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Economic Assessment of Using a Mobile Micromill® for Processing Small-Diameter Ponderosa Pine

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Abstract

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An economic assessment of an SLP5000 Diesel Micromill® was conducted to determine the maintenance and operation costs and the logistics of a mobile sawmill used to process small-diameter ponderosa pine. The Micromill® was first introduced in 1997 and has since received considerable attention. In 2003, the USDA Forest Service, Pacific Northwest Research Station conducted a detailed financial analysis of a Micromill® in Escalante, Utah. Productive and nonproductive time was recorded, and the feasibility and logistics of periodically moving the mill closer to the raw material source were assessed in terms of delivered log costs and mobilization costs. Product volume and grade recovery were collected to examine market options. Results of the analysis indicate that cashflow, support equipment, delivered log costs, and product markets significantly affect the financial viability of a mobile Micromill® enterprise.

Keywords: Small-diameter ponderosa pine utilization (Southwest), economic assessment, small-log mobile processing.

Contents

Introduction

Current wood markets limit the economic feasibility of both purchasing and hauling small-diameter ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) to existing sawmills in the Western United States owing to the low value and low recovery of merchantable products from the resource. Previous efforts to use small-diameter ponderosa pine have been successful because of favorable pulpwood markets and an ability to offset costs with the processing of larger diameter trees (greater than 12 in diameter at breast height [d.b.h.]). Presently, markets for pulpwood in the West are scarce, and the ability to offset harvesting and hauling costs with large-diameter trees is limited by reductions in timber harvests from the national forests (Haynes and Fight 2004). This, combined with years of fire suppression, has left an overabundance of small-diameter ponderosa pine (12 in d.b.h. or smaller) in the Southwest (Covington and Moore 1994). The need to identify and invest in endeavors that offset the cost of harvesting and processing this small-diameter material is underscored by increased threats of catastrophic wildfire brought on by recent drought conditions and outbreaks of insects and diseases in the region.

The Micromill® is one example of small-diameter wood-processing technology receiving attention. To facilitate sound investment in processing technology, an economic assessment was conducted on the SLP5000 Diesel Micromill® (hereafter Micromill) to identify major costs, operational barriers, and market opportunities for processed material.[1] The Micromill is a 300-horsepower dimension sawmill capable of processing 4- to 20-ft logs with a maximum large-end diameter (outside bark) of 13 in and a minimum small-end diameter (outside bark) of 4 in. Designed to cut about 850,000 to 3,500,000 ft^3 per year, depending on tree species and desired product, the mill produces four-sided cants, rough-cut lumber, and chips in a single-pass, automatic-feed system (fig. 1). The diesel model is built in a standard-sized shipping container to facilitate mobility (fig. 2). The operation is independent of utilities and major infrastructure, which allows it to be located to take advantage of temporary opportunities for fiber such as in insect-damaged and -killed stands, burned areas, and thinning operations. The mill is also suited to operate as a satellite to a large mill by processing logs into finished products or into cants for further processing. Various lumber sizes and cutting patterns can be achieved with the basic configuration (Micromill Systems 2003).

The Micromill®, a 300-horsepower dimension sawmill capable of processing 4- to 20-ft logs with a maximum large-end diameter (outside bark) of 13 in and a minimum small-end diameter (outside bark) of 4 in is one example of small-diameter wood-processing technology.

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

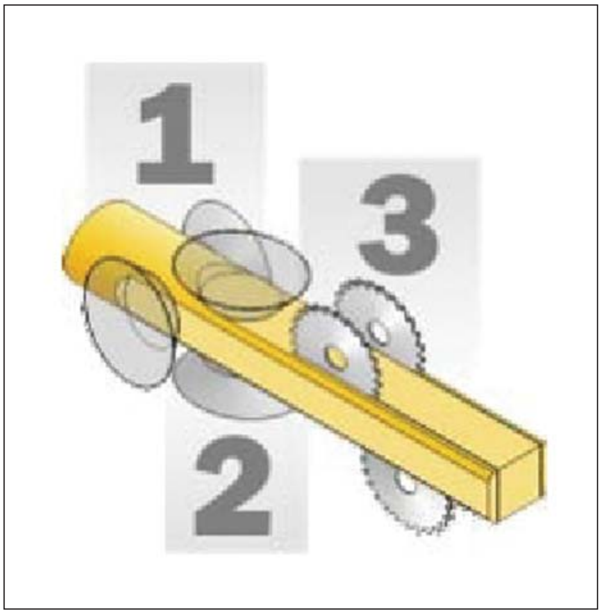

Figure 1—One-pass system of Micromill log processing (Illustration courtesy of Micromill Systems, Inc.).

Figure 2—SLP5000 Diesel Micromill® processing small-diameter ponderosa pine (Photo by Dean Parry).

Mobile Processing of Small-Diameter Logs

In many regions of the Western United States, the costs associated with the transport of small raw logs are prohibitive because of diminished solid wood and biomass processing capacity necessitating long haul distances to manufacturing facilities (Han et al. 2002, Keegan et al. 2001, Lynch 2001, USDA Forest Service 2003). Finding suitable markets for small-diameter logs is further complicated by physical characteristics and product suitability of such wood (Spelter et al. 1996). In the Southwest, for instance, small-diameter ponderosa pine is characterized by suppressed growth with reduced strength properties (Larson and Mirth 1999) and poor drying characteristics (Argenbright et al. 1978, Simpson and Green 2001, Voorhies and Blake 1981) making it a poor choice for production of dimension lumber where strength is key. The ability to develop value-added products by using small-diameter ponderosa pine is in part contingent on the ability of finished products to compete in the marketplace. Transportation and processing costs need to be minimized to make processing small-diameter logs more competitive.

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The capacity and technology to efficiently process small-diameter logs is highly variable in the Western United States. In some regions, new processing technology to handle large volumes of small logs exists. In other regions, like the Southwest, manufacturing facilities are few, making the costs associated with transporting small logs to existing facilities significant and often cost prohibitive. Mobile processing technology is one option to reduce transportation costs. The Micromill in particular, provides a low-cost alternative to capital-intensive investments associated with stationary, small-log processing mills. Mobile processing technology allows for flexibility where the availability of resource supply is inconsistent, unreliable, or where the cost of transporting logs to a stationary mill is cost prohibitive. Integrating mobile processing operations with quality end products can potentially offset the associated costs of harvesting, processing, and handling products made from small-diameter ponderosa pine (fig. 3). It also has the potential to address the growing need to economically remove an abundance of small-diameter trees from Western forests and thereby reduce the risk of catastrophic wildfire.

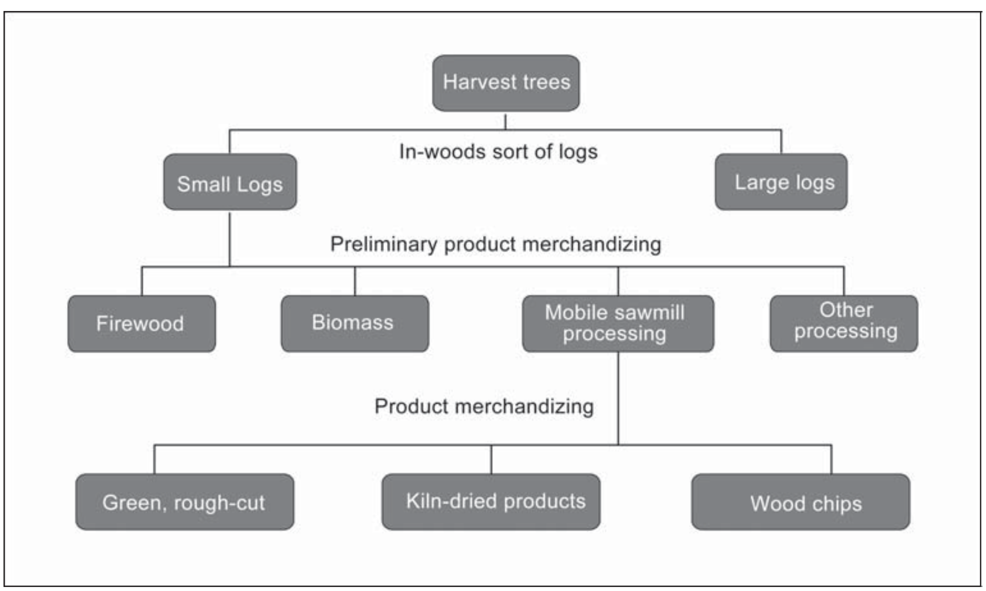

Figure 3—Vertical integration of mobile sawmill product options.

Factors to consider when investing in mobile processing include mill specific-ations, resource characteristics, and harvest systems.

There are several factors to consider when investing in a mobile processing operation. This study organizes them into three categories: mill specifications, resource characteristics, and harvest systems. Mill specifications include common considerations like price, daily production rates, saw speed, operation and maintenance costs, and transportability (Bratkovich 2003). Less obvious but important considerations are resource characteristics. Barbour and colleagues (Barbour et al. 2003, Lowell and Barbour 2002) cite the physical characteristics of the forest resource as one of the fundamental determinants of product application in the utilization of small-diameter ponderosa pine. For instance, tree height, growth rate, knot size and number, and other physical traits dictate the product markets available to the producer. Therefore, unless products are being produced for personal use, producers will need to understand current and expected retail and wholesale markets. Harvest systems are another less obvious but important consideration. Distance to the resource base, harvest season and operability, required log inventory, projected harvest volumes and management prescriptions, and other constraints such as contract specifications and log measurements influence profitability of a mobile operation (Swan 2003). Each factor influences decisions about the types of processing options feasible. Mill specifications, resource characteristics, and harvest systems are all addressed in the following analyses.

