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I am submitting herewith a thesis written by Chad Davis entitled "Evaluating the Impacts of the Tennessee Master Logger Program." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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EVALUATING THE IMPACTS OF THE TENNESSEE MASTER LOGGER PROGRAM

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Chad Thomas Davis
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Dedication

This thesis is dedicated to my father

Mr. Rick Davis.

He, throughout my childhood, introduced

me to the outdoors and gave me a

valuable admiration for the forest.

as a resource for both

timber and wildlife.

You were sitting beside me when

I shot my first deer and wild turkey,

in two separate White Oak hollows.

Thanks, Dad.

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Abstract

A field evaluation of Best Management Practices was used to determine the effectiveness of the Tennessee Master Logger Program (TMLP). The study was focussed and conducted on non-industrial private forestland (NIPF), and excluded harvests on land owned by forest industry or public forests. Completed logging jobs were scored on 4 possible disturbance areas of timber harvesting: 1) haul roads, 2) skid trails, 3) log decks, and 4) Streamside Management Zones (SMZs). These four scores were added together to yield an overall BMP score. Of 191 randomly chosen observation sites across the state of Tennessee, 38, or 19.9%, were logged by trained Master Loggers. A significant association ($p < .05$) was found between logger training and overall BMP score using a point biserial correlation. Only 17 of the 627 scores (some sites did not have all 4 areas of the harvest, for example, SMZs are not necessary on sites without streams), or 2.6%, exhibited threats to water quality. Of these 17, Master Loggers were only responsible for 3 water quality threats. Point biserial correlations also indicated that a substantial association ($p < .05$) existed between harvests completed by Master Loggers and the scores of haul roads, skid trails, log decks, and SMZ grades. This study indicates that those loggers who received training from the TMLP were more likely to implement Best Management Practices during harvesting operations on NIPF than those loggers who did not participate in the Tennessee Master Logger Program.

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Chapter 1: Introduction and Justification

In the past decade, forest management has changed dramatically from primarily timber production to include concepts under the label of resource management, such as sustainable use, ecosystem conservation, and habitat management. New management regimes range from watershed management to recreational use.

As both public and private forests have become the focus of environmental concerns, foresters have adapted management philosophies to address these concerns. Foresters have learned to manage forests for multiple-use resources. Multiple-use forest management depends upon extensive planning and caution when harvesting timber.

One concern in forested ecosystems is the impact of timber harvesting on erosion, sedimentation, and water quality. Although forestry and silvicultural activities are responsible for only a small part of the non-point source pollution problem nationwide, forest road construction and timber harvesting can impair water quality. The forestry community must plan and practice quality forest management to protect water quality to avoid expensive and perhaps unnecessary water quality regulation.

Those involved in the changing role of forest management developed Best Management Practices (BMPs) in concordance with the Clean Water Act of 1987. These practices were developed to limit the site effects of logging. The federal government supported non-regulatory compliance to be monitored by state government and agencies. Individual states devised a variety of strategies to encourage the implementation of BMPs on timber harvests.

Some states developed programs to educate loggers on the importance of BMPs on timber harvests. One such program is the Tennessee Master Logger Program (TMLP). This program strives to inform loggers on various subjects, from first aid to BMP implementation. The program began in 1992 and has been successful in reaching loggers. The number of loggers trained has steadily increased each year of the TMLP's existence. The ultimate goal of the TMLP is to produce responsible loggers and equip them with the knowledge and understanding of BMP implementation. The program's primary objective is for Master Loggers to implement BMPs more often and cause less erosion and sedimentation than before training.

A survey by the Tennessee Department of Agriculture, Forestry Division (TDA-FD) found that the overall BMP implementation rate in the state for 1996 was 62.9% (TDA 1996). However, no site evaluations were conducted to determine if the educational program of the TMLP resulted in better BMP implementation and overall performance by trained Master Loggers. Furthermore, the study did not compare BMP implementation between trained Master Loggers and non-trained loggers.

Field observation and comparisons of Master Logger harvests and harvests by non-trained loggers are needed to evaluate the effectiveness of the TMLP in educating loggers about BMPs. This study, jointly funded by the Tennessee Department of Agriculture-Forestry Division, the Tennessee Forestry Association, and the Tennessee Sustainable Forestry Initiative Committee, and the University of Tennessee Agriculture Extension Service tests the hypothesis that there is a positive association between the BMP implementation and Master Logger training. Thus, Master Loggers protect site quality, in terms of reduced erosion and sedimentation, than do non-trained loggers.

1.1 Definitions of Terms Used

The following is a list of definitions of terms used in this study. The definitions are designed to provide understanding of the terminology used to complete the evaluation of logging jobs.

A **haul road** is constructed for removing harvested timber to a public road. These are generally single lane roads that can provide access for recreational uses, as well as other silvicultural activities. These roads start at an access (county or state) road and extend to the farthest log landing.

A **skid trail** is a network of interior paths for dragging felled trees to a log landing. Skid trails emanate from log landings and extend into the main portion of the harvest.

A **log landing** or **logging deck** is a designated place where felled trees are gathered, bucked (or cut into lengths), and loaded onto trucks for hauling to a market (or processing mill). It serves as a transition point where logs are brought from skid trails and leave on haul roads. Several log landings can be used on the same tract depending on the size of the harvest.

A **Streamside Management Zone** (SMZ) is a strip of land adjacent to any water of the harvested tract where soils, organic debris, and live vegetation are managed to protect water quality from sediment, excessive temperature, logging debris, and other pollutants.

A **perennial stream** is a stream or creek that contains surface water within a well-defined channel practically year around (more than 90%) under normal weather conditions. These streams are typically shown as a solid blue line on a topographic map.

An **intermittent stream** contains water within a well-defined channel only temporarily following a rainstorm event or as long as ground water is abundant, typically between 40% and 90% of the year. Intermittent streams exhibit little or no forest litter and a small amount of bank scour. They provide no permanent aquatic habitat. These streams may be shown as a dashed blue line on a topographic map.

An **ephemeral stream** or **wet-weather stream** flows in slight depressions or drainages of the landscape only following rainfall events. Flows are evident less than 40% of the year. These flows only last a short period after the rainfall ceases. Often these streams flow in a diffuse manner. Ephemeral streams exhibit no defined channel, although there is forest litter in the drain that would actually carry water during rainstorm events. These streams do not require the inclusion of an SMZ.

A **broad-based dip** is a dip of long lengths created into a forest roadbed for achieving effective drainage.

A **water bar** is a mounded structure constructed on a forest roadbed or skid trail directing runoff away from the surface of the road or trail.

A **silvicultural activity** is any practice or activity related to regenerating, growing, or harvesting trees for production of forest products and related benefits.

Non-formal education is education that takes place outside of a formal classroom. **Extension non-formal education** programs are developed based on the needs of the participants and are conducted, usually in the local community, using methods that encourage hands-on experimental learning.

Chapter 2: Literature Review

Water quality, and its relation to forest activities, has received much attention in the past few years, especially with regards to the effects of timber harvesting on erosion, sedimentation and stream water quality. Binkley and MacDonald (1994), found that "water quality from forested watersheds was among the best in the country, whether the forests were undisturbed or managed." Although, silviculture contributes to about 1 percent of river and stream mile non-point source pollution nationwide (EPA 1995), the public perceives that forestry operations contribute an immense amount of non-point source pollution. Loggers need to be made aware of these potential water quality impacts and how to avoid them.

2.1 Site Impacts of Timber Harvesting

Erosion and sedimentation are natural processes that can be accelerated by timber harvesting. Limiting site impacts is the goal of Best Management Practices (BMPs) and concerned foresters. "Careful logging may disturb as little as 8 percent of the soil surface, in contrast to 40 percent being disturbed by careless logging" (Anderson et. al 1976). The soil disturbances by harvesting practices are caused by: 1) the effects from forest road building, or 2) the effects from use of skid trails and logging decks. Furthermore, timber harvesting can have effects on water quantity and water quality in forested watersheds. Best Management Practices were developed to limit erosion and sedimentation that could be caused by timber harvesting operations.

2.1-1: Forest Roads

Forest roads present the greatest probability of soil erosion, compaction, or rutting. Road building and road usage are the primary causes. Often, the top layer of soil is removed or displaced to create a stable level surface on which logging trucks can transport loads easily. "The movement of heavy machinery, the mass movement of soil and rock, and the permanent baring of a significant amount of soil surface area all contribute to the high potential of roads for producing sediment" (Golden et. al 1984). Hydrology provides additional insight to the understanding of site disturbance by haul roads. "... Haul roads normally intercept and concentrate seepage flow, have generally lower infiltration rates... and therefore, a greater potential for producing surface runoff and erosion" (Haupt and Kidd 1965). Researchers at the Coweeta Hydrologic Laboratory in North Carolina have concluded during silvicultural applications "poorly designed and poorly located roads are the main cause of deterioration in water quality" (Douglass and Swank 1975).

Many factors influence the degree of disturbance from forest roads. "The erosion and sedimentation of roads is a complex process involving interactions among site hydrology, soils, climate, topography, and engineering treatments" (Rummer et al 1997). All these factors interact to affect erosion potential, compaction, rutting, and runoff. Without water control measures, such as water bars or broad based dips, forest roads can become thoroughfares for runoff during rainstorm events. This can lead to washout of the road itself and/or increased sediment loads in the runoff that are deposited either in streams or elsewhere on the forest floor.

A considerable amount of research on the impacts of haul road construction and use on forestland has been conducted. In North Carolina, Douglass and Swank (1975) reported that where "roads were poorly constructed, often traversing steep grades without proper drainage, water bars, or grass cover... turbidity was much greater on a logged watershed than from an undisturbed control watershed." In central Idaho "there were 104 surface sediment flows from a possible 158 cross-ditch interval" on the haul roads of a harvested area (Haupt and Kidd 1965). Typically, however, these sediment flows do not extend long distances (Haupt and Kidd 1965, Rummer et. al 1997, Sopper 1975).

Haul roads receive a tremendous amount of traffic as every log load that leaves a harvested area exits on a road. Hence, there is an accelerated risk of compaction. "Compaction reduces the infiltration capacity of the soil, increasing surface runoff which may reach a stream with its attendant sediment" (Golden et. al 1984). On the Santee Experimental Forest in Berkeley County, SC, vehicular "traffic caused a very sharp increase in bulk density of surface soils after one or two trips and a more gradual increase in density as the number of trips increased" (Hatchell et. al 1970). The compaction of haul roads lasts for several years and can contribute to erosion and increased runoff for years to come. "They are generally maintained in a highly compacted state, thus producing surface water flow which can erode adjoining unprotected sensitive areas" (Golden et. al 1984).

When logging in wet weather conditions, rutting becomes a concern for loggers. Rutting occurs "on sites that are harvested under saturated soil conditions... Soil structure is altered by rutting because soils are at the liquid limit and have a liquid response to external forces" (Aust et. al 1995). When soils become extremely saturated and rutting occurs, harvesting operations can be shut down for several days due to the poor conditions of the forest roads. The careful design and location of roads in areas with stable soil and proper drainage could allow logging operations to continue. Rutting also causes difficulty in future land management operations, such as planting or thinning.

A study at the Francis Marion National Forest in South Carolina found that "both compaction and rutting altered soil drainage and aeration to an extent that could adversely affect root growth" (Aust et. al 1995). These reductions were more pronounced on sites with better initial drainage. Soil compaction and rutting should be minimized during harvesting operations such that the future growth of the next forest is not negatively affected.

2.1-2: Skid Trails and Logging Decks

Skid Trails. Skid trails are traversed by rubber-tired skidders or tractors on tracks and are subject to runoff, compaction, and rutting. However, skid trails are not often cleared before use as are haul roads. Therefore, forest litter and intact surface level soils often remain in skid trails, reducing the risk of erosion and overland runoff. Frequently, though, skid trails traverse steeper terrain that can lead to an accelerated risk of erosion and runoff. A logger must consider terrain and soil characteristics when deciding where to effectively locate skid trails.

Skid trails can contribute increased erosion and runoff to a harvested area. A study in Northern Mississippi of tree-length skidding reported sediment movement increases (Dickerson 1975). Other studies have had difficulties separating the runoff and erosion increases due to skid trails from that of haul roads and the area of timber removal. Furthermore, the aggressive regrowth of vegetation, particularly in the Southeast, on skid trails limits the erosion and runoff effects to only the first two years after a harvest (Hornbeck and Reinhart 1964). Riekerk (1983) found in Florida that "the induced changes in water yields and water quality became significantly less within 1 year after harvest and regeneration." Bethalmy and Kidd (1966) and Hewlett (1978) reported similar results.

