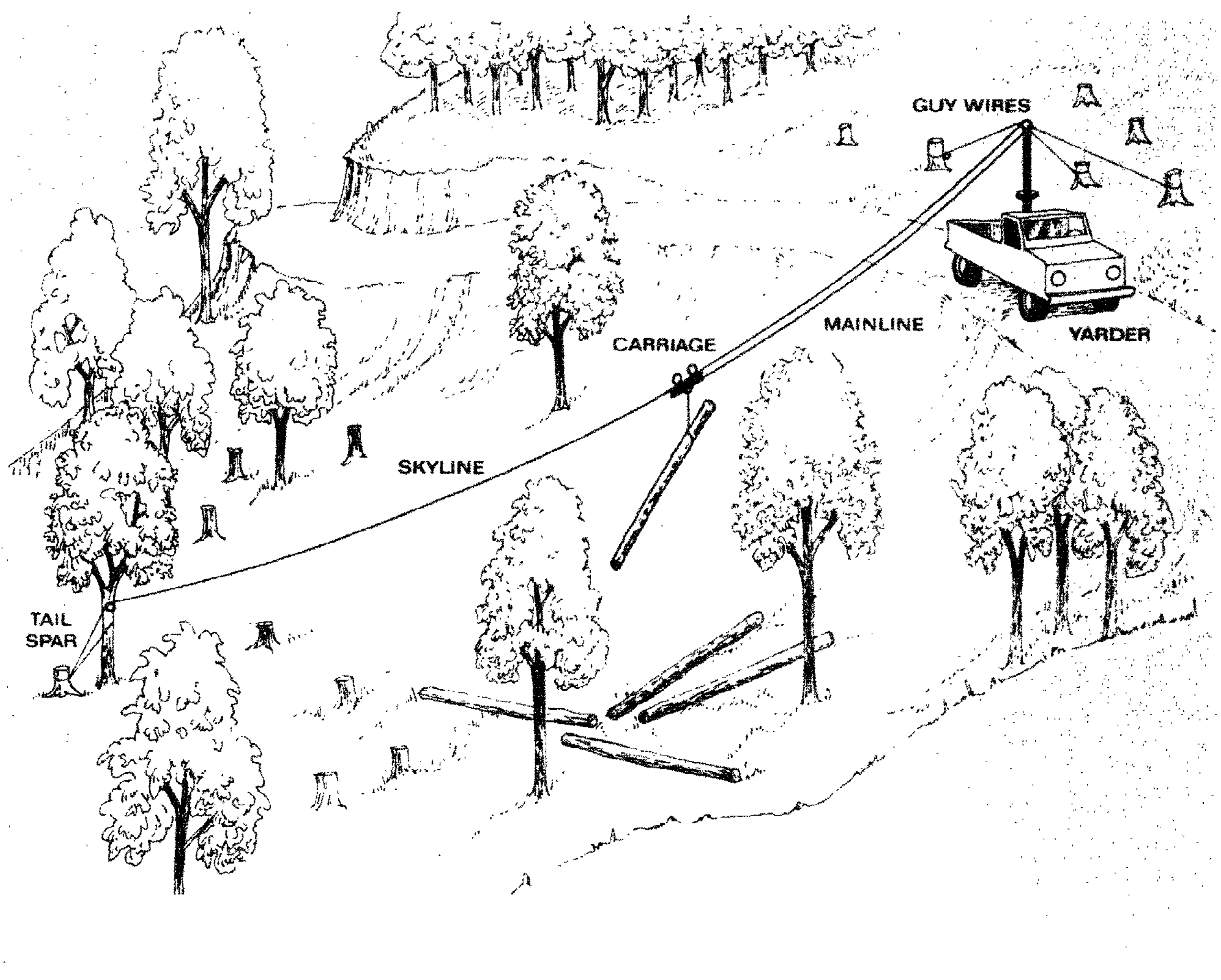
by James H. Patric

SOME ENVIRONMENTAL EFFECTS OF CABLE LOGGING in Appalachian Forests



FOREST SERVICE GENERAL TECHNICAL REPORT NE-55
1980
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

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MANUSCRIPT RECEIVED FOR PUBLICATION 22 MAY 1979

Abstract

The forestry literature, especially from the Eastern United States, was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, and fully suited to harvesting the eastern hardwood forest, has not been developed.

INTRODUCTION

FEW CAN DISAGREE that logging—including cable logging—affects the forest environment. But opinion often is divided and strongly held concerning the degree of these effects. Here, one's profession, perspective, prejudices, and even avocation will shape opinion. Does cable logging damage soil and water? Does it help or hinder wildlife and the new generation of trees? Can the visual appeal of purposefully managed young forest compare to that of old-growth timber? Surely, the logger's responses to these questions will differ from those of the recreationist; the city dweller's from his country cousin's. This report reviews the cable logging-environmental literature, particularly for the Eastern United States, and the background of practical woods experience that has stimulated our second look at cable logging in the Appalachian region (Gibson and Biller 1975).

The definitions of cable logging terms used in this paper are taken from Conway (1976). "Skidding" means hauling trees or tree segments along the ground from the stump to a collection point, i.e., landing area. "Ground skidding" means pulling the logs flat across the forest floor; wire ropes and stationary machines are used but there is no capability to lift the logs during the skidding process. The term "yarding" or "cable skidding" implies that the logs are at least partially lifted as they are pulled by wire ropes to collection points. The "high-lead" system of cable logging uses a wire rope suspended from a spar at the collection point. When yarding by the high-lead process, the cable may support little or no weight of the yarded logs, merely dragging them across the forest floor; considererable lift, however, is achieved as the logs approach the spar. The "jammer" is a variation of the high-lead system. With the "skyline," a wire rope is suspended between two or more points; logs suspended from a carriage riding along the skyline may partly drag along the forest floor or they may be fully suspended above it (Fig. 1).

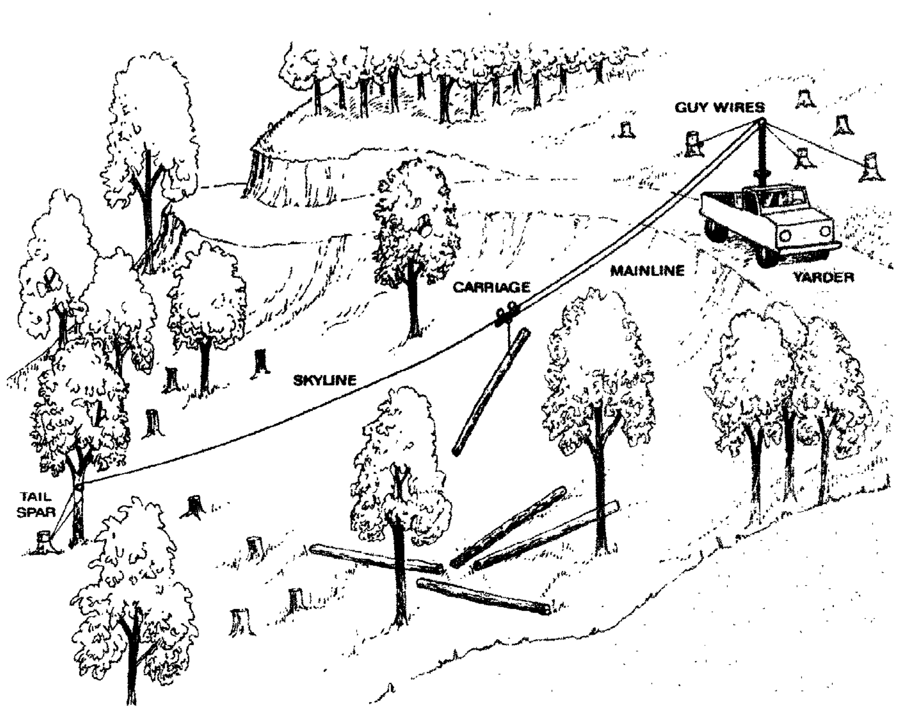

Figure 1.—Diagram illustrating some operational principles of skyline logging. Other cable logging systems embody similar principles.

With noncable systems, by contrast, machines or animals travel overland to the logs, then skid the logs across the forest floor to collection points.

IN DAYS OF YORE

The cable logging concept originated in Europe (Koroleff and Silversides 1949; Giordano 1959) but has been adapted to American conditions. In the vast Appalachian forests of 75 years ago, steam-powered cable systems supplanted the horse and ox as the primary method for skidding on steep land. During the first third of this century, the Lidgerwood (Fig. 2) skidders were the mainstay of timber harvest, yarding the old-growth timber from mountainsides to railroads (Fig. 3). Gove (1971) conveys some idea of the scale of those operations:

> An ideal setup location would allow the skidder to operate in a complete circle, reaching about 2,600 feet. The skyline was kept about 50 feet above the ground. Loaded, most of the weight was carried on the ground. Although skid trail damage usually was not severe, there were occasions when deep ruts would be gouged out near the yarding area. Some of these are still visible today. [Fig. 4]

Clarkson (1964) observed that the steam skidders "left behind a path of destruction that will scar our mountainsides for many years to come." On-the-ground examination of a 20-year-old steam skidder site (Fig. 5) in West Virginia suggested that as much as one-third of the soil had been severely disturbed, but the scars are virtually invisible beneath today's dense regrowth.

There are no known quantitative records that describe how forest streams were affected by soil disturbance of this magnitude. Many accounts, like this one by Brooks (1910), suggest substantial losses of water quality: "The natural water courses once were pure in all parts of West Virginia. Their drainage basins were covered with forests and farms, and the waters which fed the streams were clean. Many of these streams are sewers now."

