
1,200	1.09	.39	1.48
1,300	1.18	.36	1.54
1,600	1.46	.30	1.76
2,000	1.82	.24	2.06


SPACING OF EARTH SPUR ROADS WHEN SKIDDING WITH LIGHT TRACTORS - CLEAR CUT OPERATION
A = TOTAL COST SKIDDING AND SPURS
B = COST OF SPURS
C = VARIABLE COST OF SKIDDING
$2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
A
B
C
BREAK-EVEN POINT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
SPACING OF SPURS IN HUNDREDS OF FEET

Cost of Skidding and Road Construction

Selective Logging

Based on formula: $S = \sqrt{\frac{10.22 \times 7.60}{3.5 \times 17}}$

Where: Cost of road per mile = $400.00.

Skidding with RD-2 Tractor costs 17¢ per M per 100 feet of distance.

Volume cut per acre = 3.5 M.

Spacing	Var. Cost of Skidding	Road Cost	Total Cost
200'	$ .14	$4.72	$4.86
400	.29	2.37	2.66
600	.43	1.58	2.01
800	.58	1.18	1.76
1,000	.72	.95	1.67
1,200	.87	.79	1.66
1,400	1.02	.68	1.70
1,600	1.16	.59	1.75
1,800	1.31	.53	1.84
2,000	1.45	.47	1.92

Cost of Skidding and Road Construction
When
Skidding is Straight to the Road
and
Not to Skidways

Clear-Cut Operation

Based on formula: $S = \sqrt{\frac{.33 \times 40000}{7 \times 21.4}}$

Where: Cost of spur road construction = $400 per mile

Cost of skidding with RD-2 tractor = 21.4¢ per M per 100 feet of distance.

Volume per acre = 7 M.

Spacing	Var. Cost of Skidding	Road Cost	Total Cost
100'	$ .05	$4.72	$4.77
200	.11	2.37	2.48
300	.16	1.57	1.73
400	.21	1.18	1.39
500	.27	.95	1.22
600	.32	.79	1.11
700	.37	.68	1.05
800	.42	.59	1.01
900	.48	.52	1.00
1,000	.54	.47	1.01
1,100	.59	.43	1.02
1,200	.64	.39	1.03
1,300	.70	.36	1.06
1,600	.85	.30	1.15
2,000	1.07	.24	1.31

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Treatment of swamping and hooking-on costs:

The swamping and hooking on costs are included in cost reports as part of the skidding cost. Swamping consists of the clearing of branches and brush from around logs cut by the sawyers so that they may be hooked on to with a team or tractor, and, also, of cutting such trails to the logs as are necessary for the skidding device to reach them. The tractor hooker or chainer has the duty of hooking on the logs to the tractor. The question arises as to how these two costs should be treated when dividing the cost of skidding into fixed and variable components.

The hooker, for example, can work no faster than the tractor can take away the logs. If the tractor is on a long haul and makes fewer trips, the hooker must still be on the job but will do less work and as a result the cost of hooking will rise. While the case is not quite so clear in the case of the swampers, the same relation holds good; that is, the swamper will work just as fast as he is pushed by the teams or tractors. Rarely will he swamp out a large number of logs ahead, but will usually progress with his swamping just as fast as the team does with the skidding. While the reason for this is to a great extent due to the attitude of the worker that he will do no more work than he is forced to do, it is also true that the swamper must always be around when the skidding device hooks on to cut off any snipes, branches, and so forth. Thus, as with the hooking-on process, the cost per M of swamping will rise as the skidding distance increases unless at some certain distance back from the road the number of swampers is reduced, a procedure which is seldom followed.

To determine whether swamping and hooking costs should be included in the fixed and variable cost figures for skidding, fixed and variable costs are computed for the RD-2 tractor alone, roads are spaced according to this data, and the final cost is obtained by adding a charge for swamping and hooking. This cost is then compared with that obtained when hooking and swamping charges are included in the fixed and variable costs.

<u>RD-2</u>

Costs based on $1.40 per hour for tractor and driver.
.16 " " " towing winch.

$1.56 per hour Total Cost.
2.6¢ per minute.

Ave DBH Stand In.	Load B.M.	Hook & Unhook Min.	Fix. Cost per Load ¢	Fix. Cost per M ¢	Min. per 100' Distance Rd.Trip	Var. Cost per Load ¢	Var. Cost per M ¢	Var. Cost + 10% ¢	Min. per M Fix.	Var. + 10%
16	160	4.7	12.2	77	.8	2.1	13	14.3	29.4	5.5

****

Cost Swamping and Hooking

Distance Skidded	Min. to Skid 1M	Swamping Hooking 1 Swpr. 1 Hkr. Cost/M	Swamping Hooking 2 Swprs. 1 Hkr. Cost/M	Cost of Extra Swpr. per M	Min.Tractor can afford to lose/M before putting on extra swpr.	Min.Tractor can afford to lose per trip
100'	24.9 x 1.25	43¢	64¢	21¢ + 2.6¢	8	1.3
200	40.4	51	74	23	9	1.4
300	45.9	57	84	27	10	1.6
400	51.4	64	94	30	11	1.8
500	56.9	71	104	33	13	2.1
600	62.4	78	114	36	14	2.2

RD-2

$$S = \sqrt{\frac{.33 \times 40000}{14.3 \times 7}} = 11.5 \text{ stations.}$$

Skidding: Variable Cost = $\frac{11.5}{4} \times 14.3$ =$ .41/M

Fixed cost = .77

Swamping Cost (300' basis) = .57

Total Cost $1.75

Road: $\frac{400000}{12.1 \times 7 \times 11.5}$ = .41

$2.16.

The cost of $2.16 is to be compared with the cost of $2.13 per M which is obtained with the RD-2 tractor when swamping and hooking on are included in the fixed and variable costs. This difference of 3¢ in total cost of spur roads and skidding is due to the fact that the roads are really incorrectly spaced in the last example. However, the nature of the road-spacing problem is such that an error of 200 feet in spacing, which increases the spacing in this case from 9.4 to 11.5 stations, is not serious enough to be of any consequence. (See graph and cost compilation for this formula.)

The effect of size of load and hooking on time on tractor skidding costs:

When skidding with a tractor there are two errors to be avoided if skidding costs are to be at a minimum. These errors are lost time and carrying loads of less than capacity. The first of these is caused by swampers not having enough logs ready to be skidded when the tractor arrives and by blocked skidways. The second is the result of the tractor taking only what logs are swamped out and ready instead of waiting and taking a capacity load. It is commonly believed that if the tractor is kept running, tractor costs for skidding will be satisfactory and that the effect of a small load is cancelled by more frequent trips with the tractor.

Skidding costs under various conditions can be calculated by the following formula where:

V = minutes required to haul a load 100 feet round trip.

D = skidding distance in hundreds of feet.

L = load - board feet.

F = minutes of fixed time per load - hook, unhook, delay, and so forth.

c = cost of tractor operation per minute - cents.

$$\text{Total skidding cost} = \left(\frac{V \times 1000 \times D}{L} + \frac{F \times 1000}{L}\right) c$$

RD-2 -- Skidding distance 500 feet Load and fixed time standard:

$$\left(\frac{.8 \times 1000 \times 5}{160} + \frac{4.7 \times 1000}{160}\right) 3.85 = \$2.10 \text{ per M}$$

RD-2 -- Skidding distance 500 feet. Fixed time standard but load 1/2 capacity:

$$\left(\frac{.8 \times 1000 \times 5}{80} + \frac{4.7 \times 1000}{80}\right) 3.85 = \$4.20 \text{ per M}$$

RD-2 -- Skidding distance 500 feet. Load standard but fixed time doubled:

$$\left(\frac{.8 \times 1000 \times 5}{160} + \frac{9.4 \times 1000}{160} \right) 3.85 = \$3.62 \text{ per M.}$$

RD-2 -- Skidding distance 100 feet. Load and fixed time standard:

$$\left(\frac{.8 \times 1000 \times 1}{160} + \frac{4.7 \times 1000}{160} \right) 3.85 = \$1.32 \text{ per M.}$$

RD-2 -- Skidding distance 100 feet. Fixed time standard but load 1/2 capacity:

$$\left(\frac{.8 \times 1000 \times 1}{80} + \frac{4.7 \times 1000}{80} \right) 3.85 = \$2.65 \text{ per M.}$$

RD-2 -- Skidding distance 100 feet. Load standard but fixed time doubled:

$$\left(\frac{.8 \times 1000 \times 1}{160} + \frac{9.4 \times 1000}{160} \right) 3.85 = \$2.46.$$

It can be seen from the above that considerable delay time must be incurred before it would be more economical to take a load of 1/2 capacity. The time that the tractor can afford to wait before taking a reduced load will depend on the size of the load and the distance it has to be skidded. A safe rule, however, is always to carry capacity loads and to have enough swampers to supply the loads.

The following data was collected for an RD-4 skidding part of the distance with a towing winch and the rest of the distance by draw bar:

Cost based on $1.67 per hour for tractor and driver

$1.67	"	"	"	tractor and driver
.22	"	"	"	towing winch
1.10	"	"	"	1 swamper and 2 hookers
$2.99	"	"		Total Cost

5¢ per minute.

The skidding chance consisted of an average cable haul of 150 feet up a 30 per cent grade through 3 feet of snow, and an average towing distance with drawbar of 100 feet. Logs were then moved an average distance of 250 feet. Over an elapsed time of 284 minutes, with time omitted for delays not attributable to the tractor, such as, plugged skidways, 12,330 board feet were skidded. The average volume skidded per hour was thus 2,600 board feet. The average load skidded was 287 board feet. The number of logs per M ran approximately 10 which is considerably larger than the 13.5 average in hardwood so the cost of $1.15 per M at which these logs were skidded is undoubtedly lower than could be expected from hardwood logging. It may be safely concluded, however, that with this machine it is possible to skid areas which previously through inaccessibility could only have been logged at great expense or even left uncut.

An effort was at first made to separate the fixed and variable costs of the cable skidding operation. Owing to the great variety of ground conditions, irregularity of hang-up occurrences, and the fact that logs are hooked on all along the route so that hook on time cannot be separated from travelling time make this virtually impossible. The capacity of the winch spool is limited to 200 feet anyhow, so that it would be impossible to apply variable costs to road spacing formulae even if they were collected.

Data Collected When Skidding
with
RD-4 Tractor and Winch

Cable Haul	Distance	175'	Elapsed Time	Loads	
Tractor "	"	50'	38 minutes		
				250 b.m.	
				270	
				210	
				280	
				380	
				430	
				210	
				260	
				310	2600

Forwarded	38 minutes		2600
Cable Haul Distance 150' Tractor " " 25'	Elapsed Time 91 minutes	320 280 270 180 280 300 170 360 240 170 390 160 220 290 460 180	4270
Cable Haul Distance 125'	155 minutes	340 220 210 420 480 540 230 280 310 160 150 240 340 200 380 250 250 460	5460
	284 minutes		12,330 b.m.

287 b.m./load = 2600 b.m./hour Average.

One operator has listed the advantages that he attributes to the towing winch which indicate that it should be part of the equipment of all tractors used on logging operations:

1. Elimination of bunching team for RD-4 tractors and larger.
2. Ability to skid in areas which cannot be reached by other devices.
3. Ability to stump roads without the severe wear occasioned by the use of a bulldozer attachment.
4. Ability to winch itself out of bad holes and awkward positions.
5. Ability by a steady pull to move loaded trucks up steep grades and out of bad holes which formerly meant unloading and a great waste of time.
6. A minimum of swamping is required for individual logs.

The horse as a skidding device:

According to the fixed and variable cost tables for tractors and horses, the team is only more efficient than the RD-2 as a skidding device up to distances of 150 to 200 feet. At distances beyond this the team is at a disadvantage. The costs given for teams in the tables are based on a 1.78¢ per minute cost. This cost is based on 200 working days per year. If the nature of the operation is such that the teams could only be used 100 working days per year the cost per minute would rise to 2.14¢. The fixed and variable costs when operating in 16-inch timber would then become 96¢ and 51¢. Such costs would make the tractor more profitable as a skidding device for all distances:

$$D = \frac{113 - 96}{51 - 21.4} = .53.$$

When D is less than 1 the team can no longer compete.

Estimated Horse Costs when Working	Cost/Horse/Day
Barnboss	$ .10
Stable Supplies	.02
Blacksmith	.06
Vet	.02
Hay 32#/day $10 per ton	.16
Oats .6 bu/day ea. 40¢	.24
	$ .60

Estimated Horse Costs When Idle in Stable	Cost/Horse/Day
Barnboss	$ .10
Stable Supplies	.02
Blacksmith	.02
Vet	.02
Hay	.12
Oats	.18
	$ .46

Estimated Horse Costs When Idle in Pasture	
Barnboss	$ .10
Stable Supplies	.02
Blacksmith	.02
Vet	.02
Pasturage	.04
	$ .20

Depreciation per horse per year = $60.

Cost of Team as Skidding Unit:

200 Working Days/Year--Approximately 9 months of operation.

Horse Maintenance:	Cost of One Horse:
9 operating months 270 days x 60¢	$ 162
1½ months idle in stable 45 days x 46¢	21
1½ months pasture 50 days x 20¢	10
	$ 193
Depreciation	60
Total Cost per horse per Year.	$ 253

Cost/Horse/Working Day = $\$ \frac{251}{200}$ = \$1.26

Cost of Team	=	\$ 2.52
Teamster	=	3.20
Swamper	=	2.80
		\$ 8.52 = Cost skidding unit per day.
		1.78¢ = Cost per minute.

<u>100 Working Days/Year--Approximately 4 months of operation.</u>

Horse Maintenance:	Cost of One Horse:
4 operating months 120 days x 60¢	\$ 72
4 months idle in stable 120 days x 46¢	55
4 months pasture 125 days x 20¢	25
	\$ 152
Depreciation	60
Total Cost per Horse per Year.	\$ 212

Cost/Horse/Working Day = $\$ \frac{212}{100}$ = \$2.12

Cost of Team	=	\$ 4.24
Teamster	=	3.20
Swamper	=	2.80
		\$10.24 = Cost of Skidding unit per day.
		2.14¢ per minute.

Estimated Cost of Owning and Operating Caterpillar Tractors in Logging Operations

	RD-4 -- 60" Guage			RD-2 -- 50"		
Approximate Delivered Price:	$3,050			$1,750		
Working Conditions:	Excellent	Fair	Severe	Excellent	Fair	Severe
Depreciation period:						
Years	5	4	3	5	4	3
Hours	10,000	8,000	6,000	10,000	8,000	6,000
Average Investment:	$1,830	1,906	2,033	1,050	1,094	1,167
Fuel Consumption--Gals per Hour:						
Diesel Fuel	1.40	1.60	1.80			
Gasoline	.13	.13	.13	1.80	2.20	2.60
Lub.Oil,Gals/Hr.	.07	.08	.09	.05	.06	.07
Grease,Lbs/Hr.	.45	.50	.60	.36	.40	.48
Fixed Charge per Hour:						
Int.taxes,Ins.etc (10% of ave.investment/year)	$.091	.095	.102	.052	.055	.058
Depreciation	.305	.381	.508	.175	.219	.292
Repairs,including labor	.305	.381	.508	.201	.252	.336
Total fixed charge	$.701	.857	1.118	.428	.526	.686
Operating Cost per Hour:						
Operator	$.570	.570	.570	.570	.570	.570
Diesel fuel ea.7¢gal.	.098	.112	.126			
Gasoline 15¢ "	.020	.020	.020	.180	.220	.260
Lub.Oil 65 "	.046	.052	.059	.033	.039	.046
Grease 12 Lb.	.054	.060	.072	.043	.048	.058
Total operating cost	$.788	.814	.847	.826	.877	.934
Total fixed charge	.701	.857	1.118	.428	.526	.686
Total Cost per Hour	$1.489	1.671	1.965	1.245	1.403	1.620

Note: The quantities here given are typical for the conditions outlined but should be modified to meet any

(Costs by Caterpillar Tractor Co.)

special conditions encountered. For example, when operating under extremely abrasive soil conditions, the life of tracks and rollers may be reduced to the point that repairs may run as much as 30% above those given.

