CASE STUDIES IN VALUE IMPROVEMENT IN HARDWOOD TIMBER HARVESTING OPERATIONS IN THE SOUTHERN APPALACHIANS

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Case Studies in Value Improvement in Hardwood Timber Harvesting Operations in the southern Appalachians

Hylton J.G. Haynes (ABSTRACT)

Three independent case studies focused on harvesting operation value improvement:

(1) A productivity study was carried out on a new cable logging operation near Pikeville, Kentucky to document the effect of professional training on production efficiency. The crew received one full week of professional training. Prior to the professional training the productivity of the operation was established at 834 cubic feet per productive machine hour at an average piece size of 54 cubic feet. Two weeks after the training a productivity increase of 218 cubic feet per productive machine hour was established.

(2) A USDA Forest Service stewardship contracting pilot project took place at Burns' Creek, Virginia. Productivity and machine costs for the cable-logging 'swing landing' operation were determined. Stream habitat improvement was achieved through the placement of limestone in the headwaters. The yarder placed 6.21 tons of lime per productive machine hour into the creek at a cost of $53 per ton. Instead of a traditional stumpage sale, timber was merchandized by the Forest Service and stored on the landing for a roadside log sale. Benefits and opportunities for a roadside log sale were identified. Consensus from the consumers at the log-sale was that the potential value of the timber was realized.

(3) The third case study involved the analysis of the value recovered through log-making techniques (bucking) for five logging crews working in Virginia and West Virginia. An average value loss of 22 percent was calculated using the *HW-BUCK*™ bucking optimizer software package.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The hardwood lumber business, from logging to finished material, has been an important industry in the history and development of the southern Appalachian region. Forestry and forest products are still one of the top three industries that impact the economy of this region (MACED, 2002).

The Appalachian region is predisposed to many social, economic and environmental concerns, none more important than the sustainable utilization of the local Appalachian hardwood forests. It is within this context that the goal to identify opportunities for operational and marketing improvement in the harvesting of mixed southern Appalachian mountain hardwood stands will be explored.

Three separate projects constitute this effort. The first project involves the development and understanding of a learning curve for machine operators, as related to a specific cable-yarding operation. The second is a third-party system productivity, environmental management and marketing analysis of a cable-yarding operation on federal forestland. The final project will identify opportunities in the log-making (bucking) process that enable the maximization of that value recovery. The use of benefit-cost analysis and statistical analysis to evaluate the results of these projects will assist in a better understanding of this unique forestry region so that improved decisions can be made to enhance the capacity and sustainability of its' natural resources.

1.2 STUDY OBJECTIVES

The primary objective of this study is to improve harvesting operations in the Appalachian forests. Three key areas of improvement were identified and for each area a specific study was executed to quantify opportunities for performance improvement. These three key areas include:

i. The benefits of professional operator training.
ii. Extended opportunities for cable-yarders, including productivity, environmental management and marketing.
iii. Improving value recovery in the log-making (merchandizing) process.

CHAPTER 2 LITERATURE REVIEW

2.1 LEARN-CURVE EFFECT

“The improvement in labor time is generally referred to as resulting from productivity. If the improvement is, however, repetitive and predictable, it is considered as resulting from learning. In effect, progress depends on people learning, and a conventional hypothesis in industry is that they learn according to a predictable pattern often called the learning curve” (Blekaoui, 1986).

Logger education and training is an important issue in the forest industry. Gains resulting from harvest planning training and written timber harvest plans are significant (Shaffer and Meade, 1997). The need to quantify productivity improvements that can be made through training is important. An experienced operator can account for a 30 to 40 percent increase in productivity (Stampfer, 1999; Parker *et al.,* 1996; Stampfer *et al*., 2002).

The assumption is that, without operator training, operator efficiency improves through time, until maximal efficiency is achieved. With operator training this natural learn curve can be improved, whereby maximal operator efficiency is achieved within a shorter space of time. Figure 1 graphically represents this concept. The base line indicates the natural (self-taught) learn curve through time, with the intervention of a professional training event the natural learn curve is accelerated.

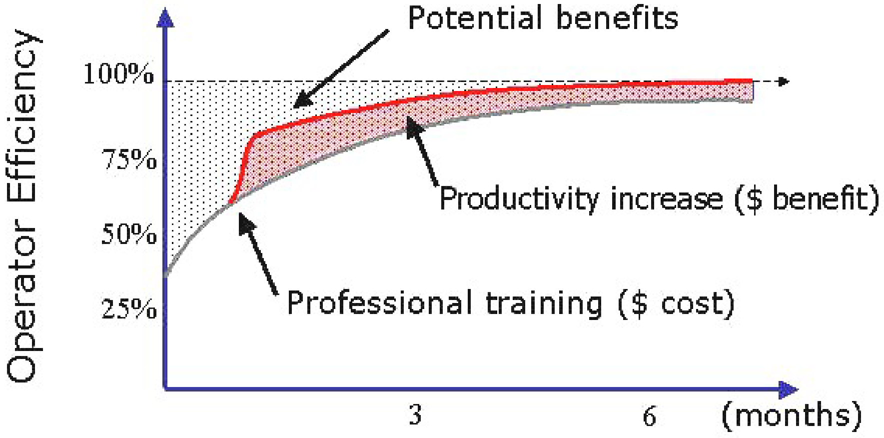


Figure 1: A graphical representation of an operator learn-curve (Visser and Haynes, 2001)

The professional training event perturbs the natural learn curve so that greater operator efficiency gains are captured earlier. This minimizes the potential benefits that are incurred whenever a machine operator is learning how to operate a new machine without training. With this improvement in operator efficiency there is a subsequent earlier increase in productivity. The monetary benefits from this behavioral change, which improves operator performance, can often offset the costs incurred by the initial investment in operator training within a short period of time. It is within this context that the first case study on a new cable yarder operator in eastern Kentucky was investigated and the productivity improvements through professional training were quantified.

2.2 CABLE-LOGGING

In the late 1970's and early 1980's a large amount of information was published regarding cable logging in the southern Appalachians (Gochennour *et al.*, 1978; Iff and Coy, 1979; Rossie, 1983; Ledoux, 1985; Sherar *et al.,* 1986). A number of these studies establish productivity levels (LeDoux *et al*, 1995). Environmental factors and logistical difficulty in reaching second growth timber on steep terrain using ground based logging methods was the primary driver for heightened interest in cable logging (Gochenour *et al.,* 1978).

Fisher *et al*. (1980) identified four reasons for promoting the potential effectiveness of small or medium cable yarders in the southern Appalachian region:

- Slopes are predominately convex and smaller cable systems with a reach of 1000 feet or less would minimize problems associated with convex slopes.
- Smaller cable systems have a lower initial capital cost and can be better matched to small and low value timber than bigger machines.
- More than 75 percent of the forestland is owned by private individuals and has a limited tract size. Small cable systems are highly mobile and can easily be moved into small tracts. In addition, these machines can usually be moved on state highways without special permits for height, weight, and width.

- The transportation of small cable systems does not require the wide roads necessary for the transport of their large western counterparts. Road building and maintenance cost may be reduced and less forestland removed from production.

These reasons still hold true but since the 1980's there have been considerably fewer cable logging operations in the region. It is estimated that 70 medium sized yarders could work on a sustainable basis to harvest the 140 million board feet (MMBF) that would be available each year in the Appalachian region (Baker *et al.*, 2001). Currently only about five yarding crews work in the southern Appalachian region, and not all of those are employed on a full time basis.

Ground-based skidder operations are still the most common extraction option because of lower logging price and consistent production. Where timber volume and value permits, helicopters are used on the steeper slopes. While the local timber companies still actively manage ground-based operations, helicopter operations are considered a 'turn-key' solution. This means the helicopter logging company carries out all aspects of the operation including planning, felling and extraction, only the loading and trucking of the timber is sub-contracted to a local crew. Concern is also increasing over the impact of timber harvesting using conventional ground-based harvesting equipment on the forest ecosystem (Huyler and Ledoux, 1994). One alternative to ground-based systems operating on steep forested slopes is the use of cable-yarding technology. Cable logging technology can minimize road construction and environmental impacts on the site compared to conventional ground-based systems, but it is more expensive to implement (Huyler and Ledoux, 1997).

The need for correct management to find utility in cable-yarding systems is being driven by both economic and environmental factors. In the short-term, increasing helicopter operation costs, due to high fuel and maintenance expenses, has lead to a need to promote cable-yarding operations as a profitable alternative to extracting timber from these mountainous southern Appalachian hardwood stands. Road construction and maintenance is one of the environmental factors that need to be considered, because it is a major source of sediment from forestry operations (Brown and Krygier, 1971; Burns, 1972; Askey and

Williams, 1984; Anderson and Potts, 1987). Up to 90 percent of the total sediment production from timber harvesting operations comes from roads (Anderson *et al*., 1976; Megahan, 1980; Rothwell, 1983; Patric, 1986; Christopher, 2002). In the long-term, the use of this alternative logging system will limit the costly intervention of road building and road maintenance practices (Coglan and Sowa, 1998) and thereby minimize the environmental and economic impact of forest harvesting operations in the region.

Contract logging and operational management expertise in cable-yarding systems in the region is still developing and the need for skill in pre-harvest planning, harvest layout and truck scheduling is critical for cable logging operations. The need to learn more about cable logging systems and the limitations thereof is becoming more important as economic and environmental constraints begin to restrict this important natural resource industry in the southern Appalachian region.

2.3 VALUE RECOVERY

The area with great potential for minimizing the large amount of value loss in the stump to mill supply chain is log manufacturing. This is especially true for the high value timber found in the southern Appalachian forests of today. Standing timber has only potential value. The actual value is only realized once the raw material has been processed at a mill. The optimization of this value is dependent on numerous factors, however the quality of bucking (merchandizing) and the pre-emptive assignment of logs for specific markets influences the outcome of this industrial supply chain.

In 1923 R.C. Bryant wrote in his textbook on American logging practices “Log-makers frequently do not give sufficient attention to securing quality as well as quantity…. A system by which timber is cut for quality as well as quantity means an increase in the percentage of the higher grades, more timber per acre and the prolonged life of the operation.” Steve Conway (1976) wrote about U.S. logging practices “In the past (and even to a certain extent today), logs were cut without regard to end use. … Least cost was, and unfortunately still is in all too many cases, the main objective. ….Failure to cut for end use can result in the loss of millions of dollars to the (forest) industry every year.”

Value recovery is maximizing the value of the raw materials through the production chain. An example is optimal bucking (merchandizing) of trees, i.e. the cutting of a tree into parts that maximize the total tree value according to the decision-makers objectives (Sessions, 1988). The definition as to what constitutes profit does depend upon the vantage point of the decision maker. For the logging contractor who buys timber from a landowner, harvests the timber, and sells the logs to a mill:

Profit = mill delivered price – stumpage cost – logging cost – transport cost.

For the mill harvesting its own timber,

Profit = selling product price – manufacturing cost – stumpage cost - logging cost – truck transport cost.

For the landowner cutting their own timber and seeking to maximize stumpage value,

Profit = mill delivered price – logging cost – truck transport cost (Sessions, 1988).

In all three contexts the maximization of value recovery through optimal bucking will improve the profit-making ability of the decision maker, however the opportunity for improved profit increases along the value supply chain. The maximization of value recovery is dependant on the costs involved in achieving an improvement.

In the ‘total quality management’ view the concept of quality is integral component of productivity because enhanced performance is also achieved through quality improvements (Edosomwan, 1995).

Cossens and Murphy (1988) identified several reasons for poor value recovery bucking:

- a lack of interest by management in achieving high levels of recovery,
- pressure by management to achieve high productivity at the expense of value recovery.
- reliance on learning by trial and error and the lack of instruction in the fundamentals that affect log making,
- great difficulty in determining the most appropriate combination of log lengths considering the complexity of log specifications, grading rules, tree characteristics, and price differentials for various end products,
- difficult work conditions that may cause an inability to see all of the tree or difficulty in implementing optimal decisions,

- log-making under a heavy physical and stressful workload,
- incorrect selection of the best location to manufacture logs,
- difficult seasonal climatic conditions,
- a lack of market place differentials for products,
- a surplus of wood in some locations.

The above-mentioned reasons are apparent in the southern Appalachian region. This may be due to the culture of the region, the nature of the mixed Appalachian hardwood stands and the inherent variability that this forest-type presents.

Bush *et al*. (1990) surveyed companies that buy hardwood lumber and found that buyers consider quality to be the major cause of dissatisfaction. The effect of poor raw material quality has not been studied extensively, however the importance of implementing a quality control system at the source of the supply chain cannot be ignored and opportunities for improvement must be explored.

2.3.1 Log Value Optimization Software

The use of dynamic programming-based methodology is preferred when dealing with individual tree bucking. Dynamic programming is an optimization method used for multi-stage decision processes because it accommodates linear and non-linear functions as well as incorporating deterministic and probabilistic elements where a solution yields a strategy for all possible conditions (Pnevmaticos and Mann, 1972). The use of dynamic programming allows for the rapid calculation of the optimal solution. Through this optimization procedure the number of combinations, in this case log pieces, are reduced and a solution generated in an efficient manner.

There are two modeling approaches used in bucking–optimization computer programs: the *one-stage* approach and the *two-stage* approach. These two approaches are driven by the primary objective of the program and the purpose for which it was designed. In the case when demand constraints exist for certain log lengths or log grades, the optimal bucking on a tree-by-tree basis often does not yield an optimal output of logs from a particular stand. The two-stage models of Eng *et al*. (1986), Mendoza and Bare (1986), and Sessions *et al*. (1989)

account for demand constraints, by integrating the allocation of the manufactured logs into the optimization program.

In the one-stage modeling approach tree data inputs like defect and shape information are primarily used in the optimization model. Most of the contemporary computer software developed to solve optimization models have been designed for softwoods. The forest products company Weyerhaeuser developed their own software package known as *VISION*™ (Video Interactive Stem Inspection and Optimization) in the late 1970's to early 1980's. The main focal point of the program was to optimize the high value raw materials from western Douglas-fir (*Pseudotsuga menziesii*) operations (Lembersky and Chi, 1986).

The *AVIS*™ (Assessment of Value by Individual Stems) one-stage software package was developed in New Zealand to enable the comparison of what log-makers are able to achieve in tree bucking to that of the optimal conversion of Radiata pine (*Pinus radiata*) stems (Geerts and Twaddle, 1985). *AVIS*™ is presently being used in the southeastern United States to compare the value recovered by mechanized harvester operators to that of the optimal value that can be recovered from Loblolly pines (*Pinus taeda*)(I.P. Conradie, Pers. Comm, 2002).

A one-stage decision simulator named *HW-BUCK*™ was developed for the northern hardwoods using a bucking optimization model that does not include any demand constraints (Pickens *et al*. 1991). *HW-BUCK*™ was used to evaluate the value recovered from Appalachian hardwood stands in Virginia and West Virginia as a component for this thesis. The general absence of demand-constraints for particular northern hardwood log grades, and the sensitivity of northern hardwood grades to the spatial arrangement of defects (Pickens, *et al*. 1992) were the main reasons why the one-stage modeling approach was applied. These computer software packages have been useful not only from a research perspective where the amount of value recovered from the tree can be optimized, but also from an educational perspective, where these packages, especially *VISION™* (Lembersky and Chi, 1986) and *HW-BUCK*™ (Pickens *et al*. 1993) were used as training tools to develop operator heuristics so that bucking skills in bucking operations could be improved.

CHAPTER 3 TRAINING IN CABLE-YARDING

3.1 INTRODUCTION

The objective of this case study is to document the change in productivity resulting from professional training for a newly established cable-logging operation in the Pikeville, Kentucky, and determine a payback period for the training costs that were incurred.

3.2 METHODOLOGY

3.2.1 Yarding Operation

Wes Hood Logging, of Norton, Virginia, purchased a *Thunderbird*™ *TY40* yarder (Figure 2) and commenced operations in July 2001. The yarder system uses an Eagle motorized slack-pulling carriage and a skidder to clear the chute (Figure 3). The logs are bucked and loaded out by a Barko 160A trailer-mounted loader.

No initial rigging training was provided, although the contractor had previously attended a two-day introductory cable-planning course at Virginia Tech. He received financial and consultative support from the company receiving the logs (B.A. Mullican Lumber Co.) and from Hank Sloan, Forest Engineer for the USDA Forest Service, Roanoke, Virginia.

Prior to the professional training event, an initial productivity study was carried out to establish the productivity on the operation during the last week of August, 2001. Two months later, in October 2001, two experienced riggers came from the Pacific Northwest to perform the training session. Ross Hojem of Chehalis, Washington, was out for 5 days and Robert Armstrong was out for 8 days to train the crew. The productivity of the system was captured again with a follow-up study in the third week of October, 2001.

Figure 2: Wes Hood Logging*: Thunderbird™ TY40* yarder with Barko 160A loader.

Figure 3: Photo showing typical southern Appalachian site conditions.

The operation had moved to a different site for the post-training study. The slope, amount of deflection, and stand characteristics were similar between the pre-training and post-training sites, although a change in average pieces size of 53.3 cu.ft to 60.0 cu.ft. was noted. This was accounted for in the data analysis. The crew remained the same between the two individual studies with the exception of the sawyers.

3.2.2 Productivity

An elemental time study was carried out using *Husky™ FS/GS* handheld computers running *Siwork3™* software. A typical yarding cycle for this operation included the carriage being sent out 'shotgun' (gravity assisted), once the stems were hooked to the mainline, the mainline drum on the yarder was activated and the carriage with load was yarded up slope to the yarder tower. At the landing the stems were unhooked. This whole sequence of events constituted a yarder cycle (Table 1). The stems at the landing were then skidded to the loader where the stems are merchandized into logs.

Table 1: Description of the individual physical parameters and time elements used in the Wes Hood cable-yarding operation

Type	Name		Description	Unit
Dependant-Variables	cycle	-	total cycle time for one turn. Productive Man Hours	0.01 min.
	loadvol	-	total volume felled for a single cycle	cu.ft
	$Prod_{yard}$	-	(loadvol/cycle)*60	$cu.ft/PMH_0$
Co-Variables	Distance	-	yarding distance	ft.
	Avgpiecesize	-	average piece volume based on large end diameter (LED) and the length estimate of each stem in the turn	cu.ft
	Piecenum	-	number of trees per cycle	n
	Train	-	block factor; 0 = no training, 1 = trained	
Times	Travel empty	-	the time required for the empty carriage to travel from the landing to the choker-setter	0.01 min.
	hook	-	the time required for the slack to be pulled from the carriage, the choker-setter to hook the load and the load to reach the carriage	0.01 min.
	travel loaded	-	the time required for the loaded carriage to travel back to the landing	0.01 min.
	unhook	-	the time required to release the chokers from the load and return them to the carriage	0.01 min
	delay	-	unproductive time	0.01 min.

Total cycle time (*cycle*) and total turn volume (*loadvol*) was combined to calculate delay free productivity. The delay time, which accounted for 42 percent of the total work time during the studies, was not used for the evaluation.

The actual stem volume of at least 35 trees was also measured on the landing at each study site to obtain a regression between the large-end diameter (LED) and length (1) actual volume. During the actual productivity study the LED was measured using calipers and the length was estimated, or measured if it did not impede productivity or compromise safety.

$$\text{Volume} = \{x_1 * \text{LED}^2\} + \{x_2 * \text{Length}\} + C \qquad \textbf{(1)}$$

3.3 PRODUCTIVITY RESULTS

A total of 55 cycles were captured prior to training and 35 cycles after training. To identify the specific area in which improvements were made, the time elements were modeled individually.

3.3.1 Carriage Out

Carriage out time is expected to have a strong correlation to extraction distance. The variability in the pre-training data set is due to the inexperience of the yarder operator. Analyzed separately, the coefficient of determination of the pre-training data set is 0.19 while the after training data set has a r^2 value of 0.69. The overall model for the carriage out phase of the operation has an $r^2 = 0.42$ (p-value < 0.000; *distance* p-value = 0.49; *train* p-value < 0.000)

$$\text{Carriage out}_{(0.01\ \text{min})} = 96 + \{0.068 * \text{Distance}_{(\text{ft.})}\} - \{52.3 * \text{Train}_{(0,1)}\} \qquad \textbf{(2)}$$

This indicates that the operator training saved on average over half a minute off each carriage out phase of the cycle. This could represent not only an increase in line speed but also a reduction in the time it took to position the carriage when it reached the ‘target’ area.

3.3.2 Hook Up

No significant difference was found in the time taken to hook up the load before and after training. However, the average turn volume increased significantly from 62.2 cu.ft. to 97.8 cu.ft., with an increase in average number of pieces of 1.3 to 1.7. This increase in average turn volume played a significant role in the overall increase in productivity after training.

3.3.3 Carriage In

As with the carriage out phase, the overall carriage in model had a low r^2 value ($r^2 = 0.44$, p-value < 0.000; *distance* p-value = 0.099; piecenum p-value = 0.011; *avepiecesize$^{0.6}$* p-value = 0.001; *train* p-value = 0.002) due to the higher variability in the pre-training data set. The following model was developed:

$$\begin{aligned}\text{Carriage in}_{\text{(0.01min.)}} = \; & 51 + \{0.101 * \text{distance}_{\text{(ft.)}}\} + \{51 * \text{piecenum}\} \\ & + \{12.3 * \text{avepiecesize}^{0.6}\text{(cu.ft.)}\} - \{130 * \text{Train}_{(0,1)}\}\end{aligned} \tag{3}$$

Average piece size has an exponent because even though productivity increases with an increase in average piece size, the relationship is not linear .The exponent value was determined through a statistical iterative process. The model indicates that the inhaul phase was reduced by 1.3 minutes on average, and that both average piece size and number of pieces influenced the overall time.

3.3.4 Productivity Model

The following overall productivity model was developed for the total data set:

$$\begin{aligned}\text{Productivity}_{\text{(cu.ft/PMH)}} = \; & -667 - \{0.70 * \text{distance}_{\text{(ft.)}}\} + 396 * \text{piecenum} + \\ & (109 * \text{avepiecesize}^{0.6}_{\text{(cu.ft.)}}) + \{218 * \text{Train}_{(0,1)}\}\end{aligned} \tag{4}$$

The r^2 for the model was determined to be 0.70, p-value for Train is 0.062, while the p-value for all other variables is less than 0.002.

Figure 4 shows the productivity function based on average piece size. For the average conditions in this study, distance traveled is 400 feet and the average piece size is 54 cu.ft, the productivity before training was 834.4 cu.ft/PMH and this was increased to 1052.2 cu.ft/PMH through the training effect. A significant increase in average number of pieces per turn of 1.3 to 1.7 was also noted.

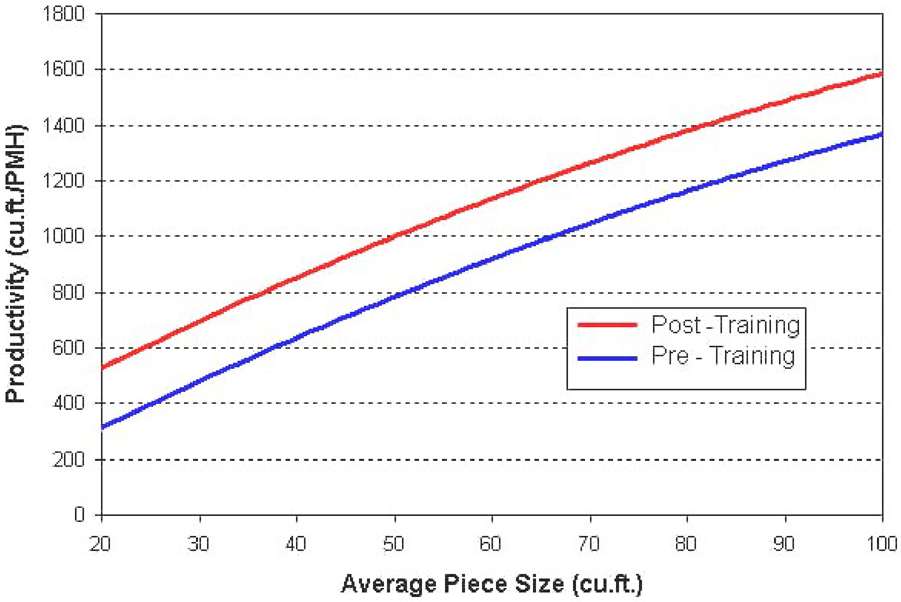


Figure 4: Productivity model based on average piece size for an extraction distance of 400ft. meters and 1.5 pieces per turn.

3.3.5 Recovery of the Cost of Training

Using cost estimates it was possible to calculate the payback period for professional training. The overall cost for the week-long training period was estimated to be $7500 ($500/trainer/day plus expenses).