Millions of acres were stripped of timber

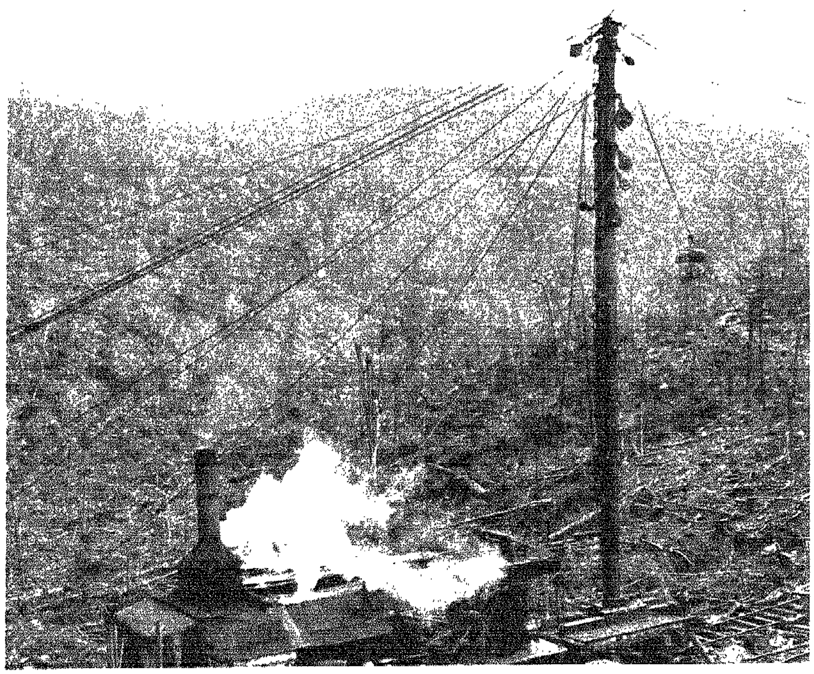

Figure 2.—High-lead logging with a Lidgerwood steam skidder. North Fork of the Gauley River, West Virginia, 1940.

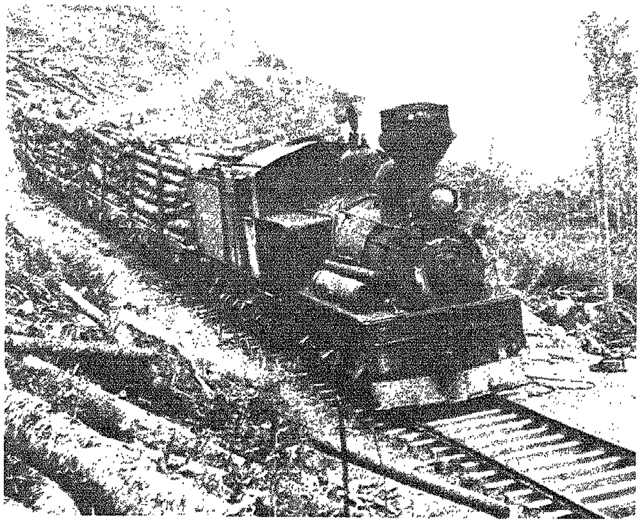

Figure 3.—A loaded log train pulled by a Shay engine. Location and date unknown.

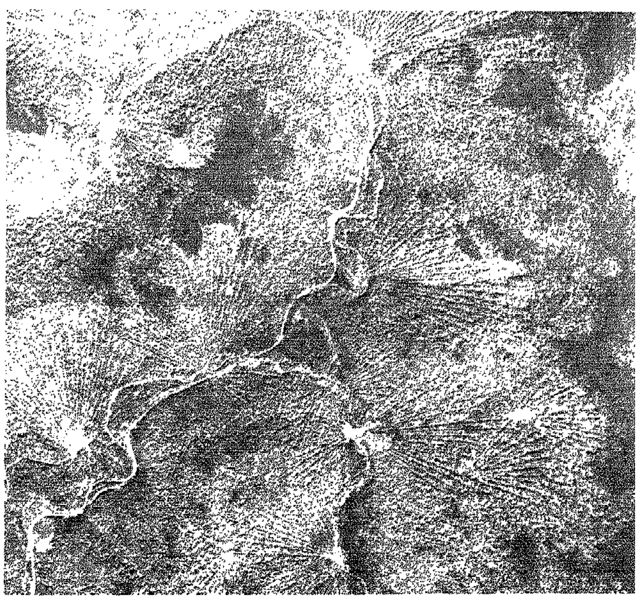

Figure 4.—Ground vegetation destroyed by steam skidding (radial patterns). A logging railroad nearly bisects the aerial photograph. Shaver's Fork, West Virginia, 1945.

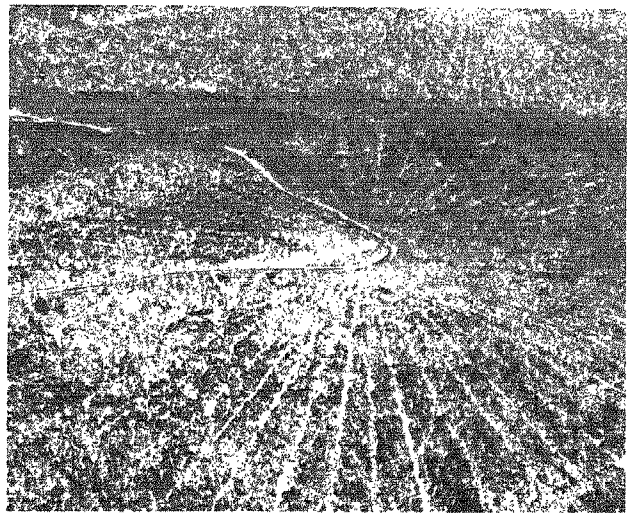

Figure 5.—Oblique aerial photograph of a radial pattern caused by steam skidding. Same vicinity as Figure 4 but taken in 1972. These patterns are invisible, lacking snow, because of dense, brushy revegetation.

and further desolated by wildfire that so often followed logging (Fig. 6). The effects on visual appeal are obvious. Logging effects on most species of wildlife are not quantified, but there must have been large changes in animal populations. Deep concern about logging practices was not widespread (Simmons 1976). Presumably, much of the land so "improved" would be farmed. Much of it was, leading to a widespread form of subsistence agriculture on

Figure 6.—Logged and burned land near Davis, West Virginia, about 1930.

land better suited to producing wood and wildlife. These lands were prime targets for erosion control during the early years of the U.S. Soil Conservation Service; Barnes (1938) said, "The problems of soil use have arisen largely from attempts to farm land unfit for farming, and from failure to make provision for use of forest soil for forest production." To this day, the return of cutover land to forest production continues in the Eastern United States.

Even where agriculture was not a factor, damage to residual forest stands by steam skidders was cause for concern:

> On examining the areas logged by horses and that logged by steam skidders at the same period, it was found that reproduction was in better condition and more advanced where horses had been used. This is accounted for by the fact that in logging with skidders most of the reproduction is either uprooted or injured so that very little young growth remains after the operation. [Lacey 1920]

Despite general indifference to—indeed, even some support for—this despoliation of Appalachian forests, there was concern. Watson (1923), for example, deplored "The steam skidder and the methods of high-lead logging [that] are forest destroyers whose extraordinary destructiveness the forester cannot hope to overcome." Eventually, the problem solved itself because the need for large-scale harvest methods disappeared as the old-growth forest disappeared. Until that time, neither the forests nor the technology were well suited to harvest methods other than clearcutting and yarding with steam skidders.

Foresters preferring harvest methods other than clearcutting deplored the steam skidder. "Skidding by overhead or ground cables would be ruinous to trees left and to advance reproduction. Partial cutting obviously is best suited to logging by animals rather than by machines" (Frothingham 1931). But even logging with animals was not without environmental damage (Fig. 7), as shown by this account of a horse logging job in New Hampshire:

> I mapped a portion of it in detail and found that 60 percent of the area was in skid trails and landings, or covered by deep windrows of logging slash. Almost every residual tree was knocked down or skinned up, and the advance reproduction was almost completely eliminated. [Simmons 1957]

The conditions characterized by this era continued over much of the Appalachian region until World War II.

The destruction that characterized turn-of-the-century logging is unlikely to recur. The harvest techniques of that era, either machine

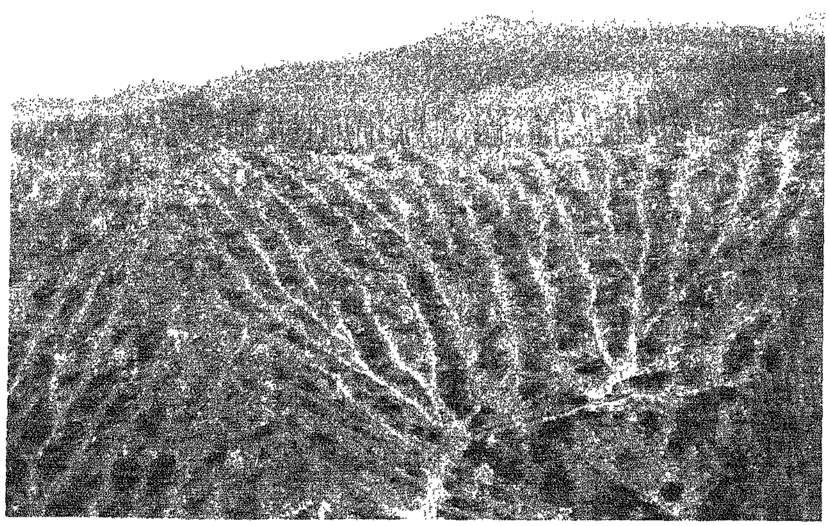

Figure 7.—A horse logging job near St. George, West Virginia, about 1965.

or animal, no longer are used. More important, timber is harvested today long before it can attain the size of old growth. And loggers are learning to protect the land. Smaller timber, improved harvest techniques, and concern by loggers as well as the public, virtually precludes the environmental ruin reminiscent of the steam skidder in its heyday (Hawley and Smith 1954).

