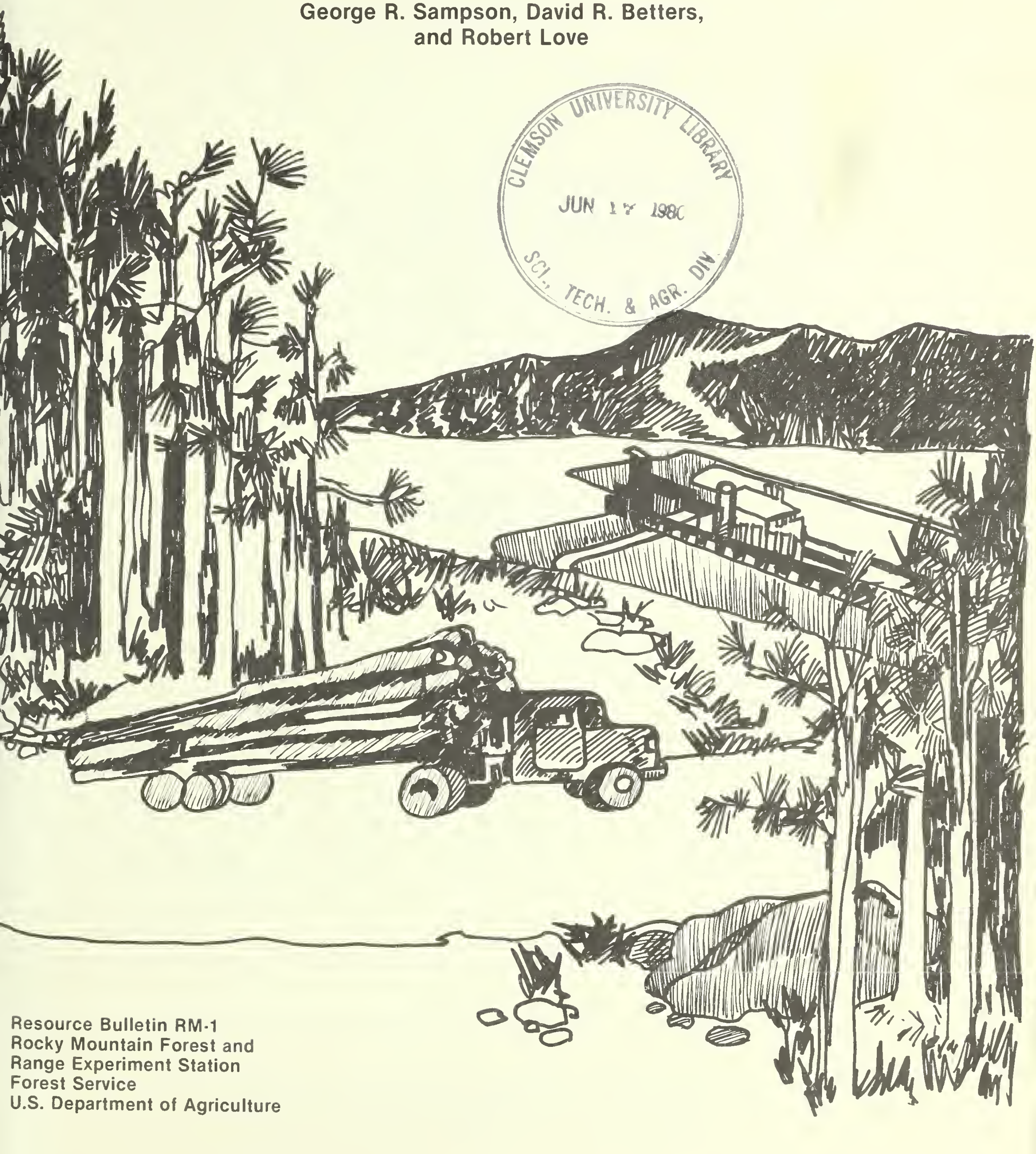
Processing Potential for Insect-Infected Front Range Forests

George R. Sampson, David R. Betters,
and Robert Love



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Abstract

Increased timber harvesting by forest industry, resulting in more intensive forest management, would be a means for combating insect problems such as the current mountain pine beetle outbreak. However, existing timber processing capacity is far less than potential annual harvest of live timber for Colorado's Front Range.

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Processing Potential for Insect-Infected Front Range Forests

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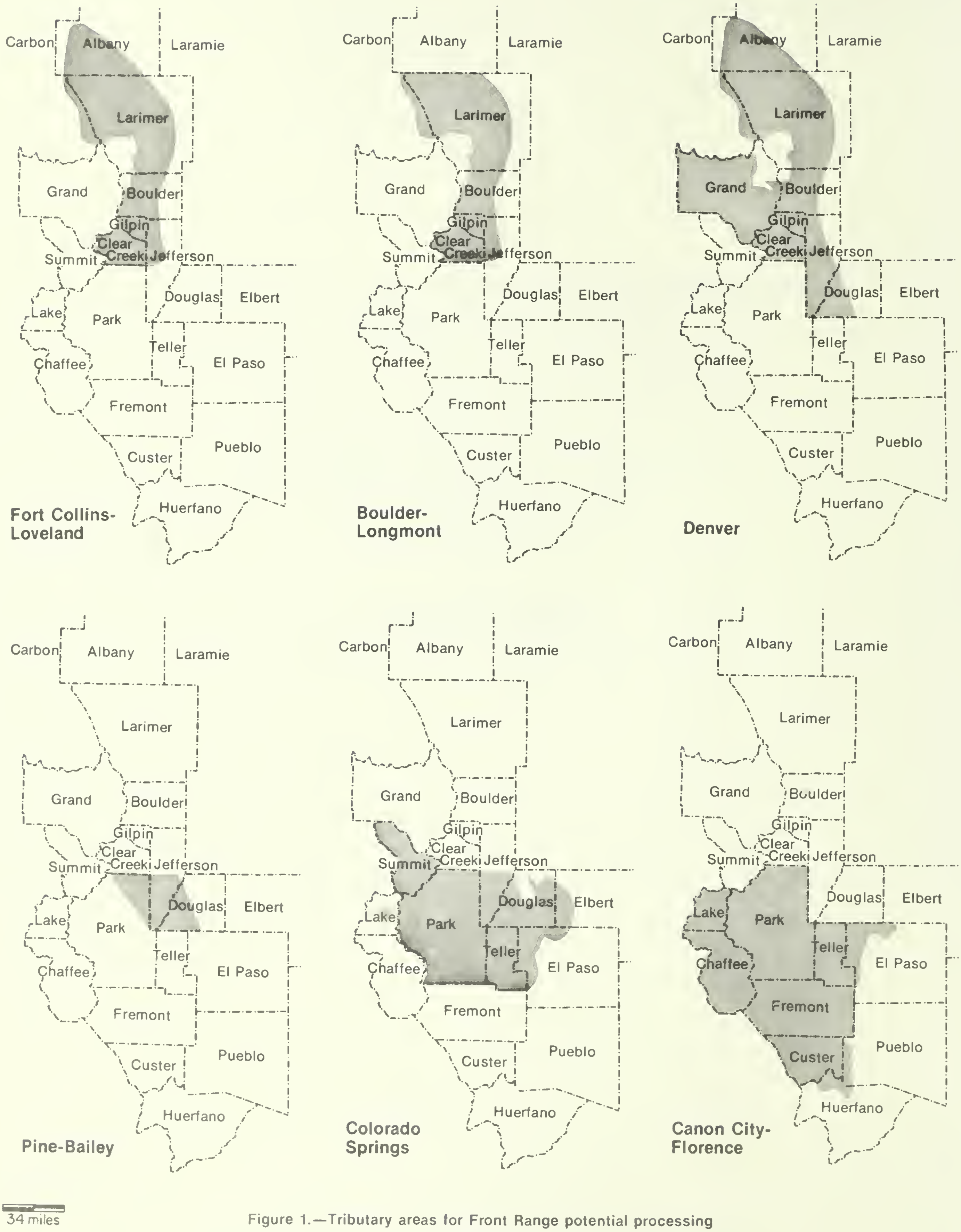

Figure 1.—Tributary areas for Front Range potential processing centers.

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Background

Much of the Front Range of the Colorado Rockies is forested, with the primary timber types being lodgepole pine, spruce-fir, and ponderosa pine (fig. 1). The mountain pine beetle (*Dendroctonus ponderosae* Hopk.) is currently in outbreak status in the ponderosa pine stands (Stevens et al. 1975). Estimates of annual timber loss vary from 5.5 to 27.3 million cubic feet.[3,4] The increasing acreages of dead timber have rapidly increased the danger of a disastrous wildfire. Many forested areas containing the ponderosa pine type are becoming heavily populated; consequently, the increase in dead timber is detrimental to treasured aesthetics and property values. Beetle infestations spread readily between forest wildlands and residential areas, often resulting in widespread destruction of ornamental or shade trees. Most beetle infestations occur in overcrowded stands where many trees are of low vigor and, consequently, have low resistance. Any effective large-scale control program to reduce these losses must include removing infested trees along with improving the general condition of the susceptible forest. Utilizing the material to be removed for salable products can finance, or at least help finance, vegetative treatments to provide multiple use benefits while at the same time supplying needed forest products for national (and local) markets.