Skid trails cross streams or drainages more frequently than haul roads. Creek crossings are a concern because the skid trail provides a focal point for runoff to enter a stream (Taylor et. al 1999). Stream crossings are the most frequent source of sediment introduction for forested streams (Rothwell 1983). Although stream crossings rarely produce long-term impacts on stream water quality or habitat quality (Miller et. al 1997), there still is potential for concern over introducing sediment into streams. A study in Vermont concluded, "sedimentation from stream crossings was above background levels at 57 percent of the crossings" (Brynn and Clausen 1991). There are several options for crossing streams, including fords, culverts or portable bridges. Portable bridges, installed and used, allow fewer negative impacts on streams (Taylor et. al 1999).

Compaction and rutting are also concerns for skid trails. Dickerson (1975) reported an average compaction of 20 percent on skid trails. Duffy and McClurkin (1974) estimated the time of recovery to prelogging soil conditions was 12 years. Compaction of skid trails can be a detriment in reforestation efforts because these trails cover a large percentage of the harvested area. In a study in South Carolina, "seedlings collected from ruts formed by wheels and tracks of tractors were much lighter in weight than seedlings from the middle of trails over which logs had been drawn" (Hatchell et. al 1995). Rutting can become a major problem in wet bottomlands or when extracting designated timber from Streamside Management Zones (SMZs) (Aust et. al 1995). Deep ruts in or near stream channels could redirect the flow of a stream or drainage.

Logging Decks. The main concern for logging decks is the degree of soil compaction. If compaction is severe, reforestation efforts on logging decks can be futile. Disking logging decks is effective, but increases the cost of reforestation. In a South Carolina experiment, "the average time required for bulk density on log decks to return to density of undisturbed soils was estimated by regression analysis to be 18 years" (Hatchell et. al 1970). In the same study, researchers found that, due to compaction and rutting, establishment and growth of planted pine seedlings were hindered most on logging decks as compared to other disturbed areas of the timber harvest.

Garbage and oil spills can be detrimental to a logging site, both aesthetically and environmentally. "Motor oil, hydraulic fluid, anti-freeze, and other petroleum products are toxic to many aquatic organisms and also affect water use" (Golden et. al 1984). If left on site, oil containers and drums can continue to pollute an area after timber harvesting has been completed.

Logging decks must be properly located away from water sensitive areas. If located too close to streams or wet areas, sedimentation could reach water sources before vegetation can recapture the site and stabilize it. Furthermore, logging decks should be stabilized either by brush, waterbars around the edges, or some planted vegetation to ensure that runoff, sediment, or other environment-degrading products do not enter the watershed.

2.1-3: Water Quantity and Water Quality

With multiple-use forest management, an enhanced interest exists in protecting the environment, forest water quantity and quality. Timber harvests can affect on forested watersheds dramatically by yielding a greater volume flow of water, introducing sediment or nutrients into streams, and increasing stream water temperature. Increasing the volume flow of forested waterways may be the controlling facet of other water quality effects, particularly in the Southeast. Hewlett (1972) found that a large amount of sediment load in Georgia's forested Piedmont streams and rivers was originally deposited during the period of peak agricultural use and is still slowly being flushed downstream. Ursic (1975) supports this idea, "the South contains a large acreage of abused and poorly stocked pinelands with fragile soils that possess a high pollution potential. Runoff and sediment from eroding lands...created sand-filled channels which are important sources of sediment today." Increased flow volume, with its stream-bank and stream-channel erosive potential could lead to increased sediment loads downstream from logged areas. Timber harvesting reduces canopy cover which has a direct effect on stream temperature even if flows are not increased.

Water Quantity. Forest trees utilize water in photosynthetic reactions to produce the sugars necessary for plant growth. Removal of vegetation reduces evapotranspiration, thereby creating more soil water and raising water table levels (Riekerk 1983) and more sub-surface flow of water reaches forested streams, increasing flow volume. "The increase in streamflow represents a diversion of rainfall from evapotranspiration to streamflow" (Aubertin and Patric 1974).

In addition to a loss of evapotranspiration, removal of forest trees reduces rainfall interception and increases rain-drop erosion. This also contributes to more water being available for surface and sub-surface flow. "Because of the wetter soil, a higher percentage of precipitation entering the site is often available for streamflow... " (Troendle and Olsen 1994).

The influx of additional streamflow volume following timber harvests has been investigated. In a study at Coweeta Hydrologic Laboratory, the increase in streamflow after removal of hardwood timber was proportional to the amount of cover removed (Douglass and Swank 1975). A small, forested watershed in West Virginia produced an increased flow of 3.4 cm "during the water year" in which clearcutting and silvicultural treatments were applied (Aubertin and Patric 1974). Riekerk (1983) studied a Florida pine flatwoods site that experienced full-length pulpwood harvest followed by windrowing, burning, bedding, and planting. This harvest exhibited a 426% increase in volume of water when compared to a control watershed. In all three of the above cases, the increase in volume flow tended to decrease and then disappear following the first few years after harvest and regeneration (Aubertin and Patric 1974, Douglass and Swank 1975, Riekerk 1983) as trees and other vegetation utilized the water for growth.

Water Quality. Forest water quality is measured in many ways, including sedimentation and turbidity, stream temperature and nutrient levels. When sustainable ecosystem management is the focus, all measures of forest water quality must be monitored during and following harvesting activities.

Sediment enters forested watersheds from erosion of newly exposed areas or from the cutting of streambanks during increased streamflow. Once in the water system, sediment is either deposited or becomes suspended and transported downstream.

Sediment can be defined as solid material which has been eroded from its original location and deposited elsewhere (Golden et. al 1984). Sediment is typically the most important and widespread pollutant in forested streams attributable to timber harvesting (Satterlund 1972). Increased sedimentation in streams can lead to redirection of channel flow and can influence the water carrying capacity of the stream, causing flooding of streamside areas (Beasley 1972). Aquatic habitats can experience negative impacts from increased sedimentation by interfering with spawning, cover, and the food chain of aquatic organisms (Brown 1974).

Sediment also provides a binding site for nutrients and chemicals and transports such pollutants downstream (Blackburn et. al 1978). In response to increased suspended sediment, Riekerk (1983) found higher levels of potassium and calcium levels in a stream associated with a high-intensity harvest. Increased levels of certain nutrients and chemicals can affect aquatic ecosystems.

Since sediment tends to be deposited where water velocity slows, it is imperative that logging slash be kept out of streams during a timber harvest. Tops and branches left in stream channels after harvest serve as compilation points for deposited sediment and the negative impacts associated with it (Hall et. al 1987).

Suspended sediment has more far-reaching effects on water quality than deposited sediment. One way to measure suspended sediment is turbidity, which is defined as particulate matter light enough to be suspended in moving water (Golden et.

al 1984). Turbidity is the main threat to water quality in forested streams (Brown 1974). Turbid water decreases light penetration in the water column. It causes water temperatures to increase due to heat absorption and generally results in lower dissolved oxygen content (Golden et. al 1984). These concepts are interrelated. "Since the capability of a liquid to hold a gas in solution is inversely proportional to its temperature, the temperature of a water body determines to a large degree how much oxygen it can hold" (Golden et. al 1984).

A change in water temperature is a key indicator of a change in water quality. Water temperature must be monitored since it is a principal regulator of biological activity in forested streams and aids in determining the composition of aquatic ecosystems (Golden et. al 1984). Most organisms in forest streams are cold-blooded and are affected by fluctuations in water temperature. For cold-blooded organisms, "metabolic activities can operate in a limited range of temperatures. Above or below this range the organism cannot survive, and an even narrower range of temperature normally defines the optimum activity and development of particular organisms" (Golden et. al 1984). In this manner, changes in stream temperature can affect aquatic habitat and the food chain in a forest stream. Moreover, species composition in aquatic ecosystems are altered as optimum ranges of temperature shift in favor of one species over another (Brazier and Brown 1973).

Another mechanism controlling stream temperature is shade from vegetative cover. "The primary source of heat for small forest streams is solar radiation directly striking the stream surface" (Golden et. al 1984). Removal of streamside vegetation increased summer maximum water temperatures in the southern Appalachians 12°F

(Swift and Messer 1971) and 11°F in the Georgia Piedmont (Hewlett 1978). Tree or brush lined channels will maintain lower stream water temperatures in the hot summer months and slightly higher water temperatures in winter (Hewlett 1972). A study in West Virginia concluded, "the fact that growing-season stream temperature increased only negligible can be attributed to the shade strip, which prevented direct solar insulation to the channel" (Aubertin and Patric 1974). Shallow, broad streams are more affected by solar insulation than deeper streams. The magnitude of temperature increase in forest streams is directly related to the amount of water surface exposed to sunlight (Brown 1974).

2.2 Pollution Legislation

The first attempt to regulate water quality was the Federal Water Pollution Control Act of 1972. This piece of legislation was amended by the Clean Water Act of 1977. Two sections of these federal acts relate to forest harvesting practices, Section 208 and Section 404.

2.2-1: Section 208

"Section 208 mandates that individual states develop management plans to identify and abate all sources of water pollution" (Goetzl and Siegel 1980). It indicates that silvicultural practices are a source of non-point pollution that must be addressed by the individual state management plans. A planning grant from the Environmental Protection Agency (EPA) provided financial assistance to the states in developing management plans. By February 1980, the EPA had approved or was in the process of reviewing the Section 208 plans from all of the Southern states (Goetzl and Siegel 1980).

For the majority of states, forestry agencies were charged with the responsibility of developing the silvicultural section of the 208 plan. Each state derived its distinct working definition of non-point source pollution. Some states adopted a general description of non-point source pollutants: "...water pollution whose source is not traceable to a particular entry point, and is usually caused by land management activities" (Goetzl and Siegel 1980). Sediment is the primary source of non-point pollution connected with timber harvesting throughout the South. However, Arkansas, South Carolina, Texas, Virginia, and West Virginia expanded the above general definition. For example, South Carolina's Pollution Control Act adds: "...and all other products, by-products, or substances not sewage or industrial waste..." (Goetzl and Siegel 1980). One can easily see how this interpretation of pollutants could be expanded to include sawdust, shavings, bark, and even decayed wood.

Most states developed similar agendas since decisions were primarily dependent upon the same sources of research and information. However, some states developed different strategies on how to control non-point source pollution. Three distinct approaches for the state 208 plans are summarized below.

The Tennessee Water Quality Control Act exempted forestry activities unless a point source discharge was created by the activity during the harvesting operation. Specifically, the act exempted

> "any agricultural or forestry activity or the activities necessary to the conduct and operations thereof or to any lands devoted to the production of any agricultural or forestry products, unless there is

> a point source discharge from a discernible, confined, and discrete water conveyance...".[1]

Tennessee was the only state to completely exempt forestry activities. However, since this original exemption, forest harvesting in Tennessee has come under increased scrutiny as a possible source of point-source pollution.

Contrary to the Tennessee legislation, the Georgia Water Quality Control Act was the only act in the southern states that specifically laid-forth detailed provisions for non-point source pollution from forestry activities. The following legislation provided the legal framework for monitoring any activity that related to timber harvest.

> "Any person desiring to erect or modify facilities or commence on the alteration of any type which will result in the discharge of pollutants from a non-point source into the waters of the State, which will render or is likely to render such waters harmful to the public health, safety or welfare, or harmful or substantially less for domestic, municipal, industrial, agricultural, recreational, or other lawful uses, of for animals, birds, or aquatic life, shall obtain a permit from the Director of the Division of Environmental Protection of the Georgia Department of Natural Resources to make such discharge."[2]

All facets of forestry, road construction, timber harvesting, and site preparation treatments could require permits before operations could commence. If enforced, this legislation could have drastic effects on the future of timber harvesting in Georgia. With this framework of legislation already in place, forestry activities could become much more detailed and complicated in the future. This is one of the many reasons that foresters and loggers, during silvicultural operations, must take extreme caution to avoid sources of erosion and sedimentation from a harvested site area.

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[1] Tennessee Code Ann. Sect. 70-324 to 70-342.
[2] Georgia Code Ann. Chap. 17-5 and Chap. 88-26.

Another different approach to the silvicultural portion of the state 208 plans were those of Alabama and Louisiana. Both states emphasized pollution that specifically affected fish, wildlife, domesticated animals, and human beings. The forestland of both states has long-been valued for its wildlife habitat and the associated economic value. In Alabama, the State Water Improvement Commission emphasized fish, wildlife, and public health over other aspects. The Louisiana Stream Control Commission Act applied only to pollution that was proven to cause harm to fish, wildlife, or human beings (Goetzl and Siegel 1980). These additional concerns for potential water quality effects go well beyond sedimentation and turbidity measures.

The final step in the state 208 plans dealt with implementation. "In all of the Southern states, Section 208 forestry plans dealing with non-point source pollution took the form of non-regulatory, voluntary forest practice guidelines to be implemented through training and educational programs" (Goetzl and Siegel 1980). This would later give rise to programs like the Tennessee Master Logger Program, the Kentucky Master Logger Program and the North Carolina ProLogger.

2.2-2: Section 404

Section 404 of the Clean Water Act prohibits wetland-designated areas to be exposed to traditional dredge and fill activities. However, in the 1977 amendment to the Clean Water Act, "Congress provided an exemption for normal forestry including harvesting, minor drainage, and road construction" (Ice 1989). Also, Section 404 cited silviculture as a land management activity that contributed non-point source pollution.

