Presentation to 1983 Annual Meeting of the
Council on Forest Engineering hosted by Caterpillar Tractor Co.,
Peoria, Illinois, USA.

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Presentation topic:

A professional program in forest engineering education.

Session theme (1983 09 28):

Present condition of North American forest engineering

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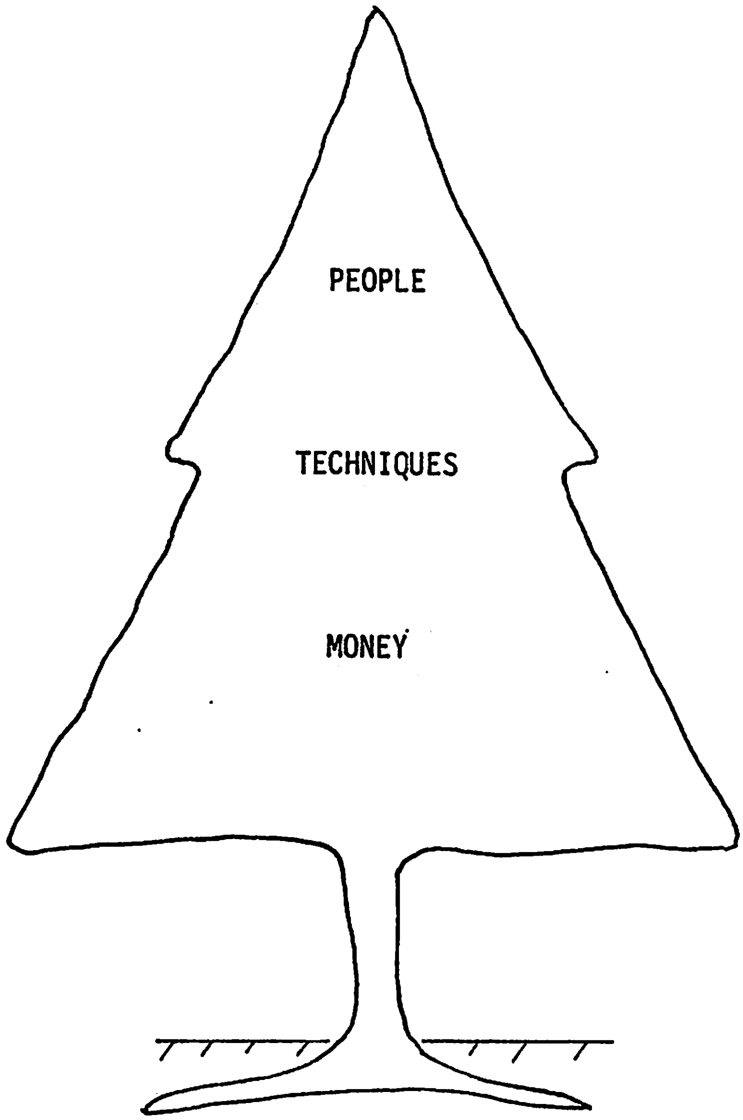
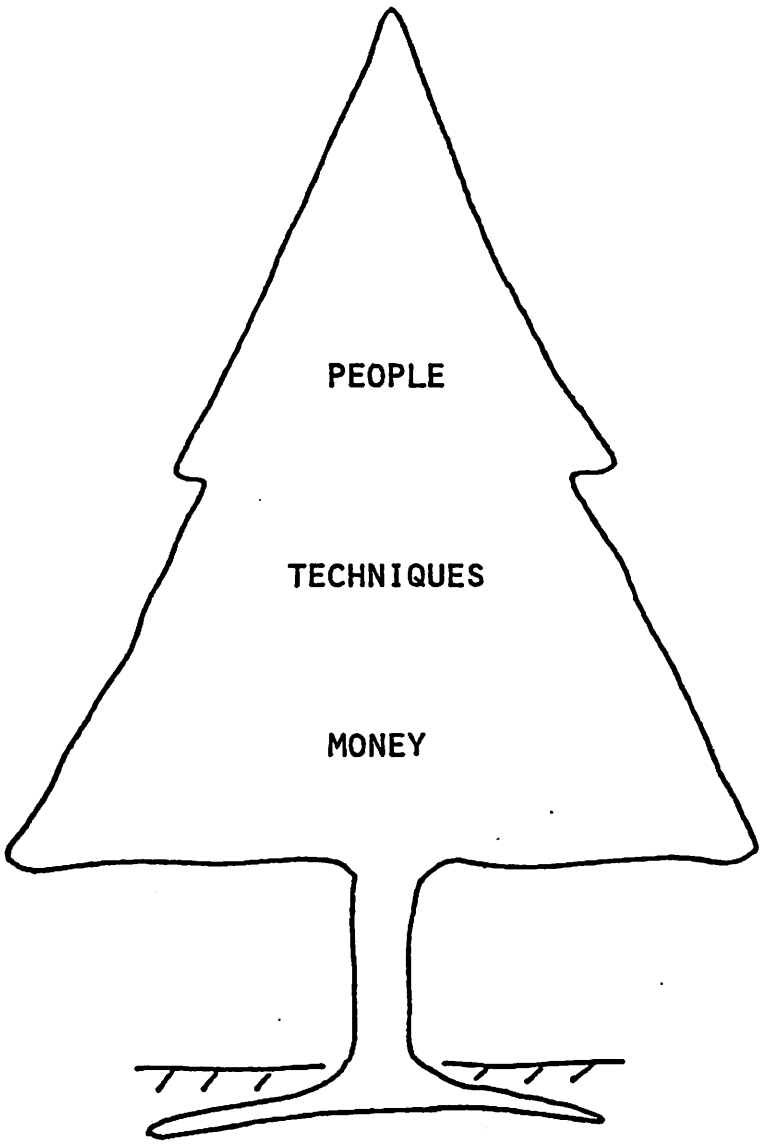