Purpose of Study

The purpose of this study is to make a general assessment of the total timber supply-demand situation in the Front Range area as a means of determining where and how timber utilization and timber harvesting might be increased. Increased timber harvesting would provide a means for increased forest management which would alleviate the long-term threat of mountain pine beetle and other forest insects and diseases. Since existing local forest industry uses all of the tree species present for making products, all species must be included in the demand-supply analysis.

This study is part of a three-pronged effort to determine what kinds of forest industry would be most profitable and where production units should be located to facilitate an adequate and feasible level of forest management for the Colorado Front Range. This assessment phase was done in cooperation with Colorado State University with detailed results in an unpublished report.[3] One related study will determine the technical suitability of Colorado's dead Front Range ponderosa pine for various products. Another study will define market potentials for wood products from the Front Range area. Production and marketing alternatives will be specificially identified and evaluated, including the potential for new industry to utilize the volume of material that should be removed from the forest to achieve the desired level of forest management.

Procedure

Six locations were chosen as logical potential processing centers within or adjacent to the Front Range. The criteria for selections included (1) availability of raw materials, (2) existence and current capacities of the local timber industry, (3) presence of transportation networks suitable for use by forest products industries, and (4) the area's topographic features. The selected potential processing centers do not, in each case, represent a precise locality. Rather, they represent an economic center, such as that formed by the cities of Fort Collins and Loveland. Tributary timbersheds for each of the potential processing centers were defined on the basis of current timber procurement practices of mills at that center. There is considerable overlap in these tributary areas as can be expected (fig. 1).

The potential processing center with the smallest tributary area is Pine-Bailey. This is due to the small size of firms there and the limited transportation system, which does not allow ready access to a larger area. Denver has the largest tributary area, again principally due to the transportation system, which provides good access to a large area.

In this assessment the timber resource considered was that on accessible commercial forest land where timber could be harvested in the foreseeable future using conventional logging methods. All standard and special components of the commercial forest land classification were included for national forests. The USDA Forest Service defines commercial forest land as land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. Areas qualifying as commercial forest land have

[3]Love, Robert, David R. Betters, Harry E. Troxell, and Warren E. Frayer. 1977. Assessment of wood raw materials in Colorado's Front Range. Unpublished report, 143 p. Colorado State University, Fort Collins.

[4]U.S. Department of Agriculture, Forest Service. [1976.] Western forest insect problem area analysis. Unpublished report, 6 p. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Denver, Colo.

the capability of producing in excess of 20 cubic feet of industrial wood per acre per year under management. For the inventory of state and private land, Colorado State Forest Service defined commercial forest land as forest land which is producing usable crops of industrial wood and is economically available either now or prospectively. Areas qualifying as commercial forest land must have: (1) either 1,500 board feet or 600 cubic feet per acre and 40 square feet of basal area per acre of trees 5 inches d.b.h. or larger; or (2) definite seedling-sapling stands with 40% crown cover or more.

All commercial forest lands in private and other public ownerships were assumed to be accessible. Acreages and volumes of timber tributary to each of these potential processing centers were estimated. Annual mortality and volume of salvable dead timber were also estimated for each tributary area. Potential timber harvests were compared with actual harvests for each tributary area.

Results

Acreage by Timber Type

Areas of accessible commercial forest land by timber type for areas tributary to the six processing centers are shown in table 1. Despite ponderosa pine being the species of current concern for timber management purposes, it is the prevalent timber type in only the Pine-Bailey and Colorado Springs tributary areas. It occupies the second largest acreage in the Fort Collins-Loveland and Boulder-Longmont tributary areas, and the third largest in the Denver and Canon City-Florence tributary areas. For the entire area shown in figure 1, ponderosa pine type accounts for 20% (411,780 acres) of the accessible commercial forest land, while lodgepole pine accounts for 31% (650,103 acres), Douglas-fir 18% (381,348 acres), spruce-fir 22% (453,577 acres), and aspen 9% (184,361 acres). The ponderosa pine type lies at lower elevations where population is concentrated; the other types occur mainly at higher elevations.

The intermingling of different species within each timbershed generally prohibits existing as well as future forest products industries from being species specific. Timber sales usually involve several species. Thus, in analyzing forest industry alternatives that might facilitate improved forest management to alleviate the mountain pine beetle epidemic, all timber species must be included.

Live and Dead Timber Volumes

Estimates of the volumes of live and salvable dead timber tributary to each of the processing centers are shown by figure 2. The estimates are presented separately for national forests and other ownerships. The Denver timbershed has the greatest volume of timber with an estimated 1,794 million cubic feet of live timber and 330 million cubic feet of dead timber. The Pine-Bailey timbershed includes only about 278 million cubic feet of live timber and 59 million cubic feet of dead timber.

For the northern tributary areas, volumes on other ownerships are greater than volumes on national forests. However, in the southern tributary areas, volumes on national forests are somewhat greater than volumes on other ownerships. Historically, probably 90% of the annual roundwood removals for wood products other than fuel in the Front Range have come from national forests, much the same proportion as for the state as a whole (Green and Setzer 1974).

Table 1.—Commercial forest land area by species for each processing center tributary area

Processing center	Spruce-fir	Douglas-fir	Lodgepole pine	Ponderosa pine	Aspen	Total
	acres					
Ft. Collins-Loveland	102,632	82,767	290,159	139,890	29,518	644,966
Boulder-Longmont	78,364	81,519	232,152	131,890	28,818	552,743
Denver	235,177	139,515	478,753	214,663	59,648	1,127,756
Pine-Bailey	40,963	70,554	31,637	90,847	16,179	250,180
Colorado Springs	144,878	191,283	88,235	240,885	55,656	720,937
Canon City-Florence	212,299	236,549	107,734	174,622	125,016	856,220
Total area[1]	453,577	381,348	650,103	411,780	184,361	2,081,169

[1]Excludes overlap between areas.

Potential Annual Harvest and Present Processing Capacities

National forest timber management plans include an annual potential yield determination, which represents the maximum sustainable production the timber resource can support under management. Since comparable timber management plans are not developed for most other public and private forest lands, reliable potential yield computations are not available for these lands. A potential annual yield was estimated for these lands by assuming a potential annual yield proportional to that for nearby national forest land.

The estimates of potential annual harvest of dead timber assume that the only dead timber removed would be on areas where live timber is scheduled for harvest. Therefore, the dead timber estimate is probably conservative for both national forest land and private land because special, unscheduled salvage sales of dead timber do occur.

The annual potential harvest for the Denver timbershed is highest with an estimated 20.7 and 3.8 million cubic feet, respectively, for live and dead timber, or a 24.5 million cubic feet total. The Pine-Bailey timbershed has the smallest annual potential harvest with 1.3 million cubic feet of live timber and 0.3 million cubic feet of dead timber for a total of 1.6 million cubic feet.

Figure 3 compares potential annual harvest, by ownerships, with existing mill capacity for each potential processing center. The potential annual harvests among timbersheds are not mutually exclusive because of overlapping tributary areas. Potential harvest volumes are, therefore, not additive. However, the processing capacities are mutually exclusive. The total annual processing capacity along the Front Range in 1976 was estimated at 14,778,000 cubic feet, which is probably slightly conservative because of the likelihood a few small mills are not included in the data. In addition, a small amount of timber is taken out of the Front Range area and processed elsewhere.

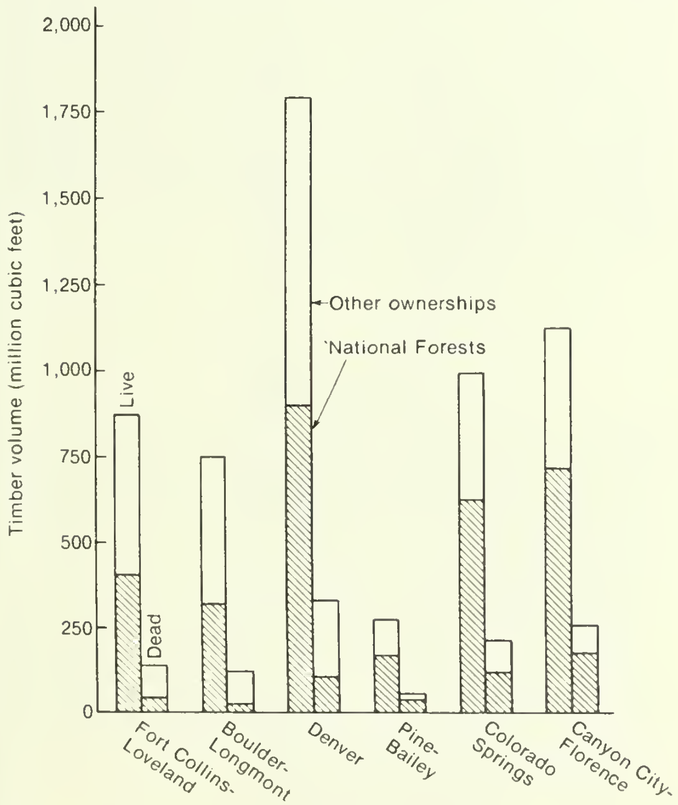

Figure 2.—Volume of live and dead timber tributary to Front Range potential processing centers.

