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SKID TRAIL PRECONSTRUCTION: A CASE STUDY OF LOGGING IMPACTS AND PRODUCTIVITY

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ABSTRACT - On a young-growth redwood/Douglas-fir selection harvest, logging productivity, leave stand damage, and areal extent of skid trails were compared and found to be similar whether or not skid trails were flagged and bladed prior to tree felling and logging. These findings differ from previous similar studies and some reasons for this are discussed. Certain situations are noted where the author feels skid trail preconstruction is advantageous.

Figure 1. Trees being directionally felled to the lead of a preconstructed trial.

Figure 2. Same view as Figure 1. Tractor is pulling logs out of their lay without leaving the preconstructed trail.

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DISCLAIMER

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Ground skidding with tracked skidding equipment and/or rubber-tired skidders is often the choice of timber operators over skyline, balloon or helicopter systems because it is usually less expensive than these other logging systems. Logistical problems, such as inadequate deflection, log size, landing and road location may also dictate the use of ground skidding. However, since the resulting soil disturbance and compaction can have deleterious effects on soil properties (Steinbrenner and Gessel, 1955; Dyrness, 1965; Sidle and Drlica, 1981) and tree growth (Youngberg, 1959; Perry, 1964; Froehlich, 1979), it is desirable to develop skidding strategies that minimize extent of these trails.

This study was designed to evaluate two skidding strategies by comparing differences in logging productivity and disturbance to soil and residual vegetation. The first, called the "preconstructed" strategy in this study, utilized skid trails that were flagged and bladed prior to tree felling. The second, or "conventional" strategy, utilized skid trails constructed by the logging contractor after trees were felled. In every case, existing skid trails were used whenever possible.

STUDY AREA

The study utilized 214 acres of the 251-acre Hare Creek 1980 Timber Sale (HC '80) on the Jackson Demonstration State Forest, Mendocino County, California. Supporting a typical even-aged 80-year-old second growth redwood/Douglas-fir stand, HC '80 was stocked with approximately 75,000 board feet per acre prior to logging in 1981. It was marked to a leave stand basal area of 175 square feet per acre, resulting in a harvest of 36,000 board feet per acre, or nine million board feet for the entire sale.

Total harvested volume consisted of 44 percent Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), 42 percent California coast redwood (*Sequoia sempervirens* [D. Don] Endl.), and 14 percent grand fir (*Abies grandis* [Dougl.] Lindl.). Approximately 50 trees per acre were harvested with an average diameter breast height (DBH) of 26 inches. Average log size was 199.8 board feet.

Slopes have generally northern aspects, range up to 50 percent and average between 20 and 30 percent. Elevations range from 700 to 1,000 feet above sea level. Predominant soil series are Hugo and Mendocino, derived from sandstone, and the erosion hazard ratings range from "moderate" to "high" (California Department of Forestry, 1980).