THE POST-WORLD WAR II ERA

By 1950, little remained of the old-growth forest in the Appalachian region. But despite some grim after effects of earlier logging, most of the cutover land had regenerated to thrifty stands of second-growth hardwoods. All of society's need for goods and services from the eastern forest would be met from these new stands. The transition to new conditions in the logging industry in the Northeast was summarized by Simmons (1977):

> Following World War II the revolution in logging methods and equipment took place. Egged on by a diminishing labor force, that demanded higher pay and easier jobs, logging operators were avidly seeking more efficient ways of doing the job. Equipment manufacturers with excess capacity due to cancellation of wartime contracts, but with many new ideas and techniques developed during the war, were quick to respond. The old two-man chainsaws, weighing upward of 100 pounds, were whittled down by stages to efficient one-man models. The crawler tractor was made a more efficient skidding machine with the addition of winches and arches. Then, in the early 50's, the rubber tired skidder was developed. . . . Motor trucks were improved, made sturdy and efficient, and log loaders were progressively improved. . . . These developments continue to the present day.

A similar transition occurred in the Southeast. There, interest in avoiding some of the environmental problems associated with logging centered at the Coweeta Hydrologic Laboratory:

> A considerable change has taken place in the last 9 years in logging methods and uses for forest products in the southern Appalachian Mountains. In 1942, when the Coweeta study of poor logging methods started, the common method of skidding was with oxen and horses. After World War II the emphasis changed from animal to power equipment appearing in the woods. After being considered an uneconomical method for 25 years, the high-lead logging system reappeared this quarter and demonstrated that it will have a place along with other power logging equipment in the southern Appalachians. At present the high-lead system is being used on a job near Highlands, North Carolina, to remove high quality logs from narow valleys with steep slopes and small coves or benches which have heretofore been considered inaccessible.[1]

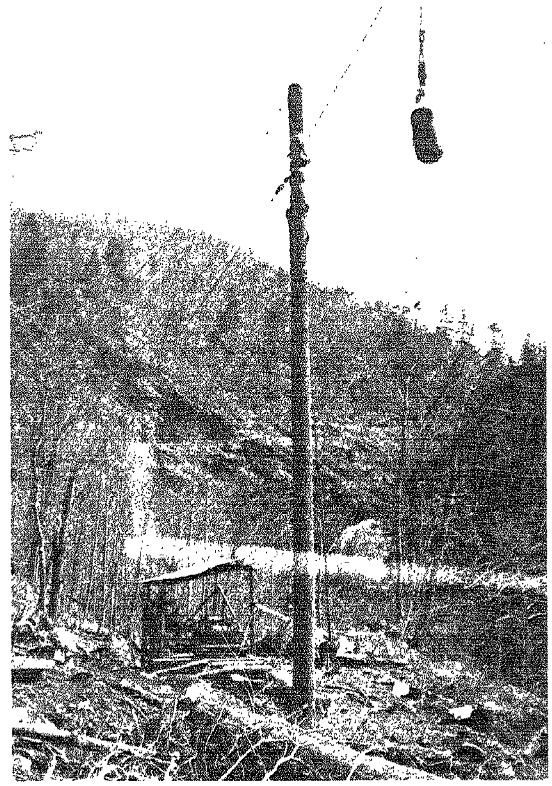

Figure 8.—Wyssen skyline system operating in the Cullasaja River drainage, near Franklin, North Carolina, about 1950.

The power logging equipment referred to was not a high-lead system; it was the Wyssen skyline (Fig. 8), and would be tested throughout the United States during the decade to follow. In tests from the Atlantic to the Pacific, in New York and Canada (Fobes 1950), the Rocky Mountains (Matson 1956), Washington (Wooldridge 1960), and Alaska (Weisgerber 1962) the findings were unanimous; the Wyssen caused little soil disturbance and no evidence of accelerated soil erosion. Herman (1960) provided the most complete account of this:

> Soil disturbance was negligible on both clearcut and selection-cut areas. Defined skid trails

[1]Unpublished quarterly report of Oct-Dec 1951. Division of Forest Influences Research, Southeastern Forest Experiment Station, Asheville, North Carolina.

Figure 9.—An A-frame skidder loading a logging truck in Georgia, 1957.

> are inconspicuous on completed settings. They are not continuous and are scattered so that water concentrations do not occur. The only evidence of exposed soil was confined to a few narrow short stretches. These were found only at points where the skyline was low and slope configuration was convex. No stretches of exposed soil exceeded 20 feet in length. These observations coincide with those made on other skyline-crane logging test areas . . .
>
> The equipment performed well when used in selectively cut dense timber. Damage to the dense residual stand, even where logs were skidded more than 150 feet, was light.

E. A. Johnson[2] expressed a counteropinion that the Wyssen system caused two or three times more damage to residual hardwood trees than did timber harvest systems then used in North Carolina.

[2]Personal communication. U.S. Forest Service Headquarters, Washington, D.C.

Present interest in cable logging as a means to protect environmental values probably stems from those tests. Minor damage to forest trees, soil, and water had been clearly demonstrated. But much adaptation of the Wyssen system was needed before its assets in terms of environmental protection could override its economic liabilities; to this day, operational costs bar its acceptance as a viable alternative for harvesting wood products under Appalachian conditions.

The concept, nevertheless, had taken root and attempts to adapt cable logging equipment to hardwood forest conditions seem nearly as limitless as human ingenuity. The simplest was the A-frame (Fig. 9). But this and similar devices often became "dead ends," unacceptable to loggers because they were poorly adapted to local conditions or because they soon became obsolete. To date, the common stumbling block of all adaptations is their inability to skid logs as cheaply as competitive systems. A complete list of cable logging devices will not be attempted, but the following examples illustrate continuing interest in applying the cable concept.

Some devices (Koreloff and Silversides 1949; Church 1972) have tried to put gravity to work. Adaptations of western logging machinery—the jammer (Bond 1959), high-lead (Pulpwood Production/Timber Harvesting 1976), skyline (Fobes 1947), tractor (Northeastern Logger 1953), and helicopter (Perkins 1963)—have applied the cable concept under eastern conditions with limited success. Cable skidding bundles of small products has been tried from Alabama (Cline 1956) to Canada (Seheult 1955). Even miniature equipment has been tried for cable skidding small products (Taylor and Richardson 1963). A new application of the skyline principle is being developed at Purdue University (Perkins 1975). Recently, sophisticated western (Pulpwood Production and Sawmill Logging 1973; Priegel 1975), European (Wendel et al. 1974), and aerial (Welsch and Abplanalp 1977) equipment has been tested in the Appalachians (Fig. 10). To date, none of these devices seems uniquely adapted to hardwood logging conditions and none is economically competitive with conventional logging systems.

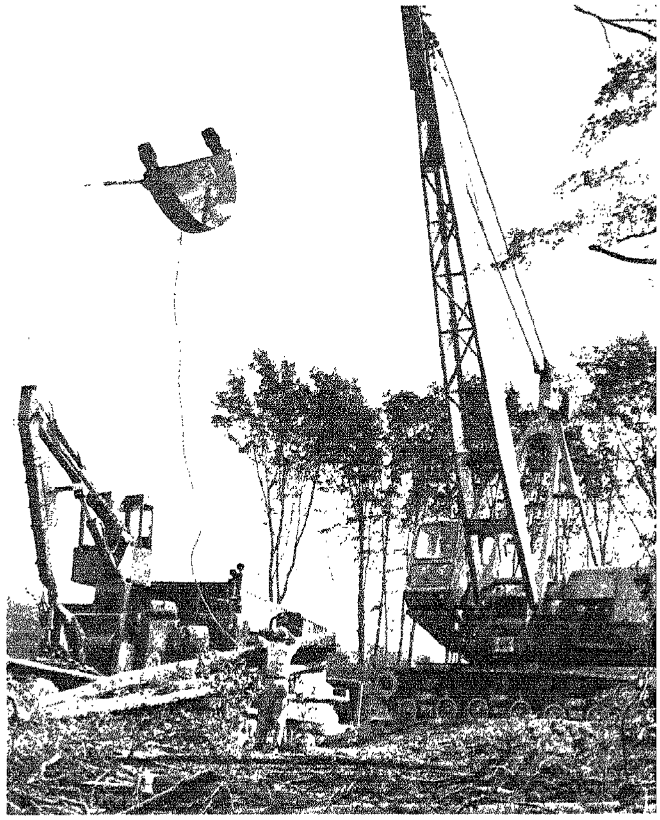

Figure 10.—Skylok skyline system yarding whole trees to a chipper. Gauley Woodlands, West Virginia, 1977.

Environmental effects

Only the effects of cable logging on soil, water, residual stands, wildlife, and visual appeal are considered in this paper. "Environment" is, of course, broader than these parameters but the effects of cable logging on air quality, energy consumption, noise, etc. have received so little attention that no discussion of them is undertaken.