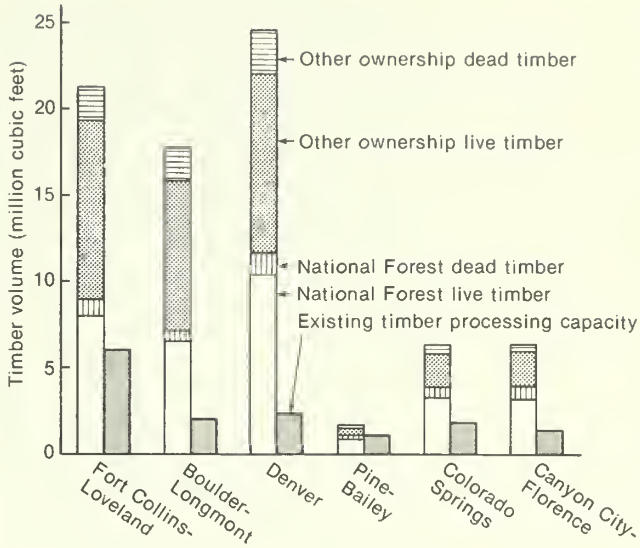

Figure 3.—Potential annual harvest by ownership and timber processing capacity by tributary area.

Thinning

A widely held theory is that the best way to achieve long term mountain pine beetle control in Front Range ponderosa pine is to harvest timber at appropriate times and thin existing stands so that residual trees are maintained in a vigorous and healthy growing condition. This is partially based on the observation that Black Hills stands with a basal area conducive to good growth have, in general, few infestations of mountain pine beetle (Stevens et al. 1975). To be effective, thinning must precede epidemic attack in a stand, but the relationship between time after thinning and increased resistance to mountain pine beetle attack is not known.

One thinning system proposed for national forest land is to thin virtually all of the accessible ponderosa pine sawtimber stands and about 25% of the poletimber stands over a 5-year period. This would affect a total of 186,700 acres of national forest land and would result in an estimated harvest of 56 million cubic feet of timber over the 5-year period. Comparable practices on private land would mean thinning more than 146,000 acres, which could yield almost 44 million cubic feet of timber in the 5-year period. The combined annual thinning volumes, given the same 5-year cutting period, amount to more than 1-1/2 times the total annual capacity of Front Range mills for processing timber of all sizes and species. As a practical matter, acreage to be thinned might be substantially less, since some stands are already at or below the desired basal area. Since only limited markets such as firewood and posts presently exist for small, low quality roundwood that would be removed in programs of this scale, such large-scale thinning is probably not feasible on a commercial basis at this time. Developing better markets will, therefore, be a critical factor in any program to treat these beetle-susceptible forests on a large scale. Disposing of this material by other means, such as burning, would also be limited due to probable adverse environmental effects of smoke on the nearby communities and negative public reaction to waste. Any large-scale thinning will undoubtedly require a viable combination of public investments and product values. Developing better markets for products manufactured from this small-size, low-grade material may be a critical factor in any program to treat these beetle-susceptible forests on a large scale.

Implication of Findings

Potential annual harvest of timber for the entire Front Range far exceeds processing capacity; this is true for each of the six processing centers. That portion of the annual harvest that is dead timber is, in general, suitable for the same products as live timber. In fact, blue-stain paneling and blue-stain beams from beetle-killed ponderosa pine have become premium products over the last 2 years. Thus, from a short-run supply viewpoint, the potential for additional processing as well as additional processing capacity would seem to be good.

The Front Range ponderosa pine timber southward from the Boulder-Golden area is not yet heavily infested with mountain pine beetle and offers some potential for control by silvicultural methods. Most private owners of ponderosa pine timber are interested in controlling the mountain pine beetle on their property and would do many things including harvesting timber or thinning to accomplish this.

Unfortunately, there are a number of factors which currently inhibit expansion of the forest products industry in the Front Range to accommodate mountain pine beetle control efforts.

Since national forests contain about 65% of all commercial forest land and 50% of the commercial ponderosa pine type in the Front Range area, whatever action is taken on the national forests will have major impact on the Front Range. However, to be effective, any program to control mountain pine beetle infestations will necessarily involve a high percentage of the intermingled ponderosa pine forests in all ownerships. The same would be true of compatible utilization and marketing efforts.

In terms of staff and timber sale preparation capability, national forests are geared approximately to current industry production levels. National forests will not be able to increase their staff levels to permit greater timber products industry capacity. Also, the Roadless Area Review and Evaluation (RARE II) program has tied up, at least temporarily, hundreds of thousands of acres of national forest land tributary to the Front Range processing centers. Meanwhile, existing forest industry will not expand and new forest industry will not be attracted to the area unless there is some assurance that greater volumes of timber will be available in the future. The USDA Forest Service needs to establish confidence of potential forest products industry investors that long-term potential harvesting on national forests will be met if there is local demand. Current and future land management planning by the national forest system will place greater emphasis on coordinating timber supply goals with private and other public owners in the same timbershed.

It is difficult to achieve a long term assured supply of timber from private forest land in the Front Range. Through the Colorado State Forest Service, many designated control areas (DCA's) have been established for combating the mountain pine beetle. The land owners within a DCA are encouraged to participate in taking unified action against the beetles. However, there is no assurance that private timber owners would continue to be interested in harvesting timber in the future when there is no mountain pine beetle outbreak. In addition, much of the private forest land is in small ownerships making harvesting expensive unless a number of such ownerships can be harvested as a block. What is needed on these private forest lands is a plan for a larger economically operative area to facilitate timber harvest and other cultural treatments. This is essentially the task that Colorado State Forest Service has taken on, and more effort in this direction is needed.

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Sampson, George R., David R. Betters, and Robert Love. 1980. Processing potential for insect-infected Front Range forests. USDA Forest Service Resource Bulletin RM-1, 4 p. Rocky Mountain Forest and Range Experiment Station.

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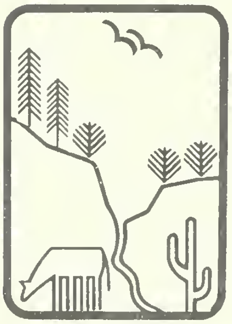
Rocky Mountains



Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

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Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

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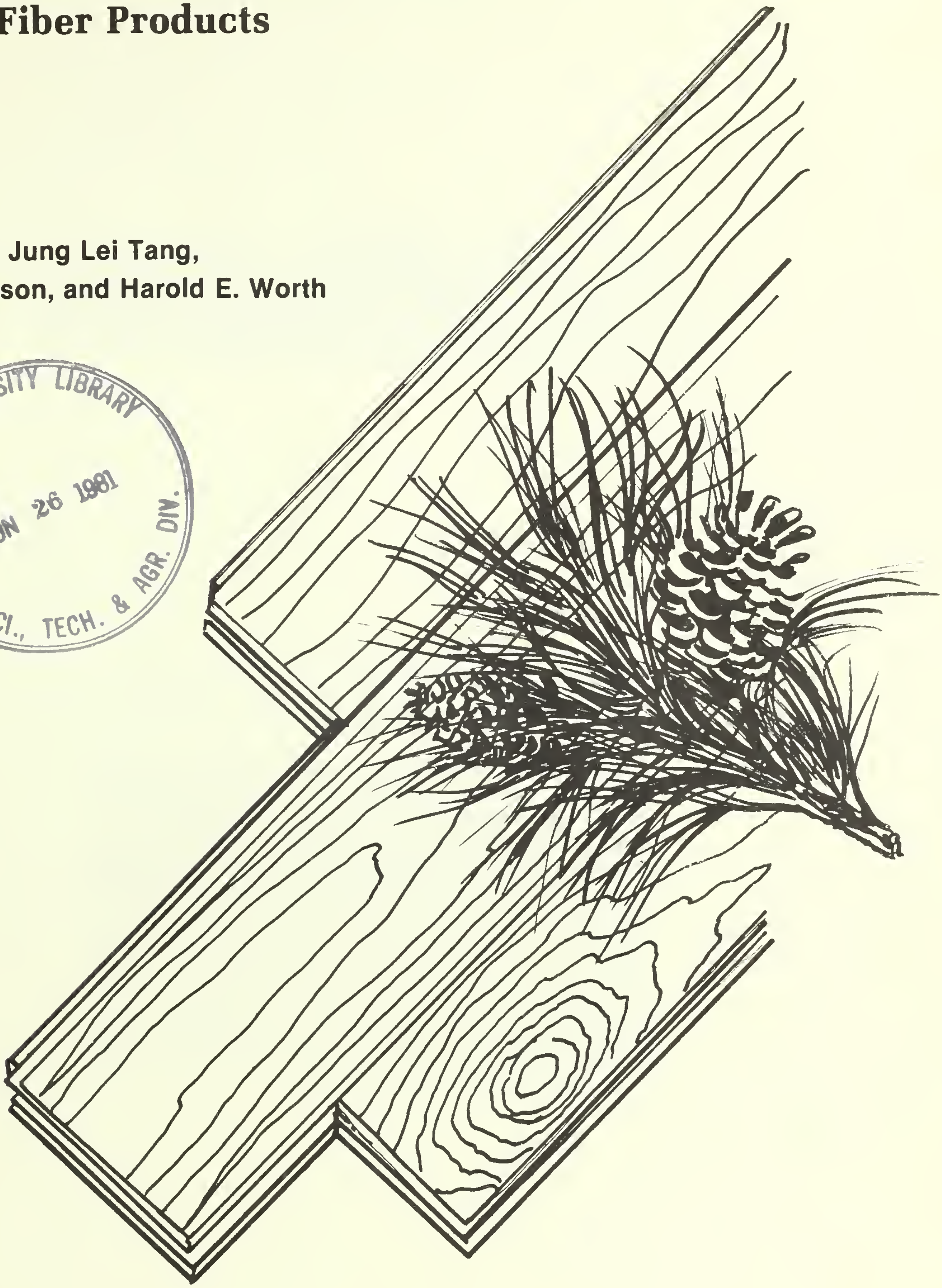
Suitability of Beetle-Killed Pine in Colorado's Front Range for Wood and Fiber Products

