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FACTORS AFFECTING THE COST OF TRACTOR LOGGING IN THE CALIFORNIA PINE REGION

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The past five years have seen a very rapid expansion in the use of tractors for logging in the pine region of California. In 1923, when a previous bulletin[2] of this series was published, steam donkey yarding, with which that study treated, was the prevailing method of yarding. During the season of 1928 probably not less than 60 per cent of the timber output of this region was yarded with tractors of the track-laying type. This remarkable increase in the use of tractors has come about largely for two reasons: First, the power employed is split up into several units with the attendant possibility of employing power in proportion to the size of the load; and second, there is considerable flexibility in application to use, for the same unit that hauls logs can also build railroads, raise and rig spar poles, move other equipment or do many of the innumerable other jobs incidental to a logging operation. With this wide use of tractors, a knowledge of the factors affecting costs is important not only to observe the relative effects of such factors but also to secure that coordination among yarding units and between yarding and loading units which will result in the lowest cost per thousand board feet of timber handled.

DESCRIPTION OF DATA AND METHODS

The data upon which the costs in this bulletin are based, were obtained by stop watch observations of tractor yarding on five different logging operations in the California pine region. These operations are fairly representative of large, medium and small log timber types. The load handled each trip was recorded by log dimensions as well as total scale. The number of trips covered by each study is shown in the summary of time distributions in tables 1 and 2. The studies by operations are designated A, B, C, D, and E. Where conditions of topography or equipment used varied on a given operation, the studies are further designated by a numeral in addition to the operation letter. Studies A and D were conducted in the large sugar pine and yellow pine timber of the southern Sierra region; study B in the

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[2] Bruce, Donald. The relative cost of yarding small and large timber. California Agr. Exp. Sta. Bul. 371:1–36. 1923.

medium-sized yellow pine timber of the central Sierra region; and studies C and E in the small-log region of the eastern and northern Sierras. The subdivisions of time recorded, were determined after a short preliminary study.

The effective time divisions were as follows:

Out—Travel time of the tractor from a position heading toward the woods, at the landing, to the next log or logs to be hauled in the woods.

Turn—Time spent in turning the tractor in the proper direction to begin the "in" and "out" trips.

Hook—Time spent in connecting the load to the tractor, measured from the end of the "turn" to the instant the load began to move.

In—Travel time of tractor with load, measured from the instant the load began to move in the woods to the instant it came to rest at the landing.

Unhook—Time of disconnecting the load from the tractor, measured from the end of the "in" to the instant when the choker or chain was free of the load.

The items of delay time were as follows:

Hung up—Time lost by reason of the tractor or load getting foul of stumps, logs, rocks, holes, etc.

Landing blocked—Time spent waiting for the landing to be cleared sufficiently to allow the load to be landed.

Tractor trouble—Time lost by reason of mechanical failure of tractor, such as stalling or breakage of parts.

Choker—Time lost by reason of choker getting fouled, unhooking prematurely, etc.

Pit—Time spent in the service pit, after starting whistle or before quitting whistle.

No cars—Loaders out of empty cars.

Waiting to pass—Waiting along tractor roads for other tractors to pass.

Helping other tractors—Assisting other tractors when "hung up."

Preparing and moving landing—Clearing out a new landing, moving loading machinery, etc.

Clearing road—Clearing stumps, logs and other debris from tractor road.

Waiting for choker setters—Waiting for choker setters to start the "hook."

Loader trouble—Time lost by reason of mechanical trouble with loading machine.

TABLE 1

Summary of Time Distribution for Skidding

	Study A			Study B-1			Study B-2		
	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip
	Minutes	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*
Effective time	7.25		35.3	8.26		56.1	5.46		68.6
Delay time	13.23		64.7	6.48		43.9	2.50		31.4
Total time of trip	20.48		100.0	14.74		100.0	7.96		100.0
Effective time:									
Out	2.12*	2.12	10.3	2.78	2.78	18.8	1.43	1.43	18.0
Turn (woods)	.34	.34	1.5	.32	.32	2.2	.25	.25	3.2
Hook	.95	.95	4.6	1.00	1.00	6.8	.52	.52	6.5
In	3.23	3.23	15.8	3.59	3.59	24.4	2.85	2.85	35.9
Unhook	.35	.35	1.7	.30	.31	2.0	.15	.15	1.9
Turn (landing)	.26	.27	1.3	.28	.29	1.9	.25	.26	3.1
Delays:									
Yarding out									
Hung up	1.11	2.52	5.6	.18	1.28	1.2	.02	.51	.2
Landing blocked	4.34	5.62	21.2	3.25	3.79	22.0	2.09	2.62	26.3
Tractor trouble	.66	3.58	3.2	.86	11.30	5.8			
Choker	.21	.96	1.0	.23	1.32	1.6	.08	.57	.9
Pit	1.41	15.56	6.9						
No cars	.15	26.21	.7						
Waiting to pass	.62	2.01	3.0	.37	2.59	2.5	.20	.59	2.5
Helping other tractors	.23	3.42	1.1	.14	3.36	1.0			
Preparing and moving landing	2.28	97.64	11.1	.87	79.89	5.9			
Clearing road	.84	4.04	4.1	.12	5.44	.8			
Waiting for choker setters				.01	.51	.1	.04	1.26	.5
Miscellaneous	1.41	53.88	6.9	.45	1.53	3.0	.08	.58	1.0
Total trips, number		343			92			30	
Average distance, feet		400			680			360	
Footage:									
Total		385,370 board feet			83,790 board feet			15,620 board feet	
Average, per trip per tractor		1,120 board feet			915 board feet			520 board feet	
Average, per day, per tractor		26,400 board feet			29,600 board feet			31,400 board feet	
Average logs, per thousand		1.5			2.6			3.5	
Total pieces, number		422			138			30	
Average pieces per trip, number		1.3			1.5			1.0	
Average slope		10 per cent, favorable			8 per cent, favorable			4 per cent, adverse	

* The individual items were obtained by dividing the total time for the item by the number of trips. The totals of these items do not in all cases correspond to the grand totals given at the head of the columns because the third place decimal has been dropped.

TABLE 1 (Continued)

SUMMARY OF TIME DISTRIBUTION FOR SKIDDING

	Study C-1			Study C-2			Study D		
	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip
	Minutes	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*
Effective time	10.97		68.6	27.02		78.4	10.86		49.7
Delay time	5.05		31.4	7.54		21.6	11.00		50.3
Total time of trip	16.02		100.0	34.56		100.0	21.86		100.0
Effective time:									
Out	3.61*	3.61	22.6	8.73	8.73	25.3	3.47	3.47	15.8
Turn (woods)	.23	.23	1.4	.36	.36	1.0	.37	.37	1.7
Hook	1.68	1.68	10.4	2.78	2.78	8.0	1.85	1.85	1.1
In	4.48	4.48	28.0	14.19	14.19	41.1	4.61	4.61	28.5
Unhook	.48	.48	3.0	.45	.45	1.3	.53	.54	2.4
Turn (landing)	.49	.49	3.0	.52	.52	1.5	.02	.35	.1
Delays:									
Yarding out							.14	2.05	.6
Hung up	.17	1.31	1.1	.27	2.53	.8	2.42	5.25	11.1
Landing blocked	1.87	3.30	11.7	3.57	5.25	10.3	.97	2.83	4.4
Tractor trouble	.77	7.95	4.8	.09	1.32	.2	1.58	8.73	7.2
Choker	.22	.77	1.3	.04	.58	.1	.48	2.47	2.2
Pit	.07	4.57	.5				.72	7.57	3.3
No cars							.73	76.77	3.3
Waiting to pass	.43	1.27	2.7	.24	2.27	.7	1.11	2.34	5.1
Helping other tractors	.05	3.07	.3	2.81	39.36	8.2	.65	9.06	3.0
Preparing and moving landing	.85	39.86	5.3				.13	26.65	.6
Clearing road	.02		.1				.76	5.30	3.5
Waiting for choker setters	.06	3.62	.4				.94	3.40	4.3
Miscellaneous	.54		3.3	.50	1.99	1.4	.38	1.74	1.7
Total trips, number	187			28			210		
Average distance, feet	720			2435			640		
Footage:									
Total	180,455 board feet			24,410 board feet			176,940 board feet		
Average, per trip, per tractor	970 board feet			875 board feet			840 board feet		
Average, per day, per tractor	28,900 board feet			12,100 board feet			18,300 board feet		
Average logs, per thousand	3.6			4.7			1.7		
Total pieces, number	387			72			252		
Average pieces per trip, number	2.1			2.6			1.2		
Average slope	12 per cent, favorable			Level			15 per cent, favorable		

* The individual items were obtained by dividing the total time for the item by the number of trips. The totals of these items do not in all cases correspond to the grand totals given at the head of the columns because the third place decimal has been dropped.

TABLE 2

SUMMARY OF TIME DISTRIBUTION FOR WHEEL YARDING

	Study B-3			Study B-4			Study C-3			Study E		
	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip	Average time per trip	Average time per occurrence	Total time per trip
	Minutes	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*	*Minutes*	*Minutes*	*Per cent*
Effective time	10.59		55.8	6.39		42.3	16.13		75.6	7.99		63.5
Delay time	8.31		44.2	8.71		57.7	5.20		24.4	4.58		36.5
Total time of trip	18.90		100.0	15.10		100.0	21.33		100.0	12.57		100.0
Effective time:												
Out	2.67*	2.67	14.1	1.77	1.77	11.7	4.58	4.58	21.5	2.23	2.27	17.7
Turn (woods)	.91	.92	4.8	.80	.80	5.3	.83	.83	3.9	.97	.98	7.7
Hook	1.49	1.50	7.9	1.04	1.04	6.9	2.18	2.18	10.2	1.40	1.40	11.2
In	4.90	4.90	25.7	2.14	2.14	14.2	7.82	7.82	36.6	3.16	3.16	25.1
Unhook	.15	.18	.8	.07	.07	.5	.27	.27	1.3	.13	.14	1.0
Turn (landing)	.47	.48	2.5	.56	.56	3.7	.45	.49	2.1	.10	.36	.8
Delays:												
Hung up	.81	3.15	4.3	.05	1.00	.3	1.36	6.81	6.4	.24	2.53	2.0
Landing blocked	3.33	6.47	17.7	5.88	6.19	39.0	1.44	2.82	6.8	1.97	3.08	15.7
Tractor trouble	1.28	10.73	6.8	2.51	40.68	16.6	.66	3.29	3.1	.48	5.82	3.8
Choker	.12	2.40	.7				.23	2.05	1.1	.01	1.47	.1
Pit	.47	119.00	2.5				.52	11.82	2.5	.19	2.48	1.5
No cars	.27	33.87	1.4							.34	24.75	2.7
Waiting to pass	.93	2.32	5.0	.08	.78	.5	.60	2.69	2.8	.16	.71	1.2
Helping other tractors	.04	.75	.2								.52	
Preparing and moving landing										.60	14.38	4.8
Clearing road	.04	.97	.2	.02	1.25	.1	.01	.28				
Waiting for choker setters	.23	6.44	1.2				.02	.72	.1	.09	1.24	.7
Loader trouble										.27	19.80	2.2
Miscellaneous	.79	2.98	4.2	.17	1.01	1.2	.37	.97	1.7	.22	1.10	1.8
Total trips, number		250			81			45			145	
Average distance, feet		750			400			1270			630	
Footage:												
Total		456,260 board feet			145,870 board feet			96,760 board feet			328,000 board feet	
Average, per trip, per tractor		1,820 board feet			1,800 board feet			2,150 board feet			2,260 board feet	
Average, per day, per tractor		46,300 board feet			57,200 board feet			48,380 board feet			86,200 board feet	
Average logs per thousand, number		2			.9			1.4			2.7	
Total pieces, number		527			84			74			527	
Average pieces per trip, number		2.1			1.0			1.6			3.6	
Average, slope		6 per cent, adverse			7 per cent, favorable			Level			5 per cent, favorable	

* The individual items were obtained by dividing the total time for the item by the number of trips. The totals of these items do not in all cases correspond to the grand totals given at the head of the columns because the third place decimal has been dropped.

Two methods of using tractors in logging were studied in the field—ground skidding, and yarding with Robinson hydraulic big wheels. The various items studied will therefore be considered separately under these two heads. In the light of data on these two methods, the possibilities of fair-lead wheel yarding are also treated briefly. The tractors studied were all 60 horse-power tractors of the track laying type manufactured by the Caterpillar Tractor Company. No other types or makes were in logging use in California at the time this study was made. The data presented should not differ materially, however, for tractors of the same general type and power. The cost figures given throughout the bulletin are based on the charges for equipment, supplies and labor given in table 3.

On all the operations studied, 32-foot log lengths predominated. This has a very important bearing on nearly all items studied under both types of logging.

GROUND SKIDDING STUDIES

In skidding, the logs were choked and the free end of the choker attached directly to the tractor. In small timber several chokers were hooked on, each trip. In large timber it became necessary to hook two or more tractors in tandem for some of the larger pieces. In such cases the scale was prorated according to the number of tractors used.

Effect of Log Diameter.—The disproportionate cost of logging small logs, while not as pronounced as in donkey logging, is still quite evident in tractor skidding. Bruce states of donkey yarding that "it costs from five to eight times as much per M.B.M. to yard logs (16 feet long) from 18-inch as those from 48-inch trees and that for trees below 18 inches in diameter costs are undoubtedly even higher." This cost ratio which is for the breast-height diameters of trees should hold also for the same log diameters. It is shown by the present study, as presented in figure 1 and table 4, that for tractor skidding it costs approximately three times as much per M.B.M. to skid logs (16-foot) averaging 18 inches in diameter as those averaging 48 inches in diameter. The cost per thousand board feet increases very rapidly below 20 inches in diameter. It is to be noted that this difference in cost is less in medium and small timber (Studies B–1 and C–1) than in large timber (Studies A and D). It is reasonable to suppose that this is due to the fact that it is much easier to get a large load of small-diameter pieces in small timber where they constitute a larger percentage of the total and where they occur in longer dimensions than in large timber where the small diameter pieces occur more frequently in the form of short, scattered, top logs.