Project Description

Several manufacturers build mobile mills that process small-diameter logs, including but not limited to, Scragg®, Wood-Mizer®, Mobile Dimension®, TimberKing®, and Economizer® (earlier version of the current Micromill). These systems use band, swing, or circular saws and are made for the individual craftsman and part-time logger or for commercial production. The Micromill was chosen for this analysis because of ongoing research by the authors on volume and grade recovery from small-diameter ponderosa pine in northern Arizona processed by using an SLP5000D Micromill. In that research, logs were shipped to Skyline Forest Resources in Escalante, Utah, who purchased a Micromill in 2001 with financial assistance from community partners and grants from the USDA Forest Service. The Micromill has since received considerable attention in the Southwest for its ability to efficiently process small-diameter logs. As a result of this research and interest in monitoring financial investments, community partners requested an expanded analysis of the Micromill operation. Community partners include the Greater Flagstaff Forests Partnership, Escalante Heritage Center, Forest Trust, and Four-Corners Sustainable Forests Partnership.

Initially, funding was provided by the Joint Fire Science Program as part of the National Fire Plan to evaluate opportunities to lower costs of fire-risk-reduction treatments. With this funding, the USDA Forest Service, Pacific Northwest (PNW) Research Station was able to assess the economics of the Micromill given different markets, mobility, and resource characteristics. Community partners were most interested in the financial, technical, and logistical aspects of a mobile Micromill for processing small-diameter ponderosa pine in the Four-Corners region of Utah, Arizona, New Mexico, and Colorado. Financial considerations include capital investment, cashflow, operation and maintenance costs, labor, delivered log costs, and product markets. Technical considerations include raw material requirements and volume and grade recovery of processed lumber. Logistical considerations include mill siting, transportation costs, residue handling, and related issues. At the request of community partners, the following questions were assessed:

- What are the fixed and variable costs associated with using a mobile Micromill system?
- What are the break-even points in terms of production volumes and markets for a mobile Micromill processing system to be economically feasible?
- Which costs most affect the economic viability of a mobile Micromill system?
- Which solid wood and biomass products are economically feasible for mobile Micromill processing?
- What technical and logistical strategies are necessary to support production of selected finished products?

The purpose of this study is to provide individuals, community partners, and businesses with an analysis of Micromill operations to facilitate sound investment in small-diameter wood processing capability. Detailed analyses are provided for different scenarios selected to represent current market options for small-diameter ponderosa pine in the Four-Corners region. Market scenarios, investment costs, and operations costs are subject to change. Variability also exists in resource supply, access, and contracting specifications within treatment prescriptions that will affect profitability. It is the responsibility of those seeking to invest in a Micromill enterprise to conduct an independent evaluation of logistics and economic feasibility (a business plan) based on their unique situation.

Method

Data were collected from various sources, both primary and secondary in nature. Primary data were obtained from Micromill Systems, Inc., representatives, owners, and operators of Micromill operations. Information was collected by observing milling operations, conducting owner/operator interviews, reviewing of maintenance and operations records, and through phone and email correspondence. Secondary data included information from the PNW Research Station, the Greater Flagstaff Forests Partnership, and from other technical, peer-reviewed, and independent reports. Such reports facilitated the identification of information on mill site preparation, product recovery, markets, and other variables of interest.

Multiple observational trips were taken to the existing Micromill operation in Escalante, Utah. Skyline Forest Resources acquired the Micromill in 2001 as a satellite mill to their conventional sawmill to more efficiently process small-diameter logs. Productivity rates were observed for ponderosa pine. Product volume and grade recovery also were measured. The following are specifications of the Micromill system as analyzed for this study:

Mill specifications	**Micromill model SLP5000D**
Description	Dimension, single pass
Base price (2003 U.S. dollars)	$392,000
Processing capacity:	
Log length	4 to 20 ft
Log diameter	4 to 13 in
Production capacity[2]	3,250 board feet/hour (softwood)
Number of employees for operations	3 to 4
Kerf [3]	.161 in

A “least-cost” approach was utilized. The least-cost approach involves analyzing several scenarios that could be used to achieve desired objectives and choosing the scenario with the least cost incurred. Scenarios were selected based on observations of existing Micromill operations and included the range of likely fixed and variable costs, and market conditions in the Four-Corners region. Fixed costs included the purchase and financing of an SLP5000D Micromill, optional attachments, and support equipment. Other fixed costs include taxes, interest, opportunity costs, maintenance, and insurance. Variable costs assessed included those associated with the operation and maintenance of a Micromill and its support equipment, labor requirements, fuel consumption, mobilization costs and setup, and costs of delivering and sorting raw logs.

[2] Production rates will differ depending on species of wood, length, diameter of logs, and product specifications. Reported rate is from manufacturer specifications of board feet processed per hour and do not include scheduled time for breaks and cleanup. Capacity is shown for test runs of 6-in logs (outside bark at large end) for square cants 4-in in size.

[3] Kerf is the width of a saw cut.

An assessment of market options, market returns, and product volume and grade recovery for small-diameter ponderosa pine is used to determine break-even points and overall economic feasibility. An attempt was made to provide an accurate assessment of economic return (income) in the Four-Corners region. Owing to the variability in markets, however, exact investment returns cannot be precisely measured. Therefore, the following assumptions were used to guide the overall analysis; specific assumptions are presented in each of the subsequent sections to develop detailed cost estimates:

- Analyses are based on a consistent, available supply of timber resources.
- Cost analyses are based on the ability to secure financing at the expressed rate.
- Support equipment will be required for mobile processing in addition to investment and operations costs for the Micromill.
- Labor requirements assume the local availability of skilled personnel.
- Economic returns are assessed for existing product markets by using small-diameter ponderosa pine in the Four-Corners region.

Fixed Costs

Financing—Micromill

Assumption—

Financing costs are necessary to determine required monthly and annual cashflow and to estimate economic return on investments. In addition to the initial purchase of the Micromill SLP5000D, investment is required for optional equipment attachments for processing large volumes of ponderosa pine. Attachments and upgrades available from Micromill Systems, Inc., include a 300-horsepower diesel engine, heavy-duty log infeed, high-pressure hydraulic filter, engine block heater for winter operations, and knife- and saw-sharpening system. Sales tax, freight costs, setup costs, and interest also are included in the analysis. Assumptions used to calculate mill financing include:

- Cost estimates are based on 2003 U.S. dollars.
- Interest rates are based on average 2003 rates.
- Financing is based on a 7-year (84-month) financing term.
- Investors are able to secure financing at the identified rate.

Costs—

Based on the above assumptions, the following tabulation provides a breakdown of the costs associated with purchasing and financing a Micromill operation. Additional considerations for the purchase of support equipment, such as forklift and front-end tractor-loader are addressed in a subsequent section. Financing costs for the SLP5000D Micromill are as follows:

Financing item	Cost
	Dollars
Total equipment package (2003 U.S. dollars)[4]	426,185
Sales tax at 0 percent	0
Mill delivery, setup, and training	7,000
Total delivered equipment price	433,185
Downpayment (30 percent)	129,956
Financed amount	303,230
Monthly payment (84-month term at 7-percent interest)	5,884
Annual financing cost	70,609

Key issues—

The tabulation above provides the costs of equipment as of September 2003 and is based on the purchase, delivery, setup, and training costs reported by Micromill Systems, Inc. Based on a 7-year financing term and a 30-percent downpayment, annual financing costs total $70,609. Capital outlay of approximately $130,000 is required in year 1 for downpayment costs. Investors may require a different equipment package resulting in different financing costs. Flexibility exists in choosing optional attachments and upgrades for specific locales and operations.

Financing–Support Equipment

Assumption—

In addition to the purchase of the mill, support equipment is required for log sorting and handling of cants and finished products. The least-cost approach assumes the purchase or lease of one small tractor-loader capable of handling logs up to 20 ft long and 13 in in diameter on the large end (outside bark). The tractor-loader also will be used for site preparation and cleanup. A 15,000-lb capacity forklift is used to handle cants. The forklift will move pallets of cants, load finished products, and provide support in moving equipment and site cleanup during mill relocation. One heavy-duty maintenance pickup truck with a commercial toolbox and fuel tank is also required to transport fuel, house tools, and provide transportation to and from the worksite for employees. In addition, a chain saw, storage bins

[4] Optional equipment for the Micromill SLP5000D includes a 300-horsepower diesel engine, heavy-duty log infeed, high-pressure hydraulic filter, 130-gal fuel tank, basic tools and cabinet, engine block heater, and Micromill knife- and saw-sharpening system.

to stack processed cants, and other small tools are required for routine operation and maintenance. The system as analyzed does not include a debarker used to remove bark, which can then be used for landscaping and related products.

Costs—

Financed amounts for support equipment reflect used equipment purchase prices as reported for the 2003 third quarter in the Green Book (PRIMEDIA 2003). Other support equipment not included in this analysis but required of contractors includes:

- Self-loading semi-trucks for log delivery and unloading.
- Chip vans and semi-truck for removal of sawdust and chips.
- Semi-trucks for finished product pickup and delivery.