Harry E. Troxell, Jung Lei Tang,
George R. Sampson, and Harold E. Worth



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U.S. Department of Agriculture

Abstract

Front Range beetle-killed ponderosa pine wood is suitable for most traditional uses of the species. Differences are: the beetle-killed timber is drier, usually blue-stained, and may contain wood borers and decay. Mechanical properties may be affected.

Acknowledgments

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Contents

	Page
Management Implications	1
Introduction	1
Timber Characteristics	2
Physical Stem Characteristics	2
Wood Properties	2
Suitability of Beetle-killed Wood for Various Products	5
Products Currently Produced	5
Potential New Products	7
Literature Cited	9

Suitability of Beetle-Killed Pine in Colorado's Front Range for Wood and Fiber Products

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Management Implications

A mountain pine beetle outbreak in Colorado's Front Range ponderosa pine was identified in 1976 as one of the most urgent forest management problems in the Rocky Mountain region. At the height of the outbreak, an estimated 27.3 million cubic feet of timber were killed each year in the Front Range.[2] Annual losses from mountain pine beetle are now declining, but substantial volumes of dead timber remain in some areas, and new beetle outbreaks are likely to occur in future years (Sartwell and Stevens 1975). The beetle-killed timber depreciates esthetics and is also a serious fire hazard. Removal of beetle-killed timber is very expensive unless part of the cost can be defrayed by selling the timber for conversion into industrial products or firewood. Consequently, the suitability of beetle-killed ponderosa pine for various uses will remain a major utilization problem for this region.

In addition, an effective program to control future beetle epidemics requires management of forest vegetation to create healthier growing conditions in timber stands. Vigorous, growing trees are less susceptible to insect attacks. For the control program to be both economically feasible and to meet national conservation objectives, it will be necessary to increase utilization of wood and fiber from the threatened living trees, recently killed trees, old standing dead trees and some of the non-threatened living trees.

Results of this study suggest that some properties of wood from standing beetle-killed trees are probably not affected enough to be of further concern, while others warrant additional study. In general, utilization characteristices of beetle-killed wood vary with the length of time trees are dead before being harvested. The longer dead trees are left in the woods, the higher the risk of excessive deterioration. About 5 years appears to be the maximum length of time dead trees will remain in utilizable condition for wood products. But utilization of this Front Range pine does not depend solely on the technical characteristics of the raw material or on product requirements. Harvesting, transportation, and processing costs are critical factors, as are the product values that can be realized in the market place. Comparisons of costs and values of products made from dead and live trees are an appropriate basis for assessing these economic factors. Such comparisons are explored in a companion study by Sampson, Betters, and Brenner (1980).

Introduction

Epidemic attacks on ponderosa pine forests of Colorado's Front Range by the mountain pine beetle (Dendroctonus ponderosae) forced forest owners in the 1970's to drastically alter plans for managing these forests. Massive numbers of beetle-killed trees left in the forest created an unacceptable scenic blight and fire hazard. Eventually, as the dead trees rot and fall down, they would also become an obstacle to regeneration and other management objectives. Further, because overcrowed stands are believed to invite heavy beetle infestations, managers consider it essential to thin out vulnerable living trees to reduce future threats and create better growing conditions. What to do with the beetle-killed and beetle-threatened trees was, and is, a major concern for forest managers and the general public alike.

The cost of removing and disposing of the dead and threatened timber was found to be higher than most owners could finance. The natural response was to seek ways to reduce this cost.

To help meet the need, this study examined beetle-killed trees, dead 5 years or less, their suitability for various products, and determined the properties that may affect or limit their use. The scope of the problem and the high cost of a definitive study of all characteristics dictated that this study be confined to an exploratory evaluation. Also, the stands and individual trees for which there was a record of their year of death were extremely limited. As a consequence, the size of the sample for which the several variable characteristics of trees could be measured was unavoidably small. Results, therefore, do not necessarily apply to other Front Range trees or forests even though reason suggests that similar characteristics might be found under like conditions. Results presented here are based on a more detailed report prepared by Tang and Troxell in 1977.[3] Related studies on the amounts and kinds of raw materials potentially available (Sampson, Betters, and Love 1980) and on the industrial capacity needed to utilize the wood (Sampson, Betters, and Brenner 1980) are reported elsewhere.

[2]U. S. Department of Agriculture, Forest Service [1976]. Western forest insect problem area analysis. 6 p. U. S. Department of Agriculture, Forest Service, Rocky Mountain Region, Denver, Colo. [Unpublished report.]

[3]Tang, Jung Lei and Harry E. Troxell. 1977. Suitability of beetle-killed pine in Colorado's Front Range for wood and fiber products. 53 p. Colorado State University, Fort Collins, Colo. [Unpublished report.]

Timber Characteristcs

Physical Stem Characteristics

Ponderosa pine timber includes a wide range of age classes and site conditions. The vigor of trees in ponderosa pine stands varies greatly. Beetle-killed trees usually are in scattered clusters, with individual trees varying in the length of time they have been dead. Two common types of damage found in standing dead ponderosa pine timber are broken tops and fire or lightning scars. Trees dead more than 2 years develop prominent checks in the wood. Such checks often appear in places where the wood is exposed as the bark loosens or falls off. These defects all tend to reduce the volume or grade yield of wood products made from dead timber.

The inner bark of beetle-killed trees is characterized by numerous main vertical bark beetle galleries, with secondary ones branching off laterally. Following bark beetle attack, the sapwood is further attacked by blue-staining fungi and ambrosia beetles. The extent of their presence in a tree is directly related to the length of the time the tree has been dead and greatly affects the suitability of the wood for lumber and other wood produce. Five years seems to be the maximum period of time standing trees can be salvaged; however, considerable deterioration is noted during and after the third year. Some usable fiber may remain in the tree for many years, particularly for fuel wood use.

Figure 1.—Selection of logs killed by the bark beetle illustrating the patterns on the end sections caused by blue-staining fungi.

Figure 2.—Sawed ponderosa pine dimension lumber from beetle-killed trees.

Wood Properties

The suitability of beetle-killed ponderosa pine wood for products depends upon several wood properties, such as specific gravity or density, shrinkage, shock resistance, mechanical strength, and visual appearance. Other properties, such as pH value, wettability, and extractive characteristics also affect suitability for other wood products.

Wood appearance.—The appearance of wood from trees that have been beetle-killed is very distinctive and often esthetically pleasing. Wood in standing dead trees usually becomes heavily blue-stained soon after death. Blue-staining is caused principally by two species of fungi, *Ceratocystis montia* Rumb and Hune, and *Europhium clavigerum* Robinson and Davidson. Blue-staining fungi always accompany the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) and invariably invade beetle-killed trees. An unusual feature is the marked tendency of the stain to appear in radial streaks or wedge-shaped areas in sapwood. This is caused by the tendency of blue-staining fungi to associate with wood parenchyma tissue of the sapwood, which usually is found in the wood rays (fig. 1). Quite often associated with blue stain is a pink or purple stain caused by an as yet unidentified species of fungus. The purple or pink stain shows the same radial pattern as the blue-staining fungi on cross-sectional pieces of wood. Figure 2 shows some larger sized borer holes and numerous smaller pin holes, often associated with dark discoloration seen in ponderosa pine lumber sawed from the standing dead trees. These holes, created by ambrosia beetles which infest the sapwood after the bark beetle attack, are most numerous in the outer portion of sapwood. Figure 2 also shows the appearance of sap-stained pieces cut from the logs and made into dimension lumber. The unstained portions of the pieces are heartwood. The decorative character of blue-stained lumber can be further enhanced by special processing. During the latter years of the 1970's, large volumes of this wood were sold as interior wall paneling and trim for homes and commercial buildings.