TABLE 3

CHARGES USED AS A BASIS FOR COSTS

Items of cost	Charge per season (Average season, 240 days)	Charge per day (8 hours)	
Skidding unit:			
Tractors:			
Depreciation (D):			
Initial cost (I) $5000. Life, 4 years,* hence $\frac{\$5000}{4}=$	$1250.00	$5.22	
Interest:			
Average annual investment $=\frac{I+D}{2}=\frac{5000+1250}{2}=\$3125$			
$3125 \times .06=$	187.50	.78	
Repairs		5.50	
Supplies:			
40 gallons gas @ 20c		8.00	
Oil, including renewal		.75	
Grease		.50	
Wire rope		1.95	
Miscellaneous		1.50	
Total, mechanical unit		———	$24.20
Labor:			
1 driver @ 80c per hour		6.40	
1 choker setter @ $4.50 per day		4.50	
Total, labor			10.90
Total, skidding unit			*$35.10*
Wheel yarding unit:			
Wheels:			
Depreciation:			
Initial cost $1750. Life, 5 years, hence $\frac{\$1750}{5}=$	350.00	$1.46	
Interest:			
Average annual investment $=\frac{I+D}{2}=\frac{1750+350}{2}=\$1050$			
$1050 \times .06$	63.00	.26	
Repairs and supplies		1.00	
Total, mechanical unit		———	$ 2.72
Tractor unit and labor (same as skidding)			35.10
Total, wheel yarding unit			*$37.82*
General charges:			
(Unit cost dependent on number of units used per landing):			
1 landing boss		$8.00	
1 tractor mechanic		7.20	
1 unhook man		4.50	
1 general utility man		4.50	
Total, general charges		———	*$24.20*
Bunching unit:			
Total, mechanical tractor unit			$24.20
Labor:			
1 driver		6.40	
1 crew boss		6.00	
3 chokermen @ $4.50 per day		13.50	
1 mechanic (average)		.75	
Total, labor		———	26.65
Total, bunching unit			*$50.85*

* This is based on an average life of 8,000 operating hours from data given by various operators. Studies of the Division of Farm Management at the University of California have shown the life of a tractor in farm use, to be 7,000 operating hours. The reason for the longer life of logging tractors is undoubtedly regular inspection and care by expert mechanics.

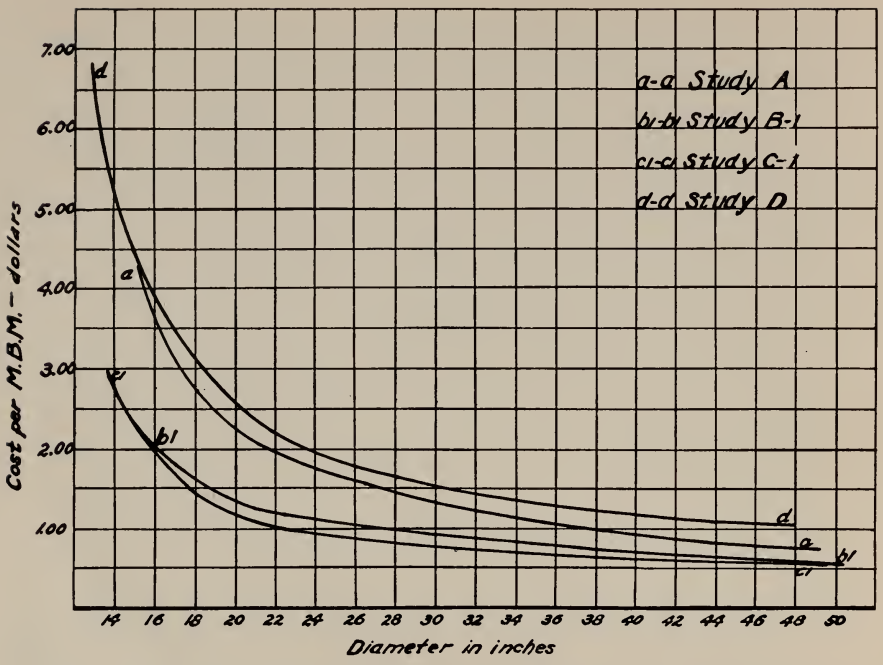

Fig. 1.—Cost of skidding logs with tractors, as influenced by log diameter.

TABLE 4

EFFECT OF LOG DIAMETER ON COST OF SKIDDING

Log diameter, inches	Cost* per M. B. M., gross scale†			
	Study A	Study B-1	Study C-1	Study D
14		$2.70	$2.75	$5.15
16	$3.55	2.00	1.93	3.85
18	2.72	1.59	1.44	3.10
20	2.25	1.32	1.18	2.56
22	1.95	1.20	1.02	2.20
24	1.76	1.12	.94	1.95
26	1.60	1.05	.87	1.79
28	1.45	.98	.82	1.65
30	1.32	.92	.77	1.53
32	1.20	.87	.72	1.42
34	1.11	.82	.68	1.33
36	1.02	.77	.65	1.25
38	.95	.73	.62	1.20
40	.89	.70	.60	1.15
42	.83	.67	.58	1.10
44	.80	.64	.57	1.07
46	.78	.61	.56	1.05
48	.76	.59	.55	1.05

* Costs given show the relationship only within each individual study as they are based on the average distance of the study in question as given in table 1.

† Scribner log rule used throughout this bulletin.

The cost effect of logging small logs is also shown in a rather startling manner by table 5. Here the logs are divided into two classes, those running 3.5 logs or less per thousand board feet and those running 4.5 logs or more per thousand board feet. Roughly these classes represent, respectively, logs greater than and less than 18 inches in diameter. The average cost of skidding is increased by 20 to 60 cents per thousand board feet by hauling in logs less than 18 inches in diameter. The more pronounced increases are undoubtedly the result of faulty organization (see Organization of Labor and Mechanical Units). When it is considered that these logs represent only 8 to 29 per cent of the volume but 20 to 48 per cent of the total cost of skidding, it is evident that some thought can well be given to the question of selective logging. Assume, for example, a stand of timber averaging 25 thousand board feet per acre, with 20 per cent of the volume represented by trees 20 inches or less in diameter at breast height and therefore containing logs less than 18 inches in diameter. With an average maximum skidding distance of 2500 feet, to only the upper side of the railroad, and with a construction cost for railroad of $1.50 per foot or $7920 per mile, the charge for railroad, if apportioned to the total 25 thousand board feet per acre, would be $1.04 per thousand (see table 17); if apportioned to the 80 per cent of the stand, that is, the 20 thousand board feet with an average tree diameter greater than 20 inches, the charge for railroad would be $1.30 per thousand. Therefore, to leave these trees standing would increase the railroad charge 26 cents per thousand board feet. But from table 5 we note that this is about the average saving in yarding cost if these trees are not logged. Since additional savings are to be expected in felling, bucking, loading and milling, it is obviously good management to leave such trees standing.

TABLE 5

Effect of Log Diameter on Average Cost of Skidding by Log Size Classes

Study	3.5 logs or less per M. B. M. (greater than 18 inches in diameter)			4.5 logs or more per M. B. M. (less than 18 inches in diameter)			Total average cost per M. B. M., for skidding
	Average cost per M. B. M.	Per cent of total by volume	Per cent of total by cost	Average cost per M. B. M.	Per cent of total by volume	Per cent of total by cost	
A	$1.29	92	80	$3.66	8	20	$1.49
B-1	1.01	76	60	2.14	24	40	1.27
C-1	.99	71	52	2.21	29	48	1.34
D	1.61	84	60	5.52	16	40	2.25

When we come to consider the diameter to which we should utilize the felled tree, a different element presents itself. A charge for stumpage and felling has now been set up for the tree and the volume removed must, in addition to bearing an increased charge for railroad development, also bear the stumpage and felling charges of the volume left. These charges for stumpage and felling may amount to $5.00 per thousand board feet or more. However, from the trend of the curves in figure 1, it is apparent that even for log diameters of 10 to 12 inches, the saving in yarding cost alone, by leaving logs of such sizes in the woods can well offset the $5.00 per thousand board feet charge for stumpage and felling. Just what the minimum diameter of utilization should be, considering all the factors of cost, bucking, yarding, loading, milling and log quality is not the purpose of this study but at least it is indicated that present utilization, commonly to 8 inches, is probably extreme and that the whole matter is well worth further study.

Effect of Size of Load.—As is to be expected, the size of load has a very pronounced effect on the cost of skidding. This is shown in figure 2 and table 6. "In," "hook" and "unhook" times are variable while other items are independent of the size of load. In all studies the cost per thousand board feet for skidding loads of 200 board feet is approximately eight times that for loads of 2000 board feet. The size of the load is in itself the important element as the average trip time remains fairly uniform, being only 15 per cent greater for a load of 2000 board feet than for a load of 200 board feet, while the cost is decreased 90 per cent.

From a study of figure 2 it is seen that the costs per thousand board feet mount quite rapidly for loads of less than 800 board feet. This point in load volume must therefore be watched carefully when dealing with those factors of skidding which have a tendency to lessen the load size, such as adverse slopes, small-diameter logs, and rough or soft surface conditions. Logging long dimensions and using plenty of chokers are means of maintaining a high average load in spite of small-diameter logs. Wheel yarding or the use of other log-supporting equipment affords a means of counteracting the load diminishing effect of adverse slope and surface conditions. In short, maintaining a high average load is largely a matter of proper organization, taking into account all the elements contributing to cost on a given operation.

The trend of the data in figure 2 and table 6 shows that 2400 board feet represents a practical maximum load for skidding. The decrease in cost beyond this point is very slight and in study B-1 there is actually an increase in cost.

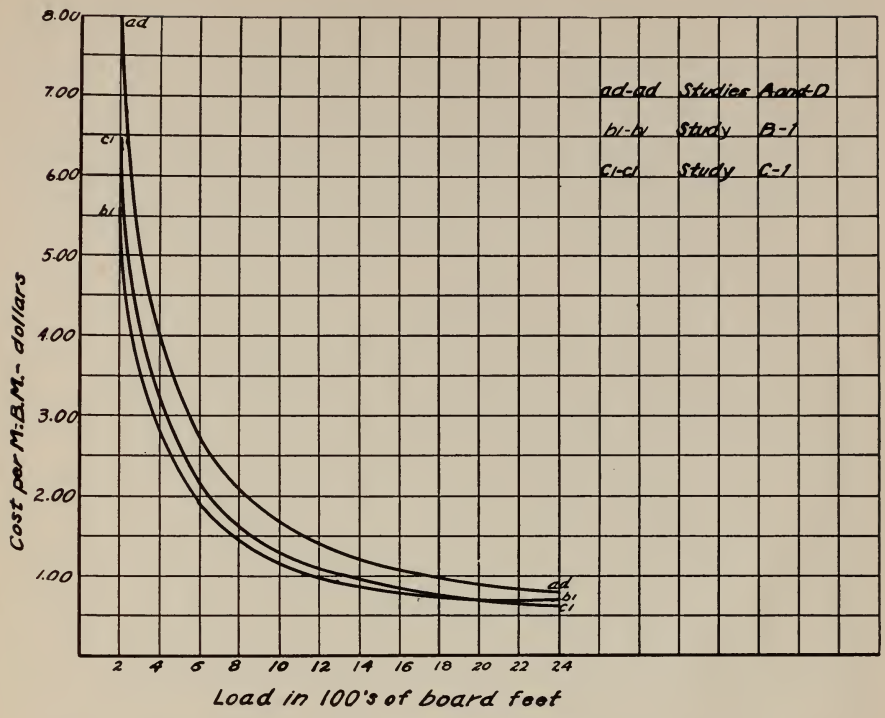

Fig. 2.—Cost of skidding logs with tractors, as influenced by size of load.