INDUSTRIAL PRODUCTION BASICS



FOREST ENGINEERING PROGRAM COMPONENTS

FOREST ENGINEERING PROGRAMME COMPONENT ELEMENTS

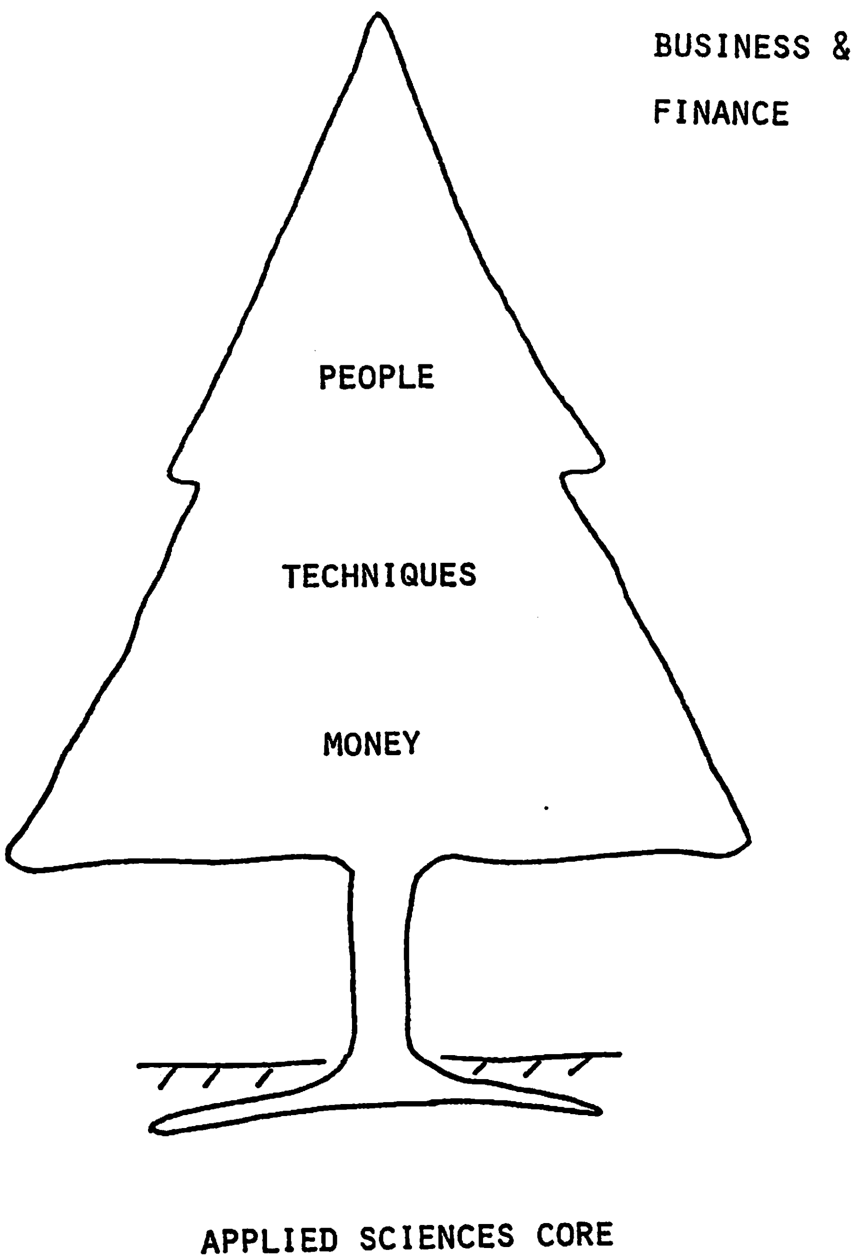
Finance & Business

Economics

Financial management

Business management

Marketing



FOREST ENGINEERING PROGRAM COMPONENTS

FOREST ENGINEERING PROGRAMME COMPONENT ELEMENTS

Forest Science & Technology

Mensuration

Biometry

Forest management

Silvics

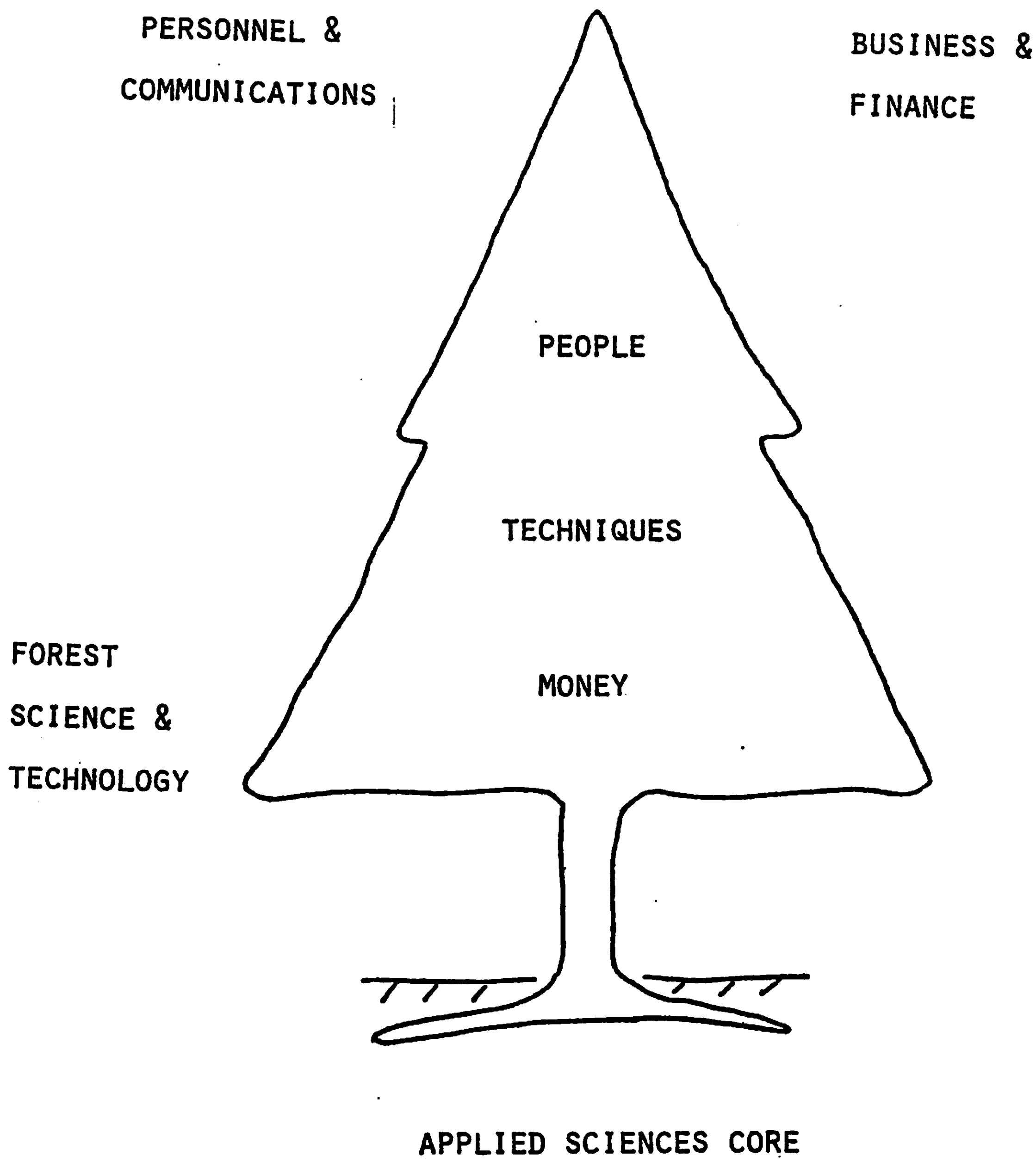
Ecology

Silviculture

Hydrology

Soils science

Wood technology



FOREST ENGINEERING PROGRAM COMPONENTS

FOREST ENGINEERING PROGRAMME COMPONENT ELEMENTS

Engineering Science & Technology

Surveying

Graphics

Mechanics

Electricity

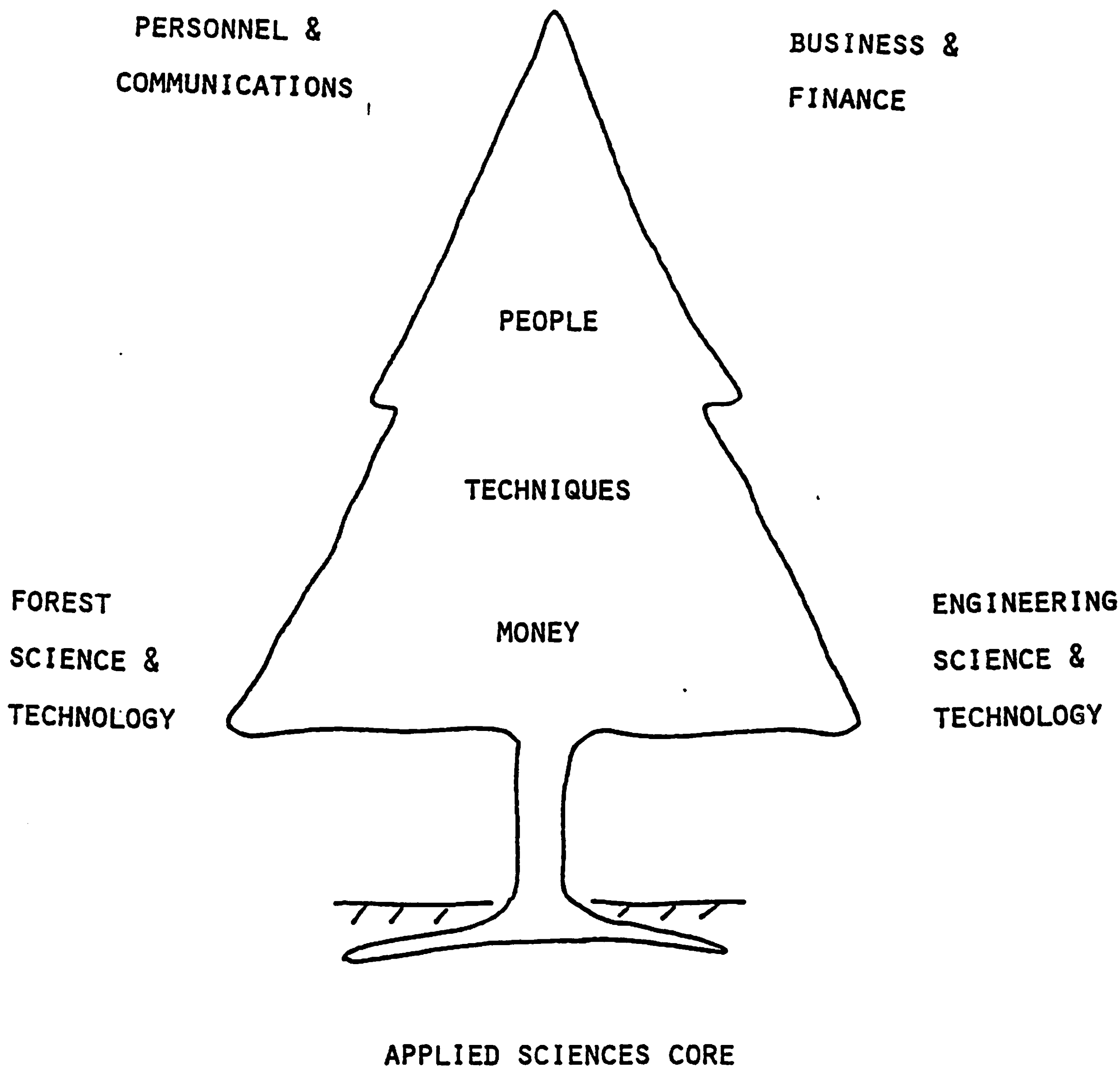
Materials

Soil mechanics

Fluid mechanics

Thermodynamics

Structures



FOREST ENGINEERING PROGRAM COMPONENTS

FOREST ENGINEERING SPECIALIZATION

Operations functions

Stand Establishment

Tree Harvesting

Delivery of forest products

Tree processing

Support functions

Transportation systems

Structures

Machine elements

Methods

Industrial Engineering

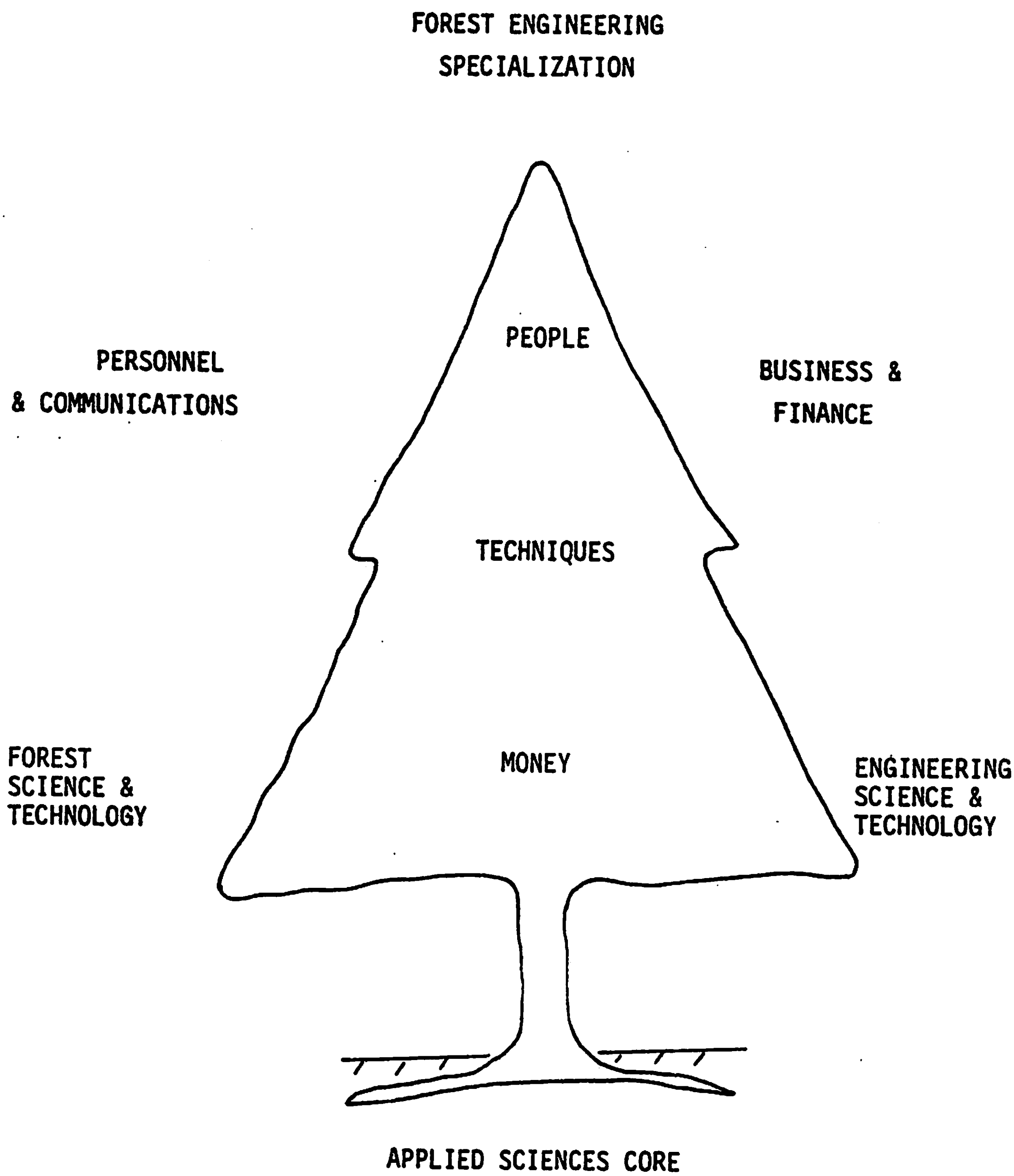
Operations Analysis

Plan

Design

Manage

Control



FOREST ENGINEERING PROGRAMME
COMPONENTS

"Soil Compaction - A Common Sense Approach" - Thomas C. Meisel, Caterpillar Tractor Co.

Compaction of the forest floor by logging vehicles is an area of concern. This is due to both environmental and financial reasons. As good managers of our natural resources and with an eye on public perception of the logging industry, we don't want to disturb the natural forest floor conditions more than necessary. With our other eye on the pocketbook, we don't want to reduce the growth rate of the leave trees or the new growth.

These concerns have intensified in recent years. Special vehicles have been specified on some sales. We are more sensitive to soil moisture levels and may shut down operations if standard Proctor test data predicts higher compaction. Equipment advertising claims include reducing compaction. Academia is publishing more papers on compaction causes and effects. Amidst this flurry of activity, the practical, working logger has a hard time trying to find out just what is really important and what is not. What is the difference between different machine types and the compaction they cause? How does ground pressure fit in?

We at Caterpillar have been sifting thru all the information available and trying to make sense out of it from a practical point of view. We compared compaction between different vehicles on special tests in the Pacific Northwest. We were a study team member with the United States Forest Service on their compaction field tests and studies. We made presentations covering our own studies and findings to various groups including the USFS in Washington, D.C. We made sure that our dealers had access to the USFS study team findings.

Let me briefly review with you the history of our involvement in forest floor compaction studies. Then we will cover the same findings and conclusions about compaction that have been presented to various groups. Finally, we will summarize the findings of the USFS compaction study team. In 1974, FMC 200 series skidders were introduced and at that time we were watching and studying these vehicles. In 1976, we had an opportunity to make our first field compaction measurements. We were able to compare a conventional D6 tractor, a 518 rubber tired skidder and an FMC. In 1977 and 1978, we planned and executed a field compaction study comparing the same three vehicles. In 1978, the Forest Service planned their compaction study. Caterpillar, John Deere, and FMC were asked to participate. Our participation included both being a member of the study team and contributing a D6 tractor. John Deere contributed a 640 wheel skidder and FMC one of their 200 series skidders. Both were also study team members. By 1979 the Forest Service study was underway in the Lake Tahoe National Forest. Dr. Froehlich of Oregon State University was conducting this study for the Forest Service. In 1980, Dr. Froehlich presented his first draft of the study results to the study team. In the same meeting, Caterpillar made a presentation to the study team on our own compaction studies.

Our presentation covered the results of our own in-house study. We looked at the compaction which was caused by the log itself. We looked at ground pressure characteristics underneath different types of log skidding vehicles and also took a look at compaction in perspective to see what effect it really had. In 1981, Dr. Froehlich presented his second draft to the study team. We at Caterpillar presented the results of our own studies to key

Forest Service people in Washington, D.C. The Forest Service wrote an interpretative summary and appended it to the front of Dr. Froehlich's report. Final publication occurred. In 1982, we at Caterpillar took the results of that study and presented them to our dealers.

Let us now review the presentation that we made to the USFS and to the study team. First, the results of our own compaction comparison. The first was near Prineville, Oregon in August, 1976. We were fortunate to find a job site with a D6, a 518, and an FMC on the same job. The undisturbed soil's dry density was between .92 and 1.06 g/cc^3 and moisture between 25 to 40%. Measuring compaction under the tracks of a D6, a 518, and an FMC 200 after six passes each we found compaction levels of .99 g/cc^3 under the D6, 1.02 g/cc^3 under the 518 and 1.00 g/cc^3 under the FMC. (We used a nuclear densitomer to measure compaction.) These results were initially confusing because we expected more difference. These "contrary to popular opinion" results led us to plan a specific test series under controlled conditions to get a better comparison. We had similar results. On a site near Eugene, Oregon, with an undisturbed dry density of .98 g/cc^3 and 35-42% moisture, we measured compaction under the vehicle tracks after 10 passes. We found 1.14 g/cc^3 under the D6, 1.11 under the FMC, and 1.18 under the 518. Nowhere near the difference we were expecting. On another site near Eugene, the undisturbed dry density was 1.0 g/cc^3 and moisture from 35 to 45%. On this site we had 26 inch wide shoes on the D6 and 67x34x25 Terra tires on the 518. After 10 passes the compaction under the machine was 1.15 g/cc^3 for the 518 and D6 and 1.08 g/cc^3 under the FMC. This was ironic in that the special treatment on the D6 and 518 had no apparent effect.

Our last comparison was between a D7 and an FMC near Coos Bay, Oregon. The undisturbed dry density ranged from .6 to .9 g/cc^3 and moisture from 30 to 35%. After 10 trips we found .97 g/cc^3 under the D7 and 1.00 g/cc^3 under the FMC. But this time we went an extra step - we measured under the log and found 1.15 g/cc^3! This makes the log appear to be more the villain than the machine. So now we begin to wonder, what is the log's ground pressure? Well, we don't know, but we can make some calculations on a practical engineering basis. Let's assume that the center of gravity of the log is 40% from the large end to allow for normal butt swell. We'll also assume that the large end is on the skidder and therefore only 40% of the log's weight is on the ground. This plot (see Fig. 1) shows what the contact area would have to be underneath three specific logs in order to give some definite ground pressure. Looking at, for example, the 15,000 lb log, in order to limit its ground pressure to 8 psi, then we can see that it must have a contact patch of about 750 sq/in. This is a very large contact patch and it is unlikely to occur under a log of this size. So the conclusion is that the ground pressure under the log is probably higher than that under the machine. We saw no significant differences in compaction between the machine types, and the log end is probably compacting more than the machine is.

Now, let's take a closer look at ground pressures underneath logging machines. For example, under track type machines, the number most people recall when they think about ground pressure is the static ground pressure. This is the number that you get from the manufacturer's specification sheet. And as you can see from Figure 2, it assumes an even distribution underneath the tractor. However the ground pressure that is important is the dynamic working ground pressure, not the static value. Under a machine doing drawbar work the dynamic working ground pressure generally has a trapezoidal or a triangular distribution with the peak ground pressure occurring underneath the rear most wheel. The dynamic ground pressure depends upon the size of the load, the amount of drawbar pull that the vehicle is exerting, and the initial balance of the vehicle. Figure 3 shows a calculated pressure distribution underneath a crawler tractor for a given size drawbar pull and initial balance and also shows what the true ground pressure is underneath this vehicle. These results are from a test done at our Peoria Proving Ground, and as you can see the measured pressure distribution has shifted forward a little bit from the calculated pressure distribution and also is a little bit larger. You can also see the contributions from the individual rollers. So we can conclude that the actual ground pressure underneath a track type vehicle is going to be considerably higher than the static ground pressure given on the manufacturer's specification sheet, and if you calculate the dynamic ground pressure you may still end up with a number that is too low.

Now, let's look at ground pressures underneath rubber tired machines. In order to calculate the ground pressure under a rubber tired vehicle we go to the tire manufacturer's specification sheet and he will give us an inflation pressure, a load, and a contact area. He gives us a lot of other information also but these are the three items we are interested in right now. The example on Figure 4 includes a 23.1 x 26 Goodyear tire 10 ply rating and the manufacturer tells us that contact area is 372 sq. in.

Now all we have to do is multiply that number by the number of tires we have and then divide our machine weight by that number and calculate our ground pressure, right? Wrong, because this contact area is true only for this inflation pressure and this load, which the manufacturer has also given us on the specification sheet. If either the load on the wheel changes or the inflation pressure changes, the contact area will also change. In fact, if you divide this spec sheet load by this spec sheet contact area you will get a number which is almost identical to the spec sheet inflation pressure of that tire. Figure 5 shows data from the tire manufacturer as to how the contact patch changes with load. Here we have plotted two tire's ground contact area as a function of load on the wheel. The first curve shows a 28,1 x 26 Goodyear timber torque tire at 20 psi. This is a common skidder tire. The other curve shows a 67 x 34 x 25 Goodyear Terra tire at 10 psi inflation, and as you would expect the high flotation tire has a larger ground contact for any given load than the conventional tire. Now that we know how the contact area changes as we change the load on the tire, we can calculate the ground pressure as we change the load. Figure 6 shows you what happens. Here the Goodyear Terra tire at 10 psi has a ground pressure which ranges from about 8 to 12 psi over the whole load scale. The conventional tire at 20 psi has a ground pressure which ranges between 18-21 psi underneath the whole spectrum of loads. So, we conclude from this that the ground pressure under load of a rubber tire is going to be approximately equal to the inflation pressure of that tire, irrespective of the size of the load. As the load increases, the contact patch increases accordingly and the end result is a fairly constant ground pressure. If we want a 15 psi ground pressure we need to choose a tire which will allow us to run at a 15 psi inflation pressure.