Specific gravity.—Specific gravity is useful as a means of predicting other properties, such as strength, shrinkage, hardness, and shock resistance; also for projecting the value of products, such as chips for pulp, firewood, and briquets. To obtain estimates of the specific gravity of beetle-killed wood, full-length increment cores were collected from a sample of 21 standing dead and five live ponderosa pine trees in the Poudre Canyon area near Fort Collins, Colo. The sample was selected from trees 10-14 inches in d.b.h. that had died within the past 5 years. These same trees were used for testing moisture content, solubility, hydrogen-ion concentration, and wettability. All the increment core samples were taken at breast height. Specific gravities for the samples are listed below:

	Specific gravity, *(mean and standard error)*
Beetle-killed	
Sapwood	0.37 ± 0.05
Heartwood	0.46 ± 0.04
Live	
Sapwood	0.41 ± 0.02
Heartwood	0.46 ± 0.03

The specific gravity of heartwood of beetle-killed timber is the same as for live timber; however, the specific gravity of sapwood is slightly lower than for sapwood of the live timber. This difference has no practical signifiance with respect to most uses but is a probable indication that some minor loss of strength can be expected.

Moisture content.—Moisture content, which is important when considering weight, shrinkage, strength, and other technical properties of wood, was determined from the increment core samples used for specific gravity determinations. Moisture contents for sapwood and heartwood are as follows:

	%Moisture content *(mean and standard error)*
Beetle-killed	
Sapwood	40 ± 11
Heartwood	32 ± 5
Live	
Sapwood	150 ± 9
Heartwood	40 ± 7

A tree's sapwood loses a substantial amount of water after the tree dies. The moisture content in beetle-killed trees was highest at the base and decreased with increasing height in the tree (Barron 1971). The amount of drying depends on the length of time the trees have been dead. As the bark breaks up and falls off, the wood dries below the fiber saturation point, generating internal stresses that result in checks or splits. Figure 3 shows prominent checks extending deeply into the logs. Other wood properties mentioned before and product yields are adversely affected by this degree of checking. Lumber yields from deeply checked trees are reduced and lumber is narrower than if the trees were sound.

Figure 3.—Checks developed in beetle-killed logs.

Mechanical strength.—Strength properties of clear wood specimens for ponderosa pine are available from James (1968), Markwardt and Wilson (1935), and the USDA Forest Service, Forest Products Laboratory (1974).

The strength properties of beetle-killed ponderosa pine are difficult to relate to past studies of blue-stained wood (Chapman and Scheffer 1940, Findlay and Pettifor 1937, Findlay and Pettifor 1939). The situation is unique in that the ponderosa pine wood being studied has been killed and left unprotected in the woods, subject to blue stain and other wood-destroying fungi, for varying periods of time. In addition, weathering degradation of wood, particularly changes in moisture content, affects wood properties. Carey[4] tested small clear specimens of wood from beetle-killed Front Range ponderosa pine and reported that modulus of rupture, modulus of elasticity, compression parallel-to-grain, and shear parallel-to-grain properties all decreased about 10% and shock resistance (toughness) was reduced by almost 53%. The implications of Carey's study and the lack of other data suggest that a more comprehensive study is needed to provide information about wood strength from standing dead trees throughout the Front Range.

Shrinkage and permeability.—Wood changes dimensions when the moisture content falls below the fiber saturation point. Because of the orthotropic characteristic of wood, dimensional changes vary in the radial, tangential, and longitudinal directions. The differential in shrinkage between radial and tangential directions is an indication of woods's tendency to check and warp during drying. In general, greater differences in shrinkage result in greater severity of drying defects.

According to previous research (Nicholas 1973), blue-staining fungi obtain their nourishment primarily from materials stored in the parenchymatous cell

[4]*Carey, P. P. 1977. A review of blue stain research—where we are today. 14 p. Colorado State University, Fort Collins, Colo. [Unpublished paper.]*

cavities of the sapwood, and little damage occurs to the cell wall structure. However, the wood becomes more permeable, because of the attack of fungi. The fungi occupy the ray cells primarily, and the growth and development of the fungal hyphae extend through the pit structures of cell walls of tracheids in the sapwood (Scheffer and Lindgren 1940). The proliferation of the hyphae probably will affect the moisture content and permeability. However, the shrinkage behavior of the wood remains the same for a given change in moisture content. Only the percentage of absorption and the rate of penetration of liquids by the wood is increased (Lindgren and Scheffer 1939). This phenomenon helps to explain the fast penetration of chemicals into blue-stained wood and accounts for a three-fold increase in chemical uptake in preservative treatment by blue-stained wood compared to normal wood. Other wood-destroying organisms such as decay fungi and the larger wood borers, further hamper utilization of beetle-killed timber and are the principal factor limiting salvage to 5 years.

Solubility changes.—Chemical constituents of the wood cell wall change when exotoxins are present, as in blue-staining and other fungal attack. Measuring the solubility of wood constituents in a 1% sodium hydroxide solution is one way of testing this deterioration. In this study, a very limited test was made using wood from the sample trees. The procedures outlined by the American Society for Testing and Materials (1980b) were followed. One bolt was taken from a tree killed about 1973, one bolt from a tree which died in 1976, and one bolt from a live tree. The sapwood of these bolts was ground into a meal of 40 to 60 mesh. The means and standard errors for solubility in sodium hydroxide are 32.79% ± 0.08%, 14.99% ± 0.09%, and 11.52% ± 0.11% for the 1973, 1976, and live bolts, respectively.

The solubility tests based on the oven-dry weight of the wood before the test were made only on sapwood, which is free of the extractives normally stored in heartwood. The large increase in dissolved substance for the tree which died in 1973, therefore, presumably comes from the main cell wall constituents. Past studies utilizing the 1% sodium hydroxide solubility test have dealt with fungal degradation of wood by brown-rot fungi. Levi (1964) emphasized that brown-rots cause a rapid increase in solubility, largely because of an acidic condition of lignin derivatives, along with a rapid depolymerization of the carbohydrates, which takes place mainly in the amorphous regions of the microfibrils. Nicholas (1973) also reported a significant increase in solubility in a 1% sodium hydroxide for decayed wood attacked by brown-rot fungi. These results, although very limited, may imply that other fungi would also increase the solubility of beetle-killed material with time after death. Seifert (1964) stated that blue-stain fungi degraded wood substance and indicated 7% loss of cellulose and a 3-4% loss of hemicelluloses. This study, based on the blue-stain fungus (*Pullularia pullulans* (deBary) Berkout) and pine wood, was conducted in Germany. These results imply that some fraction of dissolved substances are formed from the attack of blue-stain fungi on wood, but other fungi are probably responsible for most of the solubility increase.

Hydrogen-ion concentration (pH).—Hydrogen-ion concentration (pH) was tested in cold water by soaking blue-stained wood meal samples (Stamm 1961) prepared from sapwood of sixteen beetle-killed trees from the Poudre Canyon sample. These were standing trees dead from 1 to 5 years. Control samples were prepared from sapwood of five normal live trees from the Poudre Canyon site and tested by the same method.

	pH Values, *(mean and standard error)*
Green wood	4.5 ± 0.06
Beetle-killed wood	4.3 ± 0.13

The minor difference in pH is not significant and should not be a barrier for most wood products, including those in which adhesives are involved.

Wettability.—Wettability is an important property that determines the affinity of wood for liquids. It affects the transfer and penetration of glue during application and ultimately the quality of glue performance in bonding. In this study, wettability of wood from beetle-killed trees dead 4 years was compared with that of wood from living trees (fig. 4). Three samples of each were taken from trees in Poudre Canyon. The capillarity of the meal was measured at different periods of time during the course of the tests until the heights in the capillary columns reached a constant level. This comparison shows a slightly higher degree

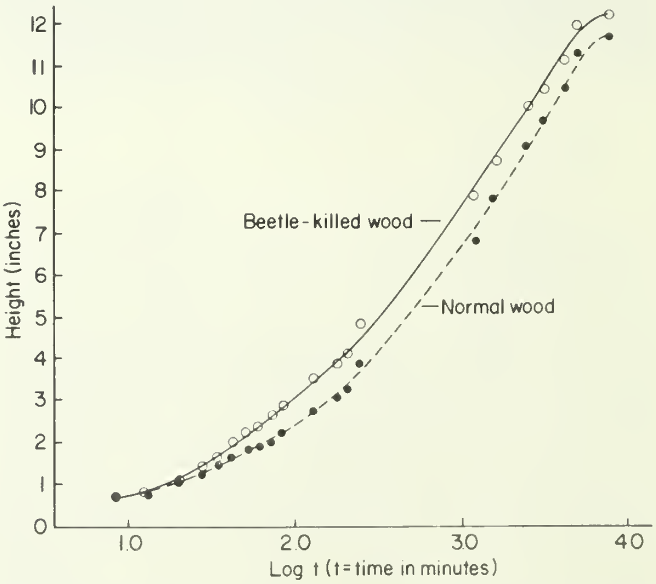

Figure 4.—Wettability of beetle-killed wood when compared with normal living wood (height means the height water rises in wood meal when packed uniformly in a 3/8-inch diameter vertical capillary tube when one open end is immersed in a reservoir of distilled water).

of wettability for wood from beetle-killed trees than for that from living trees. From this limited sample, it appears that wood from beetle-killed trees should produce glue bonds as good or better than normal wood.