TABLE 6

Effect of Size of Load on Cost of Skidding

Load in board feet	Study A (average distance, 400 feet)		Study B-1 (average distance, 680 feet)		Study C-1 (average distance, 720 feet)		Study D (average distance, 640 feet)	
	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.
	Minutes	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*
200	18.96	8.13	13.95	5.61	15.76	6.43	18.98	8.01
400	18.96	4.06	13.96	2.83	15.76	3.22	19.12	4.03
600	19.01	2.72	14.01	1.87	15.80	2.15	19.35	2.72
800	19.12	2.06	14.12	1.42	15.88	1.62	19.71	2.08
1000	19.28	1.66	14.32	1.15	16.01	1.31	20.22	1.70
1200	19.50	1.38	14.62	.98	16.20	1.10	20.74	1.45
1400	19.79	1.20	15.03	.86	16.42	.96	21.15	1.27
1600	20.15	1.08	15.56	.78	16.65	.85	21.47	1.13
1800	20.59	.98	16.28	.73	16.92	.77	21.73	1.02
2000	20.97	.90	17.22	.69	17.19	.70	21.95	.93
2200	21.41	.83	18.60	.68	17.48	.65	22.16	.85
2400	21.90	.78	20.60	.69	17.80	.61	22.38	.79

Effect of Slope.—The effect of slope has been somewhat difficult to ascertain. A wide range of slopes was not available during the time the field data were being gathered. Such differences in slope as occurred, for instance, between an operation in the southern Sierras and one in the northeastern Sierras are rendered practically useless for purposes of study by the more pronounced effects of differences in size of timber and methods of organization. It is only possible, therefore, to note the effect of slope by comparing studies on the same operation. Two studies of operation B and two studies of operation C are chosen for this purpose. These comparisons shown in table 7 are based on the total trip time at 700 foot skidding distance. From analyses of the time elements made of those operations which it was judged were functioning with a reasonable degree of efficiency, it was found that at a yarding distance of 700 feet delays should constitute not over one third of the total time. This has been used as a basis for the delay time in arriving at the total trip time in table 7. In each of these studies it is noted that the total trip time does not differ greatly for even wide variations in slope but the cost per thousand board feet does differ considerably owing to the load handled. The allowable load decreases and therefore the cost per thousand board feet increases with a decrease in favorable slopes or an increase in adverse slopes. In studies B–1 and B–2 the total trip time is practically the same for both studies but due to the smaller allowable load on the adverse 4 per cent slope of study B–2, the cost is increased 77 per cent over that of the favorable 8 per cent slope of study B–1. This difference is not so striking when comparing a favorable slope to a level slope. The increase in cost for the level slope of study C–2 is only 20 per cent greater than the favorable 12 per cent slope of study C–1. It is noted that for a favorable slope the "out" time increases considerably while the "in" time decreases only slightly with increase of slope. As to the trend in costs for favorable slopes greater than shown in table 7 no data are available in this study, but it is reasonable to suppose that there will be a gradual decrease in cost with increase in slope up to that point where it is necessary to shift to a lower gear or where the practical limit of load size is reached. Above this point there is undoubtedly an increase in skidding costs, due both to increased "out" time and to increased wear and tear on the tractor. In practice it has been found that a slope of 50 per cent constitutes a practical absolute maximum. Slopes of 10 per cent to 30 per cent in favor of the load are ideal, since they permit a large load to be handled with ease and still do not greatly increase the "out" travel time.

Because of the large increase in cost of skidding on adverse slopes it is undoubtedly good management to secure such a layout of railroads as will permit skidding only to the upper side of the track for slopes averaging greater than 6 per cent. Where a scheme of this nature would introduce long distances of adverse grades into the railroad system, such roading adjuncts as skylines or hoists can often be placed on the lower side of the track in such manner that they will permit yarding to them with slope in favor of the load.

TABLE 7

Effect of Slope on Cost of Skidding

Study	Average load	Average slope*	Elements of cost at 700-foot skidding distance					
			"Out" time per trip	"In" time per trip	Total travel time per trip	Items independent of slope per trip	Total trip time	Cost of skidding per M. B. M.
	Board feet	*Per cent*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Dollars*
B-1	915	− 8	2.83	3.66	6.49	6.07	12.56	1.10
B-2	520	+ 4	2.56	4.70	7.26	4.37	12.63	1.95
C-1	970	−12	3.53	4.37	7.90	8.27	16.17	1.36
C-2	875	Level	2.91	4.66	7.57	9.93	17.50	1.63

* Minus slopes are slopes in favor of the load, and are therefore termed "favorable" throughout this bulletin. Plus slopes are adverse to the load, and are termed "adverse."

Effect of Surface Conditions.—Surface conditions, particularly compactness of soil, are very closely related to the season of the year and to slope, in the degree of their effect on the cost of skidding. Study A was conducted in May. Here the delay due to hang-ups amounted to only 5.6 per cent of the total time (see table 1). Study D, conducted late in July, with slope and timber size practically the same, shows 11.1 per cent of total time chargeable to hang-ups. This increased hang-up time is almost entirely attributable to the more loosened condition of the soil in late summer. Again on the level or very moderate slopes of the northern Sierras, in the region of lava ash soils it has been found practically impossible to ground-skid logs in very large loads during the summer months. In the winter with a moderate depth of snow to facilitate snaking, good sized loads are readily skidded over the same type of ground. While it was, of necessity, impossible to definitely segregate the effects on skidding caused by any particular portion of a skidding trail, it was noted, nevertheless, that with surface conditions, whether soil or undergrowth, remaining uniform throughout the length of the skidding trail, delays attribu-

table to these surface conditions always occurred with greater frequency on the less steep portions of the trail. In short, surface conditions become of decreasing effect with increase of slope when the slope is in favor of the load.

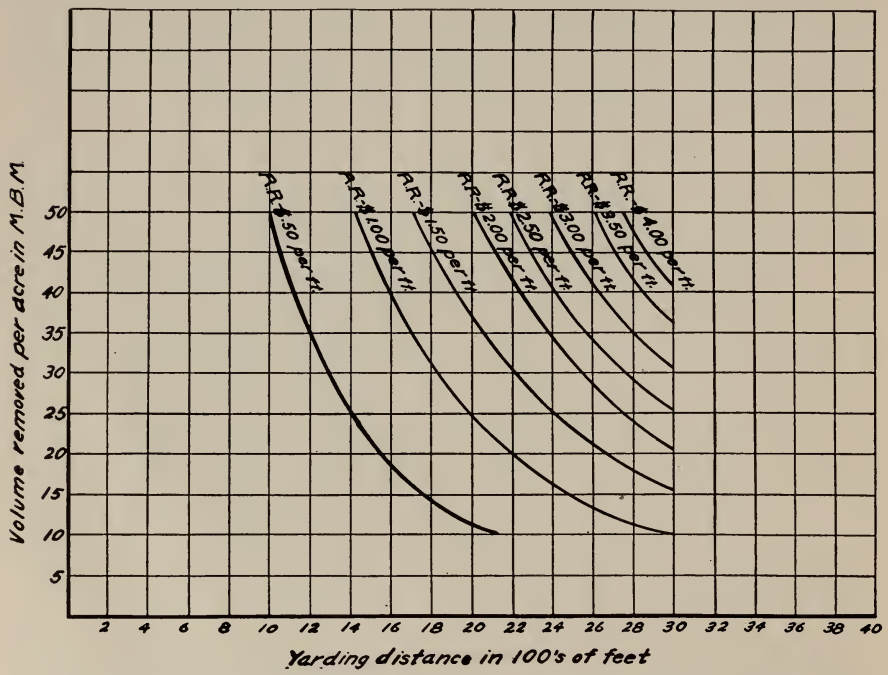

Fig. 3.—Economic skidding distance, based on volume logged per acre and cost of railroad per foot. Use of diagram:

1. Start with known volume per acre on left margin.
2. Read horizontally to the right to known cost of railroad.
3. Read down vertically to economic yarding distance.

For example, with a known stand per acre of 30 thousand board feet and a known cost for railroad of $1.50 per foot, the economic skidding distance is 2200 feet.

Effect of Yarding Distance.—Naturally, distance of skidding has a very direct bearing on cost owing to the increase in travel time with increase in distance. A knowledge of the effect of distance is important in determining the probable daily output per tractor at various distances and also in determining with given railroad costs and density of stand what the maximum skidding distance should be. With a given stand per acre and cost for railroad, the maximum distance for skidding is that which produces the lowest combined skidding and railroad costs. The maximum skidding distance under various conditions of stand density and cost of railroad is shown in figure 3, which is based on curves showing the combined costs for yarding and

railroad development for various yarding distances. The costs of yarding used are those given in table 8, while those for railroad development are given in tables 15 to 22 inclusive in the appendix. The low points of these cost curves were then used to construct the curves given in figure 3. These low points were found to be practically the same for the small, medium and large-sized logs as presented in table 8. To use figure 3 we start with the known stand per acre, that is, the volume to be logged, which for purposes of illustration we will assume to be 30 thousand board feet; we then read horizontally to the known cost of railroad, again assumed to be $1.00 per foot; and now, reading down vertically, we find the economic yarding distance to be 1800 feet.

TABLE 8

Costs of Tractor Skidding as Influenced by Distance

Maximum yarding distance	Costs of skidding					
	Timber averaging 1.5 logs per M (average load, 1100 board feet)		Timber averaging 2.5 logs per M (average load, 970 board feet)		Timber averaging 4 logs per M (average load, 970 board feet)	
	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.
Feet	*Minutes*	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*
400	11.17	.829	9.64	.805	11.29	.945
500	11.80	.876	10.15	.848	11.80	.988
600	12.44	.923	10.68	.892	12.33	1.033
700	13.07	.970	11.19	.935	12.84	1.076
800	13.71	1.017	11.72	.980	13.37	1.120
900	14.35	1.065	12.24	1.023	13.89	1.164
1000	14.97	1.111	12.76	1.067	14.41	1.208
1100	15.62	1.159	13.28	1.111	14.93	1.251
1200	16.25	1.206	13.80	1.155	15.45	1.295
1300	16.88	1.252	14.32	1.198	15.97	1.339
1400	17.52	1.300	14.85	1.243	16.50	1.383
1500	18.15	1.347	15.36	1.286	17.01	1.426
1600	18.79	1.394	15.89	1.330	17.54	1.471
1700	19.42	1.441	16.40	1.373	18.05	1.514
1800	20.06	1.488	16.93	1.418	18.58	1.558
1900	20.70	1.536	17.45	1.462	19.10	1.602
2000	21.33	1.583	17.97	1.505	19.62	1.646
2100	21.97	1.630	18.49	1.549	20.14	1.690
2200	22.60	1.677	19.01	1.592	20.66	1.733
2300	23.24	1.724	19.53	1.637	21.18	1.778
2400	23.88	1.772	20.06	1.681	21.71	1.821
2500	24.51	1.819	20.57	1.724	22.22	1.865
2600	25.15	1.866	21.10	1.768	22.75	1.910
2700	25.78	1.913	21.61	1.811	23.26	1.952
2800	26.42	1.960	22.14	1.856	23.79	1.997
2900	27.06	2.008	22.66	1.900	24.31	2.041
3000	27.69	2.055	23.18	1.943	24.83	2.084

In the preparation of table 8, an analysis of the data does not reveal any effect on yarding costs due to density of stand. If such an

effect does exist it is very slight as compared to the effects of such other items as load size and organization and is submerged by them. The costs given in the table, while based on the studies representative of the stated log size, are not merely those that were obtained but are those that should be gotten under proper organization.

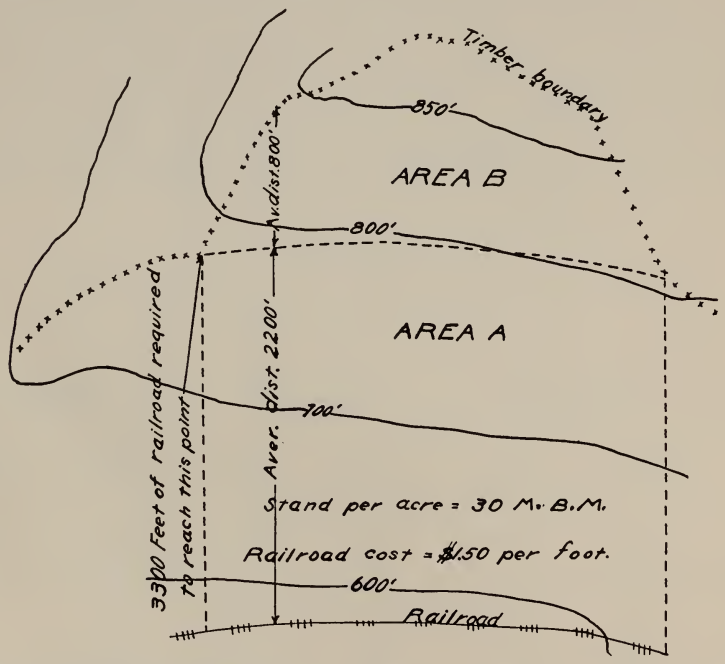

Fig. 4.—Diagram illustrating the application of data on economic distance to skid with tractors. See text.

The costs are based upon the total trip time for the average distance, which in all studies was found to be approximately 60 per cent of the maximum distance. For instance, in table 8, the average trip time of 11.17 minutes, given for timber averaging 1.5 logs per thousand and for yarding to a maximum distance of 400 feet, is for an average yarding distance of 240 feet. The delay time used in determining total trip time was calculated as stated on page 14, and from an analysis of the data was assumed to remain constant for all distances. The average loads used were actually attained and are therefore undoubtedly conservative.

No claim is made that the costs given are absolute. It is practically impossible to cover by tabular data the wide range of conditions obtaining on any given logging operation. They are, however, an indication of the proper balance which should obtain between cost of yarding as influenced by distance and cost of railroad. At present

this balance does not exist in the California pine region. Most operators are yarding from 1000 to 1500 feet regardless of cost of railroad or stand per acre. The tables indicate very clearly that the maximum skidding distance influences the cost of railroad much more than it does the cost of yarding. Therefore in tractor logging the greater likelihood of increasing logging costs comes from building too much railroad rather than from yarding too far. For example (see tables 8 and 16), with railroad costing $1.00 per foot and serving a stand averaging 25 thousand board feet per acre and 4 logs per thousand board feet, the combined yarding and railroad charges are lowest for 2000 feet at $2.51 per thousand board feet. If more railroad is built so as to decrease the yarding distance to 1400 feet, a decrease of 600 feet, the combined costs are increased to $2.63 per thousand board feet. If on the other hand the yarding distance is increased by 600 feet to a total of 2600 feet, the combined costs are increased to only $2.58 per thousand board feet. This explains why it is often cheaper to lengthen the yarding distance to log long corners of timber resulting from artificial or natural boundaries rather than to build more railroad. Such a case is presented in figure 4. Under the conditions stated on the figure, the maximum skidding distance, from figure 3, should be 2200 feet. At this distance the combined skidding and railroad cost is $2.72 per thousand board feet. In logging the timber beyond the 2200-foot distance, two possibilities present themselves: (1) To extend the skidding distance and yard area B along with area A or (2) to build railroad to area B and yard it as a separate unit. The two cases are compared below:

CASE I

Average maximum skidding distance 3000 feet:	
Railroad charge	$0.73 per M
Yarding charge	2.08 per M
Total average charge, areas A and B	$2.81 per M

CASE II

Total board footage area A, 3990 M	
Total logging cost area A = 3990 M × $2.72 =	$10,852.80
Total board footage area B, 1440 M	
R. R. cost area B (3300 + 2640) × $1.50 =	8,910.00
Yarding cost area B	
Average distance 800 feet, 1440 × $1.12 =	1,612.80
Total board footage areas A and B, 5430 M	
Total costs areas A and B	$21,375.60
Average charge areas A and B =	
$21,375.60 ÷ 5430 M =	$3.94 per M

It is noted in the above comparison that a saving of more than $1.00 per M is effected through yarding both areas to the same spur rather than build a separate spur to log area B. All such cases are specialized in character and must be decided on their own merits. The data presented in this bulletin merely serve as a basis upon which to work.