The approximate delivered price includes those attachments with which a logging tractor will normally be equipped, namely, front bumper, radiator, crankcase guard, front pull hook, upper and lower engine guards, and heavy duty track roller guard. The gasoline charge on the Diesel tractors includes the gasoline used in the starting of the engine and that used in cleaning filters, and so forth.

The fuel charge for the RD-2 is based on "tractor fuel" costing 10 cents per gallon.

Estimated Cost of Owning and Operating
Willamette - Hyster Winches

	RD-4	RD-2
Approximate Del'd Price:	$625.00	$440.00
Depreciation Period:		
Years	5	5
Hours	10,000	10,000
Average Investment:	$375.00	$264.00
Cable	100' - 5/8"	100' - 1/2"
Cost	$ 16.50	$ 12.50
Length of Life, hours	200	200

Cost per Hour:	RD-4	RD-2
Int.,Taxes,Ins.,Etc. (10% of average investment per yr)	$ .019	$ .013
Depreciation	.062	.044
Repairs including labor	.045	.030
Cable	.082	.063
Grease - 12¢ per lb.	.008	.006
	$ .216	$ .155

Estimated Cost per 100 Feet of 6 x 19 Pre-Formed Plow Steel Cable:

	Wire Center	Hemp Center
3/8"	$ 10.15	$ 8.70
7/16	11.00	9.50
1/2	12.50	10.75
9/16	14.30	12.30
5/8	16.50	14.25
3/4	22.00	19.00
7/8	27.00	23.50
1	33.70	29.00
1 - 1/8	42.00	35.00

Loading

The method in general use for loading trucks is the A-shaped horse jammer costing about $100.00 to build. The cost of operating this jammer per hour is:

Jammer depreciation Cable, etc.	$ .05
2 Hookers	.76
Crosshaul team and driver	.68
Total Cost per Hour	$1.49.
Cost per Minute	2.5¢.

This device can easily load 4,000 b.m. per hour when loading hardwoods from a clear-cut operation and if this production could be maintained by a proper supply of logs and prompt arrival of trucks, the cost per M would be:

$$\$\ \frac{1.49}{4M} = \$\ .37 \text{ per M.}$$

Actually, this cost amounts to $.70 per M or the jammer only operates, on the average, at 53% of capacity and loads 2.5 M per hour. Actually, of course, it would be impossible to obtain the $ .37

Fresh cut logs - Note freedom from brush

Loading trucks - Showing one of the hookers and the top loader.

Loading trucks - Showing the crosshaul team, jammer, and top loader.

per M cost since the jammer must be moved occasionally which requires at least one-quarter hour.

A part of the loading cost which is not included in that cost in cost reports is the lost time incurred by the truck when being loaded. The fixed cost of the truck including the driver who does the top loading is 1.54¢ per minute. Since 30 minutes are required to load a truck not including the time that the truck must wait before being loaded, an additional charge of 30 x 1.54¢ = 46¢ must be added to the loading cost.

An alternative method of loading is the use of the "Speeder Loader", a hoist mounted on a tractor. The entire unit costs $7,000 and the hourly cost of operation is estimated at $1.66, including operator, by the manufacturers. With an additional charge for 2 hookers, the cost per hour becomes $2.49. This figure is applied here to a time study of this machine in the Southern Pines. While it is admittedly hazardous to take figures from one region and apply them to another, these should not be too widely divergent since the Southern Pines have about the same weight as the Northern Hardwoods and 16-foot logs are handled in both cases.

Ave DBH of Std	Hours to Load 100 Cu Ft	Hrs to Load 1 M	Hours to Bunch 100 Cu Ft	Hours to Bunch 1 M	Hours to Bunch and Load 1 M	Total M Bunches per Hour	Total M Lded per Hour	Total M Bunch and Load per Hour	Cost Bunch per M	Cost Load per M	Cost Bunch and Load per M
16"	.13	.21	.12	.195	.405	5.1	4.7	2.4	.49	.53	$1.02
20	.09	.14	.10	.16	.30	6.2	7.1	3.3	.40	.35	.75

Maximum bunching distance -- 100 feet.

Total Production per day loading only -- 38 M.

Total Production per day bunch and load -- 19 M.

The preceding costs were taken from an actual operation and are probably analogous to the 70¢ per M loading cost of the horse jammer. The makers claim that when loading at 100 per cent capacity this machine will load 6 M per hour which would indicate a cost of $\frac{\$2.49}{6\ M} = \$\ .41$ per M. This cost is virtually the same as that obtained with the horse jammer at 100 per cent capacity.

The big advantage of this machine is its ability to yard logs when not loading. The cost of skidding with a team over a distance of 50 feet is $1.02 while the yarder will do the same job for $.49 according to the above data. Thus, if a truck were not available for loading there is no reason why this mobile unit cannot keep right on working.

According to an observer of logging operations in northern Alabama, the procedure followed when using this loader is that one tractor operates in back of the loader's bunching reach. It drops its loads as near the road as possible but does not come into specially made skidways nor attempt to bring the log right to the road if the way is blocked by previously skidded logs. The result of this is that the tractor never incurs any lost time due to plugged skidways.

Another advantage in using this machine is that when skidways are eliminated the logs may be skidded directly to the road, assuming that the brush is not too thick to prevent this. In the section of this paper devoted to skidding it has been shown that when skidding directly to an earth spur with an RD-2 the cost of spurs and skidding amounts to $2.13 per M and when skidding to skidways, $2.45 per M. Thus, there is a saving of $0.32 on the part of direct skidding where it is possible. This saving could be realized if a mobile unit such as the speeder loader were used.

To sum up the advantages and disadvantages of the speeder loader:

Advantages:

1. Reduces skidding costs
    a. By permitting skidding units to work nearer full capacity
    b. By cheap yarding cost of timber adjacent to the road.
2. Will probably give a lower loading cost.
3. Will load trucks faster and cut down the lost time due to this operation.
4. Is highly mobile so there is not time lost in moving into a new location.
5. Makes possible the elimination of skidways and the spacing of spur roads for direct skidding.

Disadvantages:

1. High initial investment and risk.
2. Expense and trouble maintaining machine, special housing, repairs, supplies, etc.
3. Machine must be run to and from camp with resulting cost. It would be impossible to service the machine in the field especially in the winter.
4. Difficulty in securing efficient operators.

Log Loaders

	Speeder Log Loader (with 22' boom and stabilizer)	Bucyrus-Erie Loadmaster (with 30' boom)
Approximate Del'd Price:	$7,000	$10,250
Depreciation Period:		
Years	10	10
Hours	20,000	20,000
Average Investment:	$3,850	$ 5,637
Fixed Costs per Hour:		
Int.,Taxes,Ins.,Etc. (10% of Ave.Investment per Year)	$ .193	$ .282
Depreciation	.350	.513
Repairs	.280	.400
Total fixed cost	$ .823	$ 1.195
Operating Costs per Hour:		
Operator	$ .500	$ .600
Diesel fuel 7¢ per gal.	.105	.175
Gasoline 15¢ per gal.	.021	.024
Lub.Oil 65¢ per gal.	.059	.072
Grease 12¢ per lb.	.065	.080
Cable	.082*	.092**
Total operating cost	$ .832	$ 1.043
Total fixed costs	.823	1.195
Total Hourly Cost	$1.655	$ 2.288

*Cable costs for Speeder Loader figured as follows:

Boom hoist line--100' of 1/2" at 10 3/4¢ per ft. - 1000 hours	$ .011
Main hoist line--150' of 5/8" at 14 1/4¢ per ft. - 300 hours	.071
	$ .082

**Cable costs for Loadmaster figured as follows:

Boom hoist line--150' of 5/8" at 14 1/4 ¢ per ft. 1000 hours life . . .	$ .021
Main hoist line--150' of 5/8" at 14 1/4¢ per ft. 300 hours life . . .	.071
	$ .092

Basic Figures for Estimating Truck Hauling Costs:

Chevrolet Truck complete with 2-speed rear axle	$ 1090	
Less -- Tire Cost	201	
		$ 889.00
Highway Frame Trailer with brakes . . .	$ 846	
Less -- Tire Cost	178	
		668.00
Cost of Truck and Trailer		$1557.00
Residual value after 2 years -- truck		389.00
Truck Write-Off per Year		250.00
Trailer written off completely in 10 years -- Cost per Year		66.80

Total Write-Off per Year on Truck and Trailer: . $ 316.80

Average Investment Truck: $\frac{889 + 389}{2} + \frac{250}{2} =$ $764

Average Investment Trailer: $\frac{668}{2} + \frac{66.80}{2} =$ 376

Total Truck Unit Investment . . . . $ 1140

Interest on Investment = $1140 x 6% = . . . 68.50

Insurance = $100 per year not including workmen's compensation.

License = $72 per Year.

Driver Wages = 57¢ per Hour.

Fixed Cost per Hour on 1600-Hour per Year Working Basis:

Driver's Wages	$ .570	
Interest	.043	.613

Amount forwarded	$ .613
License	.045
Insurance	.063
Depreciation	.198
Total Fixed Cost per Hour	$ .919
Cost per Minute	1.54¢

Average Truck Repair Cost per Year = ... $320.00

Tire Cost $557 pro-rated over 1000 hours.

Poorly Graded Earth or Snow Spur Road:

8 MPH Empty -- 2.5 MPH Loaded

			Cost per Mile
Empty:			
Gas	3.5 MPG	$	.051
Oil	. . . .		.004
Tires . . .	$\frac{56¢}{8 \text{ MPH}}$		.056
Repairs . .	$\frac{20¢}{8 \text{ MPH}}$		.025
Variable Cost		$	.136
Fixed Cost	$\frac{91.9¢}{8}$		.115
Total Cost per Mile Empty:		$	.251
Loaded:			
Gas	2 MPG	$	.090
Oil	. . . .		.005
Tires . . .	$\frac{56¢}{2.5 \text{ MPH}}$		.224

.319

Poorly Graded Earth or Snow Spur Road:
Loaded: (Cont'd)

Amount Forwarded.	2.5 MPH	$	.319
Repairs	$\frac{20¢}{2.5 \text{ MPH}}$		.080
Variable Cost		$	.399
Fixed Cost	$\frac{91.9}{2.5}$		.367
Total Cost per Mile Loaded:		$	.766
Cost per Round Trip Mile			1.017
Cost per M per Mile -- Clear Cut -- Load 2,000 b.m.			.508
Cost per M per Mile -- Partial Cut -- Load 2,300 b.m.			.440
Cost per M per 100 feet -- Clear Cut			.0096
Cost per M per 100 feet -- Partial Cut			.0083

Good Earth Spur Road:
10 MPH Empty -- 5 MPH Loaded

Empty:			Cost per Mile
Gas	4 MPG	$	.045
Oil			.003
Tires	$\frac{56¢}{10}$		.056
Repairs	$\frac{20¢}{10}$		.020
Variable Cost		$	.124
Fixed Cost	$\frac{91.9}{10}$		.092
Cost per Mile Empty		$	.216

Good Earth Spur Road:

Loaded:

Gas	2.5 MPG	. . . . $	.072
Oil		. . . .	.004
Tires . . .	$\frac{56¢}{5}$	. . . .	.110
Repairs . .	$\frac{20}{5}$	. . . .	.040
Variable Cost		$	.226
Fixed Cost	$\frac{91.9}{5}$	. . . .	.184
Cost per Mile Loaded		$	.410
Cost per Mile Round Trip			.626
Cost per M per Mile -- Clear Cut -- 2,000 b.m. load			.313
Cost per M per Mile -- Partial Cut -- 2,300 b.m. load			.273
Cost per 100 feet -- Clear Cut			.0059
Cost per 100 feet -- Partial Cut			.0052

Plank Road:

18 MPH Empty, 12 MPH Loaded

Empty:

			Cost per Mile	
Gas	6 MPG	. . . . $	.030	
Oil		. . . .	.003	
Tires . . .	$\frac{56¢}{18}$	. . . .	.031	
Repairs . .	$\frac{20¢}{18}$	. . . .	.011	
				.075

Trucks with rated capacity of 2-3 tons carry loads of 2,000 Mbm of hardwoods and 3,000 Mbm of pine.

Flat cars loaded with logs on the main line. Car capacity varies from 5M - 8M.

Plank Road:

Empty:

Variable Cost	$	.075
Fixed Cost $\frac{91.9¢}{18}$		.051
Cost per Mile Empty	$	.126

Loaded:

Gas . . . . 4 MPG	$	.045
Oil		.004
Tires . . . $\frac{56¢}{12}$		.047
Repairs . . $\frac{20¢}{12}$		.017
Variable Cost	$	.113
Fixed Cost $\frac{91.9¢}{12}$		.076
Cost per Mile Loaded	$	.189
Cost per Round Trip Mile		.315
Cost per M per Mile -- Clear Cut -- 2,000 b.m. load		.16
Cost per M per Mile -- Partial Cut -- 2,300 b.m. load		.14
Cost per 100 feet Clear Cut		.0030
Cost per 100 feet Partial Cut		.0027

Well Maintained Woods Snow Road:
15 MPH Empty -- 10 MPH Loaded

Empty:			Cost per Mile
Gas	4.5 MPG	$	.040
Oil	. . . .		.003
Tires . . .	$\frac{56¢}{15}$		.037
Repairs . .	$\frac{20¢}{15}$		.013
Variable Cost		$	.093
Fixed Cost	$\frac{91.9¢}{15}$		.061
Total Cost per Mile Empty:		$	.154

Loaded:			
Gas	2.8 MPG	$	.064
Oil	. . . .		.004
Tires . . .	$\frac{56¢}{10 \text{ MPH}}$		.056
Repairs . .	$\frac{20¢}{10 \text{ MPH}}$		.021
Variable Cost		$	.145
Fixed Cost	$\frac{91.9}{10 \text{ MPH}}$		.092
Total Cost per Mile Loaded:		$	.237
Cost per Round Trip Mile			.391
Cost per M per Mile -- Clear Cut -- 2,000 b.m. load			.196
Cost per M per Mile -- Partial Cut -- 2,300 b.m. load			.170

Well Maintained Woods Snow Road:

Loaded: (Cont'd)

Cost per M per 100 feet -- Clear Cut	$ .0037
Cost per M per 100 feet -- Partial Cut . . .	.0032

Main Haul Woods Road -- Gravel:

25 MPH Empty, 15 MPH Loaded

Empty:

			Cost per Mile
Gas	9 MPG	$	.020
Oil	. . . .		.002
Tires . . .	5.6¢ / 25		.022
Repairs . .	20¢ / 25		.008
Variable Cost		$	.052
Fixed Cost	91.9¢ / 25		.037
Total Cost per Mile Empty:		$	.089

Loaded:

Gas	5 MPG	$	.045	
Oil	. . . .		.003	
Tires . . .	56¢ / 15		.037	
Repairs . .	20¢ / 15		.013	
Variable Cost		$	.098	
Fixed Cost	91.9¢ / 15		.061	.159