The availability of independent contractors to accomplish these tasks is assumed adequate. Inability of contractors to provide self-loading log trucks would require additional investment in a large front-end tractor-loader capable of unloading log trucks.

Key issues—

Table 1 provides the costs of used support equipment as of fall 2003. Based on a 60-month financing term and a downpayment of 30 percent for the given equipment package, annual financing costs will exceed $16,000. The decision to purchase new equipment or to purchase a different equipment set could significantly affect annual financing costs. In addition, financing costs are significantly affected by the loan term and qualifying interest rate. Actual rates may be greater.

The least-cost approach assumed the use of a small tractor-loader for log sorting and other tasks as necessary. However, it may be feasible to purchase equipment designed specifically for log sorting. Log-sorting equipment will significantly increase investment costs but can lead to increased mill productivity. Increased productivity is achieved by more efficient and consistent sorting of similar-sized logs resulting in improved merchandizing of finished products (Dramm et al. 2002). Over time, the addition of appropriate log-sorting equipment may improve return on investment, but it also may complicate mobile processing.

A variety of equipment packages may be used in support of Micromill operations. If the mill is located as a satellite to a larger mill, it may not be necessary to purchase additional equipment. However, mobile processing will require substantial investment in support equipment in addition to the mill itself. The choice of equipment, purchase price, taxes, and financing will significantly affect profitability.

Table 1–Costs associated with financing support equipment purchased used

Financing item	Tractor-loader[a]	Forklift[b]	Maintenance vehicle[c]	Other equipment[d]
		Dollars		
Total equipment package[e]	20,000	40,000	15,000	1,792
Sales tax at 7.5 percent	1,500	3,000	1,125	134
Downpayment (30 percent)	6,450	12,900	4,838	0
Financed amount	15,050	30,100	11,287	0
Monthly payment[f]	356	711	267	0
Annual financing cost	4,267	8,534	3,200	0

[a] One 65-horsepower tractor-loader with front-end bucket and grapple fork attachments.
[b] One 15,000-lb capacity forklift.
[c] One 2-ton pickup truck with maintenance toolbox and 100-gallon-storage fuel tank.
[d] Other required equipment includes one new chainsaw, two cant stackers for finished products, stickers for air-drying, and one storage bin for wood slats.
[e] Equipment costs based on U.S. dollars as of September 2003.
[f] Based on a 60-month term at 7-percent interest.

Mill Siting

Assumptions—

The geographic location of the Micromill is contingent upon several factors related to transportation distance from the raw material source, cost of private or public lease of the mill site, surfacing requirements, and physical barriers to log and finished product storage. To minimize costs associated with mobilizing the mill to a new location and associated lost production time, the least-cost approach assumes the mill to be sited in a centralized location near the source of raw material but not actually on the site of active logging. The maximum cost-effective distance of the Micromill to the raw material source is highly dependent upon existing market conditions, log supply, and delivered log costs. With approximately 50 percent of small-log processing costs incurred in transportation and handling (Lynch 2001), break-even analysis for saw logs between 5- and 12-in d.b.h. is often considered less than 60 mi (Han et al. 2002). In cases where the mill will be stationary for an entire harvest season, year-around site access is necessary for finished-product and residual-waste handling. Other site requirements include:

The maximum cost-effective distance of the Micromill to the raw material source is highly dependent upon existing market conditions, log supply, and delivered log costs.

- A minimum of 3 acres for the mill site with secondary road access.
- Space for raw log delivery, storage, truck turnaround, and finished products.
- Adequate water drainage and site surfacing for periods of inclement weather.
- A minimum of a 20- by 30-ft by 4-in concrete slab with anchors for the mill sawbox.

- A minimum of a 5- by 20-ft by 4-in concrete slab with anchors for raw log infeed.
- A 4-in thick concrete slab (approximately 9 yd^3 total).

Cinder and rock pits on state and federal forest lands in the Four-Corners region often provide adequate space and proximity to the raw material source for mill siting. The availability of these and other sites is dependent upon associated laws and regulations regarding temporary facilities and use on public lands. Private industrial sites are also likely to provide many suitable locations.

Costs—

Based on the above assumptions, the following tabulation provides a breakdown of the costs associated with mill siting. Additional considerations of move-in and setup costs are addressed in a subsequent section. Specific costs for site preparation, road access, and cleanup are site-dependent. These cost considerations are included here, but no specific amounts are given:

Siting items	Site location
Concrete surfacing	• $3,000 (9 yd^3 of concrete required for a 20- by 30-ft and 5- by 20-ft, 4-in thick slab delivered within 50 mi of supplier; includes construction labor costs)
Site lease	• Cost of site lease will differ depending on landowner, acreage, and duration of lease
Road access	• Secondary road access • Culverts • Road surfacing
Site preparation	• Water drainage • Site leveling and surfacing for seasonal conditions • Raw log and finished product storage space
Water and dust abatement	• Site surfacing • Stream course protection
Site cleanup	• Concrete slab removal • Waste wood removal; cut for firewood and given away • Residual sawdust not collected for chips used in site reclamation or hauled to landfill
Total annual site cost	• Dependent on public or private landowner, acreage, and lease duration

Key issues—

The cost of the Micromill siting is a one-time cost incurred each time the mill is relocated. Additional costs related to site lease, road access, site preparation, water and dust abatement, and site cleanup may be incurred depending on the duration of site use and site-dependent characteristics. Cashflow requirements will include monthly site lease, capital outlay for construction of concrete slabs, and other site improvements as necessary.

Costs are based on the experience of existing Micromill owners. Depending on the location of mill siting, lease costs may be minimal. For example, it may be feasible to assume that the short-term siting of a mill on state or federal lands will not require a site lease. Alternatively, the lease of private industrial lands may require substantial investment depending on the duration of the site lease.

The lease and preparation of the mill site is an important consideration in the economic viability of a mobile Micromill operation. Although capital outlay and cashflow considerations are minor in relation to overall mill operations, distance from the Micromill site to available sources of raw material and ability to access and use the site during periods of inclement weather will significantly affect productivity and ultimately, profitability. Delivered log costs will be prohibitive if the location is too far from available resources. Periods of inclement weather will affect the number of productive machine hours in a given year if the location cannot accommodate incoming log trucks and outgoing delivery trucks and chip vans.

Variable Costs

Operation and Maintenance—Micromill

Assumptions—

Operating costs assessed for the Micromill system entail a broad range of considerations. Maintenance of mill saw knives and blades, sawdust blower, in-feed and out-feed decks, and diesel engine components is included. Operating costs related to fuel and oil consumption, insurance and taxes, and equipment replacement are assessed based on annual scheduled machine hours (SMHs). Also included are annual investment costs of depreciation, salvage value amortized over the life of the equipment, and opportunity cost.

Annual machine hours scheduled for the Micromill system are conservatively assumed to be 1,600 hours, or about 9.5 months operation (40-hour workweek, 21 working days/month) for the Four-Corners area to account for seasonal operations restrictions because of inclement weather (snow, monsoon rains) and periodic fire closures of the forests. Periodic disruptions in operations are also likely for major breakdowns and diminished log supply. It is assumed that the actual utilization rate of the machinery during these 1,600 hours will be no more than 75 percent to account for scheduled downtime for routine maintenance, cleanup, breaks, and resetting of saws. The resulting 1,200 hours are used to calculate total productivity (productive machine hours or PMH) and expected rates of return on investment.

Costs—

Based on the above assumptions, the following tabulation provides a breakdown of operation and maintenance costs associated with the SLP5000D Micromill. Sources of information for these figures were derived from manufacturer specifications (Micromill Systems 2003) and operation and maintenance records from Skyline Forests Resources. Additional cost considerations for support equipment are addressed in the following section. Annual operation and maintenance costs of the Micromill include:

Operation and maintenance cost items	**Unit cost**
	Dollars
Annual depreciation[5]	44,800
Opportunity costs (8-percent interest on money invested)	20,608
Insurance and taxes	15,064
Maintenance and repairs[6]	44,800
Fuel consumption	14,580
Lube, oil, and filters	5,395
Knives and saws	5,229
Total annual operation and maintenance cost	150,476

Key issues—

The annual cost of operation and maintenance for the Micromill is highly dependent upon the number of PMH each year. More hours increase maintenance and repair costs, fuel and oil consumption, and the rate at which chip knives and saw blades require sharpening and replacement. However, an increase in PMH also increases annual productivity, which will decrease the relative cost of depreciation, insurance and taxes, and the opportunity cost of money invested. Return on investment will therefore be greater with an increase in PMH.

[5] Straight-line depreciation based on a 20-percent salvage value amortized over the economic life (7 years) of the equipment.

[6] Maintenance and repair costs equal 100 percent of annual depreciation for economic life of equipment.

Productive machine hours can be increased in several ways. Simply scheduling more operating time per year will increase productive hours if there is an adequate supply of raw material and unscheduled downtime is minimal. Unscheduled time for inclement weather or natural occurrences such as forest fires is unavoidable in the Four-Corners region. Unscheduled time for maintenance and repairs can be minimized with routine preventative maintenance and adequate training of personnel. Furthermore, PMH can be increased, or at least held constant, if a continual inventory of logs is presorted and ready for processing. Logs are generally sorted into two to four size classes for the Micromill operation. Sorting based on product merchandizing allows for maximum lumber recovery and minimal time spent changing saw configuration. Onsite sorting for product merchandizing is addressed in the following section on support equipment. The cost of in-woods sorting by logging contractors is addressed in a subsequent section on delivered log costs.