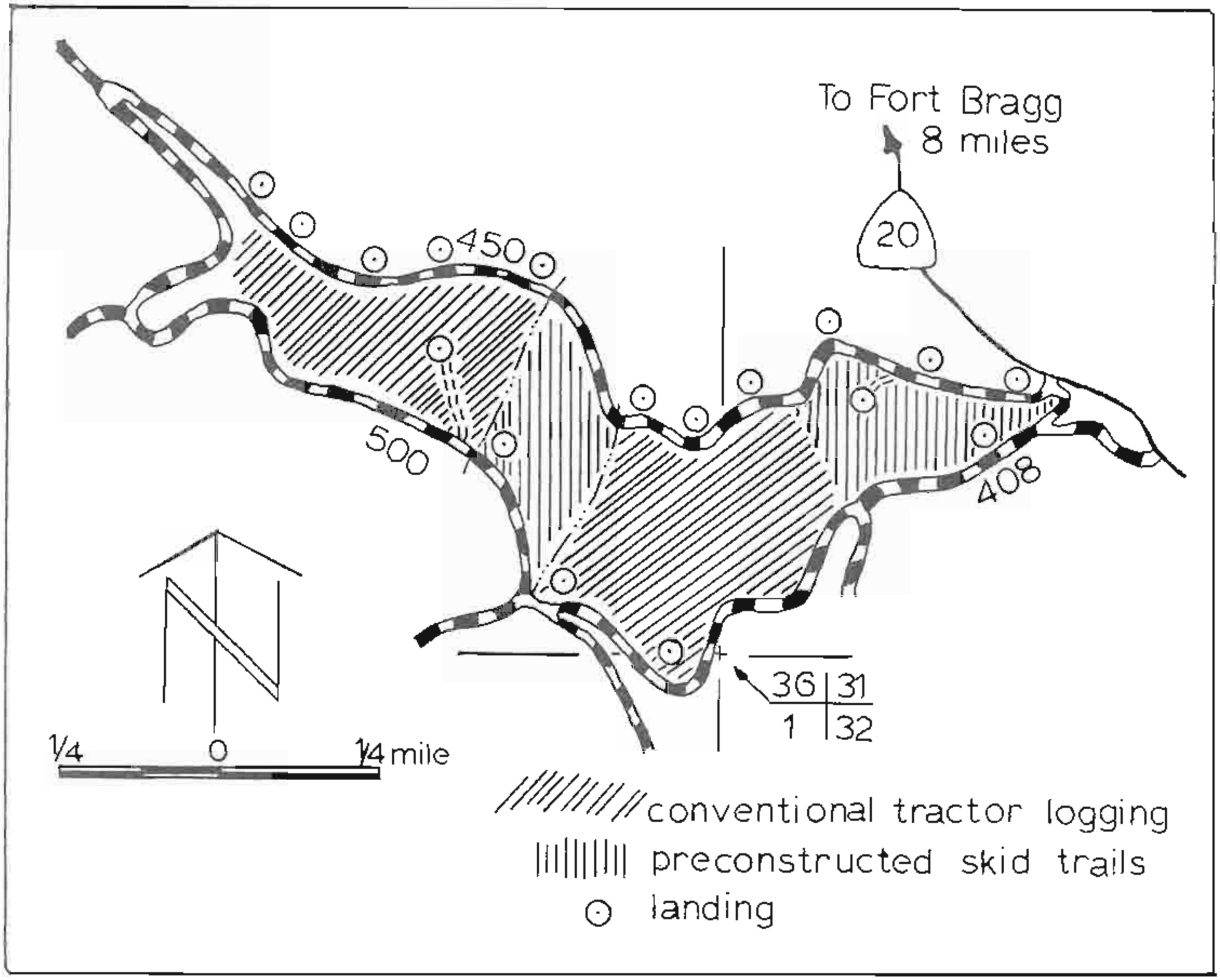

Figure 3. Hare Creek 1980 Timber Sale Study Area.

HARVEST DESIGN

Four skidding units were delineated (Figure 3). Each unit contained a variety of stand densities, slope and soil characteristics, and skidding distances. Main ridges and streams were used as boundaries, resulting in units of unequal sizes. The two conventional units totalled 163 acres while the two preconstructed units totalled 51 acres. In all units, trees were marked for harvest prior to commencement of the study and logging.

In the two preconstructed units, skid trails were flagged jointly by the logging contractor and a forester representing the landowner. Trails were laid out in a manner to ensure accessibility to all downed timber while maintaining a safe distance from sensitive areas such as streams, wet areas and potential slide areas. In most cases it was possible to locate main trails along ridges with herringbone-patterned spurs roughly paralleling contours on either side of the ridges so that steep pitches and draw crossings were kept to a minimum (Figure 4). The forester worked with the tractor operators constructing trails prior to tree felling. A Fiat-Allis 14-C dozer with angle blade was used to clear the trails. In steeper terrain (over 20 percent) some excavation was required; otherwise preconstruction merely consisted of blading brush and litter to delineate trails (see Figure 1). A total of 121 person-hours and 30 tractor-hours were spent flagging and constructing trails in the preconstructed units.

Figure 4. Parallel spur trails coming off main ridge trail.

Following trail construction, a field meeting was held with the logging contractor, fallers, tractor operators, and choker setters. The fallers were instructed to fell to the lead of the trail whenever possible, keeping in mind the landing destination of the logs and the winching capabilities of the tractors. The tractor operators were instructed not to leave the skid trails under any circumstances in the preconstructed areas.