Main Haul Woods Road -- Gravel:

Loaded: (Cont'd)

Total Cost per Mile Loaded	$	.159
Cost per Round Trip Mile		.248
Cost per M per Mile -- Clear Cut -- 2,000 b.m.		.124
Cost per M per Mile -- Partial Cut -- 2,300 b.m.		.108
Cost per M per 100 feet -- Clear Cut .		.0024
Cost per M per 100 feet -- Partial Cut.		.0020

Highway -- Hard Packed Snow, Macadam:

36 MPH Empty -- 24 MPH Loaded

Empty:

			Cost per Mile	
Gas	9 MPG	$	.020	
Oil	. . . .		.002	
Tires . . .	56¢ / 36 MPH		.016	
Repairs . .	20¢ / 36 MPH		.005	
Variable Cost		$	.043	
Fixed Cost	91.9¢ / 36 MPH		.026	
Total Cost per Mile Empty:		$	.069	

Loaded:

Gas	4.3 MPG	$	.042	
Oil	. . . .		.004	.046

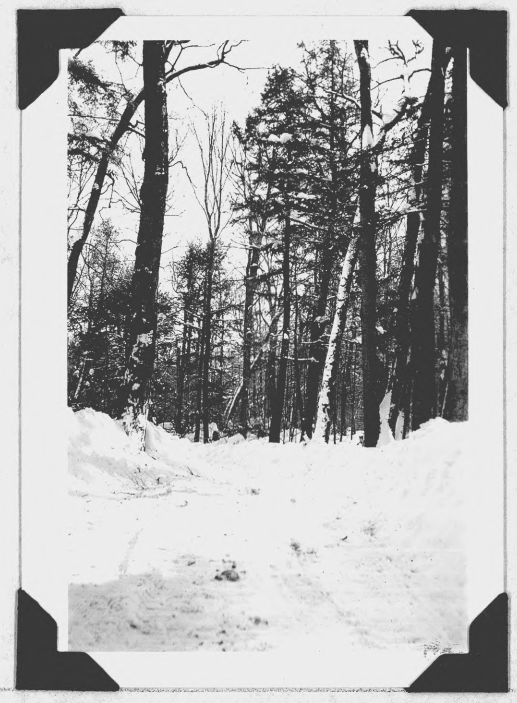
Highway -- Hard Packed Snow, Macadam:

Loaded: (Cont'd)

Amount Forwarded . . 4.3 MPG.		$	.046
Tires	56¢ / 24 MPH		.023
Repairs	20¢ / 24 MPH		.008
Variable Cost		$	.077
Fixed Cost	91.9¢ / 24 MPH		.038
Total Cost per Mile Loaded:		$	.115
Cost per Round Trip Mile			.184
Cost per M per Mile -- Clear Cut -- 2,000 b.m. load			.092
Cost per M per Mile -- Partial Cut -- 2,300 b.m. load			.080

WINTER TRUCK HAUL ROADS

Icing road with sprinkler



Typical haul road

Snowplowing with A.C. Model M and homemade plow.

Round Trip

- Truck Hauling Cost ~~Summary~~ -

Road Type:	Clear Cut Per M /Mile	Clear Cut Per M/ Station	Partial Cut Per M /Mile	Partial Cut Per M/ Station	Miles per Hour MPH Empty	MPH Loaded
1 1.Poor Earth Spur	50¢	.96¢	43¢	.82	8	2.5
omit ~~2.~~Good Earth Spur or Fair Snow Road	31	.59	27	.52	10	5
2 3.Plank	16	.30	14	.27	18	12
4.Good Snow Road Well Maintained	20	.37	17	.32	15	10
3 5.Gravel Woods Road for Main Haul	13	.24	11	.21	25	15
4 6.Highway	10	.19	8	.15	36	24

(Round trip Costs.)

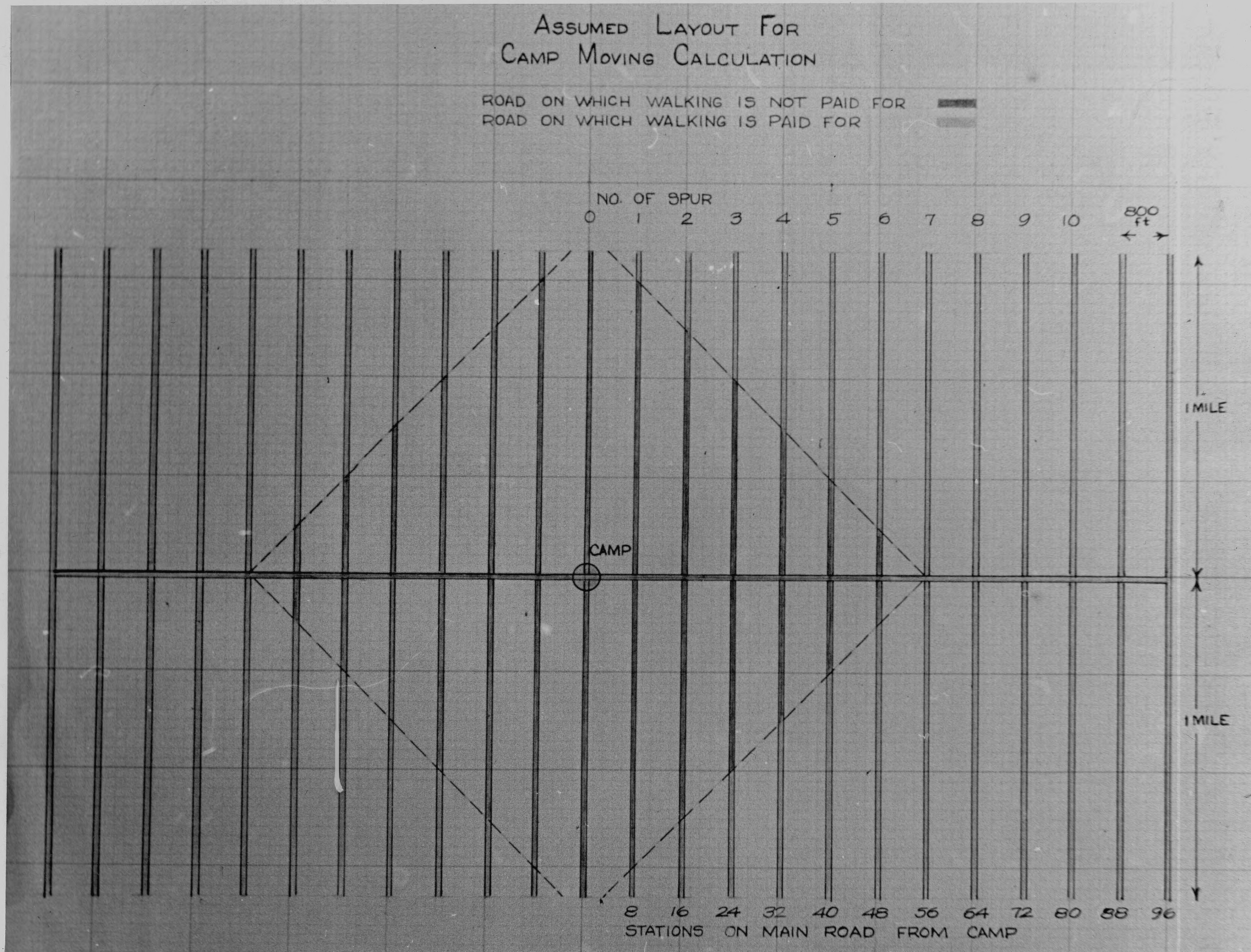
Note:

Speeds and gasoline mileage data for numbers 1, 4, and 6 of the above are based on actually observed data. The remainder are estimation only. Grades play a very important part in determining truck costs and a well surfaced road with heavy grades may be more expensive to travel over than roads of an inferior surfacing but with no grades. Grades of 9per cent against the load are the maximum for this type of hauling unit and should be kept under 5 per cent if at all possible.

Camp Cost

In the past the problem of locating a camp and determining how often it should be moved or abandoned was solved by knowing how far men and teams could walk and still have time left to put in a good working day. It was generally recognized that too far a walk fatigued men and horses to the extent that their efficiency was lowered and caused discontent. It was also understood that a camp should be so located as to put within walking distance the largest amount of timber which had to be cut. With the advent of labor unionism in the camps, another factor heretofore non-existant has put in its appearance; namely, men must now be paid overtime for walking beyond a certain distance. This last is a decided and concrete limiting factor on the distance that men can be made to walk to work; in other words, there comes a time when it is more profitable to build a new camp than to pay the men for walking. It is possible to set up a definite formula for a given set of conditions which will give the proper spacing for the camps as far as paying men for walking is concerned. It is, of course, realized that the other factors mentioned are also of great importance but it is difficult to express them definitely in dollars and cents while this last factor can be so expressed, and a spacing figure solved for on this basis is of great aid in correlating the other "judgment factors" involved.

For the sake of demonstration, the following conditions are assumed: A camp is located on a main haul road from which spurs branch every 800 feet and which extend back 1 mile. The men walk one mile away from camp free of charge and two RD-4 tractors run to and from work every day. The average volume per acre is about 7 M and the daily cut is about 50 M so that approximately 7 acres are cut-over daily. The tractor costs 1.85¢ per minute to run without driver who is not paid for driving his tractor to and from work. The speed of the tractors is 6 miles per hour when running along the roads and the cost per 100 feet is .36¢. The men walk at the average rate of 2½ miles per hour or .454 minutes per 100 feet. The average wage is 38¢ per hour and the cost per minute is .635¢. The cost of walking per 100 feet is then .635¢ x .454 min. = .29¢. The crew consists of 54 men who have to walk to and from work each day.



ASSUMED LAYOUT FOR
CAMP MOVING CALCULATION
ROAD ON WHICH WALKING IS NOT PAID FOR
ROAD ON WHICH WALKING IS PAID FOR
NO. OF SPUR
0
1
2
3
4
5
6
7
8
9
10
800 ft
CAMP
1 MILE
1 MILE
8
16
24
32
40
48
56
64
72
80
88
96
STATIONS ON MAIN ROAD FROM CAMP

The area served by each spur = $\frac{800 \times 5280}{43560}$ =

97 acres are served by spur on one side of main road or 194 acres on both sides.

$\frac{194}{7 \text{ Acres}}$ = 28 days required to clear the timber from one spur.

Since work will be done on both sides of the camp along the main road, it has been found simplest to make the computation on the basis of one-half of the crew working in each direction every day. In actual practice this would not be done but the result as far as this calculation is concerned is the same.

Therefore, 27 men will work on each side of camp and will cut over $3\frac{1}{2}$ acres. To determine how far along a spur the operation will move each successive day it is necessary to find out the equivalent of $3\frac{1}{2}$ acres in feet of spur:

$$800 \text{ feet} \times X = 3\tfrac{1}{2} \times 43560$$
$$X = 190 \text{ feet.}$$

It is assumed that the camp will be located at the intersection of a spur with the main road. Since the spur has been assumed to be just one mile long there will be no walking time to pay for on that spur. To determine the cost on the other spurs up to the point where the distance from camp along the main road to the intersection with a spur which is approximately one mile (see diagram), the following chart is presented. It must be remembered that spurs branch out on both sides of the mainhaul road and that this road thus serves a strip of timber 2 miles wide.

Spur No.	No. Days	Average Rd. Trip Distance	Cost Walking 27 men 200' 27x.29¢ =	Cost/Spur on one side of camp
1. $\frac{800}{190}$ = 4.2x2 =	8	8 Sta.	7.8¢	$ 5
2. $\frac{1600}{190}$ = 8.4x2 =	17	16	7.8¢	21
3. $\frac{2400}{190}$ = 12.6x2 =	25	24	7.8¢	49
4. $\frac{3200}{190}$ = 16.8x2 =	34	32	7.8¢	85
5. $\frac{4000}{190}$ = 21.0x2 =	42	40	7.8¢	131
6. $\frac{4000}{190}$ = 25.2x2 =	50	48	7.8¢	188
7. $\frac{4000}{190}$ = 29.4x2 =	59	56	7.8¢	258
				$ 737.

$737 x 2 = $1474. The cost of operating on both sides of camp up to a distance of 7 spurs of 5600 feet for the entire crew.

When working on spur #8 the crew walks on the average (8 + 24.6)2 = 69 Stations. The lost time for the crew for that spur alone will then be:

69 sta. x .29¢ x 56 days x 27 men = $303

And the cost for the entire crew is $606.

For every additional spur worked on, the walking distance will increase 16 stations (twice the spacing of the spurs) and the lost time cost will increase:

16 stations x .29¢ x 56 days x 27 men = $ 70

And the cost for the entire crew is $140.

The lost time incurred when running tractors to and from work starts as soon as the tractors leave camp and not, as in the case of the men, after one mile.

The cost of a tractor operating on the zero spur would be:

52.8 stations x 56 days x .36¢ = $10.60.

For each spur farther away from camp an additional charge is incurred for the additional 16 stations traveled.

56 x 16 x .36¢ = $3.22.

Thus:

To determine the total cost of traveling charges for 2 tractors up to and including spur #7 the formula for the sum of an arithmetic progression is used:

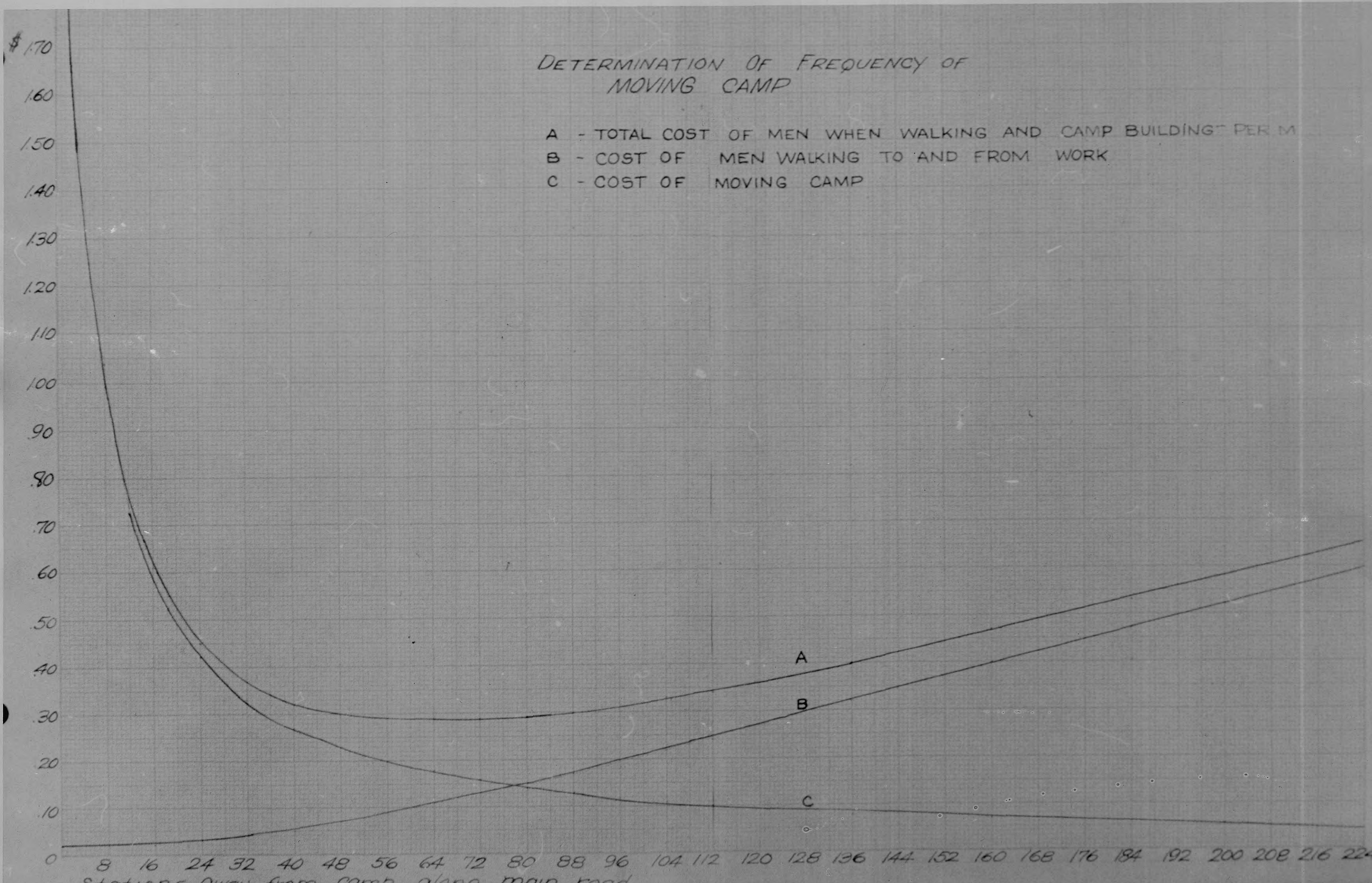
$$2 \text{ tractors} \times \frac{8}{2}\left[2 \times 10.60 + (8-1)3.22\right] = \$350.$$

From the above data a table has been worked out which gives the cost per M of lost time of tractors and men and also the cost of camp construction per M. It has been assumed here that the cost of moving to a new location and setting up camp is $4000.