The total improvement in productivity was calculated to be 217.8 cu.ft/PMH$_0$. Assuming a self-taught improvement of 8 percent over the six-week period between the pre and post time studies, and an average of 5 productive yarder hours in a workday and a log green weight is 65 pounds/cu.ft, the contractor could increase their production by at least 1.4 truckloads per day by initiating a training program. At typical logging rates, and as an indicator only, it would take three working weeks to recover the cost of training.

Training minimized set-up times and line-shifts (both operational delays), however in this case study delay time was not included. It is expected that this improvement in delay-time management would have a significant impact on improving productivity of this system. Due to time limitations, the impact of this training effect has not been examined. A more comprehensive study that includes delay time is likely to show that training has a greater influence on operator performance than this study on productive time only suggests. The random and highly variable nature of the operational and mechanical delay indicates that at least 30 days of data capture, both pre and post training would be necessary to give more meaningful results.

3.4 ON SITE OBSERVATIONS

The following list is intended to provide an overview of activities observed that hinder the efficiency or professionalism of the operation. These issues can be considered not uncommon for many of the new operations in the Appalachian region.

3.4.1 Pre - Training Observations

- Poor directional felling resulting in excessive timber breakage and hook up time. The directive was given to fell the trees as quickly as possible (Figure 5).
- Trees standing in the yarder-corridor impeded the smooth operation of the carriage operation.
- Need for infield merchandizing/log-making skills to optimize payload and improve value recovery.
- The loader position on the log deck should have been placed on the side where the truck comes in. Poor positioning prevented the yarder from working while the truck was being loaded (Figure 6).
- Excessive waste material on the landing caused operational delays for both the yarder and the waiting truck.
- Control of the haulback and mainline needed improvement to avoid overshooting the target area and dynamic loading of the mainline.

- The extraction corridor needed to be cleared of all small (un-merchantable) trees. Trees left in the corridor impeded carriage movement.
- The use of a tail spar would improve ground clearance near the end of the skyline and reduce soil disturbance.
- Unhooking under the skyline before the carriage comes to a complete halt, or working under the skyline while the carriage is in motion, is a safety concern and caused a near miss incident.

Figure 5: A stump indicating poor felling technique. No felling hinge technique was applied making the motor-manual felling operation hazardous not only to the sawyer, but also to those in close proximity.

Figure 6: Poor location of the loader resulting in operational delays when loading the truck

3.4.2 Post Training Observations

- Directional felling and delimbing was of a higher quality and led to a quicker hook-up time and less waste on the landing.
- The yarding corridor was cleared of trees, improving the movement of the carriage in an carriage out phases of the yarding cycle.
- Improved ability to operate the control levers in the yarder resulted in reduced carriage out time.
- Ability to increase the payload through greater confidence in system capabilities.
- Ability to manipulate the haulback line to increase break-out options.
- Landing was kept clear of waste and the chute area was also improved so that logs could be easily un-hooked.
- New techniques learned for line-shifts greatly reduced the operational delay time. Line shifts were being completed in 30 minutes.
- Poor advanced planning (logger given new tract less than one week before he was expected to start) meant the contractor had to spend 30 bulldozer hours pushing roads for this poorly accessible tract before he could pull his first load.

3.5 SUMMARY COMMENT ON THE LEARN-CURVE EFFECT

The promotion of cable-yarding in the Appalachians relies on the ability of new logging contractors to be successful over a long period of time. The lack of operations in the region in the last decade means that few skilled operators are available to either work with or train new crew-members. The Pacific Northwest has a higher concentration of skilled trainers who are able to travel to the southern Appalachian region and provide cable-yarding expertise. While the initial cost of training appears prohibitive, this study shows that training increases productivity and that training costs associated with can be quickly recovered through the increased productivity.

The study did not analyse the various operational and mechanical delays associated with cable yarding. The training effect is expected to have a significant influence on this time element, especially line shifts and set-up times. However a study on delays requires months of data capture. The improvement through training that is captured by this productive time only study underestimates therefore the overall training benefit. Future research on this topic should include a control yarder (no training) operation that is similar, so that a better understanding of the ‘self-taught’ learn effect can be quantified more accurately.

CHAPTER 4 BURNS' CREEK PRODUCTIVITY STUDY

4.1 BACKGROUND

Changing political and public concerns require new methods of managing forestlands. The US. Forest Service, which manages its' land for multiple objectives, is investigating ways to harvest or manage public timber stands in order to meet multi-criteria demands.

Suggestions have been made for changing Forest Service policy to address timber program issues (Liggett *et al*. 1995). One recommendation involves revising the Forest Service's production processes towards European systems to sell cut logs instead of standing timber, or, conversely to allow private contractors to perform more timber sale and harvest activities. Unlike private enterprise, the Forest Service has limited authority to set their own budgets or to reorganize operations (Liggett *et al*. 1995).

The Burns' Creek pilot project incorporated multiple land stewardship goals within an integrated contract. Contract logging, road construction and stream habitat improvement were combined into one contract (USDA Forest Service, 2001b). Public Law 105-277, Section 347 allowed for the authorization of the goods for services trade-off (the logging/restoration contractor exchanged a part of his services) in Burns' Creek that could not have been treated otherwise (USDA, 2002).

One of the components of this complementary timber sale instrument is that a third-party evaluation of the contract logging stewardship pilot project is legally mandated by the US congress (USDA, 2002). It is within this context that the following study was developed and evaluated.

4.2 INTRODUCTION

The three main objectives of the Burns' creek stewardship contracting pilot project third-party evaluation were:

- To determine an average productivity and cost of the manual falling, skidding and yarder extraction operations.

- To determine an average productivity and cost of a stream habitat treatment, and
- To identify the benefits and opportunities of roadside log sales.

4.2.1 Harvesting System Description

Johnny Hillman Logging Company began harvesting three units located in the Burns' Creek headwaters, Clinch Valley Ranger District, Virginia, at the beginning of September 2001. The use of a cable-yarder to extract the timber and deposit lime for steam habitat improvement was prescribed to avoid access road construction. The main economic benefits for using such a system is that it enables harvesting without the initial estimated $17,000 investment in road construction (Appendix A) and subsequent road maintenance expenses. The environmental impact for this operation was minimized, as a major source of erosion; roads (Anderson and Potts, 1987) were not introduced to this steep terrain area.

Standing trees on 32 acres were felled and skidded to one of three swing landings (Figure 7). The topped and partially delimbed stems were then yarded with a *Thunderbird*™ *TMY45* across the valley through a yarding corridor to a full service landing. All three yarding corridors were downhill and required a haulback line to be rigged (Figure 8). The stems were merchandized at the full service cable landing by the contractor using a CAT 320B shovel excavator with a Hultdins 32 inch grapple saw (Figure 9). Two Forest Service personnel used a market driven saw log decision matrix (Appendix B) to merchandize and mark the timber for bucking at this landing (Figure 10).

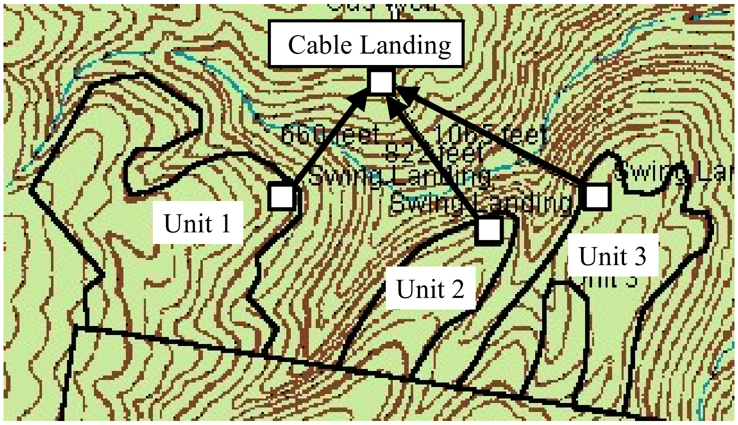


Figure 7: A topographic representation of the three harvesting units. The local of the swing landings are shown above.

Figure 8: Skyline corridor as viewed from the swing landing at Unit three.

Figure 9: CAT 320B shovel excavator with a Hultdins 32-inch grapple saw at the main cable landing

Figure 10: Forest Service personnel marking the merchandized logs at the main cable landing.

Daily tally sheets were kept with information on the species, log dimensions and product grade. At the end of each day the log ends were painted with a wax log seal to prevent decay. Five saw log grades were used to separate the log piles and were based on the log-making decision matrix the Forest Service designed using consuming mill input (Appendix B):

1. Pure Red Oak saw logs;
2. Pure White Oak and Chestnut Oak saw logs;
3. Red Oak, White Oak, Chestnut Oak Yellow Poplar, Cucumber and other hardwood logs;
4. Yellow Poplar and Cucumber peeler logs;
5. Red Oak, White Oak and other hardwood railroad tie logs.

Trading goods for services was authorized for this project through the stewardship pilot process. Small roundwood (pulpwood) was removed and sold by the contract logger, Johnny Hillman Logging (USDA, 2002), to offset the overall harvesting cost to the Forest Service

Due to the nature of the operation and the sale mechanism employed, the landing had to be made substantially larger to facilitate the storage of the respective log piles. The landing also had to accommodate the pulpwood trucks that were loaded twice a day on average throughout the duration of the operation. This removal of pulpwood inventory from the landing allowed for less overall storage space because there was no accumulation of this product on the landing. The cost of constructing the landing was estimated at $1,400 (Appendix A).

4.3 LOGGING PRODUCTIVITY STUDY METHODOLOGY

The objective of this study was to determine an average productivity and cost of the manual falling, skidding and yarder extraction operations. To do this a basic elemental time study of the felling, skidding and yarding was carried out using *Husky*™ FS/GS handheld computers running *Siwork3*™ software, and then using this information machine costs were developed.

4.3.1 Volume Measurement

The large-end diameter (LED), small-end diameter (SED) and length of the logs were measured using a caliper and logger's tape. Using Smalian's Cubic formula (Avery and Burkhart, 1994) the volume of these logs was calculated. This accurate estimation was conducted separately for the felling (60 trees), the skidding (30 trees) and the yarding (120 trees) operations. Using this information, a linear regression model (5) was created for all three sets of data.

$$\text{Volume} = \{x_1 * \text{LED}^2\} + \{x_2 * \text{Length}\} + C \tag{5}$$

During the actual productivity studies of the three different operations, only the LED and the length were measured, if it did not impede productivity or compromise safety. Using the above mentioned regression models, the volumes of the logs produced by the respective operations were estimated.

4.3.2 Case Study Elements of the Manual Felling Operation

Motor-manual felling was used in this operation. The procedure that was employed involved felling a group of trees, then de-limbing and topping the group. To account for this harvesting technique in the case study, a cycle was defined as the total time within which all the above-mentioned elements were completed for all the trees felled as a group selected group.

Table 2: Description of the individual physical parameters and time elements used in the felling operation.

Type	Name		Description	Unit
Dependant-Variables	cycle	-	total cycle time for one felling cycle. Productive Man Hours	0.01 min.
	fellvol	-	total volume felled for a single cycle	cu.ft
	$\text{Prod}_{\text{fell}}$	-	(fellvol/cycle)*60	cu.ft./PMH_0
Co-Variables	Slope	-	gradient	%
	Avgpiecesize	-	average piece volume based on large end diameter (LED) and the length estimate of each stem in the turn	cu.ft
	Piecenum	-	number of trees per cycle	n
Times	move to tree	-	time required for the sawyer to walk to the tree	0.01 min.
	fell	-	time required to fell the tree	0.01 min.
	top and delimb	-	time taken to top and delimb the trees prior to extraction	0.01 min.
	delay	-	unproductive time	0.01 min.

4.3.3 Productivity Elements of the Skidding Operation

A *John Deere 540E* skidder was employed in the ground-based extraction operation. One operational cycle for the cable skidder operation included: the hooking of a load of tree stems by the butt-end, winching the load to the skidder and driving the skidder to the swing landing where the load was unhooked. The total cycle time and total turn volume was combined to calculate delay-free productivity.

Table 3: Description of the individual physical parameters and time elements used in the skidding operation.

Type	Name		Description	Unit
Dependant- Variables	cycle	-	total cycle time for one turn. Productive Man Hours	0.01 min.
	loadvol	-	total payload for a single skidder cycle	cu.ft
	$\text{Prod}_{\text{skid}}$	-	(loadvol/cycle)*60	cu.ft./PMH_0
Co-Variables	Distance	-	skidding distance	ft.
	Avgpiecesize	-	average piece volume based on large end diameter (LED) and the length estimate of each stem in the turn	cu.ft
	Piecenum	-	number of trees per cycle	n
Times	Travel empty	-	time required for the empty skidder to travel from the swing- landing to the felled trees	0.01 min.
	hook	-	time required for the skidder operator to choke the logs and pull them into the skidder's apron	0.01 min.
	travel loaded	-	time required for the loaded skidder to travel back to the swing landing	0.01 min.
	unhook	-	time required for the chokerman to unhook the logs	0.01 min
	delay	-	unproductive time	0.01 min.

4.3.4 Productivity Elements of the Yarding Operation

A *Thunderbird™ TMY45* yarder with an *Acme™ 100* motorized slack-pulling carriage was utilized in the cable extraction operation. One operational cycle for the cable-yarder operation included: the hooking of a load of tree stems by the butt-end to the mainline running through the carriage at the swing landing and downhill yarding the load to the full-service landing where the load was unhooked. The total cycle time and total turn volume was combined to calculate delay-free productivity.

Table 4: Description of the individual physical parameters and time elements used in the yarding operation.

Type	Name		Description	Unit
Dependant-Variables	cycle	-	total cycle time for one turn. Productive Man Hours	0.01 min.
	loadvol	-	total volume felled for a single cycle	cu.ft
	$\text{Prod}_{\text{yard}}$	-	(loadvol/cycle)*60	cu.ft./PMH_0
Co-Variables	Distance	-	yarding distance	ft.
	Avgpiecesize	-	average piece volume based on large end diameter (LED) and the length estimate of each stem in the turn	cu.ft
	Piecenum	-	number of trees per cycle	n
	Brake	-	block factor; 0 = no brake, 1 = brake applied	
Times	Travel empty	-	time required for the empty carriage to travel from the landing to the choker-setter	0.01 min.
	hook	-	time required for the slack to be pulled from the carriage, the choker-setter to hook the load and the load to reach the carriage	0.01 min.
	travel loaded	-	time required for the loaded carriage to travel to the landing	0.01 min.
	unhook	-	time required to release the chokers from the load and return them to the carriage	0.01 min
	delay	-	unproductive time	0.01 min.

4.4 LOGGING PRODUCTIVITY RESULTS

4.4.1 Manual Felling Operation Case Study Results

A total of 21 cycles were captured from unit one. The observed average productivity for this operation was 1692 cu.ft. per productive man-hour. The total delay time for this operation accounted for 52 percent of the total work time (Figure 11). Mechanical delay was 4 percent of the total work time. The operational delay accounted for the rest of the delay time and comprised predominately of operator rest periods. A small portion of this time the sawyer spent helping the skidder operator set the chokers.

By combining the above data with the timed production elements the average productivity per scheduled man-hour for this operation was 812 cu.ft. The sawyer had and operational delay 48 percent of the time, and this is acceptable for a motor-manual operation (Figure 11).

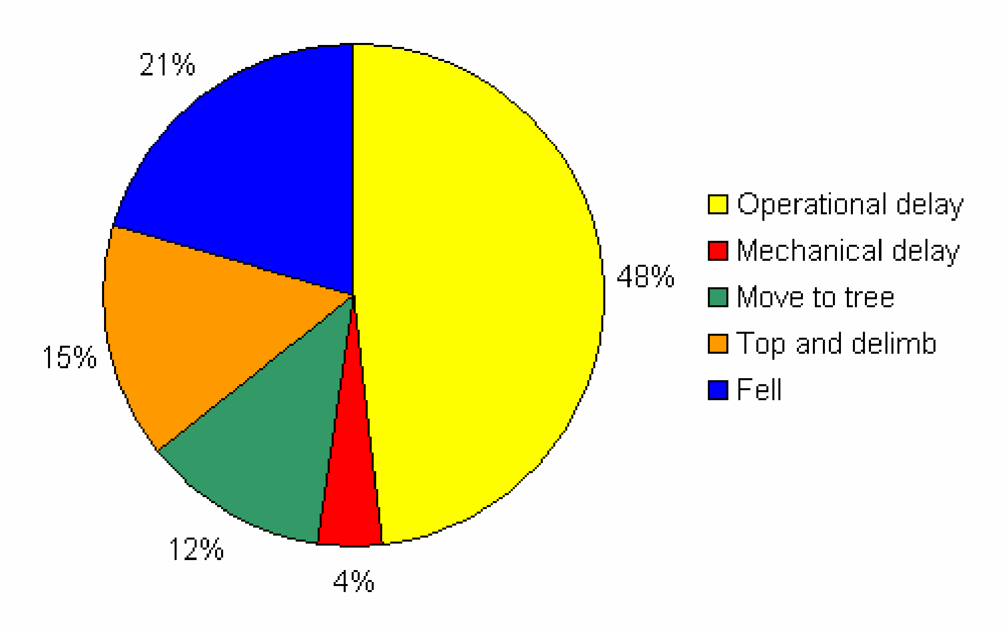


Figure 11: Percentage of time spent on each operational felling element.

Only 21 cycles were captured for this manual felling operation, a power function was used to develop a trend line in Figure 12 and is described by equation (6).

$$\text{Productivity}_{\text{(cu.ft./PMH)}} = 1040 * \{\text{piecenum}\}^{0.26} \tag{6}$$

Using this equation, *piecenum* accounts for 30 percent of the variability in productivity (r^2 is 0.30) (Figure 12). This equation leads to the observation that the sawyer's productivity increases with an increase in the number of trees cut per cycle. A comprehensive time study focusing on the productivity of a manual felling operation may validate this initial finding, however due to the small number of observations validation is inconclusive. The estimated total cost for this felling operation, based on the average production per scheduled man-hour was calculated as $5.54 per one hundred cubic feet (ccf or cunit) (Appendix C).

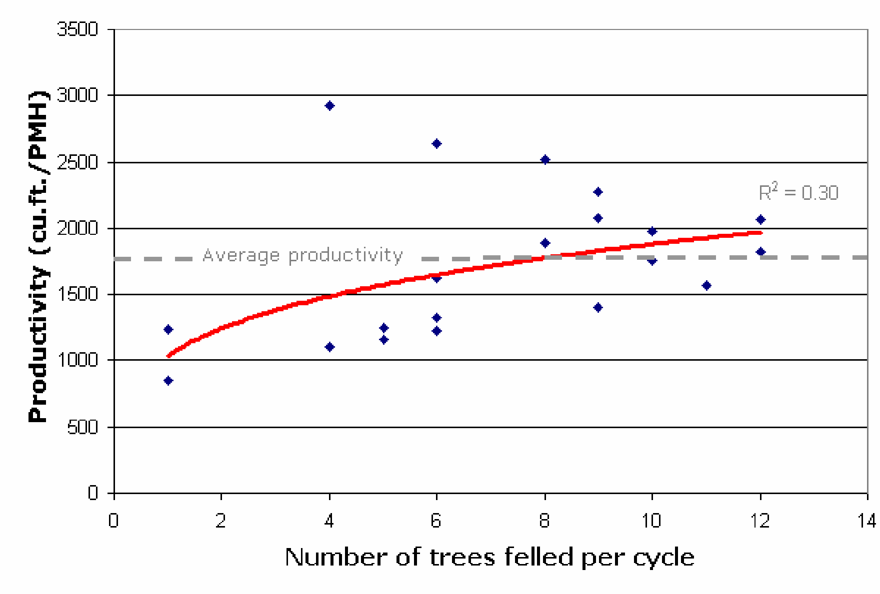


Figure 12: Sawyer productivity versus number of trees felled per cycle.

4.4.2 Skidding Operation Productivity Study Results

A total of 31 cycles were captured from unit three. The observed average productivity for this elemental time study was 850 cu.ft. per productive machine hour (based on: average piece size = 42 cu.ft.; average skidding distance = 630 feet; average number of pieces = 3). The total delay time accounted for 38 percent of the total time, therefore the average productivity was 527 cu.ft. per scheduled machine hour. Using this equation (7):

$$\text{Productivity}_{\text{(cu.ft./PMH)}} = -475.3 + (90.0 * \text{avgpiecesize}^{0.6}{}_{\text{(cu.ft.)}}) + (278.5 * \text{piecenum}) - (0.6 * \text{distance (ft.)}) \qquad \mathbf{(7)}$$

The variables: *avgpiecesize*$^{0.6}$, *piecenum* and *distance* account for 68% of the variability in productivity ($r^2 = 0.68$, p-value for average piece size = 0.010, while all the other variables < 0.000) (Figure 13). The above linear regression model explains the effect of distance on the skidding operation; the longer the lead distance, the lower the predicted productivity.

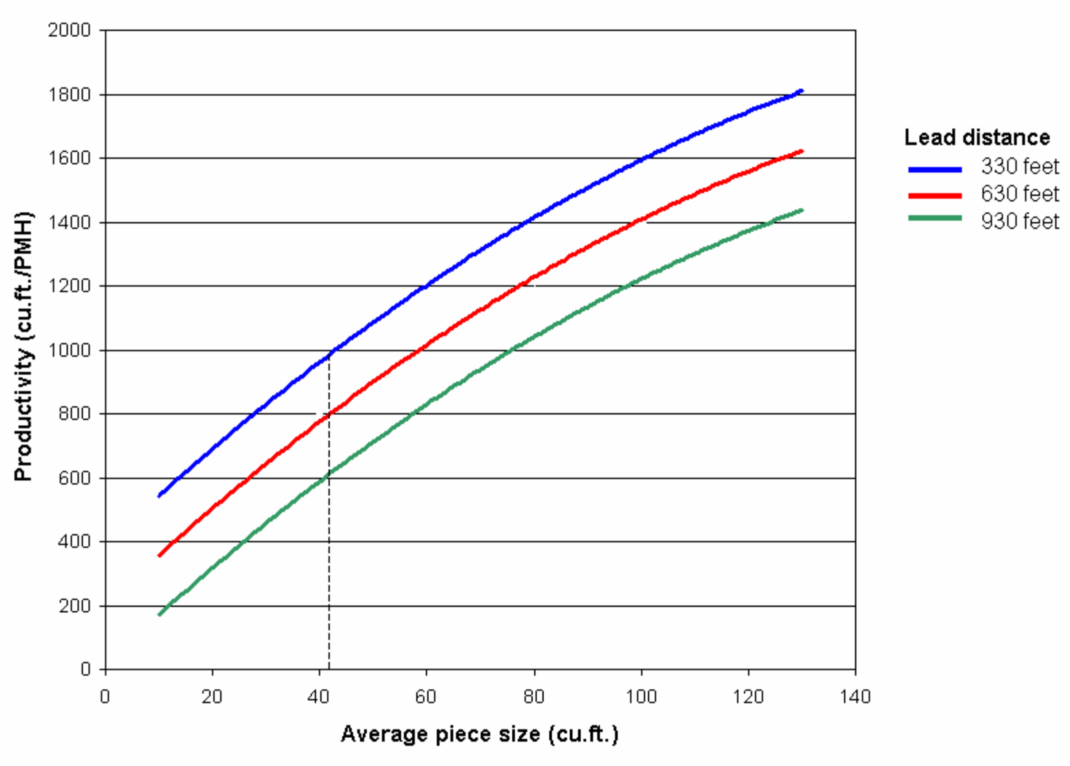


Figure 13: Skidder productivity model based on average piece size for an extraction distance of 330, 630 and 930 feet and 3 pieces per turn.

Within this productivity model there are several outliers (indicated by the gray circles, Figure 14). However, it can be reasoned that the points above the dotted line are influenced by a high travel loaded time and the points below the line are influenced by an exceptionally short hook time.