The number of productive machine hours will not only significantly affect operation and maintenance costs but will also determine the annual investment costs and ultimate mill profitability. To maximize the number of productive hours for each scheduled period of operation, it is imperative that mill owners and operators have a good understanding of how to process different tree species and have the ability to maximize product potential from each size of log with given characteristics such as taper or amount of defect. Owners and operators will need to adjust their schedules and PMH according to their unique circumstances.

Operation and Maintenance—Support Equipment

Assumptions—

In addition to the operation and maintenance of the mill itself, various support equipment is necessary for efficient processing. As previously identified, the least-cost approach assumes the purchase of one small tractor-loader, forklift, heavy-duty maintenance vehicle, and associated small equipment. Like operation and maintenance costs for the Micromill, costs for the tractor-loader, forklift, and maintenance vehicle are based on fuel and oil consumption, insurance and taxes, and equipment replacement. Also included are annual investment costs of depreciation, salvage value amortized over the life of the equipment, and opportunity cost.

Annual machine hours scheduled for support equipment are assumed to be 1,600 hours based on a 40-hour workweek. The PMH of support equipment will differ depending on the function of each piece of machinery. It is assumed that the 65-horsepower tractor-loader will be productively used for 1,200 hours per year, or whenever the Micromill is in operation. Based on observations of the Skyline

Forests Resources mill, the forklift and maintenance vehicle will be used less often at a rate of approximately 800 and 400 PMH, respectively; the chain saw will be used for approximately 240 PMH.

Costs—

Based on the above scenario, table 2 provides a breakdown of operation and maintenance costs associated with the identified equipment. Sources of information for these figures are the 2003 third quarter in the Green Book (PRIMEDIA 2003), manufacturer specifications, and equipment productivity studies collected by Fight et al. (2003).

Key issues—

Interviews with existing Micromill owners revealed that log sorting is a significant issue for the production efficiency of the mill. Log sorting can be divided into two steps. The first entails a preliminary in-woods sort by logging contractors where logs are placed into size classes; large logs (generally >12-in outside bark, large end) are grouped for non-Micromill utilization, and small logs (generally ≤12-in outside bark, large end) are sorted for Micromill processing. The second step entails a small-end sort to remove logs with significant taper and a high proportion of defect. The remaining merchantable logs are sorted into two to four size classes depending on available markets and desired products.

The cost of in-woods sorting by logging contractors is addressed in a subsequent section on delivered raw log costs. The cost of secondary sorts for product merchandizing is included in table 2 to the extent that the tractor-loader is used for manual sorting of logs. Assuming 1,200 PMH, the tractor-loader will sort delivered small logs into relevant size classes prior to positioning them on the raw log in-feed chain for processing. Depending on the volume and rate of logs received, more or less time may be required for secondary sorting.

Annual PMH for the tractor-loader, forklift, and other support equipment is based on general assumptions provided by mill owners and is subject to change based on individual circumstances of production rate, raw log volume, distance to site, and operator proficiency. They are provided to identify key input costs associated with Micromill processing but should not be used as the sole basis for detailed business planning.

Contrary to the operation of the Micromill, it is most cost efficient to minimize PMH for all support equipment. Proficiency in operating the loader for log sorting and the forklift to handle cants is critical. Other methods of secondary log sorting are also possible, particularly when the Micromill is used as a satellite processor to

Table 2–Annual operation and maintenance costs of support equipment

Operation and maintenance cost items	Tractor-loader	Forklift	Maintenance vehicle	Chain saw
	Dollars			
Annual depreciation[a]	3,200	6,400	2,400	0
Opportunity costs[b]	1,088	2,176	816	0
Insurance and taxes	1,004	2,008	753	0
Maintenance and repairs[c]	3,200	6,400	2,400	257
Fuel consumption	3,159	3,240	3,240	—
Lube, oil, and filters	1,169	1,199	1,199	—
Total annual operation and maintenance cost	12,820	21,423	10,808	257

— Amount is negligible.

[a] Straight-line depreciation based on the purchase of used equipment and duration of financed loan over 5-year economic life of equipment.

[b] Opportunity costs are equal to 8-percent interest on money invested.

[c] Equals 100 percent of annual depreciation.

a large log mill. In these situations, it may be most cost effective for all log sorting (primary in-woods and secondary) to take place by using mechanized log sorters and by using the tractor-loader simply for placing logs on the in-feed chain. Purchase of mechanized log sorting equipment will significantly increase the cost of investment but may increase productivity in the long run.

Labor Requirements

Assumptions—

The amount of labor required to operate and maintain the Micromill is based on information from Skyline Forest Resources and manufacturer recommendations. The cost of labor is based on skill level, maintenance requirements, employee fringe benefits and burden, and scheduled annual machine hours. Two scenarios are examined. The first assumes a standard 40-hour workweek with one highly skilled operator/supervisor, one person for log sorting and loading, and two people on the green chain handling cants. The second scenario assumes the same number and skills of employees over a 50-hour workweek with time-and-one-half overtime rate. Workers' compensation rates reflect employer burden for mill operations. All other figures quoted are based on standard employer burdens as reported by the U.S. Department of Labor, Bureau of Labor Statistics (2003a-d).

The least-cost approach assumes that employees are responsible for all labor and routine maintenance associated with the Micromill operations, with the exception of concrete slab construction and crane operations for mill siting. Basic support personnel are responsible for equipment operation of the tractor-loader for log sorting, mill infeed operation and necessary site preparation, and for the forklift to stack and load processed cants. Support personnel also are used for handling cants, site cleanup, blade and knife sharpening, and other technical support as needed. One highly skilled operator is responsible for the operation and maintenance of the Micromill. Functions include employee supervision, log milling, product merchandizing and sales, scheduled machine maintenance, knife and blade sharpening and change-out, log yard organization, and all other functions not directly the responsibility of support personnel. Specific labor requirements and considerations include:

- All applicable labor laws and contract requirements.
- Employee fringe benefits.
- Employee insurance and liability.
- Scheduled annual machine hours.
- Skill sets of available employees in an area.

The availability of highly skilled employees is a concern throughout the Four-Corners region because of the general lack of forest products manufacturing capacity in the region. Short of conducting a labor assessment, areas with existing forest products manufacturing facilities are assumed to have an adequate labor pool from which to draw. In other areas it will be necessary to relocate or train existing employees. Basic support personnel are assumed to be available throughout the study region.

Costs—

Based on the above assumptions, table 3 provides a breakdown of the costs associated with required labor and employee skills. Overlap with special duties related to move in and setup and site mobilization are addressed in other sections.

Key issues—

Labor costs presented in table 3 represent an employer burden of 38.5 percent for each employee. Cost considerations are subject to change contingent upon the actual time the mill is scheduled to be in operation. During periods of prolonged inactivity owing to inclement weather or availability of logs, it may be necessary to lay off employees. Although this will reduce overhead costs, mill productivity will decrease significantly, whereas an increase in hours to 50 per week will significantly increase productivity.

Table 3–Costs associated with required labor and employee skill levels

Labor and wage costs	Basic support employees[a] (three employees)	Highly skilled employee[b] (one employer)	Total cost
	– – – – – – – – – – – – – *Dollars*	– – – – – – – – – – –	
Hourly wage rate (dollars/hour)	9.00	16.50	
Weekly wages paid (40 hours/week)	360.00	660.00	
Employer burden:[c]			
Weekly fringe benefits (0.115)	41.40	75.90	
Unemployment compensation (0.035)	12.60	23.10	
Workers' compensation (0.120)	43.20	79.20	
Social security (0.075)	27.00	49.50	
Liability (0.040)	14.40	26.40	
Per-employee weekly cost (40 hours/week)	498.60	914.10	
Total weekly cost (40 hours/week)[d]	1,495.80	914.10	2,410
Total yearly costs (40 hours/week)[d]	77,782	47,533	125,315
Overtime benefits:			
Overtime rate (dollars/hour)	13.50	24.75	
Overtime amount (10 hours/week)	135.00	247.50	
Per-employee weekly cost (50 hours/week)	633.60	1,161.60	
Total weekly cost (50 hours/week)[d]	1,900.80	1,161.60	3,062
Total yearly costs (50 hours/week)[d]	98,842	60,403	159,245

[a] Employee responsibilities: tractor-loader and forklift operation, log sorting, mill infeed operation, site preparation, cant handling, cant stacking, truck loading, site cleanup, blade and knife sharpening.

[b] Employee responsibilities: supervision of all employees and operations, equipment operation, mill operation, scheduled mill maintenance, product merchandizing and sales, knife and blade sharpening and change-out, and log yard organization.

[c] Employer burden is individually calculated for benefits, unemployment and workers' compensation, and social security and liability (U.S. Department of Labor, Bureau of Labor Statistics 2003a-d); calculated by multiplying weekly wages by figure in parenthesis.

[d] Total for three support employees and one skilled employee.

The increase in mill productivity at 50 hours per week even with the incremental cost of overtime labor will significantly increase the profitability of the mill. However, this is highly contingent upon the availability of logs, adequate markets for increased production, and employee willingness to work overtime. The decision to increase production, even temporarily, will require additional cashflow for a larger inventory of logs, labor requirements, and increased maintenance and repair.

Additional labor considerations not included here are administrative functions, sales and marketing, and other nonproduction tasks. Depending on the ownership structure of the Micromill enterprise, administrative and related functions could be accomplished by a larger firm that provides support services. For an independently owned operation, additional labor and overhead cost may be incurred that are not considered in this analysis.