On graph it will be noted that the break-even point is not exactly at the same point as minimum cost according to the total cost curve. This is probably due to the fact that men and tractors have been calculated separately on a different basis from each other.

From the graph it is seen that the men can be made to walk anywhere from 48 to 88 stations along the main road and still obtain minimum cost, or .9 mile to 1.7 miles. When the additional walking distance on the spur is considered, the maximum walking distance in each case would be 1.9 miles and 2.7 miles.

No. Spurs Away from Camp	No. Spurs Logged	Mbm Cut	Camp Cost perM	Cost Lost Time Wlkg.	Cost Lost Time Trac.	Total Cost Lost Time	Cost Lost Time perM	Total Cost Camps and Wlkg. per M
0	1	1360	$2.95	---	$ 21	$ 21	.02	$2.97
1	3	4080	1.02	$ 10	49	59	.02	1.04
2	5	6800	.59	52	83	135	.02	.61
3	7	9500	.42	150	124	274	.03	.45
4	9	12200	.33	320	170	490	.04	.37
5	11	15000	.27	582	224	806	.05	.32
6	13	17700	.23	958	284	1242	.07	.30
7	15	20400	.20	1474	350	1824	.09	.29
8	17	23100	.18	2080	423	2503	.11	.29
9	19	25800	.16	2826	502	3328	.13	.29
10	21	28500	.14	3712	587	4299	.15	.29
11	23	31200	.13	4738	679	5417	.17	.30
12	25	34000	.12	5904	778	6682	.20	.32
13	27	36700	.11	7210	885	8095	.22	.33
14	29	39500	.10	8656	994	9650	.24	.34
17	35	47600	.08	13812	1366	15178	.32	.40
20	41	55800	.07	20236	1796	22032	.40	.47
23	47	64000	.06	27972	2284	30256	.47	.53
25	51	69500	.06	33800	2641	36441	.52	.58


DETERMINATION OF FREQUENCY OF MOVING CAMP
A - TOTAL COST OF MEN WHEN WALKING AND CAMP BUILDING PER M
B - COST OF MEN WALKING TO AND FROM WORK
C - COST OF MOVING CAMP
$ 1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
8 16 24 32 40 48 56 64 72 80 88 96 104 112 120 128 136 144 152 160 168 176 184 192 200 208 216 224
Stations away from camp along main road.
A
B
C

Transportation System for Summer Logging

When selecting a road pattern for summer logging operation there are three alternatives to select from:

#1. Earth spur roads running at right angles to the mainhaul road, skidding being directly to these roads.

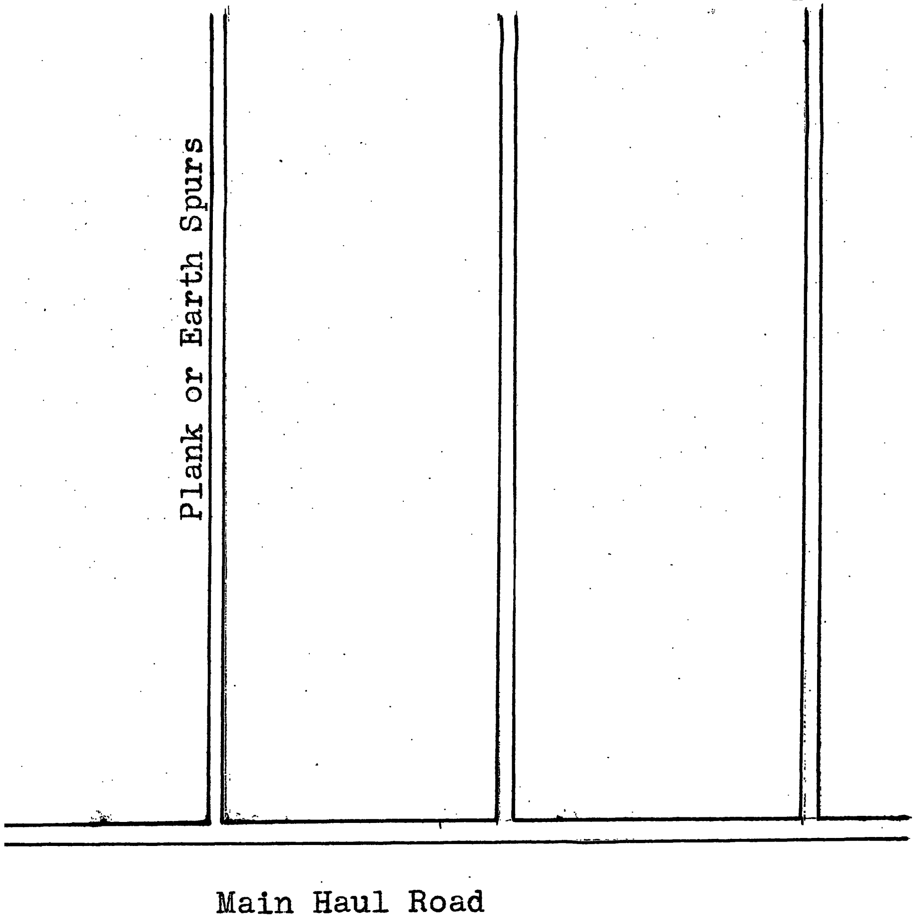
#2. Plank roads running at right angles to the mainhaul road, skidding being directly to these roads.

#3. Use of a secondary road system in which plank roads are run at right angles to the mainhaul road and from these plank roads earth spurs are run at right angles. Skidding is to the earth spurs.

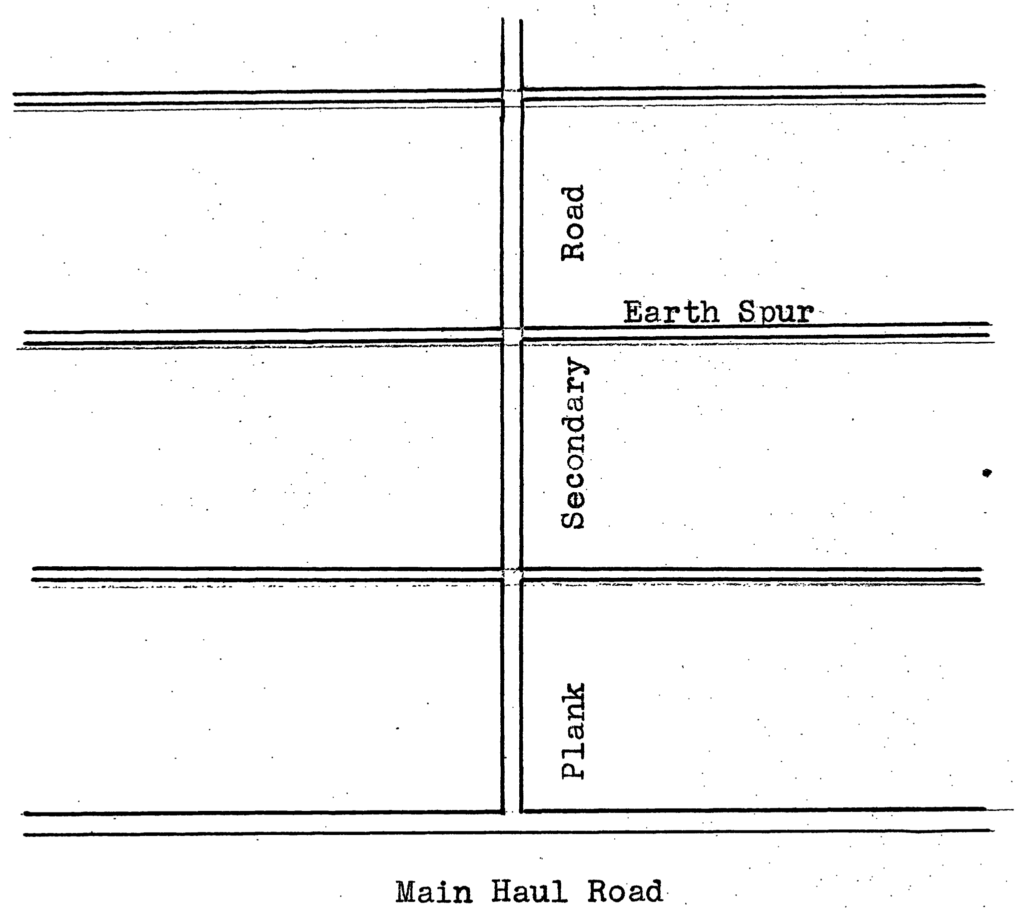
The question is, therefore, to determine how the roads in each of these systems should be spaced and then when each system should be used. First, the spacing is determined:

The spacing of spur roads to which logs are skidded has been dealt with in the portion of this paper devoted to Skidding. The results are

TRUCK HAUL ROAD SYSTEMS



Spur Roads Direct To Main Haul Road



Secondary Road System

summarized here again:

When using Earth Roads costing $400 per mile 7.2 stations is the proper spacing for RD-2 tractor. Cost of roads is 66¢ per M and variable cost of skidding 66¢ per M.

When using Plank Roads costing $1,200 per mile 12.5 stations is the proper spacing for RD-2 tractor. Cost of roads is 114¢ and variable cost of skidding 114¢ per M.

The spacing of secondary roads is a function of volume per acre, the cost of the secondary roads, and the cost of hauling on the dirt spurs to the secondary roads. In these calculations two rates of speed have been assumed for hauling with trucks on earth spur roads to demonstrate the changes that are required when hauling costs change. Costs at speeds of 8 MPH empty and 2.5 MPH loaded have been compared with costs at speeds of 10 MPH empty and 5 MPH loaded.

<u>Spacing of Plank Secondary Roads:</u>

A. Cost of hauling (8 - 2.5MPH) per M per 100' on earth spur = .96¢.

Volume per acre = 7 M.

Cost of plank road per mile = $1,200.

Spacing $= \sqrt{\frac{.33 \times 120000}{.96 \times 7}}$ = 77 stations or 1.46 miles.

Cost of Plank Road per M = $\frac{120000}{12.1 \times 77 \times 7}$ = 18¢ per M.

Cost of hauling on Spur Road = $\frac{77}{4} \times .96$ = 18¢.

B. Cost of hauling (10 - 5 MPH) per M per 100' on earth spur = .59¢.

Volume per acre = 7 M.

Cost of Plank Road per mile = $1,200.

Spacing $= \sqrt{\frac{.33 \times 120000}{.59 \times 7}}$ = 98 stations or 1.85 miles.

Cost of Plank Road per M = $\frac{120000}{12.1 \times 7 \times 98}$ = 14.5¢ per M.

Cost of hauling on spur road = $\frac{98}{4} \times .59$¢ = 14.5¢.

The decision as to which road pattern is adopted depends mainly on whether dirt roads can be hauled on at all and, if so, how fast can the tracks safely haul on them. The next calculation presented is to determine how far back the timber should extend from the mainhaul road before plank spurs (#1) would be more economic than earth spurs (#2).

Cost of Skidding to Earth Spur + Cost of Earth Spurs + Cost Hauling on Earth Spurs =

Cost of Skidding to Plank Spur + Cost of Plank Spurs + Cost Hauling on Plank Spurs

Above put in Figures:

56¢ + 66¢ + .96D = 114¢ + 114¢ + .3D

D = 146 stations or 2.75 miles.

Cost of Secondary Road Spacing

Clear-Cut Operation

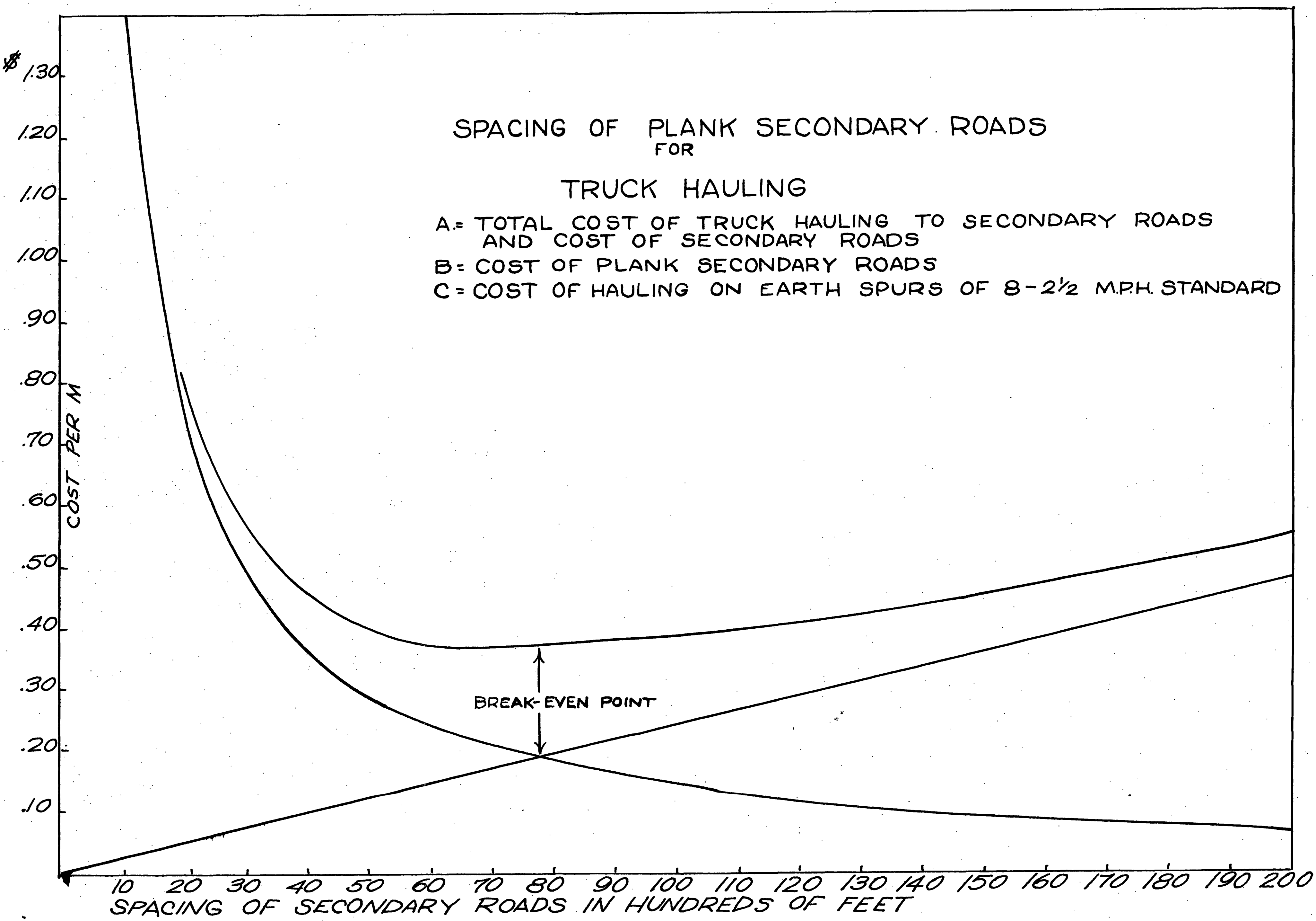
Based on formula: $S = \sqrt{\frac{.33 \times 120{,}000}{.96 \times 7}}$

Where: Cost of secondary road per mile = $1,200

Cost of hauling per M per 100 feet on earth spur = .96¢
(Speeds 8MPH empty and 2.5 MPH loaded)

Volume per acre = 7 M.