TABLE 9

OUTPUT PER DAY PER TRACTOR

(Slope 6 to 20 per cent favorable to the load)

Maximum skidding distance	Output per day per tractor		
	Timber averaging 1.5 logs per thousand (Load 1100 board feet)	Timber averaging 2.5 logs per thousand (Load 970 board feet)	Timber averaging 4 logs per thousand (Load 970 board feet)
Feet	*Board feet*	*Board feet*	*Board feet*
400	47,300	47,530	40,740
500	44,000	45,590	38,800
600	41,800	43,650	36,860
700	39,600	41,710	35,890
800	38,500	38,900	34,920
900	36,300	37,830	32,930
1000	35,200	35,890	32,010
1100	33,000	34,920	31,040
1200	31,900	32,980	30,070
1300	30,800	32,010	29,100
1400	29,700	31,040	28,130
1500	28,600	30,070	27,160
1600	27,500	29,100	26,190
1700	26,400	28,130	25,220
1800	25,300	27,160	24,250
1900	25,300	26,190	24,250
2000	24,200	25,220	23,280
2100	23,100	25,220	22,310
2200	23,100	24,250	22,310
2300	22,000	23,280	21,340
2400	22,000	22,310	21,340
2500	20,900	22,310	20,370
2600	20,900	21,340	20,370
2700	19,800	21,340	19,400
2800	19,800	20,370	19,400
2900	18,700	20,370	18,430
3000	18,700	19,400	18,430

Output per Day per Tractor.—The output per day per tractor for various timber sizes is shown in table 9. These data are figured upon the same basis as those presented in table 8. Data on output are of importance when balancing the logging operation with regard to number of tractors and their coordination with loading equipment. As an example, the economic maximum yarding distance for timber averaging 15 thousand board feet per acre and railroad costing 50 cents per foot is shown in figure 3 as 1700 feet. From table 9 we see

that at 1700 feet, in small timber, the daily output per tractor is approximately 25 thousand board feet. If the daily capacity of the loading equipment is 300 thousand per day, twelve tractors should be used under the conditions stated. In like manner if the maximum distance is limited by artificial or natural boundaries, the number of tractors needed for the given distance can readily be ascertained.

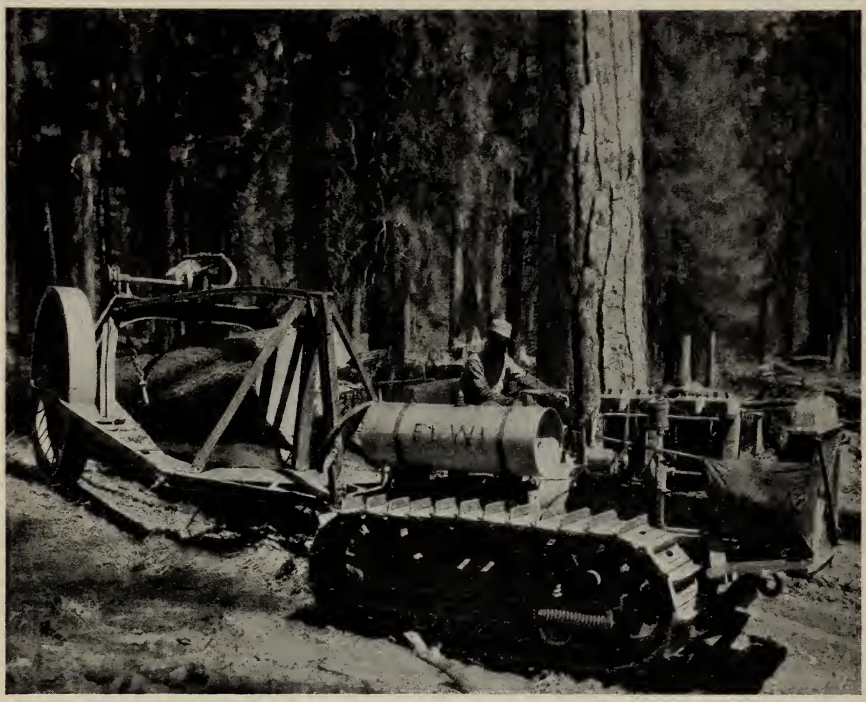

Fig. 5.—Big-wheel yarding. Sixty horse-power tractor and Robinson hydraulic-lift big wheels. The lever directly back of the tractor driver operates the valve to control the flow of oil to and from the oil cylinder at the top of the arch. (Photo by courtesy of the Caterpillar Tractor Co.)

BIG-WHEEL YARDING STUDIES

The only type of big-wheel yarding studied in the field was that with Robinson hydraulic-lift big wheels (see figure 5), since they were the type mainly used when the data were gathered. Slip-tongue big wheels, adapted to tractor use, were used to a small extent. Their chief advantage lies in their cheapness, light weight and simplicity. This advantage is undoubtedly offset by the smaller load which they are capable of handling. Both of these types require that the logs be bunched in suitable sized loads. This bunching cost constitutes a very

appreciable percentage of the yarding cost, especially in small timber. To get away from this cost of bunching and still to obviate the hang-ups incidental to skidding on the ground, these types of big wheels are rapidly being superseded by the fair-lead type of wheel (see figure 11). This method of yarding logs will be referred to later.

The factors considered under skidding will also be considered under wheel yarding. Log size is of importance only in bunching. After the logs are once bunched, the size of log does not have any striking effect on the time involved in transportation with big wheels. Bunching will therefore be considered first.

Effect of Bunching.[3]—The data on bunching were gathered on one operation in the small log region of the northern Sierras. The bunching was done with 60 horse-power tractors. The data on crew and costs are presented in table 3. On this operation the logs were first pulled into loose piles and later rolled into compact bunches. Enough logs were pulled out for about five or six bunches before rolling. Procedure throughout the pine region varies widely in the methods and equipment used. This is reflected in the spread of bunching costs which range from $.40 to $1.00 per thousand board feet. It is to be noted that even at the lowest figure, bunching constitutes a very important item in the total yarding cost. It is felt that the operation studied was of reasonable efficiency and therefore can be taken as fairly representative of the cost of bunching logs in small and medium sized timber by this method.

The effect of log size or volume on bunching is shown in figure 6 and table 10. Figure 6 shows the time cost per thousand board feet for diameters of 13 to 41 inches. Table 10 shows the actual monetary cost as well as the time cost for loads of 100 to 1300 board feet. The high cost of small logs is more in evidence here than in skidding, due to the necessity of handling individual pieces. Logs averaging 18 inches in diameter cost four times as much per thousand board feet to bunch as those averaging 38 inches. At 38 inches the cost increases slightly to 42 inches. Bunching is unnecessary above this size because one log constitutes a good sized load. It should be remembered in this connection that 32-foot log lengths predominated on this operation.

The outstanding factor of bunching cost is the number of pieces handled per bunch. No great difference in time of handling was noted for pieces of 100 board feet as compared to pieces of 2000 board feet.

[3] Bunching data here presented are the work of W. H. Horning, as part of this general study. They are taken from his thesis "The role of bunching in tractor logging," submitted for the degree of Master of Science in Forestry in the graduate division of the University of California, May, 1928.

TABLE 10

Influence of Log Size (Volume) on Cost of Bunching per M. B. M.

Volume of 16-foot log, M. B. M.	Items of time varying with volume, minutes per M. B. M.	Items of time independent of volume, minutes per M. B. M.	Total time, minutes per M. B. M.	Cost per M. B. M.
100	16.63	1.72	18.35	$1.94
200	9.80	1.72	11.52	1.22
300	6.82	1.72	8.54	.90
400	5.23	1.72	6.95	.74
500	3.77	1.72	5.49	.58
600	2.94	1.72	4.66	.49
700	2.17	1.72	3.89	.41
800	1.65	1.72	3.37	.36
900	1.30	1.72	3.02	.32
1000	1.00	1.72	2.72	.29
1100	1.01	1.72	2.73	.29
1200	1.14	1.72	2.86	.30
1300	1.40	1.72	3.12	.33

Average time per piece.....4.21 minutes
Average number of pieces per bunch.....3.86
Average volume per bunch.....2330 board feet
Average volume per piece..... 600 board feet
Average time per bunch.....16.55 minutes
Average cost per M. B. M.....$0.75*

* This is for timber actually handled in bunching and not for total volume yarded.

TABLE 11

Influence of Load on Cost of Wheel Yarding per M. B. M.

Load	Study B-3 (average distance 750 feet)		Study B-4 (average distance 400 feet)		Study C-3 (average distance 1270 feet)		Study E (average distance 630 feet)	
	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.
Board feet	*Minutes*	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*
600	18.30	2.62	14.91	2.12	19.79	2.84	11.70	1.70
800	18.37	1.97	14.93	1.60	19.83	2.13	11.75	1.28
1000	18.45	1.58	14.95	1.29	19.95	1.72	11.80	1.03
1200	18.54	1.33	14.97	1.07	20.16	1.44	11.86	.86
1400	18.62	1.14	15.00	.92	20.43	1.25	11.94	.75
1600	18.70	1.00	15.05	.81	20.73	1.11	12.01	.66
1800	18.78	.90	15.09	.72	21.02	1.00	12.09	.59
2000	18.86	.81	15.12	.65	21.33	.92	12.16	.53
2200	18.95	.74	15.15	.59	21.64	.85	12.24	.49
2400	19.04	.68	15.17	.54	21.95	.79	12.32	.45
2600	19.12	.63	15.20	.50	22.25	.74	12.40	.42
2800	19.21	.59	15.22	.47	22.54	.69	12.47	.39
3000	19.30	.55	15.24	.44	22.87	.66	12.55	.37
3200	19.40	.52	15.25	.41	23.10	.62	12.63	.34
3400	19.50	.49	15.27	.39	23.38	.59	12.71	.33

The important element is, therefore, the average time per piece which in this case was found to be 4.21 minutes. The high cost of bunching small timber is consequently due to the large number of pieces required to make a load, since the cost of bunching is in direct proportion to the number of pieces handled. This is of the utmost importance to operators who must buck their timber in 16-foot lengths in the woods.

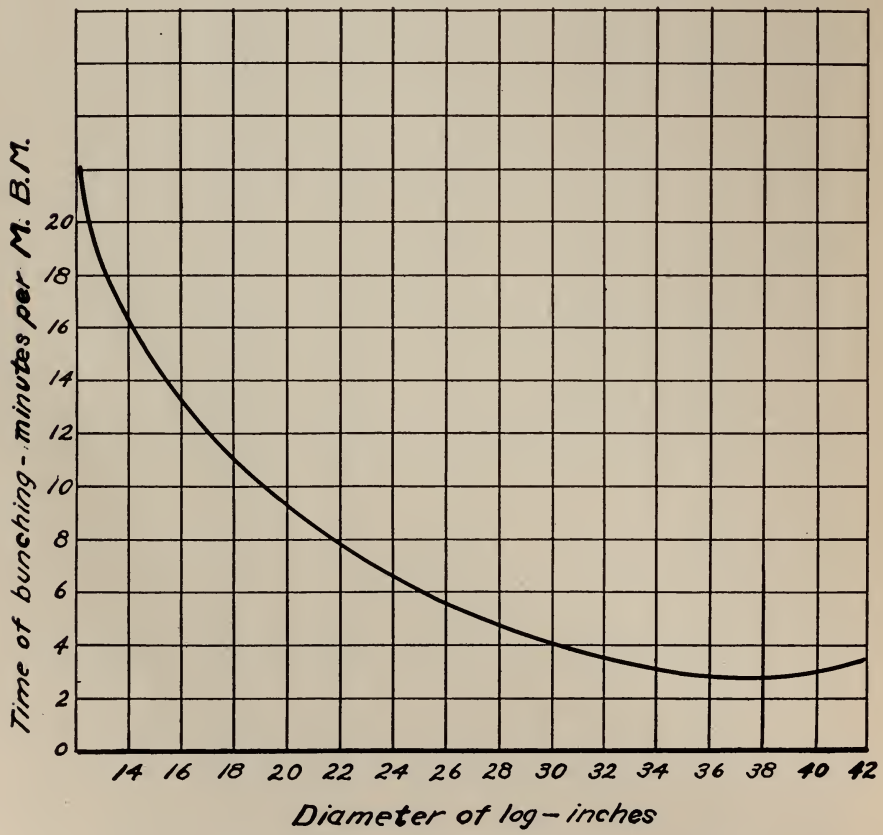

Fig. 6.—Time cost of bunching logs as influenced by diameter.