Delivered Raw Log Costs and Inventory

Assumptions—
Several factors, including harvest conditions, quality of logs, and hauling distances will influence actual delivered-log prices. Harvest conditions are affected by operability, which is a function of slope, natural barriers, and seasonality. They are also a function of the number of trees being cut, size of trees, and spacing between trees not harvested. The quality of logs being cut is influenced by the amount of defect present, such as sweep, breakage, weather check, and decay. Lastly, transportation of raw logs to the mill site will affect delivered-log costs. Lynch (2001) and others (Han et al. 2002) estimate that where raw logs are transported 60 mi or less, transportation can account for up to 50 percent of raw log costs. Based on these studies, the least-cost approach assumes that the Micromill will be relocated closer to the raw material source when transportation distances meet or exceed 60 mi.

The cost of raw logs delivered to the mill site and the quantity of log inventory will significantly affect profitability and required cashflow. Based on interviews of log buyers in the Four-Corners region during fall 2003, it is assumed for this analysis that the cost to purchase delivered small-diameter ponderosa pine logs (≤12-in outside bark, large end) will range between $165 and $200 per thousand board feet (MBF) within a 60-mi radius.

The required inventory of raw logs available for processing will depend on seasonality of forest conditions, the availability of timber supply, and the number of SMH per year for the Micromill. Factors affecting seasonality in the Four-Corners region can include summer monsoon rain, winter snow and spring runoff, and forest fire restrictions. Federal land timber supply is affected by forest fires, as well as by appeals and litigation and delays in planning. Annual SMH coupled with available timber supply and harvest seasonality may require greater inventory. One approach is to assume “just-in-time” delivery of logs to the mill site, whereby logs are immediately processed and sold to awaiting customers. This scenario requires minimal investment in an inventory of logs. However, this may not be feasible given the confounding factors of log supply discussed above. Therefore, for the current analysis, it is conservatively estimated that a 3-week inventory of 270 MBF is required for 120 SMH (18 MBF/day for 15 workdays).

Costs—

For 270 MBF of inventory with delivered-log costs ranging from $165/MBF to $200/MBF, total cashflow ranges from $44,350 to $54,000. Raw log costs are subject to change based on size of log, species, condition, and transportation distance.

Key issues—

As previously discussed, interruptions in SMH and PMH can significantly affect profitability. Investment in 270 MBF of log inventory provides a consistent supply of material during periods when weather, fire, or other factors disrupt supply, thus increasing annual SMH and PMH. The cashflow required for log inventory also covers operations between the time the logs are purchased and the time when payment is received for finished products produced with the Micromill. A minimum 30-days accounts payable is common practice for payment on delivery of finished products. Additional cashflow may be required when payment for raw logs is due before payment received for finished products. This does not include the cost of compounding interest for investment in log inventory, which is in addition to onhand cash. Two months of nonproductive time is factored in to account for inclement weather and disruptions in log supply, but the timing of disruptions will further influence required log inventory. Because of the sensitivity of economic return to the cost of delivered logs, both $165/MBF and $200/MBF are assessed in a subsequent section.

Relocation Costs and Equipment Setup

Logistics and Per-Move Costs

Assumptions—

Logistics and per-move cost of the Micromill are integral parts of the economic assessment. Site lease and preparation were previously considered in a separate section to provide a detailed accounting of cost considerations. **The number of moves per year is dependent upon raw log supply, transportation thresholds, and locations.** Related analysis is jointly assessed in a subsequent section.

The least-cost approach of relocating the Micromill involves renting a crane, two freight trailers, and personnel to move and transport the mill, associated equipment, and support machinery. The process of relocating the mill typically takes 2 to 3 days by using hired labor for the crane and trucks and existing

Micromill employees[7] (Micromill Systems 2003). The least-cost approach assumes that mill employees will not need lodging or per diem and will commute daily to the mill site (no additional costs incurred).

Preparation for the new mill site should occur before transporting the mill to minimize rental costs for the crane and freight trailers, as well as to minimize lost production time. A minimum of four laborers will be needed to assist in the Micromill relocation; it is assumed that the same mill laborers will work at all new locations. These labor costs are included in the annual labor costs considered in a previous section.

Costs—

Based on the above scenario and key assumptions, relocation costs include crane rental with operator (at $100/hr) of $700 and rental of two freight trucks at $2/truck/mile. Thus, a 60-mi move would cost $940 ($700 + $240). By comparison, a 100-mi move would cost $1,100 ($700 + $400). Costs are on a per-move basis. Additional considerations with move-in cost were addressed in a preceding section.

Key issues—

Based on transportation costs, it is expected that the Micromill will be relocated within 60 mi of the raw material source. By incorporating existing mill laborers, the only other labor required is a crane operator and two freight drivers, which are included in rental costs. It should again be noted, however, that this figure does not include related costs of site preparation, lease, and construction of a concrete slab.

Market Return

There are many finished product options associated with the Micromill. We investigated products and available markets for the Four-Corners region. Mill productivity and lumber recovery data collected by Lowell are used to determine viable market scenarios.[8] Economic returns are specifically assessed for a mix of green, rough-cut lumber, kiln-dried and surfaced lumber, and byproducts from chips. In the case of kiln-dried and surfaced lumber, rough-cut cants processed by using the Micromill are transported to secondary processing facilities for further manufacturing. Current and expected market prices were gathered by analyzing

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[7] Porters, O. 2003. Micromill mobilization costs and logistics. Owner and operator of Gerrard Plantations (August 21).

[8] Information on file with the USDA Forest Service, Pacific Northwest Research Station, Forestry Science Laboratory, Ecologically Sustainable Production of Forest Resources Team, 620 SW Main, Suite 400, Portland, OR 97205.

national and local trends shown in market reports compiled by the Western Wood Products Association from 1971 to 2002 for Rocky Mountain ponderosa pine (Haynes 2003). Other market options and niche markets may be available in different regions of the country or under different market conditions.

Mill Productivity

Assumptions—

The production capacity of the Micromill differs according to tree species, average log diameter, and log length. It is also dependent upon the skill of the operator to maximize mill speed and ensure logs are sorted for product optimization. The Micromill is capable of producing flatsawn and quartersawn lumber by using a single-pass system that increases productivity. Log lengths need to include adequate trim to produce standard end-product dimensions. Green target sizes will need to allow for drying shrinkage, sawing variation, and planer allowances.

In table 4, observed and published Micromill production capacities are provided for the SLP5000D model. Published rates are based on a 12-ft log length for presorted spruce (*Picea* spp.), pine, and fir (Micromill Systems 2003). Observed rates are based on 8-ft log lengths for presorted ponderosa pine with an average butt end log diameter of 8 in, cut into a 4-in square cant.[9] To compare published and observed rates, use hourly production for 4-in square cant. Observed differences will result from variability in operator experience, average log diameter, and cant size. Productivity rates, combined with grade recovery, are provided to assess market returns for ponderosa pine in the Four-Corners region.

Grade Recovery

Assumptions—

To determine the economic return from small-diameter trees, it is necessary to know how much product can be manufactured from trees of various diameters and the finished product grades. A sample of 1,343 ponderosa pine logs from Flagstaff, Arizona, was scaled, and cubic and Scribner volumes were calculated (USDA Forest Service 1985, 1991; Western Wood Products Association 1998). Two sizes of cants were manufactured: 4- by 4-in and 3- by 3-in, along with a small volume of 1-in boards. Lumber from each log was tracked from sawmill through kiln and planer. Following kiln-drying and planing, lumber from each log was tallied for size and grade. By using gross cubic log volume, green lumber recovery for logs

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[9] Steed, S. 2003. Personal communication. Owner and operator, Skyline Forest Resources, P.O. Box 379, Escalante, UT 84726.

Table 4–Observed and published production rates for the Micromill SLP5000D

Specification	Production rate					
	Observed[a]	– – – – – – – – *Published*[b] – – – – – – – –				
Average butt-end log diameter (in)	8	12	10	8	6	4
Square cant size (in)	4	8	7	6	4	3
Estimated feed rate (ft/minute)	55	50	55	60	65	70
Hourly production (board feet)	3,000	12,250	10,375	6,500	3,250	2,125
Monthly production (thousand board feet)	504	2,050	1,750	1,100	550	350

[a] Based on 8-ft log length, 21 working days/month, and one 8-hour shift per day. Figures are based on a continuous run of presorted ponderosa pine with an average butt-end diameter of 8 in.

[b] Based on 12-ft log length, 21 working days/month, and one 8-hour shift per day. All figures are based on a continuous run of presorted, uniform-sized spruce, pine, or fir logs.

with a small-end diameter inside bark of 3 to 7 in averaged 66.2 percent. Surfaced, dry lumber recovery averaged 46.5 percent. Results are presented in cubic scale; small, shorter logs often have no measurable Scribner scale (no merchantable volume) because scaling equations are better suited for larger trees (USDA Forest Service 1985). As an alternative, mill owners may use a per-log cost to calculate price, or a weight scale could be developed. Lumber grade recovery data from the logs of trees harvested in Flagstaff are presented in table 5 and used in the analysis to select viable market scenarios.

Key issues—

Table 5 shows that of the 4- by 4-in Standard and better lumber, 51 percent was derived from ponderosa pine logs with a 6-in small-end diameter. Most of the remaining lumber in this grade came from trees with a 5-in top (42 percent). However, it is not possible to determine maximum market return across all size classes because the sample data are not representative of the distribution of tree size classes across a given forest area. The sample represents the range of diameters present and was stratified by diameter class. The range of markets available for small-diameter ponderosa pine is assessed in the following section.