Spacing	Hauling Cost Earth Spurs	Plank Secondary Road Cost	Total Cost
10 stations	$ .02	$ 1.41	$ 1.43
20	.05	.71	.76
30	.07	.47	.54
40	.10	.35	.45
50	.12	.28	.40
60	.14	.24	.38
70	.17	.20	.37
80	.19	.18	.37
90	.22	.16	.38
100	.24	.14	.38
110	.26	.13	.39
120	.29	.12	.41
130	.31	.11	.42
160	.38	.09	.47
180	.43	.08	.51
200	.48	.07	.55



SPACING OF PLANK SECONDARY ROADS
FOR
TRUCK HAULING
A = TOTAL COST OF TRUCK HAULING TO SECONDARY ROADS AND COST OF SECONDARY ROADS
B = COST OF PLANK SECONDARY ROADS
C = COST OF HAULING ON EARTH SPURS OF 8-2½ M.P.H. STANDARD
BREAK-EVEN POINT
$ 1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
COST PER M
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
SPACING OF SECONDARY ROADS IN HUNDREDS OF FEET

In the preceding calculation the hauling cost on dirt spurs is based on the 8 - 2.5 MPH basis. All hauling on plank roads is estimated at a cost to conform with speeds of 18 MPH empty and 12 MPH loaded. When the hauling speed on earth spurs increases to 10 - 5 MPH, the following is true:

$$66¢ + 66¢ + .59D = 114¢ + 114¢ + .3D$$

$$D = 330 \text{ stations or } 6.2 \text{ miles.}$$

This means that when the timber extends farther from the mainhaul road than 146 stations when the hauling speeds are 8 - 2.5 MPH or 330 stations when the hauling speeds are 10 - 5 MPH, plank spurs are more economic than earth spurs. Otherwise, the contrary is true and earth spurs are more economic.

The next question is to decide whether plank spurs (#2) are more economic than a secondary road system (#3). The costs under the two systems are as follows:

Plank Spur System	8-2.5 MPH	10-5 MPH
Variable cost of skidding to plank spurs	$1.14	$1.14
Road Cost of plank spurs	1.14	1.14
	$2.28	$2.28.

Secondary Road System	8-2.5 MPH	10-5 MPH
Variable cost of skidding to earth spur	$ .66	$ .66
Cost of earth spur roads	.66	.66
Cost of plank secondary roads	.18	.145
Cost of hauling on earth spurs to plank road	.18	.145
	$1.68	$1.61.

Thus, the secondary road system is always cheaper since the logs are cheaper delivered on the plank road of that system than on the plank road of the spur system and from that point on, the hauling cost to the main road is the same. Therefore, if it is possible to haul on dirt roads and use the secondary road system, this system should always be used in preference to plank spurs. The saving indicated is 60¢ per M when trucks operate at 8-2.5 MPH and 67¢ per M when trucks operate at 10-5 MPH.

The last question to be solved is to find when the secondary road system (#3) is more economic than the earth spur road system (#1). To determine this, either of two formulae may be used:

$$C\frac{D}{2} = \frac{CS}{4} + \frac{R}{V} + \frac{HD}{2} + \frac{dl}{(V \times A)\ (D - d)}$$

Where:

D = the maximum direct hauling distance on earth spurs to the mainhaul road in hundreds of feet.

S = the spacing of plank secondary roads in hundreds of feet.

R = the cost of plank road construction per acre on spacing used in cents.

V = volume cut per acre in Mbm.

C = the cost of hauling per M per 100 feet on dirt roads.

H = the cost of hauling per M per 100 feet on plank roads.

d = the length of deadline in hundreds of feet.

dl = cost of deadline in cents.

A = the area served by 100 feet of plank road.

<u>Hauling Speeds on Earth Road 8 - 2.5 MPH</u>:

$$\frac{.96\ D}{2} = \frac{.96 \times 77}{4} + \frac{1.29}{7} + \frac{.3 \times D}{2} + \frac{43000}{(17.7 \times 7)(D-19)}$$

D = 76 stations or 1.44 miles.

This means that unless the timber extends farther from the mainhaul road than 1.44 miles, dirt spur roads are more economic than the secondary road system.

Hauling Speeds on Earth Road 10 - 5 MPH:

$$\frac{.59D}{2} = \frac{.59 \times 98}{4} \times 14.5 \times \frac{.3 \times D}{2} \times \frac{56000}{(22.5 \times 7)(D-24.5)}$$

D = 200 stations or 3.8 miles.

The above can be solved also by a more simple formula:

Cost of Plank Secondary Road Per M + Cost Hauling on Dirt Spurs + Cost Hauling on plank to Main-haul road =

Cost of hauling to mainhaul road on dirt spurs.

The above word formula put in figures:

$$14.5¢ + 14.5¢ + \frac{.3D}{2} = .59\frac{D}{2}$$

D = 200 stations or 3.8 miles.

Cost of Operation with Secondary Road System
as Compared with
Operation Using Earth Spurs of 10-5 MPH Standard

****

Distance from Mainhaul Road Stations	Cost Hauling on Dirt Rds. to Plk.Rd. & Cost Plk.Rd.		Cost Hauling on Plk.Rd.		Total Cost using Secondary Rd.System	Cost Hauling to Mainhaul Rd. on Dirt Spurs
20	$.29/M	+	$.03/M	=	$.32/M	$.06/M
40	.29		.06		.35	.12
60	.29		.09		.38	.18
80	.29		.12		.41	.24
100	.29		.15		.44	.30
120	.29		.18		.47	.36
140	.29		.21		.50	.41
160	.29		.24		.53	.47
180	.29		.27		.56	.53
200	.29		.30		.59	.59
220	.29		.33		.62	.65
240	.29		.36		.65	.71
260	.29		.39		.68	.77
280	.29		.42		.71	.83
300	.29		.45		.74	.89

Road Costs in preceding figures:

Plank -- $1,200 per Mile.

Earth -- 400 per Mile.

Hauling Cost per 100 feet per M:

Plank -- .30¢.

Earth -- .59¢.

On the basis of the preceding preliminary guiding calculations, roads have been outlined on the operation map. With the exception of the mainhaul road, the roads planned for this operation were put in without any field work and are thus subject to considerable correction. Timber types and ownership were the factors considered in planning these roads.

<u>Estimation of Cost of Mainhaul Road</u>:

This road will be gravelled and provided with proper drainage and will be of the same standard as the present partially completed C.C.C. road running into the area. Estimated speeds on this road are 15 MPH loaded and 25 MPH empty.

Built and ready for use	1.16 Mi.		
Partially built by C.C.C.	1.12 "	x 1000 =	$1120
New Road Construction	3.86 "	x 1500 =	5800
R.R. Grade Converted	2.25 "	x 1000 =	2250
	8.39		
Total Cost of Mainhaul Road			$9170.

7¢/M.

Estimation of Cost of Secondary Roads:

Spur No.	Length	Type	Cost per Station	Total Cost
S 1	132 Sta.	Plank	$22.80	$3010
	106	Earth	7.60	810
S 2	200	Plank	22.80	4600
S 3	120	Plank	22.80	2780
	160	Earth	7.60	1220
N 1	225	Plank	22.80	5140
	40	Earth	7.60	300
N 2	225	Plank	22.80	5140
	40	Earth	7.60	300
N 3	160	Plank	22.80	3650
	66	Dirt	7.60	500

Total Cost of Secondary Roads	$27450
Cost per M	21.4¢
Ideal Cost as per Formula	18¢
Estimated Cost of Spur Roads	$91000
Cost per M	72¢
Cost of Entire Road System	$ 127620

Spur Roads:

The cost of spur roads according to formula should be 66¢ per M for the spacing adopted. Actually, the deadline road, that is, roads built by necessity through non-timber bearing land, raises the cost to 72¢ per M. This was determined by estimating the number of forties that would have to be "roaded" in order to take out the timber. If it seemed probable from the map that the forty would have to have roads through it, in spite of some unmerchantable swamp, the roads were considered as built and the timber available as having to bear the charges for the waste land. When spacing spur roads 7.2 stations apart, 1 station of road serves 1.66 acres. The total area in acres to be roaded having been determined, the area figure was divided by 1.66 to determine the number of stations of spur road to be built. The total cost of this amount of spur road thus determined was then divided by the total volume on the area to get the cost per M.

Calculation: Estimated Area to be Roaded = 19900 as Compared with Actual Timber-Bearing Land of 17,950 acres.

$$\frac{19900}{1.66} = 12000 \text{ stations of road to build.}$$

$$12000 \times \$7.60 = \$91000 \quad \text{Total cost of Spurs.}$$

$$\frac{91000}{125680} = 72¢ \text{ per Mbm.}$$

It is not always possible to build a secondary road system so that the proper economic areas can be served by the roads built. Nevertheless, it is necessary to remove the timber with the resulting higher costs. A mainhaul road, for example, has to be run through a given area to remove a certain amount of timber. The question involved is, just how good a mainhaul road should be built? The following formula is used to determine how long a mainhaul road (or a secondary road) should be before raising its standard:

$$\frac{N}{2}(a + aN) + RN = \frac{N}{2}(a' + a'N) + R'N$$

Cost of hauling + Cost road = Cost hauling + Cost improved Road.

a = the cost of hauling timber tapped by one spur road the distance that these spur roads are from each other, in this case, 7.2 stations.

a'= the cost of hauling the same amount of timber the same distance on a higher standard of road.

R = the cost of that amount of mainroad necessary to reach from one spur to the next. 7.2 stations.

R'= the cost of the same amount of mainroad of an improved standard.

N = the length of the road in spur spacing units (7.2) before the higher standard of road is economic.

As an example, this formula is applied to spur #1. The average length of the spurs tapping is road as scaled from the map approximately 60 stations. The volume tapped by each spur is determined as follows:

$$\frac{60 \times 7.2}{4.356} = 100 \text{ acres} \times 7 \text{ M} = 700 \text{ M.}$$

a' = 7.2 stations x .30¢ x 700M = $15.10.

a = 7.2 stations x .96¢ x 700M = 48.40.

R' = 22.80 x 7.2 = $164.

R = 7.60 x 7.2 = 55.

$$\frac{N}{2}(48.40 + 48.40N) = \frac{N}{2}(15.10 + 15.10N) - 164N$$

N = 5.9 Units of 7.2 stations = 42 stations.

This means that if the secondary roads only had to reach back 42 stations, a dirt road would give costs as low as a plank road when the road and hauling costs were balanced against each other. In the event that the secondary road had to reach out more than 42 stations, however, plank road should be used. It would be a serious mistake to first go in and log back 42 stations by dirt road and then decide to build a plank road since high hauling costs for the first 38 stations would be incurred uselessly.

Estimated Cost of Road Hauling if Plank Were Used on Spur #1 (Spur is 31 Spur Spacing Units Long):

Hauling Cost = $\frac{31}{2}$ (15.10 + 15.10 x 31) = $7500 (for all timber).

Road Cost = $\frac{225}{7.2}$ stations = 31 x 55 = 5,100

$12,600

Estimated Cost of Road and Hauling if Earth Road Used on Which Speeds are 8 MPH Empty and 2.5 MPH Loaded:

Hauling Cost $\frac{31}{2}$ (48.40 + 48.40 x 31) = $ 24,000

Road Cost 225 stations x 7.60 = 1,700

$ 25,700.

Saving through using plank road: $13,100

The problem of determining whether or not a plank road is justified is not always so simple as the above example might indicate, since it is not always possible to obtain an average width which is applicable to the entire length of the road. In some cases due to ownership and type, the area served by the road is at times very wide, and again very narrow. Such a case was presented in Spur #1. The road here was divided into 20-chain segments for the sake of simplicity instead of using the spur spacing figure.

Owing to the inaccuracy of working with a large scale map this shortcut should not seriously affect the final result. The timber that would come to each road segment is determined by scaling the acreage of adjoining land from the map and multiplying it by the average stand per acre, in this case 7 M. The distance that the timber from each segment must be hauled is scaled from the map and with this information the cost of hauling the timber from each segment can be calculated. With this information at hand it can be seen whether or not the increased cost of road construction in building a plank road would be offset by a decrease in hauling costs.

One item which appears at first to complicate matters is that Hemlock on this spur must be hauled in the opposite direction to be loaded on the railroad. Actually, this state of affairs makes little difference in the type of road to be used as species are fairly evenly distributed and it makes little difference which way the timber moves as far as hauling costs are concerned, there being no decided grade. If, however, the Hemlock were all bunched in a stand located on the end of the road toward the railroad, the situation might be changed. This is seldom the case, however.

The following calculation in tabular form was made for the spur in question:

Volume	Distance from M.H. Rd.	Cost Hlg. on Plank 15¢	Cost Hlg. on Dirt 50¢	Cost Hlg. on Good Snow Rd. 20¢/M/Mi.
980 M	1/2 Mi.	$ 73	$ 243	$ 97
840	3/4	94	313	125
700	1	105	350	140
840	1 1/4	157	500	200
1540	1 1/2	346	1150	460
1540	1 3/4	403	1340	540
840	2	250	830	334
		$1428	$4726	$1896
Cost of Road		2400	800	1200
		$3828	$5526	$3096

The above procedure was used to determine what type of road to build in other situations but the calculations are not presented here for the sake of brevity.