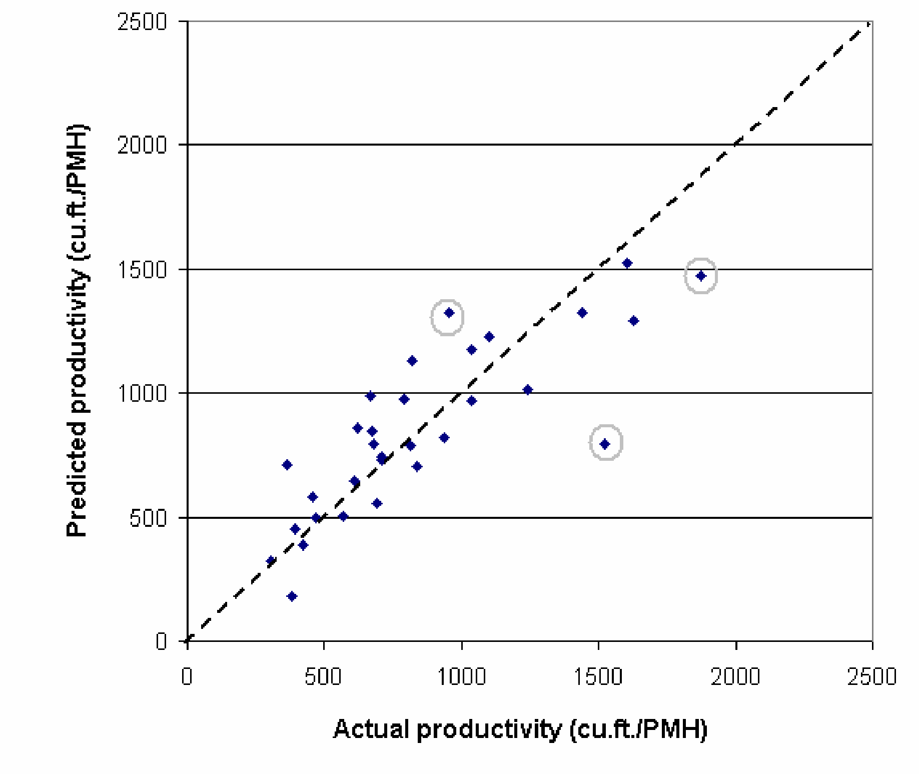


Figure 14: Predicted cu.ft. per productive machine hour versus the actual cu.ft. per productive machine hour

The estimated total cost for this skidding operation, based on the average production per scheduled machine hour was calculated at $13.03/ccf (Appendix D). An important component of this cost calculation and the others that follow, was that the labor rates were based on average labor rates of several states as defined by the Forest Service *Logcost 4.0 Excel*™ spreadsheet (USDA, 2001a). Labor fringe benefits were also included.

Kluender and Stokes (1994) were used for this comparison because the engine capacity of the cable skidders, age of the technology (1994 skidder was used in the Burns' Creek study) and slope were similar in both studies. Relative to the study by Kluender and Stokes (1994), the skidding operation was very productive, however this can be attributed to the large average piece size and average turn volume (Table 6).

The whole swing landing system worked well according to design, however the 'bottle-neck' in the system was the skidding operation. A newer, more reliable cable-skidder would have improved the productivity of this harvesting operation.

Table 6: A comparison of two cable skidding time study data.

	Kluender and Stokes, 1994	Burns' Creek
Skidder horsepower	120	119
Species	Southern Pine	Hardwood
Slope (%)	5-10	12-15
Number of Observations	34	31
Travel empty time (min.)	3.03	2.44
Travel loaded time (min.)	2.86	3.13
Position time (min.)	0.64	n.a.[1]
Hook time (min.)	2.87	3.60
Unhook time (min.)	0.50	1.00
Total Time (min.)	9.90	10.17
Travel empty distance (ft.)	982	635
Travel loaded distance (ft.)	881	635
Intermediate/position 9ft.)	11	n.a.[2]
Total distance (ft.)	1874	1270
Volume/turn (cu.ft.)	76.7	**85.0**
Stems (number)	3.6	3.2
Average piece size (cu.ft.)	21.3	**26.6**
Productivity (ccf/hr)	4.40	5.27

[1] position time was incorporated into the travel loaded time element

[2] intermediate/position distance was incorporated into both the travel loaded and travel empty distances.

4.4.3 Yarding Operation Productivity Study Results

A total of 186 cycles were captured, 89 cycles from unit one, 57 cycles from unit two and 40 cycles from unit three. The average observed productivity for this downhill yarding operation was 868 cu.ft. per productive machine hour (based on: average piece size = 49 cu.ft.; average yarding distance = 863 feet; average number of pieces = 2). The total delay time, which accounted for 33 percent of the total work time during the study, was not used for the productive time evaluation. Mechanical delay accounted for 6 percent of the total work time.

Total delay time accounted for 33 percent of the time, so the average productivity was 581 cu.ft. per scheduled machine hour. The cycle time data of all three units were used to develop this model. Using this equation (8), the variables: $avgpiecesize^{0.6}$, *piecenum*, distance and brake factor account for 71% of the variability in productivity (r^2 is 0.71 p-value for distance is 0.321 while all the other variables were less than 0.000).

$$\text{Productivity}_{(\text{cu.ft./PMH})} = -587.9 + \{87.7 * \text{avgpiecesize}^{0.6}{}_{(\text{cu.ft.})}\} + \{305.9 * \text{piecenum}\} - (0.05 * \text{distance}_{(\text{ft.})}) - 275.5 * \text{brake}_{(0,1)} \quad \textbf{(8)}$$

It should be noted that for equation (6) if the haulback drum-brake is engaged to slow the carriage on the inhaul phase, then the value of one is used for the brake variable. If the operator does not use the braking system then zero is used for the brake variable (Figure 15).

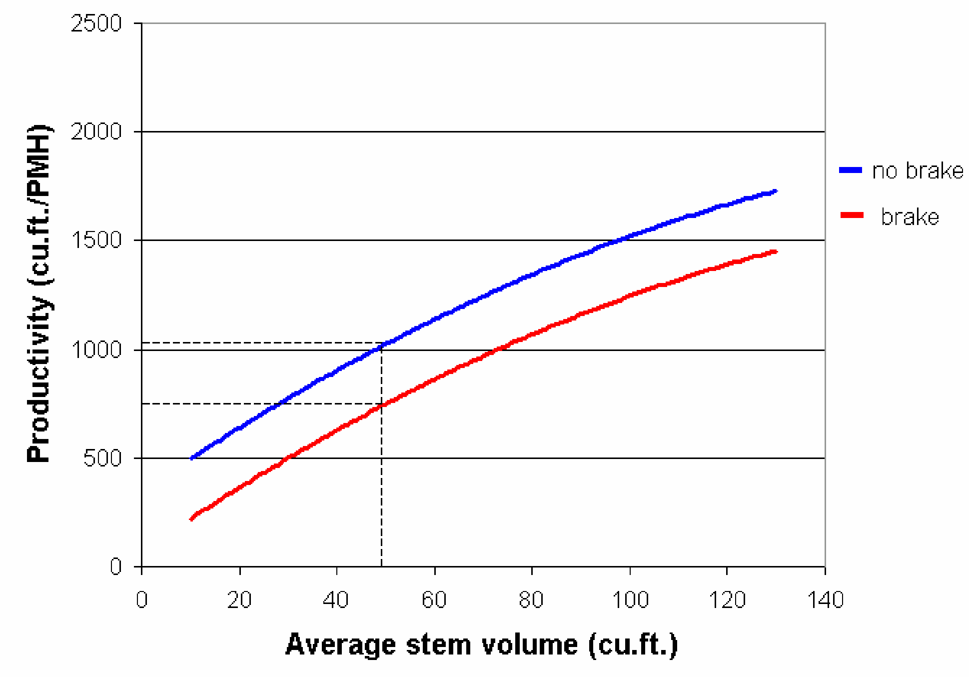


Figure 15: Yarder productivity model based on average piece size for an average extraction distance of 840 feet and an average of 2.45 pieces per turn.

Within this productivity model there are several outliers (indicated by the gray circles in Figure 16). They can be explained by a high piece size and a high number of pieces relative to the rest of the time study sample population.

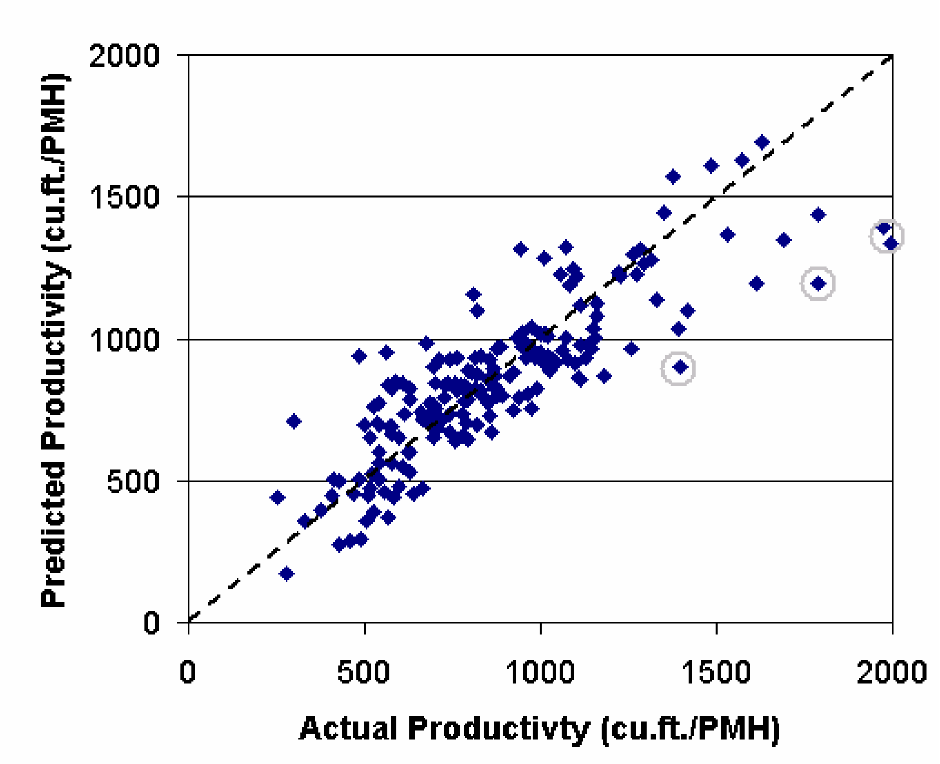


Figure 16: Predicted cu.ft. per productive machine hour versus the actual cu.ft. per productive machine hour.

The estimated total cost for this yarding operation, based on average productivity per scheduled machine hour, is $33.11/ccf (Appendix E). An explanation for the low relative cost can be shown through the nature of the operation measured. This operation was primarily yarding pre-bunched tree-lengths from a fixed point (swing landing), thereby improving the operational efficiency of the operation as the lead distance to which the carriage was pulled from was constant and the choker-setter had a more uniform terrain to work on.

The difference between the Burns' Creek yarder operation and Huyler and LeDoux (1997) uphill cable-yarder study (Table 7) is the short hook-up times on this operation due to the use of a swing landing system and the outhaul element is slower due to the use of a haul-back line. The swing landing allows for a more consistent payload, which allows for a more efficient operation. The other operations presented in the table also demonstrate these differences, but the differences are less apparent due different operational factors.

Table 7: Average delay-free yarder cycle times (in minutes) from studies of five separate cable yarding systems

	Sherar *et al.* (1986)	Biller and Fisher (1984)	Huyler and LeDoux (1997)	Visser and Stampfer (1998)	Burns' Creek Yarding operation (2001)
Outhaul	1.32[1]	0.52	0.43	0.31	**1.41**
Hook	1.75	2.25	2.22	1.50	**1.27**
Inhaul	2.15	1.77	2.70	1.19[3]	2.97
Unhook	0.47	0.96	n.a[2]	0.64	0.70
Total Cycle time	4.99	5.50	5.35	3.65	6.36

[1] This operation used a swing yarder. The swinging phase added to carriage out and carriage in times.

[2] Unhooking time is contained in the "inhaul" time

[3] A portion of this is waiting for the yarder operator to finish loading before pulling the logs to the landing.

4.5 STREAM HABITAT TREATMENT

As a part of the Forest Service's multiple-use objective, the Forest Service was concerned with improving of fish habitat within and downstream of this harvest operation. This area of southwestern Virginia has naturally acidic water systems. To improve the water quality for fish habitat, the Forest Service prescribed the addition of lime to the headwaters of the Burns' Creek watershed.

A two-ton capacity concrete bucket was attached to the carriage. The lime was placed in front of the yarder tower with a dump truck. A backhoe was then used to load the bucket (Figure 17) choker setters were used to open the faucet of the cement bucket directly over the 'target' zone for the lime placement (Figure 18).

The opportunity to use the cable-yarder to transport the lime was initiated because the Forest Service was also planning a silvicultural prescription for the same tract of land. This was beneficial for two reasons: no extra costs for helicopter placement of the lime and no change in the set up of the yarder, except for the addition of a bucket.

Figure 17: Tractor-mounted backhoe loading the bucket with lime.

Figure 18: Two chokermen line up the bucket before opening the faucet in order to place the lime

4.5.1 Stream Habitat Treatment Productivity Study Methodology

The objective of this study was to determine the average operation productivity and cost of a steam habitat treatment. An elemental time study of the lime placement yarding operation was carried out using *Husky*™ FS/GS handheld computers running *Siwork3*™ software (Table 8). This productivity information was used to develop machine costs.

Elements of the Steam Habitat Treament Operation

Total cycle time and total turn volume was combined to calculate delay-free productivity. The volume per cycle was determined by the amount of lime that was initially placed in front of the yarder tower. All cycles had full bucket loads, so the assumption that each load had the same weight was made.

Table 8: Description of the individual physical parameters and time elements used in the lime operation.

Type	Name		Description	Unit
Dependant- Variables	cycle	-	total cycle time for one turn. Productive Man Hours	0.01 min.
	loadwt	-	total payload for a single yarder cycle	cu.ft
	$\text{Prod}_{\text{lime}}$	-	(loadvol/cycle)*60	cu.ft./PMH_0
Co-Variables	Distance	-	yarding distance	ft.
	Avgwt	-	average weight of the loaded lime	tons
Times	load bucket	-	time required to load the bucket with the backhoe	0.01 min.
	outhaul loaded	-	time required to haul the bucket to Burns' Creek	0.01 min.
	unload bucket	-	time required to lower the bucket and place the lime into the creek	0.01 min.
	inhaul empty	-	time required to haul the bucket from the placement zone	0.01 min
	delay	-	unproductive time	0.01 min.

4.5.2 Stream Habitat Treatment Results

A total of 11 cycles were captured. The average productivity measured for the lime placement study was 6.21 tons per productive machine hour. The delay time accounted for 6 percent of the total time over the short period that this operation was studied. As the 21 tons of lime became depleted over time, the bucket loading time increased notably (Figure 19). The average loading time per cycle was 5 minutes 41 seconds compared to the final loading time of 11 minutes 13 seconds.

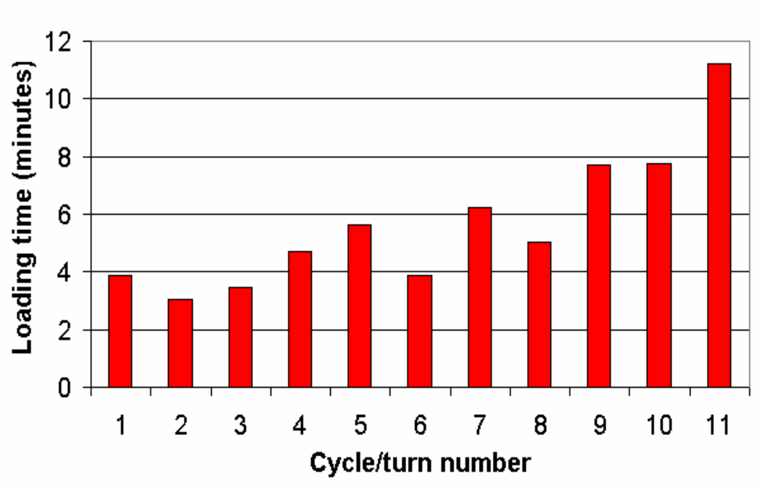


Figure 19: The amount of time required to load the bucket per cycle with the tractor-mounted backhoe.

During this part of the study, the yarder had a mechanical availability of 94 percent. This results in a cost of $33.83 per ton of lime placed in the stream. This costing excludes all yarder set-up times and mechanical, operational and social delays. Typical availability of the mounted backhoe and the bucket was not included in the costing exercise.

The cost of the lime, tractor mounted backhoe and the bucket was not included in the costing exercise. Typically availability is 60 percent, in which case the estimated total cost for this operation, based on the average production per scheduled machine hour was $52.99/ton (Appendix F).

4.5.3 Discussion on Stream Habitat Treatment

The logging/restoration contractor was only remunerated on the volume of timber harvested from the three units. The added responsibility of the lime placement operation was facilitated through the authority of exchange of goods for services (Public Law 105-277; H.R. 4328; Section 347), where the contractor exchanged the lime placement services for the pulpwood logged on the project (USDA, 2001). Through this legal mechanism, the Forest Service was able to lime Burns' creek and treat the timber stands in one operation. The use of an integrated contract allowed for a more efficient and timely stewardship treatment to the project area.

4.6 COMPARISON OF TIMBER SALE METHODS

For the Burns' Creek timber sale, the Forest Service decided to sell the high-grade bucked logs at the full service yarder landing to targeted markets, as opposed to selling stumpage.

A 'stumpage sale', common in the southeastern United States forestry industry, involves trees that are sold standing. The forest owner finds an end-user for the logs and then contracts the trees to be cut and transported. In most instances the end-user bids on a tract of standing timber and then sub-contracts the harvesting of the standing timber. The end-user has final say as to how and where the standing timber is utilized. A 'hot deck' system at the landing is primarily used; the timber is extracted and merchandized just before it is loaded and hauled to a mill.

In a 'roadside' log sale the landowner takes over the responsibility of contracting the services of the harvesting crew. The landowner, represented by the Forest Service in this project, decides how the standing timber is merchandised, under the premise that they can maximize the value of the timber being harvested by making many products available to a varied market. A 'cold deck' system is used and the logs are stored until the harvesting is completed. They are then put on sale to the end-user, who bids on this value-added product. The opportunity to merchandize and add-value to the timber products is captured by the landowner.

The 'roadside' log sale approach as mentioned by Liggett *et al*. (1995) is designed to achieve a 'working environment' where the contractor/logger provides a service that meets the public service regulatory needs. Simultaneously, they are ensuring fiscal efficiency is maximized throughout this facet of the operational management process. Therefore, the log buyer for a 'log sale' and contractor, this system has the following benefits:

- not having to pay a lump sum up front,
- simple haul only and
- supervision of harvesting is unnecessary.

4.6.1 Telephone Survey

Telephone interviews were conducted with four Appalachian hardwood lumber companies during the first week of February 2002. Three of the companies were participants in the Burns' Creek log sale and were involved with the sealed-bid sale that took place on January 10, 2002 (Appendix G). The fourth company had an interest in this sale mechanism and agreed to participate in the interview. Comments of each interview were then summarized.

Advantages of the log sale as perceived by the consuming mills:

- Products are pre-sorted on site.
- Smaller volumes, may allow smaller timber consumers accessibility to products lower down the supply chain at a lower cost.
- Allows the consuming mill to purchase specific products and avoid other products.
- The guesswork involved in estimating volume and quality was minimized because the actual quantity and quality of the logs was visible.
- The purchasing mill improved their cash-flow because the throughput-time component of the procurement operation was reduced from the usual three week to two months to three days.
- The purchasing mill incurred no logging liabilities; the logging responsibility is placed solely on the landowner and contractor.
- There were no supervision overhead costs incurred by the purchasing mill for the harvesting and merchandising operation.
- The sales as an opportunity to improve inventory levels in a short amount of time. (This is dependant on the status of the timber purchasing and lumber markets at the time of the sale).

Disadvantages of the log sale, as perceived by the consuming mills:

- Less flexibility in the ability to customize the merchandizing process to their needs.

- Some high-grade logs were not merchandized to quality requirements and some errors were made in bucking the logs. The consuming mills felt they had lost an opportunity in this primary raw material market.
- The consuming mills would have preferred longer saw logs so they could capture the high-end log markets.
- On this specific sale the logs sat for too long (October 2001 to January 2002). High temperatures caused sap staining of the high-grade red oak and white oak logs.
- Logs at the bottom of the pile were difficult to examine at the time of the sale, and was compounded by 14 inches of snow covering the log piles on the day of the sale.
- The time differential between the design and implementation of the merchandizing decision matrix needs to be shortened. By the time of the log sale, the market, for which the decision matrix was designed, had changed, causing the consuming mills to lose opportunity that the current market presented.

4.6.2 Discussion on the Log Sale

The log sale was well received by the industry as an alternative to the stumpage sale. According to the consuming mills interviewed, the sale was a success and the potential value of the timber was realized.

The need for comprehensive planning and execution will be critical, especially if this type of sale is to be implemented by private landowners. From the perspective of the Forest Service this type of sale does provide an alternative means for them to market timber. For example, this specific Burns' Creek Sale had been presented as a stumpage sale on two separate occasions and attracted no buyers. The log sale mechanism allows the Forest Service to treat areas that it could not with traditional methods.

Log sales are dependent on the site and quality of standing timber. The need for a large landing to display the log inventory over long periods of time is paramount to the execution of the sale. The sale of high quality logs can be maximized from this type of sale. However, there is an opportunity to auction superior logs on an individual basis which should be pursued.

CHAPTER 5 VALUE RECOVERY

5.1 INTRODUCTION

During the months of June and July of 2002 value recovery data was collected from five Georgia Pacific logging contractor crews in Virginia and West Virginia. Two crews were supplying the Green Valley Georgia-Pacific Corp. Mill, two the Rainelle Georgia-Pacific Corp. Mill and one crew the Richwood Georgia-Pacific Corp. Mill (Table 9).

The objective of this study was to determine the amount of value that was being lost due to poor bucking decisions in southern Appalachian hardwood stands and whether there was a significant difference between the value recovered by the *HW-BUCK*™ (Pickens, 2002) bucking decision optimizer and the actual logs that were made by the five buckers.

Table 9: Bucker operator description.

Bucker	Experience (years)	Loader operated hydraulic bucking saw system	Rack spacing (ft.)	Pre-marking
Green Valley 1	10-15	✓	4	
Green Valley 2	5-10	✓	2	
Rainelle 1	15-20	✓	4	
Rainelle 2	15-20	✓	4	✓
Richwood 1	25 +	✓	4	

5.2 METHODOLOGY

Value recovery data was collected in a similar fashion for all five logging crews. The trees were either skidded to the landing, or to an open area, where the necessary descriptive data about each individual tree was recorded. The descriptive data included the defect data collection and shape data collection. Once this data was collected and the species identified, the tree was assigned an identification number that was sprayed on the butt end and top end of the tree. Post- bucking data was collected at the landing once the log-maker had completed merchandizing the tree.

5.2.1 Defect Data Collection

The parameters used to describe the individual defects are summarized (Table 10) and the data was recorded manually (Appendix P). A fixed reference point (butt-end) was always used when estimating the orientation of a defect, i.e. the clockwise angle was relative to the data recorder working from the butt-end towards the top-end of the tree. Defect codes describing the defects were used (Appendix P)

Table 10: Data parameters for individual defects

Defect	Parameters	Units
Knot, burl, scar	• Distance of defect from tree butt;	ft.
	• Clockwise angle of defect center from the upper surface of the stem;	degrees
	• Defect length;	in.
	• Defect width.	in.
Seam, split	• Distance of start of defect from tree butt;	ft.
	• Clockwise angle of start of defect from the upper surface of the stem;	degrees
	• Distance of end of defect from tree butt;	
	• Clockwise angle of end of defect from upper surface of the stem.	ft. degrees
Fork, bulge	• Distance of start of defect from tree butt;	ft.
	• Distance of end of defect from tree butt.	ft.
Decay, stain, heart	• Distance of start of defect from tree butt;	ft.
	• Distance of end of defect from tree butt;	ft.
	• Defect diameter at start;	in.
	• Defect diameter at end.	in.

5.2.2 Shape Data

The shape data were collected simultaneously with the defect data. Under normal operational conditions the entire tree would have been skidded to the landing, where it would have been topped and broken out into the various products. Due to the quantitative nature of the data, and the need to determine the sweep of the more valuable timber, the trees were topped at 10-12 inches so offset templates could be attached to both ends of the trees.

The offset templates used were wooden semi-discs that had a clearly defined center. Holes were drilled radially at 45-degree intervals, were spaced at one-inch intervals and were clearly numbered. The semi-discs where fixed to the butt and top-ends of each tree so that the centers of the semi-discs lined up with the central axis of the tree and not the pith. The holes in the semi-discs were used as reference points from which the string was attached from one template to another along the bole of the tree. Both a vertical and a horizontal offset reference lines had to be established for every tree measured.

Diameter and sweep measurements were taken at uneven intervals along the tree length. Measurements were taken where one or both of these features abruptly changed, or at 3-4 ft. intervals, whichever was less. Sweep is measure relative to a straight line running from the center of the ends of the tree. Using both the vertical and horizontal offset reference lines, deviations of the tree's central axis from this line was measured. The sweep data points were measured at the same point along the stem where the diameter measurements are taken. The diameter at each interval was measured twice using a caliper, including both large and small diameter measurements where possible.