Section 404 also has implications for bottomlands and has caused debate over whether flooded areas created by beaver dams should be managed as wetland. The interpretation of Section 404 by various federal agencies (Corps of Engineers, Natural Resources Conservation Service, EPA) and the various definitions of what composes a wetland have limited some management options for private forestland owners and forest industry. Wetland areas are a source of concern when logging and must be considered and included in the design of a timber harvest.

2.2-3: The Reformation of 1987

Water quality was again the focus of federal legislators in 1987 when they again revised the Clean Water Act. "Section 319 of this Act mandated that each state prepare an assessment of non-point source problems and a management plan for controlling non-point source pollution" (Lickwar et. al 1990). The Act required that forest management plans detail specific mechanisms to control pollution emanating from harvesting activities (Hohenstein 1987). States developed certain guidelines for controlling pollution. Best Management Practices (BMPs) were the product of this process.

The federal government allowed state governments the option of regulatory or voluntary compliance mechanisms to ensure water quality. The EPA supported voluntary compliance and most of the Southern states (all but Maryland) chose this option to encourage the implementation of developed BMPs. In addition, the EPA promised careful scrutiny of voluntary, or non-regulatory, approaches.

2.3 Best Management Practices

After the Clean Water Act of 1987, many states developed Best Management Practices (BMPs) and encouraged loggers to implement them during harvesting operations. The EPA defined a BMP as:

> "...a practice or combination of practices, that are determined by a state, or designated area-wide planning agency, after problem assessment, examination of alternative practices, and appropriate public participation, to be the most effective, practicable, (including technological, economic and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level with compatible with water quality goals."[3]

These strategies were designed to control or minimize non-point source pollution resulting from silvicultural practices—such as erosion and sediment delivery to streams. The implementation of Streamside Management Zones (SMZs) was also recommended to limit effects to forested streams. Although a comparison of various state BMP guidelines yields a list of similar recommended practices, each state developed their BMPs independent of other states. Years of research suggesting similar on-site effects of forest harvesting were the primary reason for the similarity in recommended practices. However, differences do exist because of specific geographical differences among the states. For example, in addition to SMZs, Florida BMPs suggest leaving a buffer strip around any existing sinkhole (FDA 1993). North Carolina has a unique SMZ strategy for all creeks in the Neuse River Basin, requiring an extra 25 feet of buffer zone. This is not a requirement in other river basins of the state.

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[3] Rey 1980

2.4 Benefits of Implementing BMPs

Foresters and loggers must be cognizant of potential site implications of harvesting activities and how to avoid them. Land management can influence erosion and sedimentation in forested areas. However, a study at the Fernow Experimental Forest in West Virginia concluded that similarly forested lands can be conventionally harvested, using simple common-sense practices, without impairing the quality of water draining from harvested areas (Aubertin and Patric 1974). Implementation of BMPs can have positive impacts for loggers and timberland owners. "Logging practices which protect water quality and soil productivity values usually are beneficial in other ways, such as reducing total mileage of roads and skid trails, lowering equipment maintenance costs, and providing better protection of roads and lower maintenance costs for future use" (Golden et. al 1984).

2.4-1: Forest Roads

Forest roads are a potential source of water quality problems associated with timber harvests. Implementation of BMPs can minimize the amount of erosion and sedimentation resulting from forest roads. Simple measures, such as the inclusion of waterbars, can drastically redirect the flow and erosive power of runoff.

Several studies have indicated that the most important practice to reduce adverse potential impacts of forest roads on water quality is careful planning before the timber harvest (Arnold 1963, Douglass 1975, Kochenderfer 1970). Road location and design are two key components of pre-harvest planning. The state of Virginia conducted a study where loggers were educated and encouraged to pre-plan forest roads. Trained loggers received higher mean BMP implementation scores than a control group of non-trained loggers (Meade and Schaffer 1997).

The construction of water control measures, such as waterbars and turnouts, along with the implementation of other BMPs following a timber harvest can reduce the site impacts of forest roads. Waterbars and turnouts slow the flow of water and turn the water off the road, thus eliminating a direct path of flow. This becomes more important as the slope of a road increases. Stabilization of road surfaces by vegetation can significantly reduce the amount of sediment emanating from forest roads following a harvest (Swift 1984).

Careful planning, combined with mechanisms employed at the conclusion of the harvest, such as water bars and turnouts, can keep increases in stream sediment to minor levels. During a study in Alabama, two observed watersheds experienced no adverse impacts on sediment concentrations after timber harvesting operations (Betson 1979). The roads in both watersheds were pre-planned. Additionally, dips and outslopes were installed and roads were revegetated following the conclusion of the harvest.

2.4-2: Skid Trials and Logging Decks

Skid Trails. Skid trails can cause water quality problems when traversing steep terrain, operating within SMZs, and crossing creeks or drainages. Waterbars and turnouts reduce washout and the associated sediment that could enter streams by guiding water flow from the skid trail.

The grade traversed by skid trails is of particular interest. Steeper grades increase the velocity and erosive force of water draining along the surface (Golden et. al 1984). The potential detriments of skid trails only increase as the slope of the trail increases. "Steep bare skid trails have a high potential of moving soil down slope and forming large rills or even gullies" (Golden et. al 1984). Keeping grades below 10 percent and following along the contour can significantly reduce the amount of erosion from skid trails (Kochenderfer 1970, Patric and Aubertin 1977). A study in Idaho observed a harvest where skid trails were limited to 9 percent grade and water control measures, such as waterbars and cross-drains, were implemented. "Displaced soil was contained in all but a few instances by the next erosion control structure downslope" (Haupt and Kidd 1965).

Throughout and after harvesting, stream crossings represent the largest source of sediment introduced to streams (Rothwell 1983). The best way to avoid water quality problems is to avoid stream crossings. In some instances, this is not an option. Appropriate stream crossings are imperative to minimize the impact on stream water quality. "Operating skidders in and across stream channels directly produces stream sediment and can result in the collapse of stream banks and gouging of both channel beds and stream banks" (Golden et. al 1984). Some crossing mechanism, other than fords, results in less impact of forested streams. In Florida, portable crossings significantly reduced rutting from 15 inches for a control (crossed by ford) to 5 inches after 75 passes (Hislop 1996). The easiest and most cost-efficient mechanism for crossing streams is a portable bridge. "By spanning the stream, bridges keep fill and equipment out of the water better than any other stream-crossing option" (Blinn et. al

1999). Furthermore, waterbars should be installed where a skid trail approaches a stream crossing to divert the flow of runoff.

Log Decks. Stabilization of logging decks, either by vegetation or logging slash, can reduce sediment-laden runoff (Hatchell et. al 1970). Waterbars, installed around the edges of the deck, can further minimize erosion. Location is also important. Flat landings, engineered away from water sensitive areas, prevent any surface runoff from reaching a stream.

2.4-3: Streamside Management Zones (SMZs)

Equipment operation within the SMZ can have drastic effects on a site and water quality. Rutting can change the hydrology of a streamside area and may eventually redirect the flow of a stream (Schoenholtz 1994). In order to prevent such effects, logging in SMZs must be halted during wet-weather days. Skidding adjacent to the stream channel could influence the flow of the stream and must also be avoided.

Streamside Management Zone's have two main purposes: 1) to provide shade to the stream and maintain water temperatures and 2) to provide a filter zone for runoff where sediment can be deposited before entering the stream (Golden et. al 1984). The width of the SMZ needed for shade protection "is related to the effectiveness of buffer strips through a complex interrelation of canopy density, canopy height, stream width, and stream discharge" (Brazier and Brown 1973). The benefits of SMZs were shown in a clearcut area at Pickett State Forest in Tennessee where the riparian canopy was not removed and seasonal stream temperatures were unaffected by logging (Pelren et. al 1990). At Coweeta Hydrologic Laboratory, Douglass and Swank (1975) reported stream temperature increases from the normal 66°F to 73°F or more where all streamside vegetation was harvested. In a control where no streamside vegetation was cut, water temperatures were unchanged. The literature on SMZs concludes that if a buffer strip is left to shade a forest stream, water temperatures are not adversely affected by the treatment of the watershed (Swift and Baker 1973).

Maintaining an SMZ can be a major factor in limiting the introduction of sediment into a forested stream after timber harvest. The SMZ serves as a buffer to physically separate a forested stream from the disturbed area of a timber harvest. Forest litter, organic matter, and any low vegetative cover are the most critical parts of an SMZ affecting its ability to serve as a filter zone for runoff (Golden et. al 1984). Therefore, minimal disturbance to the forest floor and shrubby vegetation of SMZs is critical for the strip to force sediment deposition and water infiltration before runoff reaches the stream (Meginnis 1935, Reinhart 1964).

2.5 BMP Implementation Studies

State agencies throughout the Southeast have conducted BMP implementation studies to monitor the effectiveness of voluntary compliance. These studies have focused on randomly surveying timber harvests for the inclusion and effectiveness of various BMPs. No study has separated groups of loggers by training or classification level. Although, some differences in methodology are present among the studies, the results are presented in a similar manner. Table 2.1 is a summary of BMP implementation studies conducted in the Southeast. Percentages of sites where BMPs

Table 2.1: Report of BMP Implementation Studies Throughout the Southeastern States

State	BMP Implementation		Source
	Adequate	Inadequate	
Alabama*	65.2%	34.8%	Henry and Bliss 1994
Kentucky	48.0%	52.0%	Stringer 1998
Louisiana	80.0%	20.0%	Liu et. al 1994
South Carolina	84.7%	15.3%	Adams et. al 1995
Tennessee	62.9%	37.1%	TDA 1996
Virginia	92.0%	8.0%	VDOF 1992

* Only the West Central area of the state was observed.

were adequately applied range from a low of 48.0% in Kentucky to a high of 92.0% in Virginia. Across all state surveys, adequate BMP implementation was observed on 72.1% of the sites observed.

Voluntary compliance seems to be effective in combating non-point source pollution from timber harvests. The state of Virginia has the most developed program to monitor voluntary compliance of BMPs. The program was envisioned as a four-phase process, beginning in 1972. The first three phases were non-regulatory in application, with BMP implementation rates increasing from 42% in Phase I to 92% during Phase II to a projected 95% in Phase III (Aust et. al 1992). Phase IV, presently a hypothetical scenario, calls for regulatory compliance of BMP implementation. It is assumed that BMP compliance would be 99% during this hypothetical phase. However, a study of the cost to benefit ratio for each phase of implementation concluded, "Phase IV was predicted to yield only slight increases in water quality benefits, yet almost doubled total costs as compared to Phase III" (Aust et. al 1992). This study indicates that voluntary compliance of BMPs can be as effective at maintaining water quality as regulated compliance.

Non-regulatory BMP compliance is the norm among Southern states. Maryland is the only state in the Southeast to have government-regulated BMP compliance (Ellefson and Cheng 1992). Hawks et. al (1993) conducted a comparison of Maryland's regulatory and Virginia's voluntary programs to ensure BMP implementation. They measured level of BMP compliance by state standards and concluded, "there was no direct evidence to suggest that either state's approach is better at obtaining BMP compliance; both seemed reasonably effective." However, the cost of the program, measured as technical support, BMP training, and enforcement, in each state yielded a distinct advantage to Virginia's voluntary approach. Maryland's cost were \$1.70-\$3.20 per thousand board feet (MBF) of harvested timber, while Virginia only spent \$0.50-\$0.58 per MBF.

2.6 Tennessee Master Logger Program

The Tennessee Master Logger Program (TMLP) strives to educate loggers about the importance of BMP implementation in order to minimize site impacts of timber harvesting. The visionaries of this program, founded in 1992, recognize that the future of the forest industry and the forest as a resource in the state of Tennessee depends upon the education of those that work closely with it. The mission of the Tennessee Master Logger Program is "to enhance the professionalism of the Tennessee logger through a complete educational process designed to improve the health and well-being of the logging industry and the forest resource" (Clatterbuck and Hopper 1996). The project is under direction and authority of the Tennessee Forestry Association (TFA) with collaboration from the Tennessee Department of Agriculture, Forestry Division (TDA-FD), the University of Tennessee Agricultural Extension Service, the USDA Forest Service, and the Tennessee Valley Authority.

Loggers are educated during five all-day sessions that cover the following topics: 1) first-aid on the logging site, 2) safety procedures which minimize the risk of injuries while logging, 3) business management, 4) forest ecology and silviculture—to provide loggers with overlying silvicultural objectives of forest management, and 5) the purpose and how-to knowledge of implementing Best Management Practices. Each day consists of a half-day of instruction and a half-day of field observation, in order for loggers to visually comprehend the subject matter of the morning session.

Besides educating loggers, the TMLP has the goal of encouraging the use of BMPs once the loggers have been trained. This is accomplished by foresters from TDA-FD providing a list of certified Master Logger graduates to private landowners interested in harvesting their timber. The TDA-FD also randomly visits ongoing logging operations.