For many years, the forestry profession has been aware of the need to better protect our forest environment:

> Concern for the quality of man's environment is one of the most potent forces in this highly urbanized society. Public concern often is evident in the whole field of natural resources, but it is sharply focussed on management of forest land, and particularly on publicly owned land. . . . It is imperative that forest land be managed to minimize impacts on soil, water, air, wildlife, and esthetic values. [Resler and Buckman 1973]

Experience suggests that cable logging is a promising means to minimize the environmental impacts of wood products harvest on forested land in the mountainous East.

Effects on soil. Packer's (1967) review established that logging roads are primary sources of eroded soil in the managed forest. A logging road is defined as any prepared travel route whereon mineral soil has been exposed and compacted by human use (Fig. 11).

Burke (1975) maintained that improperly located and constructed timber access roads and landings cause the greatest adverse impact of all activities relating to timber harvest (Fig. 12). Frothingham (1931) recognized

Figure 11.—Removal of the organic cover from logging roads exposes the underlying soil to accelerated erosion. Soil compaction and rutting by machinery worsen erosion.

Figure 12.—Carelessly built logging road and landing located too close to a stream. Here, eroded soil quickly becomes stream sediment. Location and date unknown.

Figure 13.—Several cubic feet of soil were eroded per lineal foot of this carelessly built and managed logging road. Near Franklin, North Carolina, 1952.

that there was little danger of serious erosion from tree cutting on unburned land, pointing instead to deeply worn skid trails as the greater threat (Fig. 13). The same thought was expressed by Kidd and Kochenderfer (1973); nevertheless, the role of roads as prime erosion sites in forests finds only grudging acceptance within the logging fraternity and is often unrecognized. This lack of acceptance seems strange because logging roads are everywhere in the eastern forest; Lull and Reinhart (1965) estimated 1,620 miles in the upper Potomac River Basin alone. Pruett (1975) estimated that 3 to 7 percent of the total forest area may be in roads. Kochenderfer (1977) measured from 6 to 16 percent of the soil bared by roads on more than 1,000 acres of freshly logged land in West Virginia. Dissmeyer (1976) estimated even more, up to 25 percent, bared by logging on mountainous land. Methods to control soil erosion on such roads are well known (Kochenderfer 1970) but too often are not applied.

Walbridge (1960) proposed the use of self-propelled cable skidders in Tennessee as "about the only means of mechanizing skidding in terrain exceeding 35 percent slopes other than riddling the area with skidding roads." Experience substantiates this assertion in the West as well as the East, although careful planning also reduces area in logging roads (Mitchell and Trimble 1959). Burke

Figure 14.—Soil disturbance accompanying modern skyline harvest on the Gauley Woodlands. The forest litter has been mixed with surface soil but there has been no evidence of accelerated erosion. West Virginia, 1977.

(1975) stated that "a well-planned running skyline system can substantially reduce access road mileage" by perhaps one-third of the roads built during high-lead logging (Binkley 1965). Limited eastern experience bears out that these reductions are possible; Kochenderfer and Wendel (1978) report less roads where cable systems were used:

Skidding system	*Acres served per mile of road*
Wheeled skidder	20
Jammer	31
Skyline	80

Thorsen[3] found that 5 acres of land in roads served 117 acres of land logged with a high-lead system in Georgia, about 1 mile of road per 40 acres of land. In West Virginia, cable logging required fewer roads than tractor harvest, with the only required road on a ridge top above each cutting unit.[4] Megahan and Kidd (1972) lucidly expressed the environmental benefits of fewer logging roads, their western experience being fully applicable to eastern conditions:

> Jammer logging in the past has required a dense network of roads with a maximum road spacing of about 400 feet. In steep country this may disturb soil on 25 percent of the total logging area. Skyline logging systems permit road spacing up to 1,600 feet or more, depending on the local conditions. This reduces the area dis-

[3]James Thorsen. Unpublished report on file at the Tocoa District Headquarters, Chattahoochie National Forest, Tocoa, Georgia.

[4]Personal communication from Dr. Bruce Brenneman, WESTVACO, Rupert, West Virginia.

turbed by perhaps 75 percent and may provide a greater buffer area for sediment deposition between the roads and the stream channel. Thus, by far the greatest benefit to be derived from skyline logging systems with respect to erosion reduction results from reduced road mileage.

Logging, even by cable systems (Fig. 14), also disturbs the soil on nonroaded forest land. These effects have been evaluated many times in the West. Ruth (1967), for example, reported 15.8 percent of the mineral soil exposed by high-lead systems, only 6.4 percent by skylines. Logging with a tractor disturbed much more soil than did a skyline, with 36.2 percent as opposed to 2.8 percent severely disturbed (Klock 1975). Soil disturbance by tractor may be almost three times greater when slopes exceed 40 percent (Garrison and Rummell 1951). The effects of logging on western soils were cogently summarized by Swanston and Dyrness (1973):

Method	*Bare soil (%)*	*Compacted (%)*
Tractor	35.1	26.4
High-lead	14.8	9.1
Skyline	12.1	3.4
Balloon	6.0	1.7

There are many claims of minimal soil disturbance by cable systems in the East, but few precise reports. Ponder,[5] Aydelott et al.,[6] Douglass,[7] and Knight (1976) were impressed with the lack of disturbance to mineral soil during and after jammer logging in the southeast (Fig. 15). In Georgia, McCoy[8] reported 10 to 15 percent of the soil disturbed by high-lead logging on transects chosen as most disturbed on the cutting unit. For the entire cutting unit, less than 6 percent of the soil was disturbed.[9] Prater (1973) reported so little

Figure 15.—Note the lack of soil disturbance after skidding with a tractor and cable system. South Carolina, 1957.

soil damage (in Louisiana) that not even the most avid environmentalist was disturbed. Such glowing, though unquantified, evaluations attract interest but provide little concrete basis for comparing soil disturbance among logging systems.

Dickerson (1968) made these comparisons in Mississippi:

Logging methods	*Soil area disturbed (%)*
Rubber-tired skidder	17
Crawler tractor	14
Mule	12
A-frame (a cable system)	12

After use of a skyline in West Virginia (Fig. 16), Patric and Gorman (1977) observed no change in bulk density of B_2 horizon soil (Fig. 17), no decrease of infiltration rates, and no evidence of accelerated soil erosion. These results pertain to logged land, not to roads or skid trails. The authors reported the following degrees of soil disturbance:

[5]Felix Ponder, Jr. Typewritten report of erosion plot check on file at Jefferson National Forest Headquarters, Roanoke, Virginia.

[6]D. Gray Aydelott and Thomas E. Elson. Typewritten evaluation of cable logging demonstration on file at Jefferson National Forest Headquarters, Roanoke, Virginia.

[7]Personal communication from James E. Douglass, Coweeta Hydrologic Laboratory, Franklin, North Carolina, Feb. 11, 1974.

[8]Personal communication from William J. McCoy, Soil and Watershed Staff Officer, Chattahoochee National Forest, Gainesville, Georgia.

[9]Personal communication from Earl Priegel, U.S. Forest Service, Atlanta, Ga.

Figure 16.—The URUS, a small European skyline system tested near Parsons, West Virginia, 1976-1977.

Degree	*Percent of area*
Severe (B horizon exposed including roads and skid trails)	2.9
Slight (A horizon exposed)	6.8
None (No more than litter rearrangement)	90.3

Perhaps the most thoroughly documented report on soil damages caused by logging was from New York (Craul 1976). There, increased bulk density on skid trails decreased macroporosity, water availability, and infiltration (Fig. 18). It was estimated that these changes increased the erosion potential 0.024 ton per acre of logged land, increasing by 50 percent the erosion rate for forest land reported by Patric (1976). Lull's (1959) review of the compaction literature suggests that the increased bulk density observed by Craul (1976) is a relatively short-lived phenomenon. Reinhart (1964), too, showed that reduced infiltration was restricted to skid roads in West Virginia.

Figure 17.—Note typical lack of disturbance to subsoil beneath a lightly used skid trail about 4 months after logging, near Franklin, North Carolina, 1952.

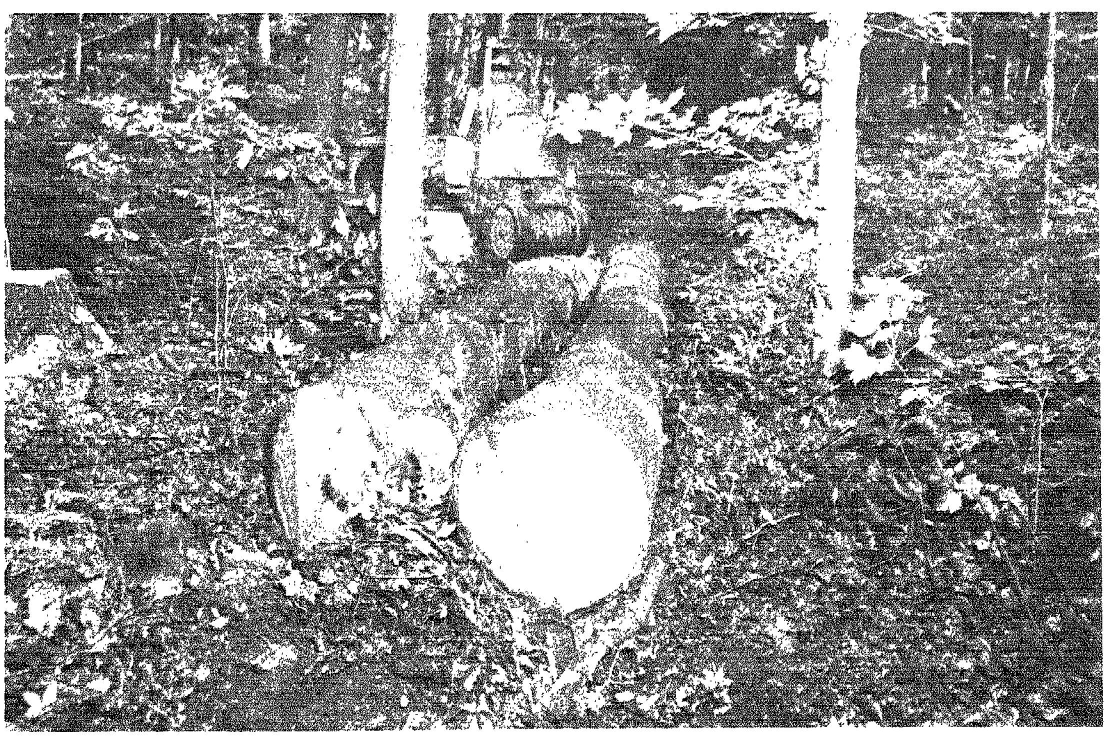

Figure 18.—Note lack of surface disturbance during cable skidding by tractor. Somerset County, New Jersey, 1954.