In the two conventionally logged units, marked trees were felled prior to the entry of logging equipment, and tractor operators "pushed trail" through downed timber until an adequate trail system was developed. Each unit was logged to one or more landings as shown in Figure 3.

MEASUREMENTS

Two timekeepers were employed fulltime to monitor skidding equipment. Working in tandem, one timekeeper was stationed on the landing while the other was in the woods at the point of log hook-up. Utilizing two-way radios, stop watches, and a clinometer, they recorded skid distance, slope, skid time, number of logs per turn, time spent choking logs, positioning tractors, winching, unhooking logs at the landing, and delays. Nearly 1,000 hours of equipment time were monitored in this manner and a total of 1,400 skid cycles were selected for statistical analysis.

This analysis was designed to equally represent the four skidding units and two pieces of skidding equipment. These two pieces, a Fiat-Allis 14-C crawler tractor and a FMC-210 tracked skidder, were selected from the numerous pieces of equipment used during the harvest because each had approximately 700 monitored skids, divided equally between preconstructed and conventionally logged units. These 1,400 analyzed skid cycles represent a 20 percent sample of all skidding activity on the HC '80 Timber Sale. Both machines were equipped with 65 feet of winch line. Generally, chokers were not preset.

Estimates were made of the leave stand volume that was severely damaged in skidding and felling operations. Any merchantable tree (10 inches DBH or greater) that was deemed unlikely to survive another rotation due to damage was marked for cutting, and DBH was measured and recorded. Ocular estimates of damage severity were made utilizing the following criteria:

1-roots: exposed or crushed for 33 percent of circumference for redwood, 25 percent for fir.

2-bole: for redwood, more than half the tree's circumference girdled; for fir, more than one-third girdled.

3-leader: for redwood, top broken at a diameter of 10 inches or greater; for fir, any visible breakage in top.

Using only DBH measurements of damaged trees, an accurate volume estimate was possible utilizing tariff cruise principles described by Anthony (1981). This procedure resulted in a 100 percent sample estimate of merchantable leave stand volume lost to logging damage.

To determine extent of skid trail disturbance, all trails were walked and linear distances measured using a Topometric Hip-chain. To determine average trail width, 200 random widths were measured. By multiplying lengths by the average width of 13 feet, a 100 percent sample of skid trail areal disturbance was made. Data were analyzed using an Apple II microcomputer. In all, over 15,000 data entries were made for skidding time components. Volume estimates were made for 897 trees damaged in logging, and over 16 miles of skid trails were measured.

RESULTS AND DISCUSSION

Skidding Production

Skidding production factors are summarized for the FMC in Table 1 and for the Fiat-Allis in Table 2. Combined means for both machines are summarized in Table 3. The skid cycle times are shown, as are the "bunching" element subcycle times, which accounted for over half the total skid cycle time in all units.

The combined daily production averaged 26.1 thousand board feet (MBF) per machine in the conventionally logged units and 30.9 MBF per machine in the units where skid trails were preconstructed.

The cost of skid trail preconstruction was $64.41/acre, or $1.79/MBF. Even after adjusting for this added cost, the combined skidding cost (Table 3) was still eight percent less for the preconstructed units than for the conventionally logged units ($19.69/MBF versus $21.50/MBF, respectively).

This difference, while not statistically significant, can be accounted for primarily by the difference in skid distances, which averaged 2.4 times greater for the conventionally logged units. This resulted in longer inhaul and outhaul times, which accounted for 31 percent of the total skid cycle time in the conventional units compared to 22 percent in the preconstructed units.

Size and topography of units and locations of landings certainly contributed to this difference in skid distances. Also important, however, is the fact that in the conventionally logged units the location and orientation of skid trails were determined primarily by tractor operators and/or choker setters who may have had a tendency to push individual trails further than optimal from the landings they were feeding. Working in downed timber, tractor operators may lack the opportunity and incentive to develop an appreciation for the "big picture" of landing and trail location and layout. On the other hand, when trails are laid out prior to tree felling, it is easier to reconnoiter the area on foot and design a "feeder" trail system better tailored to the locations of individual landings.