As of this study, the Master Logger Program has successfully educated and graduated 1113 logging professionals.

2.7 Non-Formal Educational Programs

Non-formal methods of education, like those used in the Tennessee Master Logger Program, have proved to be effective in achieving higher standards in forestry and related agricultural fields. A group of Virginia loggers was trained to pre-plan timber harvests in an intensive 2-day workshop taught by instructors from Virginia Tech's Department of Forestry. Meade and Schaffer (1997) studied the effects on 3 different criteria between trained loggers and a control group of loggers not receiving training. They concluded, "Trained loggers achieved a higher mean score than control group of loggers in BMP implementation and scores of landowner satisfaction, and had less weather-related downtime."

Logger response to non-formal training programs has shown to be good in other states, as well. After a 3-day educational program in Kentucky covering similar topics as the TMLP, 94% of participants said they would be willing to attend additional training in the future (Reeb 1996). In a Minnesota survey of loggers, "almost 90% of the respondents indicated they would be willing to attend future workshops if they were of value to their business and available at little cost" (NGI 1992). Workshops were conducted in response to this demand. To the attending loggers, safety and environmental regulation topics were among the highest rated topics (Smidt and Blinn 1994).

Extension education was used in California to help ranchers improve their resources and establish ecologically sustainable grazing management systems. Surveys were issued to short-course participants and a "majority of respondents had implemented at least one ranching practice presented in the short course" (Richards and George 1996). One of the reasons given by respondents for implementing a practice was to cope with regulatory constraints.

Non-formal education was again successful in fisheries management in New York State. Participatory learning was used to get owners of fisheries resources directly involved with management activities (Green et. al 1993). A survey of participants reported that 84% of respondents had implemented a management recommendation learned in the extension program, and another 5% planned to do so in the next year (Green et. al 1993).

The non-formal education of the Tennessee Master Logger Program strives to make loggers aware of the potential effects of erosion and sedimentation associated with timber harvesting and provides loggers with practices to minimize soil movement. Based on the prior beneficial outcomes of non-formal education in agriculture managment, one would expect the TMLP to produce similar results.

Chapter 3: Methods

Various sources were considered in identifying logging operations statewide: county extension agents, area foresters within the Tennessee Department of Agriculture, Forestry Division (TDA-FD), industry foresters' knowledge of gatewood receipts, and surveys to forest landowners and loggers. The TDA-FD was selected to supply a compiled list of completed logging jobs. The TDA-FD source provided the most readily available and reliable information with the least bias of other considered sources.

Area foresters within the TDA-FD provide a map each year to the state office indicating the occurrence of logging operations within their defined region. Maps were compiled for 1997 and 1998. Along with the location of each logging site, area foresters also provided the following information: 1) landowner, 2) logger, 3) acreage, and 4) dates of operation.

All logging operations were excluded that had occurred on industrial land or national and state forests, since this study was focussed on non-industrial private forestland (NIPF). Industrial or public land harvests are generally planned and supervised by professional foresters trained with the appropriate knowledge of implementing Best Management Practices (BMPs). Thus, the inclusion of BMPs is probably more frequent on industrial or public land when compared to NIPF lands. Concern for future land productivity is another reason for forest industry to include BMPs on their forests.

Furthermore, harvests less than 20 acres in size were excluded to avoid areas being cleared for residential development. The remaining NIPF sites were placed in a spreadsheet format. The following information was recorded where available: 1) County, 2) Forest Inventory Analysis (FIA) Region, 3) Logger's name, 4) Landowner's name, 5) year of harvest, and 6) acreage of harvest. This process provided 313 logging operations statewide for site evaluation.

3.1 Sample Size

The calculated sample size used in this study assumes the following: a 15% increase in BMP implementation rate for Master Loggers versus non-trained loggers would be a noteworthy increase to determine if the education of the Tennessee Master Logger Program had affected logger performance. Table 3.1 shows that for a test of significance at the 5% level and a probability of 90%, the largest plausible sample size is 190.

The second facet of sample size selection was stratification of the state by USDA Forest Service regions. The Forest Inventory Analysis (FIA) 1989[4] data for Tennessee partitions the state into 5 regions: 1) West, 2) West Central, 3) Central, 4) Plateau, and 5) East (May 1991). Table 3.2 shows the net annual removals for each FIA section of the state. The amount of timber harvested in each region, as a percentage of the overall state removals, was the means of stratification. This removal percentage matched the percentage of overall sites surveyed in an individual region. For example, since 14 % of

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[4] Since 1999 FIA data were not published at the time of site selection, 1989 FIA data had to be used.

Table 3.1: Number of Replications (with data analyzed in two classes) Required for a Given Probability of Obtaining a Significant Result.

Test of Significance at 5% level, probability 90%, for one-tailed tests.

	P_2-P_1 = Larger minus Smaller % of Success			
Smaller % Success	5	10	15	20
5	460	145	76	48
10	740	210	105	64
15	990	270	130	77
20	1190	320	150	88
25	1360	360	165	96
30	1500	390	175	100
35	1600	410	185	105
40	1670	420	190	105
45	1710	430	190	105
50	1710	420	185	100

Cochran and Cox (1957), Table 2.1a.

Stratification was necessary in order to place more emphasis on the regions that were more affected by logging. This ensured that more samples were taken where the most timber was harvested, and thus, where the largest possible impact to erosion,

Table 3.2: Net Annual Timber Removals and Number Of Observations by FIA Region and Statewide (May 1991)

FIA Region	Net Annual Removals*	Percent of State Total	No. Sites Observed
West	34.6	16%	30
West Central	51.1	23%	44
Central	30.2	14%	26
Plateau	48.6	22%	42
East	56.0	25%	49
Statewide	220.5		191

* Measured in Million Cubic Feet

sedimentation, and water quality might occur. The resulting percentages and number of sites observed in each region were as follows: West—16%, 30 sites; West Central—23%, 44 sites; Central—14%, 26 sites, Plateau—22%, 42 sites, East—25%, 49 sites, yielding a total of 191 sites observed statewide.

3.2 Site Selection

Sites were allocated into FIA regions and then each individual site was assigned a random number. Observation sites were identified using the lowest "x"[5] amount of random numbers for each region. For example, in the Central region, TDA-FD foresters provided 45 possible sites. The lowest 26 random numbers were used to identify which particular sites to observe within the Central region.

Data from the TDA-FD area forester maps were recorded in various formats. Some foresters recorded the landowner, logger, dates of harvest, and acreage, while others only provided portions of this data. For example, some county maps had no landowner name included. The differing degrees of information resulted in some pre-determined observation sites on industrial or public lands. If any selected site could not be located or accessed, or was publicly or industrially owned, it was dropped from the sample. The site with the next lowest random number was added for observation in that region. In this manner, random selection and stratification were maintained.

5 This number is defined by the removal percentages of each region from the FIA data.

3.3 Evaluation Form

An evaluation form for field observation was composed after a review of previous studies. The final evaluation form combined elements of many of these studies. Two in particular were the Tennessee Department of Agriculture, Forestry Division survey forms (TDA 1996) and those used at the University of Kentucky (Stringer 1996). The examination of these inspection forms helped to emphasize which specific BMPs should be evaluated in this study. The evaluation form used for this study is located in Appendix A.

3.4 Rating System

For each of the four areas of harvest on the evaluation form (haul roads, skid trails, logging decks, and SMZs), performance of BMP implementation was rated from 1-5, with 1 being the lowest. A harvest area received a score of 1 if a threat to water quality was induced either by a bad practice or by neglecting a necessary BMP. Scores for each harvest area were pre-ranked by determining which BMPs constituted a certain score. This was necessary to eliminate as much subjectivity as possible when evaluating a site. An explanation of the rating system is displayed in Appendix B. The typical scores of each section are explained below.

The typical haul road received a score of 2 when sensitive areas were avoided and rock was used either as an apron or hauling surface. The typical skid trail received a score of 3 when sensitive areas were avoided and streams were crossed correctly. Typical logging decks were scored a 4 when a sufficient distance from water-sensitive areas was maintained, the site was free of garbage and oil spills, and no drainage occurred from the surface of the deck. There was not a typical SMZ, since each varied depending on the specific characteristics of each stream and the harvesting operation. The ratings of the SMZs reflect this statement. Some tracts had perennial streams, others only had intermittent or ephemeral streams, some had both types, and some harvested areas had no streams. Further, perennial streams require more SMZ width and higher basal areas than do intermittent or ephemeral streams (Brown 1974, Golden et. al 1984.)

Revegetation of the surface was required for loggers to receive a 5 rating on both haul roads and logging decks, since stabilization of exposed surfaces reduces runoff (Swift 1984). However, the additional criteria for each section had to be met in conjunction with the revegetation of these surfaces (ex. water bars, turnouts, and broad-based dips). A logger could receive a 5 for skid trails without revegetation since these, often interior paths, tend to naturally revegetate well.

After each harvest area was rated individually, all scores for a particular site were accumulated to produce an overall percentage score for each site. Overall implementation scores were calculated on a percentage basis since every logging job observed did not have all four areas of the harvest. For example, SMZs are not necessary on sites without streams. Therefore a site without SMZs might receive a 2 for haul roads, a 3 for skid trails, and a 4 for logging decks. That total is 9 of 15, or an overall percentage score of 67%. If the site dictated that SMZs be used, the possible total increased to 20. Assuming an SMZ rating of 4, this yielded 13 out of 20, or an overall percentage score of 70%.

Validation and Verification. A panel of professionals with experience in timber harvesting and BMP implementation was selected to review the rating system used in this study for validity and consistency. The panel consisted of 1) a member of the faculty of forestry extension at the University of Tennessee, 2) a forest industry procurement forester, 3) a consulting forester, and 4) a land manager and private landowner. The panel was given the rating system and the evaluation form with an explanation of how the observation sites were to be evaluated.

Three sites, ranging from good to poor performance, were selected for the panel to evaluate. On two of the three sites, all four harvest areas were observed and scored by the panel. The third observed site did not require an SMZ. Therefore, each observer recorded 19 different harvest area scores. Of the 76 scores recorded by the panel, 70 were the same. Of the 6 that differed somewhat, only one researcher scored the harvest area differently than the other three panel members. In essence, the rating system used in this study was reproducible by others, indicating that the rating system was valid.

3.5 Identification of Master Loggers

After completion of the site observations, the Tennessee Forestry Association's list of trained Master Loggers was cross-referenced with the observed logging operations. A crew of loggers was designated as Master Loggers if there was one trained logger on the site during the operation. Cross-reference of logger names had to be completed after site observation to eliminate bias towards either group of loggers. Delineation of loggers as Master Loggers or non-trained loggers was necessary to compare BMP implementation between those trained by the Tennessee Master Logger Program and those not trained.

3.6 Statistical Analysis

A point biserial correlation coefficient was used for data analysis (SAS 1988). This statistical technique produces a correlation between one interval scale variable (harvest area score) and another genuine dichotomus variable (Master Logger or non-trained logger) on a nominal scale (Kirby et. al 1986). The harvest area score variables analyzed were haul road score, skid trail score, log deck score, and SMZ score. By definition, the statistical null hypothesis (H_O) was that the correlation coefficient (r) was equal to zero, indicating no correlation between the harvest area score variable and logger training. Correlations were conducted for both statewide totals and for individual FIA regions. If point biserial correlation coefficient tests proved significant, the conclusion was that there was an association between the type of logger (Master Logger or non-trained logger) and the harvest area variable being analyzed.

The value of the correlation coefficient, r, was also used to indicate the strength of association between logger training and harvest area score. One accepted set of descriptors was proposed by Davis (1971):

Coefficient, r	Description
.70 or higher	Very Strong Association
.50 to .69	Substantial Association
.30 to .49	Moderate Association
.10 to .29	Low Association
.01 to .09	Negligible Association

Chapter 4: Results and Discussion

Results are reported by (1) overall state totals and by (2) individual FIA regions. For both statewide and FIA region results, the means and ranges of the two logger groups are reported first and the statistical data second. Furthermore, results of the four harvest area scores, (1) haul roads, (2) skid trails, (3) logging decks, and (4) SMZs, will be addressed individually.

4.1 Percentage of Sites Completed by Master Loggers

The number of sampled sites harvested by Master Loggers statewide was 38 of 191, or 20% (Table 4.1) of the total sites observed. The percentages varied by FIA region, from a high of 40% in the West Central region to a low of 4% in the Central region.

Table 4.1: Number and Percentage of Master Logger Sites Observed In Each FIA Region and Statewide

FIA Region	Number of Master Logger Sites	Total Sites Observed	% Master Loggers
East	9	50	18%
Plateau	7	42	17%
Central	1	26	4%
West Central	19	48	40%
West	2	25	8%
Statewide	38	191	20%

In general, the number of loggers tends to be higher in regions where more timber is harvested. Due to increased harvesting competition and increased threat of timber harvesting regulations, many loggers see benefit in completing the Master Logger course. Furthermore, landowners are becoming more aware of the possible site impacts of logging. The training received from the Tennessee Master Logger Program (TMLP) gives loggers a competitive edge in areas with landowners who are concerned with Best Management Practices.