Effects on water. Packer's (1967) review established that it was not the cutting of trees but the method of logging, primarily road practices, that increases sediment in streams draining logged land. Bates (1924) had recognized this problem nearly half a century earlier:

> Any road, built with ordinary care and provision for drainage, and traversing a section of mountain forest land, will have and does have a greater effect on streamflow as measured in terms of erosion, than would the cutting of the entire section of timber, or its burning, provided the burned or cut area was not afterward disturbed.

Reinhart's (1975) statement was even broader:

> . . . we have for the Appalachian Highlands the most complete and detailed information available anywhere on the response of streams to management of their watersheds by man . . . Research and general observation have amply demonstrated that it is not the cutting of trees, but the baring and compaction of mineral soil incident to removal of products that caused major erosion and sediment damage. This observation may seem simple and self-evident, but it is often ignored in present-day arguments about forest practices.

There is ample evidence to support the contention that wood products can be harvested by conventional (i.e., noncable) methods, on good roads, without ill-effects to water (Northeast. For. Exp. Stn. 1975). If this is possible with conventional systems, it is almost certain that ill-effects will not be caused by cable logging. Unfortunately, most of the supportive evidence is not quantitative.

With erosion controls conscientiously applied, cable logging was reported to cause little apparent change in water quality in Georgia (Black and Clark 1958; Aydelott et al.),[9] in North Carolina (Vogenberger and Curry 1959), in Virginia (Virginia Division of Forestry 1955), and in Pennsylvania (Heagy 1960). Perhaps nowhere have the methods needed to protect water quality been described more concisely than by Walker:[10]

> Prior to logging, a series of contour secondary roads were punched in by the contractor under Coweeta personnel supervision. Grades of 3 to 5 percent with short pitches were maintained. Long dips of 30 to 50 feet at stream crossings provided water diversions. Closed culverts were installed at streams. Logging was done uphill to a haul road with an A-frame power skidder. Maintenance was performed daily to keep structures open. Following the logging of a section of haul road, deeper water diversions were constructed and oats, rye, or rye grass planted. Fertilization accompanied seeding. Even though rainfall was 7 inches above normal during logging, damage to water quality was negligible.

Stream turbidity on the watersheds studied by Walker differed little from that on permanently forested watersheds.[11] Several years later, the logging roads were grass covered and some trees were growing on them. Skid trails caused by A-frame logging (Fig. 19) were barely visible. In short, there was no evidence of accelerated soil erosion or of reduced water quality.

The road practices described by Walker[10] were applied on a larger scale several years later in North Carolina (Hewlett and Douglass 1968). Sediment production was increased temporarily by about 50 percent, an effect attributed to attempts to "improve" the trout habitat. On this watershed, logs were winched to tractors, a form of ground skidding developed for reaching between roads and into hard-to-get-at places (Northeastern Logger 1953).

Just one of many reports is cited to show how careless logging can damage water quality (Delaware Basin Research Center):[12]

> The site was on a steep mountainside and covered a large area with a light cut per acre. Skidding was done during the past winter and spring by tractor, with skid trails generally running perpendicular to the contours. No attempt was made to avoid water courses and, as a result, flowing water got into the tractor ruts. Erosion was accelerated by the running water until the ruts are now 3 to 4 feet deep in places. These eroding ruts appear to have taken the place of original stream channels. Thus a source of erosion and sedimentation has been developed which may take a number of years to be corrected by nature.

Western experience closely parallels that for the East. There, too, the impact of logging activities on water quality is determined largely by the extent to which a forested area is disturbed by the network of access roads

[10] Laurence C. Walker. Typewritten report on file at the Coweeta Hydrologic Laboratory, Franklin, North Carolina, 43 p.

[11] Laurence C. Walker. Typewritten graduate report for University of Georgia. On file at the Coweeta Hydrologic Laboratory, Franklin, North Carolina, 43 p.

[12] I. C. Reigner. Unpublished quarterly report for August 1950. Division of Forest Influences Research, Northeastern Forest Experiment Station, Broomall, Pennsylvania.

Figure 19.—A-frame yarding logs on steep mountains near Franklin, North Carolina, 1952. Both A-frame sites and skid paths were fully revegetated and could not be traced by 1960.

and by the movement of logs from stump to landing. The U.S. Environmental Protection Agency (1976) published a massive review of the pertinent literature; of the several cable systems, skylines in general least affect the site and, presumably, water quality.

East or West, the principles for maintaining clear streams, during and after logging, are deceptively simple. (a) As nearly as possible, maintain an unbroken litter cover (Fig. 20). Although logging residues are ugly (Fig. 21), they actually reinforce the litter cover and its erosion control function. (b) Build the fewest roads possible, design and maintain them correctly, and pull logs to roads (Fig. 22) by cable methods. (c) Stabilize eroding roads with brush (Fig. 23) or grass, a particularly important measure where eroded soil can quickly be transformed to stream sediment (Fig. 24). (d) Since litter-covered forest soil erodes very slightly, stream channels are the major source of sediment on most eastern forest land (Fig. 25). Logging machinery must be kept out of channels, even on tiny tributary streams (Fig. 26), if dirty water is to be avoided.

Although there is abundant evidence that tree cutting greatly influences the quantity as well as the timing of streamflow (Northeast. For. Exp. Stn. 1975), there is no evidence that methods of logging influence these properties of forest streamflow.

Figure 20.—An unbroken litter cover on the forest floor almost always prevents accelerated erosion of soil. The littler cover absorbs the entire kinetic energy of falling rain and facilitates the infiltration of rain as fast as it falls. Illinois, 1930.

Figure 21.—Logging residues are unsightly but add greatly to the soil-protective function of the forest floor. Michigan, 1957.

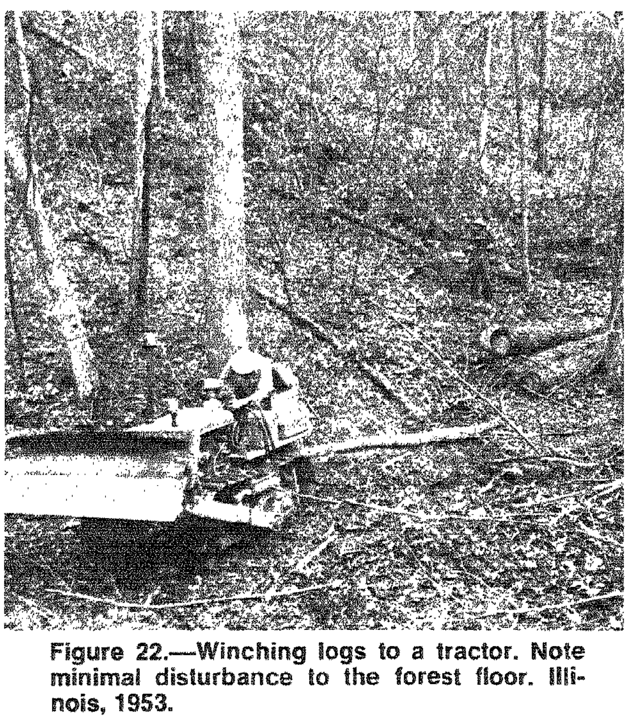

Figure 22.—Winching logs to a tractor. Note minimal disturbance to the forest floor. Illinois, 1953.

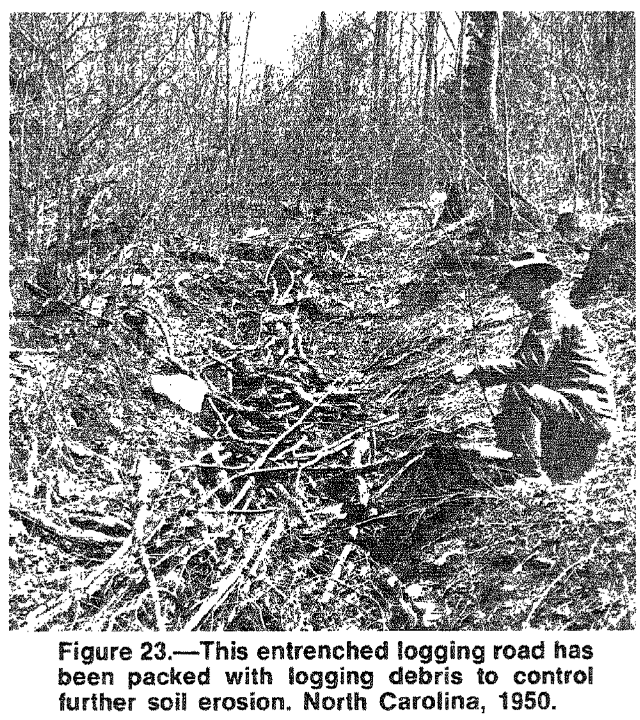

Figure 23.—This entrenched logging road has been packed with logging debris to control further soil erosion. North Carolina, 1950.