Let's review what we have seen so far. Underneath track machines the static specification sheet ground pressure is not a meaningful number. The dynamic ground pressure is more significant and the calculated dynamic ground pressure may still be lower than the true ground pressure. Underneath rubber tired machines the contact area is not a constant and the calculated ground pressure will not be accurate if you use the single contact area from the manufacturer's specification sheet. The ground pressure will be close to the tire's inflation pressure. If it weren't for the carcass stiffness of the tire the ground pressure would be exactly identical to the inflation pressure of the tire. So, the conclusion that we draw from this is that the ground pressures underneath tracked and rubber tired log skidders are more equal than is generally assumed. This helps to explain why we found very similar compaction beneath the two machine types in our tests.

Now, let's take a look at compaction in perspective. What are it's effects? Let's take a hypothetical case. We will assume that the undisturbed density of the soil is 1 g/cc^3. This is a number fairly close to what we have found in our tests in the Pacific Northwest. We will assume that every place our vehicle goes on this area increases the compaction 25% to to 1.25 g/cc^3. Now, as you've seen from our test results, this is a high number and we generally don't compact that much but we want to be fair. Let's assume that the skidding vehicle covers 25% of the total area. In other words, 25% of our area is skid trails. And our last assumption is that we will have 1% growth reduction on our trees for every 1% increase in compaction. In the literature we generally find no effect on growth rates until compaction exceeds the level of 1.25 g/cc^3 but we want to be fair. So what we are doing is compacting 25% of our area by 25%. Therefore we have a 25% growth reduction on 25% of our area and if we do nothing to reduce compaction we would expect a 6.25% reduction in our growth rate. Now as we have seen from our field studies it is almost impossible to reduce compaction more than perhaps 20% by changing the type of vehicle. Figure 7 shows that a 20% reduction in compaction caused by the vehicle would be a change in our growth rate reduction from 6¼% to 5%, not very much. More benefit is available by reducing the amount of area which is exposed to the skid trails. So we conclude that a change in technique offers more potential to lower growth reduction than a change in machine characteristics.

Let's summarize now everything that we have said. Tracked machine's ground pressures are going to be higher than the spec sheet figures. A tire's ground pressure is going to be very close to its inflation pressure. Both machine types are going to compact approximately equivalent amounts. Reducing the skid trail area has much more potential to reduce the effects of compaction than changing the type of machine.

I would like to quickly cover some of the highlights of the Forest Service's Interpretative Summary from their forest floor compaction study which was done by Dr. Henry Froehlich of Oregon State University. This report is titled "Predicting Soil Compaction on Forested Land" and was published in December, 1980 as a final project report to the USFS by Dr. Froehlich and several graduate assistants of the Forest Engineering Dept. of OSU. The interpretative summary covers the report's significant points and interpretations and conclusions from them by the USFS. Authors of the summary were: Chuck Gowdy and Bob Meurisse, soil scientists; Virgil Binkley and Don Studier, logging engineers; J. C. Schwarzhoff, forest engineer; Bob Hinshaw, geo-technical engineer, and Ben Lowman, mechanical engineer. Ben was also project leader. You will note that these are technical people and not bureaucrats.

The tests compared a Caterpillar D6 with 18 inch shoes, a John Deere 640 wheel skidder with 23.1 x 26 tires and an FMC 210 CA tracked skidder on four sites in the Tahoe National Forest. Some highlights from the summary include:

One study result was a preliminary empirical equation to predict compaction. In this equation the machine's calculated dynamic ground pressure only affects the answer by about 1%.

The moisture content on the test site soils was not as significant as had been thought and the standard Proctor test grossly overestimated actual skid trail densities.

Water infiltration rates under the vehicle tracks were the same after 20 trips for all three vehicles. After compaction these rates remained high enough to absorb all but the heaviest rainfall rates in the area.

The pressure of the logs contributes to compaction also. This study did not differentiate between vehicles and logs.

Here are the conclusions from the summary: First: the standard Proctor curve does not work to predict compaction or optimum moisture on forest floor soils. It overestimates compaction. The forest floor soil does not behave like a typical construction soil. Second: the two most significant variables in the proposed predictive equations were the number of trips and the cone penetrometer index. This means that what is of most importance is how many times you go over the soil and what the soil was like when you started. Third: the greatest increase in soil density occurs near the surface and becomes progressively less with depth. At 6" the bulk density measured only about 50% of that at 2". The increase below 12" was negligible. Forest floor compaction is basically a surface phenomena and below 12" there was no compaction. Fourth: the first few trips do most of the damage. Fifth: soils and the soil moisture content vary within a small area and you must account for that variability in order to make a comparison of changes in density following ground skidding. Sixth: air permeability changes were similar to the soil's bulk density. The major change occurred with the first few trips. Seventh: the results of this study indicate that there was no practical compaction difference between machine types on the sites where testing was done. In the author's opinion this study did not show justification for differentiating between machine types to minimize compaction.

I hope that this presentation has been helpful to you in clearing up some of the confusion regarding compaction by logging vehicles.

Thank you.

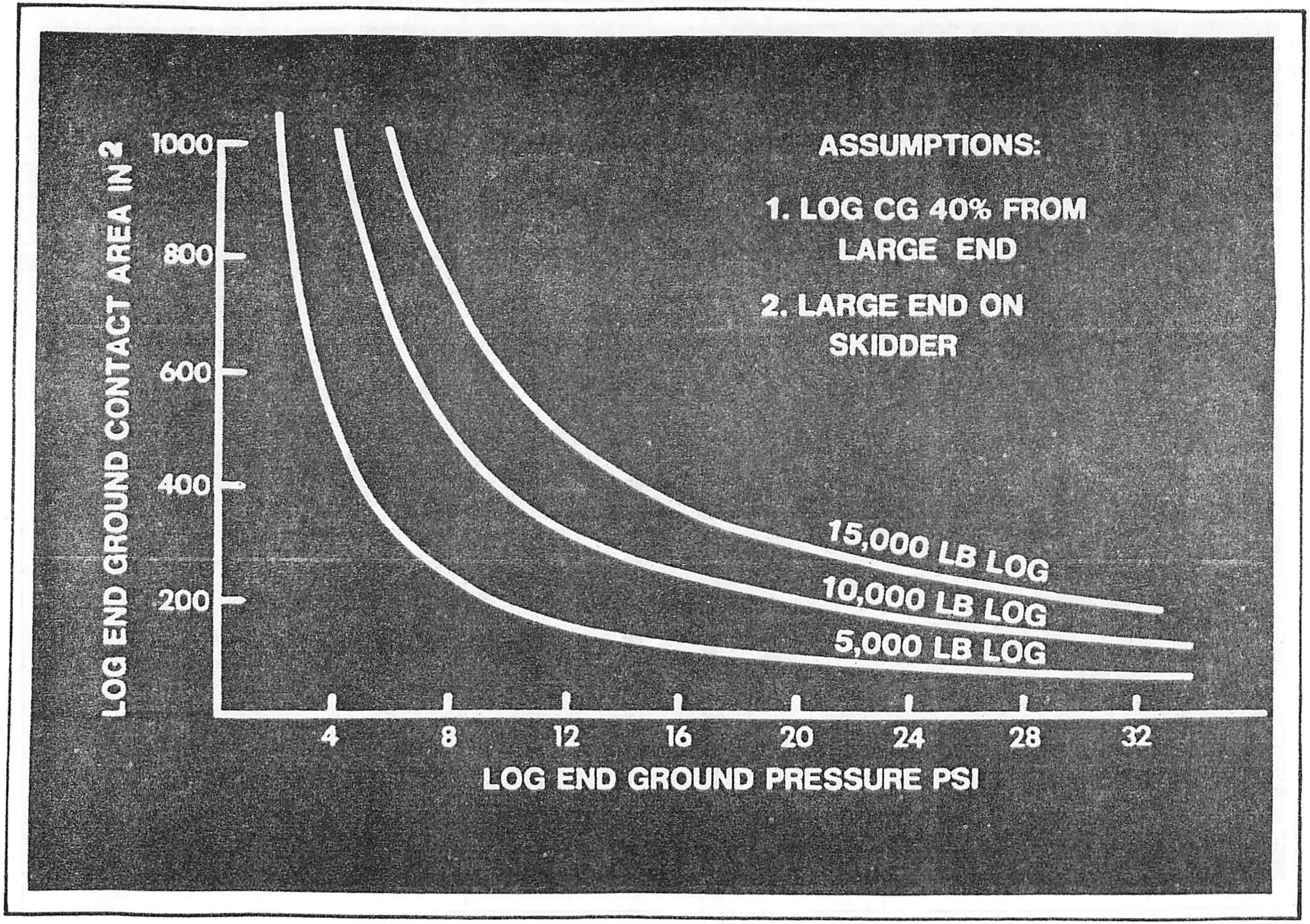


FIGURE 1: CONTACT PATCH AREA NEEDED TO GIVE A SPECIFIC LOG END GROUND PRESSURE.

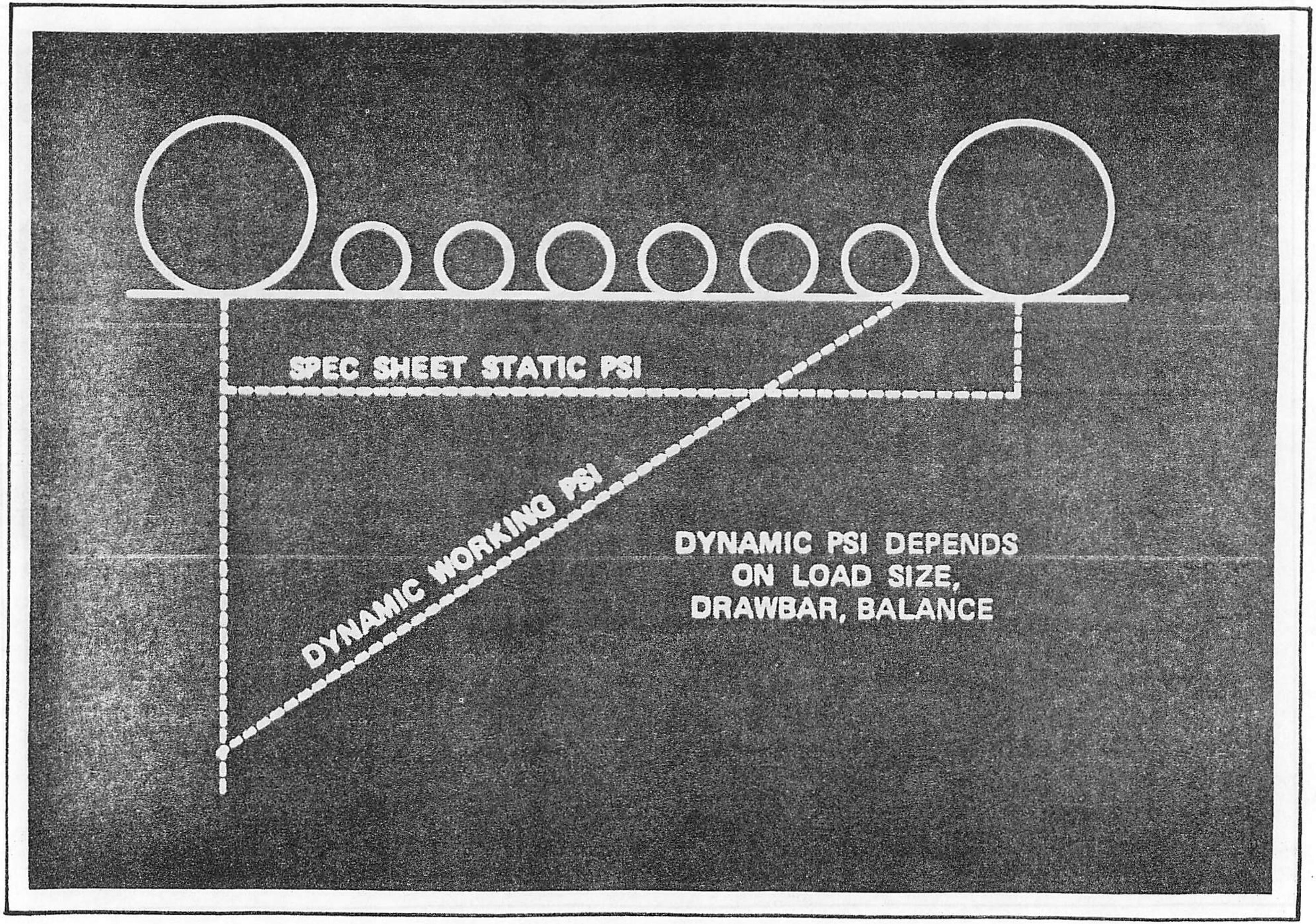


FIGURE 2: GROUND PRESSURE DISTRIBUTIONS UNDER TRACKED LOG SKIDDERS.