Spur No.	Vol. Hem.	Vol. Hdwd.	Rd.Type	Hlg. Rate perM /Mi.	Distance to Bonnie-ville	Distance to Maren-isco	Cost Haul to Bonnie-ville	Cost Haul to Maren-isco
N 1	9402	9402	Spur	50¢	.6	.6	30¢	30¢
			Plank	16	2.0	2.0	32	32
			MainHaul	13	8.5		110	
			Highway	10	1.5	10.0	15	100
					12.6	12.6	187	162
N 2	9948	9558	Spur	50	.7	.7	35	35
			Plank	16	2.0	2.0	32	32
			M.H.	13	6.5	2.0	85	26
			Highway	10		9.0		90
					9.2	13.7	152	183
N 3	10273	10356	Spur	50	.6	.6	30	30
			Plank	16	1.5	1.5	24	24
			M.H.	13	5.0	4.5	65	58
			Highway	10		9.0		90
					7.1	15.5	119	202
North of Cp. 6	3378	2984	Spur	50	.5	.5	25	25
			M.H.	13	2.0	6.5	26	85
			Highway	10		9.0		90
					2.5	16.0	51	200
North Bonnie-ville	1558	3254	Spur	50	.5	.5	25	25
			M.H.	13	.5	8.5	7	110
			Highway	10		9.0		90
					1.0	18.0	32	225
S 1	6849	9812	Spur	50	.5	.5	25	25
			Plank	16	1.75	1.5	28	24
			M.H.	13		5.0		65
			Highway	10		9.0		90
					2.25	16.0	53	204
S 2	5710	5710	Spur	50	.25	.25	13	13
			Plank	16	2.00	2.0	32	32
			M.H.	13	5.00	4.5	65	59
			Highway	10		9.0		90
					7.25	15.75	110	194

Spur No.	Vol. Hem.	Vol. Hdwd.	Rd.Type	Hlg. Rate perM /Mi.	Distance to Bonnie- ville	Distance to Maren- isco	Cost Haul to Bonnie- ville	Cost Haul to Maren- isco
S 3	4295	4295	Spur	50	.25	.25	13	13
			Plank	16	1.0	1.0	16	16
			M.H.	13	8.5		110	
			Highway	10	3.0	10.0	30	100
					12.75	11.25	169	129
T46 R42 Sec.1,2,11	4895	4895	Spur	50	.75	.75	38	38
			M.H.	13	8.5		110	
			Highway	10		9.0		90
					9.25	9.75	148	128
T47 R42	3380	3380	Spur	50	.5	.5	25	25
			M.H.	13	7.5	1.0	97	90
			Highway	10		9.0		13
					8.0	10.5	122	128
			To Spur					
T46 R41 Sec.12	560	560	Spur	50	1.5	2.25	75	113
			CCC Rd.	13		5.0		65
			Highway	10		12.5		125
					1.5	19.75	75	303
T46 R41 Sec.10 14,15	1770	1770	Spur	50	.5	1.25	25	63
			CCC Rd.	13		5.0		65
			Highway	10		12.5		125
					.5	18.75	25	253

Hauling Cost Summary

Spur No.	% Hdwd from Spur	Cost Hlg. /M	Wghted Cost	% Hem from Spur	Cost Hlg. /M	Wghted Cost
	Hardwood			Hemlock		
N 1	14.3	1.62	.23	15.2	1.62	.24
N 2	14.5	1.83	.27	16.0	1.52	.24
N 3	15.7	2.02	.32	16.5	1.19	.20
N Cp 6	4.4	2.00	.09	5.4	.51	.03
N Bon'ville	5.0	2.25	.11	2.5	.32	.01
S 1	14.9	2.04	.30	11.0	.53	.06
S 2	8.7	1.94	.17	9.3	1.10	.10
S 3	6.5	1.29	.08	6.9	1.29	.09
Sec 1,2,11	7.4	1.28	.09	7.9	1.28	.10
Sec 35,36	5.1	1.28	.07	5.5	1.22	.07
Sec 12	.8	3.03	.02	.9	.75	.01
Sec 10,14,15	2.7	2.53	.07	2.9	.25	.01
	100.0%		$1.82	100.0%		$1.16

Hemlock is hauled either to Bonnieville or Marenisco whichever gives the lower cost.

Cost Summary for Summer Logging by Truck

Clear-Cut Operation

Delivered in Pond at Marenisco

****

Hardwood:

Cost Item --		Cost per M --
Sawing		$ 2.25
Skidding -- Using RD-2 or Model M Tractor. .		1.79
Loading Trucks		
Jammer Crew	.70	
Truck waiting time and top loader $\frac{1.54¢ \times 30"}{2\text{ M}}$ =	.23 .	.93
Hauling		1.82
Unloading and Scaling Time -- Trucks		.23
Roads		1.00
Road Maintenance		.20
Camps		.30
Overhead		
Clerk $100/Month		
Foreman 150		
Skidboss 100		
Blacksmith 100 $520 1200M cut/Month		.43
Total Logging Cost		$8.95

Cost Summary for Summer Logging by Truck

Clear-Cut Operation

Cost Delivered on Cars either at Marenisco or Bonnieville, Whichever Place Is Hauled to More Cheaply.

****

Hemlock:

Cost Item --	Cost Per M --
Sawing	$ 2.25
Skidding	1.79
Loading Trucks	.93
Hauling	1.16
Unloading & Scaling Time -- Trucks	.23
Loading Railroad Cars	1.10
Roads	1.00
Road Maintenance	.20
Camps	.30
Overhead	.43
Total Logging Cost	$ 9.39

Costs of Railroad Operation:

There are three common logging procedures when the railroad is used as the main log hauling device:

1. Skid directly to the railroad.
2. Sleigh haul to the railroad.
3. Dray haul to the railroad.

Cost when skidding directly to the railroad:

Spacing of railroad spurs when railroad costs $2,500 per mile to build, and RD-4 tractors are used for skidding:

$$S = \sqrt{\frac{.33 \times 250000}{7 \times 17.6}} = 26 \text{ stations.}$$

Skidding -- variable cost	$= \frac{26}{4} \times 17.6 =$	$1.14 /M
fixed cost	=	1.25
Total Cost		$2.39
R.R. Cost -- $\frac{250000}{12.1 \times 7 \times 26}$	=	1.14
		$3.53 /M.

Cost of Logs delivered in Marenisco:

Sawing	$2.25	
Skidding	2.39	
RR operation and loading	2.39	7.03

SLEIGH HAUL

Chevrolet 1½ Ton Truck Drawing Sleigh Carrying 2,000 M

Note that back of truck is filled with sand bags.

Another View Of Sleigh Haul Unit. Truck is Equipped With Two Speed Rear Axle

Cost of Logs delivered in Marenisco: (Cont'd)

Amount forwarded	$ 7.03
RR construction	1.14
Camps	.30
Overhead	.43
Freight	3.14
Total Cost	$12.04.

<u>Cost when sleigh hauling to railroad</u>:

With this method of logging the advantage is gained by building the railroad spurs farther apart than when direct skidding, and then by the use of trucks or tractors haul the logs on sleighs to the landings built at intervals along the railroad. The timber near the railroad lines is, however, skidded in directly to avoid handling charges for loading and hauling which are greater than the cost of direct skidding. When laying out an operation of this type the factors that must be determined in advance are:

1. How far apart shall the railroad spurs be built?
2. How far apart shall the sleigh roads be built?
3. For what distance should timber be directly

skidded to the railroad instead of being sleigh-hauled?

Cost of sleigh road per mile = \$400.

Cost of RR spur per mile = \$2,500.

Spacing of sleigh roads = 7.2 stations (See section on skidding)

Cost hauling per M per 100' = .33¢ or 17.5¢ per M per Mile.

<u>Railroad Spacing:</u>

$$S = \sqrt{\frac{.33 \times 250000}{7 \times .33}} = 190 \text{ stations or } 3.6 \text{ miles.}$$

Hauling cost $\frac{190}{4} \times .33¢ = \$ .16$

RR construction cost

$$\frac{250000}{12.1 \times 7 \times 190} = .16$$

To determine the proper distance for direct skidding the following formula is used:

$$CD = C\ S/4 + (H \times D) + L$$

Where:

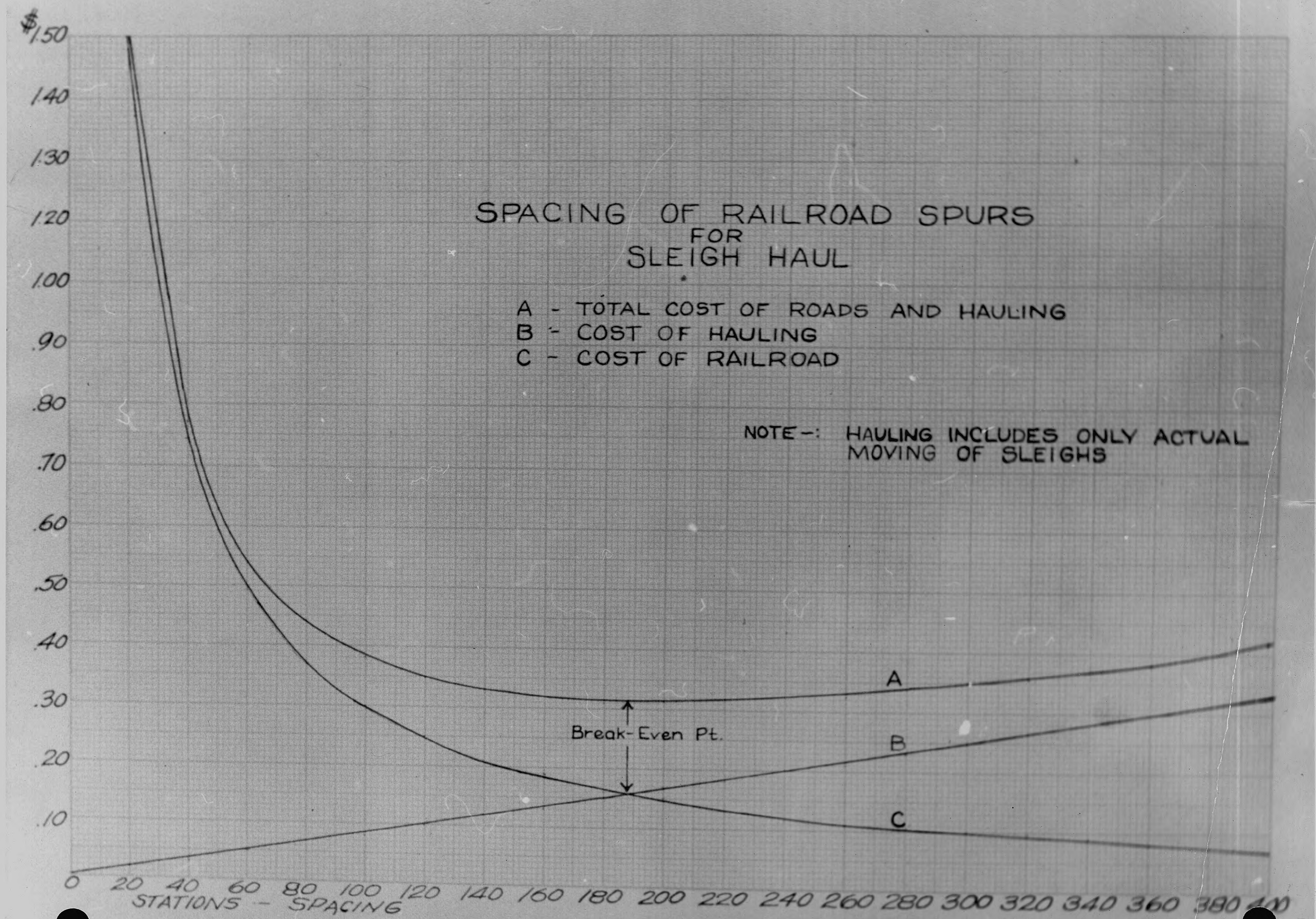
D = the distance to be solved for.

C = cost of skidding per M per 100 feet.

S = spacing of roads.

H = cost of hauling per M per 100 feet.

L = cost of loading sleighs per M.


SPACING OF RAILROAD SPURS
FOR
SLEIGH HAUL
A - TOTAL COST OF ROADS AND HAULING
B - COST OF HAULING
C - COST OF RAILROAD
NOTE -: HAULING INCLUDES ONLY ACTUAL MOVING OF SLEIGHS
Break-Even Pt.
A
B
C
$1.50
1.40
1.30
1.20
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
STATIONS - SPACING

RD-2 tractor to be used for skidding direct:

$$21.4D = \frac{21.4 \times 7.2}{4} + .33\ D + 70$$

D = 5.2 stations = the proper distance to skid direct.

Cost of skidding direct:

Variable cost $\frac{5.3}{2} \times 21.4$	=	$ .57
Fixed Cost	=	1.13
$\left(\frac{5.3 \times 2}{190} = 5.6\%\right)$		$ 1.70 x 5.6% = $ .10

Hauling by sleighs:

Actual sleigh haul = $\frac{\frac{190}{2} + 5.3}{2} \times .33$	=	$ .17
Loading sleighs	=	.70
Lost time trucks 15" x 1.5"	=	.23
Skidding to sleigh road	=	1.79
		$2.89x94.4% =$2.72
		$2.82

Sawing	2.25
Sleigh roads	.66
Road maintenance	.20
Railroad construction	.16
Railroad loading and operation	2.39
Camps	.30
Overhead	.43
Freight	3.14
Total cost of sleigh haul	$12.35

Dray Haul Operation:

In this type of operation logs are first bunched by horses from a maximum distance of 200 feet. Then with A jammers the logs are loaded on small drays with a capacity of 1 Mbm. The drays are in turn pulled to the railroad with RD-4 tractors and loaded on cars with a mechanical loader. It is necessary to swamp out dray roads but it is not feasible to space these roads as close as the cost of 50¢ per station would indicate that they should be. The roads are spaced instead about 400 feet apart, one to each skidway on the railroad. More numerous roads would require that the jammers in the woods would have to be moved too often, an operation which holds up both skidding and loading. The tractor pulls a dray to the landing, leaves it there and brings back an empty, and so forth.

Data:

Tractor delay time per trip	=	10 minutes
Hook on to dray - 2 times	=	4 minutes
Unhook dray - 2 times	=	2 minutes
		16 minutes.

Estimated speed with dray = 1.4 minutes per 100 feet round trip.

Dray haul using Caterpillar RD4

Average load 1 Mbm.

Lima gear type logging locomotive

Average dray load = 1 Mbm.

Cost of tractor and driver per hour = \$ 1.89.

Cost of tractor and driver per minute = 3.16¢.

Cost of railroad per mile = \$2,500.

Cost of dray road per mile = \$26.

Spacing of railroad = $\sqrt{\frac{.33 \times 250000}{4.4 \times 7}}$ = 52 stations or 1 mile.

Theoretical spacing of dray roads = $\frac{10.22 \times 50}{7 \times 43}$ = 1.3 stations.

To determine the proper distance to skid direct to the railroad with horses:

$$C'D = (C \times D) + L + C'\frac{S}{4}$$

Where:

C' = cost of skidding with teams per 100' in cents.

D = to be solved for.

C = cost of draying per 100' round trip in cents.

L = loading drays and fixed cost of tractor.

S = spacing of dray roads.

Loading with jammer = \$ .70

Fixed time tractor = .50 (16" x 3.16¢)

\$ 1.20

Cost of hauling per 100' with dray = 1.4" x 3.16¢ = 4.4¢.

$43\ D = 4.4D + 117 + \frac{43 \times 4}{2}$ D = 5.3 stations.

Cost of skidding direct to railroad:

Variable cost $\frac{5.3}{2} \times 43$ = $ 1.14

Fixed cost = .80

$ 1.94 x 10% = $ .19

Cost of dray haul:

Skidding to drays --

Variable cost - .427 x 43 x 4 = $ .74

Fixed cost = .80

$ 1.54

Loading drays and fixed cost tractor = 1.20

Draying $\frac{\frac{52}{2} + 5.3}{2} \times 4.4¢$ = .68

$ 3.42 x 90% = 3.07

Cost of railroad construction:

$\frac{250000}{12.1 \times 7 \times 52}$ = .57

Cost of dray roads: $\frac{2600}{12.1 \times 7 \times 4}$ = .08

Sawing: = 2.25

Railroad operation and loading: = 2.39

Camps: = .30

Overhead: = .43

Freight: = 3.14

Cost delivered in Marenisco on cars $12.42

RAILROAD LOADING WITH McGIFFORD

STEAM LOADER

McGifford loader in action. Note car stakes piled in foreground of picture. Their use depletes growing stock of forest and is an expensive item in operations.