Market Options

Assumptions—

MicroMill Systems, Inc., reports a wide range of products utilizing 3- to 13-in logs (diameter outside bark, large end) including 1- by 4-, 1- by 6-, 2- by 4-, 2- by 6-, 4- by 4-, 6- by 6-in, and other variations. However, dimension lumber products (e.g., 2 by 4 in and 2 by 6 in) are generally not a viable option for small-diameter ponderosa pine because of the high proportion of juvenile wood (Erickson et al.

Table 5–Percentage of size-class grade recovery for ponderosa pine[a]

		Log small-end diameter (in)				
Lumber size	**Lumber grade**	**3**	**4**	**5**	**6**	**7**
Inches		*Percent*				
1 by 4	Common and better	0	0	0	38	62
1 by 4	3, 4, and 5 Common	0	0	2	71	27
3 by 3	Standard and better	1	46	52	1	0
3 by 3	Economy	6	64	28	2	0
4 by 4	Standard and better	0	2	42	51	5
4 by 4	Economy	0	11	51	30	8

[a] Data from Lowell.

2000, Larson and Mirth 1999). Small-diameter ponderosa pine in the Southwest is characterized by suppressed growth with poor strength properties and poor product drying capabilities (Argenbright et al. 1978, Voorhies and Blake 1981). Independent studies by Lowell and Green (2001) suggest that sawing of appearance-grade lumber (1-in thick boards) might be a more valuable alternative when processing logs in the 5- to 10-in small-end diameter classes. These boards are used for interior shelving, facing, and other less demanding structural purposes. Fencing, landscaping timbers, siding, pallets, posts, and poles are other potential solid wood options.

Three types of products manufactured with the MicroMill are assessed here for ponderosa pine. The first are green, rough-sawn products: 1- by 4-in boards and 4- by 4-in cants used for pallets and fencing. The second are kiln-dried and surfaced 1- by 4-in and 1- by 6-in boards, and 4- by 4-in flitches intended for remanufacturing into finished lumber. The third are byproducts such as “dirty” chips produced in sawing logs and used for commercial wood pellets and biomass for energy production. Chips are considered dirty when they contain bark and other impurities. Prices for landscaping and mulch are not assessed because of the requirement to add an additional piece of machinery (a debarker) to the mill operation; equipment is required to remove the bark from logs for these uses. Product options are examined for high, low, and average wholesale markets. In addition, observed markets for the Four-Corners region, as assessed in October 2003, are provided to reflect proven product markets.

Costs—

What follows in table 6 are projected gross market returns for assessed Micromill products under different market conditions. Gross returns are based on Rocky Mountain ponderosa pine prices as compiled by the Western Wood Products Association from 1971 to 2002 (Haynes 2003). Invoices submitted to the association by a sample of mills are used to establish high, low, and average markets for the past 5 years, which were selected to represent the most likely range of short-term economic returns.

Key issues—

The difference in market prices between green, rough-sawn lumber and kiln-dried and surfaced lumber is significant. However, the cumulative cost of secondary processing can exceed $115/MBF for milling, kiln drying, and surfacing (see footnote 9). Transportation costs also are incurred to haul rough-cut cants to a secondary facility. One justification for secondary processing is that between 25 and 30 percent more wood can be hauled per load in square form rather than round (Markstrom 1982). Assuming 300 cants (6 by 6 in by 16 ft 6 in long) per truckload and 49.5 BF/cant, average truckload volume is 14.85 MBF. A 300-mi roundtrip at $1.15 per mile amounts to $345 in total costs, or $23/MBF ($345 ÷14.85 MBF). For this scenario, an additional $138/MBF ($115/MBF + 23/MBF) is required in market return to offset the cumulative costs for secondary processing and transport. **Additional processing is only practical if the finished product results in a higher grade.** If the Micromill operates onsite as a satellite to a larger mill or if a secondary processing facility is closer, secondary processing may be more feasible.

Raw logs greater than 8 in on the small end (outside bark) are capable of producing 6- by 6-in rough-cut cants suitable for secondary processing. Smaller logs (5- to 8-in small-end diameter, outside bark) will likely be processed for lower quality 4- by 4-in cants and 1- by 4-in boards. **The actual mix of rough-sawn and secondary products will differ according to the number, size, taper, and grade of logs harvested. The mix of lumber grades within secondary processed products and rough-cut products also may differ.** For instance, the large number of knots and other characteristics common to small-diameter ponderosa pine commonly diminishes the percentage of cants processed into 1- by 4-in and 1- by 6-in Common and better lumber.

The dirty chips produced when manufacturing cants and the clean chips in surfacing lumber can account for 35 percent or more of the original raw log depending on size of log and desired cut dimensions. Although byproducts generally do not provide substantial profit, they can provide additional revenue. The

Table 6–Projected gross market returns for ponderosa pine lumber, inland mills, 1998-2002

		Market scenario[a]			
Product size	**Finished product grade**	**Observed**	**Low**	**Average**	**High**
In		*Dollars per thousand board feet*			
Kiln dried, surfaced:[b]					
1 by 4, 6	2 Common and better	530	453	500	548
1 by 4, 6	3 and 4 Common	275	201	245	278
4 by 4	Standard	350	—[c]	—[c]	—[c]
4 by 4	Economy	300	—[c]	—[c]	—[c]
Green, rough sawn:					
4 by 4	Standard, Economy	200	—[c]	—[c]	—[c]
1 by 4	3 Common, Utility	220	164	190	219
1 by 4	5 Common, Economy	150	110	134	155
Byproducts[d]					
Wood chips	Dirty, including bark	4-20/BDT	—[c]	—[c]	—[c]

[a] Observed markets are for ponderosa pine products sold in the Four-Corners region in October 2003. Low, average, and high market prices were compiled by the Western Wood Products Association and reported by Haynes (2003).

[b] Kiln-dried, planed products will require additional manufacturing and transportation to a secondary processing facility independent of mobile Micromill operations.

[c] The Western Wood Products Association does not compile price data for this category.

[d] Chip byproducts are "dirty" owing to bark and other impurities. Chip prices are based on biomass purchases for bioenergy powerplants and pellet manufacturing in the Southwest (per bone dry ton [BDT], zero percent moisture). Prices will differ significantly based on distance to market.

market for dirty chips in the Four-Corners region ranges from $4/bone dry ton (BDT; zero percent moisture content) to $20/BDT (see footnote 9); regional markets are diminished because of the lack of processors within a reasonable haul distance. Micromill operations located closer to pellet or bioenergy markets may bring substantially greater return.

Annual Costs and Break-Even Analysis

Annual fixed and variable costs are assessed against predicted annual revenue to provide investors with an estimate of the minimum amount of revenue needed to be financially solvent. Total revenue is derived from the sale of green products and kiln-dried and surfaced products identified in table 6. Three break-even scenarios are analyzed based on total costs reported in table 7 and likely mobile processing options. Because of the sensitivity of economic return to variable log costs, delivered-log prices are analyzed for $165/MBF and $200/MBF.

Table 7–Annual fixed and variable costs of mobile Micromill processing

Processing costs	Total annual cost	Total cost (per MBF)[a]
	Dollars	
Fixed costs:		
Downpayment (30 percent; year 1 only)—		
MicroMill	129,956	36.10
Support equipment[b]	24,188	6.72
Annual financing—		
MicroMill	70,609	19.61
Support equipment[b]	16,001	4.44
Site lease and preparation[c]	3,000	.83
Total fixed costs—		
Year 1	243,754	67.71
Successive year	89,610	24.89
Variable costs:		
Annual operation and maintenance—		
MicroMill	150,476	41.80
Support equipment[b]	45,307	12.59
Annual labor (40 hours/week)	125,315	34.81
Annual raw log inventory[d] —		
$165/MBF delivered-log cost	594,000	165.00
$200/MBF delivered-log cost	720,000	200.00
Mill relocation[c]	900	.25
Total variable costs—		
$165/MBF delivered-log cost	915,998	254.44
$200/MBF delivered-log cost	1,041,998	289.44

[a] Total costs are assessed on an annual per-thousand-board-foot (MBF) basis for 3,600 MBF of production.

[b] Includes tractor-loader, forklift, and maintenance vehicle.

[c] Site lease costs are highly variable depending on landowner and duration of lease. Price includes cost of constructing a concrete pad for the mill. Additional costs will be incurred with each move.

[d] Based on 3,600 MBF inventory of small-diameter ponderosa pine (≤12 in large-end diameter, outside bark).

[e] Cost is on a per-move basis.

Market Scenarios

The three market scenarios are:

Market scenario 1–100 percent of logs are processed into green, 4- by 4-in by 8-ft cants.

Market scenario 2–50 percent of logs are processed into green 1- by 4- and/or 6-in 3 Common grade lumber; the remaining 50 percent are processed into kiln-dried and surfaced 1- by 4- and/or 6-in 2 Common and better grade boards.

Market scenario 3–50 percent of logs are processed into green, 4- by 4-in by 8-ft cants; the remaining 50 percent are processed into kiln-dried and surfaced 4- by 4-in by 8-ft cants graded Standard and better.