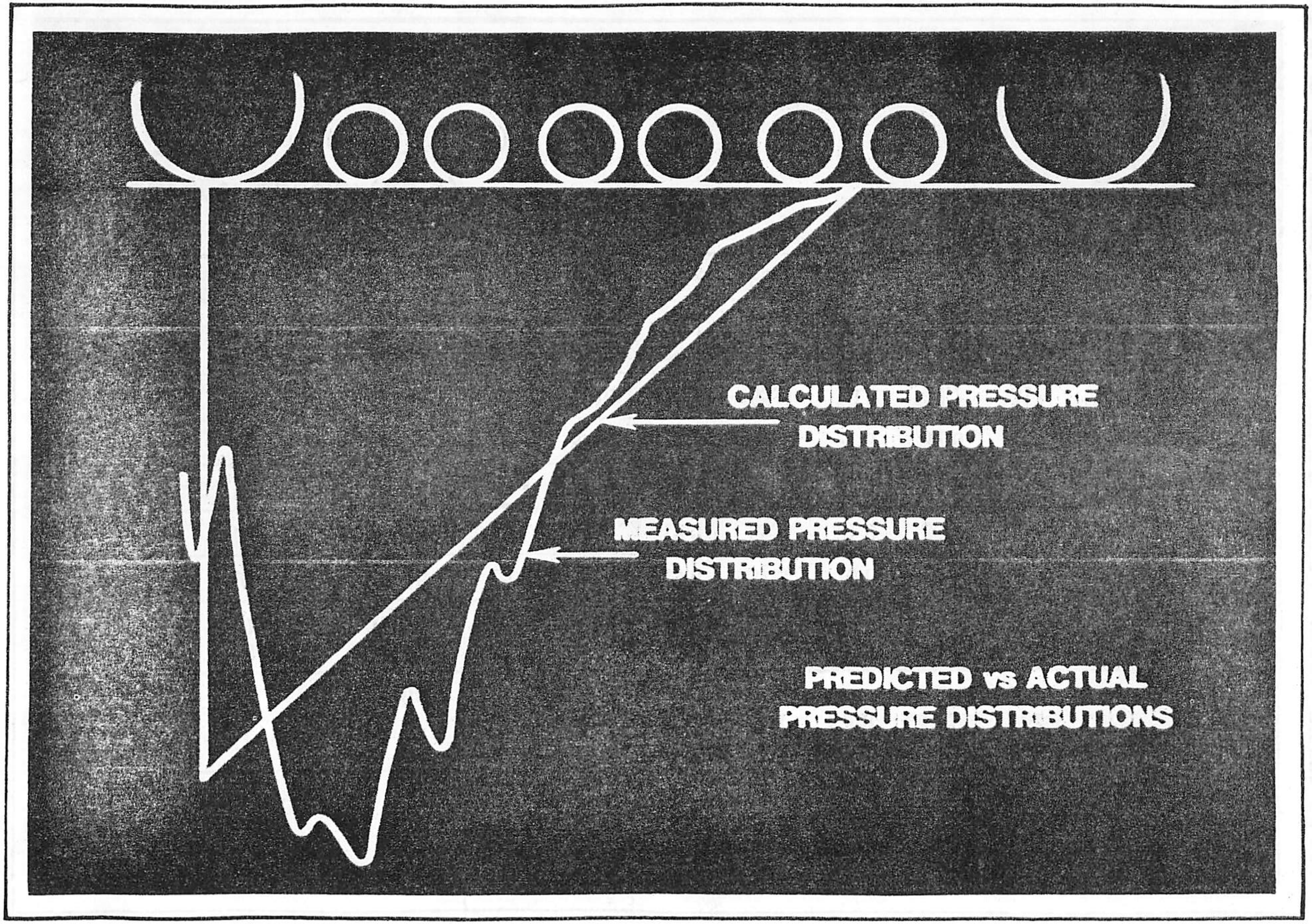


FIGURE 3: RELATIONSHIP BETWEEN PREDICTED AND ACTUAL GROUND PRESSURE DISTRIBUTIONS UNDER TRACKED VEHICLE.

Logger-Skidder Tires

Size	PR		Rim	Inf.	Load	Ovl Width	Ovl Dia.	Loaded Sect & Gr.	Static Loaded Radius	Revs Per Mile	Cent Area	Weight
16.9-30*	8	TT	W15L	25	5070	16.9	58.2	18.5	26.7	355	204	226
	10	TT	W15L	30	5640	16.9	58.2	18.5	26.7	355	204	227
18.4-26	10	TT	DW16	25	5700	19.0	57.3	20.6	26.6	356	170	351
18.4-34	10	TT	DW16	25	6450	19.0	65.6	21.0	30.4	313	207	435
23.1-26	10	TT	DW20	20	7160	23.4	62.5	25.4	28.3	335	372	495
24.5-32	12	TT	DW21	20	8700	24.7	71.3	27.3	32.6	289	371	671
28L-26	10	TT	DW25	15	7010	27.7	65.8	30.0	29.7	317	404	633
30.5L-32	12	TT	DW27	20	10390	29.7	73.6	31.4	32.9	286	496	779
	16	TT	DW27	25	11840	29.7	73.6	31.4	32.9	286	496	872
30.00-33**	12	TL	22.00-3	20	31300	34.2	96.9	35.7	39.7	235	1221	1641

*Logger Special (LS-1)

**Timber Torque XT (LS-3)

FIGURE 4: PAGE FROM GOODYEAR TIRE SPECIFICATION BOOK.

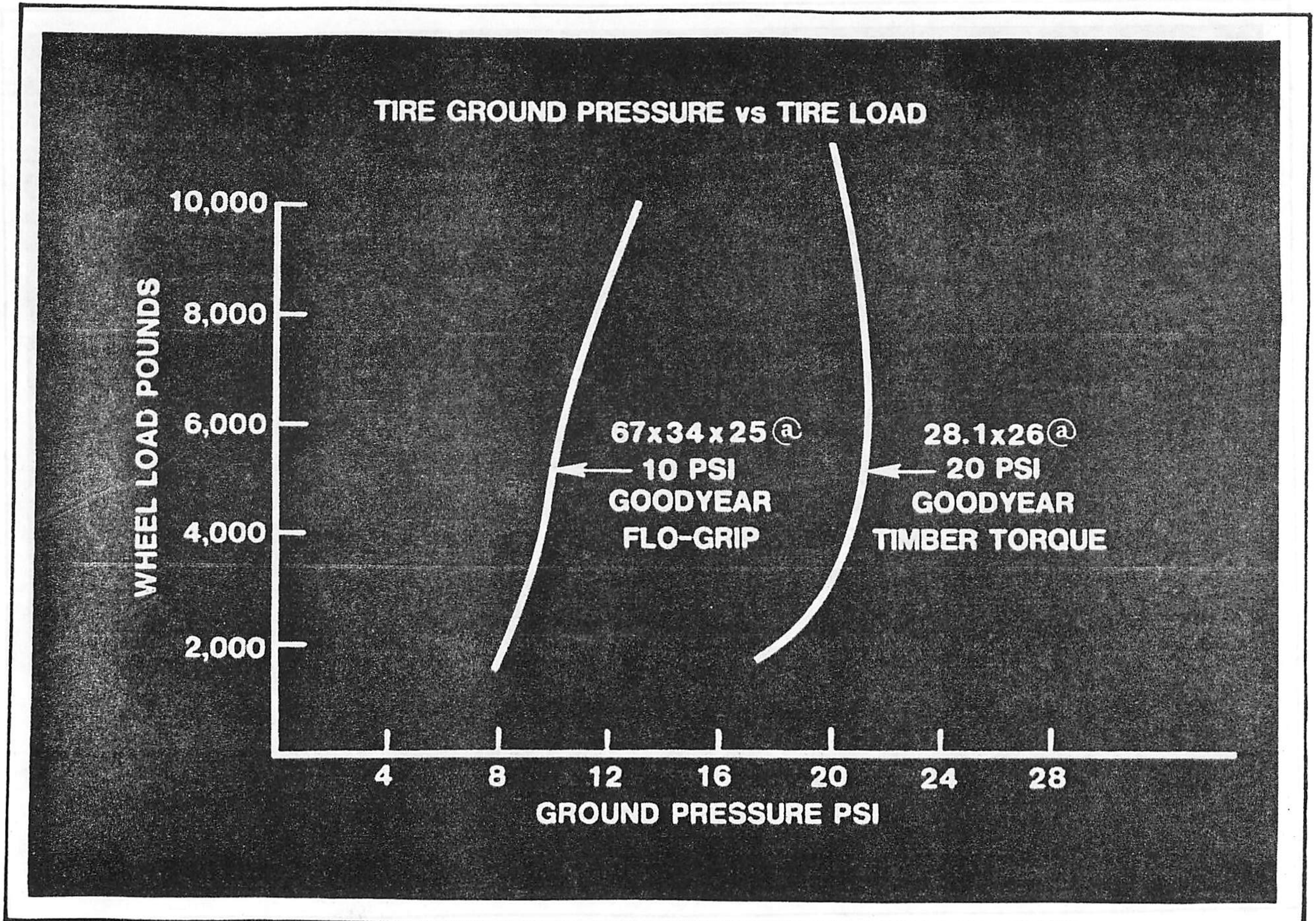


FIGURE 6: SHOWS RELATIONSHIP BETWEEN GROUND PRESSURES AND WHEEL LOAD FOR SKIDDER TIRES FROM FIGURE 5 DATA.

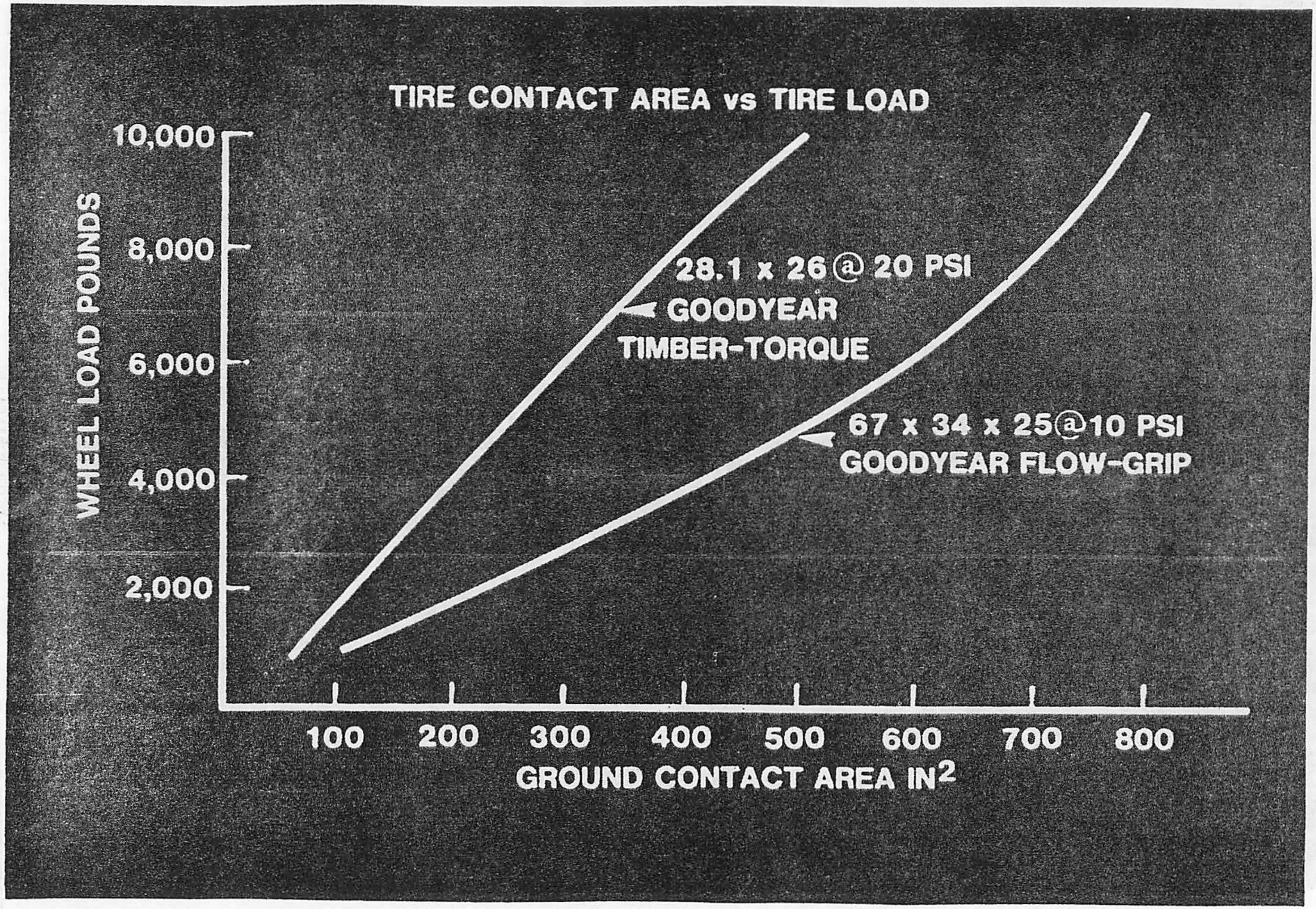
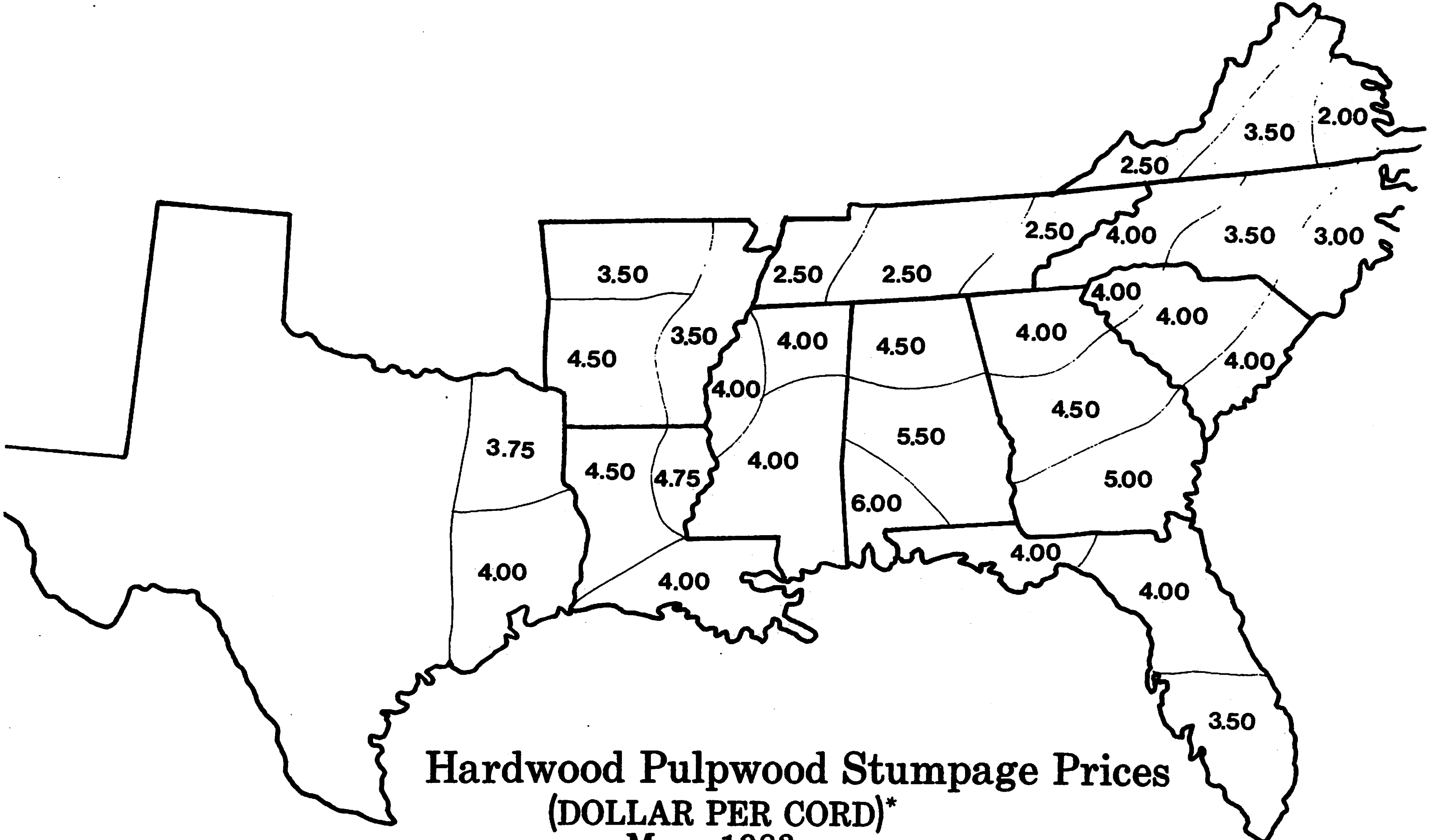


FIGURE 5: RELATIONSHIP BETWEEN CONTACT AREAS AND TIRE LOADS FOR TWO COMMON SKIDDER TIRES. (DATA FROM GOODYEAR ENGINEERING.)