Suitability of Beetle-Killed Wood for Various Products

An efficient and effective utilization program for Front Range beetle-killed and live ponderosa pine requires a diversified product mix because there is a wide variety of tree sizes and volumes per acre to be removed. New products not now being produced in the area must be considered if the available volume of live and dead timber is to be fully utilized.

Products Currently Produced

The major wood products now manufactured from ponderosa pine by the Front Range wood-using industry were investigated first. The information collected provides the main basis for predicting which wood products can be produced from beetle-killed, Front Range ponderosa pine.

Boards, dimension lumber, and timbers.—Figure 5 illustrates the various sizes and grades of boards, dimension lumber, and timbers typically produced from beetle-killed trees. A recent lumber recovery study found that lumber yield from some standing dead ponderosa pine trees approached that for live trees.[5] However, in general, a higher percentage of low-grade products will be obtained from dead trees. More narrow boards from the logs of dead trees should be expected. The general concept applicable to live trees that the higher grade lumber is cut from the clear outer sapwood layer seldom applies to beetle-killed trees, because stain, decay, and insect attack most frequently occur in that area. Blue-stained wood is generally allowed in dimension lumber, (e.g., studs) but decay is restricted.

The suitability of beetle-killed wood for studs depends on the degree of deterioration. Generally, the sound wood of beetle-killed ponderosa pine should perform satisfactorily. To confirm this, static bending tests were performed on a sample of 304, 2- by 4-inch studs obtained from 350 ponderosa pine trees (124 living and 226 beetle-killed) sampled from Roosevelt National Forest, Colo.[5] Beetle-killed trees were dead for varying periods of time up to 5 years.

The results show a trend for both normal and beetle-killed wood toward reduced strength and stiffness with progressively lower lumber grade (table 1). Within a grade, however, average values for fiber stress at proportional limit, modulus of rupture, and modulus of elasticity were not significantly different for normal and beetle-killed wood. Sources of variation such as

Figure 5.—Various sawn products from beetle-killed logs—boards, dimension lumber, and timbers.

differences in density, knots, grain deviations, etc. tended to overshadow any effects of wood deterioration that may have been associated with mountain pine beetle attack in this small sample.

Paneling.—The presence of blue-stained sapwood of dead trees presents no special technological problems in the manufacture of paneling, and the natural discoloration in the wood makes it attractive to many users for decorative uses. In the Front Range region, blue-stained paneling from beetle-killed ponderosa pine wood is now being manufactured and marketed successfully (figure 6).

It is important to maintain high manufacturing standards in producing blue-stained paneling. Paneling for interior use should be delivered at a moisture content of about 5-8% to assure best performance in service. These levels may be achieved by air-drying in the Front Range during certain months, but kiln drying may be necessary or desirable to fumigate the lumber. Fungal activity is arrested when the moisture levels fall below 20%, but the eggs and larvae of insects such as roundheaded borers, termites, and carpenter ants that may be present in beetle-killed trees continue to function at lower moisture content. To assure an insect-free paneling product, manufacturing procedures must make certain any insects in the wood are killed. One way to do this is to heat the wood to temperatures higher than 180° F, as would be done in normal kiln drying.

Pallets.—Beetle-killed ponderosa pine seems to be suitable for pallets. Although one manufacturer had blue-stained wood pallets rejected by a customer who uses pallets in contact with foodstuffs, there is no evidence that blue-stain is harmful in this respect. Naturally occurring defects such as knots, checks, splits, shakes, diagonal or spiral grain, pitch pockets, and decay which affect strength of wood and consequently pallet performance, are no more of a factor in blue-stained than in normal wood. Blue-stained pieces, especially from dead timber, should be examined carefully and determined to be sound wood before they are selected for pallet construction.

[5]*Woodfin, Richard O. 1979. A utilization question—lumber recovery from dead ponderosa pine on Colorado Front Range? USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg. [Unpublished report.]*

Table 1.—Mean bending properties of four grades of 2 x 4 studs from normal and beetle-killed ponderosa pine.

Stud grade	Number of tests	Fiber stress at proportional limit[2]	Modulus of rupture	Modulus of elasticity
		pounds/square inch		*pounds/square inch X 10[3]*
Construction[3]	30	3,705(28)	5,549(37)	1,383(20)
	33	3,952(34)	5,255(39)	1,401(18)
Standard[3]	25	3,392(38)	4,660(33)	1,352(18)
	44	3,038(42)	4,266(46)	1,256(20)
Utility[3]	39	2,334(39)	3,564(34)	1,137(22)
	45	2,596(38)	3,589(40)	1,163(18)
Economy[3]	31	1,786(46)	2,933(35)	1,039(21)
	57	2,357(32)	3,419(39)	1,054(19)
Total	304			

[1]*All tests were conducted on air-dry stock at about 6.5% moisture content. Test studs were 1 1/2 inches by 3 1/2 inches; loading was on the 1 1/2-inch face, and the test span was five feet.*

[2]*The upper figure is for normal wood; the lower figure for wood from beetle-killed trees; numbers in parentheses are coefficients of variation, in percent.*

[3]*Differences between mean values for normal and beetle-killed wood by each property for each stud grade were, in all cases, not significant at the 5% level.*

Figure 6.—Blue-stained paneling.

Fencing.—Appearance, as well as moderate resistance to decay, insect attack, and weathering is important for fencing. Of all the important strength properties, bending strength and nail-holding are of major importance for installation and long service life of fencing. There are few difficulties in the manufacture of fencing products from beetle-killed ponderosa pine wood. Protection against fungi and insects can be improved by simple preservative treatments. Figure 7, illustrates use of beetle-killed wood for functional decorative fencing.

Round timbers.—Beetle-killed ponderosa pine is probably best suited for applications that are not highly engineered, such as fence posts, barn poles, corral poles, and mine props. For these uses, strength properties of any member of appropriate size are usually greater than needed, and minor strength reduction in beetle-killed timber would not create a safety hazard. Round timbers from beetle-killed trees would be less suitable for utility poles and piling, where risk of failure from undetected decay or brash wood is unacceptable.

The presence of blue-stain should facilitate preservative treatment, but industry may regard this as a problem rather than a benefit because blue-stained wood tends to absorb preservative at a rate three times greater than unstained wood and tends to retain more of the preservative than is required.

Houselogs.—Houselogs are being increasingly used nationwide, but particularly in the mountain regions. Houselogs are now widely used throughout the Rocky Mountain West, including the Front Range for structures such as second homes, motels, churches,

Figure 7.—Fence posts, fence boards, and rails from beetle-killed logs.

restaurants, and year-round family residences. While ponderosa pine is not the most widely used houselog species, it helps satisfy a market for logs 7 inches in diameter and larger at the smaller end and 20 to 24 feet in length. There are no specific restrictions which preclude the use of beetle-killed trees for houselogs. The industry actually prefers sound dead trees because the moisture content is closer to in-service conditions, and fewer fabricating and use problems are encountered. For satisfactory performance, houselogs need to be dry when they are cut and fitted, and abnormal wood and irregular grain should be minimized to avoid problems in cutting logs. Consequently, relatively sound logs are required as a raw material.

Firewood.—There has been increased demand for wood for use in home fireplaces and wood-burning stoves. Dead ponderosa pine is well-suited for firewood because of its low moisture content, which makes it ready for marketing and use with less drying time. Its high resin content, which makes it ignite and burn more readily than less resinous woods is another plus.

Potential New Products

Composite panel products.—Ponderosa pine wood and fiber is particularly well-suited for composite panel products (Barger and Fleischer 1964, Markstrom, Lehman, and McNatt 1976). Particleboard utilizing ponderosa pine is manufactured in several locations in the western United States. Particleboard made from this species is preferred for several uses, such as furniture cores.

Maloney et al. (1976) revealed that dead trees of white pine and lodgepole pine could be used effectively for various types of composition board, including particleboards with only minor changes needed to optimize commercial board formulations. Lehmann and Geimer (1974), working with Douglas-fir forest residues for structural particleboard, found that only when badly decayed wood was added to the raw material was the quality of the particleboard seriously affected.

To examine the suitability of beetle-killed ponderosa pine for particleboard, six particleboard panels were manufactured and tested. The objective was to assess the effect of the dead wood on bonding characteristics using typical particleboard adhesives. Wood particles were prepared in a laboratory flaker from both live and dead trees. A screen analysis was then made to compare the differences between the wood from beetle-killed and live trees. It was found that the proportion of small particles increased slightly with beetle-killed wood dead 4 years (table 2). This is due to to changes in physical, mechanical and chemical properties that take place following beetle attack. Figure 8 illustrates the chip gradation documented in table 2. The row at the top is the screenings of the beetle-killed wood and the light colored chips at the bottom are those made from green wood.