The methodology used to collect the shape data collection, did not include bark thickness measurements. To remedy the situation an equation (9) (Grosenbuagh, 1974) was utilized:

$$D_{ib} = D_{ob} * (DBH_{ib} / DBH_{ob}) \tag{9}$$

Where: D_{ib} = diameter inside bark

D_{ob} = diameter outside bark

DBH_{ib} = diameter at breast height inside bark

DBH_{ob}= diameter at breast height outside bark

The average DBH_{ib}/ DBH_{ob} ratios Appalachian hardwood species (Martin, 1981) was used to calculate the estimated diameter inside bark and bark thickness was then determined through the use of equation (10). The bark thickness values were used to make the *Shape.bas* files.

$$\text{Bark thickness} = (\text{Observed } D_{ob} - \text{Estimated } D_{ib})/2 \qquad \textbf{(10)}$$

Another more accurate method to determine bark thickness is to measure the bark thickness of the several tree species that are under investigation. Using diameter at breast height (DBH), height, and species as predictor variables and bark thickness as the dependant variable a regression model could be developed for each of the species (Pickens, J.B. <jpickens@mtu.edu> (2002, July 10.)

5.2.3 Post-Bucking Data

Post-bucking data included collecting the identification number, length and SED of each log including cull sections. The position of the log in relation to the tree was also noted. Co-operation of the log-maker in this final phase was critical for the accurate and safe collection of information.

5.2.4 Data preparation

The shape and defect data that was collected was then inputted into the computer using software written in the *QBasic*™ programming language Noble, S.D., <sdnoble@mtu.edu> (2002, July 23) [Personal email]. The *Shape.bas* and *Defect.bas* programs create a 'user-friendly' data-logging interface that allows for the easy creation of shape and defect files that can be read by *HW-BUCK*™ decision simulator.

5.3 HW-BUCK OPTIMIZATION

HW-BUCK™ uses dynamic programming to select the optimal sequence of the bucking decisions. This optimization procedure was driven by the software package *HW-BUCK*™ and can be described as a process whereby all possible combinations of logs and cull sections that can be cut from the tree are evaluated. This evaluation followed by the selection of the sequence of cuts that produces the highest monetary value (Pickens *et al*. 1992).

HW-BUCK™ has been designed with a minimum tolerance distance between possible cuts of 2 inches. The program uses recognized grading rules that account for deductions in sweep, holes, seams, forks and bulges (Timber Prod. Assoc. of Mich. and Wisc., 1988) to simulate manual grading and scaling (Pickens *et al*. 1992).

5.4 SOFTWARE LIMITATIONS

The *HW-BUCK*™ bucking decision simulator was initially designed as a computerized training tool, to help hardwood log buckers improve value recovery. The software package creates an environment whereby the trainee plays the bucking 'game" by observing one of 150 actual hardwood stems, and then selects their bucking cuts. The image includes defects and sweep, and can be rotated to see stem shape and hidden defects. After the trainee has selected cuts, the software presents their results beside the optimal bucking pattern for comparison. This software package also has the flexibility to use different prices and veneer grading rules, as well incorporate trees from the users region (Pickens, 1996).

HW-BUCK™ was initially designed to accommodate tree dimensions that occurred in the Northern hardwood forests of the United States. Because of this, there were some limitations that were experienced when using *HW-BUCK*™ in the southern Appalachian region. The hardwood species grown in this region differ in species composition, grow faster and are generally larger than their Northern hardwood forest counter-parts. A major limitation was that the software could not accommodate tree lengths greater than 50 feet. This problem was overcome in part by evaluating only the high value portion of the tree bole. *HW-BUCK*™ also did not allow for trees with a girth greater than 30-inches, three of the 155 trees that were measured had to be excluded from the *HW-BUCK*™ component of the analysis.

With the larger trees came more defect and shape entries, in a few cases the tree description had to be modified in order for it to be accepted by the optimizer. Only thirty defects per tree were accommodated, and of that only twenty defects represented by ellipses (knots), four as lines (seams), four as interior defect (heart rot and stain) and three as forks or bulges. Only twelve shape entries were accepted by the software package. In order to overcome these limitations for the larger trees, some of the defect and shape inputs were ignored. This strategy applied was to exclude defects that were not as significant; for example a medium bark distortion (one-inch by one-inch) in the latter stages of the tree-bole is no is not as important as a unsound knot (4-inch by 4-inch) in the first sixteen feet of the tree-bole. It was through this process of elimination that the trees were accommodated into the program. When a tree could not be fitted into the software package it was excluded from the sample population. Only other four trees were excluded. From an initial population of 155 trees, 148 were accepted into the program for analysis.

In *HW-BUCK*™ the trimming allowance is set at eight-inches. The trimming allowance used by the consuming mills in this study was four-inches (Appendices I, K and M). The rigor to which this program default is set is less stringent, because the programmers assumed that the consuming mills would accept logs with a two-inch trimming allowance shortfall Pickens, J.B. <jpickens@mtu.edu> (2002, July 29) [Personal email].

The program default in *HW-BUCK*™ allowed for only three veneer and three saw-log grades in eight, ten, twelve, fourteen and sixteen foot log classes. This was limiting to this value recovery study because the log grades used by the consuming mills in this study were more precisely defined using both diameter and length log classes that included more than three saw-log grades. To overcome this problem, the program was setup so that some of the log grades were moved into the programmable veneer log grades. Where log grades could not be accommodated into the value decision matrix, the mean value was used. Fortunately this strategy was only used in the select and mill grade saw-log products that had a very low value, and subsequent low impact on the outcome of the optimization analysis.

Logs with lengths of nine foot and greater than 16 foot were also accepted by the consuming mills but not by *HW-BUCK*™. To overcome this practical problem, the results of the optimization were adjusted to reflect a more true value recovery result. This type of manipulation involved using the price sheets to determine what the value of the log that the bucker was cutting and comparing that to the optimal solution. The optimal solution would break the buckers log into two logs, and the value of those two logs was used in the result achieved by the bucker. This problem presented itself where for example black cherry (*Prunus serotina*) trees were being cut into veneer logs of twenty and twenty-two feet. The optimal solution would make two cuts, one ten-foot log and one twelve-foot log. In the case of the buckers' solution one sixteen-foot veneer log was accounted for. To accommodate this an adjustment needed to be made to truly reflect the value that was recovered by the bucker, because that second cut in the twenty-two foot log would have been made at the wood-yard under more controlled circumstances. Ten percent of the sample population analyzed presented this problem. As for the nine-foot logs the values in the buckers' solution were adjusted, however the optimal solution were not adjusted, as this parameter was not included in the program set-up. The nine foot log length, is an anomaly that the creators of this bucking optimization had difficulty integrating into the code of the program, and felt that because it is such an uncommon log length that it would not be worth while to incorporate at time of its development Pickens, J.B.<jpickens@mtu.edu> (2002, July 12) [Personal email]. It is also not possible in the *DOS* based format to capture the solution image, and this is some-what limiting in the further statistical of the tree-by-tree solution.

In the *Windows*™ version that is being developed at Michigan Tech University, all of the above limitations have been dealt with, except that of the uneven log lengths, and this is because of the computer programming code that has been used in the development of this software package. The new *Windows*™ version of *HW-BUCK*™ is due to be completed by the end of September.

Demand-constraints do play an important role in the southern Appalachian logging environment and the demand for veneer does vary seasonally Loving, M.W. <MWLOVING@GAPAC.com> (2002, July, 12) [Personal email]. The development of a two-stage hardwood optimizer may offer some utility to the consuming mills that work out of the southern Appalachian region. Other issues with regards to the actual defining of veneer parameters within the program need to be addressed, as there are many more constraints that determine a veneer log over and above a prime saw-log. Subjective quality constraints like color; texture, concentricity of growth rings and the amount of heart discoloration vary from hardwood species to hardwood species. For example for Sugar Maple (*Acer saccharum*) and Green Ash (*Fraxinus pennsylvanica*) the desirable portion of the bole is the wood that has minimal heart discoloration. For species like Black Cherry (*Prunus serotina*) and Red Oak (*Quercus rubra*) that dominate the southern Appalachian veneer industry, the desirable portion of the bole is where there is maximal heart discoloration as this produces the dark red colors that are sought after by veneer markets. Another example is the color classification that is found in the In White Oak (*Quercus alba*) veneer market, whereby the yellow straw color is highly sort after as opposed to the red color that some varieties of this species present. The same parameter also holds true for Black Cherry where the desirable color is dark red as apposed to the cherry 'bubble-gum' pink color. The quality issues that are described above are in part handled by the optimizer, however some of these quality parameters could be improved upon in not only actual program, but also in the tree description phase of the data collection process Loving, M.W. <MWLOVING@GAPAC.com> (2002, July, 12) [Personal email].

5.5 VALUE ESTIMATION

Two *HW-BUCK™* limitations that have a direct influence on the value ascribed to manufactured logs are that it has only been designed to accommodate International ¼ and Scribner Decimal C Log Rules, and there is only capacity for three saw-log grades. To overcome these limitations, the US dollar per thousand board feet (MBF) Doyle Log Rule prices used by the Georgia-Pacific Corporation, were modified so that a more realistic log value could be realized with this bucking optimization software package.

5.5.1 Scribner Decimal C Value Estimation

The Doyle (USDA, anon.) and Scribner Decimal C (USDA, 1949) Log Rule tables were used to develop conversion factors for average volumes so that prices per Doyle MBF could be adjusted to realistic price per Scribner Decimal C MBF. A ratio (Doyle:Scribner Decimal C) for each expected log diameter and log length a class was developed. This ratio was then multiplied by the price per Doyle MBF value as presented by the Georgia- Pacific Corporation. The above-mentioned formula is based on the assumption that the Scribner Decimal C overestimates volume in logs with diameter inside bark ranges from 10-inches to 25-inches (Schnur and Lane, 1948). Intuitively this methodology makes sense, because using this formula, the price per Doyle Log Rule MBF is higher than the price per Scribner Decimal C (Tables 10-12).

5.5.2 Saw-log Grade Value Estimation

All three mills had more than three saw-log grades, however these grades were more based on length and diameter of the log as apposed to the quality of the logs. In order to simplify the pricing matrix of these three mills (refer to Appendices H, J and L) the average prices for each major grade per species: Prime grade, Clear Grade and Mill/Select grade were determined. This manipulation of the price information allowed for the use of *HW-BUCK*™ given its limitation, but at the same time allowed a more realistic pricing outcome once the optimization values had been generated (Table 11-13).

Table 11: Green Valley Mills' modified Open Market Log Prices. All prices in US. dollars per MBF Scribner Decimal C Rule (March 17, 2002) (refer to Appendix O for scientific name of species)

Species	**Veneer 1**	**Veneer 2**	**Veneer 3**	**Prime Grade**	**Clear Grade**	**Select & Mill Grade**
Ash	-	-	-	303	281	134
Am. Basswood	-	-	-	293	259	117
Cherry	2700	2250	1600	1075	945	391
Sugar Maple	1600	1200	-	710	675	204
Red Maple	-	-	-	453	405	154
Red Oak	960	-	-	665	608	184
Scarlet Oak	800	560		300	225	124
White Oak	-	-	-	410	270	124
Chestnut Oak	-	-	-	325	248	124
Yellow Poplar*	-	-	-	303	259	134

* Yellow Poplar and Cucumber peelers (10" SED and greater, in 8'9" and 17'6" lengths) were priced at $184/MBF

Table 12: Rainelle Mills' modified Open Market Log Prices. All prices in US dollars per MBF Scribner Decimal C Rule (May 29, 2001) (refer to Appendix O for scientific name of species)

Species	**Veneer 1**	**Veneer 2**	**Veneer 3**	**Prime Grade 14'-16'**	**Prime Grade 8'-12'**	**Clear Grade 14'-16'**	**Clear Grade 8'-12'**	**Select & Mill Grade**
Ash	900	-	-	402	355	300	257	138
Am. Basswood	-	-	-	420	374	324	267	126
Cherry	2925	-	-	1790	1620	1461	1343	841
Sugar Maple	1440	-	-	1195	1025	888	758	469
Red Maple	-	-	-	470	385	343	285	221
Red Oak	960	-	-	810	735	639	575	373
White Oak	900	-	-	355	290	231	183	99
Chestnut Oak	-	-	-	310	268	193	155	86
Yellow Poplar	-	-	-	364	300	265	208	113

Table 13: Richwood Mills' modified Open Market Log Prices. All prices in US dollars per MBF Scribner Decimal C Rule (March 26, 2001) (refer to Appendix O for scientific name of species)

Species	**Veneer 1**	**Veneer 2**	**Veneer 3**	**Prime Grade 14'-16'**	**Prime Grade 8'-12'**	**Clear Grade 14'-16'**	**Clear Grade 8'-12'**	**Select & Mill Grade**
Ash	-	-	-	374	323	268	225	118
Am. Basswood	-	-	-	420	374	324	267	123
Cherry	4050	3150	2000	1769	1599	1380	1219	641
Sugar Maple	1440	1120	-	1195	1025	888	758	429
Red Maple	-	-	-	470	385	343	285	200
Red Oak	1040	880	-	779	704	596	533	301
White Oak	900	560	-	355	290	231	183	99
Chestnut Oak	-	-	-	310	268	193	155	86
Yellow Poplar	-	-	-	262	204	167	119	54

5.6 RESULTS

All bucking cuts for the 155 stems were measured to within an eighth of an inch. Out of those 155 trees, 510 logs were manufactured. Figure 20 shows the percentage of under cut versus over cut logs. There is an opportunity that is being lost every time a log is being under-cut. This is because 15 percent of logs were under-cut, and the value of the log may not be fully realized because under-cut logs are then sold in the next lower log length category.

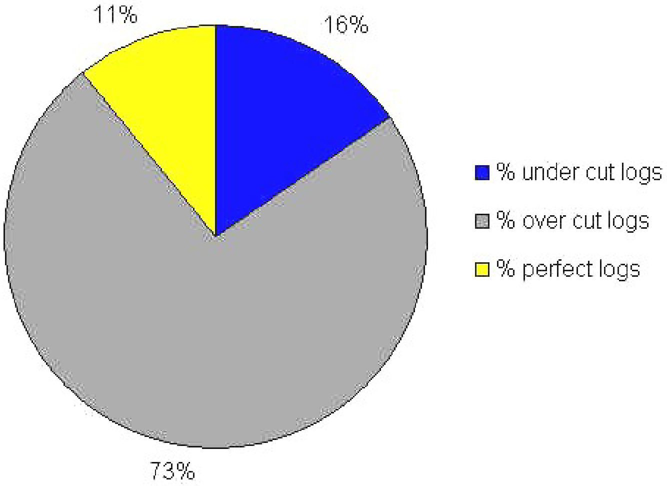


Figure 20: Percentage of under, over and perfect logs that were cut by the five log-makers investigated.

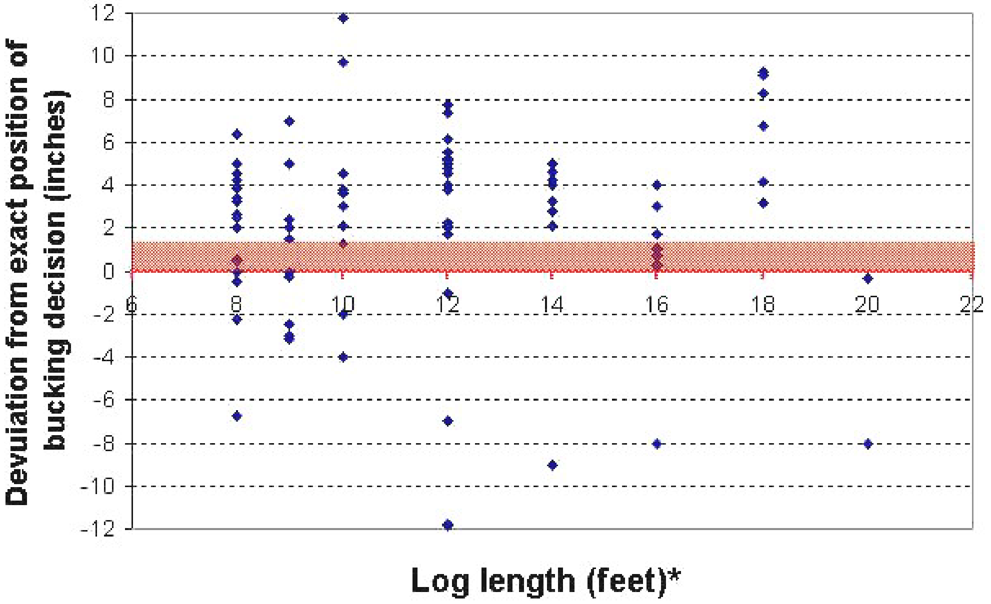
Georgia-Pacific Corporation sawmill specification sheets clearly states to timber procurement foresters that “logs with less than four inches trim will be reduced to the next lower acceptable length” (Appendices I, K, M). For this study a tolerance of 1.5 inches above the trimming allowance was set. All cuts below the trimming allowance were defined as ‘under cut’ logs, all logs cut between the trim allowance and the tolerance limit of 1.5 inches were defined as ‘perfect’ logs and logs cut outside of this tolerance limit were defined as ‘over cut’ log.

Accurate cutting is critical not only to the performance of the logger, but it directly impacts the value recovered from the forest that is being harvested and directly impacts the value that can be recovered by the sawmill and the company as a whole. Figure 20 shows that 15 percent of the logs that were manufactured by these five logging companies were under cut and value lost. 74 percent of the logs were over-cut, and opportunity lost. How much loss is being compounded in the manufacture of all the subsequent logs that follow the original over-cut bucking decision made along the bole of the tree can only be surmised because this is a separate study unto itself.

Table 13 shows that two buckers out perform the other buckers: Rainelle bucker 1 (Ra1) and Richwood bucker (Ri1). Assuming that the overall bucking decision making ability of all buckers investigated is equal, Ra1 and Ri1 perform to a higher standard of bucking accuracy. Their standard deviation from the absolute target was 3.6 inches, which means that 68 percent of the time they were within 3.6 inches of the absolute target cut – as defined by a cut with a trim allowance of 4-inches for every log. The performance of these two buckers, when compared to the Green Valley bucker 2 (GV2) (Std. Dev. of 5.6), was 65 percent more accurate. Ri1 and Ra1 had the lowest undercut percentages, whereas GV2 had the highest under cut percentage. Looking at these two important accuracy performance criteria, Ri1 is the best performer, because not only is the cutting accuracy within 3.6 inches of the ‘absolute target’, but when the bucker does deviate from the target zone, he is causing an under cut 5 percent of the time. Figures 21 – 25 clearly show this trend through the use of quality control charts.

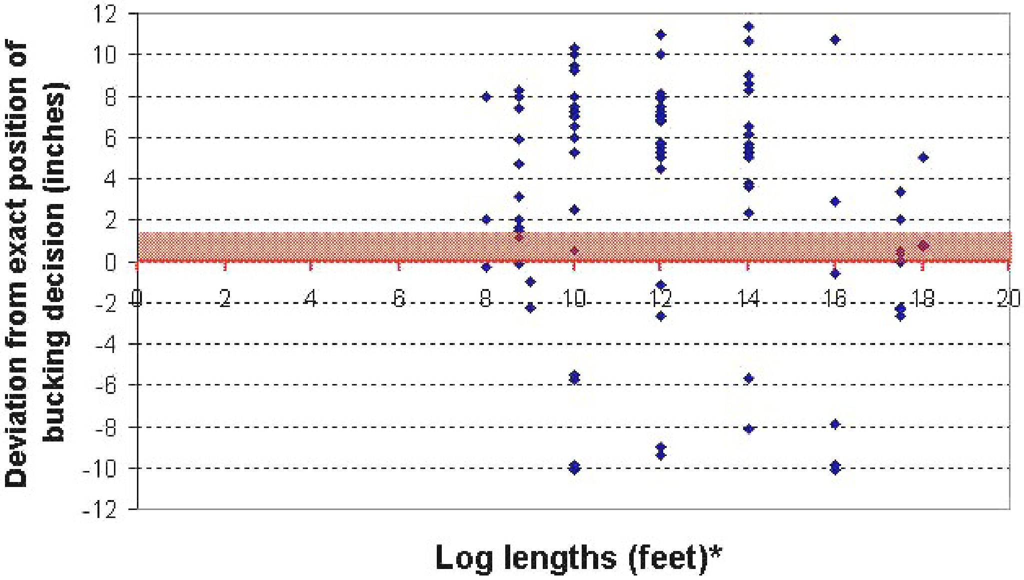
Table 13: Summary statistics for the five log-makers that were investigated.

Summary Statistics	Green Valley Bucker 1	Green Valley Bucker 2	Rainelle Bucker 1	Rainelle Bucker 2	Richwood Bucker 1
Std. Deviation	4.7	5.6	3.6	4.0	3.6
Sample Variance	21.7	31.5	12.9	16.2	12.7
Range	23.6	21.5	20.6	19.0	21.3
Minimum	-11.9	-10.1	-10.5	-11.5	-11.0
Maximum	11.8	11.4	10.1	7.5	10.3
No. of logs made	87	91	109	110	113
% under cut logs	17	23	12	20	5
% over cut logs	74	72	69	70	85
% perfect logs	9	5	19	10	10



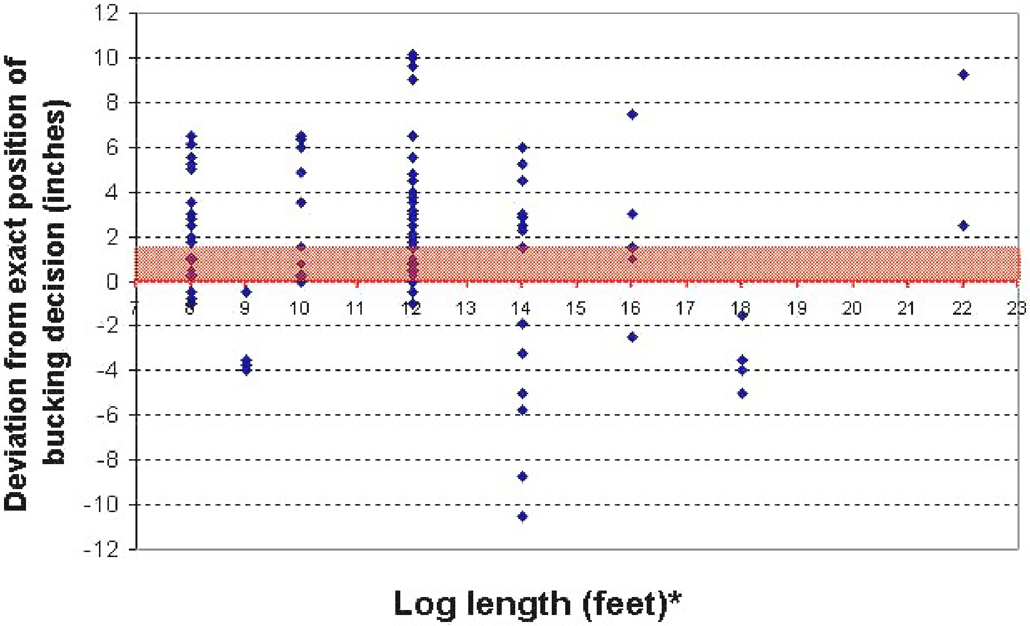
* The log length includes the four-inch trim allowance.

Figure 21: A quality control chart depicting the precision of the actual bucking cuts for the Green Valley Bucker 1. The red zone indicates the tolerance level, set at 1.5 inches



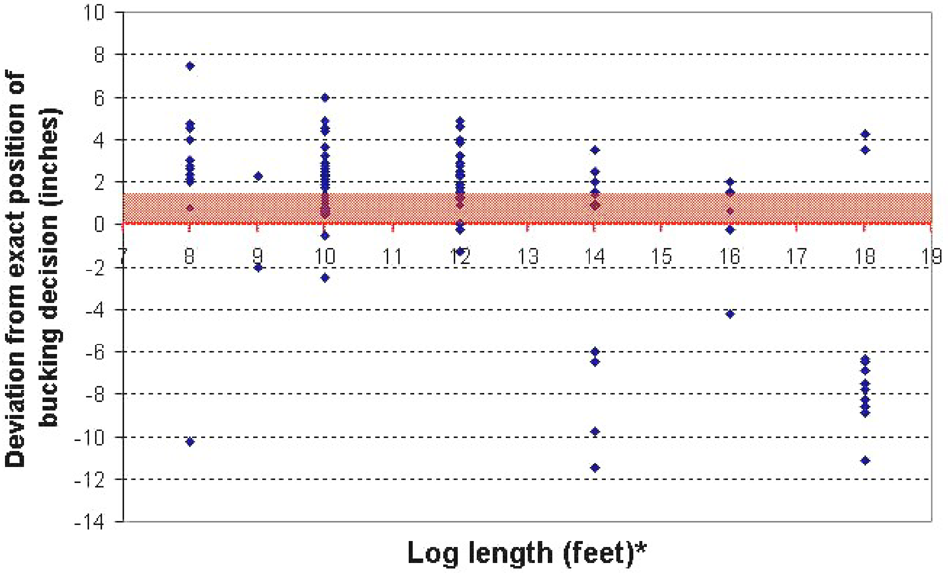
* The log length includes the four-inch trim allowance, peeler log lengths of 17'6" and 8'9" have been included.