CONSTRAINTS ON FOREST ENGINEERING IN THE INLAND SOUTH

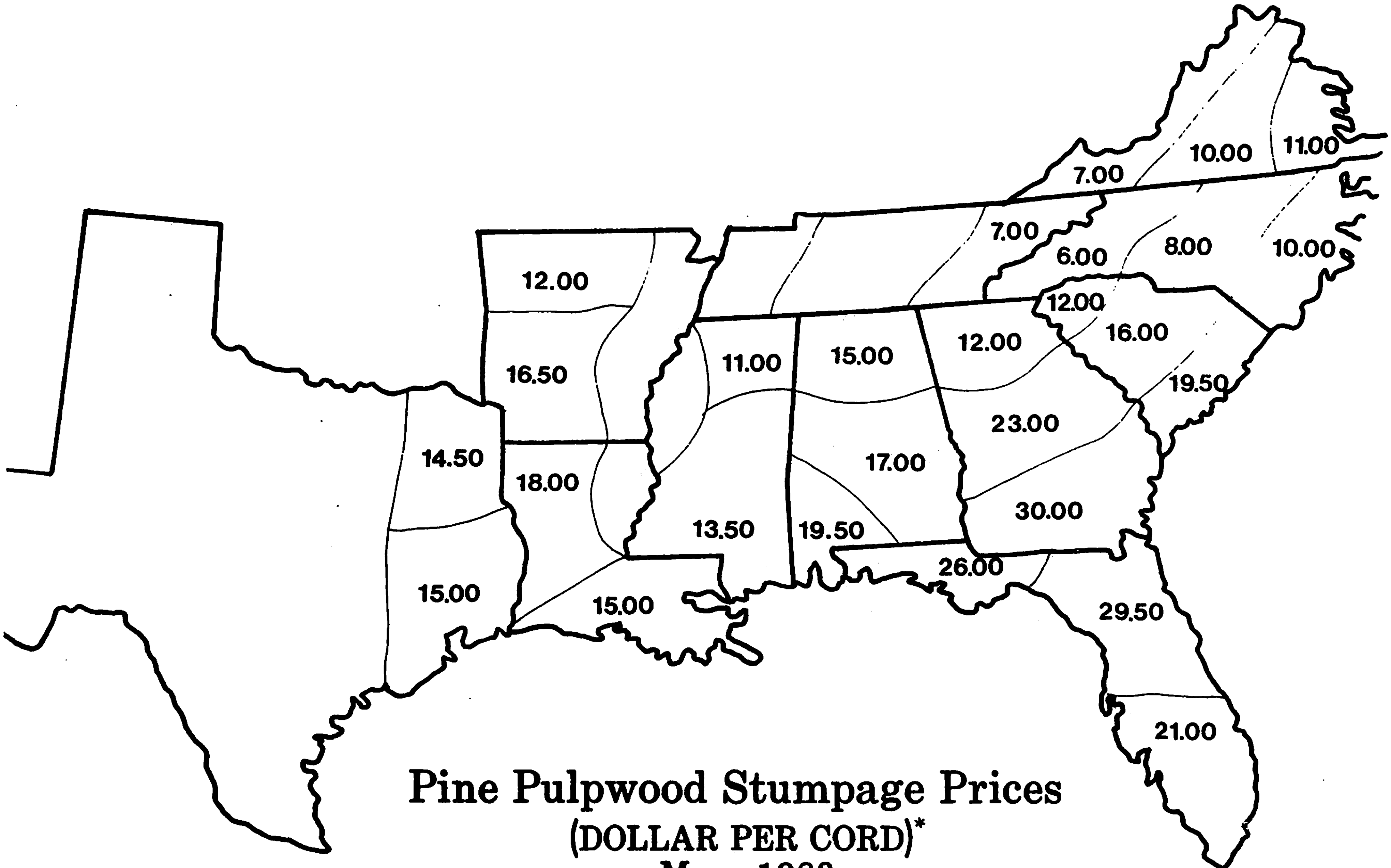
Presented To The
Council on Forest Engineering, September 28, 1983

Dennis T. Curtin
Forest Resources Development Program
Tennessee Valley Authority
Norris, Tennessee 37828



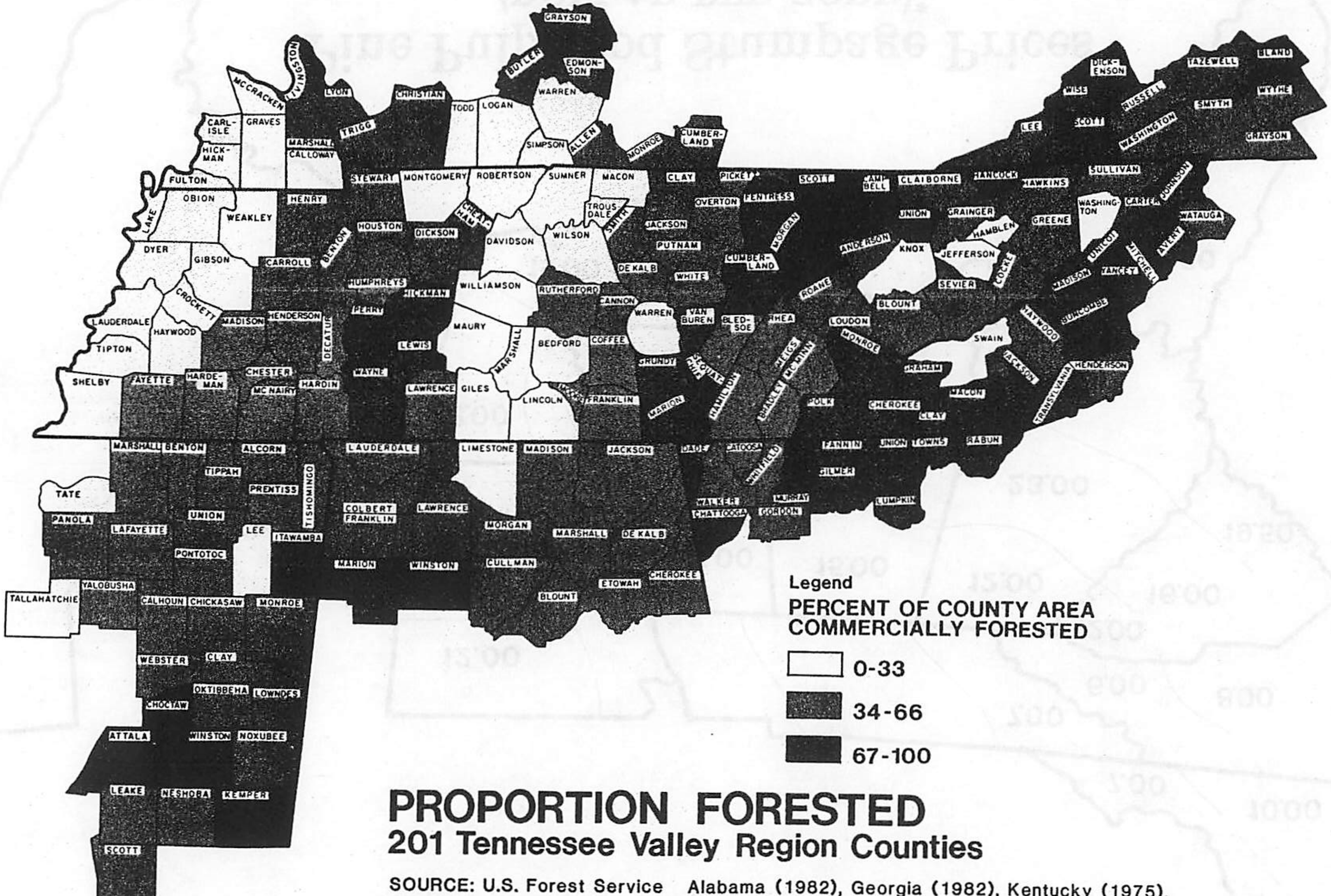
Hardwood Pulpwood Stumpage Prices
(DOLLAR PER CORD)*
May, 1983

*SOURCE: Timber Mart - South
May, 1983



Pine Pulpwood Stumpage Prices
(DOLLAR PER CORD)*
May, 1983

***SOURCE: Timber Mart - South**
May, 1983



PROPORTION FORESTED

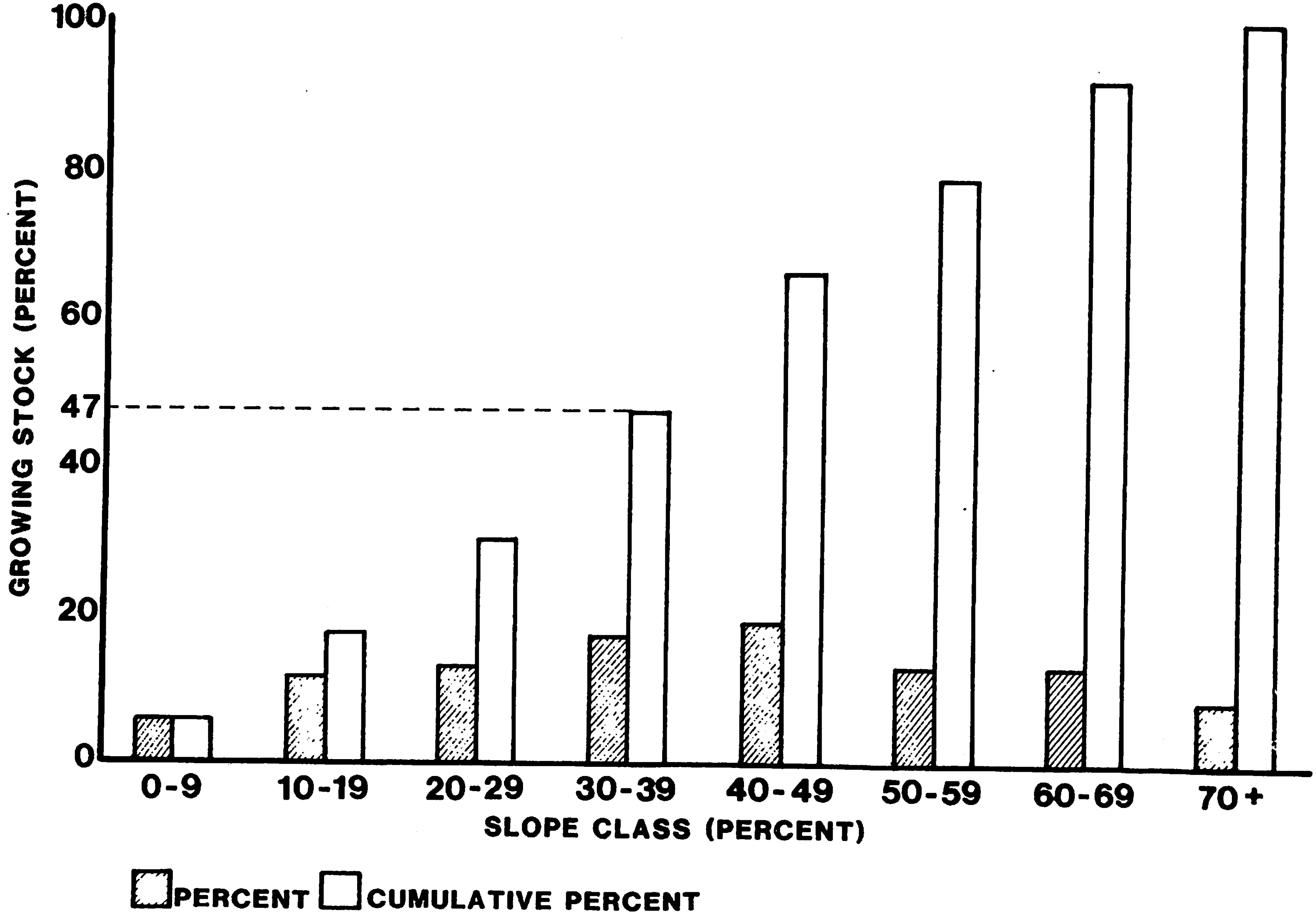
201 Tennessee Valley Region Counties

SOURCE: U.S. Forest Service Alabama (1982), Georgia (1982), Kentucky (1975), Mississippi (1977), North Carolina (1974), Tennessee (1980), Virginia (1977)