Another factor that contributed to the difference in total skid cycle times was the amount of time attributed to the "Delay" component. Although delays were independent of skidding distance, more than twice as much delay time per skid was recorded in the conventionally logged units. This difference is significant at the 99 percent confidence level. The major factor accounting for this difference was the amount of time required in the conventional units to move logs out of the way so that skid trails could be built with a minimum of damage to downed timber. This problem was largely averted in the preconstructed units as the fallers were usually able to fell to the lead of the trails, and those logs that did block the preconstructed trails were easily pulled out of their lay without damage or delay (Figures 1 and 2).

While the difference in delay times between the two skidding strategies is statistically significant, the delay component was not an overriding factor in either the preconstructed or conventional units, accounting for only 7.5 and 12.1 percent, respectively, of total skid cycle times. The extra cost of delays due to trail clearing in the conventionally logged units was about $1.35/MBF more than in the preconstructed units.

Bunching time, which included tractor positioning, log choking, hooking and winching, accounted for the greatest proportion of skid cycle time in each system. Although bunching accounted for a greater percentage of total cycle time in the preconstructed units than in the conventionally logged units (62.5 versus 50.8), total bunching times did not differ significantly. Neither did any of the individual elements of the bunching sybcycle differ significantly between the two strategies.

Previous studies of "predesignated" (Froehlich, et al., 1981) and "preplanned" (Bradshaw, 1979) skid trail systems have also shown undramatic differences in productivity when compared to more conventional ground skidding methods. Bradshaw (1979) concluded that productivity was 10 to 11 percent better for conventional skidding while my data indicates an 11 percent lower productivity for conventional skidding. Froehlich, et al, (1981) reported little or no difference in productivity. Judging from these three studies, it is probably fair to say that productivity is neither greatly enhanced nor seriously decreased when skid trails are flagged and/or constructed prior to tree felling and logging.

Like Froehlich, et al, (1981), we found shorter average positioning, hooking and skidding times in preconstructed trail units. However, average winching times in our study were nearly identical (only five percent less for preconstructed units), while Froehlich, et al. (1981) concluded that conventional skid trail systems required fewer winch cycles and less total winching time.

Although the purpose of this study was to compare logging systems, not equipment performance, examination of Tables 1 and 2 reveals some notable productivity differences between the Fiat-Allis and the FMC. For example, the cost advantages of the preconstructed trail system were more pronounced for the Fiat-Allis than for the FMC.

Other notable differences in machine performance were the lower average delay and positioning times for the FMC and lower choker setting and hooking times for the Fiat-Allis. Finally, overall skidding costs were lower for the FMC due to its larger average turn size, number of turns per day, and slightly lower operating cost, which according to the logging contractor, was $47.50/hour compared to $49.00/hour for the Fiat-Allis.

Damage to the Leave Stand

Logging damage to residual timber was nearly identical under the two strategies. Volumes that were harvested due to severity of logging damage totalled 2.53 MBF/acre in the preconstructed units and 2.61 MBF/acre in the conventionally logged units. This amounted to 6.32 and 6.52 percent, respectively, of the leave stand volume. In all units, the species composition of damaged trees was similar to that of the leave stand. Also, skidding strategy did not significantly affect the number of damaged trees per acre, of which there were 4.5 in the preconstructed units and 4.1 in the conventional units.

These results differ from those of Froehlich, et al, (1981), who concluded that "skidding to designated skid trails produced less damage to residual trees than does conventional tractor yarding." It should be noted, however, that damage criteria were quite different in the two studies. Froehlich, et al. (1981) recorded frequency of stem wounds greater than ten square inches, while the HC '80 study estimated merchantable volume loss from the leave stand.

Figure 5. Example of a problem that could have been avoided with a preplanned skid trail system. Here an ephemeral draw was crossed unnecessarily, resulting in accelerated erosion in the draw and the undermining of two merchantable trees that have fallen over.