The loading crew, consisting of two hookers, two tailers down, one top loader and one jammer bullcook. The hoist operator cannot be seen. Note the expensive skidway necessary on this operation.

Sleigh haul to main line railroad:

In T46 R41 where the mainline railroad runs through a considerable portion of the ownership, there is a possibility of sleigh hauling hardwood directly to this line and then freighting the logs to Marenisco. The chief advantage here is that no company railroad operation is necessary and no construction of railroad spurs.

Costs are estimated as follows:

Sawing		$ 2.25
Skidding		1.79
Loading	.70	
Lost time trucks	.23	.93
Sleigh haul - 1 mile		.18
Sleigh roads .66 + 12%		.74
Road maintenance		.20
Railroad loading		1.10
Camps		.30
Overhead		.43
Freight		3.14
Total cost		$11.06.

When comparing the costs of railroad logging, using the three methods indicated of Direct Skidding to the Railroad, Sleigh Haul, and Dray Haul, with the costs indicated for trucking, it must be remembered that no allowance has been made for deadline in the estimation of railroad and sleigh road construction costs. Where the ownership is fairly continuous these costs will probably be increased by about 12 - 15%, but where the ownership is very broken the costs will be considerably higher. It can be safely estimated that the lowest possible cost of logs delivered in Marenisco by railroad logging will be about \$12.04 + (1.14 x 15%) = \$12.22 per Mbm.

The cost of truck logging is shown as \$8.95 per Mbm. This cost is based on the expectation that dirt spurs may be used and that hauling costs will be as computed. Judging from past experience with trucking contractors the trucking cost as computed is low. Previously, \$2.50 was paid for a haul of about 10 miles, all but one mile of which was on the highway. This rate of \$2.50 includes truck loading and unloading time as well as the actual hauling. The computed cost is as follows:

Hauling	\$ 1.82
Loading time	.23
Unloading time	.23
	\$ 2.28.

The average haul will be approximately 14 miles, 4 miles of which will be on woods roads. The hauling cost of $2.28 is based on the assumption that trucks be operated 1600 hours per year, that roads be built to the standards indicated, and that trucks be loaded and unloaded promptly.

Assuming that the best contract price to be obtained amounts to $3.00 per M for the entire area, a figure which should be more than adequate to allow for a reasonable amount of lost time and a fair profit to the contractor, the cost of truck logging would then be $9.67 per M.

If it were found that only plank roads could be used the cost of logging by truck would rise again:

Sawing	$ 2.25
Skidding - RD-2 roads spaced 12.5 stations	2.27
Loading trucks	.70
Contract hauling estimate	3.00
Plank spurs $1.13 + 12%	1.36
Mainhaul road	.07
Road maintenance	.20
Camps	.30
Overhead	.43
Cost delivered in Marenisco	$10.58 per M.

This should be the top figure when logging with trucks and so it may be safely estimated that the change from railroad to truck logging will result in a saving of at least $1.50 per M and probably as high a saving as $2.00. The railroad equipment at present on hand is obsolete and out of commission and could not be replaced except at considerable expense. The railroad operation costs as listed in these calculations at $2.39 per M did not include a cost of depreciation for either locomotives or loader which had previously been written off. Such depreciation costs would have to be met again with the acquisition of new equipment and the railroad logging expense would be considerably increased over $12.22 per M figure.

-0-

Estimation of Costs under Selective Logging

From the stand table prepared for this area it is found that cutting to and including the 18" diameter class will remove approximately 50% of the volume of the stand. This degree of cutting, in which on the average 3 1/2 M per acre is removed, will leave sufficient timber capital for a future cut 20 years hence and appears satisfactory for sustained yield management.

Since the larger trees in the stand are cut under such a program the logs handled are larger and this fact results in lowered costs for skidding, loading, sawing, and hauling. However, since lower volumes are removed per acre, other costs which generally have a fixed per acre cost, such as, roads and camps, will rise. When selective logging is thought of by most lumbermen, this last factor only is considered and as a result it is held that selective logging is uneconomic, when actually, all factors considered, quite the contrary is the case.

Skidding:

The cost of skidding depends upon the distance skidded and the greater this cost becomes the lower becomes the road cost since the roads are farther apart. The spacing formula used previously is again resorted to in order to bring these two costs to a minimum. Dirt spurs costing $400 per mile are first considered and then plank at $1200 per mile. Skidways are used.

<u>RD-2 Tractor</u>:

$$S = \sqrt{\frac{10.22 \times 7.60}{3.5 \times 17}} = 11.4 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 11.4 x 17 =	$ .83
Fixed cost	=	.90
Total skidding cost		$ 1.73

Cost of earth spur road $\frac{40000}{12.1 \times 3.5 \times 11.4}$ .83

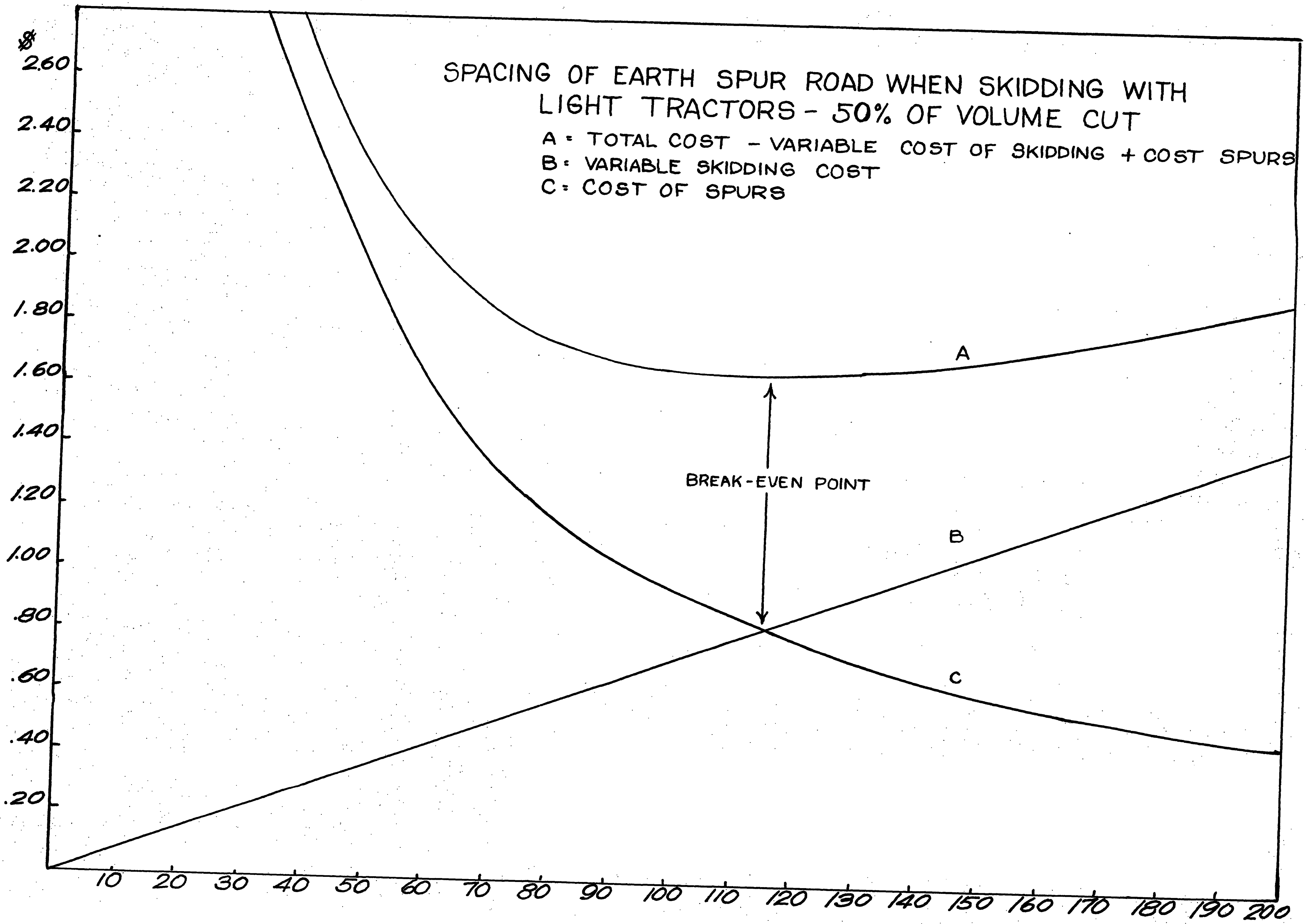
<u>RD-4 Tractor</u>:

$$S = \sqrt{\frac{10.22 \times 760}{3.5 \times 14.5}} = 12.4 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 14.5 x 12.4 =	$ .77
Fixed cost	=	1.03
Total skidding cost		$ 1.80

Cost of earth spur road $\frac{40000}{12.1 \times 3.5 \times 11.4}$ .77


SPACING OF EARTH SPUR ROAD WHEN SKIDDING WITH LIGHT TRACTORS - 50% OF VOLUME CUT
A = TOTAL COST - VARIABLE COST OF SKIDDING + COST SPURS
B = VARIABLE SKIDDING COST
C = COST OF SPURS
BREAK-EVEN POINT
A
B
C
$
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

Teams:

$$S = \sqrt{\frac{10.22 \times 760}{3.5 \times 43}} = 7.2 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 7.2 x 43	=	$ 1.33
Fixed cost		=	.65
Total skidding cost			$ 1.98

Cost of earth spur road $\frac{40000}{12.1 \times 7.2 \times 3.5}$ 1.32

When plank spur roads are used the costs are as follows:

RD-2 Tractor:

$$S = \sqrt{\frac{10.22 \times 22.80}{17 \times 3.5}} = 19.8 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 19.8 x 17	=	$ 1.43
Fixed cost		=	.90
Total skidding cost			$ 2.33

Cost of plank spur road $\frac{120000}{19.8 \times 12.1 \times 3.5}$ 1.44

RD-4 Tractor:

$$S = \sqrt{\frac{10.22 \times 22.80}{14.5 \times 3.5}} = 21.5 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 21.5 x 14.5	=	$ 1.33
Fixed cost		=	1.03
Total cost of skidding			$ 2.36

Cost plank spurs $\frac{120000}{12.1 \times 3.5 \times 21.5}$ 1.32

Teams:

$$S = \sqrt{\frac{10.22 \times 22.80}{43 \times 3.5}} = 12.3 \text{ stations.}$$

Cost of skidding --

Variable cost	.427 x 12.3 x 43	=	$ 2.25
Fixed cost		=	.65
Total skidding cost			$ 2.90

Cost of plank spurs $\frac{120000}{12.1 \times 3.5 \times 12.3}$ 2.30

The tractor skidding costs as used in the preceding calculations are based on the costs worked out in the tractor time study previously discussed. The loads to be hauled under selective logging were estimated since it is not known exactly what sized loads would be carried. The figures should be conservative since an average load of 220 b.m. was hauled in the Pine operation studied by the light tractors and the selective logging costs used here are based on a 200 b.m. load.

The Forest Service study gives the costs of skidding logs from trees of various diameter classes. These costs do not distinguish between fixed and variable costs but give a flat figure for an average skidding distance of 400 feet with horses. These costs for the various DBH classes were applied to the stand and stock table for the stand being studied in order to secure a comparative figure:

- Skidding -- Clear Cut -

DBH Inches	% Volume in Diam. Class (Stand Table)	Cost Skidding for Diam. Class (Bul.164)	Weighted Cost
10	6.0%	$ 5.94	$ .36
12	8.2	4.43	.39
14	12.5	3.76	.47
16	19.0	3.00	.57
18	16.8	2.41	.41
20	14.5	2.00	.29
22	12.2	1.76	.22
24	5.8	1.57	.09
26 +	5.0	1.46	.07
	Average Cost		$ 2.87

- Skidding -- Selective Cut -

18	31.0	2.41	.75
20	26.6	2.00	.53
22	22.6	1.76	.40
24	10.6	1.57	.17
26	9.2	1.46	.13
	Average Cost		$ 1.98

The skidding costs thus obtained of $2.87 for clear-cut operation and $1.98 for selective operation can be applied to the fixed and variable tractor costs as determined for clear cutting and thus obtain an estimate on how these costs will be affected by selective cutting.

Thus:

$$\frac{287}{198} = \frac{21.4}{x}\text{(RD-2 variable cost clear cut)}$$

x = 14.6¢ RD-2 variable cost under selective operation.

$$\frac{287}{198} = \frac{113}{x}\text{(RD-2 fixed cost clear cut)}$$

x = 78¢ RD-2 fixed cost under selective operation.

The costs used in the calculations are 17¢ and 90¢ for fixed and variable costs respectively and probably minimize the economic advantage of skidding on a selective logging operation. Another factor which may enter in here is that the costs from the Forest Service report are for team skidding. Since the team cannot haul big logs at the same rate of speed as little logs, the variable cost of skidding cannot be much reduced by handling bigger logs and the only cost that will be greatly reduced will be the fixed cost of skidding. For this reason, when using horse skidding costs as a basis on which to estimate tractor costs, another element of conservatism enters in since a tractor will maintain the same rate of speed over a wide range of loads. For this reason tractors should always be preferred to team skidding on selective logging jobs and, also, because such a job necessitates longer skidding at which the team is at great economic disadvantage.

Loading:

Costs from the Forest Service study for loading railroad cars by steam loader are pro-rated according to the volume distribution of the stand and stock table in the same manner that skidding costs were. In this manner the cost of loading Hemlock on cars can be determined for a selective operation. The same ratio should be approximately correct for truck loading, also, and should be on the safe side since in the case of the steam loader several small logs were bundled by chains and lifted at once while they must be lifted singly in most cases by the horse jammer. This procedure would accentuate the saving to be realized in the handling of larger logs. Data collected by Townsend bears out the ratio obtained by the previous method.

Zon, Raphael and Garver, R.D. Selective Logging in the Northern Hardwoods of the Lake States. Technical Bulletin No. 164. U.S.F.S.

Townsend, C.R. Mechanized Logging. Woodlands Section Canadian Pulp and Paper Association.

- Loading -- Clear Cut -

DBH Inches	% Volume in Diam. Class (Stand Table)	Cost Loading for Diam. Class (Bul.164)	Weighted Cost
10	6.0%	$ 1.46	.09
12	8.2	1.18	.10
14	12.5	.95	.12
16	19.0	.79	.15
18	16.8	.67	.11
20	14.5	.58	.08
22	12.2	.52	.06
24	5.8	.47	.03
26	5.0	.44	.02
	100.0%	Average Cost	$ .76

- Loading -- Selective Cut -

18	31.0	.67	.21
20	26.6	.58	.15
22	22.6	.52	.12
24	10.6	.47	.05
26 +	9.2	.44	.04
	100.0%	Average Cost	$ .57.

The cost of loading railroad cars for a clear-cut operation is $1.10 on the operation studied. Using the above ratio with this cost gives the cost to be expected on a selective operation:

$$\frac{.76}{.57} = \frac{1.10}{x}$$

x = 83¢ the cost of loading railroad cars on a selective operation.