Figure 22: A quality control chart depicting the precision of the actual bucking cuts, for Green Valley Bucker 2. The red zone indicates the tolerance level, set at 1.5 inches.



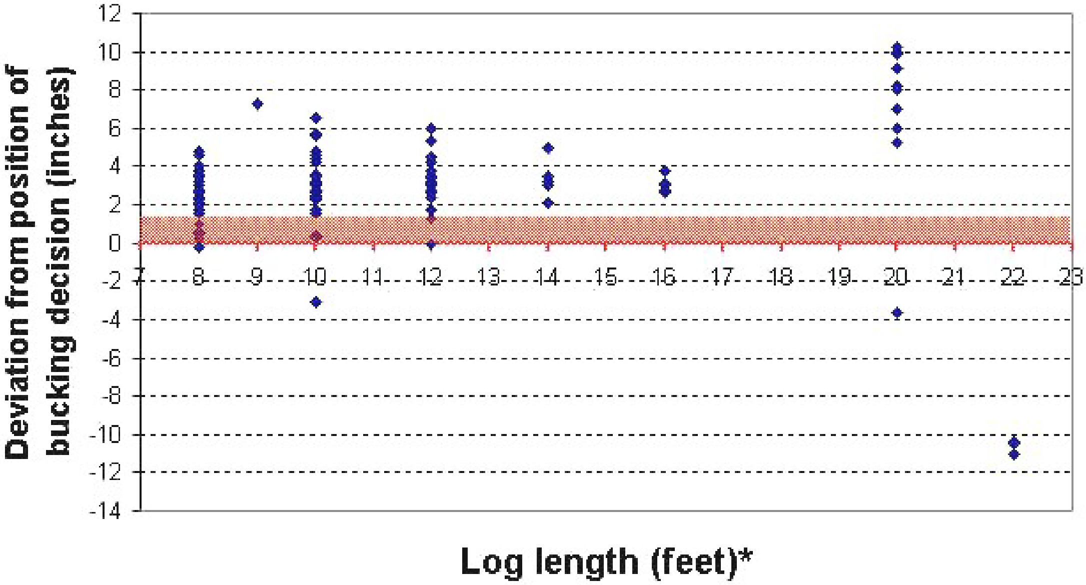
* The log length includes the four-inch trim allowance.

Figure 23: A quality control chart depicting the precision of the actual bucking cuts, for Rainelle Bucker 1. The red zone indicates the tolerance level, set at 1.5 inches



* The log length includes the four-inch trim allowance.

Figure 24: A quality control chart depicting the precision of the actual bucking cuts, for Rainelle Bucker 2. The red zone indicates the tolerance level, set at 1.5 inches



* The log length includes the four-inch trim allowance.

Figure 25: A quality control chart depicting the precision of the actual bucking cuts, for Richwood Bucker 1. The red zone indicates the tolerance level, set at 1.5 inches

Table 14 shows the variability in the five logging sites with regards to the species mix that was being merchandized for this value recovery study. It also indicates that there might be a relationship between the number of logs to the value that is recovered, i.e. is the greater the average number of logs made per tree, the greater the amount of value recovered.

Table 14: Species breakout and value recovery data as pertaining to the five logging sites that were observed.

Species	**Green Valley Bucker 1**	**Green Valley Bucker 2**	**Rainelle Bucker 1**	**Rainelle Bucker 2**	**Richwood Bucker 1**
Green Ash	0	0	1	0	0
Am. Basswood	0	1	2	0	0
Cherry	0	0	2	0	28
Sugar Maple	6	0	10	3	2
Red Maple	0	1	3	1	1
Red Oak	11	5	5	19	2
Scarlet Oak	1	0	0	0	0
White Oak	3	4	0	2	0
Chestnut Oak	6	1	1	0	0
Yellow Poplar	3	16	4	3	0
Hickory	0	1	0	0	0
No. of trees bucked	30	29	28	28	33
No. of logs made	87	91	109	110	113
Avg. no. of logs/tree	2.9	3.1	3.9	3.9	3.4
Buckers' solution ($)	1474	1760	4104	4136	15008
Optimal solution ($)	2397	2169	5397	5656	18348
Difference ($)	923	409	1293	1520	3340
Value recovered (%)	62	81	76	73	82

Value loss is calculated as follows(11):

$$\text{Value loss}_{(\%)} = \frac{100(\text{optimal solution value}_{(\$)} - \text{buckers' solution value}_{(\$)})}{\text{optimal solution value}_{(\$)}} \qquad \textbf{(11)}$$

Studies of softwood bucking practices in the US Pacific Northwest and New Zealand showed that value loss ranged between 5 to 26 percent (Geerts and Twaddle 1985, Sessions *et al*. 1989, Twaddle and Goulding 1989). Similar studies on hardwood bucking practices in the US Northwoods revealed that the value loss ranged between 39 to 55 percent (Pickens *et al*., 1992). The value loss percentages by the buckers' investigated in this study showed a range of 18 percent to 38 percent value loss (Figure 26). Depending on the tolerance level of management, for the level of value loss that is considered acceptable, certain operations have management strategies put in place to rectify the situation so that performance is kept within acceptable limits.

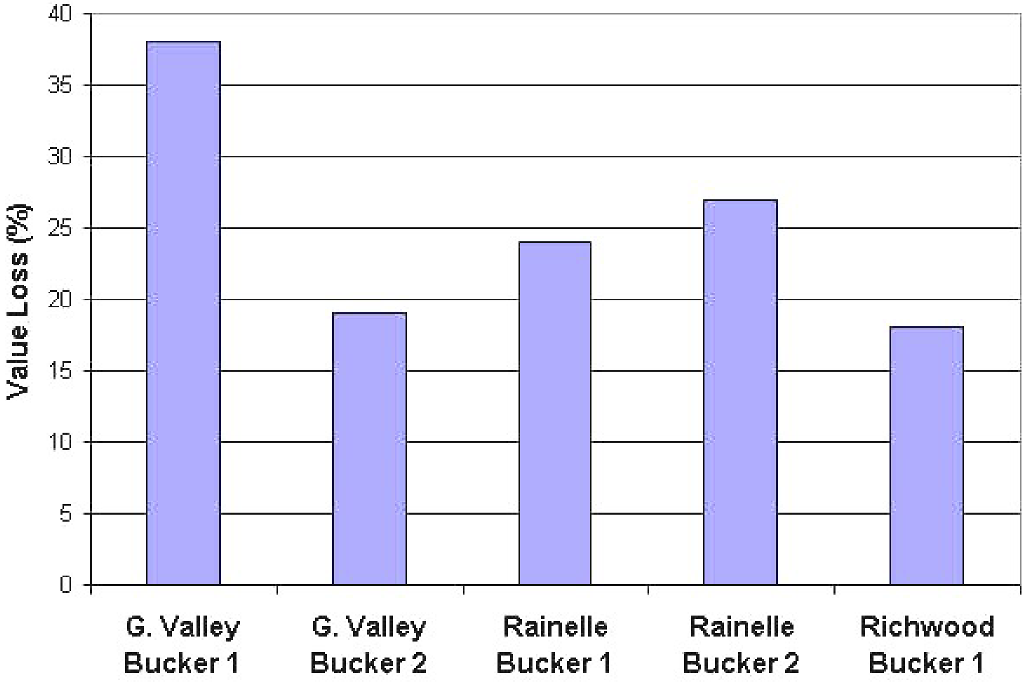


Figure 26: Average value loss based on current open market log prices presented in tables 10, 11 and 12.

5.6.1 Paired Samples t-Test

H_o: Optimal solution = Buckers' solution
H_a: Optimal solution > Buckers' solution

One hundred and fifty five data points were collected and 148 trees that were accepted by the *HW-BUCK*™ software package. Both the optimal and bucker solutions were generated by this software package on a tree-by-tree basis. As expected both the buckers' solution and the optimal solution were highly correlated with a correlation coefficient of 0.979 and a p-value of less than 0.000. The mean difference between these solutions was $50.59, with a standard deviation of $68.61 and standard error of $5.64. The t-value is 8.969 with 147 degrees of freedom. The difference between these two solutions is found to be highly significant with a p-value less than 0.000. Therefore the null hypothesis that the optimal and bucker solutions are equal is rejected. Further statistical analysis, as to why there is this difference is warranted.

5.7 STATISTICAL - CONTROL AND BENCHMARKING

In any production process a certain amount of inherent variability will always exist. This natural variability is the cumulative effect of many small, essentially uncontrollable causes. There are, however instances where variability arises due to operator errors or poorly adjusted equipment. X-bar charts can be used to examine and control the mean output from a process. R charts can be used to in a similar way, except individual sample ranges are plotted for a process. These statistical quality control charts may be of use in identifying areas in log manufacturing of poor value-recovery performance (Murphy, 1987). Zero percent value loss may not be a management objective, as the cost of achieving this optimum may out weigh the benefits of such a strategy. It is up to management to determine what an acceptable benchmark for value loss and implement some kind of quality control program using statistical quality control techniques.

Figure 20 is an example of quality control chart that could be used by a forestry company to monitor the level precision with which the buckers are cutting. This type of information could easily be collected by the log-scalars daily, and management could at least detect when the cutting accuracy has become unacceptable.

Benchmarking is another form of monitoring that could be applied to this forestry operation problem. The formal definition of benchmarking is “the continuous process of measuring products, services and practices against those of the companies toughest competitors or companies renowned as industry leaders.” (Camp and Kelsch, 1993). The purpose of benchmarking should be viewed as an opportunity to establish more credible goals and pursue continuous improvement. Data Envelopment Analysis (*DEA*) is a benchmark technique that measures the relative efficiency of production units that utilize comparable technology to perform similar tasks. Observations in a data set are rated based on the efficiency of other observations in the analysis. The performance of a system is measured in relation to efficient rather than average operations for the data set. An estimate of the amount of waste in terms of input conversion to outputs is compared to similar systems. The performance of a given system is effectively compared to a benchmark, with the benchmark being the highest performing system in the analysis. *DEA* provides the analyst with a value that quantifies the technical efficiency of the observations for a system (LeBel 1996).

Figure 22 clearly identifies the best performer out of the peer group of five southern Appalachian buckers (decision making units). In this case a simple one input, one output CCR model was used (Charnes, *et al*. 1978). In this instance the input was the optimal solution in dollars, as this is the potential value of the raw material (trees) that were being processed. The output value was the value that was the realized by the decision-making unit (DMU), in this case the buckers’ solution in dollars. Through linear programming the best virtual input and output by weights are assigned to each DMU so as to maximize the virtual input: virtual output ratio. The potential to develop this into a more comprehensive tool will allow management to better control the performance of the infield merchandizing operations.

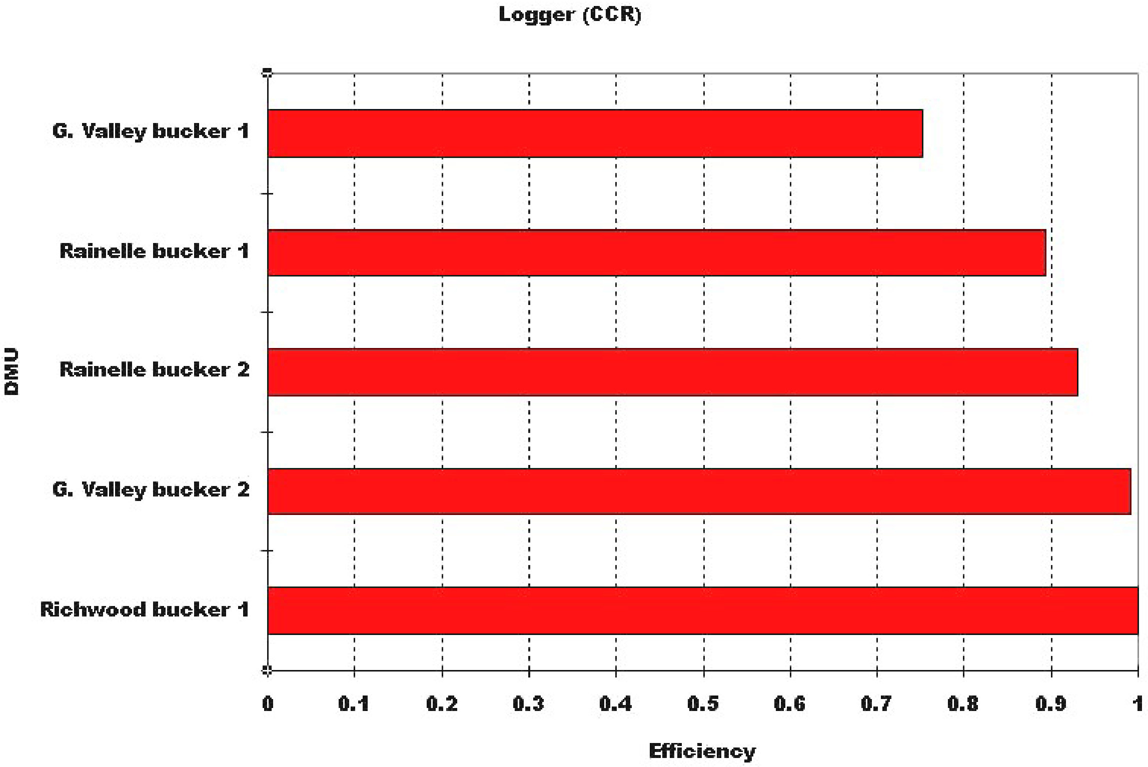


Figure 27: A bar chart of the *DEA* scores in ascending order.

5.8 DISCUSSION ON VALUE RECOVERY

The opportunity for improved performance in value recovery in the southern Appalachian hardwood logging industry is not dissimilar to the opportunity that exists in the hardwood logging operations of the US Northwoods. Similar studies on hardwood bucking practices in the US Northwoods revealed that the value loss ranged between 39 to 55 percent (Pickens, *et al*., 1992). The value loss percentages by bucker investigated in this study showed a range of 18 percent to 38 percent value loss (Figure 26). The potential for improved value recovery can be done through firstly improved managerial control systems and secondly through the integration of the new *Windows*™-based *HW-BUCK*™ software into a logger training program, where bucking heuristics can be modified to accommodate new pricing schedules that change seasonally (Pickens *et al*. 1993).

CHAPTER 6 CONCLUSION

Three case studies were carried out to identify areas where there is an opportunity for performance improvement in hardwood timber harvesting operations in the southern Appalachians:

(1) The promotion of cable-yarding in the Appalachians relies on the ability of new logging contractors to be successful over a long period of time. The lack of operations in the region in the last decade means that few skilled operators are available to either work with or train new crew-members. The Pacific Northwest has a higher concentration of skilled trainers who are able to travel to the southern Appalachian region and provide cable-yarding expertise. While the initial cost of training appears prohibitive, this study shows that the training causes an increase in the productivity and that costs associated with training can be quickly recovered through the increased productivity.

(2) The productivity studies of the swing-landing operation at the Burns' creek stewardship pilot project, although comparable to other studies, could be improved through the implementation of new technology. Through this action of technology transfer and 'good' harvest practices, the sustainability of this important logging system alternative will be become more accepted in the region and not only will the skill base develop, but the environmental impact through forest operations in the region will be minimized. Through the legal mechanism (Public Law 105-277; H.R. 4328; Section 347) the logging/restoration contractor was able to not only apply a silvicultural prescription to federal land, but also improve the stream habitat through lime placement. The use of an integrated contract allowed for a more efficient and timely treatment to the project area.

The log sale strategy that was implemented at the Burns' creek stewardship pilot project was well received by the industry as an alternative to the stumpage sale. According to the consuming mills interviewed, the sale was a success and the true value of the timber was realized. The potential for its use in other operations is however dependant on the quality of the timber being harvested, the area available for stacking the log inventory at the log deck and the season in which the operation is executed. Planning is critical for this type of raw material sales strategy.

(3) The opportunity for improved performance value recovery in the southern Appalachian hardwood logging industry is not dissimilar to the opportunity that exists in the hardwood logging operations of the Northwood hardwoods' of the United States. *HW-BUCK*™ proved to be a valuable analysis tool, however there limitations. The development of a new improved *MS-Windows*™ based version will improve not only the development of buckers' heuristic decision making skills, but the ability for forest product companies to monitor and control the value recovered from this resource, so that not only logging operations and forest product companies can be sustained.

Opportunities for performance improvement in industrial Appalachian mountain hardwood harvesting operations needs to expanded upon these initial findings. The capacity for further applied research, through a continual process of purposing will be critical for the sustainable use this natural resource in this region. A synergistic relationship between industry and academia needs to be forged so that applied research in forest engineering can best prepare this region for the future.

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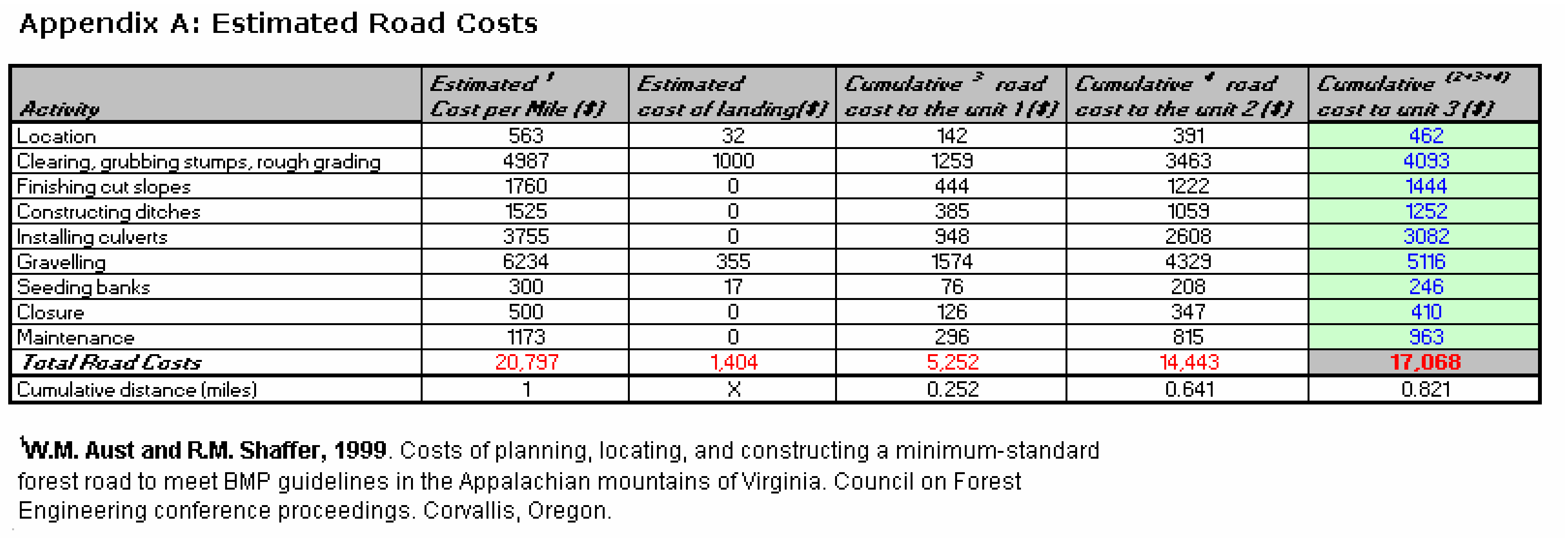
8. APPENDICES



Appendix A: Estimated Road Costs

Activity	Estimated [1] Cost per Mile ($)	Estimated cost of landing($)	Cumulative [3] road cost to the unit 1 ($)	Cumulative [4] road cost to the unit 2 ($)	Cumulative (2+3+4) cost to unit 3 ($)
Location	563	32	142	391	462
Clearing, grubbing stumps, rough grading	4987	1000	1259	3463	4093
Finishing cut slopes	1760	0	444	1222	1444
Constructing ditches	1525	0	385	1059	1252
Installing culverts	3755	0	948	2608	3082
Gravelling	6234	355	1574	4329	5116
Seeding banks	300	17	76	208	246
Closure	500	0	126	347	410
Maintenance	1173	0	296	815	963
Total Road Costs	20,797	1,404	5,252	14,443	**17,068**
Cumulative distance (miles)	1	X	0.252	0.641	0.821

[1] **W.M. Aust and R.M. Shaffer, 1999**. Costs of planning, locating, and constructing a minimum-standard forest road to meet BMP guidelines in the Appalachian mountains of Virginia. Council on Forest Engineering conference proceedings. Corvallis, Oregon.