Effect of Size of Load.—The effect of load is even more pronounced in wheel yarding than in ground skidding. With the lack of friction, due to the load being supported, load has less effect on the time of the average trip. As can be ascertained from table 11 the trip time for a 3400 board feet load on an average is increased only 9 per cent over that for 600 board feet, while the cost per thousand board feet is decreased 81 per cent. In all studies the cost of yarding loads of 600

board feet is approximately five times that of loads of 3400 board feet. The trend of the data shown in figure 7 indicates that the practical maximum load is probably not greater than 4000 board feet. With this pronounced effect of size of load it is readily seen that with log lengths of 16 feet there is danger on the one hand of excessively high yarding costs if small bunches are the rule and on the other hand, of excessively high bunching costs if a high average load is maintained.

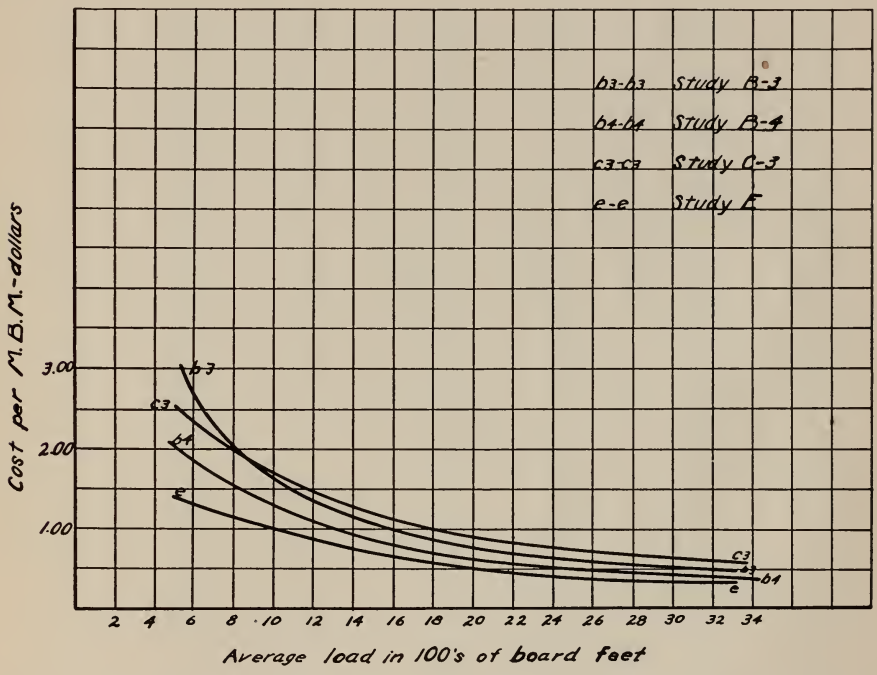

Fig. 7.—Cost of yarding with Robinson big-wheels as influenced by size of load.

Effect of Slope.—The cost of wheel yarding logs is not influenced to such a great extent by slope as is the cost of ground skidding. With a supported load, the size of allowable load is not affected to as great a degree by variations in slope. However, there is still an increase of cost with decrease of favorable slope and increase of adverse slope as shown in table 12. The costs as given are calculated on the same basis as explained on pages 14 and 18, and do not include the cost of bunching. Just as in the case of ground skidding the element which controls difference in cost of yarding on favorable slopes as against adverse slopes is size of load.

TABLE 12

COST OF WHEEL YARDING AS INFLUENCED BY DISTANCE

Maximum yarding distance	Adverse slope, 1 to 7 per cent (Average load 1800 board feet)		Level (Average load 2200 board feet)		Favorable slope, 1 to 10 per cent (Average load 2200 board feet)	
	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.	Time of average trip	Cost per M. B. M.
Feet	*Minutes*	*Dollars*	*Minutes*	*Dollars*	*Minutes*	*Dollars*
400	10.60	.52	10.60	.42	9.32	.38
500	11.06	.54	11.06	.45	9.77	.40
600	11.53	.57	11.53	.47	10.20	.41
700	11.99	.59	11.99	.49	10.63	.43
800	12.46	.62	12.46	.50	11.06	.45
900	12.93	.63	12.93	.52	11.50	.46
1000	13.40	.66	13.40	.54	11.94	.48
1100	13.87	.68	13.87	.56	12.37	.50
1200	14.33	.71	14.33	.58	12.81	.52
1300	14.81	.73	14.81	.60	13.24	.54
1400	15.27	.76	15.27	.62	13.67	.55
1500	15.74	.78	15.74	.64	14.11	.57
1600	16.20	.80	16.20	.65	14.55	.59
1700	16.67	.82	16.67	.67	14.98	.60
1800	17.14	.84	17.14	.69	15.41	.62
1900	17.61	.87	17.61	.71	15.84	.64
2000	18.08	.89	18.08	.73	16.29	.66
2100	18.54	.92	18.54	.75	16.72	.68
2200	19.02	.94	19.02	.77	17.15	.69
2300	19.48	.96	19.48	.79	17.58	.71
2400	19.95	.98	19.95	.81	18.02	.73
2500	20.41	1.01	20.41	.82	18.46	.75
2600	20.89	1.03	20.89	.85	18.89	.76
2700	21.35	1.06	21.35	.86	19.32	.78
2800	21.82	1.08	21.82	.88	19.76	.80
2900	22.28	1.10	22.28	.90	20.19	.81
3000	22.75	1.13	22.75	.92	20.63	.83
3100	23.22	1.15	23.22	.94	21.06	.85
3200	23.69	1.17	23.69	.96	21.50	.87
3300	24.15	1.19	24.15	.98	21.93	.89
3400	24.62	1.22	24.62	.99	22.37	.90
3500	25.09	1.24	25.09	1.01	22.80	.92
3600	25.56	1.26	25.56	1.03	23.23	.94
3700	26.03	1.29	26.03	1.05	23.67	.96
3800	26.49	1.31	26.49	1.07	24.10	.97
3900	26.96	1.33	26.96	1.09	24.54	.99
4000	27.43	1.36	27.43	1.11	24.97	1.01

While definite data are lacking for wheel yarding on favorable slopes greater than 10 per cent, the cost per thousand board feet evidently increases beyond this point. The "out" time is bound to increase markedly and, undoubtedly, without a commensurate increase in the size of the average load. As was stated under skidding, it is above 10 per cent on favorable slopes that ideal conditions for skidding are encountered. It is therefore logical to suppose that the point is soon reached on slopes greater than 10 per cent where skidding is to

be favored over wheel yarding since there is no bunching cost entailed and since wheel yarding costs are probably increasing.

Effect of Yarding Distance.—Distance has the same general influence on cost of yarding with wheels as on cost of ground skidding. The increase in cost with increase in distance is not as rapid, however, due to the larger load handled. The costs of wheel yarding for distances up to 4000 feet, and for favorable, level, and adverse slopes, are shown in table 12.

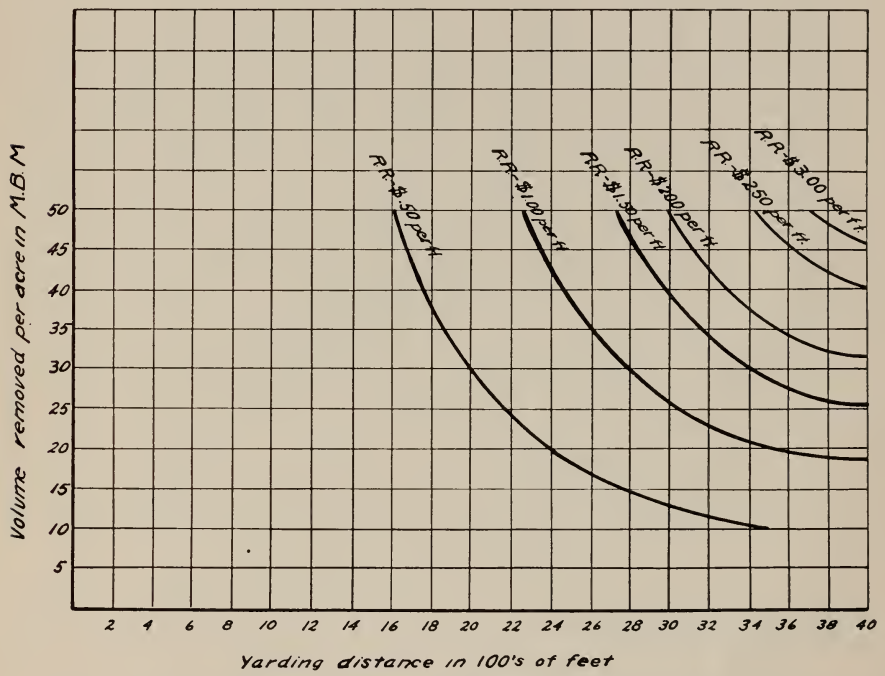

Fig. 8.—Economic yarding distance with Robinson big wheels for level and favorable slopes up to 10 per cent, based on volume removed per acre and cost of railroad per foot. Use of diagram:

1. Start with known volume per acre on left margin.
2. Read horizontally to the right to known cost of railroad.
3. Read down vertically to economic yarding distance.

For example, with a known stand per acre of 30 thousand board feet and a known cost for railroad of $.50 per foot, the economic yarding distance is 2000 feet.

The question of the most efficient distance for wheel yarding is just as important as for ground skidding. The economic maximum distance is shown in figures 8 and 9.[4] No great difference was found

[4] It should be noted both for these figures and for those covering skidding that they are extended for distances somewhat beyond the original data. It is possible, therefore, that for distances greater than one-half mile the trends of tractor operating costs may differ from those indicated. This would alter the cost of yarding and necessarily the economic maximum yarding distance.

between level and favorable slopes so the data were combined in figure 8. The effect of adverse slope is to shorten the economic maximum distance, as shown in figure 9. These figures are based upon the combined costs given in table 12 and tables 15 to 22 (see Appendix), inclusive.

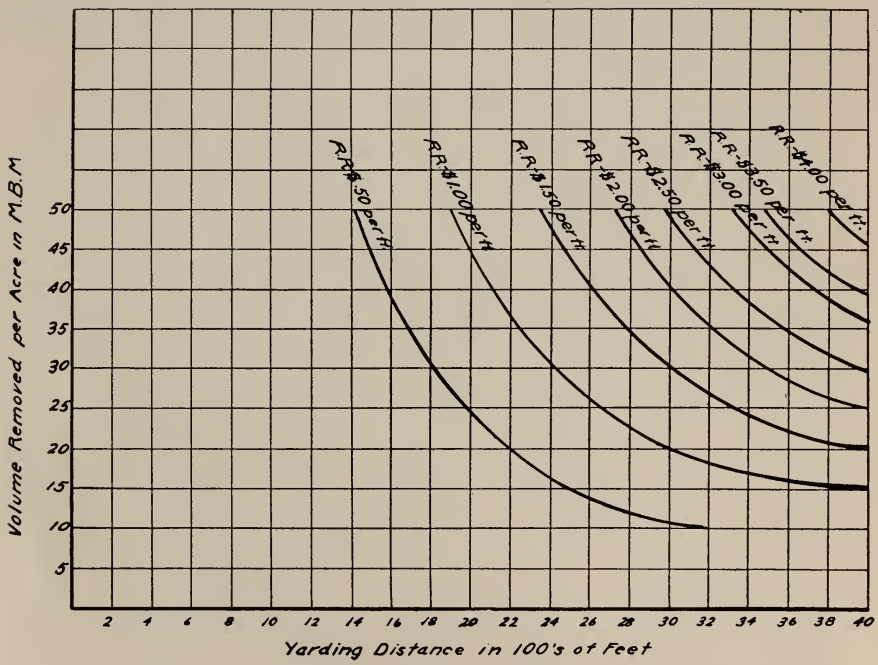

Fig. 9.—Economic yarding distance with Robinson big wheels for adverse slopes of 1 to 7 per cent, based on volume removed per acre and cost of railroad per foot. Use of diagram:

1. Start with known volume per acre on left margin.
2. Read horizontally to the right to known cost of railroad.
3. Read down vertically to economic yarding distance.

For example, with a known stand per acre of 30 thousand board feet and a known cost for railroad of $.50 per foot, the economic yarding distance is 1800 feet.

Wheel yarding is unquestionably more effective than ground skidding on adverse and level grades because of the lesser influence of surface conditions with a supported load. But on favorable slopes the distance yarded determines which method gives the cheaper cost. On favorable slopes the distance at which wheel yarding becomes cheaper than ground skidding under various conditions of log size and bunching cost is shown in figure 10. This is based on data contained in tables 8 and 12. The figure shows that in large timber where the bunching cost is most likely to be 50 cents per thousand board feet,

wheel yarding becomes the cheaper method at 600 feet. In medium-sized timber, the bunching cost will average closer to 75 cents per thousand board feet, and here wheel yarding becomes the cheaper method at 1600 feet. In the same manner, wheel yarding is found to become the cheaper method at 2100 feet for small logs where bunching is very likely to cost as much as $1.00 per thousand board feet.