Figure 24.—Erosion control is especially important when soil washed from poorly located roads can be carried directly into streams. Virginia, 1956.

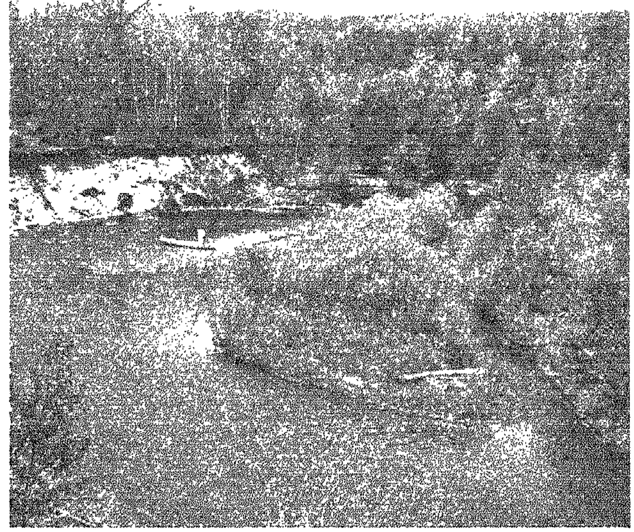

Figure 25.—Stream channels almost always erode more rapidly than other parts of forest landscapes, but seldom are sites of erosion and deposition as apparent as in this stream. Michigan, 1970.

Figure 26.—Skidding logs, even in tiny headwater streams, greatly accelerates the rates of channel erosion. Near Franklin, North Carolina, 1946.

Residual stand damage. Long ago, Lacey (1920) concluded that:

> . . . any system of logging is bound to destroy much of the reproduction. It is, therefore, a matter of using the less destructive means. On examining the area logged by horses [parallel skid trail patterns near the center of Fig. 27] and that logged by steam skidders [radial skid trail patterns, Fig. 27], it was found that reproduction was in far better condition and far more advanced where horses had been used.

But lest horse logging be held blameless in residual stand damage (Fig. 28), consider this observation by Simmons (1957):

> . . . in West Virginia . . . we tried to establish some permanent camera points which would show residual stands following logging of which we were particularly proud. At almost every one of these points the good residual trees were destroyed or damaged by the horse loggers, usually because they were in the way of a skid trail or a landing area.

Westveld (1926) too, reported 18 to 20 percent damage after horse logging in New Hampshire. Despite such observations, Frothingham (1931) concluded that "greatest destruction occurs when cable skidding is done with powerful, stationary donkey engines." Simmons (1959), on the other hand, found that the volume and number of trees damaged, regardless of care in logging, was about the same with all methods.

The effect of care in logging is clearly evident in data from the South. There, loblolly pine was prized more than hardwood and was logged more carefully (McKinney 1934):

	Old field		*Forest grown*	
	Pine	*Hard-wood*	*Pine*	*Hard-wood*
Residual stand damage (%)	12	35	19	39

With the development of smaller and more mobile skidders, ruinous damage to residual trees was no longer an accepted fact.[13] Mechanized thinning by several methods used in the Lake States caused similar numbers of injuries (Biltonen et al. 1976). When reasonable precautions were taken to minimize injury during selection logging in the Central States, less than 10 percent of the residual stands were damaged (Deitschmann and Herrick 1957).

[13]Logging specialist, Joseph H. Smith, Northeastern Area, U.S. Forest Service, Morgantown, West Virginia.

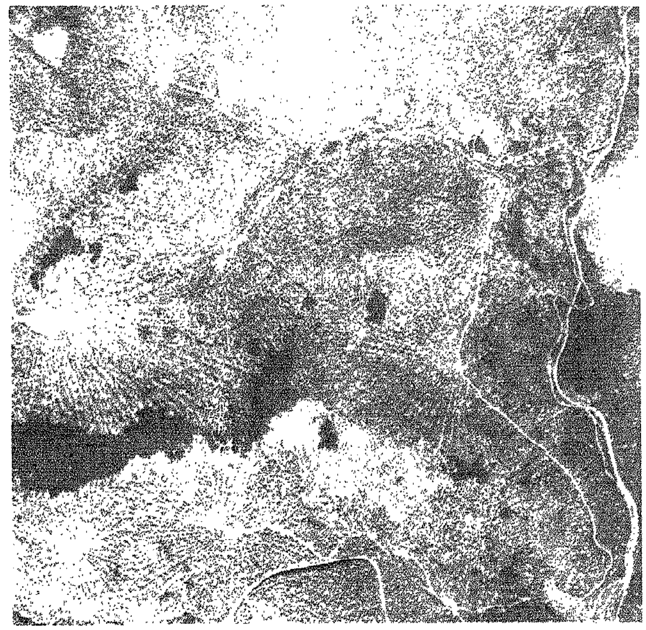

Figure 27.—Aerial view; skidding patterns caused by horses (center of photo) and steam skidders (radial patterns). Shaver's Fork, West Virginia, 1945.

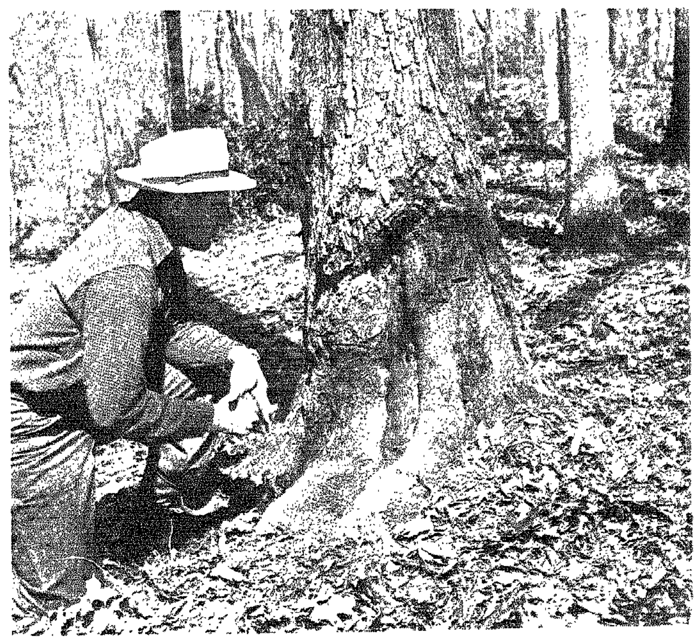

Figure 28.—Tree injury caused by cable abrasion or impact of skidding log. North Carolina, 1955.

But in Virginia, large tractors caused less damage than small tractors (King 1963). Injury was similar for wheeled skidders and crawler tractors in New York (Nyland and Gabriel 1972). Damage caused by tractors differed little from that caused by horses in the Lake States (Perkins 1969). These highly variable evaluations probably bear out the truth of Simmons' (1957) conclusion that lack of planning and careless practices can cause excessive damage by any harvest system.

The felling crew can do much to avoid skidding injury (Herrick and Deitschman 1956), a fact also noted by Wendel and Kochenderfer (1978). Herrick and Deitschman (1956) concluded that less than 10 percent of the residual trees, and these mostly saplings (Meyer et al. 1966), should be damaged by logging operations conducted with reasonable care.

Residual stand damage is held to low levels with cable systems. Only 7 percent of the residual trees (34 per acre) sustained yarding injury during skyline logging in West Virginia (Wendel and Kochenderfer 1978). Aulerich et al. (1974) found nearly the same number of wounded trees after tractor and skyline thinning in Douglas-fir, but Lysons and Twito (1973) reported little stand damage by skyline systems in partial cuts.

Wildlife. The abundance of animal life in forests is directly related to energy gradient. In most forests, the availability of solar energy decreases with crown depth until little is available on the forest floor. Animal species are adapted to meet their energy needs at rather specific levels within this distributive system (Webb 1973). Deer browse from the branches of younger trees and brush. Wild turkey, small game, and songbirds seek sunlight at various levels for warmth, nesting areas, and food (Fig. 29). In areas where forests are managed to meet these energy needs, wildlife populations have increased in nearly every instance (Miller 1973).

Because many animal species are specialized to rather rigidly defined energy strata (Fig. 30), diversity among species tends to be higher where energy distribution is most diverse. Therefore, it is tree cutting and not the logging system that is of paramount significance to wildlife. To paraphrase Wing (1951),

Figure 29.—Raccoon in hollow tree. Tree-denning animals require large, old trees. Vermont, 1962.

Figure 30.—Ring-neck pheasant. Wildlife that live and feed on the ground or in openings cannot thrive in dense stands of large and mature trees. West Virginia, 1929.

it is not so much a matter of what is cut or how it is logged, as how much is cut and where. The effects of cutting on wildlife tend to vary with scale of cutting relative to size of home range among the animals of interest.[14] Of all the cutting methods, group selection (Minckler 1975) provides the scale of cutting of greatest value to wildlife (Fig. 31). Roads, too, benefit wildlife by providing diversity of food and cover (Fig. 32), as do openings created by logging. Openings made by logging roads also tend to distribute energy diversely from the tree canopy to the forest floor.