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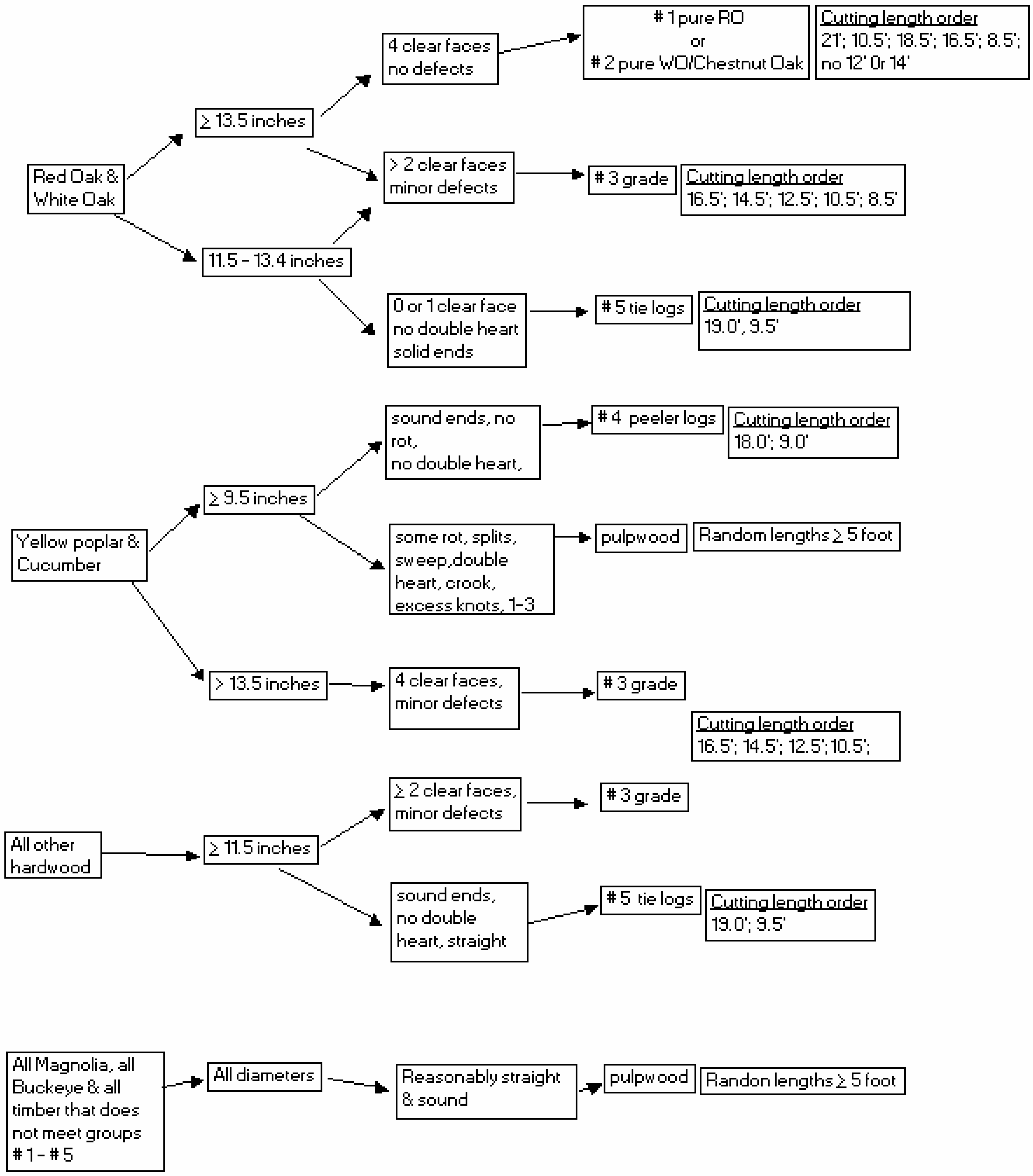
Appendix B: Forest Service Merchandizing Decision Matrix



Appendix C: Manual Felling Machine Costs

Manual Felling Machine Costs

Machine: **Stihl 088** ***Year Purchased:*** **2001** **Date:** **September 2001**

a	Power (hp)	5.4	h	Fuel price ($/gal)	1.17
b	Current new price ($)	640	i	R + M as % of depreciation	40
c	Current used price ($)	50	j	Proportion of ACI as Loan	0.75
d	Hours per year	1200	k	Proportion of ACI as Owner Equity	0.25
e	Expected life (years)	1	l	Loan interest rate (%)	11
			m	Owners interest rate (%)	7
			n	Weighted interest rate ((j*l)+(k*m))/100	10

Fixed Costs

p	Depreciation	$= (b-g-c)/(e*d)$	0.49
q	Average capital invested	$= \frac{(b-c)(e+1)}{2*e} + c$	640.00
r	Interest charged per hour	$= (n*q)/d$	0.05
s	Insurance	$=(q*0.05)/d$	0.03

Total Fixed Costs per Hour: 0.57 (p+r+s)

Variable Costs

t	Fuel; either $= 0.04*a*h$ or = fuel consumption/hour*h	0.25
u	Oil $= 0.20*t$	0.05
v	Repairs & maintenance $= (i*p)/100$	0.20

Total Variable Costs per Hour: 0.50

Machine Cost per Hour: 1.07

Labor Costs

x	Labor rate ($/SMH)	31.34
y	Labor fringes (%)	40

Total Labor Costs ($/SMH) 43.88

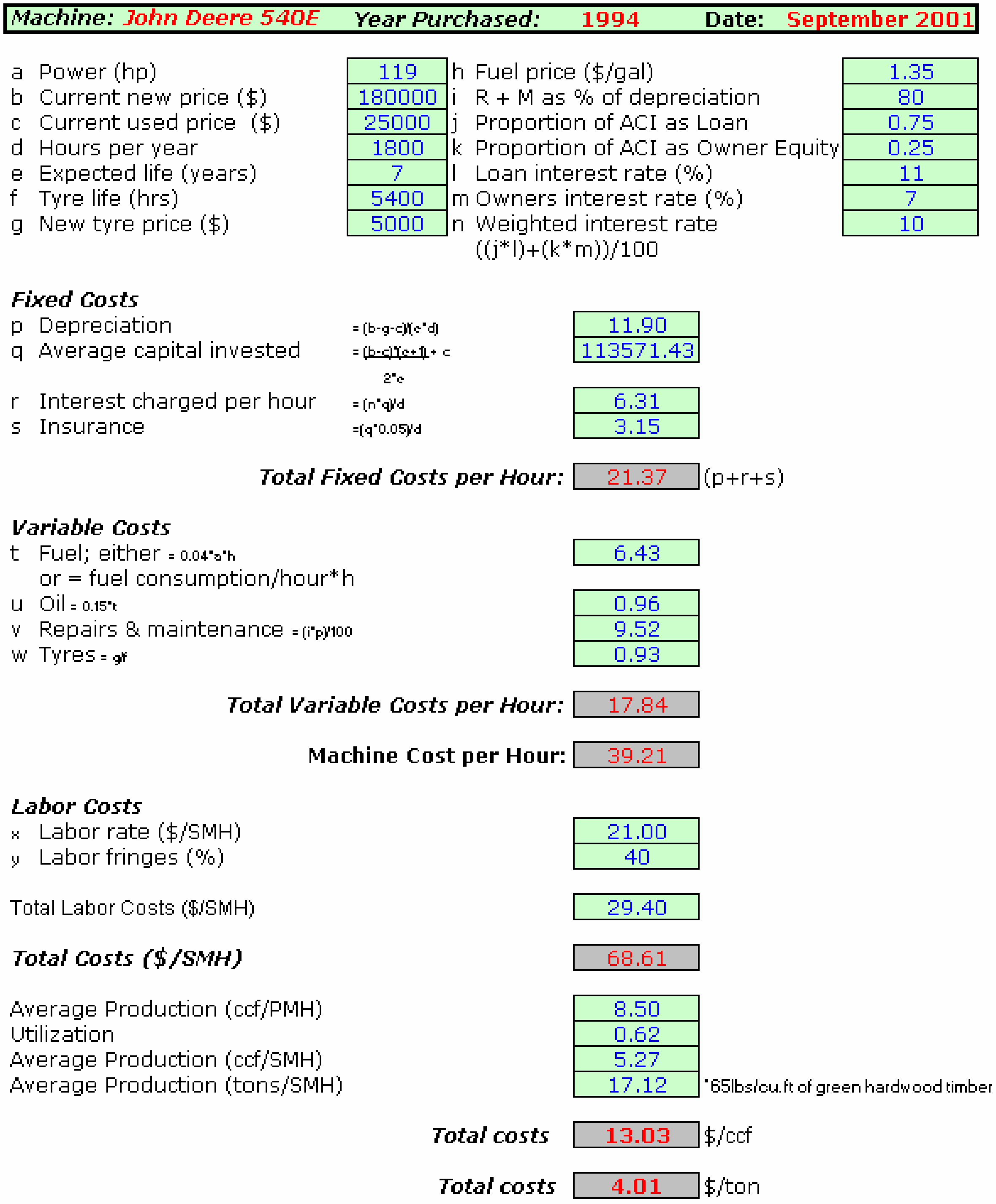
Total Costs ($/SMH) 44.95

Average Production (ccf/PMH)	16.92	
Utilization	0.48	
Average Production (ccf/SMH)	8.12	
Average Production (tons/SMH)	26.39	*65lbs/cu.ft of green hardwood timber

Total costs **5.54** $/ccf

Total costs **1.70** $/ton

Appendix D: Skidder Machine Costs



Machine: John Deere 540E **Year Purchased: 1994** **Date: September 2001**

a	Power (hp)	119	h	Fuel price ($/gal)	1.35
b	Current new price ($)	180000	i	R + M as % of depreciation	80
c	Current used price ($)	25000	j	Proportion of ACI as Loan	0.75
d	Hours per year	1800	k	Proportion of ACI as Owner Equity	0.25
e	Expected life (years)	7	l	Loan interest rate (%)	11
f	Tyre life (hrs)	5400	m	Owners interest rate (%)	7
g	New tyre price ($)	5000	n	Weighted interest rate ((j*l)+(k*m))/100	10

Fixed Costs

p	Depreciation	=(b-g-c)/(e*d)	11.90
q	Average capital invested	= $\frac{(b-c)*(e+1)}{2*e} + c$	113571.43
r	Interest charged per hour	=(n*q)/d	6.31
s	Insurance	=(q*0.05)/d	3.15

Total Fixed Costs per Hour: 21.37 (p+r+s)

Variable Costs

t	Fuel; either = 0.04*a*h or = fuel consumption/hour*h	6.43
u	Oil = 0.15*t	0.96
v	Repairs & maintenance = (i*p)/100	9.52
w	Tyres = g/f	0.93

Total Variable Costs per Hour: 17.84

Machine Cost per Hour: 39.21

Labor Costs

x	Labor rate ($/SMH)	21.00
y	Labor fringes (%)	40
	Total Labor Costs ($/SMH)	29.40

Total Costs ($/SMH) 68.61

Average Production (ccf/PMH)	8.50	
Utilization	0.62	
Average Production (ccf/SMH)	5.27	
Average Production (tons/SMH)	17.12	*65lbs/cu.ft of green hardwood timber

Total costs **13.03** $/ccf

Total costs **4.01** $/ton

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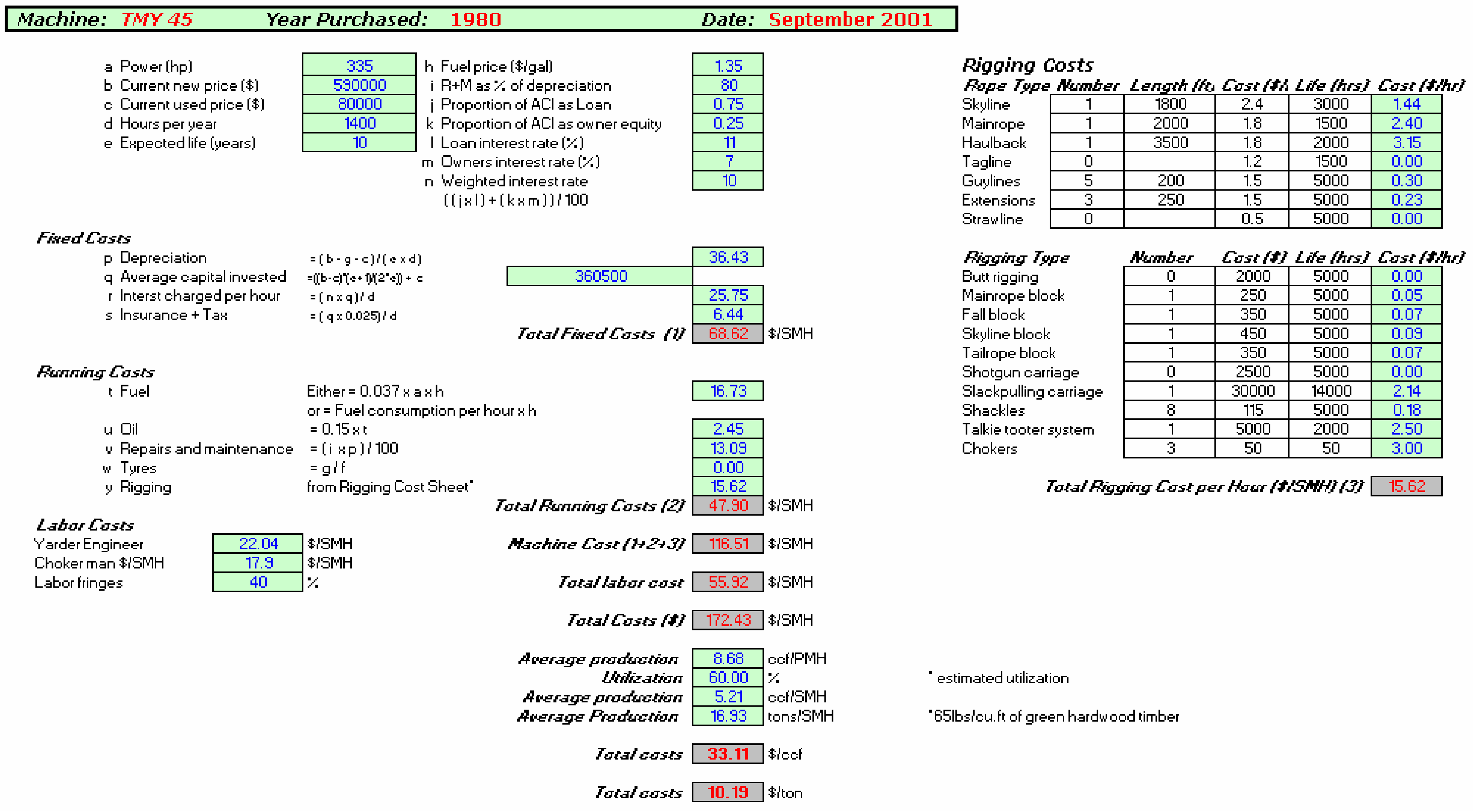
Appendix E: Cable-Yarder Machine Costs



Machine: TMY 45 **Year Purchased:** 1980 **Date:** September 2001

a	Power (hp)	335	h	Fuel price ($/gal)	1.35
b	Current new price ($)	590000	i	R+M as % of depreciation	80
c	Current used price ($)	80000	j	Proportion of ACI as Loan	0.75
d	Hours per year	1400	k	Proportion of ACI as owner equity	0.25
e	Expected life (years)	10	l	Loan interest rate (%)	11
			m	Owners interest rate (%)	7
			n	Weighted interest rate ((j x l) + (k x m)) / 100	10

Fixed Costs

p	Depreciation	= (b - g - c) / (e x d)		36.43	
q	Average capital invested	=((b-c)*(e+1)/(2*e)) + c	360500		
r	Interst charged per hour	= (n x q) / d		25.75	
s	Insurance + Tax	= (q x 0.025) / d		6.44	
			Total Fixed Costs (1)	68.62	$/SMH

Running Costs

t	Fuel	Either = 0.037 x a x h or = Fuel consumption per hour x h		16.73	
u	Oil	= 0.15 x t		2.45	
v	Repairs and maintenance	= (i x p) / 100		13.09	
w	Tyres	= g / f		0.00	
y	Rigging	from Rigging Cost Sheet*		15.62	
			Total Running Costs (2)	47.90	$/SMH

Labor Costs

Yarder Engineer	22.04	$/SMH
Choker man $/SMH	17.9	$/SMH
Labor fringes	40	%

Machine Cost (1+2+3)	116.51	$/SMH
Total labor cost	55.92	$/SMH
Total Costs (4)	172.43	$/SMH
Average production	8.68	ccf/PMH
Utilization	60.00	%
Average production	5.21	ccf/SMH
Average Production	16.93	tons/SMH
Total costs	**33.11**	$/ccf
Total costs	**10.19**	$/ton

* estimated utilization

*65lbs/cu.ft of green hardwood timber

Rigging Costs

Rope Type	***Number***	***Length (ft***	***Cost ($/***	***Life (hrs)***	***Cost ($/hr)***
Skyline	1	1800	2.4	3000	1.44
Mainrope	1	2000	1.8	1500	2.40
Haulback	1	3500	1.8	2000	3.15
Tagline	0		1.2	1500	0.00
Guylines	5	200	1.5	5000	0.30
Extensions	3	250	1.5	5000	0.23
Strawline	0		0.5	5000	0.00

Rigging Type	***Number***	***Cost ($)***	***Life (hrs)***	***Cost ($/hr)***
Butt rigging	0	2000	5000	0.00
Mainrope block	1	250	5000	0.05
Fall block	1	350	5000	0.07
Skyline block	1	450	5000	0.09
Tailrope block	1	350	5000	0.07
Shotgun carriage	0	2500	5000	0.00
Slackpulling carriage	1	30000	14000	2.14
Shackles	8	115	5000	0.18
Talkie tooter system	1	5000	2000	2.50
Chokers	3	50	50	3.00

Total Rigging Cost per Hour ($/SMH) (3) 15.62

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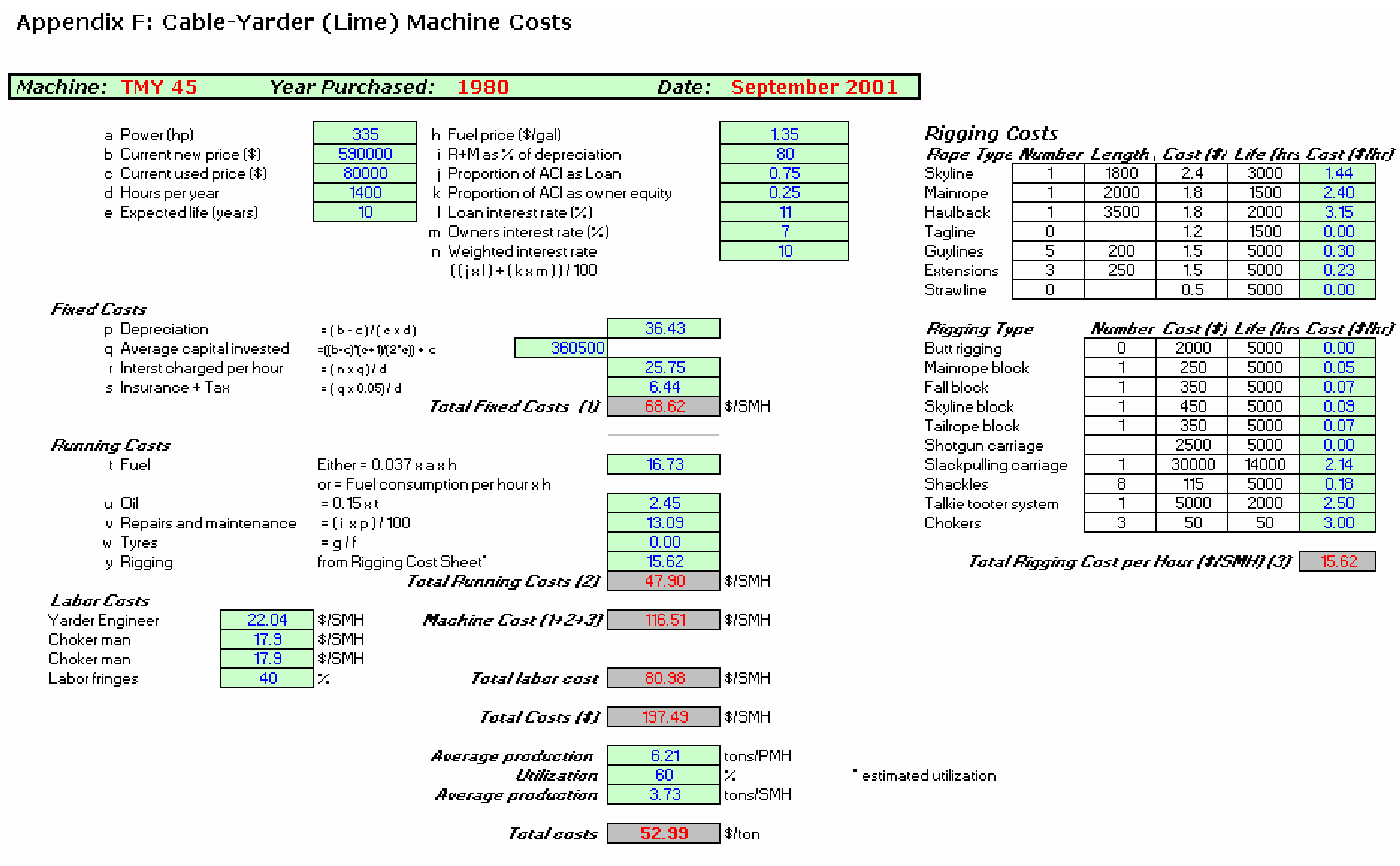

Appendix F: Cable-Yarder (Lime) Machine Costs

Machine: TMY 45 **Year Purchased:** 1980 **Date:** September 2001

a	Power (hp)	335		
b	Current new price ($)	590000		
c	Current used price ($)	80000		
d	Hours per year	1400		
e	Expected life (years)	10		
h	Fuel price ($/gal)			1.35
i	R+M as % of depreciation			80
j	Proportion of ACI as Loan			0.75
k	Proportion of ACI as owner equity			0.25
l	Loan interest rate (%)			11
m	Owners interest rate (%)			7
n	Weighted interest rate ((j x l) + (k x m)) / 100			10

Fixed Costs

p	Depreciation	= (b - c) / (e x d)		36.43	
q	Average capital invested	=((b-c)*(e+1)/(2*e)) + c	360500		
r	Interst charged per hour	= (n x q) / d		25.75	
s	Insurance + Tax	= (q x 0.05) / d		6.44	
			Total Fixed Costs (1)	68.62	$/SMH

Running Costs

t	Fuel	Either = 0.037 x a x h or = Fuel consumption per hour x h		16.73	
u	Oil	= 0.15 x t		2.45	
v	Repairs and maintenance	= (i x p) / 100		13.09	
w	Tyres	= g / f		0.00	
y	Rigging	from Rigging Cost Sheet*		15.62	
			Total Running Costs (2)	47.90	$/SMH

Labor Costs

Yarder Engineer	22.04	$/SMH
Choker man	17.9	$/SMH
Choker man	17.9	$/SMH
Labor fringes	40	%

Machine Cost (1+2+3)	116.51	$/SMH
Total labor cost	80.98	$/SMH
Total Costs ($)	197.49	$/SMH
Average production	6.21	tons/PMH
Utilization	60	%
Average production	3.73	tons/SMH
Total costs	52.99	$/ton

* estimated utilization

Rigging Costs

Rope Type	***Number***	***Length ,***	***Cost ($/***	***Life (hrs***	***Cost ($/hr)***
Skyline	1	1800	2.4	3000	1.44
Mainrope	1	2000	1.8	1500	2.40
Haulback	1	3500	1.8	2000	3.15
Tagline	0		1.2	1500	0.00
Guylines	5	200	1.5	5000	0.30
Extensions	3	250	1.5	5000	0.23
Strawline	0		0.5	5000	0.00

Rigging Type	***Number***	***Cost ($)***	***Life (hrs***	***Cost ($/hr)***
Butt rigging	0	2000	5000	0.00
Mainrope block	1	250	5000	0.05
Fall block	1	350	5000	0.07
Skyline block	1	450	5000	0.09
Tailrope block	1	350	5000	0.07
Shotgun carriage		2500	5000	0.00
Slackpulling carriage	1	30000	14000	2.14
Shackles	8	115	5000	0.18
Talkie tooter system	1	5000	2000	2.50
Chokers	3	50	50	3.00

Total Rigging Cost per Hour ($/SMH) (3) 15.62

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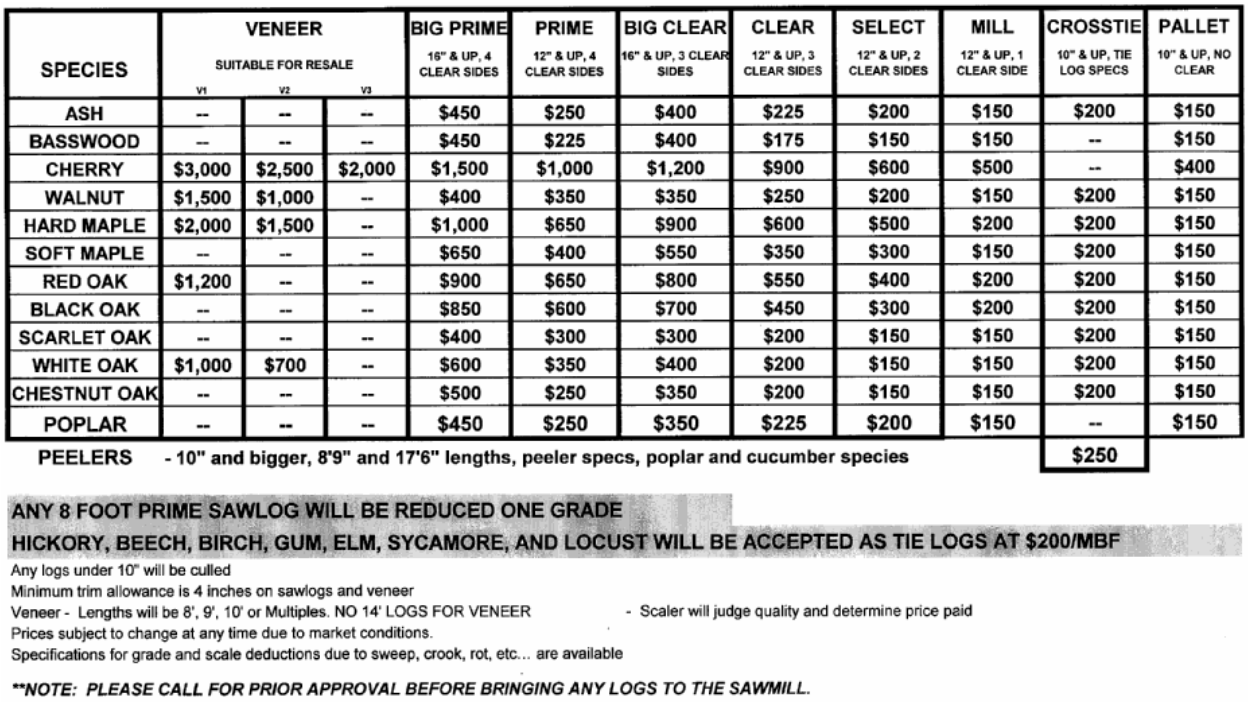
Appendix G: Questions for the Forest Service Stewardship Project

1. What type of forest products' company do you purchase for?
2. How was the timber purchased, ie. Are you a wood dealer/broker or an actual consumer?
3. What do you think are the main benefits of such a system?
4. Would you rather bid on logs separately or as a group?
5. Do you prefer to purchase the logs by sealed bid, or would you prefer an open auction?
6. How would you rate the quality of the logs that were on sale? (scale 1-5)
7. When did you learn of this sale?
8. Was this enough time to prepare for the sale?
9. What do you think are the main disadvantages of the sale?
10. Where do you think improvements can be made in this type of marketing approach?
11. Do you think that the stumpage sale is still the best option to sell the timber?
12. What types of problems do you foresee with this type of sale?
13. How did you factor in your logging costs?
14. Do you think that the price of the log piles sold are commensurate with that of a stumpage sale, or do you think that the timber price reflects the true value?
15. Were you able to quantify the products more accurately versus a stumpage sale?
16. Were you satisfied with the merchandizing of the timber, or do you think that you would have cut the logs differently?
17. What other thoughts would you like to share on this issue?