Costs—

To estimate cost-to-revenue ratios, similar units of analysis are needed to aggregate costs, production, and revenues. All variables are measured on a per-thousand-board-feet-of-production basis. Annual production rates are based on observed hourly productivity of the SLP5000D Micromill for ponderosa pine. Assuming an observed hourly production rate of 3 MBF (table 4) and a conservative utilization rate of 1,200 PMH annually, annual production is estimated at 3,600 MBF (3 MBF x 1,200 PMH). This rate is used to calculate break-even points for the different market scenarios assessed for a 5-year period.

Fixed costs—

Initial downpayments of 30 percent for the purchase of the Micromill and support equipment are most of year 1 fixed costs (which total about $68/MBF), but will lead to decreased fixed costs in succeeding years. Annual financing for the mill and support equipment is $19.61/MBF and $4.44/MBF, respectively. In addition, fixed costs will be increased by the annual cost of site lease and preparation (assumed here to be one move per year). Total fixed costs for year 1 are nearly $244,000. Successive annual fixed costs are equal to the amount of site lease and preparation plus annual financing costs. Total fixed costs for successive years are approximately $90,000 and remain the same regardless of the volume of board feet processed.

Variable costs—

Based on the previously identified figures, annual labor costs are $34.81/MBF, and operation and maintenance for all equipment contributes an additional $54.38/MBF in variable costs. Assuming a delivered raw log cost of $165/MBF, annual variable costs are about $254/MBF or $916,000; assuming a delivered cost of $200/MBF, annual variable costs are about $289/MBF or $1,042,000. Delivered raw logs are nearly 65 percent of total variable costs. Because they compose the bulk of total costs and because delivered logs are likely to be the most variable of all costs, reducing these costs to increase economic return is sensible. Siting the mill closer to the raw material source is one option to reduce log prices. Costs of labor and operation will fluctuate depending on PMH.

Total costs—

Fixed costs plus variable costs equal total costs of about $322/MBF in year 1 based on a delivered-log price of $165/MBF and about $357/MBF in year 1 based on a delivered price of $200/MBF. To break even in the first year of operation, investors would need $322 and $357, respectively, in revenue for each thousand board foot of production. Spreading out the downpayment payback over more time lowers the revenue needed per thousand board foot to break even. For instance, assuming a delivered-log price of $200/MBF, $335/MBF of total costs are incurred in year 2 ([year 1 fixed costs, $243,754 + year 2 fixed costs, $89,610] ÷ [year 1 production, 3,600 MBF + year 2 production, 3,600 MBF] + annual variable costs, $289/MBF). Therefore, a minimum of $335/MBF of revenue is needed to break even in year 2. Breaking even by year 3 will require $328/MBF in revenue based on the same assumptions.

Break-even analysis—

The profitability for each scenario for a 5-year period is reported in table 8. Based on observed markets for the Four-Corners region, the $200/MBF of revenue generated from the sale of rough-cut, green 4- by 4-in by 8-ft cants in market scenario 1 is not adequate to sustain mobile Micromill operations, regardless of whether delivered-log prices are $165/MBF or $200/MBF. Market scenario 2 assumes that 50 percent of rough-cut cants will be transported to a secondary processing facility for increased market return. As previously reported, it is assumed that milling, drying, and surfacing of cants incurs an additional $138/MBF for secondary processing and a 300-mi roundtrip transport. Based on an observed market return of $392/MBF for 2 Common and better lumber ($530/MBF revenue - $138/MBF, secondary processing and transport) and $220/MBF for green 3 Common, an average return of $306/MBF is realized. This is adequate to offset total costs and produce a profit after year 3 for delivered-log costs of $200/MBF and under.

Table 8–Five-year break-even analysis showing cumulative profit (loss) for assessed solid-wood markets based on delivered-log costs of $165/MBF and $200/MBF

				Net return					
				Market scenario 1[c]		Market scenario 2[f]		Market scenario 3[g]	
Year	Mill production	Fixed cost[a]	Total cost[b]	Full financing[d]	Third-party Financing[e]	Full financing[d]	Third-party financing[e]	Full financing[d]	Third-party financing[e]
$165/MBF delivered-log cost									
	Thousand board feet	*Dollars*							
1	3,600	243,754	1,159,751	-439,751	-195,998	-58,151	185,602	-418,151	-174,398
2	7,200	89,610	2,165,359	-725,359	-635,748	37,841	127,452	-682,159	-592,548
3	10,800	89,610	3,170,967	-1,010,967	-921,356	133,833	223,444	-946,167	-856,556
4	14,400	89,610	4,176,575	-1,296,575	-1,206,964	229,825	319,436	-1,210,175	-1,120,564
5	18,000	89,610	5,182,183	-1,582,183	-1,492,572	325,817	415,428	-1,474,183	-1,384,572
$200/MBF delivered-log cost									
1	3,600	243,754	1,285,751	-565,751	-321,998	-184,151	59,602	-544,151	-300,398
2	7,200	89,610	2,291,359	-851,359	-761,748	-88,159	1,452	-808,159	-718,548
3	10,800	89,610	3,296,967	-1,136,967	-1,047,356	7,833	97,444	-1,072,167	-982,556
4	14,400	89,610	4,302,575	-1,422,575	-1,332,964	103,825	193,436	-1,336,175	-1,246,564
5	18,000	89,610	5,308,183	-1,708,183	-1,618,572	199,817	289,428	-1,600,183	-1,510,572

[a] Year 1 fixed costs are equal to the total of downpayment, annual financing costs, and site lease and preparation. Successive-year fixed costs are equal to the total of annual financing costs, and site lease and preparation.

[b] Total costs are equal to annual fixed costs plus annual variable costs.

[c] Market scenario 1 is assessed for 100 percent of logs processed into green, rough-cut, 4- by 4-in by 8-ft cants. Revenue equals $200/thousand board feet (MBF).

[d] Private investor is responsible for the full purchase price and financing of the SLP5000D Micromill and related support equipment.

[e] A third party is responsible for the purchase and financing of the SLP500D Micromill and support equipment.

[f] Market scenario 2 is assessed for 50 percent of logs processed into green, rough-cut 1- by 4-in or 1- by 6-in 3 Common grade boards ($220/MBF), and 50 percent of logs processed into 1- by 4-in or 1- by 6-in 2 Common and better grade boards (kiln-dried and surfaced). Average revenue equals $306/MBF.

[g] Market scenario 3 is assessed for 50 percent of logs processed into green, rough-cut, 4- by 4-in by 8-ft cants ($200/MBF), and 50 percent of logs processed into 4- by 4-in by 8-ft Standard and better cants (kiln dried and surfaced). Average revenue equals $206/MBF.

Market scenario 3 also assesses economic return based on 50 percent of rough-cut cants processed at a secondary facility. An average return of $206/MBF is realized assuming 4- by 4-in by 8-ft cants are graded Standard and better ($350/MBF revenue - $138/MBF, secondary processing and transport) and the remaining logs are processed into rough-cut 4- by 4-in by 8-ft cants ($200/MBF). As in market scenario 1, there is inadequate revenue to offset the costs of production for this scenario.

Where profit margins are small, the added revenue created from the sale of byproducts may be significant even though they are not likely to greatly affect total economic return. On average, approximately 5 BDT of dirty chips are produced per day per 18 MBF of production (approximately 0.28 ton/MBF). Assuming a favorable market of $20/BDT for bioenergy production (TSS Consultants 2002), $5.60 in revenue is added per thousand board foot, which more than covers the cost of support equipment financing. Additional costs may be incurred for disposal if markets for dirty chips are not available.

Key issues—

The break-even analysis is provided to illustrate the minimum amount of revenue needed to simply cover the costs of production. Based on the market scenarios, mobile processing of small-diameter ponderosa pine is not a feasible enterprise for market scenarios 1 and 3; only market scenario 2 is feasible, and only if the assumed lumber grades can be achieved. It should be noted that the volume of finished product could exceed the scaled volume of merchantable material resulting in an overrun, which would increase profitability. Since information is lacking on predicted overrun or under-run scenarios for small-diameter ponderosa pine, they were not assessed. Instead, the predicted volume of merchantable raw logs was assumed equal to the volume of finished products.

Another way to increase profitability is to decrease the fixed costs of equipment purchase through third party purchase of the mill, such as by the federal government or a private foundation through a grant. Each market scenario was analyzed based on the purchase of the Micromill and support equipment whereby all purchase costs and annual financing incurred by an investor are equal to $0.00. The mill owner only incurs expenses for annual variable costs. The reduction in total fixed costs with third-party financing is approximately $244,000 in year 1 or about $68/MBF, and approximately $90,000 in successive years or $25/MBF (table 7). Although the financial returns are increased for all three scenarios, markets 1 and 3 still do not provide adequate revenue to offset costs (table 8).

Relative to variable costs, particularly for delivered logs, the decreased cost resulting from third-party purchase is not adequate. Market scenario 2 remains profitable by a greater margin.

The break-even analysis illustrates that mobile processing of small-diameter ponderosa pine, independent of the purchase and operation of the Micromill, is feasible given favorable market conditions. However, it is not an economically feasible enterprise given poor to average markets or when a high percentage of finished products are low-quality lumber. If markets improve or the delivered price of raw logs decreases through subsidization or other means, mobile operations could become more feasible. The processing of small-diameter ponderosa pine also could become more viable if located on site or closer to a secondary processing facility increasing the range of finished products possible. However, as the mill is located farther away from raw material sources and closer to secondary processing facilities, delivered log prices may increase.