In making the particleboard shown in figure 9, the furnish used was screened for particle sizes between 5 and 20 mesh.

The appearance of the boards was good. Panels made from beetle-killed ponderosa pine had a slightly blue color, but in all other respects were similar to panels made from live timber. The boards were evaluated by determining the density, modulus of rupture (MOR), internal bond (IB), thickness swelling (TS), and water absorption (WA). Procedures followed American Society for Testing and Materials (1980a), except for the water absorption test where a sample size of 3 x 3 inches was used, and in the thickness swelling test, only the thickness at the center point of the sample face was measured before and after the water soaking.

The results are tabulated in table 3. It should be noted that the mean MOR was above 1,600 psi, which is the requirement of Commercial Standard CS236-66 for type 1-B-1 board, but below 2,400 psi, the requirement of type 1-B-2 (U. S. Department of Commerce 1966).

Because wood used to make the particleboard was chipped under extreme conditions to assess the maximum particle fragmentation that could be expected, some substandard particleboard properties were anticipated. By selecting the 5-20 mesh portion of the furnish for making the panels, where the thickness-to-length ratio of the furnish particles was large, test

Table 2.—Screen analysis comparing the fragmentation of wood flaked from living and beetle-killed ponderosa pine trees on a weight-basis.

Screen sizes	Normal wood	Beetle-killed wood (dead for 4 years)
	Percentage of flakes on screen	
6 mesh	45.5	34.9
6 - 20 mesh	44.5	51.0
20 mesh	10.0	15.0
Average MC percent	6.3	6.0

values were lower than should ever occur in actual production. However, internal bond test values were very high and some wood failure was observed, which is a characteristic of good internal bonds. In thickness swelling and water absorbtion, the beetle-killed wood values were slightly higher (less desirable) than those of boards made from normal wood. It is reasonable to expect that the addition of wax to the binder mix would improve these properties.

These preliminary tests indicate that suitable furnish can be made from beetle-killed ponderosa pine. The effect of mixing such furnish with furnish from live trees or other available species still needs to be determined. Because there appear to be enough mill and forest residues in the Front Range to supply one or more board plants of economic size, the critical factor in composition board production may be the ability of the producer to obtain raw material at an acceptable cost.

Plywood.—Possibilities for utilizing beetle-killed wood for veneer and plywood are highly speculative. Live ponderosa pine should yield a quality of veneer that could be considered for plywood. Technical suitability depends on the physical and mechanical properties of the wood, tree size and form, knot size, and other defects that determine veneer yield and grade (Yerkes and Woodfin 1972). Surface checks and the lower and more variable moisture content of beetle-killed trees would probably result in severe veneer cutting problems. Lutz (1971) pointed out, however, that the moisture problem can be reduced by putting water back into the wood before cutting. In the particleboard tests the more permeable beetle-killed wood did not cause any appreciably detrimental effect in gluing.[2] It is, therefore, reasonable to assume no unsolvable gluing problems would develop with veneer. Because there were no major differences in pH values between

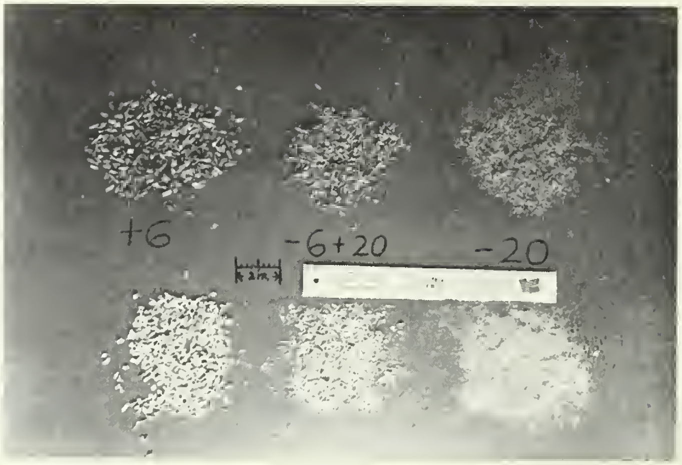

Figure 8.—Wood chips made from beetle-killed and normal green wood in the laboratory flaker.

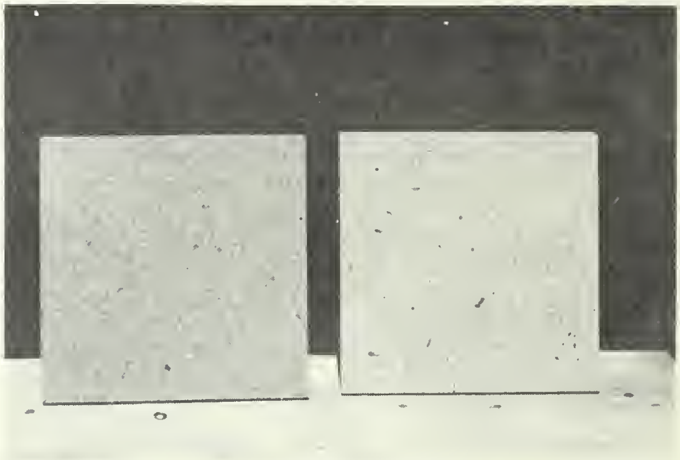

Figure 9.—Particleboard made in the CSU laboratory from beetle-killed wood and normal wood.

Table 3.—Properties of particleboard made from living and beetle-killed ponderosa pine wood.

	Normal green wood Average	Normal green wood Coefficient of Variation (%)	Beetle-killed wood Average	Beetle-killed wood Coefficient of Variation (%)
Density (#/ft³)	48	4	46	4
MOR (Psi)	2,338	10	2,145	15
IB (Psi)	192	23	178	11
Thickness swelling (TS) (% of original thickness)	40.7	2	44.3	2
Water absorption (WA) (% of final weight)	47.3	4	41.5	3
M.C. of samples (% of oven-dried wt.)	3.94	2	4.01	1

normal and stained material, veneer from dead trees could be expected to show good glue bonding characteristics. However, the higher wettability and high absorbtion rate noted in preservative treatment indicate the potential for starved glue bonds. The degree of wood deterioration and resulting weakening in mechanical strength properties of wood associated with blue-stain could limit the suitability of the veneer and plywood made from beetle-killed wood for structural uses. However, decorative uses analogous to the blue-stained lumber paneling discussed above should be entirely feasible.

Pulp and paper.—The technical feasibility of using beetle-killed ponderosa pine wood for pulp and paper products depends on the effects of moisture content, blue-stain fungi, and deterioration by decay on the quality and yield of pulp and on the consumption of chemicals. Information on the combined effects of these factors is scarce. Levi and Dietrich (1976) claimed that chemical requirements increase with the percentage of blue-stained wood involved and the degree of pulp whiteness desired. The pulp yield and strength from blue-stain fungi infested wood is not known. However, decay in the wood would seriously reduce both yield and quality of the pulp.

As reported earlier, solubility tests with 1% sodium hydroxide revealed a substantial cell wall weight loss in wood killed by beetles 4 years earlier. From this, it might be assumed that beetle-killed wood is less attractive for pulping than normal wood, but further study would be needed to verify these limited results. However, blue stain alone should not prevent use of this raw material for pulp and paper. A 95% blue-stained sulfate pulp required only 2.5% to 5% more standard bleaching agent than unstained pulp (Levi and Dietrich 1976). This slightly higher chemical usage affects the economics of production, but does not negate the possibility that pulp of good quality and strength can be produced from blue-stained wood.

The high captial cost of a mill, large water requirements, and pollution hazards all discourage conventional chemical pulping installations in the Rocky Mountains. The Front Range situation probably would require a pulping method which has low water requirements, minimal pollution hazards, and a smaller capital investment.

Laminated wood.—Ponderosa pine, including beetle-killed wood might be used for laminated wood products. The prime advantage of laminated wood lies in its potential for upgrading product performance and values.

Through lamination, wood characteristics can be modified by selectively placing laminae of the greatest strength in sections of a member where highest stresses will occur. These increased strength properties combined with the possibility of making large-sized laminated wood products from small diameter trees offer major product advantages. Beetle-killed wood should be suitable for many laminated wood products, if by careful selection weaker material could be placed in noncritical parts of laminated members. Recent studies at Colorado State University with lodgepole pine (King 1977 and Tichy 1975) suggest that laminated dimension lumber is a product that could be potentially considered for beetle-killed ponderosa pine. Since practically all large dimension framing lumber consumed in Colorado comes from outside the region, there may be an economic advantage in local production of laminated lumber 2-inch x 10-inch x 16-foot; 2-inch x 12-inch x 16-foot; and 3-inch x 8-inch x 16-foot, nominal joist sizes.

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Front Range beetle-killed ponderosa pine wood is suitable for most traditional uses of the species. Differences are: the beetle-killed timber is drier, usually blue-stained, and may contain wood borers and decay. Mechanical properties may be affected.