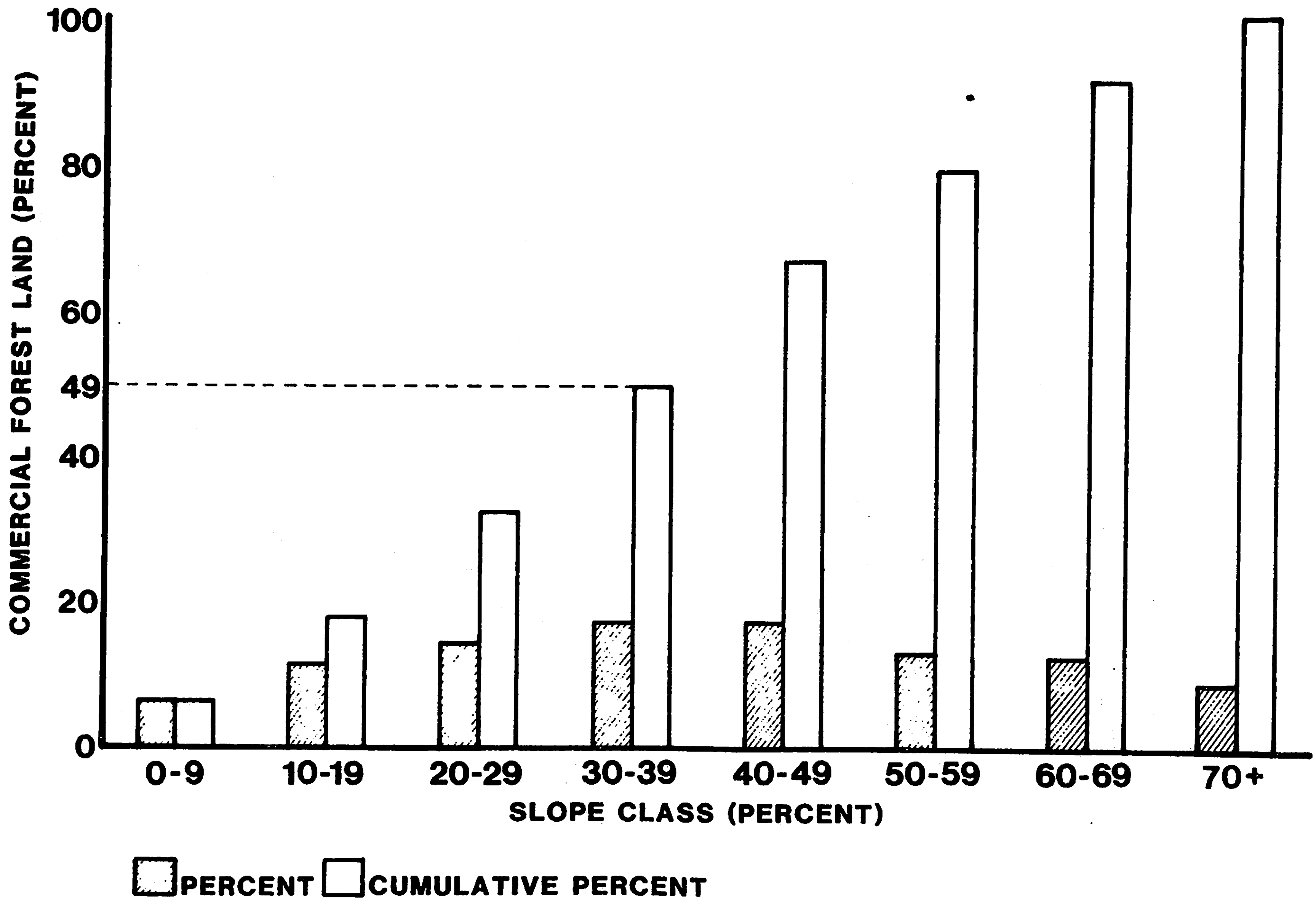
PERCENT OF GROWING STOCK ON COMMERCIAL FOREST LAND BY SLOPE CLASS

FOR

MOUNTAIN AND ESCARPMENT COUNTIES IN VIRGINIA (1977) AND NORTH CAROLINA (1974)



PERCENT OF COMMERCIAL FOREST LAND BY SLOPE CLASS
FOR
MOUNTAIN AND ESCARPMENT COUNTIES IN VIRGINIA (1977)
AND NORTH CAROLINA (1974) (9.7 MILLION ACRES)



PERCENT OF COMMERCIAL FOREST LAND BY SLOPE CLASS
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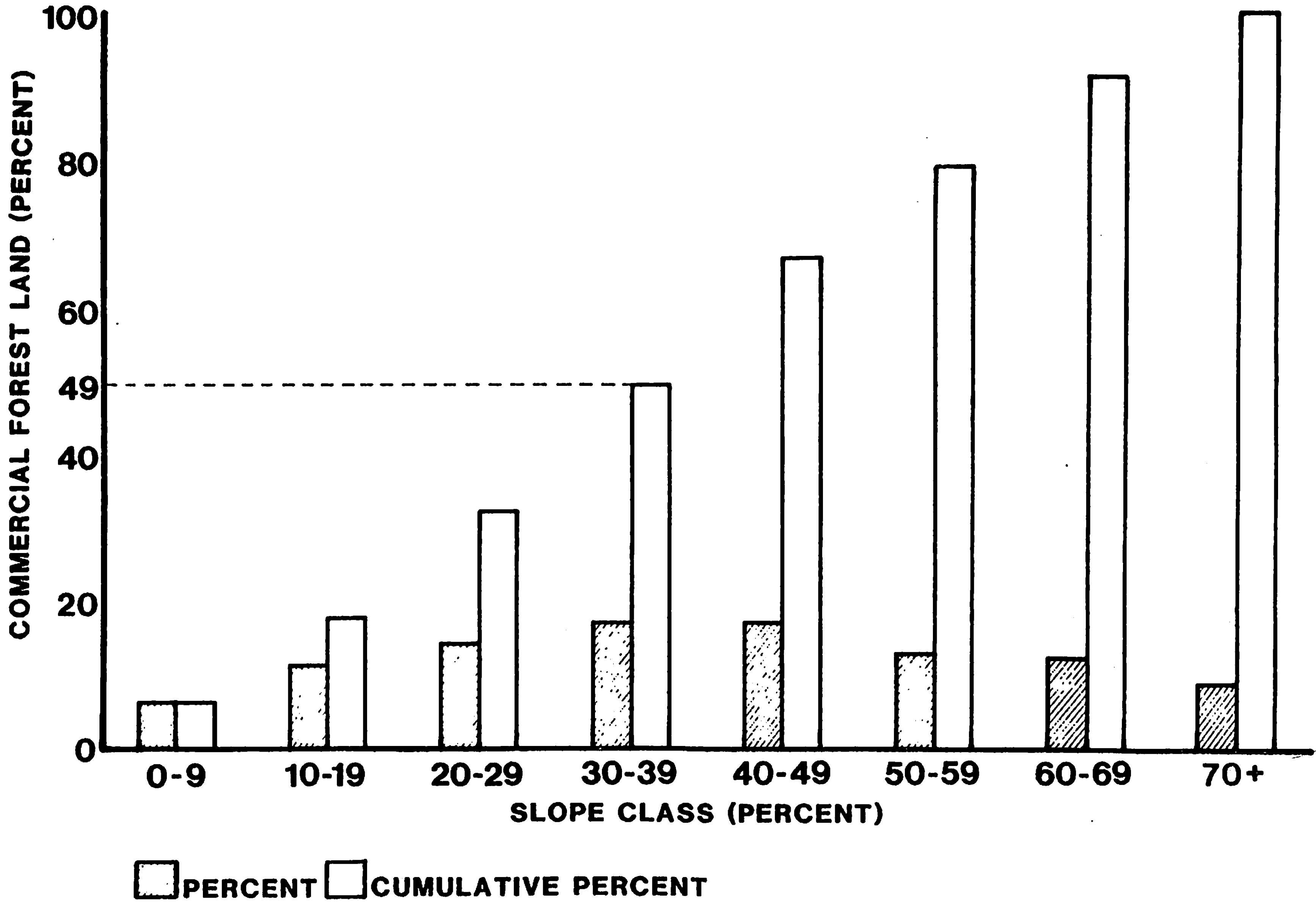
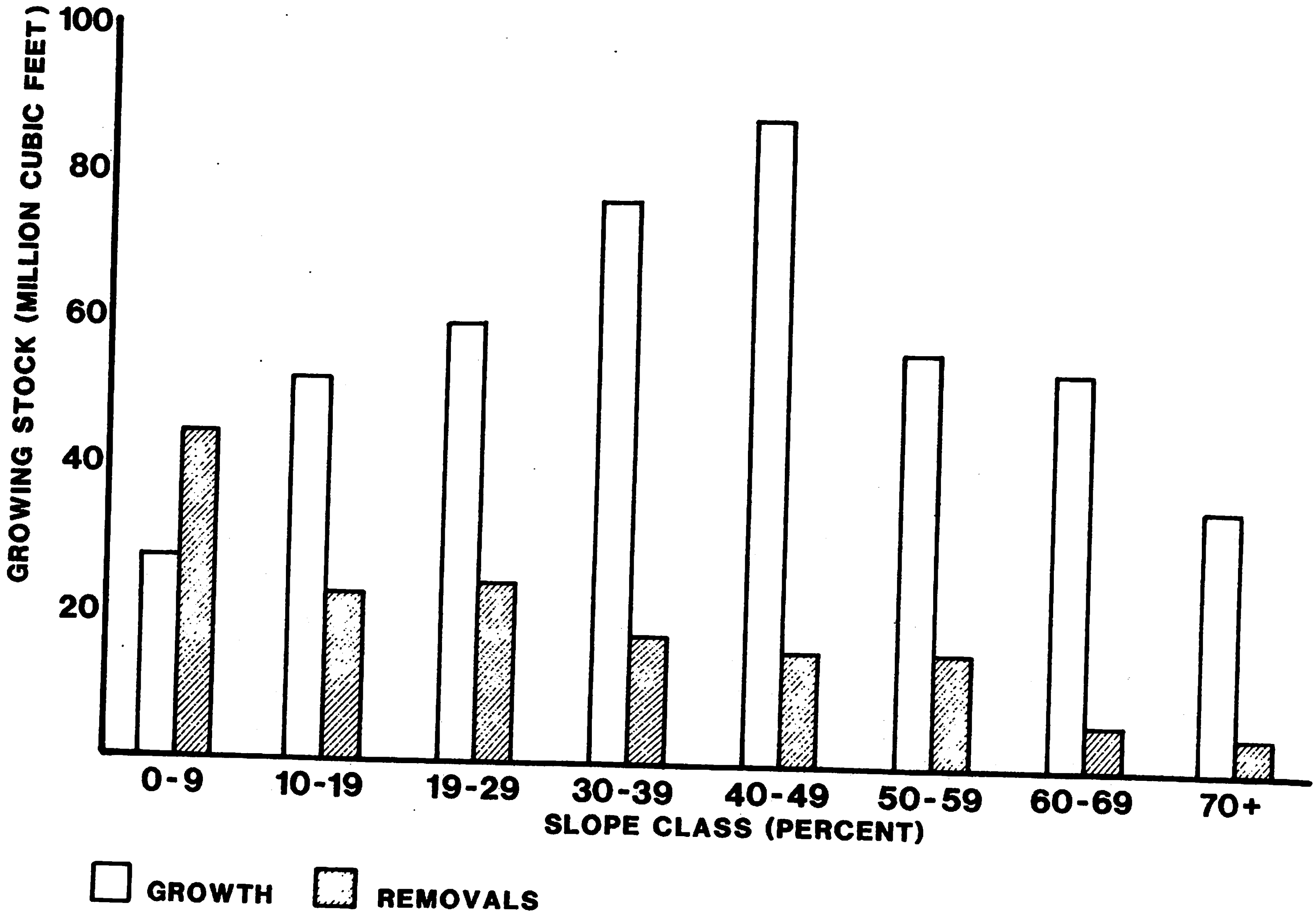
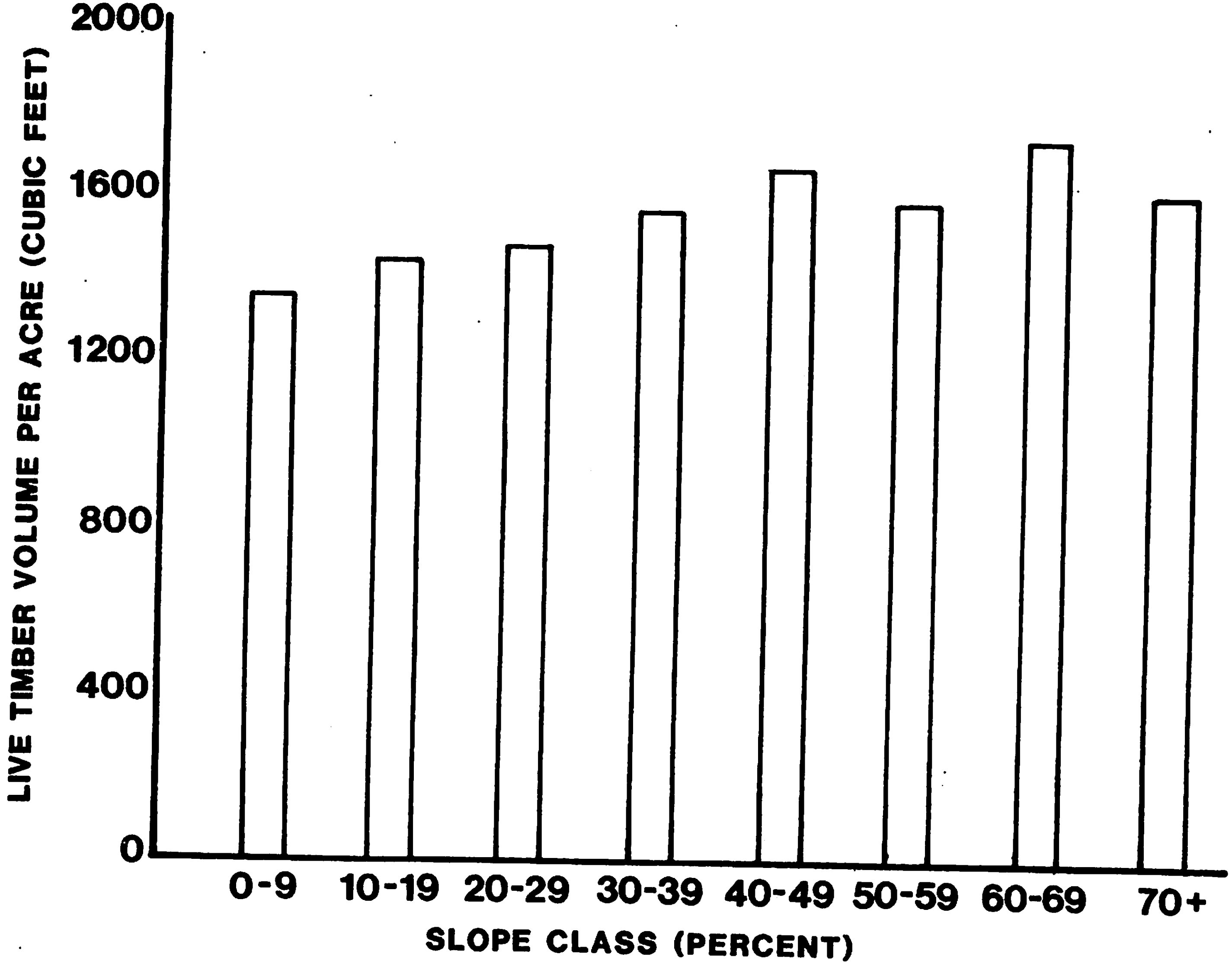


NET ANNUAL GROWTH AND ANNUAL REMOVALS OF GROWING STOCK ON COMMERCIAL FOREST LAND BY SLOPE CLASS
FOR
MOUNTAIN AND ESCARPMENT COUNTIES IN VIRGINIA (1972–1977)
AND NORTH CAROLINA (1969–1974)