Another option is to increase the utilization rate of the Micromill by increasing operations to a 50-hour workweek. Assuming an observed hourly production rate of 3 MBF (table 4) and an increase in utilization to 1,500 PMH annually (2,000 SMH), annual production is estimated at 4,500 MBF (3 MBF x 1,500 PMH). Variable costs decrease slightly. Scenarios 1 and 3 remain unprofitable, while scenario 2 increases in profitability. Similar profit margins result when also increasing the utilization rate to account for a longer operating season of 11 months (2,300 SMH).

A market option is to seek niche markets for which small-diameter ponderosa pine products are better suited. The markets assessed herein are based on traditional lumber markets in which products must compete with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and various southern pines like shortleaf pine (*Pinus echinata* (Mill.)), loblolly pine (*Pinus taeda* (L.)), and longleaf pine (*Pinus palustris* (Mill.) Michx.), which have more desirable strength and hardness properties. Niche markets such as fiber-reinforced polymer glue-laminate beams, wood/plastic composite cabinet panels and molding, and wood-hardening treatments used for flooring and fire-resistant decking are examples of value-added products with substantially greater market return (Mater Engineering 2002). However, most will require secondary manufacturing, which does not guarantee greater economic return for unfinished Micromill products.

Finally, does the investment in a mobile Micromill cover the costs of simply transporting all logs to a stationary mill for processing? To answer this, it is assumed that 100 percent of logs are shipped to a sawmill with a roundtrip distance of 300 mi. All logs are processed into kiln-dried and surfaced lumber where 50 percent result in 1- by 4-in or 1- by 6-in 2 Common and better grade boards ($530/MBF observed market price) and the remaining, 1- by 4-in or 1- by 6-in 3 Common grade lumber ($275/MBF observed market price) (table 6). The average market price for processed lumber for this scenario is $403/MBF. Assuming logs are shipped in round form as opposed to square cants, volume per load is reduced by 30 percent resulting in 11.1 MBF per truckload. The adjusted cost to transport raw logs 300 mi is $31/MBF. Total transportation and processing costs equal $146/MBF, including $115/MBF for processing. Subtracting transportation and processing costs from average market price results in an average return of $257/MBF. Assuming raw log cost of $200/MBF, revenue is reduced to $57/MBF. Raw log costs are assumed to be greater in this case because of the competitive disadvantage of distance from the resource and the likelihood that log deliveries will include larger, more valuable logs to offset transportation costs. The remaining $57/MBF must be great enough to cover all fixed costs of investment as well as variable costs for operation and maintenance. Depending on the age and condition of the stationary mill, fixed costs, and operation and maintenance likely will exceed this amount. Certainly, net revenue increases as the resource is closer to the mill; delivered-log prices decrease as will total transportation costs. Based on this scenario, the purchase of a Micromill is a preferred alternative where market returns approximate those in market scenario 2 analyzed above.

Discussion

When deciding to invest in small-log-processing technology, it is important to consider the combined market return for the mix of products manufactured at or with the Micromill. Although higher value products can be produced with the Micromill, the availability of high-quality logs, distance to markets, and the ability to find a buyer will dictate which products to manufacture. Also, other factors affect profitability. The following is a synthesis of critical costs and key factors to consider in the decision to invest in mobile processing.

Cashflow Requirements

Optimizing productivity, quality control of products and seeking markets, will initially require a substantial amount of time. Productivity will be lower during initial operations to allow for training employees and configuring the mill to the most financially efficient operation. It is expected that revenue generated from the sale of finished products will begin 3 months or more after the initial purchase of the raw logs. Depending on investment costs, operations and maintenance, labor, and the costs of delivered raw logs, cashflow required for the first 3 months could exceed $450,000. Additional cashflow is contingent upon the timing of finished product sales and delivery. Onhand cash will be necessary to maintain operations through intermittent periods of unscheduled downtime and variable market cycles to ensure an adequate supply of raw logs available for processing. Approximately $65,000 of onhand cash is necessary for a 15-day inventory of logs based on production of 18 MBF/day. This does not include the cost of compounding interest for investment in log inventory, which is in addition to onhand cash.

Key Factors Affecting Profitability

There are numerous factors affecting the profitability of a mobile Micromill enterprise; many are interdependent. Although each has been discussed in prior sections, they are discussed here to aid in understanding the relationships among them.

Resource inventory and management goals—
Before investing in a Micromill, or any other mobile mill technology, it is crucial to understand the characteristics of the forest resource available for harvest. Significant among these factors is determining if there is a sufficient and consistent volume of small-diameter material to pay off investments. The species composition and its physical characteristics (Barbour et al. 2003) within the supply region also must be taken into account as well as access to the timber, given existing transportation networks. It is equally important to understand the goals of the resource manager and his or her management constraints to ensure that a consistent supply of logs will be available for the duration of the capital investment. Projected sale volumes, log quality, and harvest cycles are important factors to consider (Swan 2003).

Log handling, sorting, and transportation—
Costs are incurred each time a log is handled, whether they are for harvesting and skidding, forwarding to the landing, delimbing and loading, transportation to the mill, scaling, sorting, and processing. Therefore, it is important to match in-woods harvesting and handling operations with the type and size of logs suited for the mill. If the Micromill is a stand-alone operation (not situated as a satellite to a larger mill), it will be advantageous to conduct a preliminary sort at the log landing to ensure only small-diameter logs are transported to the Micromill site. Subsequent sorting into diameter classes may then take place at the mill site for product optimization.

Unscheduled downtime—

The amount of time the Micromill is operating affects the quantity of products that can be sold to consumers. In the case of small-diameter timber, more logs generally have to be processed to obtain the volumes necessary to be economically viable. Unscheduled downtime reduces the overall volume processed in a given year. Unscheduled downtime may include any number of factors like weather conditions or fire restrictions, to which a mobile mill will be more susceptible. It also may include major breakdowns of the mill or breakdowns associated with the logging contractor that disrupts the supply of logs to the mill. Supply disruptions leading to unscheduled downtime also may include appeals and litigation or project planning when procuring federal- or state-owned timber.

Productive machine hours—

This analysis was based on PMH for a 40-hour workweek. Increasing the hours of operation from 40 to 50 hours per week or adding a second shift will significantly affect return on investment. Additional operation and maintenance costs will be incurred for an increase in PMH, but the investment payback period with compounding interest would be decreased.

Product markets—

It is not enough to know that certain products can be manufactured from different species and diameters of trees, you must also know whether there are markets for the types and amounts of material proposed for harvest (Spelter et al. 1996). In the case of small-diameter ponderosa pine, it is unlikely that dimension lumber (without physical modification) will be a strong market because of its poor structural properties (Erickson et al. 2000). Similarly, alternative manufactured ponderosa pine products will have to compete in markets with other species. Lumber grade recovered also will affect market return. Expertise in milling ponderosa pine will affect how logs are sorted and merchandised to maximize lumber grade recovery. Attention to the volume and quality of byproducts produced and associated markets for woodchips is necessary.

Secondary manufacturing—

Further processing of rough-cut, green cants produced by the Micromill will significantly increase the per-unit value of ponderosa pine products. However, additional processing costs will be incurred. These costs include transportation to the processing facility, the remanufacturing, kiln drying, and surfacing. The economic return realized from any secondary processing must exceed its costs. It is also important to understand product recovery capabilities of secondary processing facilities to achieve desired returns.

Other costs—
In addition to those factors listed above, there are other costs ranging from administrative and overhead costs for office expenses and accounting, to costs for site preparation and cleanup, property lease, and road access. Other factors not identified in this assessment also may affect feasibility of a mobile Micromill enterprise.

Conclusion

The proceeding analyses allow for increased understanding of the key costs and market options for the SLP5000D Micromill to facilitate sound investment in mobile small-wood processing technology. Other issues not fully addressed include the sensitivity of changes in assumptions, unforeseen cost increases, transportation thresholds, changes in markets and economic climate, and monthly pro forma balance sheets. Assumptions made in the study are based on a least-cost approach that reflects observed operations of existing Micromill owners. A conservative estimate is used to derive break-even points for fixed and variable costs, and market returns. There are a number of alternative scenarios likely to produce competitive results depending on site-specific factors. Raw material costs for small-diameter ponderosa pine are not expected to increase without improved markets for finished products, yet there are a number of variable costs that can change.

Specific transportation thresholds were not identified in the analysis. The decision of when to move the mill and the maximum allowable distance to the raw material source is highly dependent upon existing market conditions, log supply, and delivered-log costs. The distance to markets and secondary processing facilities also will influence mill relocation.

It is difficult to identify an optimal mix of finished products for small-diameter ponderosa pine with respect to changing consumer demand, variable markets, and economic conditions. Markets are subject to a complex array of uncontrollable factors. For these reasons, a comprehensive financial plan and monthly/yearly pro forma are not provided, but are necessary for making investment decisions. The purpose of this study was to quantify important costs and market options. It is not a substitute for a comprehensive business plan. Cashflow requirements and economic return will differ depending on access to capital, magnitude of operations, and markets realized.

Metric Equivalents

When you know:	Multiply by:	To get:
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters
Yards (yd)	.914	Meters
Acres	.405	Hectares
Miles (mi)	1.609	Kilometers
Cubic feet (ft^3)	.0283	Cubic meters
Cubic yards (yd^3)	.765	Cubic meters
Gallons (gal)	3.78	Liters
Pounds (lb)	454	Grams
Tons	907	Kilograms

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