Group selection is a logical harvest method for small scale operations (Minckler 1975), but it becomes inappropriate when there is a large investment in expensive cable logging systems.[14] WESTVACO, for example, clearcuts 40-acre blocks in West Virginia (Parker 1976) in order to operate their large machines efficiently (Fig. 33). Thus, wildlife management is linked to economics, with group selection a logical choice on small forest properties, but an awkward and expensive alternative on large holdings. Probably only the smallest, most mobile, and least costly of the cable systems will find economic use as a group selection harvest method.

Cable logging effects on soil and water have clear implications for fish. Any logging system that materially increases sediment in streams can injure fish populations. Since cable logging has the least effect on soil erosion and stream sedimentation of all harvest systems, presumably it is the least injurious to fish. No literature was found that bears directly on how cable logging affects fish.

Visual appeal. The pleasure that people derive from all of their senses is strongly conditioned by their expectations.[15] Thus, to most urban people, the aftermath of logging appears untidy and generally destructive (Fig. 34). People closer to the land view logging more tolerantly, but even they consider it a necessary evil unlikely to improve a forest

[14]Personal communication from John D. Gill, Wildlife Biologist, U.S. Forest Service, Morgantown, West Virginia.

[15]E. M. Gould, Jr. Unpublished report, Harvard University, Harvard Forest, Petersham, Massachusetts, 43 p.

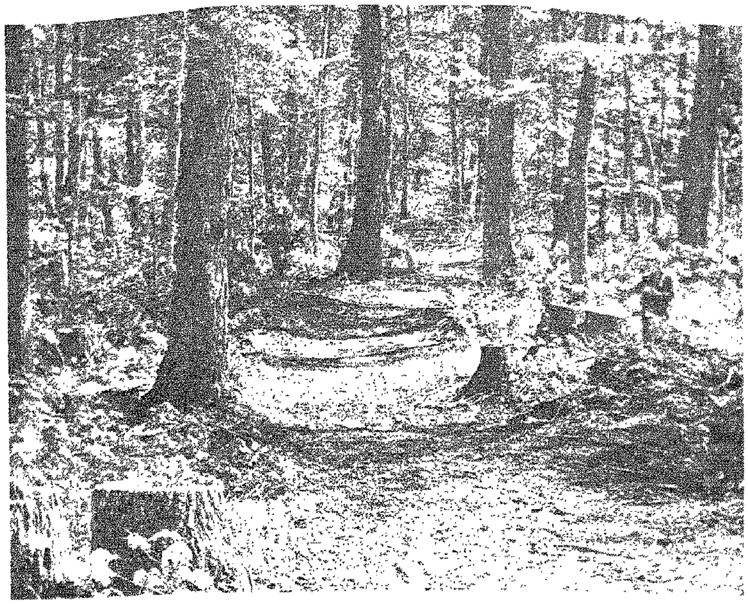

Figure 31.—Wood products harvest by group selection creates many forest openings, usually less than ½ acre. These small openings leave large amounts of the forest edge so favored by wildlife. Michigan, 1962.

Figure 32.—Well-kept logging roads, too, provide large amounts of forest edge. Virginia, 1965.

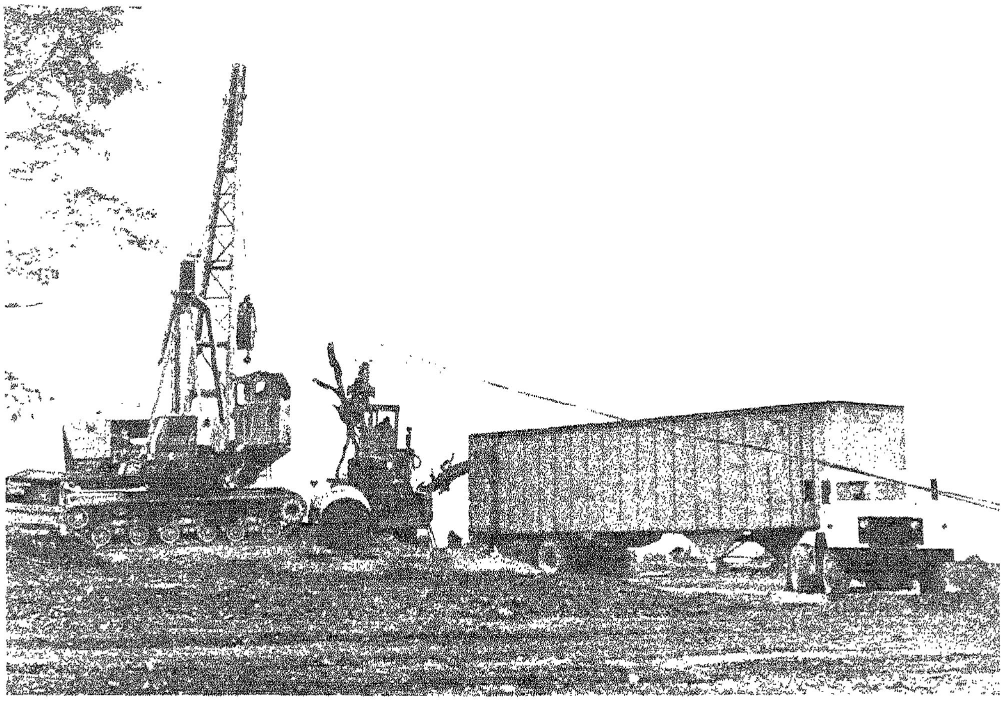

Figure 33.—On the Gauley Woodlands, whole trees are chipped into vans and trucked to a paper mill. West Virginia, 1977.

Figure 34.—High-grading leaves inferior trees for the new crop and wasted wood. Visual appeal is minimal but slash enhances the soil protective role of the forest floor. New York, 1938.

landscape. Some critics even believe that "sawlog forestry" destroys the beauty of a countryside and should be stopped. A more moderate approach places esthetic value on a par with timber, water, wildlife, and other longer recognized values of the forest (Gainer and Lohr 1970). It is public expectation of visual pleasure in the forests, and public experience of visual displeasure, that has placed the forestry profession squarely on the hot seat of controversy:

> Most of the criticisms of forest cutting practices that have been voiced in recent years have been aimed specifically at clearcutting, and boil down to displeasure with the appearance of fresh clearcut areas. Attempts to minimize slash and soil disturbance, limits on the size openings and their proximity to older ones have helped some, but clearcuts remain unpleasant sights for many forest users. [Marquis 1977]

In dealing with the problems of timber production and landscape amenity, Gould[15] conceived of the "misfit" as any deleterious situation detracting from the forest's visual appeal. Gould's definition of misfits is more easily

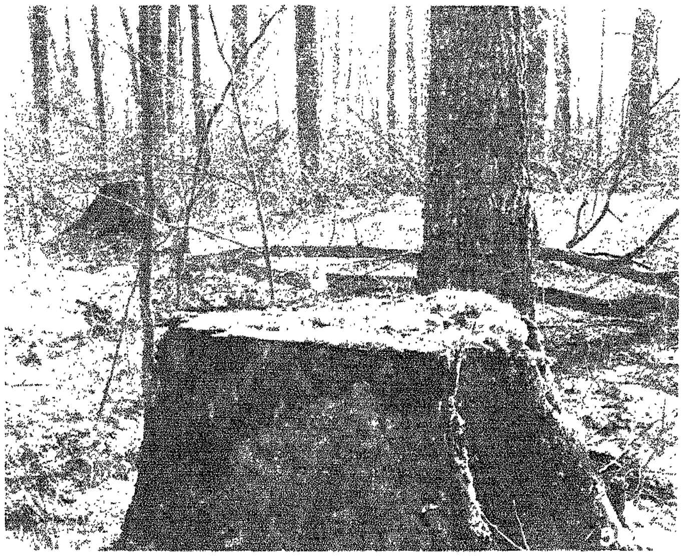

Figure 35.—Stumps, unutilized trees, and logging slash are visual misfits in this selectively harvested forest. Michigan, 1960.

Figure 36.—A well-cared-for opening has great visual appeal and offers easier travel than the surrounding forest. Michigan, 1956.

grasped than is the usual nebulous application of esthetic theory to a forest setting. Briefly, misfits are disorganizations in the usual forms of forest materials, or they are physical obstacles to traversing and viewing the forest (Fig. 35).

To some extent, this definition of misfits supports the notion that beauty is in the eye of the beholder. Nevertheless, it is possible to make certain generalizations about misfits and visual appeal. Most observers prefer least disturbance in forests (Wilhite and Sise 1974). Openings add visual appeal (Fig. 36), although they should be tailored to their locale (Brush 1976). Variety (Fig. 37) is a major criterion of visual appeal (Cook 1972). Partial cuts (Fig. 38) usually are preferred to clearcuts (Echelberger 1976). In one survey, recreationists preferred cut and uncut stands almost equally, a departure from the usual choice of uncut stands (Shafer 1969). Visual landscape harmony is reduced by patterns of timber harvest and by overly obtrusive logging roads (Trimble et al. 1974). The list of such study results might extend almost indefinitely. It seems long enough, however, to suggest that the dearth of misfits that follows carefully controlled cable logging can help foresters meet the visual expectations of many people (Fig. 39). Others, too, have tried to list misfits, then evaluate the capability of logging systems to achieve selected characteristics. Excerpts from one such summary[16] reflect the subjectivity of any visual evaluation:

Figure 37.—Even a well-kept logging road offers scenic relief from the unbroken forest. Virginia 1955.