Although the TMLP has educated approximately 1200 loggers, no good estimate exists of the statewide number of logging professionals. Therefore, the exact percentage of loggers that have completed the Master Logger course is unknown. Forest industry has spurred many TMLP participants because of company policy to contract only with trained loggers, especially on company land harvests. No such mechanism exists on non-industrial private forestland (NIPF), even though some loggers harvest timber on both NIPF and industry land. Thus, the percentage of sites harvested by Master Loggers on NIPF is probably less than the percentage on industry land.

Since sampled sites were harvested either in 1997 or 1998, only loggers who had received training prior to the year of harvest were considered Master Loggers. The TMLP had trained 792 loggers through 1998. Over 400 more loggers were trained in 1999. Thus, a smaller pool of Master Loggers was available for sites selected in 1997 or 1998. If sites were selected in early 2000, one would expect the percentage of Master Logger sites observed, both statewide and by FIA region, to increase (relative to this study), due to a larger probability of Master Logger sites being chosen.

Percentages of observed Master Logger sites in both the Central and West regions (4% and 8% respectively) were lower than desired. The allocation of sample plots in each region was based on timber removals, not the number of Master Loggers. Therefore, regions with lower timber removals had a lower number of plots observed. Forest industry involvement is less in these lower harvest regions and, thus, there are fewer Master Logger graduates among the logging professionals in that particular region.

4.2 Statewide Results

4.2-1: Statewide Means and Ranges

Overall BMP Scores. Statewide values of overall BMP scores for Master Loggers was 75.1% compared to 60.4% for non-trained loggers (Table 4.2), with ranges (53 for Master Loggers and 55 for non-trained loggers) being similar for both groups. However, the maximum and minimum values for Master Loggers were higher than for non-trained loggers.

Table 4.2: Means and Ranges for Statewide Scores by Harvest Area

Harvest Area	Training	Mean	No. Obs	Maximum	Minimum
Overall BMP Score	ML	75.1	38	93	40
	non-ML	60.4	153	80	25
Haul Roads	ML	3.2	33	4	2
	non-ML	2.3	125	4	1
Skid Trails	ML	3.8	38	5	1
	non-ML	2.8	153	5	1
Log Decks	ML	4.0	38	5	3
	Non-ML	3.8	153	5	1
SMZs	ML	4.0	23	5	1
	Non-ML	3.3	64	5	1

Haul Roads. The statewide average score for haul roads for Master Loggers was 3.2 (out of 5) compared to 2.3 for non-trained loggers (Table 4.2).

No logger, trained or untrained, received the maximum score of 5. Revegetation of haul roads was the key factor in scoring a 5 on haul roads (see Appendix B). None of the sampled logging operations statewide had any evidence of revegetation, ie. seeding or planting, on the haul road surface.

Only non-trained loggers received minimal scores of 1, indicating a threat to water quality resulted from the haul road. No threats to water quality were observed on Master Logger harvested sites statewide.

Figure 1.1 shows the statewide distribution of the two groups of loggers. Distributions are similar between the groups when compared on a percentage basis. However, there is a right-shift in the peak of the distribution of haul road score for Master Loggers from the non-trained logger distribution. Raw data for haul roads is reported in Appendix C, Table A-1.

Skid Trails. The statewide average score for skid trails for Master Loggers was 3.8 (out of 5) compared to 2.8 for non-trained loggers (Table 4.2).

Statewide ranges of both logger groups were the same, each taking on all values from 1 to 5. The requirements for a maximum score on skid trails were different than those for haul roads. Skid trails were capable of scoring 5 without specific attempts at revegetation, due to the rapid rate at which these surfaces tend to revegetate (Hornbeck and Reinhart 1964). Both groups of loggers recorded minimum scores of 1, indicating a threat to water quality. Master Loggers were responsible for 2 such cases statewide,

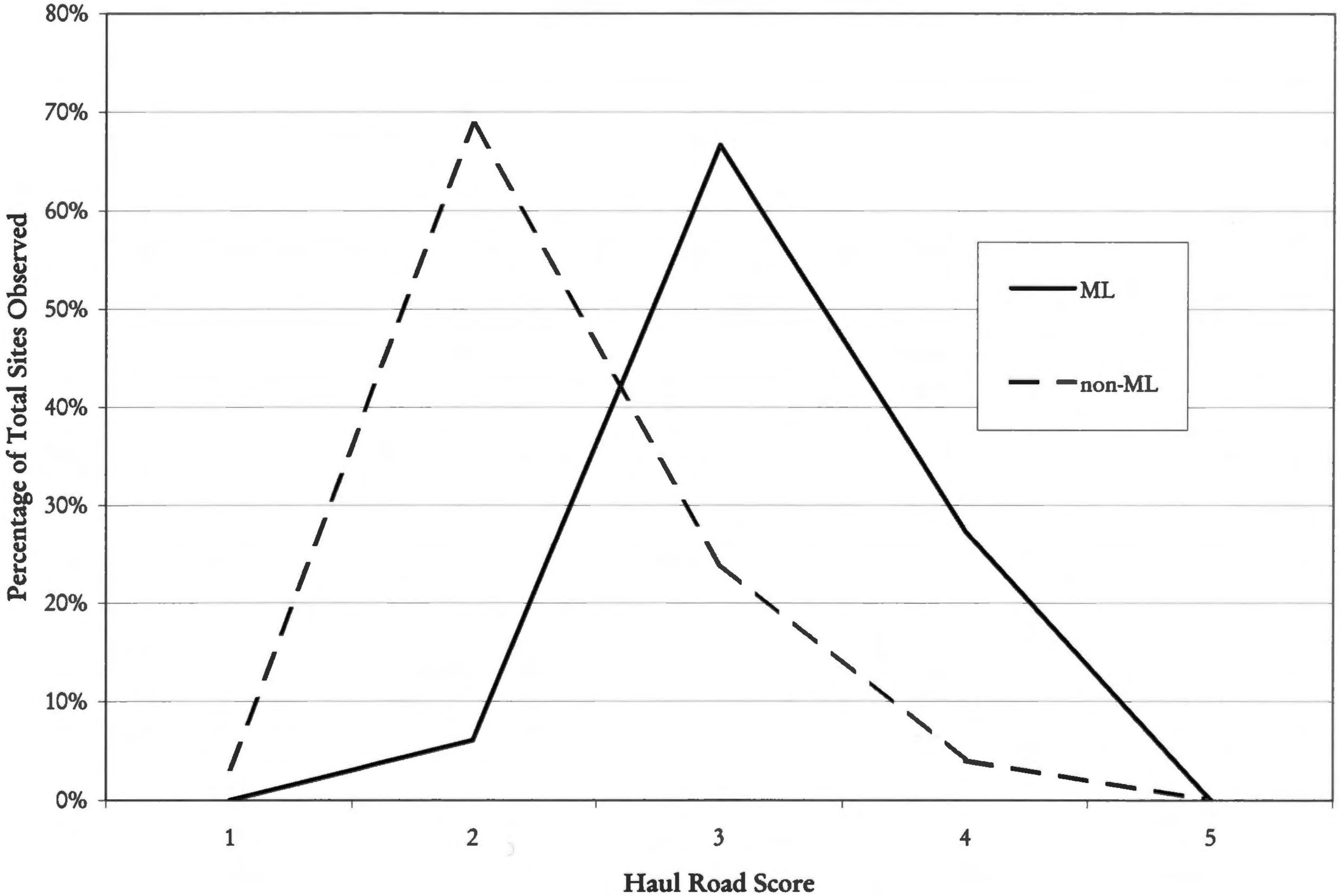

Figure 1.1: Statewide Results of Haul Road Score by Master Logger Training

while the number of threats to water quality for non-trained loggers totaled 7 statewide (Appendix C, Table A-2).

Figure 1.2 shows the statewide distribution of the two groups of loggers. Distributions are similar between the groups when compared on a percentage basis. Master Logger score for skid trail shifted right when compared to non-trained loggers. Raw data for skid trails is reported in Appendix C, Table A-2.

Log Decks. The statewide average score for log decks for Master Loggers was 4.0 (out of 5) compared to 3.8 for non-trained loggers (Table 4.2).

Statewide ranges for log deck scores varied less for Master Loggers than non-trained loggers. Master Logger scores ranged from 3 to 5 and non-trained logger scores ranged from 1 to 5. There were no water quality threats identified on Master Logger sites and non-trained loggers only tallied one threat to water quality statewide.

Figure 1.3 shows the statewide distribution of the two groups of loggers. Distributions are similar between the groups when compared on a percentage basis. Raw data for log decks is reported in Appendix C, Table A-3.

Streamside Management Zones. The statewide average score for SMZs for Master Loggers was 4.3 (out of 5) compared to 3.3 for non-trained loggers (Table 4.2). Statewide ranges of SMZ scores were the same for both logging groups. Although minimum scores of 1 indicate threats to water quality among both logger groups, there were only 3 total incidents of 87 observed (Appendix C, Table A-4). Scores of 5 were recorded by Master Loggers on 61% (14/23) of observed sites, while non-trained loggers only scored the maximum level on 6% (4/64) of the sites observed.