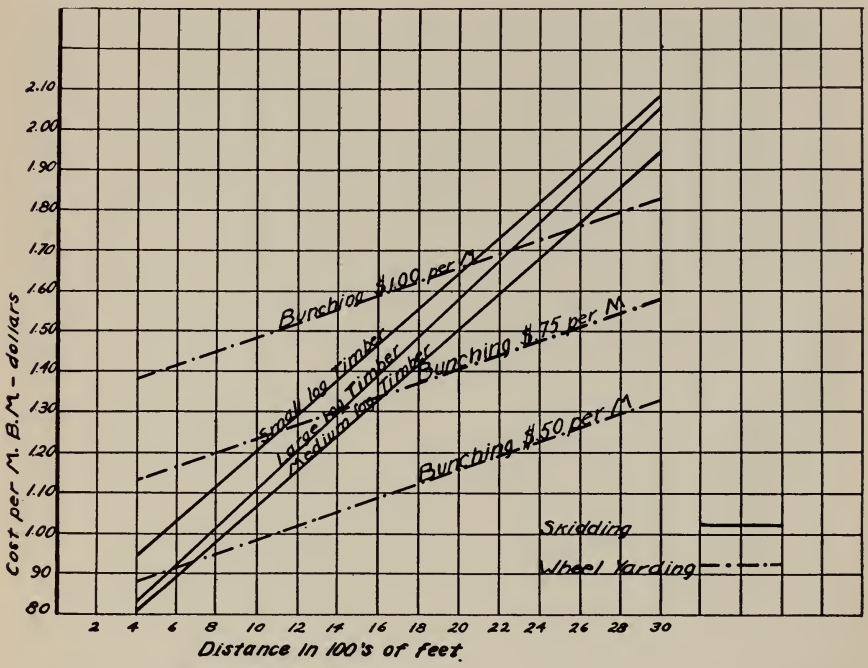

Fig. 10.—Diagram showing comparative costs of yarding logs by skidding, and with Robinson big wheels for varying sizes of timber and varying costs of bunching. The diagram applies to favorable slopes only.

Output per Day per Unit.—The data on daily output for yarding with Robinson big wheels is shown in table 13. This table was prepared and is used in the same manner as the table on output for skidding (table 9). The most common use of such a table is to determine the number of wheel units to be used for a given distance and a given capacity of loading equipment.

FAIR-LEAD WHEEL YARDING

Wheel yarding with hydraulic big wheels is rapidly giving way to yarding with fair-lead wheels. In this type of wheel yarding the tractor is equipped with a single drum at the rear (see figure 11), from which a cable is run through a fair-lead mounted on the arch

bar of the big wheels. The chokers are then attached to a hook in the end of this cable. In operation, the cable is pulled in with the desired number of logs attached until the load is suspended under the arch.

TABLE 13

OUTPUT PER DAY PER WHEEL-YARDING UNIT

Maximum yarding distance	Adverse slope, 1 to 7 per cent (Average load 1800 bd. ft.)	Level (Average load 2200 bd. ft.)	Favorable slope. 1 to 10 per cent (Average load 2200 bd. ft.)
Feet	*Board feet*	*Board feet*	*Board feet*
400	81,000	99,000	112,200
500	77,400	94,600	107,800
600	73,800	90,200	103,400
700	72,000	88,000	99,000
800	68,400	83,600	94,600
900	66,600	81,400	90,200
1000	63,000	77,000	88,000
1100	61,200	74,800	83,600
1200	59,400	72,600	81,400
1300	57,600	70,400	79,200
1400	55,800	68,200	77,000
1500	54,000	66,000	74,800
1600	52,200	63,800	72,600
1700	50,400	61,600	70,400
1800	50,400	61,600	68,200
1900	48,600	59,400	66,000
2000	46,800	57,200	63,800
2100	45,000	55,000	61,600
2200	45,000	55,000	61,600
2300	43,200	52,800	59,400
2400	43,200	52,800	57,200
2500	41,400	50,600	57,200
2600	41,400	50,600	55,000
2700	39,600	48,400	52,800
2800	39,600	48,400	52,800
2900	37,800	46,200	50,600
3000	37,800	46,200	50,600
3100	36,000	44,000	48,400
3200	36,000	44,000	48,400
3300	34,200	41,800	46,200
3400	34,200	41,800	46,200
3500	34,200	41,800	46,200
3600	32,400	39,600	44,000
3700	32,400	39,600	44,000
3800	32,400	39,600	44,000
3900	30,600	37,400	41,800
4000	30,600	37,400	41,800

The drum is then dogged and the load hauled to the landing. No time study was made of this type of yarding but it is desired to present a few considerations with regard to its possibilities, because it does offer a means of increasing the average volume handled per trip over that of ground skidding without entailing the bunching charges incidental to the use of Robinson big wheels. It is assumed that the average load will be 1500 board feet, considerably more than occurs

in ground skidding, but somewhat less than occurs with Robinson big wheels. In addition, it is assumed that the total trip time will be half way between that for ground skidding and that for Robinson wheels. Since the system is one in which only one end of the load is supported, it is believed that these assumptions are conservative. The data presented in table 14 are based on the foregoing assumptions.

Fig. 11.—Fair-lead wheel yarding. Note the drum mounted on the rear of the tractor, for hauling in the logs. This big wheel is equipped with Athey truss wheels. It is also equipped with the same type of wheel as shown in figure 5. (Photo by courtesy of the Caterpillar Tractor Co.)

Comparison with tables 8 and 12 for ground skidding and Robinson wheel yarding, respectively, shows that yarding with fair-lead wheels is the cheapest of the three methods under the given conditions of load. However, it is possible to handle a much larger load with Robinson wheels than is the common practice at present. If this is done and if at the same time, the bunching cost is held down to a moderate price, it is very likely that yarding with Robinson wheels is cheaper than with fair-lead wheels especially for the longer distances. For example, the cost of fair-lead wheel yarding to a maximum distance of 2500 feet is shown in table 14 as $1.21 per thousand board feet.

Table 12 shows the average trip time for Robinson wheel yarding at the same maximum distance, as being 18.46 minutes. At $.086 per minute the cost per trip is therefore $1.59. If now an average load of 3000 board feet per trip is maintained, the cost per thousand becomes $0.53. Under these conditions, then, Robinson wheel yarding is the cheaper so long as the bunching cost remains less than $0.68 per thousand. These comments on fair-lead yarding are offered merely as indications of possible limits of the system. Further study should be made of this type of logging.

TABLE 14

FAIR-LEAD WHEEL YARDING

(Probable data for moderate slopes)

Maximum yarding distance	Total time of average trip	Output per day per unit (Load 1500 board feet)	Cost per M. B. M. (Load 1500 board feet)
Feet	*Minutes*	*Board feet*	*Dollars*
400	10.01	72,000	.59
500	10.51	67,500	.62
600	11.00	64,500	65
700	11.50	61,500	.68
800	12.00	60,000	.71
900	12.50	57,000	.74
1000	12.99	55,500	.77
1100	13.49	52,500	.80
1200	13.99	51,000	.83
1300	14.48	49,500	.85
1400	14.98	48,000	.88
1500	15.48	46,500	.91
1600	15.97	45,000	.94
1700	16.47	43,500	.97
1800	16.97	42,000	1.00
1900	17.47	40,500	1.03
2000	17.96	39,000	1.06
2100	18.46	39,000	1.09
2200	18.96	37,500	1.12
2300	19.45	36,000	1.15
2400	19.95	36,000	1.18
2500	20.45	34,500	1.21
2600	20.94	34,500	1.24
2700	21.44	33,000	1.26
2800	21.94	31,500	1.29
2900	22.14	31,500	1.32
3000	22.93	31,500	1.35
3100	23.43	30,000	1.38
3200	23.93	30,000	1.41
3300	24.42	28,500	1.44
3400	24.92	28,500	1.47
3500	25.42	27,000	1.50
3600	25.91	27,000	1.53
3700	26.41	27,000	1.56
3800	26.91	25,500	1.59
3900	27.41	25,500	1.62
4000	27.90	25,500	1.65

ORGANIZATION OF LABOR AND MECHANICAL UNITS

From the foregoing data it is immediately seen that organization has a great deal to do with the successful use of tractors in logging. Proper balance of yarding and loading equipment has already been mentioned under output per day, for both skidding and wheel yarding. A more specific example of this occurred on study A (see table 1) where four tractors were used. The average maximum distance was limited to about 650 feet by the fact that the logging was being done between two railroad spurs. At this distance the output per tractor is 40 thousand board feet per day. The capacity of loading equipment used was 120 thousand board feet at an absolute maximum. Under these conditions three tractors would have been ample for yarding and the fourth could have been released for such a use as railroad grading. But balance of equipment is not the only phase of organization bearing on successful tractor logging. Supervision of both men and procedure is also highly important. Lack of it is responsible for the high percentage of time lost "waiting for choker setters" and for the low average load in study D. Short-dimension logs have a tendency to decrease the average load and therefore increase the cost per thousand board feet. Avoiding an unnecessarily high proportion of short lengths or diminishing the effect of their presence through proper choice of equipment is largely a matter of careful planning and organization. Rates of pay, method of payment, number of chokers used, type of bunching employed are other factors of organization the effect of which can very quickly be reflected in the cost of yarding.

USE OF TRACTORS IN FOREST MANAGEMENT

No one development of recent years has been so readily applicable to selective logging as tractor yarding; whether such selective logging be for the purpose of taking out only the commercially valuable species or to promote sustained yield management. This applicability is due to the ease with which tractors can go around obstacles and to the absence of such special rigging charges as occur in the placing of auxiliary bull blocks, in order to practice selective logging with donkey equipment.

Two common demands of good forestry practice in tractor logging are the holding of tractor travel to well defined skidding trails and turn-out places and the avoidance of choking two logs at ends adjacent

to the same cut. In the latter case one log must first be pulled up alongside the other in order to avoid "side swiping" young reproduction. The additional time spent in observing these forestry practices on operations C–1 and D which were located on timber sales of the United States Forest Service over that which occurred on the private lands of operations A and B-1 was found to be negligible. Studies of the United States Forest Service[5] have also shown that tractors, properly used, cause a remarkably low damage to the residual stand, especially the pole sizes. These studies apply to ground skidding which in general causes less damage than wheel yarding. In the final analysis, the use of tractors, with regard to forestry practice, is largely one of organization. If the attitude and determination of the operator is to the end that forestry shall be practiced and proper organization is secured with this in view, very little if any additional expense accrues to the logging operation.

SUMMARY

The data obtained from these studies lead to the following outstanding conclusions:

1. Other factors being equal, small-diameter logs cost considerably more to yard by ground skidding than do large-diameter logs, owing to the difficulty of maintaining a high average load per trip. This can be somewhat offset by logging in long dimensions or by hauling a larger number of logs per trip.

2. It is economy to leave small-diameter trees standing.

3. Size of load is the biggest factor affecting the cost of yarding because the increase in the total trip time is nowhere proportionate to the increase in the size of the load. The size of the load is basic to the factors of log size, slope and surface conditions.

4. Slope produces a greater effect on the cost of ground skidding than on wheel yarding. Increase of adverse slopes materially decreases the load per trip and therefore increases the cost per thousand board feet for both methods of yarding. Favorable slopes of 10 per cent to 30 per cent are ideal for skidding, with the practical maximum at 50 per cent.

[5] Unpublished data of the Branch of Forest Management, District 5, United States Forest Service.

5. The larger possibility of excessive yarding cost comes from yarding short of the economic maximum distance rather than beyond it.

6. Bunching cost is a very large factor of yarding cost in the use of Robinson big wheels. The cost of bunching is practically in direct proportion to the number of pieces handled per bunch.

7. The main requisite for successful tractor logging is proper organization. The very important item of maintaining a high average load per trip is largely a matter of proper supervision, and proper balance of equipment is the result of careful planning.

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Thanks are especially due the following logging executives who so kindly gave permission for these studies to be conducted on their operations and who gave much information on the general aspects of tractor logging: Mr. H. R. Lowell, formerly General Manager Yosemite Lumber Company; Mr. T. R. Wills, Logging Superintendent, The Red River Lumber Company; Mr. D. H. Steinmetz, General Manager, Pickering Lumber Company; Mr. Tom Jackson, Assistant Manager, Lumber Division of Fruit Growers Supply Company; Mr. Elmer Hall, Logging Superintendent, The McCloud River Lumber Company; and Mr. C. D. Terwilliger, General Manager, Clover Valley Lumber Company. Professor W. H. Horning of the Pennsylvania State Forest Academy, in addition to securing the data on bunching, gave many valuable suggestions. Much information on tractor operating costs was obtained from Professor R. L. Adams, Farm Management Division, University of California, and from Mr. J. H. Howell, Caterpillar Tractor Company. Many valuable suggestions have been offered by numerous other individuals, especially my colleagues in the Division of Forestry and the members of the staff of the California Forest Experiment Station, to all of whom thanks are given. Mention should also be made of the work of Mr. Myron T. Bunger and Mr. James G. Osborne, students in the Division of Forestry, who respectively did considerable of the field work and computations.