Appendix H: Green Valley Mill Log Price List **(all prices per MBF Doyle Rule)**



SPECIES	VENEER SUITABLE FOR RESALE			BIG PRIME 16" & UP, 4 CLEAR SIDES	PRIME 12" & UP, 4 CLEAR SIDES	BIG CLEAR 16" & UP, 3 CLEAR SIDES	CLEAR 12" & UP, 3 CLEAR SIDES	SELECT 12" & UP, 2 CLEAR SIDES	MILL 12" & UP, 1 CLEAR SIDE	CROSSTIE 10" & UP, TIE LOG SPECS	PALLET 10" & UP, NO CLEAR
	V1	V2	V3								
ASH	--	--	--	$450	$250	$400	$225	$200	$150	$200	$150
BASSWOOD	--	--	--	$450	$225	$400	$175	$150	$150	--	$150
CHERRY	$3,000	$2,500	$2,000	$1,500	$1,000	$1,200	$900	$600	$500	--	$400
WALNUT	$1,500	$1,000	--	$400	$350	$350	$250	$200	$150	$200	$150
HARD MAPLE	$2,000	$1,500	--	$1,000	$650	$900	$600	$500	$200	$200	$150
SOFT MAPLE	--	--	--	$650	$400	$550	$350	$300	$150	$200	$150
RED OAK	$1,200	--	--	$900	$650	$800	$550	$400	$200	$200	$150
BLACK OAK	--	--	--	$850	$600	$700	$450	$300	$200	$200	$150
SCARLET OAK	--	--	--	$400	$300	$300	$200	$150	$150	$200	$150
WHITE OAK	$1,000	$700	--	$600	$350	$400	$200	$150	$150	$200	$150
CHESTNUT OAK	--	--	--	$500	$250	$350	$200	$150	$150	$200	$150
POPLAR	--	--	--	$450	$250	$350	$225	$200	$150	--	$150
PEELERS	- 10" and bigger, 8'9" and 17'6" lengths, peeler specs, poplar and cucumber species									$250	

ANY 8 FOOT PRIME SAWLOG WILL BE REDUCED ONE GRADE

HICKORY, BEECH, BIRCH, GUM, ELM, SYCAMORE, AND LOCUST WILL BE ACCEPTED AS TIE LOGS AT $200/MBF

Any logs under 10" will be culled

Minimum trim allowance is 4 inches on sawlogs and veneer

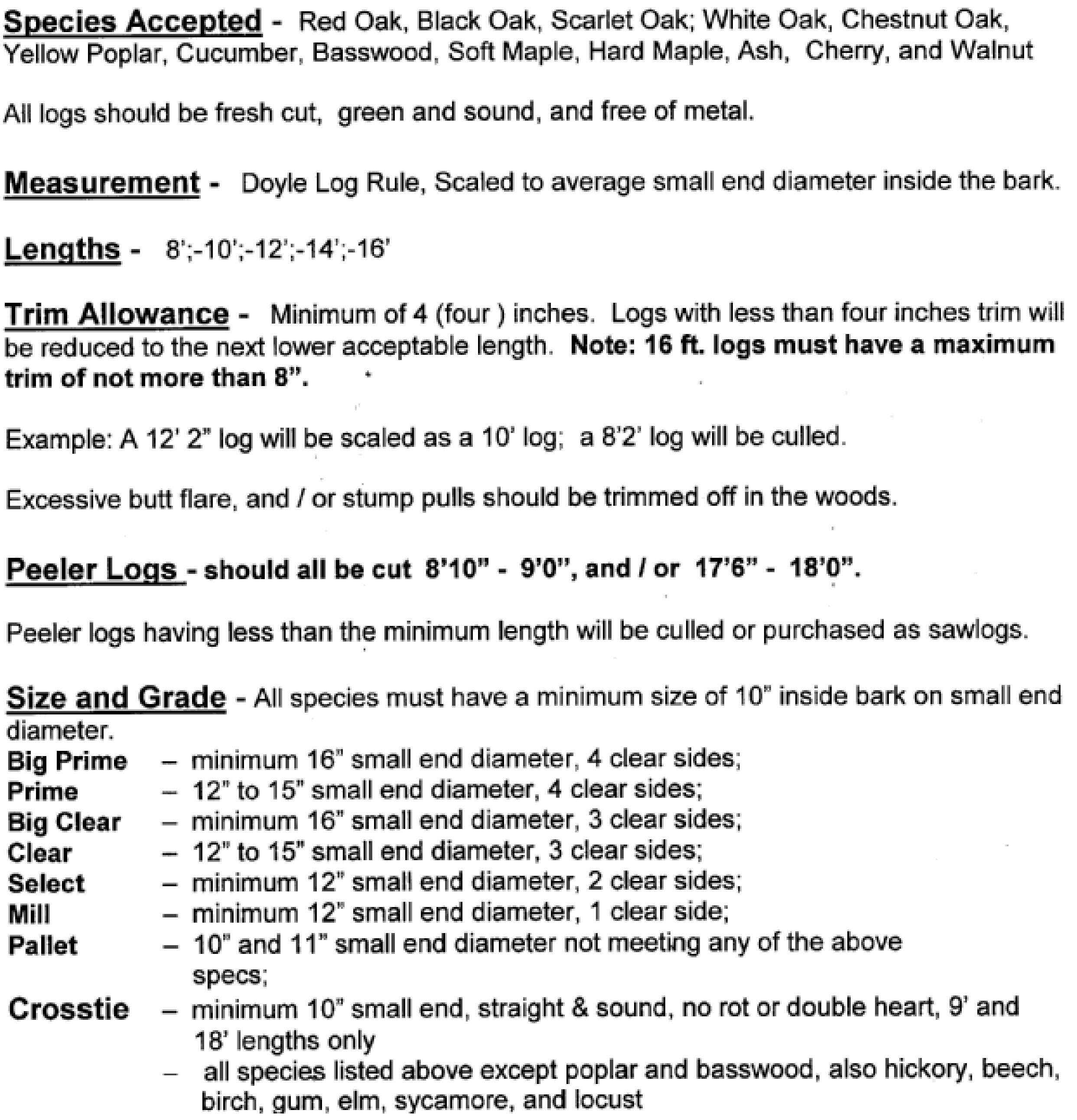
Veneer - Lengths will be 8', 9', 10' or Multiples. NO 14' LOGS FOR VENEER - Scaler will judge quality and determine price paid

Prices subject to change at any time due to market conditions.

Specifications for grade and scale deductions due to sweep, crook, rot, etc... are available

***NOTE: PLEASE CALL FOR PRIOR APPROVAL BEFORE BRINGING ANY LOGS TO THE SAWMILL.*

Appendix I: Green Valley Mill Specifications



Species Accepted - Red Oak, Black Oak, Scarlet Oak; White Oak, Chestnut Oak, Yellow Poplar, Cucumber, Basswood, Soft Maple, Hard Maple, Ash, Cherry, and Walnut

All logs should be fresh cut, green and sound, and free of metal.

Measurement - Doyle Log Rule, Scaled to average small end diameter inside the bark.

Lengths - 8';-10';-12';-14';-16'

Trim Allowance - Minimum of 4 (four) inches. Logs with less than four inches trim will be reduced to the next lower acceptable length. **Note: 16 ft. logs must have a maximum trim of not more than 8".**

Example: A 12' 2" log will be scaled as a 10' log; a 8'2' log will be culled.

Excessive butt flare, and / or stump pulls should be trimmed off in the woods.

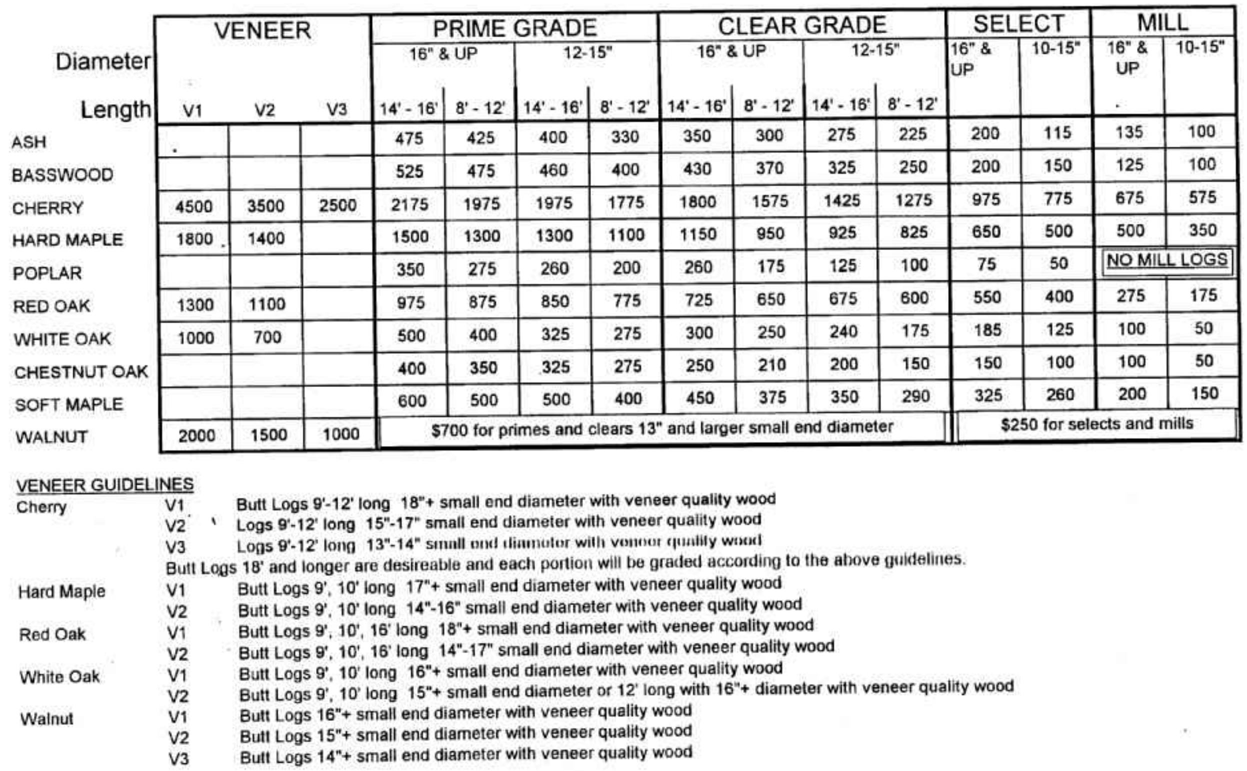
Peeler Logs - should all be cut 8'10" - 9'0", and / or 17'6" - 18'0".

Peeler logs having less than the minimum length will be culled or purchased as sawlogs.

Size and Grade - All species must have a minimum size of 10" inside bark on small end diameter.

Big Prime – minimum 16" small end diameter, 4 clear sides;
Prime – 12" to 15" small end diameter, 4 clear sides;
Big Clear – minimum 16" small end diameter, 3 clear sides;
Clear – 12" to 15" small end diameter, 3 clear sides;
Select – minimum 12" small end diameter, 2 clear sides;
Mill – minimum 12" small end diameter, 1 clear side;
Pallet – 10" and 11" small end diameter not meeting any of the above specs;
Crosstie – minimum 10" small end, straight & sound, no rot or double heart, 9' and 18' lengths only
– all species listed above except poplar and basswood, also hickory, beech, birch, gum, elm, sycamore, and locust

Appendix J: Rainelle Mill Log Price List **(all prices per MBF Doyle Rule)**



	VENEER			PRIME GRADE				CLEAR GRADE				SELECT		MILL	
Diameter				16" & UP		12-15"		16" & UP		12-15"		16" & UP	10-15"	16" & UP	10-15"
Length	V1	V2	V3	14' - 16'	8' - 12'	14' - 16'	8' - 12'	14' - 16'	8' - 12'	14' - 16'	8' - 12'				
ASH				475	425	400	330	350	300	275	225	200	115	135	100
BASSWOOD				525	475	460	400	430	370	325	250	200	150	125	100
CHERRY	4500	3500	2500	2175	1975	1975	1775	1800	1575	1425	1275	975	775	675	575
HARD MAPLE	1800	1400		1500	1300	1300	1100	1150	950	925	825	650	500	500	350
POPLAR				350	275	260	200	260	175	125	100	75	50	NO MILL LOGS	
RED OAK	1300	1100		975	875	850	775	725	650	675	600	550	400	275	175
WHITE OAK	1000	700		500	400	325	275	300	250	240	175	185	125	100	50
CHESTNUT OAK				400	350	325	275	250	210	200	150	150	100	100	50
SOFT MAPLE				600	500	500	400	450	375	350	290	325	260	200	150
WALNUT	2000	1500	1000	$700 for primes and clears 13" and larger small end diameter								$250 for selects and mills			

VENEER GUIDELINES

Cherry	V1	Butt Logs 9'-12' long 18"+ small end diameter with veneer quality wood
	V2	Logs 9'-12' long 15"-17" small end diameter with veneer quality wood
	V3	Logs 9'-12' long 13"-14" small end diameter with veneer quality wood
	Butt Logs 18' and longer are desireable and each portion will be graded according to the above guidelines.	
Hard Maple	V1	Butt Logs 9', 10' long 17"+ small end diameter with veneer quality wood
	V2	Butt Logs 9', 10' long 14"-16" small end diameter with veneer quality wood
Red Oak	V1	Butt Logs 9', 10', 16' long 18"+ small end diameter with veneer quality wood
	V2	Butt Logs 9', 10', 16' long 14"-17" small end diameter with veneer quality wood
White Oak	V1	Butt Logs 9', 10' long 16"+ small end diameter with veneer quality wood
	V2	Butt Logs 9', 10' long 15"+ small end diameter or 12' long with 16"+ diameter with veneer quality wood
Walnut	V1	Butt Logs 16"+ small end diameter with veneer quality wood
	V2	Butt Logs 15"+ small end diameter with veneer quality wood
	V3	Butt Logs 14"+ small end diameter with veneer quality wood

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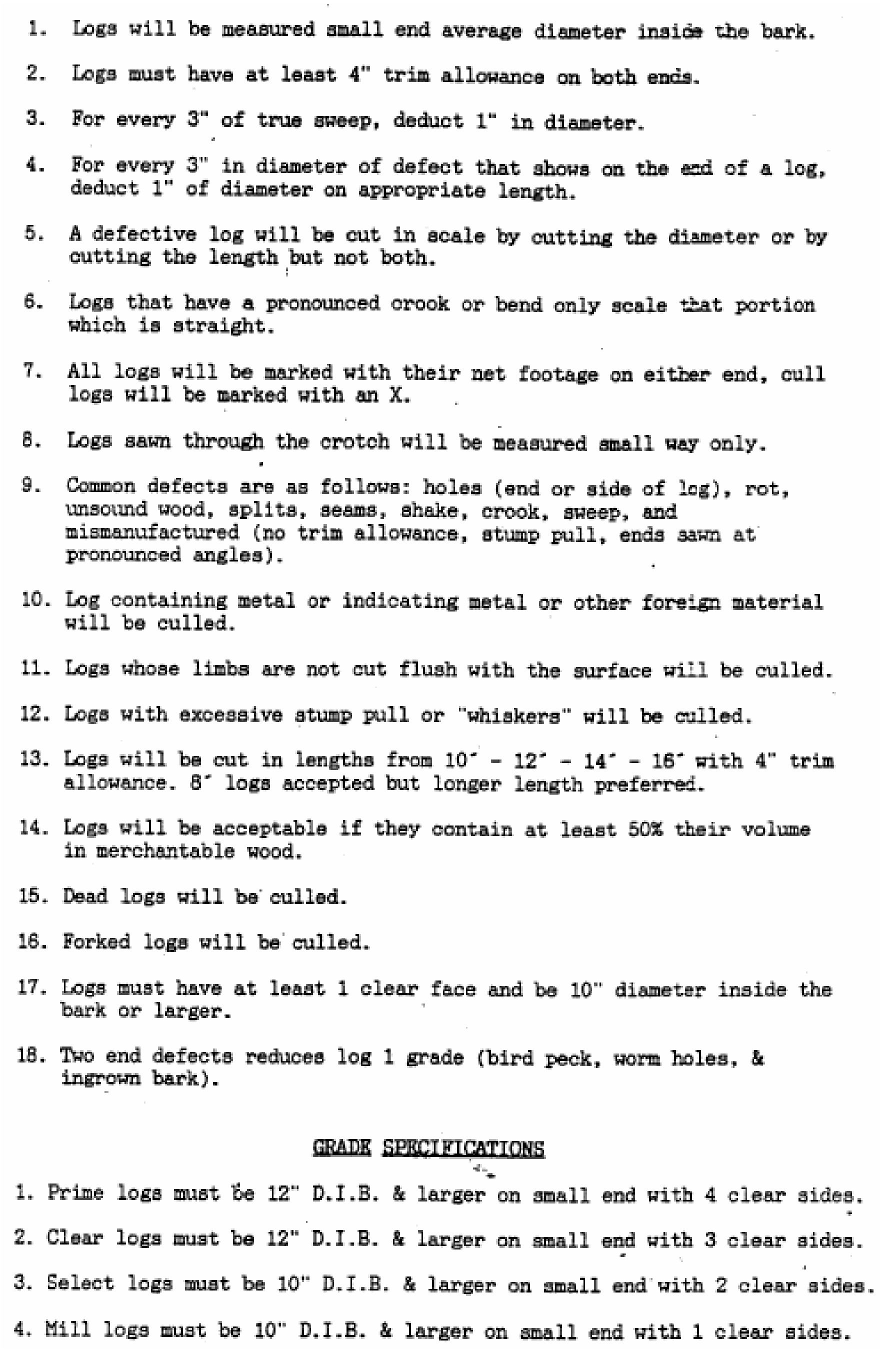
Appendix K: Rainelle Mill Specifications

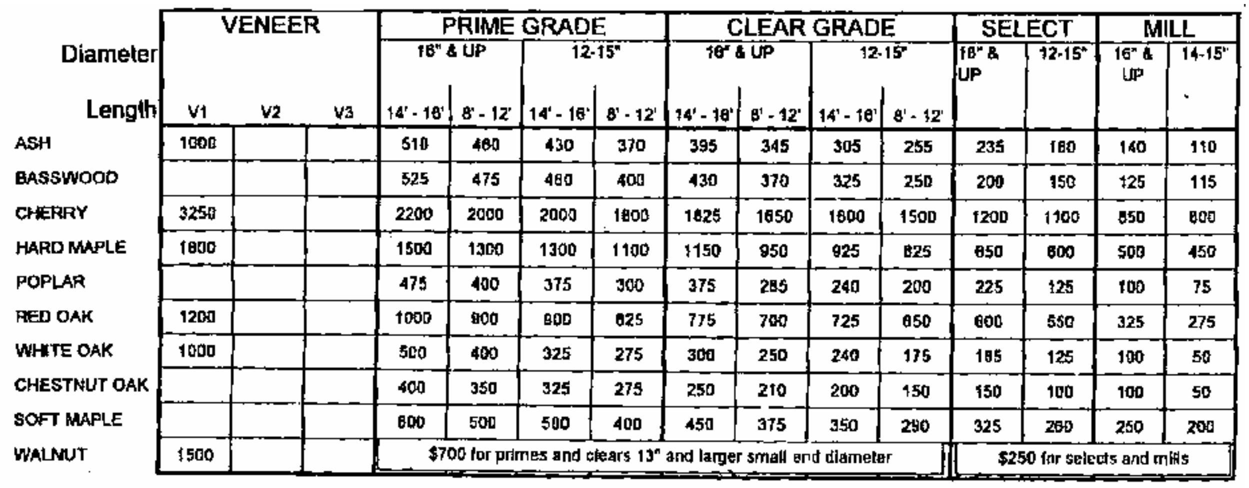


1. Logs will be measured small end average diameter inside the bark.
2. Logs must have at least 4" trim allowance on both ends.
3. For every 3" of true sweep, deduct 1" in diameter.
4. For every 3" in diameter of defect that shows on the end of a log, deduct 1" of diameter on appropriate length.
5. A defective log will be cut in scale by cutting the diameter or by cutting the length but not both.
6. Logs that have a pronounced crook or bend only scale that portion which is straight.
7. All logs will be marked with their net footage on either end, cull logs will be marked with an X.
8. Logs sawn through the crotch will be measured small way only.
9. Common defects are as follows: holes (end or side of log), rot, unsound wood, splits, seams, shake, crook, sweep, and mismanufactured (no trim allowance, stump pull, ends sawn at pronounced angles).
10. Log containing metal or indicating metal or other foreign material will be culled.
11. Logs whose limbs are not cut flush with the surface will be culled.
12. Logs with excessive stump pull or "whiskers" will be culled.
13. Logs will be cut in lengths from 10' - 12' - 14' - 16' with 4" trim allowance. 8' logs accepted but longer length preferred.
14. Logs will be acceptable if they contain at least 50% their volume in merchantable wood.
15. Dead logs will be culled.
16. Forked logs will be culled.
17. Logs must have at least 1 clear face and be 10" diameter inside the bark or larger.
18. Two end defects reduces log 1 grade (bird peck, worm holes, & ingrown bark).

GRADE SPECIFICATIONS

1. Prime logs must be 12" D.I.B. & larger on small end with 4 clear sides.
2. Clear logs must be 12" D.I.B. & larger on small end with 3 clear sides.
3. Select logs must be 10" D.I.B. & larger on small end with 2 clear sides.
4. Mill logs must be 10" D.I.B. & larger on small end with 1 clear sides.