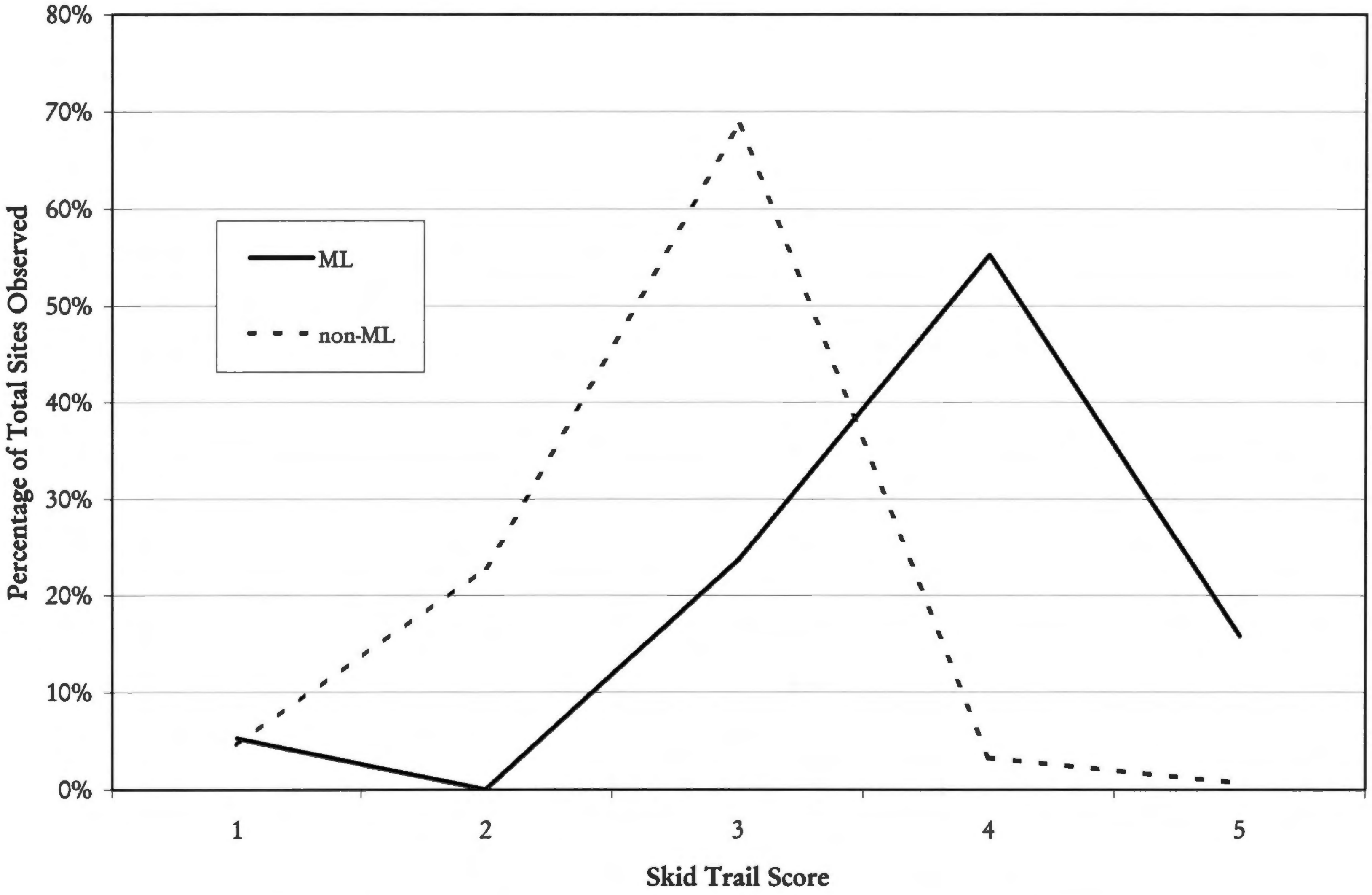

Figure 1.2: Statewide Results of Skid Trail Score by Master Logger Training

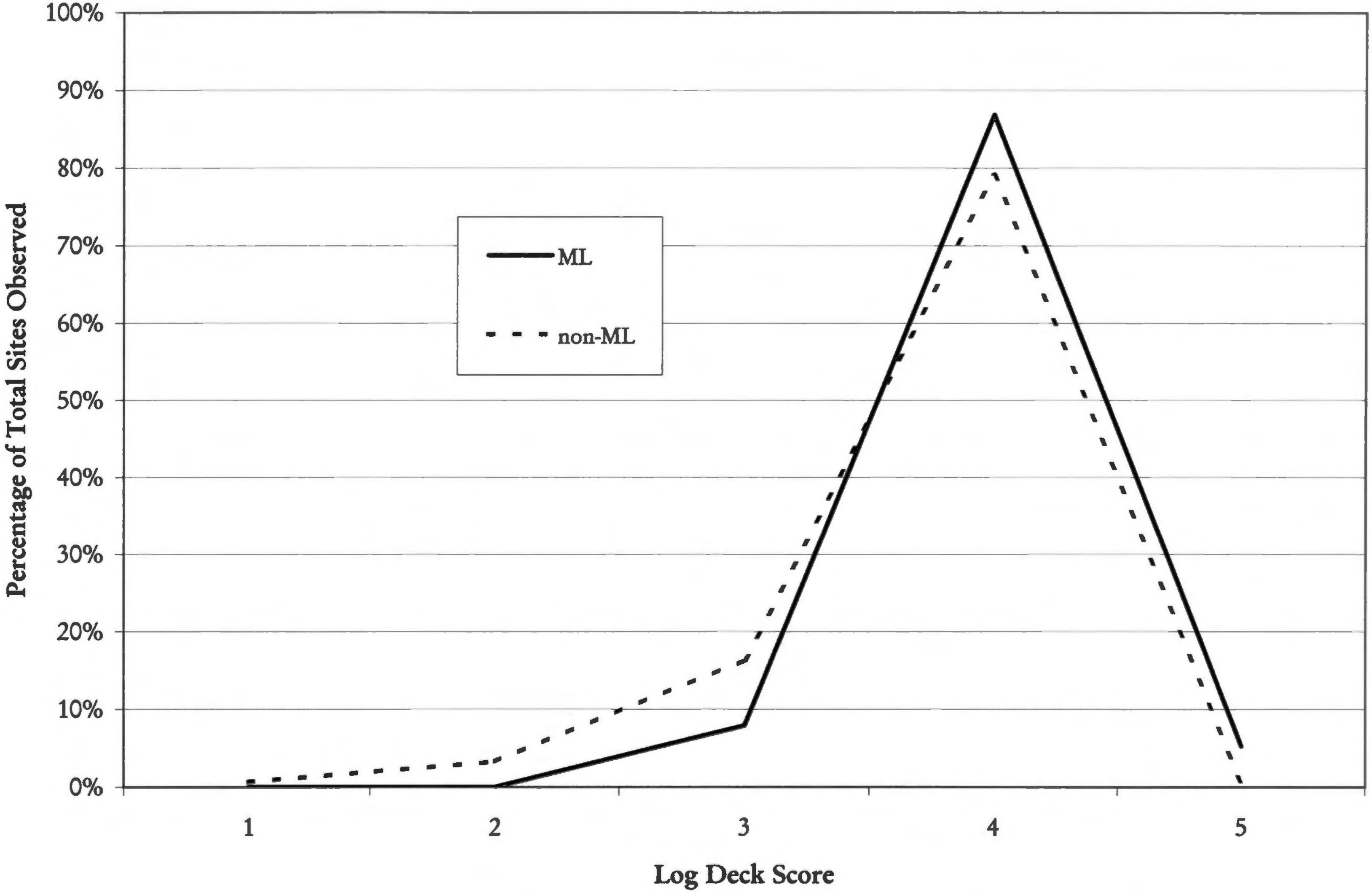

Figure 1.3: Statewide Results of Log Deck Score by Master Logger Training

Figure 1.4 shows the statewide distribution of the two groups of loggers. Raw data for SMZs is reported in Appendix C, Table A-4.

4.2-2: Statewide Statistical Results

Overall BMP Scores. Statewide values for overall BMP score proved to be a significant association using a point biserial correlation (α = .05) between logger training and overall BMP score with a |Pr>F| = 0.0001 (Table 4.3). Therefore, one can reject the null hypothesis (H_O) and conclude that there is a relationship between overall BMP score and Master Logger training. Statewide, the relationship between logger training and harvest area score was a substantial association (Davis 1971) with the correlation coefficient, r, equal to 0.52.

Table 4.3: Statistical Results for Statewide Scores by Harvest Area

H_O: There is an independent relationship between harvest area score and Master Logger training.

Harvest Area	Training	Mean	Std Dev	Pr > F	r	Significance
Overall BMP Score	ML	75.11	11.26	0.0001	0.52	Yes
	non-ML	60.40	9.21			Reject H_O
Haul Roads	ML	3.22	0.55	0.0001	0.54	Yes
	non-ML	2.28	0.59			Reject H_O
Skid Trails	ML	3.76	0.91	0.0001	0.51	Yes
	non-ML	2.73	0.63			Reject H_O
Log Decks	ML	3.97	0.37	0.023	0.16	Yes
	non-ML	3.76	0.55			Reject H_O
SMZs	ML	4.30	1.14	0.0001	0.43	Yes
	non-ML	3.30	0.87			Reject H_O

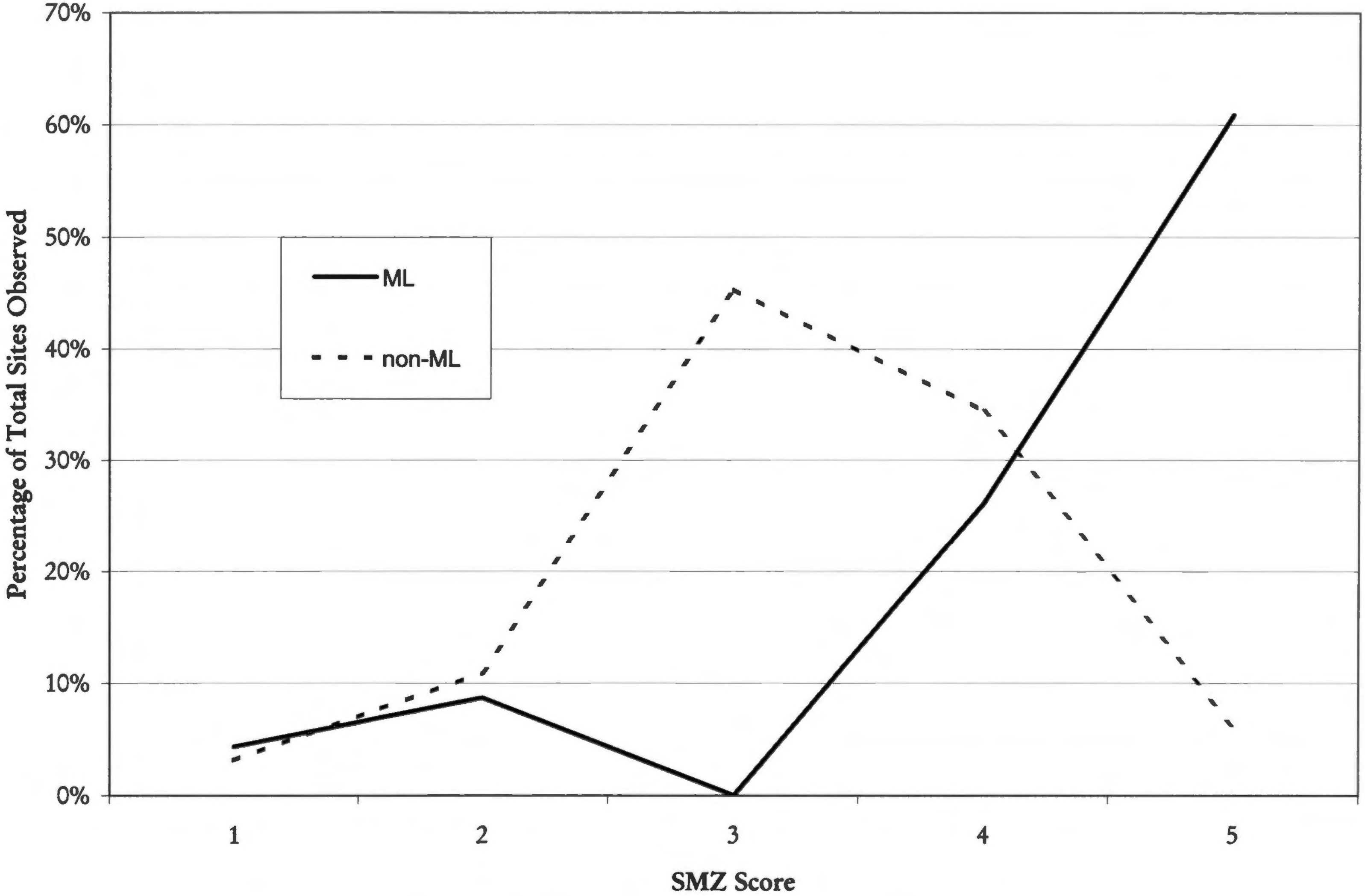

Figure 1.4: Statewide Results of SMZ Score by Master Logger Training

Haul Roads. Statewide values for haul road score showed a significant association between logger training and haul road score with a |Pr>F| = 0.0001 (Table 4.3) using a point biserial correlation (α = .05). Therefore, rejecting the null hypothesis (H_O) concludes that there is an association between haul road score and Master Logger training. The correlation coefficient, r, was equal to 0.54 for statewide haul road results. According to Davis' (1971) interpretation of correlation coefficients, the association between haul road score and logger training was a substantial association.

Skid Trails. Statewide values for skid trail score proved a significant association between logger training and skid trail score with a |Pr>F| = 0.0001 (Table 4.3) using a point biserial correlation (α = .05). Therefore, one can reject the null hypothesis (H_O) and conclude that there is a relationship between skid trail score and Master Logger training. The correlation coefficient, r, was equal to 0.51 for statewide skid trail results. According to Davis' (1971) interpretation of correlation coefficients, the association between haul road score and logger training was a substantial association.

Log Decks. Statewide values for log deck score exhibited a significant association between logger training and log deck scorewith a |Pr>F| = 0.0232 (Table 4.3) using a point biserial correlation (α = .05). Therefore, one can reject the null hypothesis (H_O) and conclude that there is a relationship between log deck score and Master Logger training.

The correlation coefficient, r, was equal to 0.16 for statewide results. According to Davis' (1971) interpretation of correlation coefficients, the association between haul road score and logger training was a low association.

Although log decks had a low association with logger training, averages of both logger groups indicated adequate BMP usage on log decks. All scores on log decks (n=191, combining logger groups) averaged 3.8. This indicates that loggers, trained and non-trained, followed recommended practices by locating decks on flat areas with sufficient distances from water sensitive areas. Both Master Loggers and non-trained loggers were responsible in cleaning up trash and oil canisters from the deck site before completing the job (see Appendix B).

One facet of log decks that could be improved is stabilization, either by revegetation or scattering logging slash on top of the exposed surface. Only 3 decks of the 191 (2%) observed had been stabilized (Appendix C, Table A-3). Master Loggers stabilized log decks on 5% (2/38) of sites observed and non-trained loggers used a method of stabilization on 1% (1/153) of the log decks observed.

Streamside Management Zones (SMZs). Statewide values for SMZ score showed a significant association between type of logger and SMZ score with a $|Pr>F| = 0.0001$ (Table 4.3) using a point biserial correlation ($\alpha = .05$). Therefore, rejecting the null hypothesis (H_O) concludes that there is a relationship between SMZ score and Master Logger training. The correlation coefficient, r, was equal to 0.43 for statewide SMZ results. According to Davis' (1971) interpretation of correlation coefficients, the association between haul road score and logger training was a moderate association.

4.3 FIA Region Results

Observed sites were stratified by USDA Forest Service regions. The Forest Inventory Analysis (FIA) 1989 data for Tennessee partitions the state into 5 regions: 1) West, 2) West Central, 3) Central, 4) Plateau, and 5) East (May 1991). Stratification was necessary in order to place more emphasis on the regions that were more affected by logging. This ensured that more samples were taken where the most timber was harvested, and thus, where the largest possible impact to erosion, sedimentation, and water quality might occur.