APPENDIX

Tables on Railroad Costs (Tables 15 to 22)
Glossary of Logging Terms

TABLE 15

CHARGES PER M. B. M. FOR RAILROAD COSTING $.50 PER FOOT

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	5.50	3.66	2.75	2.14	1.78	1.53	1.34	1.19	1.07
500	4.36	2 91	2.18	1.74	1.45	1.23	1.08	.97	.88
600	3.62	2.41	1.81	1.45	1.21	1.03	.91	.80	.72
700	3.11	2 07	1.55	1.24	1.04	.89	.78	.69	.62
800	2.72	1.81	1.36	1.09	.91	.78	.68	.60	.54
900	2.42	1.61	1.21	.97	.81	.69	.61	.54	.48
1000	2.18	1.45	1.09	.87	.73	.62	.55	.49	.44
1100	1.98	1.32	.99	.79	.66	.57	.50	.44	.40
1200	1.82	1.21	.91	.73	.61	.52	.45	.40	.36
1300	1.68	1.12	.84	.67	.56	.48	.42	.37	.34
1400	1.55	1.06	.78	.62	.52	.44	.39	.35	.31
1500	1.45	.97	.73	.58	.48	.41	.36	.32	.29
1600	1.36	.91	.68	.54	.45	.39	.34	.30	.27
1700	1.28	.86	.64	.51	.43	.37	.32	.28	.26
1800	1.21	.81	.61	.48	.40	.35	.30	.27	.24
1900	1.15	.77	.57	.46	.38	.33	.29	.25	.23
2000	1.09	.73	.54	.44	.36	.31	.27	.24	.22
2100	1.04	.69	.52	.42	.35	.30	.26	.23	.21
2200	.99	.66	.50	.40	.33	.28	.25	.22	.20
2300	.95	.63	.47	.38	.32	.27	.24	.21	.19
2400	.91	.61	.45	.36	.30	.26	.23	.20	.18
2500	.87	.58	.44	.35	.29	.25	.22	.19	.17
2600	.83	.56	.42	.34	.28	.24	.21	.19	.17
2700	.81	.54	.40	.32	.27	.23	.20	.18	.16
2800	.78	.52	.39	.31	.26	.22	.19	.17	.16
2900	.75	.50	.38	.30	.25	.22	.19	.17	.15
3000	.73	.48	.36	.29	.24	.21	.18	.16	.15
3100	.70	.46	.35	.28	.23	.20	.18	.16	.14
3200	.68	.45	.34	.27	.22	.19	.17	.15	.13
3300	.66	.43	.33	.26	.22	.19	.17	.15	.13
3400	.64	.42	.32	.25	.21	.18	.16	.14	.13
3500	.62	.41	.31	.25	.21	.18	.16	.14	.12
3600	.60	.40	.30	.24	.20	.17	.15	.13	.12
3700	.59	.39	.29	.24	.20	.17	.15	.13	.12
3800	.57	.38	.28	.23	.19	.16	.14	.12	.11
3900	.56	.37	.28	.23	.19	.16	.14	.12	.11
4000	.54	.36	.27	.22	.18	.15	.13	.12	.11

TABLE 16

Charges per M. B. M. for Railroad Costing $1.00 per Foot

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	11.00	7.34	5.50	4.40	3.66	3.14	2.75	2.44	2.20
500	8.73	5.82	4.36	3.49	2.91	2.48	2.18	1.94	1.74
600	7.24	4.82	3.61	2.89	2.41	2.07	1.81	1.61	1.45
700	6.22	3.84	3.10	2.48	2.07	1.77	1.55	1.38	1.24
800	5.45	3.63	2.72	2.18	1.81	1.56	1.36	1.21	1.09
900	4.85	3.23	2.42	1.94	1.61	1.38	1.21	1.10	.97
1000	4.36	2.91	2.18	1.74	1.45	1.25	1.09	.97	.87
1100	3.97	2.65	1.98	1.59	1.32	1.13	.99	.88	.79
1200	3.64	2.43	1.82	1.46	1.21	1.04	.91	.81	.73
1300	3.36	2.25	1.68	1.34	1.12	.96	.84	.75	.67
1400	3.10	2.07	1.55	1.24	1.04	.89	.78	.69	.62
1500	2.90	1.93	1.45	1.16	.97	.83	.73	.64	.58
1600	2.72	1.81	1.36	1.09	.91	.78	.68	.60	.54
1700	2.56	1.71	1.28	1.02	.85	.73	.64	.57	.51
1800	2.42	1.61	1.21	.97	.81	.69	.61	.54	.48
1900	2.30	1.53	1.15	.92	.77	.66	.57	.51	.46
2000	2.18	1.45	1.09	.87	.73	.62	.54	.48	.44
2100	2.08	1.39	1.04	.83	.69	.59	.52	.46	.42
2200	1.98	1.32	.99	.79	.66	.57	.50	.44	.40
2300	1.90	1.27	.95	.76	.63	.54	.48	.42	.38
2400	1.82	1.21	.91	.73	.61	.52	.46	.40	.36
2500	1.74	1.16	.87	.70	.58	.50	.44	.39	.35
2600	1.66	1.12	.84	.67	.56	.48	.42	.37	.34
2700	1.61	1.08	.81	.65	.54	.46	.40	.36	.32
2800	1.56	1.04	.78	.62	.52	.44	.39	.35	.31
2900	1.50	1.00	.75	.60	.50	.43	.38	.33	.30
3000	1.45	.97	.73	.58	.49	.42	.36	.32	.29
3100	1.40	.94	.70	.56	.47	.40	.35	.31	.28
3200	1.36	.91	.68	.55	.46	.39	.34	.30	.27
3300	1.32	.88	.66	.53	.44	.38	.33	.29	.26
3400	1.28	.86	.64	.51	.43	.37	.32	.29	.26
3500	1.24	.83	.62	.50	.42	.36	.31	.28	.25
3600	1.21	.81	.61	.49	.41	.35	.31	.27	.24
3700	1.18	.79	.58	.47	.40	.34	.30	.26	.24
3800	1.15	.77	.57	.46	.39	.33	.29	.26	.23
3900	1.12	.75	.56	.45	.38	.32	.28	.25	.22
4000	1.09	.73	.55	.44	.37	.31	.27	.24	.22

TABLE 17

CHARGES PER M. B. M. FOR RAILROAD COSTING $1.50 PER FOOT

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	16.47	10.99	8.26	6.60	5.50	4.72	4.13	3.67	3.30
500	13.09	8.73	6.55	5.23	4.36	3.74	3.27	2.91	2.62
600	10.83	7.23	5.43	4.34	3.61	3.11	2.71	2.41	2.17
700	9.33	6.21	4.66	3.73	3.11	2.66	2.33	2.07	1.86
800	8.18	5.44	4.08	3.26	2.72	2.33	2.04	1.81	1.63
900	7.27	4.84	3.63	2.91	2.42	2.07	1.81	1.61	1.45
1000	6.54	4.36	3.27	2.62	2.18	1.87	1.64	1.45	1.31
1100	5.95	3.97	2.98	2.38	1.98	1.70	1.49	1.32	1.19
1200	5.46	3.64	2.73	2.18	1.82	1.56	1.36	1.21	1.09
1300	5.04	3.36	2.52	2.01	1.68	1.44	1.26	1.12	1.01
1400	4.69	3.13	2.34	1.87	1.56	1.34	1.17	1.04	.94
1500	4.38	2.92	2.19	1.75	1.46	1.25	1.09	.97	.88
1600	4.08	2.72	2.04	1.63	1.36	1.17	1.02	.91	.82
1700	3.84	2.56	1.92	1.54	1.28	1.10	.96	.86	.77
1800	3.63	2.42	1.81	1.45	1.21	1.04	.91	.81	.73
1900	3.44	2.29	1.72	1.37	1.15	.99	.86	.77	.69
2000	3.27	2.18	1.64	1.31	1.09	.94	.82	.73	.66
2100	3.12	2.08	1.56	1.25	1.04	.89	.78	.69	.62
2200	2.98	1.98	1.49	1.19	.99	.84	.74	.66	.60
2300	2.85	1.90	1.42	1.14	.95	.81	.71	.63	.57
2400	2.73	1.82	1.36	1.09	.91	.78	.68	.61	.55
2500	2.61	1.74	1.30	1.04	.87	.75	.65	.58	.52
2600	2.51	1.67	1.25	1.00	.84	.72	.63	.56	.50
2700	2.42	1.61	1.21	.97	.81	.69	.61	.54	.47
2800	2.34	1.56	1.17	.94	.78	.67	.58	.52	.46
2900	2.26	1.50	1.13	.90	.75	.65	.56	.50	.45
3000	2.18	1.45	1.09	.87	.73	.62	.55	.48	.44
3100	2.10	1.40	1.05	.84	.70	.61	.53	.47	.42
3200	2.04	1.36	1.02	.81	.68	.59	.51	.46	.41
3300	1.98	1.32	.99	.79	.66	.57	.49	.44	.40
3400	1.92	1.28	.96	.77	.64	.55	.48	.43	.39
3500	1.87	1.24	.94	.75	.63	.53	.47	.42	.38
3600	1.82	1.21	.91	.73	.61	.52	.46	.41	.37
3700	1.77	1.18	.88	.71	.60	.51	.44	.40	.36
3800	1.72	1.15	.86	.69	.58	.50	.43	.39	.35
3900	1.68	1.12	.84	.68	.56	.48	.42	.38	.34
4000	1.64	1.09	.82	.66	.55	.47	.41	.37	.33

TABLE 18

Charges per M. B. M. for Railroad Costing $2.00 per Foot

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	22.00	14.67	11.00	8.80	7.34	6.29	5.50	4.89	4.40
500	15.82	11.63	8.74	6.99	5.82	4.99	4.37	3.88	3.49
600	14.46	9.65	7.25	5.79	4.82	4.13	3.62	3.22	2.90
700	12.41	8.28	6.20	4.96	4.14	3.55	3.11	2.76	2.48
800	10.88	7.27	5.45	4.35	3.64	3.11	2.72	2.42	2.18
900	9.68	6.47	4.85	3.88	3.24	2.77	2.42	2.15	1.94
1000	8.74	5.82	4.37	3.49	2.91	2.50	2.18	1.94	1.74
1100	7.95	5.30	3.97	3.18	2.65	2.27	1.98	1.76	1.59
1200	7.28	4.86	3.64	2.92	2.43	2.08	1.82	1.62	1.46
1300	6.72	4.49	3.37	2.69	2.24	1.92	1.68	1.49	1.35
1400	6.24	4.17	3.12	2.50	2.08	1.78	1.56	1.39	1.25
1500	5.83	3.89	2.92	2.33	1.95	1.67	1.46	1.30	1.17
1600	5.45	3.63	2.72	2.18	1.82	1.56	1.36	1.21	1.09
1700	5.13	3.42	2.56	2.05	1.71	1.46	1.28	1.14	1.02
1800	4.85	3.23	2.42	1.94	1.62	1.38	1.21	1.08	.97
1900	4.60	3.06	2.29	1.84	1.53	1.31	1.15	1.02	.92
2000	4.37	2.91	2.18	1.75	1.45	1.25	1.09	.97	.87
2100	4.17	2.77	2.08	1.66	1.39	1.19	1.04	.92	.83
2200	3.98	2.65	1.99	1.59	1.32	1.13	.99	.88	.79
2300	3.80	2.53	1.90	1.52	1.27	1.08	.95	.84	.76
2400	3.64	2.43	1.82	1.46	1.21	1.04	.91	.81	.73
2500	3.48	2.33	1.74	1.39	1.16	.99	.87	.78	.70
2600	3.35	2.24	1.68	1.34	1.12	.96	.84	.75	.67
2700	3.23	2.15	1.62	1.29	1.08	.92	.81	.72	.65
2800	3.12	2.08	1.56	1.25	1.04	.89	.78	.69	.62
2900	3.01	2.00	1.51	1.20	1.00	.86	.75	.67	.60
3000	2.91	1.94	1.45	1.16	.97	.83	.73	.65	.58
3100	2.82	1.88	1.40	1.13	.94	.81	.70	.63	.57
3200	2.73	1.82	1.36	1.09	.91	.78	.68	.61	.55
3300	2.65	1.76	1.32	1.06	.89	.75	.66	.59	.53
3400	2.57	1.71	1.28	1.03	.86	.73	.64	.57	.51
3500	2.50	1.67	1.25	1.00	.83	.71	.63	.56	.50
3600	2.43	1.62	1.21	.97	.81	.69	.61	.54	.49
3700	2.36	1.57	1.18	.94	.79	.68	.60	.52	.47
3800	2.30	1.53	1.15	.92	.77	.66	.58	.51	.46
3900	2.25	1.50	1.12	.90	.75	.65	.56	.50	.45
4000	2.19	1.46	1.09	.88	.73	.63	.55	.49	.44

TABLE 19

CHARGES PER M. B. M. FOR RAILROAD COSTING $2.50 PER FOOT

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	27.53	18.35	13.76	11.00	9.19	7.88	6.88	6.12	5.51
500	21.85	14.55	10.90	8.73	7.28	6.25	5.47	4.85	4.37
600	18.09	12.05	9.05	7.25	6.04	5.17	4.53	4.02	3.62
700	15.52	10.36	7.77	6.21	5.18	4.45	3.89	3.46	3.11
800	13.62	9.09	6.82	5.45	4.54	3.88	3.41	3.03	2.72
900	12.11	8.09	6.07	4.85	4.04	3.46	3.03	2.69	2.42
1000	10.90	7.28	5.47	4.37	3.64	3.12	2.73	2.43	2.18
1100	9.94	6.63	4.97	3.97	3.31	2.84	2.48	2.21	1.99
1200	9.12	6.08	4.56	3.65	3.04	2.60	2.28	2.02	1.82
1300	8.42	5.62	4.21	3.37	2.81	2.41	2.11	1.87	1.68
1400	7.83	5.22	3.91	3.13	2.61	2.24	1.95	1.74	1.56
1500	7.31	4.87	3.65	2.92	2.43	2.09	1.82	1.62	1.46
1600	6.82	4.54	3.41	2.72	2.27	1.94	1.70	1.51	1.36
1700	6.42	4.28	3.21	2.57	2.14	1.83	1.60	1.43	1.28
1800	6.07	4.04	3.03	2.43	2.02	1.73	1.52	1.35	1.21
1900	5.75	3.83	2.87	2.30	1.92	1.64	1.44	1.28	1.15
2000	5.47	3.64	2.73	2.18	1.82	1.56	1.36	1.21	1.09
2100	5.20	3.46	2.60	2.08	1.73	1.49	1.30	1.15	1.04
2200	4.96	3.31	2.48	1.99	1.65	1.42	1.24	1.10	.99
2300	4.75	3.16	2.37	1.90	1.58	1.36	1.19	1.05	.95
2400	4.55	3.04	2.28	1.82	1.52	1.30	1.14	1.01	.91
2500	4.35	2.91	2.18	1.74	1.45	1.24	1.09	.97	.87
2600	4.19	2.79	2.09	1.68	1.40	1.20	1.05	.93	.84
2700	4.04	2.69	2.02	1.61	1.34	1.15	1.01	.90	.81
2800	3.90	2.60	1.95	1.56	1.30	1.11	.97	.87	.78
2900	3.76	2.51	1.88	1.50	1.25	1.08	.94	.84	.75
3000	3.64	2.42	1.82	1.45	1.22	1.04	.91	.81	.73
3100	3.52	2.34	1.76	1.40	1.18	1.00	.88	.78	.70
3200	3.41	2.27	1.71	1.36	1.14	.97	.85	.76	.68
3300	3.31	2.20	1.66	1.33	1.10	.95	.82	.74	.66
3400	3.21	2.14	1.61	1.29	1.07	.92	.80	.72	.64
3500	3.13	2.08	1.56	1.26	1.04	.89	.78	.70	.63
3600	3.04	2.02	1.52	1.22	1.01	.87	.76	.68	.61
3700	2.96	1.97	1.48	1.18	.99	.84	.74	.66	.60
3800	2.88	1.92	1.44	1.15	.96	.82	.72	.64	.58
3900	2.81	1.87	1.41	1.12	.93	.80	.70	.63	.56
4000	2.74	1.82	1.37	1.09	.91	.78	.68	.61	.55