By the same procedure the cost of loading trucks is calculated. The cost under a clear plan would have been 70¢.

$$\frac{.76}{.57} = \frac{.70}{x}$$

x = 52¢ the cost of loading trucks on a selective operation.

Sawing Costs:

Sawing costs have been calculated in two ways. The ratio as shown by the Forest Service figures has been applied to a known clear cutting cost and also a cost has been built up be means of a piece rate as was done in the section devoted to sawing logs in this paper. Using first the Forest Service Data:

- Sawing Cost -- Clear Cut Operation -

DBH Inches	% Volume in Diam. Class (Stand Table)	Cost Loading for Diam. Class (Bul.164)	Weighted Cost
10	6.0%	$ 3.38	$ .20
12	8.2	2.91	.24
14	12.5	2.57	.32
16	19.0	2.29	.43
18	16.8	2.08	.35
20	14.5	1.91	.28
22	12.2	1.79	.22
24	5.8	1.69	.10
26 +	5.0	1.60	.08
	100.0%	Average Cost	$2.22

- Sawing Cost -- Selective Operation -

18	31.0	$ 2.08	$ .64
20	26.6	1.91	.51
22	22.6	1.79	.40
24	10.6	1.69	.18
26	9.2	1.60	.15
	100.0%		$1.88.

To determine the cost of sawing on a selective operation when the clear cutting cost is $2.25 per M:

$$\frac{2.22}{1.88} = \frac{2.25}{x}$$

x = $1.93 per M cost of sawing on a selective operation.

The cost worked out on a piece rate basis for the Hardwood Type is:

DBH	% of Vol.	Ave. Top Dia.	Vol. /16' Log	Rate /Lin. Foot	Cost per Log	Cost per M	Wghtd. Cost
18"	31	13	100 bm	1¢	16¢	$1.60	$ .50
20	27	14	110	1	16	1.46	.39
22	22	15	140	1.5	24	1.71	.38
24	11	16	160	1.5	24	1.50	.17
26	9	17	180	2.0	32	1.78	.16
							$1.60

Cost of sawing per M gross volume = $1.60.

Cost of sawing per M after 10% correction for defect = $1.76

Cost of filer, sawboss and equipment .16

Total cost of sawing per M $1.92.

The sawing cost worked out on a piece rate basis for the Hemlock Type is:

18	32	12	80	1¢	16¢	$2.00	$ .64
20	27	13	100	1	16	1.60	.43
22	20	14	110	1	16	1.46	.29
24	10	15	140	1.5	24	1.71	.17
26	11	17	180	2.0	32	1.78	.20
							$1.73

Cost of sawing per M gross volume = $1.73.

Cost of sawing per M after 10% correction for defect = $1.91

Cost of filer, sawboss and equipment .16

$2.07.

Average cost of sawing for both types = $2.00 * Selective operation.

Road Cost:

The spacing of the secondary roads surfaced with plank depends on the hauling cost per 100 feet per M on the earth spur roads and on the volume per acre.

$$S = \sqrt{\frac{120000 \times .33}{82 \times 3.5}} = 117 \text{ stations.}$$

82¢ = the cost of hauling per M per 100' on earth roads

$1200 = the cost per mile of plank roads

3.5M = the volume per acre.

If the roads are spaced at 117 stations, the cost of hauling on the spurs will be:

$$\frac{117}{4} \times .82 = 24¢.$$

Road cost of plank road

$$\frac{120000}{12.1 \times 3.5 \times 117} = 24¢.$$

When making a detailed study of the secondary road system for clear cutting it was found that variations in road pattern, deadline, and so forth, raised the cost of secondary roads 12 per cent. Therefore, to make the costs from both types of operations comparable the cost of secondary roads is raised to 27¢ per M.

To obtain the cost of the mainhaul road the estimated cost of this road of $9,170 is prorated over a cut of one-half the total volume on the area or 64,000 Mbm. This results in a charge of 14.3¢ per Mbm.

On the basis of previous skidding calculations, the RD-2 has been chosen as the most efficient skidding machine when roads costing $400 per mile are used. The cost of roads when using this machine should be 83¢ per M if the entire area were a solid block of timber carrying 7M per acre. However, owing to deadline road that must be built through swamps and improper spacing that may result from topography this cost is raised 10 per cent as was the cost for the clear-cutting operation so as to make the costs comparable. Spur cost is then 92¢ per M.

The total road cost if the entire cost of the road system were charged off against the cut during the first cycle would be:

Spurs	$ .92
Secondary road	.27
Mainhaul road	.14
Total cost per Mbm	$1.33.

However, since subsequent cuts will be made every 20 years for an indefinite period, the entire road cost should not be charged off against the first cut. The road grades will be usable when the time to make the second cut arrives and the surfacing alone will have to be attended to. Here it has been assumed that the spurs are all charged off against the first cut, that the cost of planking but not the cost of the secondary road grade is charged off, and that the secondary road grades and the main-haul roads are capitalized as permanent assets subject to no depreciation. Any maintenance work costs should be charged off as incurred. The road cost on this basis will be:

Spurs	$ .92
Secondary Grade 1/3 of cost .66 x .27¢	.18
Total cost of roads per M under Selective operation.	$1.10

Hauling Costs:

It is estimated that trucks hauling logs from a selective operation will be able to carry average loads of 2,300 b.m. as against loads of 2,000 b.m. carried from clear-cutting operations. The basis for this estimate is the average load carried from an actual hardwood operation where only the best logs were hauled and averaged 11 to the Mbm, whereas, the average from most clear-cutting operations is 13.5 logs. The hauling costs thus estimated are given in the portion of this paper dealing with truck hauling.

On each type of road the cost of hauling selectively cut logs is 87 per cent the cost of hauling logs from a clear-cut operation:

$$\frac{2,000}{2,300} = 87\%.$$

Another factor to be considered is that on the selective operation the secondary plank roads are spaced at 117 stations instead of 77 stations. This means that a longer haul on earth spur roads is required in the former.

The cost of hauling on spurs:

$\frac{77}{4}$ x .96¢ = 18¢ Clear-cut operation.

$\frac{117}{4}$ x .82¢ = 24¢ Selective operation.

On plank, mainhaul, and highway haul, the hauling costs on the selective operation may be considered as 87 per cent of the clear-cut costs.

For the sake of comparison with the clear cutting operation example presented previously, 90 per cent is selected as a figure which is probably close to correct when all types of roads are considered.

Cost of hauling hardwood clear cut = \$1.82

Cost of hauling hardwood selective cut = 1.82 x 90% = \$1.64 per M

Cost of hauling hemlock clear cut = \$1.16

Cost of hauling hemlock selective cut = 1.16 x 90% = \$1.04 per M.

Road Maintenance:

Road maintenance charges will probably remain about the same, or, if anything, be reduced by selective logging since under that system one station of spur road serves 2.62 acres or 9.2 Mbm and under clear-cutting one station serves 1.66 acres or 11.6 M. Over a given piece of road there would then be less hauling and, therefore, lower maintenance charges. However, in the absence of any actual data the maintenance charge for a selective operation is left at the same figure as for a clear-cut operation.

Camp Costs:

Camp costs will go up under selective logging, especially if the large, expensive, 100-man camps are maintained. Small portable 40 - 50-man camps are much better adapted to the mechanical logging suggested and also to selective logging since an excessive charge is not required to establish them in a new location. It is estimated that the camp cost will rise from 30¢ to 40¢ in the absence of any further data.

Camp Overhead:

Camp overhead charges will remain the same regardless of whether clear-cutting or selective cutting is practiced since they vary according to volume of production rather than according to the size of the log handled or the volume per acre logged.

Summary of Costs

for

Selective Logging Operation

Delivered in Pond at Marenisco

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Hardwood:		Cost per M
Sawing		$ 2.00
Skidding - Using RD-2 Tractors		1.73
Loading Trucks		
Jammer crew	.52	
Truck waiting time & top loader $\frac{30" \times 1.54¢}{2.3M}$ =	.20	.72
Hauling on Trucks		1.64
Unloading and scaling time - Trucks		.20
Roads		1.10
Road Maintenance		.20
Camps		.40
Overhead		
Clerk $100 per month		
Foreman 150		
Skidboss 100		
Blacksmith 100 $520 -- 1200 M cut / Month .		.43
Total logging cost		$ 8.42

Summary of Costs for Selective Logging Operation

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Loaded on cars either at Marenisco or Bonnieville, whichever place is hauled to more cheaply:

<u>Hemlock</u>:	<u>Cost per M</u>
Sawing	$ 2.00
Skidding	1.73
Loading Trucks	.72
Hauling on Trucks	1.04
Unloading and scaling time	.20
Loading railroad Cars	.83
Roads	1.10
Camps	.40
Overhead	.43
Road Maintenance	.20
Total logging cost	$ 8.65

Conclusion:

Among the laws of management as laid down by Gillette and Dana are the Law of Standard Performance and the Law of the Separation of Planning from Performance. The explanation of the first law is that the possible production from men and machines must be known and that every effort must be made to obtain this "standard performance". It is clear, after comparing the skidding, loading, hauling, and sawing costs as reported in the past with those which would result if men and machines were operating at capacity, that standard performance has not been obtained in the past. The difficulty with setting up standards of performance in the logging industry is the great variety of conditions which must be met and which change from day to day as the operation moves to different "chances" and meets different weather conditions. One is apt to reason on this account that standards of performance are of little application in logging; that, for example, the spacing of roads according to standard performance data is without a sound basis. On examination of the calculations presented here, especially the graphs, it is seen that great leeway exists in which one can work and not materially raise costs. For example, in the spacing of spur roads for RD-2 on a clear-cut operation, the optimum spacing is 720 feet. However, it is seen that spacing can be from 500 - 1,000 feet without raising costs very much. The same is true with skidding data. For example, the variable cost of the RD-4 is considerably lower than the RD-2, yet the spacing is only changed from 720 to 800 feet, a very minor consideration in light of the leeway possible in both cases.

Standards of performance, aside from use in designing logging systems and determining whether or not men and machines are operating as they should, are necessary for the estimation of future logging costs, for setting rates for jobbers, and setting piece rates.

The second law of Separation of Planning from Performance is also of utmost importance in the logging industry where it has been violated probably more than in most industries --

"A common error in management is in the assumption that the man on the job in direct charge of the work is the man best fitted to plan and improve. Nothing is further from the truth. The mental inertia that resists a change in methods of performing work is almost beyond the comprehension and is found in all types of men, low and high. For maximum economy of performance the planning of methods of doing work should be the sole function of a manager who is not a workman himself nor in direct charge of the workmen".

If the logging system is to be designed correctly, it must not, therefore, in most cases, be left to the man in direct charge of the work. It is impossible in most cases for the men engaged in woods labor to comprehend or be sympathetic to such methods as have been recommended here and if the work is left in their hands conditions will change little.

The calculations and costs presented in this paper are general in form and apply to the entire area. Each forty, however, will present its own problems of topography, volume per acre, distance of haul, size of timber, and so forth. Every problem that arises must be met to fulfil these specific conditions.

The costs for the different methods of logging are, therefore, chiefly of value as a basis of comparison of one logging method with the other. The total costs may vary up or down depending on the wage scale paid, the logging chance, weather conditions, and so forth. It cannot be emphasized too much that the cost of logging every forty will vary and that this cost must be estimated on the ground.

However, when formulating policy, such a procedure is impossible. Each method must be studied in the light of available performance data and resulting costs. The estimating of costs as in this paper is, therefore, to be considered as something in the nature of a prospectus.

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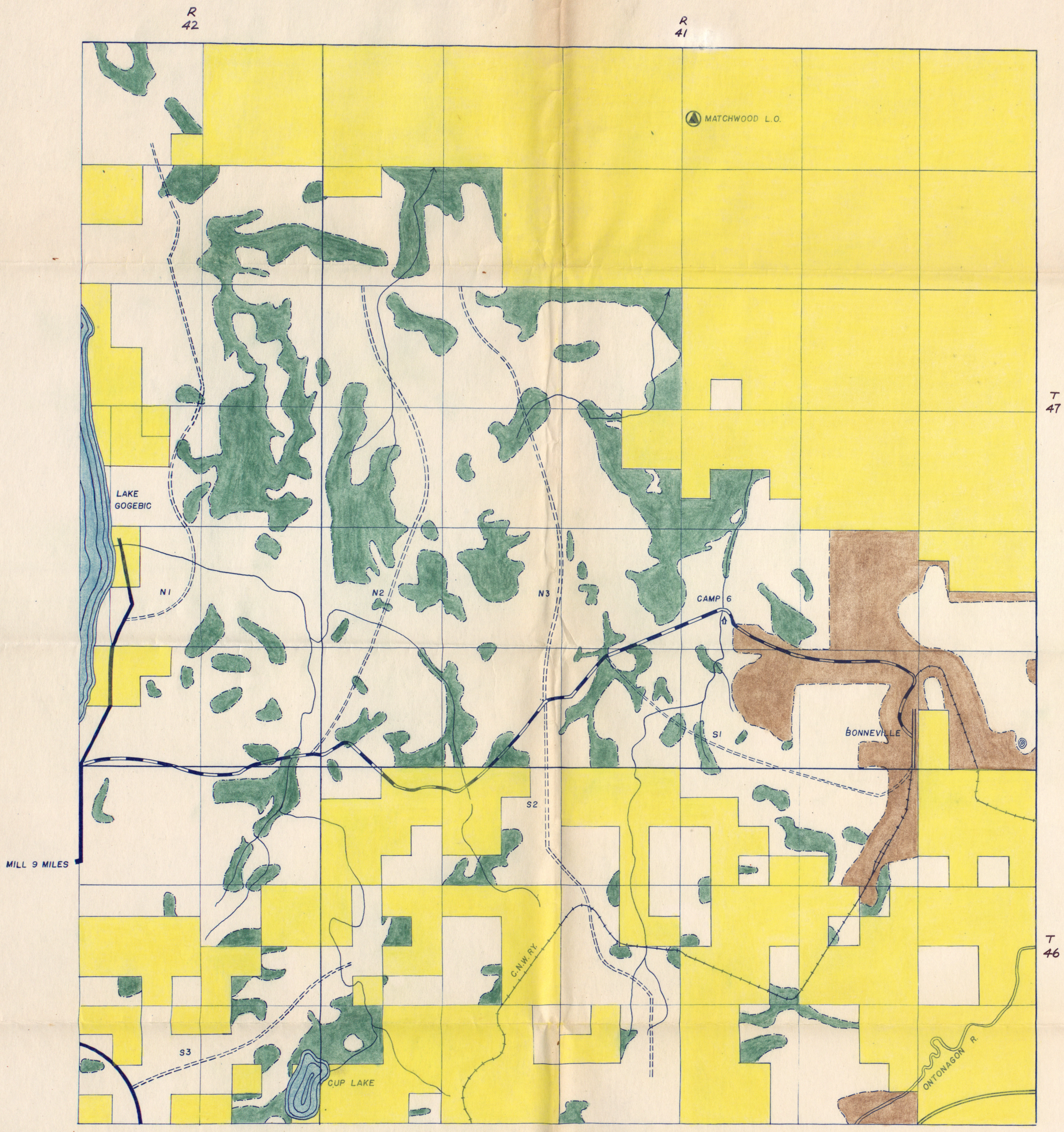
TRANSPORTATION SYSTEM
CLEAR CUT OPERATION



SCALE 2 INCHES = 1 MILE

LEGEND

highway
mainhaul road
secondary plank road
railroad
type line
stream
saw log area
swamp area
cut-over area
alien land

PLAN BY *R.R. Edgar*