The number of Master Logger observations in two of the FIA Regions were not sufficient to draw significant conclusions about the relationship of logger training and BMP implementation. In the Central region, only 4% (1/26) of the sites observed were harvested by Master Loggers (Table 3.1). In the West region, Master Loggers completed 8% (2/27) of the harvests observed. Thus, these two regions will be excluded from the following discussion. However, means, ranges and standard deviations of harvest area scores for each logging group are reported in Appendix D for the Central (Table A-5) and West (Table A-6) FIA Regions.

4.3-1: East Region

For all harvest areas, Master Logger mean scores in the East FIA Region were higher than non-trained loggers (Table 4.4). Master Loggers accounted for 28% (9/41) of the haul roads observed, 22% (9/50) of the skid trails and log decks observed, and 25% (6/24) of the SMZs observed.

Table 4.4: Harvest Area Scores for the East Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	No. Obs	9	9	9	6
	Mean	3.4	4.2	3.9	4.8
	Maximum	4	5	4	5
	Minimum	3	3	3	4
non-ML	No. Obs	32	41	41	18
	Mean	2.3	2.6	3.6	3.3
	Maximum	4	4	5	4
	Minimum	1	1	1	1

Statistical Results. A point biserial correlation test ($\alpha = 0.05$) indicated a significant association between logger training and haul roads, skid trails, and SMZs (Table 4.5) for the East region. Correlations between the logger training and log deck scores proved to be a non-significant association.

The correlation coefficient, r, was equal to 0.56 for haul roads, indicating a substantial association (Davis 1971). For skid trails, r equaled 0.70 and showed a substantial association. The relationship between logger training and SMZs in the East can be described as a moderate association with r equal to 0.59.

Table 4.5: Statistical Results of Harvest Scores for the East Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	Mean	3.4	4.2	3.9	4.8
	Std Dev	0.5	0.7	0.3	0.4
Non-ML	Mean	2.3	2.6	3.6	3.3
	Std Dev	0.8	0.7	0.8	1.1
	r	0.56	0.70	0.15	0.59
	$\lvert Pr > F \rvert$	0.0003	0.0001	0.295	0.0024
	Significance	Yes	Yes	No	Yes
	Accept/Reject	Reject Ho	Reject Ho	Accept Ho	Reject Ho

Standard deviations, in general, were larger among the non-trained logger group than the Master Logger group. This indicates that the distribution of Master Logger harvest area scores were tighter and the ranges smaller than non-trained logger scores (Appendix C, Table A-1, A-2, A-3, A-4).

4.3-2: Plateau Region

Master Logger mean scores in the Plateau FIA Region were higher for all harvest area scores than non-trained loggers (Table 4.6). Master Loggers accounted for 16% (5/31) of the haul roads observed, 17% (7/42) of the skid trails and log decks observed, and 15% (2/13) of the SMZs observed.

Statistical Results. A point biserial correlation (α = 0.05) was used to determine the relationship between logger training and harvest area score. In the Plateau region, a significant relationship was found between logger training and haul roads,

Table 4.6: Harvest Area Scores for the Plateau Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	No. Obs	5	7	7	2
	Mean	3.2	3.9	4.0	5.0
	Maximum	4	4	4	5
	Minimum	3	3	4	5
Non-ML	No. Obs	26	35	35	11
	Mean	2.4	2.6	3.9	3.3
	Maximum	4	3	4	5
	Minimum	1	1	3	2

skid trails, and SMZs (Table 4.7). Thus, one can reject the null hypothesis that there is no association between logger training and harvest area score.

Correlations for log deck scores proved to be a non-significant association. Therefore, accepting the null hypothesis concludes that there is no association between logger training and log deck score.

The correlation coefficient, r, was equal to 0.56 for haul roads, 0.65 for skid trails, and 0.67 for SMZs. All three of these correlations indicated a substantial association (Davis 1971) between logger training and harvest area score for the Plateau.

Standard deviations, in general, were larger among the non-trained logger group than the Master Logger group for all harvest areas. The standard deviation of 0.00 for Master Loggers on log decks and SMZs indicates that all observed Master Logger log decks and SMZs scored the same.

Table 4.7: Statistical Results of Harvest Scores for the Plateau Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	Mean	3.2	3.9	4.0	5.0
	Std Dev	0.5	0.4	0.0	0.0
Non-ML	Mean	2.4	2.6	3.9	3.3
	Std Dev	0.5	0.6	0.4	0.8
	r	0.56	0.65	0.16	0.67
	$\mid Pr > F \mid$	0.001	0.0001	0.298	0.0121
	Significance	Yes	Yes	No	Yes
	Accept/Reject	Reject H_O	Reject H_O	Accept H_O	Reject H_O

4.3-3: West Central Region

Master Logger averages in the West Central FIA Region were higher for all harvest area scores than non-trained loggers (Table 4.8). Master Loggers accounted for 37% (16/43) of the haul roads observed, 40% (19/48) of the skid trails and log decks observed, and 46% (12/26) of the SMZs observed.

Statistical Results. Point biserial correlations (α = 0.05) were used to determine the relationship between logger training and score of harvest area. In the West Central Region, a significant association was found between the type of logger and haul roads, skid trails, and SMZs (Table 4.9). Thus, one can reject the null hypothesis that there is no relationship between logger training and harvest area score.

Correlations for log deck scores proved to be a non-significant association. Therefore, one can accept the null hypothesis and conclude that there is no relationship between logger training and log deck score. Both groups of loggers had similar log deck mean scores.

Table 4.8: Harvest Area Scores for the West Central Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	No. Obs	16	19	19	12
	Mean	3.2	3.5	4.0	4.2
	Maximum	4	5	5	5
	Minimum	2	1	3	2
Non-ML	No. Obs	27	29	29	14
	Mean	2.3	3.0	3.8	3.4
	Maximum	4	4	4	4
	Minimum	2	2	3	2

Table 4.9: Statistical Results of Harvest Scores for the West Central Region

Training	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	Mean	3.2	3.5	4.0	4.2
	Std Dev	0.5	1.1	0.5	1.1
Non-ML	Mean	2.3	2.9	3.8	3.4
	Std Dev	0.5	0.5	0.4	0.6
	r	0.65	0.34	0.26	0.43
	$\mid Pr > F \mid$	0.0001	0.0172	0.076	0.0292
	Significance	Yes	Yes	No	Yes
	Accept/Reject	Reject H_O	Reject H_O	Accept H_O	Reject H_O

The correlation coefficient, r, was equal to 0.65 for haul roads, indicating a substantial association (Davis 1971). For skid trails, r equaled 0.34 and showed a moderate association. The relationship between logger training and SMZs in the West Central can be described as a moderate association with r equal to 0.43.

Standard deviations, in general, were smaller among the non-trained logger group than the Master Logger group for all harvest areas. This is a different result than in the East and Plateau regions. Only the standard deviations for skid trails and SMZs were higher for Master Loggers than non-trained loggers. The larger standard deviations are a direct result of atypically poor performances of a few Master Loggers in the West Central region (Appendix C, Table A-1, A-2, A-3, A-4).

4.4 Use of Waterbars

Use of waterbars, to limit the erosive power of runoff on haul roads and skid trails, is the key BMP influencing the overall score and area scores of both groups of loggers. First, loggers were given a point for including waterbars on haul roads and skid trails (see Appendix B). Second, waterbars limit runoff from washing out roads and trails. Evidence of washout on haul roads or skid trails was a point deduction in score. Third, waterbars can prohibit sediment-laden runoff from entering streams if they are installed before a haul road or skid trail crosses a creek. Sedimentation in streams is a threat to water quality and resulted in a score of 1. Combining these three factors, the inclusion of waterbars could change scores on haul roads from a 1 to a 3 and on skid trails from a 1 to a 4 (see Appendix B).

Haul Roads. Table 4.10 shows the relationship between the inclusion of haul road waterbars and the type of logger. Statewide, Master Loggers correctly employed waterbars on 86% of haul roads, while non-trained loggers only correctly used waterbars on 9% of haul roads. This result showed a significant association using a point biserial correlation. The association between logger training and use of waterbars on haul roads was very strong (Davis 1971) with the correlation coefficient, r, equal to 0.71.

Significant associations were found within three of the five FIA regions: the East, Plateau, and West Central regions (Table 4.10). The percentage of correct use of waterbars for Master Loggers ranged from 50% in the Plateau region to 93% in the West Central region. The highest percentage of correct use for non-trained loggers was 20% in the West Central region.

In the East FIA Region, r was equal to 0.64, indicating a substantial association between logger training and the use of waterbars on haul roads. For the Plateau, r equaled 0.70 and showed a substantial association. The relationship between logger training and haul road waterbar use in the West Central can be described as a very strong association with r equal to 0.71.

Table 4.10: Relationship Between the Inclusion of Haul Road Waterbars and Master Logger Training.

H_O: There is an independent relationship between haul road water bar use and Master Logger training.

FIA Region	Training	Correct	Incorrect	% Correct	Pr > F	r	Significance
East	ML	6	1	86%	0.0001	0.64	Yes
	Non-ML	4	25	14%			Reject H_O
Plateau	ML	1	1	50%	0.0001	0.70	Yes
	Non-ML	0	25	0%			Reject H_O
West Central	ML	14	1	93%	0.0001	0.71	Yes
	Non-ML	5	20	20%			Reject H_O
Statewide	ML	23	4	85%	0.0001	0.71	Yes
	Non-ML	10	101	9%			Reject H_O

Both the Central and West regions had a low number of observations of Master Logger haul roads. Therefore, these FIA regions are not included in the statistical analysis of waterbar use on haul roads.

Skid Trails. Table 4.11 exhibits the relationship between skid trail waterbar inclusion and the groups of loggers. Master Loggers implemented waterbars on skid trails at 72% of the sites observed statewide, while non-trained loggers only did so on 5% of the skid trails observed. These percentages showed a significant association using a point biserial correlation. The association between logger training and use of waterbars on haul roads was substantial (Davis 1971) with the correlation coefficient, r, equal to 0.70.

Significant associations were found within three of the five FIA regions:

Table 4.11: Relationship Between the Inclusion of Skid Trail Waterbars And Master Logger Training.

H_O: There is an independent relationship between skid trail waterbar use And Master Logger certification.

FIA Region	Training	Correct	Incorrect	% Correct	Pr > F	r	Significance
East	ML	7	1	88%	0.0001	0.85	Yes
	Non-ML	1	40	2%			Reject H_O
Plateau	ML	5	1	83%	0.0001	0.90	Yes
	Non-ML	0	35	0%			Reject H_O
West Central	ML	12	7	63%	0.0002	0.51	Yes
	Non-ML	4	25	14%			Reject H_O
Statewide	ML	26	10	72%	0.0001	0.70	Yes
	Non-ML	7	141	5%			Reject H_O

the East, Plateau, and West Central regions. The percentage of correct use of waterbars on skid trails for Master Loggers ranged from a low of 63% in the West Central to 88% in the East. The non-trained logger percentage was no higher than the 14% in the West Central region.

In the East FIA Region, r was equal to 0.85, indicating a very strong association between logger training and the use of waterbars on skid trails. For the Plateau, r equaled 0.90 and showed a very strong association. The relationship between logger training and SMZs in the West Central can be described as a substantial association with r equal to 0.51.

As with the haul road evaluation, both the Central and West regions had a low number of observations of Master Logger skid trails. These FIA regions were not included in the statistical analysis of waterbar use on skid trails.

These data indicate that the Tennessee Master Logger Program gave loggers the understanding, background, and the knowledge of waterbar implementation on both haul roads and skid trails.

Chapter 5: Conclusions and Suggestions

The Tennessee Master Logger Program has contributed to improved logger BMP implementation in the state of Tennessee. There is a substantial association between BMP implementation and Master Logger training, where the statewide overall BMP score Master Loggers was 75.1% compared to the non-trained logger group's mean of 60.4%.

There was a positive association between BMP implementation and harvest area score statewide for all four harvest areas: haul roads, skid trails, log decks, and SMZs. Master Logger mean scores on all four areas of harvest were higher on a statewide level than non-trained loggers. Within the East, Plateau, and West Central FIA Regions, Master Loggers scored higher on haul roads, skid trails and SMZs than non-trained loggers.

Both logger groups, Master Loggers and non-trained loggers, implemented BMPs on log decks. The mean scores for both groups were similar on the statewide level and in the individual FIA regions. The only BMP that could have improved these mean scores was revegetation of the log deck surface.

The major BMP practice that differentiated Master Loggers and non-trained loggers was the inclusion of waterbars on haul roads and skid trails. There was a very strong association between the inclusion of water bars on both paths and Master Logger training. Master Loggers correctly implemented waterbars on 85% of the haul roads observed statewide and on 72% of the skid trails observed statewide. Non-trained loggers only correctly employed waterbars on 9% of the haul roads observed and on 5% of the skid trails observed statewide.