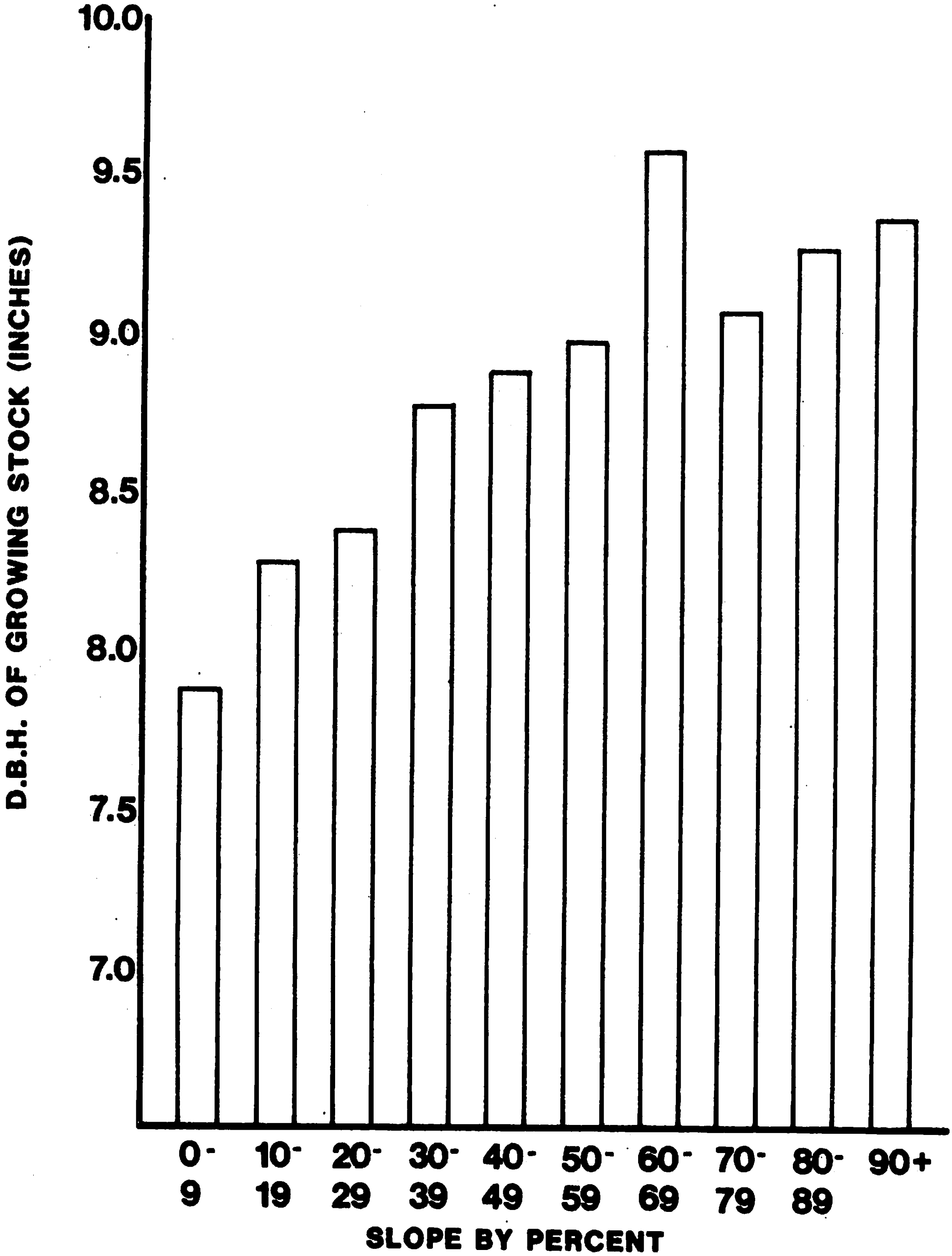
AVERAGE NET VOLUME PER ACRE OF LIVE TIMBER ON COMMERCIAL FOREST LAND BY SLOPE CLASS
FOR
MOUNTAIN AND ESCARPMENT COUNTIES OF VIRGINIA (1977) AND NORTH CAROLINA (1974) (9.7 MILLION ACRES)



AVERAGE D.B.H. (INCHES) OF GROWING STOCK BY SLOPE CLASS

FOR

MOUNTAIN AND ESCARPMENT COUNTIES OF VIRGINIA (1977) AND NORTH CAROLINA (1974)



WHOLE TREE CHIPPING

Presentation for
Council on Forest Engineering

Peoria, Illinois

September 29, 1983

Jeff Hoyle

WHOLE TREE CHIPPING PRESENTATION FOR COUNCIL ON FOREST ENGINEERING

The first whole tree chipper was built in 1970 to dispose of trees killed by the Dutch Elm disease. Since that time, whole tree harvesting has advanced rapidly and has revolutionized the way we harvest timber. A whole tree chipping operation is a capital intensive harvesting system rather than a labor intensive harvesting system such as conventional short and longwood operations. A few of the benefits of the more efficient whole tree harvesting system are: (1) procurement benefits, (2) aesthetic benefits, (3) operational benefits, and (4) land management benefits.

PROCUREMENT BENEFITS

From a procurement standpoint, utilization of whole tree chipping methods in areas of limited timberland resources usually provides enough additional benefits to override the high initial capital expenditures and increased production costs of these operations. Actual fiber yield increases of 40-60 percent are consistently reported due mainly to increased utilization of previously unmerchantable timber, cull, branch wood and tops discarded by conventional logging systems.

Evidence supports a reduction in stumpage costs per cord due to increased utilization of fiber volume in whole tree chipping operations. This, in turn, gives the bidder a competitive advantage over conventional harvesting operations because of the ability to bid higher with the anticipation of overrun. Also, due to an increase in available fiber, it seems reasonable to assume that there would be a savings in land investment, road building, and site preparation costs to produce a cord of wood. This reduction in required timberland base will reduce the drain within a procurement area. This, in turn, will reduce the relative procurement area required to supply a mill.

AESTHETIC BENEFITS

The reduction of logging slash that comes with whole tree utilization has a pronounced aesthetic impact, thereby reducing social pressure. With increased demand on the part of non-industrial landowners to have clean harvests, aesthetic considerations are gaining importance. The non-industrial private landowner's major objection to the conventional harvesting system has been the mess that is left after the harvest is completed, which they view as a waste of resources. Whole tree chipping contractors have found stumpage more available than conventional loggers due to the improved condition of the site after harvesting is completed. Both public and private landowners are specifying contractual requirements that whole tree chippers must be used in harvesting operations on their land.

OPERATIONAL BENEFITS

Other major advantages incurred by utilizing whole tree chipping operations include the consistency of fiber deliveries from a fully mechanized system since they are not as sensitive to weather conditions as more labor intensive conventional systems. The safety of operations can be enhanced since there are usually no laborers on the ground. Most workers are within protective cabs of feller bunchers or grapple skidders. Significantly, more highly skilled operators are drawn to these mechanized operations. Another advantage is exhibited in the use of whole tree chipping operations for thinnings and for harvesting stands once considered unmerchantable. Stands considered to be unmerchantable with conventional logging methods are now whole tree chipped for a profit.

LAND MANAGEMENT BENEFITS

A company lands manager is significantly benefitted by whole tree chipping operations. A number of standard pre-harvest activities such as timber marking, site preparation and hazard reduction can be eliminated or significantly reduced by whole tree harvesting. It is evident that a substantial total cost reduction can be obtained by employing whole tree chipping rather than conventional systems. Many companies have reported a savings of between 20-30 dollars per acre in replanting operations following whole tree harvesting.

These results are attributed mainly to the reduction or elimination of certain costly site preparation activities. Conventional clear-cutting operations tend to discard large quantities of logging slash and residue as opposed to a whole tree chipping operation which utilizes almost all the above-ground portion of the tree. This leaves the root system, some branches and leaves to decompose and supply the soil with needed nutrients. By eliminating the large amounts of logging debris left by conventional harvesting, whole tree chipping has greatly reduced the chance of forest fires and leaves the area ready for the establishment of the next timber crop.

CONCLUSION

Advances in screening systems and the demand for alternative energy sources are opening more markets for whole tree chips. The dirt separator, which removes about 90% of all sand and grit in field chips, combined with improved screening systems, is allowing more and more pulp mills to use whole tree chips in their operations. Boiler systems that use whole tree chips and other wood residues are being installed, not only at the pulp and paper mill sites, but at schools, brick kilns, office buildings, prisons, etc. The ability to screen and sell basically two commodities -- pulp furnish and hog fuel -- gives whole tree chipping operations further economic advantages. In addition to hog fuel, whole tree chips are being used in composting operations, as animal feed and bedding, mulching and are also being mixed with coal to reduce the effects of acid rain.

As you can see, whole tree chipping has come a long way from solving the disposal problem of elm trees. Whole tree chipping now allows us to compete in world pulp and paper markets, due to reduced furnish costs, and helps reduce our dependence on foreign energy sources.

We at Morbark are optimistic about the future of whole tree chipping and are dedicated to developing markets for whole tree chips and the equipment to produce these chips economically.

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FOREST ENGINEERING, STATUS AND OUTLOOK
WITHIN
THE FOREST SERVICE

By

Sotero Muniz
Director of Engineering
Forest Service USDA

Presented to
The 6th Annual Council on Forest Engineering
Peoria, Illinois

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TOPIC: FOREST ENGINEERING, STATUS AND OUTLOOK WITHIN THE FOREST SERVICE

PRESENTED BY: Sotero Muniz

Mr. Chairman, Ladies and Gentlemen. I bring you personal regards from R. Max Peterson, Chief of the Forest Service, who could not be with you today. He and I wish you a successful and productive 6th Annual Council. From the look of your agenda, you have an ambitious and fast moving meeting arranged. I'll try to keep pace with your themes.

There are 4 separate, but related, points to my presentation:

- Forest Engineering Related Research.
- Forest Service Equipment Development and Testing.
- Integrated Logging Systems Planning.
- Future Outlook--Forest Engineering Needs of the Forest Service.

Point No. 1. Forest Engineering Related Research.

Perhaps the best way to address this topic is to describe several Research efforts or projects that are presently underway related to Forest Engineering.

Heli-Stat

Program Development. The development of helicopter and balloon logging in recent years has provided a valuable method for conducting environmentally sound timber harvest operations on steep terrain and on fragile soils. A substantial increase in available timber supply has resulted. The helicopter and the balloon, however, have limited economic yarding, range, and weather conditions. Currently, about 1 mile is the maximum distance for economical transportation of logs. Also, the number of logs that can be moved in a single trip is limited. There are numerous areas where it is not economical or environmentally practical to construct logging roads to within 1 mile of a tract of timber. Capability to yard longer distances with heavier payloads is very desirable. The development of the Heli-Stat is designed to meet the needs for removal of larger loads over greater distances.

Program Objectives. (1) To design, fabricate, and field test a lighter-than-air heavy-lift aerial vehicle that will economically yard logs to a distance of at least 6 miles. This vehicle is called the Heli-Stat. It combines 4 helicopters with a helium-filled balloon. The helicopters provide dynamic lift and the balloon static lift. Initial studies indicate this vehicle will lift approximately 26 tons and transport the logs up to 6 miles at a cost comparable to conventional helicopter logging. With the cooperation of the U.S. Navy, a contract was let to Piasecki Aircraft Corporation in September 1980, to design and fabricate the demonstration model of the Heli-Stat. The Navy has provided the helicopters and has acted as COR for the contract.

(2) To demonstrate to the logging industry that the concept of a lighter-than-air heavy-lift vehicle is practical and safe and to provide private industry and the Federal Government with the basic knowledge about the feasibility of such a vehicle for various heavy-lift and long distance transportation capabilities.

(3) To prepare and offer timber sales from remote areas currently uneconomical to log under existing technology. The greater yarding distance could extend access to as much as 63,000 acres as compared to present systems that access to about 3,100 acres from a single setting.

Landslide Hazard Models (INT-3751)

In our Intermountain areas of Utah, Nevada, and Idaho, research work on sediment transport from roads, harvest areas, and mass failures is underway. Models are being developed which can probably be used in many geographic areas.

Harvesting Concepts (NC-3701)

These are being investigated for natural and plantation stands. Walking type feller bunchers have been tested. Wheeled equipment (TIMCO) has been demonstrated on slopes up to 55 percent. The small but dense Tag Alder stands show promise for energy. The topwood harvester which uses an auger cutter has been demonstrated once in cooperation with TVA. The chunk wood machine has received much commercial interest. A coperative agreement has been made with the Missoula Equipment Development Center to build a commercial model.

Residual balers for biomass recovery are showing promise. Walking equipment and high floatation-tired vehicles are needed in muskeg areas. Research in these areas is cooperatively pursued in the Pacific Northwest and Alaska (PNW-3701).

Mobile Chippers, site compaction studies and thinning research is underway in our Southern Station (SO-3701).

In the Northeast Area, future direction involves an overview of Cable Logging Systems and modifications that may be needed in the East (NE-3701).

Research Outlook

Timber sales are becoming more and more complex. Constraints are being placed which affect such factors as vehicle track width, allowable soil pressures, and sediment generation. Research scientists and practitioners need to pool their skills to evaluate needs, constraints, capabilities, costs, and methodology.

Future direction will move harvesting considerations and proposals into timber stands on steep slopes. Multispan systems will be needed to avoid midslope roads and the integration of resource values, uses, and costs will become even more difficult.

Gathering a body of knowledge via Research efforts is fairly straightforward. The transfer of this knowledge and technology is apparently more difficult.

Point No. 2. Forest Service Equipment Development and Testing.

The activities of the two Forest Service Equipment Development Centers at San Dimas, California, and Missoula, Montana, literally span all of the disciplines and interests within the Forest Service. One of our more significant projects is the Substitute Earth Anchor System (SEAS)

SEAS - As the timber harvest moves into more and more difficult terrain, the Forest Service places more reliance on cable logging systems. Such systems require adequate anchors to safely support equipment towers. Current projections estimate that natural anchors, such as deep rooted tree stumps, which have in the past been the sole means of anchoring cable systems, do not exist on 10 percent of present sites. As operations move into more remote areas and higher elevations, this percentage will increase. Shallow rooted stumps on upper slopes in southeastern Alaska pose a special problem. In FY 1976, Timber Management funded the development of a substitute earth anchor system (SEAS) for cable yarders by the San Dimas Equipment Development Center. The Center developed and tested a highly promising tipping plate anchor, but test results lacked a consistency needed for field application. The Forest Service recently accelerated the project by contracting with Foster Miller Company of Boston, Massachusetts, to perform the required work.

The contract involves four tasks. The design analysis and testing phase will develop information needed for an improved understanding of the dynamic behavior of logging systems in order to specify load requirements for SEAS. Another phase will develop field soil and rock testing methods and equipment. A third task will develop anchor testing equipment to test holding capacity of anchors under static and dynamic loading conditions. The last task will design, develop, fabricate, and test SEAS for logging operations and other tie-down applications. Field testing data will assist sale area planning and layout, logging cost estimation, and development of other timber sale support costs.

Other Equipment Development projects include the design, development, and manufacture of proto-type equipment for several phases of Forest Engineering work. Small yarders, radio controlled winches, and lateral yarders. Nursery planting and thinning equiment, road and trail maintenance equipment, traffic counters, brush and slash disposal equipment, forestry tools of all types, fire suppression equipment and systems, and hundreds of applications you are all familiar with.

These Centers represent impressive and extensive achievements pure and simple, past and present. Even in times of budget cutbacks and personnel ceiling restrictions, the Forest Service will retain capability, if even to a lesser degree, to continue to respond to the special equipment development needs of the Forest Service and of Forest Engineering.