Area Disturbed by Skid Trails

Skid trails covered 12.38 percent of the area in the preconstructed units and 12.63 percent of the area in the conventionally logged units. The nearly identical areal impact of skidding under the two strategies offers the strongest explanation for similarities in leave stand volume damage. Froehlich, et al, (1981) noted that trees closest to skid trails were most frequently damaged. In that study, areal extent of skid trails in conventionally logged areas was three to five times greater than in the area with predesignated skid trails, and residual stem damage was about three times greater. Thus, their data indicate a roughly proportional relationship between skid trail area and residual tree damage. Our data also indicate a proportional relationship between skid trail area and leave stand damage, though both area disturbed by skid trails and damage to residual trees were comparable whether or not skid trails were preconstructed.

A probable explanation for this difference between the two studies is the enforcement of a standard contractual requirement for all timber sales on the Jackson Demonstration State Forest which limits skid trail spacing to a minimum average distance of 100 feet. Thus, even in conventionally logged areas, there is an upper limit to the percentage area that can be devoted to skid trails. As it happens, our 12.63 percent figure in the conventionally logged units corresponds closely to the 11 percent figure found by Froehlich, et al. (1981) where predesignated skid trails were spaced at 100 foot intervals. Thus, it can be concluded that about 11 to 13 percent of a logged area is the maximum that will be devoted to skid trails where a 100-foot spacing limitation is enforced.

Most previous studies of conventional tractor logging have shown skid trail areal coverage in excess of 20 percent (Steinbrenner and Gessel, 1955; Dyrness, 1965; Froehlich, 1976; Bradshaw, 1979). These studies represented situations where tractor operators were allowed considerable freedom to drive up to individual turns of logs, which also helps to explain the reduced need for winching in the conventionally logged areas studied by Bradshaw (1979) and Froehlich et al. (1981). However, where loggers are limited to skid trail spacings of 100 feet or greater (due to law, contractual provisions, topography, etc.), the difference in productivity and damage between conventional logging and a preconstructed strategy becomes less evident.

SOME MANAGEMENT CONSIDERATIONS

Although the HC '80 data do not indicate clear superiority of one strategy over the other, there are distinct advantages to skid trail preconstruction that should be considered.

The first, and probably most obvious advantage, is that delineating skid trails prior to harvest offers the landowner greater control over the impact of logging (Figure 5). Presumably, the landowner (or a forester representing the landowner) has long-term management objectives for his land and is in the best position to design a skid trail system to meet these objectives. Furthermore, once such a system has been established, activities such as planting, precommercial thinnings, and rotation re-entry, can take advantage of those trails.

Froehlich, et al. (1981) reported that tracts with several intermediate harvests can have skid trail coverage in excess of 80 percent. By designing, constructing, and possibly mapping an adequate skid trail system at the outset, there will be little need for major alteration or expansion in the future. On the other hand, where repeated entries to a tract are made by successive timber operators without a planned skid trail system, opportunities for using existing trails will be lost, especially after timber felling has obscured ground detail.

To summarize, it is recognized that skid trails have a negative effect on soil productivity. By planning and controlling where skid trails are to be located, it is possible in the long run to minimize the area that must be sacrificed for this purpose.

A second major advantage to trail preconstruction that was recognized during the course of this study is the potential for improved tree marking techniques and strategies in stands that are selectively harvested. In this study, trees were marked prior to trail construction; in the study conducted by Froehlich, et al. (1981), fallers selected trees to be felled after skid trails were delineated. A trail system established prior to tree marking or selection offers several advantages. Not only is access facilitated for marking, cruising, and intermediate stand treatments, but tree markers can anticipate damage and mark accordingly. Thus, the problem of more frequent damage to residual stems nearest skid trails can be mitigated by giving priority to those high risk trees when marking to given leave stand specifications, and a higher degree of quality control of the stand can be maintained.

CONCLUSIONS

1. Productivity was marginally better for units where skid trails were preconstructed, primarily due to shorter skid distances and delay times.
2. The areal extent of skid trails was nearly identical for the two strategies. Each had between 12 and 13 percent of area in skid trails following logging.
3. Damage to the leave stand was nearly identical for the two strategies (2-3 MBF/acre), and the amount of damage was proportional to the percentage area in skid trails.
4. Contractural limitations on skid trail spacing that require a minimum average distance of 100 feet between trails in all logged areas may explain the difference in findings between this study and previous similar studies in which vegetation and soil disturbances were much greater in conventionally logged areas.