TABLE 20

Charges per M. B. M. for Railroad Costing $3.00 per Foot

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	33.00	22.00	16.50	13.20	11.00	9.45	8.25	7.33	6.60
500	26.22	17.47	13.10	10.47	8.74	7.50	6.55	5.73	5.24
600	21.72	14.47	10.86	8.70	7.25	6.21	5.42	4.82	4.34
700	18.13	12.42	9.32	7.45	6.22	5.33	4.66	4.14	3.72
800	16.35	10.90	8.18	6.55	5.45	4.67	4.08	3.63	3.26
900	14.53	9.72	7.28	5.83	4.85	4.16	3.63	3.23	2.91
1000	13.09	8.75	6.57	5.25	4.73	3.75	3.27	2.91	2.62
1100	11.92	7.97	5.97	4.78	3.97	3.41	2.98	2.65	2.38
1200	10.92	7.31	5.47	4.38	3.65	3.13	2.73	2.43	2.18
1300	10.10	6.75	5.05	4.04	3.37	2.89	2.52	2.24	2.02
1400	9.40	6.27	4.70	3.76	3.13	2.68	2.33	2.07	1.86
1500	8.77	5.85	4.38	3.51	2.92	2.46	2.18	1.93	1.74
1600	8.19	5.45	4.09	3.27	2.73	2.34	2.04	1.81	1.63
1700	7.70	5.13	3.87	3.08	2.57	2.20	1.92	1.71	1.54
1800	7.28	4.85	3.64	2.91	2.43	2.08	1.82	1.61	1.45
1900	6.90	4.60	3.45	2.76	2.30	1.97	1.72	1.53	1.38
2000	6.56	4.38	3.28	2.62	2.18	1.87	1.64	1.45	1.31
2100	6.24	4.15	3.12	2.49	2.08	1.78	1.56	1.38	1.25
2200	5.95	3.97	2.96	2.38	1.99	1.70	1.49	1.32	1.19
2300	5.70	3.80	2.85	2.28	1.90	1.63	1.42	1.26	1.14
2400	5.46	3.64	2.73	2.18	1.82	1.56	1.36	1.21	1.09
2500	5.23	3.49	2.61	2.09	1.74	1.49	1.30	1.16	1.05
2600	5.03	3.35	2.51	2.01	1.68	1.43	1.25	1.12	1.01
2700	4.84	3.22	2.42	1.94	1.61	1.38	1.21	1.07	.97
2800	4.67	3.11	2.34	1.87	1.56	1.33	1.17	1.04	.93
2900	4.50	3.01	2.26	1.80	1.50	1.29	1.13	1.00	.90
3000	4.36	2.91	2.18	1.74	1.45	1.24	1.09	.97	.87
3100	4.23	2.82	2.12	1.69	1.41	1.21	1.05	.94	.85
3200	4.10	2.73	2.05	1.64	1.37	1.17	1.02	.91	.82
3300	3.97	2.65	2.00	1.59	1.33	1.13	.99	.89	.79
3400	3.85	2.57	1.94	1.54	1.29	1.10	.96	.86	.77
3500	3.74	2.50	1.88	1.50	1.25	1.07	.94	.83	.75
3600	3.64	2.43	1.82	1.46	1.22	1.04	.91	.81	.73
3700	3.54	2.36	1.78	1.42	1.18	1.01	.88	.79	.71
3800	3.45	2.30	1.73	1.38	1.15	.99	.86	.77	.69
3900	3.37	2.25	1.68	1.34	1.12	.96	.84	.75	.68
4000	3.28	2.19	1.64	1.31	1.09	.94	.82	.73	.66

TABLE 21

CHARGES PER *M.* B. M. FOR RAILROAD COSTING $3.50 PER FOOT

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	38.50	26.66	19.24	15.40	12.82	11.00	9.63	8.55	7.70
500	30.53	20.35	15.26	12.20	10.17	8.65	7.64	6.78	6.11
600	25.28	16.88	12.65	10.12	8.45	7.24	6.33	5.61	5.06
700	21.72	14.50	10.86	8.70	7.25	6.21	5.44	4.83	4.35
800	19.05	12.70	9.53	7.61	6.35	5.48	4.76	4.23	3.81
900	16.94	11.30	8.47	6.78	5.65	4.85	4.24	3.76	3.39
1000	15.28	10.18	7.63	6.10	5.10	4.36	3.82	3.39	3.05
1100	13.88	9.26	6.94	5.55	4.63	3.96	3.48	3.09	2.78
1200	12.73	8.50	6.37	5.10	4.25	3.64	3.19	2.83	2.55
1300	11.76	7.86	5.88	4.70	3.92	3.36	2.94	2.61	2.35
1400	10.87	7.25	5.43	4.35	3.62	3.11	2.62	2.42	2.17
1500	10.09	6.77	5.08	4.06	3.38	2.90	2.54	2.26	2.03
1600	9.52	6.35	4.76	3.81	3.18	2.72	2.38	2.12	1.91
1700	8.96	5.98	4.48	3.59	2.99	2.56	2.25	1.99	1.79
1800	8.48	5.65	4.23	3.39	2.83	2.42	2.12	1.88	1.70
1900	8.04	5.35	4.02	3.21	2.68	2.30	2.01	1.79	1.61
2000	7.63	5.09	3.82	3.05	2.54	2.18	1.91	1.70	1.53
2100	7.27	4.85	3.64	2.91	2.42	2.08	1.82	1.62	1.46
2200	6.94	4.63	3.47	2.78	2.32	1.98	1.73	1.54	1.39
2300	6.65	4.43	3.32	2.66	2.22	1.90	1.66	1.48	1.33
2400	6.37	4.25	3.18	2.55	2.12	1.82	1.59	1.42	1.27
2500	6.10	4.07	3.05	2.44	2.03	1.74	1.52	1.35	1.22
2600	5.86	3.91	2.93	2.35	1.96	1.67	1.47	1.30	1.17
2700	5.65	3.76	2.83	2.26	1.88	1.61	1.41	1.25	1.13
2800	5.45	3.63	2.72	2.18	1.82	1.56	1.36	1.21	1.09
2900	5.26	3.51	2.63	2.10	1.75	1.50	1.31	1.17	1.05
3000	5.09	3.40	2.54	2.04	1.70	1.45	1.27	1.13	1.02
3100	4.91	3.28	2.46	1.97	1.64	1.40	1.23	1.09	.99
3200	4.76	3.18	2.38	1.91	1.59	1.36	1.19	1.06	.96
3300	4.62	3.08	2.31	1.85	1.55	1.32	1.16	1.03	.93
3400	4.48	2.99	2.24	1.80	1.50	1.28	1.13	1.00	.90
3500	4.36	2.91	2.18	1.75	1.46	1.24	1.09	.97	.87
3600	4.24	2.83	2.12	1.70	1.42	1.21	1.06	.94	.85
3700	4.13	2.75	2.06	1.65	1.38	1.18	1.04	.92	.83
3800	4.02	2.68	2.01	1.61	1.34	1.15	1.01	.90	.81
3900	3.92	2.62	1.96	1.57	1.30	1.12	.98	.87	.79
4000	3.82	2.55	1.91	1.53	1.27	1.09	.96	.85	.77

TABLE 22

Charges per M. B. M. for Railroad Costing $4.00 per Foot

Maximum yarding distance	Stand per acre in M. B. M.								
	10	15	20	25	30	35	40	45	50
Feet	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
400	44.05	29.38	22.21	17.60	14.63	12.57	11.00	10.05	8.80
500	34.88	23.26	17.44	13.96	11.61	9.99	8.72	7.75	6.98
600	28.92	19.28	14.45	11.58	9.64	8.27	7.23	6.42	5.79
700	24.84	16.40	12.41	9.94	8.28	7.10	6.21	5.51	4.96
800	21.76	14.51	10.88	8.71	7.25	6.22	5.44	4.83	4.35
900	19.34	12.90	9.69	7.75	6.46	5.52	4.84	4.30	3.87
1000	17.42	11.62	8.73	6.98	5.82	5.00	4.36	3.88	3.49
1100	15.86	10.59	7.95	6.35	5.29	4.53	3.97	3.53	3.18
1200	14.54	9.80	7.28	5.83	4.85	4.16	3.64	3.24	2.91
1300	13.43	9.06	6.73	5.38	4.48	3.84	3.36	2.99	2.69
1400	12.81	8.36	6.21	4.97	4.14	3.55	3.11	2.76	2.48
1500	11.59	7.81	5.80	4.64	3.87	3.32	2.90	2.58	2.32
1600	10.88	7.33	5.45	4.36	3.63	3.11	2.72	2.42	2.18
1700	10.23	6.90	5.13	4.10	3.42	2.93	2.56	2.28	2.05
1800	9.70	6.52	4.85	3.88	3.23	2.76	2.42	2.15	1.94
1900	9.19	6.18	4.59	3.67	3.06	2.63	2.29	2.04	1.83
2000	8.73	5.88	4.37	3.49	2.91	2.50	2.18	1.94	1.74
2100	8.32	5.60	4.16	3.32	2.77	2.38	2.08	1.85	1.66
2200	7.95	5.34	3.97	3.18	2.65	2.27	1.98	1.76	1.59
2300	7.60	5.12	3.80	3.04	2.53	2.17	1.90	1.69	1.52
2400	7.29	4.91	3.64	2.91	2.43	2.08	1.82	1.62	1.46
2500	6.97	4.70	3.48	2.79	2.32	1.98	1.74	1.55	1.39
2600	6.70	4.52	3.35	2.68	2.24	1.92	1.67	1.49	1.34
2700	6.46	4.35	3.23	2.58	2.15	1.84	1.61	1.43	1.29
2800	6.23	4.20	3.12	2.49	2.08	1.78	1.56	1.38	1.24
2900	6.02	4.05	3.01	2.41	2.00	1.72	1.50	1.34	1.20
3000	5.81	3.92	2.91	2.33	1.94	1.66	1.45	1.29	1.16
3100	5.61	3.79	2.82	2.25	1.88	1.61	1.40	1.25	1.12
3200	5.44	3.67	2.73	2.18	1.82	1.56	1.36	1.21	1.09
3300	5.27	3.56	2.65	2.11	1.76	1.51	1.32	1.17	1.06
3400	5.12	3.45	2.57	2.05	1.71	1.47	1.28	1.14	1.03
3500	4.99	3.35	2.50	2.00	1.67	1.42	1.24	1.11	1.00
3600	4.85	3.26	2.43	1.94	1.62	1.38	1.21	1.08	.97
3700	4.72	3.17	2.36	1.89	1.57	1.35	1.18	1.05	.94
3800	4.60	3.09	2.30	1.84	1.53	1.32	1.15	1.02	.92
3900	4.48	3.02	2.25	1.79	1.50	1.28	1.12	.99	.89
4000	4.37	2.94	2.19	1.75	1.46	1.25	1.09	.97	.87

GLOSSARY OF LOGGING TERMS

Big Wheels.—Two-wheeled vehicles with large diameter wheels used for transporting logs. Developed first for use with horses. Modifications have been lately developed for use with tractors (see figures 5 and 11 in text. (One of these modifications (figure 11) has substituted a track-laying wheel for the large-diameter round wheel.

Bull Block.—A large block used to guide the line around obstacles where logs are hauled by moving cables. It is equipped with a sheave about 24 inches in diameter and 8 to 10 inches wide and a large-throated shackle to allow the passage of the hooks and other rigging used in this system of log haulage.

Bunching.—Process of rolling logs into compact piles for transportation with big wheels or other equipment.

Choker.—Piece of cable used to attach logs to hauling equipment. One end is wrapped around the end of the log and hooked on itself; the other is equipped with an eye for hooking to the hauling equipment.

Donkey.—Stationary engine used for power in moving-cable systems of logging.

Fair-lead.—Sheaves or rollers used to guide a moving cable.

Hoist.—An inclined railroad over which cars are hauled by moving cables. Sometimes restricted to that case where the load is hauled up. In the case of the load being lowered it is then termed an incline.

Rigging.—General term used to designate the cable equipment used in moving-cable systems of logging. The verb designates the act of preparing the cables for log haulage.

Skidding.—Hauling logs by snaking them over the surface of the ground.

Sky line.—Cable supported above the surface of the ground, from which is suspended a carriage which wholly or partially supports logs to facilitate their transportation.

Spar tree.—High pole or tree used to support the cable rigging used in certain types of moving-cable logging systems. Two spar poles are used with sky lines.

Yarding.—The initial movement of logs from the felled tree to a central point for transportation with other equipment. Refers to larger quantities of logs than does bunching. (See Bunching.)

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