[16]Unpublished report furnished by Dr. David Marquis, U.S. Forest Service, Warren, Pennsylvania, 186 p.

Desired visual characteristic	Logging system						
	Horse	Wheeled skidder	Crawler tractor	Jammer	High lead	Sky-line	Heli-copter
Low road density	1	2	2	1	2	3	3
Small landings	3	2	2	2	2	2	1
Flexibility for feathering edges and leaving islands	3	2	2	2	1	3	3
Flexibility for shaping clearcuts	3	3	3	2	2	3	3
Capability for small clearcuts	3	3	3	2	2	2	3
Low damage to residual trees	3	2	2	2	1	2	3
Low surface disturbance	3	1	1	1	1	2	3

Scale: 3—most compatible; 2—moderately compatible; 1—least compatible.

Figure 38.—Removal of an occasional large tree maintains the forest character of land harvested by selection systems. Virginia, 1942.

Apparently the authors were unaware either of the destructive potential of horse logging or that jammer logging—from an environmental standpoint—represents a considerable advance over systems currently used in the Eastern United States.[17]

Cable logging shows promise in forest land management where visual appeal is important. Is this not implied in the following quotation?

> Multiple-use management, or more specifically, timber-aesthetics management of forest stands for timber production and dispersed wildland recreation activities requires a knowledge of the kind of stand that will best serve the recreation purpose of the area and the silviculture skill to maintain or modify the stand for both timber and aesthetics. In this respect, one of the most important objectives of timber aesthetics management is to shorten the post-logging period during which most types of recreational activities, except hunting, are usually restricted. [Shafer 1967]

[17]Kochenderfer, James N., and G. W. Wendel. Costs and environmental impacts of harvesting timber in Appalachia with a truck-mounted crane. [In process]

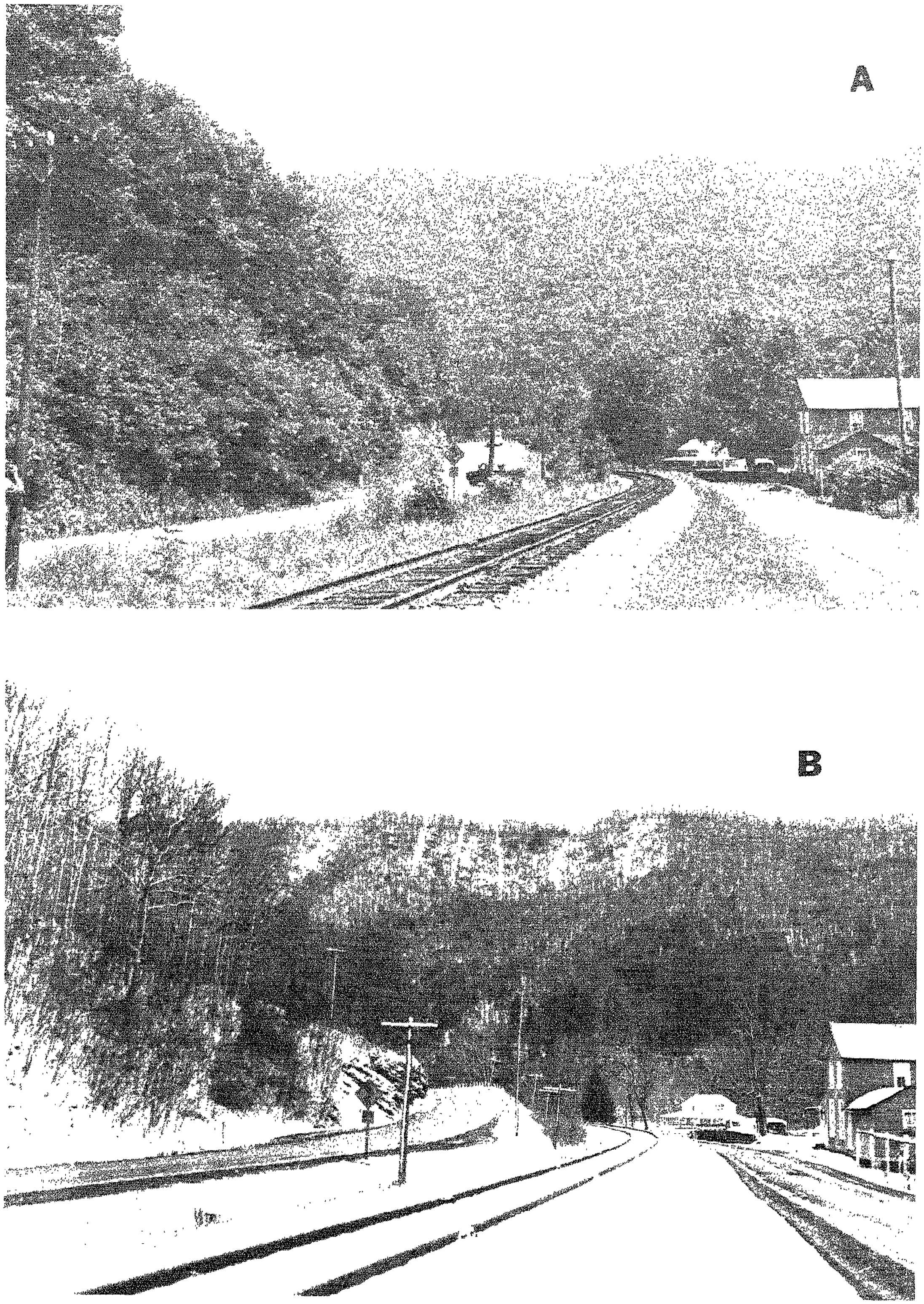

Figure 39.—Skyline logging near Parsons, West Virginia, 1977. In summer (a) observers are unaware that the ridge in the background was heavily harvested. Only with snow on the ground (b) are the skyline paths visible.

DISCUSSION

The past decade or two has witnessed a significant shift in the goals of many Americans with respect to forest land management: The production of wealth is no longer the primary goal. For better or worse, the safeguarding of amenity values (e.g., clean water, abundant wildlife, visual appeal) is often held above production of wealth. Thus, much thought and planning are directed to lessening the impact of wood products harvest on environmental values of the forest.

On perhaps our largest scale of planning, the Forest Service's Multiple Use Advisory Committee calls for greater emphasis on esthetics and landscape architecture during wood products harvest on the National Forests (USDA 1976). Clearcutting in small patches and avoiding destruction of ground cover are among management measures recommended. This Committee also recommends that Forest Service research develop new knowledge of soil and water resources, and that problems hindering effective management of these resources be solved. New and improved harvest practices for use on steep slopes and fragile soils are two such problems. Cable logging may offer the best approach to solving the management as well as the research problems on publicly owned land.

Planners on private land also seek to develop more efficient harvest techniques. Here, esthetic values cannot be neglected but economic values must take precedence. Here, too, the cable logging concept looms large, but a machine competitive with conventional wood products harvest systems—especially on gently sloping land—has yet to be built. The right machine must safeguard environmental values and it must fully meet the economic needs of forest land managers who derive their livelihood from wood products harvest.

Wider use of cable logging might go far toward solving problems of nonpoint pollution of forest water resources, particularly in mountainous topography. Public Law 92-500 places control of nonpoint pollution foremost in the planning of many foresters at the national, state, and local levels. But somehow, an often overlooked principle must be brought to the attention of those who deal with nonpoint pollution: Perpetually limpid water is delusory.

> Pollution can never be totally eliminated, only reduced through various means. Thus, the level of pollution is not an "either-or" choice between the spotlessly clean environment and the dirty environment, but rather a choice between various levels of pollution. [Sesco 1973]

Cable logging may be our best choice for holding nonpoint pollution of forest streams at acceptable low levels.

This review provides a representative but by no means exhaustive look at the literature on the environmental effects of cable logging. Perhaps the most useful outcome of it is assurance that cable logging can minimize some unwanted effects on the forest environment stemming from our economy's ever increasing need for wood products. But even cable systems must be operated efficiently and conscientiously if society is to realize their full potential to provide the needed amenity and economic values from the eastern forest. There is no substitute for the careful direction of skilled and dedicated people. Lacking such direction, no harvest system can provide these values. Given proper application of the cable logging concept and the skills to apply it, cable systems should be relied on increasingly for wood products harvest acceptable to all people concerned with forests and the environment. No harvest method is known that better protects environmental values.

Years ago, a Russian forester (Tkatchenko 1930) expressed a thought that is relevant to this discussion:

> The history of science abounds in striking examples of definite ideas having been expressed by early thinkers, poets, and the people in general, before finding universal recognition. . . . The so-called "new ideas" are frequently only a synthesis of old ones expressed at different times, which failed to fall on ground favorable for their propagation. . . . Our domain of forestry likewise presents instances of modern ideas whose origin ascends to remote antiquity.

Tkatchenko wrote of ideas whose time has come; in this case, cable logging in Eastern United States. Today's devices do indeed synthesize principles developed years ago, and even now are under technological refinement. The cable logging concept, its steam-powered form rendered obsolete by cutting the old-growth forest, may yet become preeminent in harvesting the second growth.

CONCLUSIONS

Given conscientious and skilled application of the cable logging concept:

1. Soil, water, and visual resources of the eastern forest are better protected than by any other system for harvest of wood products.
2. No harvest system is less damaging to residual trees or is more beneficial to forest wildlife.
3. A cable logging system has yet to be developed that is optimally operational in the eastern forest.

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U.S. GOVERNMENT PRINTING OFFICE 1979 —603-111/61

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