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Table 1

SKIDDING PRODUCTIVITY SUMMARY AND CYCLE TIMES FOR FMC-210

	Preconstructed	Conventional
Ave. Skid Distance (ft.)	216.6 *	718.9 *
Logs Per Turn	5.9	6.1
Volume Per Turn (MBF)	1.18	1.22
Turns Per Day	28.0	26.7
Volume Per Day Per Machine (MBF)	33.0	32.6
TOTAL SKIDDING COSTS ($/MBF)	17.07	17.28

SKIDDING CYCLE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Outhaul	2.1	11	2.8	14
Inhaul	1.9	10	2.5	13
Bunching (see below)	13.0	67	11.9	59
Unhooking	1.6	8	1.5	7
Delays	0.7 *	4	1.5 *	7
TOTAL CYCLE TIME	19.3	100	20.2	100

BUNCHING SUBCYLCE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Choker Setting	7.3	56	6.7	56
Positioning	0.6	5	0.6	5
Winching	3.7	28	3.3	28
Hooking	1.4	11	1.3	11
TOTAL BUNCHING TIME	13.0	100	11.9	100

* Difference is statisically significant (P=.01).

Table 2

SKIDDING PRODUCTIVITY SUMMARY AND CYCLE TIMES FOR FIAT-ALLIS 14-C

	Preconstructed	Conventional
Ave. Skid Distance (ft.)	387.8 *	983.9 *
Logs Per Turn	5.1	5.8
Volume Per Turn (MBF)	1.02	1.16
Turns Per Day	28.7	20.9
Volume Per Day Per Machine (MBF)	29.2	24.2
TOTAL SKIDDING COSTS ($/MBF)	19.76	23.84

SKIDDING CYCLE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Outhaul	2.2 *	12	4.5 *	18
Inhaul	2.0 *	11	4.1 *	16
Bunching (see below)	10.6	56	11.9	46
Unhooking	1.6	8	1.6	6
Delays	2.1 *	11	3.7 *	14
Trail Construction 1/	0.3	2	0	0
TOTAL CYCLE TIME	18.8	100	25.8	100

1/ Total machine and operator time averaged over all skids.

BUNCHING SUBCYLCE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Choker Setting	4.7	45	5.5	46
Positioning	1.3	12	1.6	13
Winching	3.5	33	3.9	33
Hooking	1.1	10	0.9	8
TOTAL BUNCHING TIME	10.6	100	11.9	100

* Difference is statisically significant (P=.01).

Table 3

SKIDDING PRODUCTIVITY SUMMARY AND CYCLE TIMES
WEIGHTED AVERAGE FOR FMC-210 AND FIAT-ALLIS 14-C

	Preconstructed	Conventional
Ave. Skid Distance (ft.)	370.4 *	894.1 *
Logs Per Turn	5.6	5.9
Volume Per Turn (MBF)	1.10	1.18
Turns Per Day	28.1	22.1
Volume Per Day Per Machine (MBF)	30.9	26.1
Preconstruction Costs ($/MBF)	1.79	0
TOTAL SKIDDING COSTS ($/MBF)	19.69	21.50

SKIDDING CYCLE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Outhaul	2.2 *	11	3.9	16
Inhaul	1.9 *	10	3.5 *	14
Bunching (see below)	11.8	62	12.4	51
Unhooking	1.6	8	1.6	7
Delays	1.4 *	7	3.0 *	12
Trail Construction 1/	0.3	2	0	0
TOTAL CYCLE TIME	19.2	100	24.4	100

1/ Total machine and operator time averaged over all skids.

BUNCHING SUBCYLCE TIMES

	Preconstructed		Conventional	
	Minutes	Percent of Total	Minutes	Percent of Total
Choker Setting	6.0	51	5.9	48
Positioning	0.9	8	1.2	10
Winching	3.6	30	3.7	30
Hooking	1.3	11	1.5	12
TOTAL BUNCHING TIME	11.8	100	12.3	100

* Difference is statisically significant (P=.01).

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