Point No. 3. Integrated Logging Systems Planning.

Integrated planning is the most difficult and the most important performance challenge we have. We understand the components of Forest Engineering singularly and well. The area to be harvested, the economics of each species, the location of landings, the construction of a road. The falling, limbing, and bucking of a tree. The transport of logs, the manufacturing cycle. Taken singularly, each of these components is relatively simple. But, when each of these simple components overlaps others and affects them, the combination of effects becomes geometric. Intangible values must be considered--but how, and to what extent. Literally dozens of laws and regulations all apply to a given area of land.

The stewards of the land must integrate competing interests, values, directions, and costs while having responsibilities to produce outputs. We have difficulty in assessing problems when we don't have all of the data. We also have difficulty in assessing problems because we have too much data.

Some of the future difficulties facing Forest Managers are the eventual harvesting in what are today marginal lands. Marginal because of topography, economics, or limited technology. Reforestation problems, smaller logs, higher wood costs, and environmental concerns will persist. The economy, costs, markets, and integration of research findings and knowledge to help in all of these aspects need effective management.

The consequences of our decisions are magnified because the results persist for such a long time. Add personalities, politics, and public opinions and the planning task takes on unbelievable proportions.

The challenge and the solution become inseparable -- to bring together the right mix of interdisciplinary skills and manage their interactions efficiently to solve the problem at hand.

Forest Engineering, it seems to me, needs to examine the stump to stump cycle and identify what part of that cycle it will become expert in addressing. Forest Engineering then needs to determine how much of the rest of the cycle it can afford to become knowledgeable about. This knowledge is needed to identify the affects of other actions on the Forest Engineering area of expertise, as well as the effects of the Forest Engineering on the other areas of expertise in the stump to stump cycle.

If I have any advice to this Forest Engineering audience it is: Define the job you will set out to do. Excel in the tasks of that job. Understand the other jobs to be done, but don't try to do them. You will be sought for the job that you excel in and that job well done will contribute to better solutions and performance.

Point No. 4. Future Outlook.

The Forest Service is in a cutback mode. The intake of any new skills and new people is at a low point. As desirable as a lot of skills are for us, we are making do with what we have. We are making do because it is the Forest Service way to take care of its people. As long as we are in a cutback mode, we will retrain our own people or make the best fit we can.

That is not to say that the future is hopeless for any person with Forest Engineering degrees or training. The Forest Service needs these skills, but new hires are few and far between because of budgets.

We are, nevertheless, proceeding with regional efforts to clarify Office of Personnel Management classification and examining procedures.

A Forest Engineering Institute (FEI) for the South is being initiated. Our Regions are strengthening their logging - Forest Engineering capabilities. We continue to support the FEI at Oregon State and send Forest Service Engineers and Foresters to the short courses and the 2-year course.

Computer systems applications will play an increasing part of our overall Engineering work. Remote sensing continues to show promise and should be tracked by the Forestry and Engineering professions to insure that we adopt this technology when it becomes available, affordable, and more effective than alternate tools.

The use of wood as fuel will continue. Helicopter, cable systems, and other aerial systems for harvest and transport of logs will ebb and flow with markets and pricing. More stringent utilization standards will follow regional demands and scarcity, and eventually some of us older folks will retire and leave room for you younger, well trained, integrated resource planners and decisionmakers of tomorrow.

If there is time, I'd be happy to respond to questions.

DIESEL ENGINE DIAGNOSTIC INSTRUMENTS AND PROCEDURES

Barry Savage - Caterpillar Tractor Co.

SLIDE:

1. INTRO SLIDE (TRACTOR CATERPILLAR)

2. Today I would like to concentrate my discussion on the CATERPILLAR diesel engine diagnostic tool program which has been under active development since the mid 1970's.
3. We started by creating a good foundation of basic tools to perform most of the system test and adjust functions. We are now moving into the new technologies as well as creating more complex diagnostic and analysis sytems.

6. Our test systems are being aimed at developing those key indicators that will help predict when a certain repair should be
7. scheduled and preferably before catastrophic system
8. failure occurs. Locating the source of the problem quickly, thus reducing the labor and parts expenses.

9. In the late 1970's we decided there was ample opportunity for improvement in the areas of:
   Cost vs. Capability
   Durability
   Weight and Size
   Electronic Reliability
   Accuracy
   Ease of Interpretation
   and Complex Test Procedures

10. The diagnostic instruments had to be field portable:
    Have Standardized Cables
    Operate on 11 to 40 V DC
    Shop Tool had to be Switchable for 110-220 Volts, 50 or 60 Hertz (Cycles)
    Be Selectable for Metric - U.S. or be Dual Scale
    and last but not least be Light Weight

11. To achieve electronic reliability:
    The DC powered tools had to survive 150 Volt Surges
    All Signal Lines had to be Protected against Short Circuits
    There is Reverse Polarity Protection
    Electronic Components Receive Three Thermal Shocks from 0 degree C to 100 degree C
    The assembled tool then has a "Burn In" for 100 hours at 60 degree C while operating at 40 Volts

12. Product support is provided by:
    Using Standardized Circuits
    Servicing Proprietary and Critical Parts
    Providing Complete Test, Repair and Calibration Instructions as well as Component Specifications
    Supplier Repair
    and 1 Year Warranty

13. We are using a Modular Concept to:
Avoid repeating same function in different groups
Have expandable capability
and commonality
Make tools updatable rather than outdated

14. The multi-tachometer is an example of the versatility and expandability designed into the tools.
The tachometer is programmable for an input count per revolution of 0.5 (two revolutions per count) to 256 while maintaining an accuracy of +/- 1 RPM up to 10,000 RPM.

15. There are a variety of transducers available
Tach generator
Mag Pick-up
Photo-head
16. and a high pressure fuel line pick-up
17. which has a special amplifier to permit use on prechamber and direct injection engines.
18. The multitach is a two channel device, therefore it may be desirable to have an autoprogrammer which is an add on module
19. that just plugs in. This allows setting the pulse per revolution rate for each channel so that a mechanic could check engine fan speed with the photo-head and the engine speed with either the tach-generator or mag pick-up without reprogramming for each channel.

20. Engine speed adjustment is critical to both performance and fuel economy. The Set Point Indicator was developed to reduce the skill level required to accurately set the governor. The tachometer attaches to the Set Point Indicator to display the governor speed setting. The instrument is a two channel device also so that two engines can be matched. With this combination, engine governors can be set precisely to achieve optimum performance and fuel economy.

Another important engine setting is the fuel injection timing. One degree change can effect fuel economy by $\frac{1}{2}$%. Also faulty injection timing in many instances is responsible for poor engine performance. Most CATERPILLAR engines are now equipped with an automatic timing advance. The Dynamic Timing Indicator is
22. used to check the engine timing over the full speed range and has an accuracy of 0.2 crankshaft degrees. This
23. instrument reduces the manhours required to check the injection timing by 3 to 400%. It is more accurate and also checks the advance unit which can not be checked statically.
24. The same Timing group will now be adaptable to spark ignited engines with this small signal conditioner.
25. As we have developed engine analysis systems, we have found accurate fuel rate testing to be a crucial piece of information. It is necessary to ensure the fuel system is delivering adequate fuel at full load RPM without overfueling.
26. The engine power and fuel efficiency varies with RPM as well as load. To be able to draw valid conclusions, about an engine's performance, your diagnostic system must have reference to this type of fuel map information.

27. We are just now announcing this low cost fuel rate display which will mate with the Fluidyne Fuel Flow Transducer Head which Caterpillar has had available since 1974. It will be able to display flow rates to the nearest 1/10 gallon per hour between 2 and 80 gallons per hour. It is designed to be used with CAT engines that can have their return flow shut off. (We suggest fuel flow be cut off with a manual shut off valve in place of the fuel flow solenoid. The solenoid has a tendency to leak causing fuel rates to appear too high.)

28. We are developing a load profile system that will be able to record the supply and return fuel rates and will be fully temperature compensated and accept rates up to 400 gallons per hour which occurs on engines with unit injectors. It will be able to give instantaneous as well as totalized fuel rates over real time increments as well as histogram data based on RPM.

29. Another time saver is the Infrared Thermometer. The instrument reads the infrared energy emitted from a surface and converts the energy level to an equivalent temperature.

30. The instrument has an accuracy of +/-1 degree up to 300° F and 1% of reading between 300° and 2500° F. Its main application is very rapid, non-intrusive temperature comparisons. For

31. example: measuring oil temperature into and out of an oil cooler, water temperature rise across an engine and on some engine the comparison of individual cylinder exhaust temperatures.

32. It has a very narrow field of view (1 degree) which allows measuring a spot 0.5 inches at a distance of 30 inches. One crucial exclusive was developing a thermal shock capability. All commercial portable IR thermometers are subject to large errors if the ambient temperature changes quickly. This can cause reading errors of 30 or more degrees, by going from one area to another where the ambient is 25° C or more different. Our arrangement signals the shock on the display and recovers its accuracy in 5 or 10 minutes depending on the size of the shock instead of 1 to 1 1/2 hours for the typical thermometers.

33. Another new technology for the heavy equipment industry is the borescope. The borescope brings aircraft and medical technology to the diesel engine field. With this device a mechanic can inspect:

34. a piston crown, valves and cylinder walls without removing the head. Of course many other cavities and passages can be inspected without disassembly. The instrument is approximately 24 inches long, 0.250 inches diameter and is available to view ahead, at right angles to the side and rearward. A magnifying lens and camera adapters are also available.

35. We are developing a field portable fuel sulphur analyzer. By knowing the fuel sulphur content of each new batch of fuel delivered to the engine, ...

36. you will be able to select an oil with sufficient acid neutralizing capability to prevent excessive engine wear in the standard oil change period.

37. Caterpillar recommends that the oil used in the engine have a TBN (Total Base No.) based on D2896 test method that is 20 times the fuel sulphur level.

38. In other words, for fuel with a 1% sulphur content, oil with a 20 TBN should be used and it should be changed out when the TBN level reaches 10, or the standard change hours are accumulated.

Caterpillar <u>no longer</u> recommends the oil change period be cut in half when fuel sulphur exceeds .5% as we previously recommended. Typically we have recommended ACD oil that has a TBN of 10 which is acceptable for 0.5% sulphur level. That oil grade should not be used with fuel above .5% sulphur.

Caterpillar is working towards an easy method to read TBN depletion in the field so the 50% point can be found hopefully using oil lab equipment that is already in place rather than requiring a $16,000 TBN tester.

39. Crankcase oil contamination and condition analysis can be a very effective diagnostic tool.

40. You are all familiar I'm sure with oil sampling and analysis programs Caterpillar has been offering since 1970. Atomic absorbtion analysis

41. determines the wear metals and other contaminates which are

42. good indicators of what is happening inside the engine. These are some of the wear metals it can find.

43. Infrared analysis compares the used oil against new oil. Oil

44. deteriation is detected and the necessary corrective action

45. can be taken, such as find the cause of the oil overheating before bearings are damaged due to lack of lubrication. It can spot effects of sulphur, water, fuel dilution and soot along with other chemical changes in the oil.

46. A very successful diagnostic procedure has been the On-Highway Truck Power Analysis Report (PAR).

47. This is a test procedure that allows a service technician to measure the performance of the engine over the full speed and load range of the engine and compare the results with a .....

48. computer generated expected performance for the given vehicle.

49. When a discrepancy does occur, the measured engine parameters for: injection timing, fuel rate and manifold pressure along with the truck wheel horsepower and the miles per hour are compared to specifications over the full speed range thus allowing a quick and accurate diagnosis.

50. We are working toward many derivatives of this program. We have recently announced the MARINE PAR program.

51. Here are some of the interpretation curves for towbar installation. This program has been highly successful on more than 50 field investigations in finding malfunctioning engines and more importantly, poor engine installations which have caused the engines to wear out in a fraction of their expected life. Look for this approach to go into other fields, such as gen-sets as well as portions of the technique being applied to systems such as cooling and air flow analysis.

52. To help with these anlaysis programs, Caterpillar has developed a way to supply the full engine test and performance parameters to the field.

53. It will be announced shortly and will be published on a series of microfiche. Each engine power and performance configuration will have a unique test performance number which will relate to a specific chart. With this information, you will be able to duplicate in-plant testing of any engine and compare it to the norms for that arrangement and will know the typical durations that are allowed for each parameter.

54. Engine diagnostics would not be complete if we left out the electrical system. Caterpillar machines now have a built in electrical diagnostic system that make it possible for a very inexperienced individual to check out the complete.....

55. Starting and Charging system with a simple go-no-go instrument.

56. There is a diagnostic connector located on the machine dash panel or near the engine starter. The instrument is connected to the machine and put through a start cycle.

57. The operator observes the light sequence on the instrument noting any descrepancies. The complete check out takes about three one-half minutes. The instrument and the built-in system is designed to locate failed components as well as to locate components that have deteriorated to a point where they may cause unscheduled downtime.

58. Other electrical system instruments include a clamp on AC/DC ammeter with a range of 1 to 1000 amperes.

59. Also a digital multimeter. These instruments are generally used by people with electrical knowledge, however accidents do happen so they are

60. protected against incorrect hookup and being dropped.

61. Caterpillar has developed several electrical system emulators to teach mechanics how the systems operate and how to trouble shoot them. This training aid covers the Electronic Monitoring System (EMS) for our machines and include 20 typical faults by pushing different buttons on the face. Every switch and connector and transducer in the system is reproduced. A similar training aid has been developed for the scraper transmission shift system.

62. This is a freon detector which we have available. You are probably wondering why I am showing that since we are talking about engine diagnostics. Well, many engines run freon compressors or are located near them and it takes only a few hours operation with a low concentration of freon in the air to eat up a set of piston rings. This device works like a geiger counter and can find concentrations down to 5PPM, in a matter of seconds.

63. I will close with a look at what the future may be. This is a prototype field portable computerized diagnostic system. It will be able to measure temperatures, pressues, flows, speeds, voltages, current, resistance, vibrations, emulate control system and just about anything

64. else you can think of in real time. With appropriate software it will analyze the collected data compared to specifications and past performance data for a given complete engine or just a portion of the engine.

65. Using trend analysis it will be capable of projecting a need for repairs or adjustments.

66. As we look to the future, we see linear and torsional vibration and noise analysis coming into their own. The hardware is becoming available to lead the man through the data gathering phase and download the data into a computerized analyzer that will take all the guess work out of the interpretation. It stores the signatures and does trend analysis and will alarm the operator when a given parameter is expected to leave the acceptable zone within a certain number of inspection periods.

67. Well, that about sums it up. This has been a brief overview of a very complex topic. You have seen where we have come from and a brief glimpse about where we are headed. We believe we will have the diagnostic systems to meet the challenge of the 90's...developing the performance as well as repair indicators. That will help service personnel predict condition and expected life of equipment systems so that most catastrophic failures will be avoidable. This will result in the lowest possible parts and labor costs and result in satisfied customers.