Appendix L: Rainelle Mill Log Price List ((all prices per MBF Doyle Rule)



	VENEER			PRIME GRADE				CLEAR GRADE				SELECT		MILL	
Diameter				16" & UP		12-15"		16" & UP		12-15"		16" & UP	12-15"	16" & UP	14-15"
Length	V1	V2	V3	14' - 16'	8' - 12'	14' - 16'	8' - 12'	14' - 16'	8' - 12'	14' - 16'	8' - 12'				
ASH	1000			510	460	430	370	395	345	305	255	235	160	140	110
BASSWOOD				525	475	460	400	430	370	325	250	200	150	125	115
CHERRY	3250			2200	2000	2000	1800	1825	1650	1600	1500	1200	1100	850	800
HARD MAPLE	1800			1500	1300	1300	1100	1150	950	925	825	850	800	500	450
POPLAR				475	400	375	300	375	285	240	200	225	125	100	75
RED OAK	1200			1000	900	800	825	775	700	725	650	600	550	325	275
WHITE OAK	1000			500	400	325	275	300	250	240	175	185	125	100	50
CHESTNUT OAK				400	350	325	275	250	210	200	150	150	100	100	50
SOFT MAPLE				600	500	500	400	450	375	350	290	325	260	250	200
WALNUT	1500			$700 for primes and clears 13" and larger small end diameter								$250 for selects and mills			

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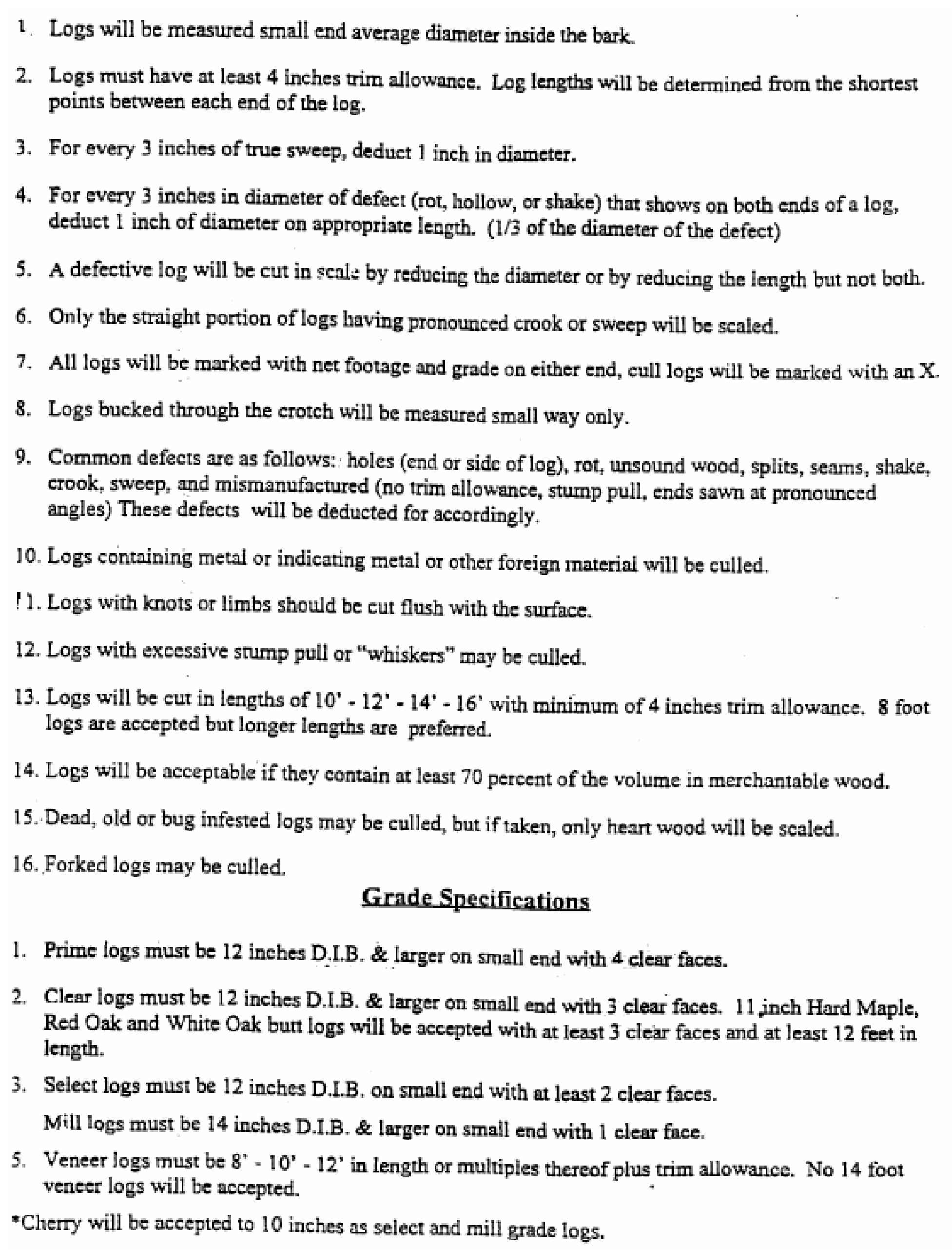
Appendix M: Richwood Mill Specifications



1. Logs will be measured small end average diameter inside the bark.
2. Logs must have at least 4 inches trim allowance. Log lengths will be determined from the shortest points between each end of the log.
3. For every 3 inches of true sweep, deduct 1 inch in diameter.
4. For every 3 inches in diameter of defect (rot, hollow, or shake) that shows on both ends of a log, deduct 1 inch of diameter on appropriate length. (1/3 of the diameter of the defect)
5. A defective log will be cut in scale by reducing the diameter or by reducing the length but not both.
6. Only the straight portion of logs having pronounced crook or sweep will be scaled.
7. All logs will be marked with net footage and grade on either end, cull logs will be marked with an X.
8. Logs bucked through the crotch will be measured small way only.
9. Common defects are as follows: holes (end or side of log), rot, unsound wood, splits, seams, shake, crook, sweep, and mismanufactured (no trim allowance, stump pull, ends sawn at pronounced angles) These defects will be deducted for accordingly.
10. Logs containing metal or indicating metal or other foreign material will be culled.
11. Logs with knots or limbs should be cut flush with the surface.
12. Logs with excessive stump pull or "whiskers" may be culled.
13. Logs will be cut in lengths of 10' - 12' - 14' - 16' with minimum of 4 inches trim allowance. 8 foot logs are accepted but longer lengths are preferred.
14. Logs will be acceptable if they contain at least 70 percent of the volume in merchantable wood.
15. Dead, old or bug infested logs may be culled, but if taken, only heart wood will be scaled.
16. Forked logs may be culled.

Grade Specifications

1. Prime logs must be 12 inches D.I.B. & larger on small end with 4 clear faces.
2. Clear logs must be 12 inches D.I.B. & larger on small end with 3 clear faces. 11 inch Hard Maple, Red Oak and White Oak butt logs will be accepted with at least 3 clear faces and at least 12 feet in length.
3. Select logs must be 12 inches D.I.B. on small end with at least 2 clear faces.

Mill logs must be 14 inches D.I.B. & larger on small end with 1 clear face.

5. Veneer logs must be 8' - 10' - 12' in length or multiples thereof plus trim allowance. No 14 foot veneer logs will be accepted.

*Cherry will be accepted to 10 inches as select and mill grade logs.

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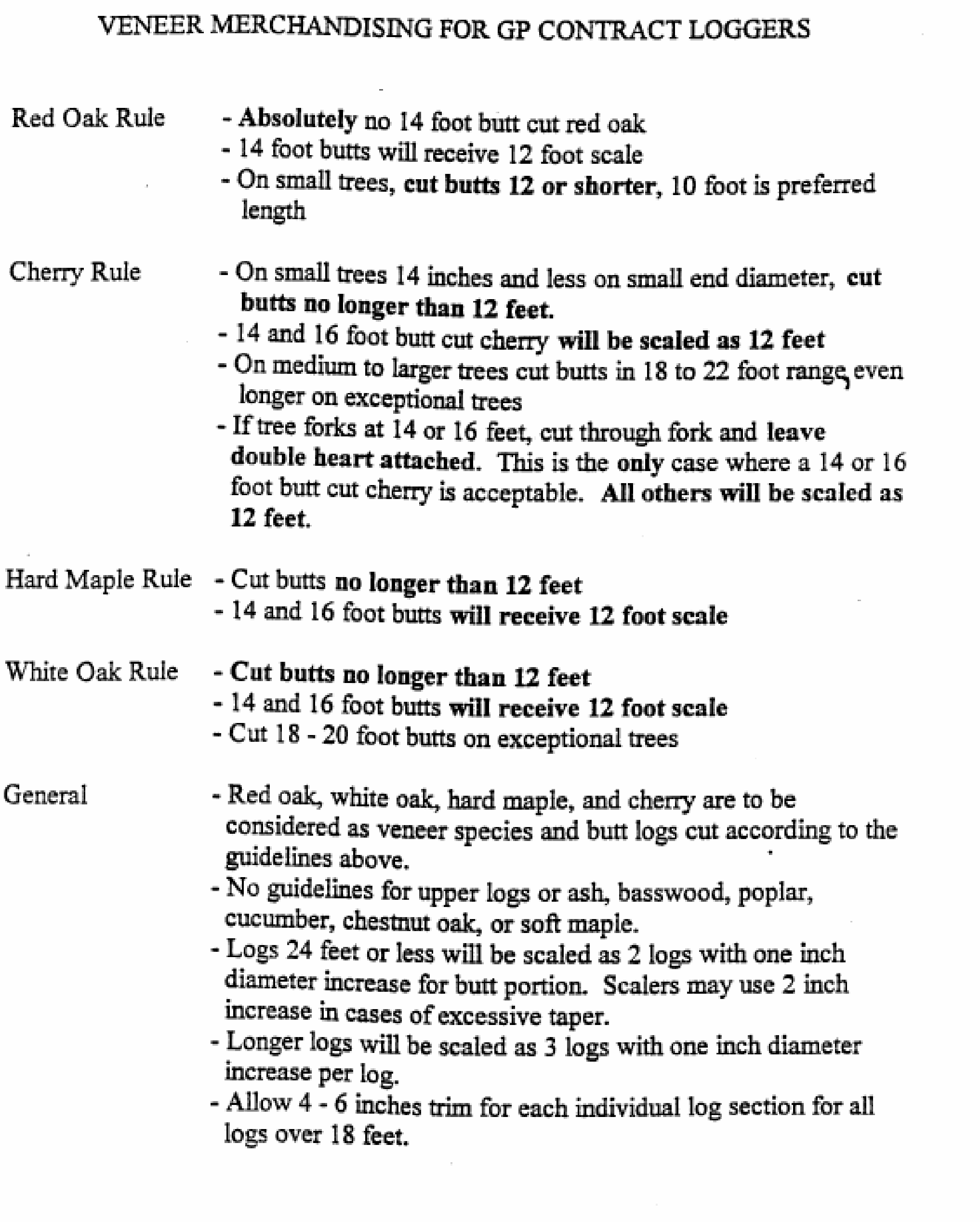
Appendix N: Richwood Mill Veneer Specifications



VENEER MERCHANDISING FOR GP CONTRACT LOGGERS

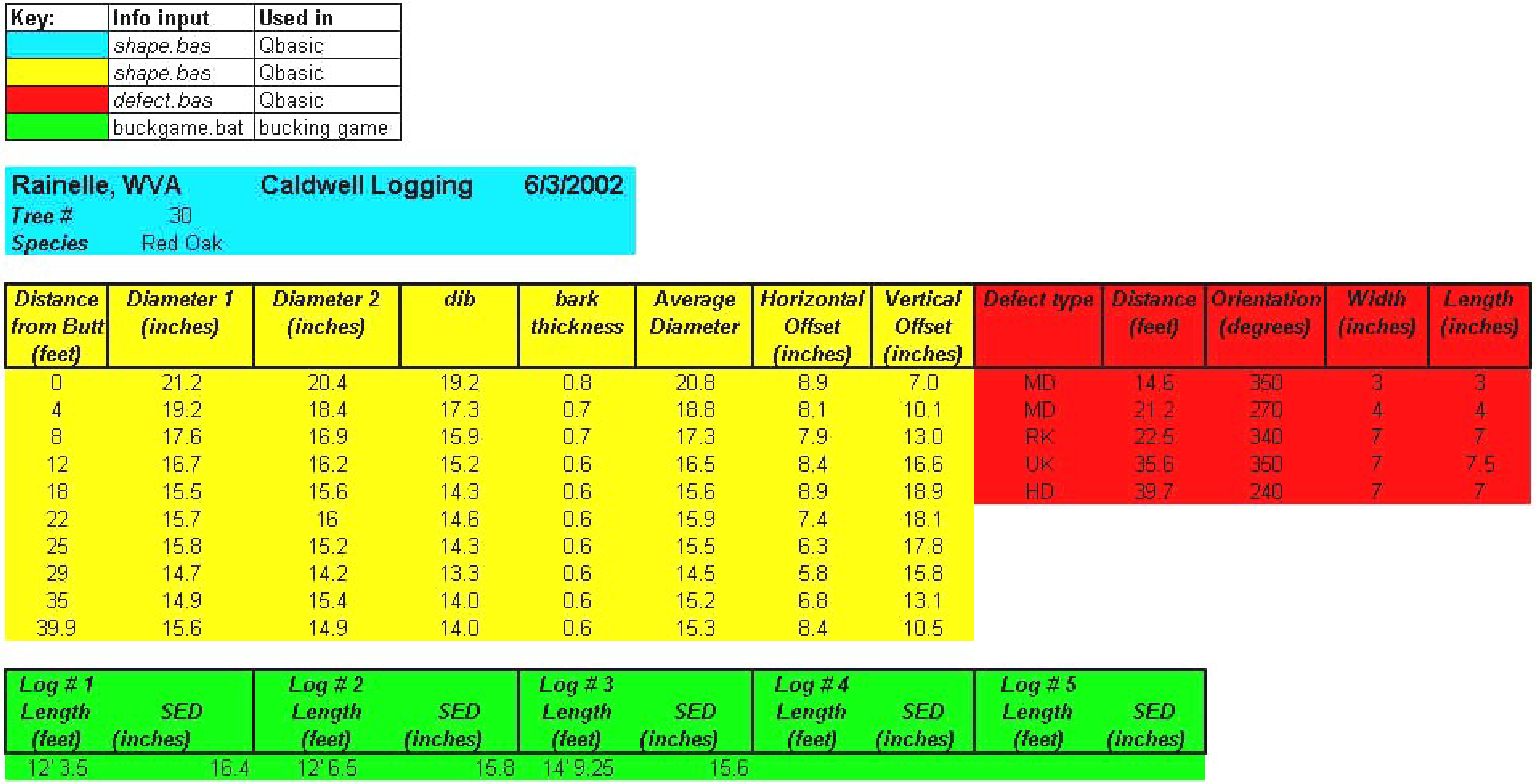
Red Oak Rule	- **Absolutely** no 14 foot butt cut red oak - 14 foot butts will receive 12 foot scale - On small trees, **cut butts 12 or shorter**, 10 foot is preferred length
Cherry Rule	- On small trees 14 inches and less on small end diameter, **cut butts no longer than 12 feet.** - 14 and 16 foot butt cut cherry **will be scaled as 12 feet** - On medium to larger trees cut butts in 18 to 22 foot range, even longer on exceptional trees - If tree forks at 14 or 16 feet, cut through fork and **leave double heart attached.** This is the **only** case where a 14 or 16 foot butt cut cherry is acceptable. **All others will be scaled as 12 feet.**
Hard Maple Rule	- Cut butts **no longer than 12 feet** - 14 and 16 foot butts **will receive 12 foot scale**
White Oak Rule	- **Cut butts no longer than 12 feet** - 14 and 16 foot butts **will receive 12 foot scale** - Cut 18 - 20 foot butts on exceptional trees
General	- Red oak, white oak, hard maple, and cherry are to be considered as veneer species and butt logs cut according to the guidelines above. - No guidelines for upper logs or ash, basswood, poplar, cucumber, chestnut oak, or soft maple. - Logs 24 feet or less will be scaled as 2 logs with one inch diameter increase for butt portion. Scalers may use 2 inch increase in cases of excessive taper. - Longer logs will be scaled as 3 logs with one inch diameter increase per log. - Allow 4 - 6 inches trim for each individual log section for all logs over 18 feet.

Appendix O: Scientific names for common trees measured.

Sugar (Hard) Maple – *Acer saccharum*
Red (Soft) Maple – *Acer rubrum*
Pignut Hickory – *Carya glabra*
American Basswood – *Tilia Americana*
Black Cherry – *Prunus serotina*
Green Ash – *Fraxinus pennsylvanica*
Yellow (Tulip) Poplar – *Liriodendron tulipifera*
Northern Red Oak – *Quercus rubra*
Chestnut Oak – *Quercus prinus*
Scarlet Oak – *Quercus coccinea*
White Oak – *Quercus alba*

Seiler, J.R.and Peterson, J.A. 2002 Dendrology at Virginia Tech [on-line]; available from http://www.cnr.vt.edu/dendro/dendrology/map/wv.htm Internet; accessed 11 August 2002.

Appendix O: An example of the data collection sheet.



Key:	Info input	Used in
🟦	*shape.bas*	Qbasic
🟨	*shape.bas*	Qbasic
🟥	*defect.bas*	Qbasic
🟩	buckgame.bat	bucking game

Rainelle, WVA **Caldwell Logging** **6/3/2002**

Tree # 30

Species Red Oak

Distance from Butt (feet)	*Diameter 1 (inches)*	*Diameter 2 (inches)*	*dib*	*bark thickness*	*Average Diameter*	*Horizontal Offset (inches)*	*Vertical Offset (inches)*
0	21.2	20.4	19.2	0.8	20.8	8.9	7.0
4	19.2	18.4	17.3	0.7	18.8	8.1	10.1
8	17.6	16.9	15.9	0.7	17.3	7.9	13.0
12	16.7	16.2	15.2	0.6	16.5	8.4	16.6
18	15.5	15.6	14.3	0.6	15.6	8.9	18.9
22	15.7	16	14.6	0.6	15.9	7.4	18.1
25	15.8	15.2	14.3	0.6	15.5	6.3	17.8
29	14.7	14.2	13.3	0.6	14.5	5.8	15.8
35	14.9	15.4	14.0	0.6	15.2	6.8	13.1
39.9	15.6	14.9	14.0	0.6	15.3	8.4	10.5

Defect type	*Distance (feet)*	*Orientation (degrees)*	*Width (inches)*	*Length (inches)*
MD	14.6	350	3	3
MD	21.2	270	4	4
RK	22.5	340	7	7
UK	35.6	350	7	7.5
HD	39.7	240	7	7

Log # 1 Length (feet)	*SED (inches)*	*Log # 2 Length (feet)*	*SED (inches)*	*Log # 3 Length (feet)*	*SED (inches)*	*Log # 4 Length (feet)*	*SED (inches)*	*Log # 5 Length (feet)*	*SED (inches)*
12' 3.5	16.4	12' 6.5	15.8	14' 9.25	15.6				

Haynes, H.J.G. 2002. Case Studies in Value Improvement in Hardwood Timber Harvesting Operations in the southern Appalachians. M.S. thesis, Virginia Polytechnic and State University, Blacksburg, Virginia.

APPENDIX P

Defect Code	Defect Type	Defect Description*
AC	Adventitious Bud Cluster	A localized group of adventitious buds, often originating from wounding or bruising of the cambium. Adventitious bud clusters often develop into clusters of short-lived fine twigs; when this happens, a bump usually develops that contains small bark pockets along with the twig knots.
AD	Ant or Bark Scarrer Damage	If a hole has remained open for a period of time, decay fungi can enter. Carpenter ants will then excavate the rotten wood and enlarge the galleries to make their nest cavities. Recent fresh attacks by the bark scarrer appear as open holes about one-quarter inch or less in diameter. They are identified by their round, irregular outline and by their nonpenetration of the wood. The work of the bark scarrer and borers results in a frothy exudation, which turns a dirty brown. Bark scarrer attacks can result in an overgrowth, appearing as a vertical slit with callus area on both sides.
AK	Individual Adventitious Bud	Subnormal buds found at points along the stem. They arise from latent or dormant buds in the leaf axils of the young stem and persist for an indefinite number of years within the cortical-cambial zone. These buds can be activated at any time during the life of the tree in response to various stimuli, leading to the development of an epicormic branch.

B	Bump	A protuberance on the tree or log surface that is overgrown with bark. It may be abrupt with steep surfaces, or it may be a smooth undulation that tapers gradually in all directions to the normal contour of the log. The majority of bumps cover projecting sound or rotten limb stubs, a cluster of adventitious buds, or a concentration of ingrown bark over a scar.
BS	Butt scar	Generally a triangular-shaped break in the bark or wood at the butt end of the first log caused by fire, logging, or other means.
Bu	Bulge	A general enlargement of the stem of a tree or log—a barreling effect—often without an evident cause such as a knot or callus formation. It may be near a branch stub, rotten knot, knothole, wound, or other point of entry for fungi that can cause rot. It usually suggests a cull section, the extent of the rot indicated by the farthest limits of the deformation.
CBPk	Closed Bird Peck	Occluded holes caused by bird attacks that are filled with callus tissue. Holes can appear singularly, linearly, or in groups. Damage usually extends into the wood in the form of bark flecks, callus pockets, and stain spots.

Haynes, H.J.G. 2002. Case Studies in Value Improvement in Hardwood Timber Harvesting Operations in the southern Appalachians. M.S. thesis, Virginia Polytechnic and State University, Blacksburg, Virginia.

CL	Closed Lesion	A relatively localized, spindle-shaped necrotic canker consisting primarily of bark and cambium. A lesion starts as a small area of dead bark resulting from a wound caused by cambium-mining insects, mechanical wounding, fungal diseases, or gnawing of the bark by red squirrels. A spot of gum then appears, and gum continues to ooze through the bark down the trunk, where it hardens and darkens. Healing of the crack results in coarse vertical folds of ingrown bark. A closed lesion shows a prominent rib of callus, folded bark, and abnormal wood projections of the surface of the log.
DK	Dead Knot	Remnant of a branch consisting of all or a part of the stub. The knot consists of dead tissue but shows no presence of decay and may be as hard as the surrounding wood.
DKC	Dead Knot w/ Callous Growth	Remnant of a branch consisting of all or a part of the stub. The knot consists of dead tissue but shows no presence of decay and is covered or surrounded either partially or wholly with callous growth.
Fla	Flange	Triangular, buttress- or wing-like formations projecting from the base of the butt log. Exaggerated projections of the normal stump flare sometimes extend 7 or 8 feet and seem to be related to wetness and softness of site. Flanges occur outside the milling frustrum of the log but have no relation to blemishes in the underlying wood.
GBS	Overgrown Bark Seam	A seam that has healed to the point where a patch of bark is partially or wholly enclosed in the wood.

GD	Grub Damage	A scar in the bark resulting from grub work. Usually a sharp pucker consisting of a pitted core, not over 1/4 inch in diameter, surrounded by callous tissue and distorted bark over an area 3/4 inch to 2 inches in diameter. In severe cases a round "plaster" of callous tissue as large as 3 inches in diameter may occur.
GSS	Overgrown Sound Seam	Longitudinal radial separation of the fibers in a log overgrown with callous tissue and showing no signs of decay. They are usually caused by wind, frost, or lightening.
GSU	Overgrown Unsound Seam	Longitudinal radial separation of the fibers in a log overgrown with callous tissue but has decay beneath and possibly to the sides of the callous. They are usually caused by wind, frost, or lightening.
HD	Heavy Bark Distortion	An indicator of an overgrown knot identified by the characteristic pattern of concentric circles encompassing the defect indicator. Bark distortions differ from "overgrown knots" in that there is no height associated with the indicator.
KCl	Knot Cluster	Two or more knots or branches growing in a more or less inseparable group and usually elevated above the normal surface.

LD	Light Bark Distortion	An indicator of an overgrown knot identified by the characteristic pattern of concentric circles encompassing the defect indicator. Light distortions show only a slight amount of curvature in the surrounding bark plates, and the bark pattern shows only slight variance from normal. Since the internal knots associated with light bark distortions are usually buried deep within the log, it is not considered a grading defect in factory-grade logs. Bark distortions differ from "overgrown knots" in that there is no height associated with the indicator.
MD	Medium Bark Distortion	An indicator of an overgrown knot identified by the characteristic pattern of concentric circles encompassing the defect indicator. Medium distortions show signs of the concentric circles, but the circles are broken in several areas by the normal bark pattern starting to reform. Bark distortions differ from "overgrown knots" in that there is no height associated with the indicator.
MH	Medium Hole	Unoccluded openings in the bark, 3/16 to 1/2 inch in diameter, which sometimes penetrate into the wood beneath. They include entrance and emergence holes of wood-boring insects, increment-borer and tap holes, and openings made by sapsuckers.
OBPk	Open Bird Peck	Unoccluded openings in the bark caused by bird attacks. Generally, the holes show no signs of callus tissue formation. Open bird peck is an indication of a recent attack and usually doesn't affect the underlying wood.

OK	Overgrown Knot	A knot that has been completely overgrown but is clearly outlined by circular or other configurations in the bark. Overgrown knots differ from bark distortions in that there is an obvious height attribute of the defect when compared to the normal log surface.
OKC	Overgrown Knot w/ Callous Growth	A knot that has been completely overgrown but is clearly outlined by circular or other configurations in the bark. The knot is covered or surrounded either partially or wholly with callous growth.
OKCl	Overgrown Knot Cluster	Two or more overgrown knots growing in a more or less inseparable group.
Op	Operational Defect	Cracks, splits, brooming, splinter pull, "barber chair", holes, etc., that result from felling, skidding, or loading.
Oss	Open sound Seam	Longitudinal radial separation of the fibers in a log with no evidence of callous tissue or decay. They are usually caused by wind, frost, or lightening.
R	Rot	Advanced decay, not identifiable with a knot or branch.
RK	Rotten Knot	A knot where advanced decay is present and extends beyond the area of the limb stub.
RKC	Rotten Knot w/ Callous Growth	A rotten knot covered or surrounded either partially or wholly with callous growth. Advanced decay is present and extends beyond the area of the limb stub.

SK	Sound Knot	Remnant of a branch consisting of all or a part of the stub. The knot shows no indication of decay and is as hard as the surrounding wood.
SKC	Sound Knot w/ Callous Growth	Sound knot covered or surrounded either partially or wholly with callous growth. The knot shows no indication of decay and is as hard as the surrounding wood.
SW	Sound Wound	Damage to the stem due to natural causes such as a limb falling against another tree or from logging. The wood underneath is sound and callous overgrowth may be open or closed or any degree of coverage of the wound.
UK	Unsound Knot	Remnant of a branch consisting of all or a part of the stub. The knot shows presence of decay and is not as hard as the surrounding wood. The amount of decay is normally confined to the limb stub.
UKC	Unsound Knot w/ Callous Growth	Unsound knot covered or surrounded either partially or wholly with callous growth. The knot shows presence of decay and is not as hard as the surrounding wood. The amount of decay is normally confined to the limb stub.

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*Defect descriptions taken from; Carpenter, R., D. Sonderman, E. Rast and M. Jones. 1989. Defects in hardwood timber. USDA Forest Service Agriculture Handbook No. 678, Washington, DC.; Rast, E. 1982. Photographic guide of selected external defect indicators and associated internal defects in northern red oak. USDA Forest Service Research Paper NE-511, Broomall, PA.; and Bulgrin, E. Circa 1960. Manual of standard procedures for diagramming hardwood trees and primary products. USDA Forest Service Internal Document.