5.1: Suggestions for the TMLP

One specific BMP that requires special attention among both logger groups is revegetation of exposed surfaces, particularly on haul roads and log decks. None of the 158 haul roads observed statewide and only 3 of the 191 (1.6%) of the log decks observed statewide showed any evidence of revegetation (planting or seeding) attempts. Revegetating exposed surfaces is a timely and costly BMP for loggers to implement. Some assistance, be it financial or otherwise, from the landowner or other agency is perhaps necessary to ensure revegetation of haul road and log deck surfaces. The TMLP should place more emphasis on the importance of revegetating haul roads and log decks to minimize erosion and runoff.

Another area requiring further BMP attention is creek crossings of both haul roads and skid trails. A majority of the water quality threats resulting from haul roads and skid trails were the result of faulty crossings, either by the mechanism, or lack of, used to cross (ie. ford, portable bridge, etc.) or the reluctance to install waterbars on either side of the actual crossing. Loggers should understand the importance of installing culverts or portable bridges when crossing creeks or drainages to protect the stream channel and to ensure water quality. Installing waterbars on either approach to the crossing will divert runoff from directly entering the water source.

Future educational efforts of the Tennessee Master Logger Program should emphasize alternative creek crossings other than fords for use on haul roads and skid trails. Furthermore, instructors should emphasize the importance of using waterbars to limit erosion and runoff from haul roads and skid trails, especially at the approaches to creek or drainage crossings. A final suggestion to Master Logger programming is to underscore the importance of SMZs in protecting water quality. Particularly, loggers must comprehend the importance of not disturbing the forest floor and shrubby vegetation. These are the components of an SMZ that slow runoff and, thus, filter out sediment before it reaches a water source.

The Tennessee Master Logger Program should assemble a collection of data pertaining to the sizes of operation for each logger that attends the program. Forest industry seemed to spur the initial interest in the program by sending company contracted loggers through the educational program. Thus, it would reason that the population of loggers trained by the TMLP is skewed toward larger operations that have assurances of timber receipts at mills and, sometimes, financial support from industry. However, smaller logging operations would seem to benefit more from the training than logging firms that are contracted by professionally trained foresters. The TMLP should focus efforts on attracting loggers that contain smaller crews and smaller and less efficient equipment.

As stated earlier, the number of participants for the Tennessee Master Logger Program has increased steadily since its inception in 1992. Based on the results of this research, it appears it would be beneficial if the program could intensify efforts to reach even more loggers in the upcoming years.

Furthermore, the TMLP should encourage landowner participation since these individuals are primarily responsible for land management activities on private forestlands. By educating landowners on the benefits of BMPs, the TMLP could encourage landowners to check and ensure the inclusion of BMPs before loggers leave the site. Landowners must take initiative and part of the responsibility in protecting site and water quality on timber harvests.

5.2: Suggestions for Future Logger Evaluation Studies

Master Logger observed sites in two of the five FIA Regions (Plateau and West) were not sufficient to gather definitive conclusions about the influence of the Tennessee Master Logger Program on BMP implementation and logger performance. A representative sample of Master Logger sites in these two FIA Regions, along with the other regions, would contribute to better understanding of the value of the TMLP.

Site observations for future studies should not be conducted with prior knowledge as to whether a Master Logger or non-trained logger harvested the site. To eliminate this bias, two researchers may be required, one gathering potential sites to be observed and another conducting the actual site observations. The observer needs only to be provided with the location of the harvest. Furthermore, sites to be observed could be assigned a value, numeric or alphabetic, and then cross-referenced with the name of the logger after all sites have been observed. Then, this list of observed loggers could be cross-referenced to a list of Master Logger graduates.

Input from the observed loggers is necessary to control for the variation in the sizes of operation. Loggers with better equipment are more prepared to construct more efficient BMPs than loggers with substandard equipment. Such information would lend even more credence to the positive impact of the educational programming of the TMLP on BMP implementation.

This study only focussed on timber harvests conducted on non-industrial private forestland (NIPF), and thus, only reflects logger performance on NIPF. To gain a complete comprehension of the impact of logger performance in the state of Tennessee and the Southeast in general, it may be beneficial to observe harvests on both industrial private forestland and public or state lands, in addition to NIPF. Although most government and forest industry lands are managed by professional foresters and most require that harvests be conducted by trained Master Loggers, a study on NIPF, forest industry and government land would provide further insight into BMP implementation throughout the state of Tennessee and, more regionally, throughout the Southeast.

One measure of sufficient BMP implementation is landowner satisfaction. A survey of landowners that have had timber harvested either by a Master Logger or non-trained logger could be conducted to determine if the performance of Master Loggers has resulted in higher levels of landowner approval and satisfaction.

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Appendices

Appendices

Appendix A

FIA Region_______________ **Master Logger** **NON-Trained Logger**

I. General Characteristics

FIA Region ____________ Date of Inspection ____________
County ____________ Date of Harvest ____________
Acreage ____________ Aid of Forester ____________
Logger ____________, Master-Logger or Non-Master-Logger
Landowner ________________________________

II. Site Characteristics

A. Physiographic Region
1. Blue Ridge ______
2. Southern Appalachians ______
3. Cumberland Plateau ______
4. Highland Rim ______
5. Central Basin ______
6. Southern Coastal Plain ______
7. Mississippi Silty Uplands ______
8. Mississippi Valley Alluvial ______

B. Terrain Type
1. Wetland ______
2. Bottomland ______
3. Flatland ______
4. Rolling Hills ______
5. Steep Upland ______

C. Drainage Features
1. Perennial Stream ______
2. Intermittent Stream ______
3. Ephemeral Stream ______
4. Lake/Pond ______
5. None Present ______

III. Haul Roads

A. BMP's Used and Effectiveness

	Correct	Incorrect	Not Used	N/A
1. Broad Based Dips				
2. Waterbars				
3. Culverts				
4. Turnouts				
5. Avoid Sensitive Areas				
6. Rock Used				
7. Stabilized with Seed				

	YES	NO	N/A
B. Stream Crossings Used?	_____	_____	_____
1. Bridge	_____	_____	_____
2. Culvert and Fill	_____	_____	_____
3. Debris	_____	_____	_____
4. Ford	_____	_____	_____

C. Concentrated Flows Dumping Into Streams? _________

D. Is amount of rutting acceptable? __________

E. Is washout of road visible? _________

Overall Rating for Haul Roads: _________ (1-5)

IV. Skid Trails

A. BMPs Used and Effectiveness

	Correct	Incorrect	Not Used	N/A
1. Broad Based Dips				
2. Waterbars				
3. Turnouts				
4. Avoid Sensitive Areas				
5. Stabilized with Seed				

	YES	NO	N/A
B. Stream Crossings Used?	_____	_____	_____
1. Bridge	_____	_____	_____
2. Culvert and Fill	_____	_____	_____
3. Debris	_____	_____	_____
4. Ford	_____	_____	_____

C. Concentrated Flows Dumping Into Streams? _________

D. Is amount of rutting acceptable? __________

E. Is washout of trail visible? _________

Overall Rating for Skid Trails: _________ (1-5)

V. Logging Decks

	YES	NO	N/A
A. Are the decks located a sufficient distance from water sensitive areas?	____	____	____
B. Locations free of garbage including oil and gasoline canisters and spills?	____	____	____
C. Locations stabilized with seed following use?	____	____	____
D. Are locations draining into streams?	____	____	____

Overall Rating for Logging Decks: ________ (1-5)

VI. Streamside Management Zones

	YES	NO	N/A
A. Are SMZs present?			
1. Perennial	_____	_____	_____
2. Intermittent	_____	_____	_____

B. Residual Basal Area in SMZ __________

	YES	NO	N/A
C. Streamflow restricted by crossings or down trees?	____	____	____

Overall Rating for SMZs: __________ (1-5)

VII. Notes

Appendix B

Explanation of Rating System for Harvest Areas

Score	Haul Road	Skid Trail	Log Deck	SMZ
1	A threat to water quality induced	A threat to water quality induced	A threat to water quality induced	A threat to water quality induced
2	ASAs[1] Rock Used on Road	ASAs Washout Visible Rutting Visible	Deck not level **and** Garbarge or Oil Present Drainage from Deck Present	SMZ too thin for slope Insufficient BA[2] Tops **or** Slash in Stream
3	ASAs Rock Used Waterbars **or** Turnouts **or** BBDs[3]	ASAs NO Washout NO Rutting	Deck not level **OR** Garbarge **or** Oil Present	2 of the above 3
4	ASAs Rock Used Waterbars **and** Turnouts **and** BBDs	ASAs NO Washout **or** Rutting Waterbars **and** Turnouts	Sufficient distance from water and deck level NO Garbage **or** Oil NO Drainage	1 of the above 3 Ex.) tops in stream
5	ASAs Rock Used Waterbars **and** Turnouts **and** BBDs Revegetation of Road Surface	ASAs NO Washout **or** Rutting Waterbars **and** Turnouts Revegetation of Surface	Sufficient distance from water **and** deck level NO Garbage **or** Oil NO Drainage Revegetation of Surface	SMZ width sufficient Sufficient BA NO tops or slash in stream NO streamflow restriction

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[1] Avoid Sensitive Areas
[2] 60-70 Sq. Ft/Acre for Perennial Streams and 40-50 Sq. Ft/Acre for Intermittent Streams
[3] Broad Based Dips

Appendix C

Table A-1: Frequency of Haul Road Scores Within Each FIA Region.

FIA Region	Certification	Haul Road Score 1	2	3	4	5	Total
East	ML	0	0	5	4	0	9
	non-ML	3	19	8	2	0	32
Platea	ML	0	0	4	1	0	5
	non-ML	0	17	9	0	0	26
Central	ML	0	0	1	0	0	1
	non-ML	0	19	3	0	0	22
West Central	ML	0	1	11	4	0	16
	non-ML	0	21	5	1	0	27
West	ML	0	1	1	0	0	2
	non-ML	1	10	5	2	0	18
Statewide	ML	0	2	22	9	0	33
	non-ML	4	86	30	5	0	125

Table A-2: Frequency of Skid Trail scores within each FIA Region.

FIA Region	Certification	Skid Trail Score 1	2	3	4	5	Total
East	ML	0	0	1	5	3	9
	non-ML	3	13	24	1	0	41
Platea	ML	0	0	1	6	0	7
	non-ML	2	11	22	0	0	35
Central	ML	0	0	0	1	0	1
	non-ML	1	4	20	0	0	25
West Central	ML	2	0	6	8	3	19
	non-ML	0	5	21	3	0	29
West	ML	0	0	1	1	0	2
	non-ML	1	2	18	1	1	23
Statewide	ML	2	0	9	21	6	38
	non-ML	7	35	105	5	1	153

Table A-3: Frequency of Log Deck Scores within each FIA Region.

FIA Region	Certification	Log Deck Score 1	2	3	4	5	Total
East	ML	0	0	1	8	0	9
	non-ML	1	4	5	31	0	41
Platea	ML	0	0	0	7	0	7
	non-ML	0	0	5	30	0	35
Central	ML	0	0	0	1	0	1
	non-ML	0	1	3	21	0	25
West Central	ML	0	0	2	15	2	19
	non-ML	0	0	7	22	0	29
West	ML	0	0	0	2	0	2
	non-ML	0	0	5	17	1	23
Statewide	ML	0	0	3	33	2	38
	non-ML	1	5	25	121	1	153

Table A-4: Frequency of SMZ Scores Within Each FIA Region.

FIA Region	Certification	SMZ Score 1	2	3	4	5	Total
East	ML	0	0	0	1	5	6
	non-ML	1	3	6	6	2	18
Platea	ML	0	0	0	0	2	2
	non-ML	0	1	7	2	1	11
Central	ML	0	0	0	1	0	1
	non-ML	0	1	5	1	0	7
West Central	ML	0	2	0	4	6	12
	non-ML	0	1	7	6	0	14
West	ML	1	0	0	0	1	2
	non-ML	1	1	4	7	1	14
Statewide	ML	1	2	0	6	14	23
	non-ML	2	7	29	22	4	64

Appendix D

Table A-5: The Ranges of Harvest Scores in the Central Region

Certification	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	No. Obs	1	1	1	1
	Mean	3.00	4.00	4.00	4.00
	Std Dev	--	--	--	--
	Maximum	3	4	4	4
	Minimum	3	4	4	4
Non-ML	No. Obs	22	25	25	7
	Mean	2.14	2.76	3.80	3.00
	Std Dev	0.35	0.52	0.50	0.58
	Maximum	3	3	4	4
	Minimum	2	1	2	2

Table A-6: The Ranges of Harvest Scores in the West Region

Certification	Statistic	Haul Roads	Skid Trails	Log Decks	SMZs
ML	No. Obs	2	2	2	2
	Mean	2.50	3.50	4.00	3.00
	Std Dev	0.71	0.71	0.00	2.83
	Maximum	3	4	4	5
	Minimum	2	3	4	1
non-ML	No. Obs	18	23	23	14
	Mean	2.44	2.96	3.83	3.43
	Std Dev	0.78	0.71	0.49	1.01
	Maximum	4	5	5	5
	Minimum	1	1	3	1

Vita

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