Keywords: *Pinus ponderosa*, *Dendroctonus ponderosae*, forest products

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Great
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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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Mountain Pine Beetle, Timber Management, and Timber Industry in Colorado's Front Range: Production and Marketing Alternatives

George R. Sampson, David R. Betters, and Robert N. Brenner

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Mountain Pine Beetle, Timber Management, and Timber Industry in Colorado's Front Range: Production and Marketing Alternatives

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Abstract

Current harvest levels and processing capacity do not take full advantage of timber potentially available in six Front Range timbersheds. Four alternatives for utilizing this resource were analyzed using a goal programming technique. Multiproduct operations based on numerous small sawmills appear to offer the best solution.

[1]*Headquarters is at Fort Collins, in cooperation with Colorado State University.*

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Management Implications

Marketing and management costs aside, the most profitable type of industry expansion would be a multiproduct operation that could convert each size and species of timber into the highest value end product. Such an operation would be selling finished lumber, some rough lumber, fenceposts, blue-stain paneling, timbers, firewood, and a host of other items. Determining marketing and management costs of a complex multiproduct firm were not included in the scope of this study, so potential profitability of such a firm cannot be accurately estimated. Along conventional lines, the best possibilities for industry expansion are probably small sawmills, due to the nature of the timber supply and industry uncertainty about long-term timber availability.

It is not clear whether the recent surge in firewood volume use along the Front Range will continue. It is likely that firewood use will remain high, but value for firewood will remain low enough relative to sawn or roundwood products that firms with manufacturing capabilities will continue to find it profitable to channel suitable timber into manufacture of these other products. Most primary manufacturers of forest products probably will find it necessary to produce and market firewood from harvesting and mill residue to maintain profits.

Introduction

This study is the third in a series, conducted to determine the potential for increasing timber harvest and utilization to facilitate forest management in Colorado's Front Range. It includes examination of product possibilities or mixes for local areas, based on existing markets, local timber processing capabilities, and harvesting, processing, and marketing costs.

The analysis here follows two previous, related studies. The first (Sampson et al. 1980) identified existing and potential processing centers and current processing capacity along Colorado's Front Range, defined the timbershed tributary to each, and determined the potential annual timber harvest (silvicultural harvest that could be maintained in perpetuity) for each timbershed. The second (Troxell et al. 1980) examined the suitability of beetle-killed pine for wood and fiber products.

Forest Management Objectives

Timber harvests from National Forest land in the Front Range generally have been well below the potential, probably because of a lack of suitable, local, industrial processing capacity, combined with a lack of high value markets for products from local timber species. Economic incentives are needed to increase timber harvest, and thereby provide the vegetation management necessary to meet long-range multiple use goals which are similar for National Forest, Bureau of Land Management, and State of Colorado lands.

Private forest land in the Front Range lacks this clear management goal. Prior to the recent mountain pine beetle infestations, very little timber was being harvested from private lands. However, after the beetle infestations and the resulting patches of dead timber, many private owners changed their attitudes. A recent survey for parts of the Front Range indicated that more than half of the private land owners would sell timber in the future (Colorado State Forest Service and U.S. Forest Service 1977).

Study Assumptions and Purpose

This study is based on the premise that increased annual timber removals from the Front Range forests (up to the limit of potential annual harvest) will help meet long range, forest management goals. One purpose of this study is to determine how short-run shifts in harvesting and processing priorities might affect the forest industry profitability in the Front Range. Another purpose is to determine if increased timber harvesting and utilization are physically and economically possible, given existing timber supplies, product markets, and harvesting, processing, and transportation costs.

Study Area

The Front Range area generally stretches from the Wyoming border to the vicinity of Canon City, Colo., and lies east of the Continental Divide. Colorado's Front Range forests include ponderosa pine, Douglas-fir, Engelmann spruce, true firs, and lodgepole pine.

The forest land in this study area (fig. 1) includes five National Forests including two Wilderness Areas, a National Park, private lands, forests owned by the State of Colorado, and some forests administered by the Bureau of Land Management. Much of the ponderosa pine type is under private ownership, primarily small parcels used for residential purposes.

The ponderosa pine stands of the Front Range have a long history of mountain pine beetle infestations, and in the mid-1970's were in the midst of a major outbreak (Stevens et al. 1975). Estimates of annual timber losses varied from 5.5 to 27.3 million cubic feet.[2,3] In addition to depreciating esthetics, and thereby land values, the dead trees are also a fire hazard (McCambridge et al. 1979). Many stands of ponderosa pine in the Front Range are overcrowded and vulnerable to mountain pine beetle as well as other insects and diseases.

Because direct control methods of felling and burning or other treatments for destroying the beetles in infested trees have not been very successful, silvicultural treatments have been suggested as a means for creating healthier, beetle-resistant ponderosa pine stands (Myers 1974, Sartwell and Stevens 1975). However, current forest industry processing capacity along the Front Range is far less than the potential annual harvest (Sampson et al. 1980).

Methods

The phases involved in this study included: (1) identifying existing or potential forest products processing centers; (2) defining timbersheds tributary to each processing center; (3) developing information on timber supply (including harvesting and processing costs) for each timbershed; (4) determining existing industry processing capacity and level of production; (5) defining market areas for Front Range forest products; (6) estimating product values within the market areas; (7) developing alternative harvesting policies for Front Range timber; and (8) analyzing the alternative harvesting policies. Phases 1 through 4 were accomplished in an earlier study (Sampson et al. 1980).

Tributary timbershed boundaries for the processing centers are shown in figure 1. The boundaries are based on the subjective judgement of federal and state timber managers. Overlap in timbershed areas obviously does occur, but this study assumed fixed boundaries between timbersheds to allow use of goal programming for analysis. Data on actual procurement areas was reported in another paper (Sampson et al. 1980).

Market areas were determined by finding where Front Range forest products are currently being sold or where they could be sold profitably. This was accomplished by contacts with Front Range processors and wholesalers in potential market areas.

In general, the market areas extended from the Front Range south to New Mexico, north to Wisconsin, and east to Ohio. The market area was further defined by distance zones. These distance zones were 0-5 miles, 5-80 miles, 80-200 miles, 200-900 miles, and 900-1,300 miles. Each market zone was an area of similar product values. The relative marketability of each product for each of these zones was determined through marginal analysis. This was determined by subtracting production costs from the estimated wholesale value of the product in the zone. These costs included stumpage, harvesting, milling, and transportation, and an allowance for profit and risk.

The alternative harvesting policies developed were based on actions that might be taken on a large scale basis either to thin stands to create mountain pine beetle resistant residual timber or to salvage timber that had already been killed. The first harvesting alternative involved a hypothetical thinning program.

Because mountain pine beetle outbreaks usually occur in timber stands where the basal area is greater than 150 square feet per acre, a thinning program which would reduce growing stock level to about 80 square feet per acre should be successful in creating beetle resistant residual stands (Myers 1974, Sartwell and Stevens et al. 1975). A theoretical Front Range thinning program was assumed for this analysis. It was assumed that (1) thinning should occur on all of the ponderosa pine sawtimber acreage and 25% of the ponderosa pine poletimber acreage, and (2) the program should cover a 5-year period. Average removals would be about 300 cubic feet per acre.

A second alternative harvesting policy required giving top priority to harvesting ponderosa pine that had been beetle-killed in the two previous years. The third alternative policy was the existing harvesting situation with no preference given to any class of timber.

Alternative production and marketing alternatives were analyzed using goal programming.[4] A goal program was formulated for each processing center on a case study basis. Each goal program was solved four times with each solution based on a different set of assumptions. The goal program was used to analyze the effects of changing priorities on the following alternatives: (1) making maximum, economical use of the recommended ponderosa pine thinnings while maximizing residual profits with potential annual harvests of other species, (2) utilizing as much of the ponderosa pine mortality as possible while maximizing residual profits with potential annual harvests of all species, and (3) maximizing residual profits with potential annual harvest of all species along with ponderosa pine

[2] *Love, Robert, David R. Betters, Harry E. Troxell, and Warren E. Frayer. 1977. Assessment of wood raw materials in Colorado's Front Range. Unpublished report, 143 p. Colorado State University, Fort Collins.*

[3] *U.S. Department of Agriculture, Forest Service. [1976]. Western forest insect problem area analysis. Unpublished report, 6 p. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Denver, Colo.*

[4] *Goal programming is a mathematical technique analogous to linear programming, except that it permits ranking of goals according to the decisionmaker's ordinal priority.*

Figure 1.—Processing centers and associated timbersheds.

mortality. These three alternatives were constrained by the maximum production capacity for each product. A fourth alternative was similar to the third, except current mill production and current harvest levels for each type timber were used as constraints instead of maximum capacity and potential annual harvest.

Each of the four goal program formulations was modified by adding market constraints to reflect more realistic market situations. In this sensitivity analysis, only 10% of the total volume of a product produced and sold under the basic goal program solution was permitted to be sold in the 0-to-5 miles marketing zone. The timber supply assumptions, mill capacity assumptions, market assumptions, and priority goals used in formulating each of the goal programming alternatives are summarized in table 1.

Results and Discussion

Potential Annual Timber Removals

It was assumed that estimated potential annual removals from private ownerships would be available. Current (1976) annual removals, potential annual removals, and existing forest products industry's processing capacity for each of the tributary timbersheds are shown in figure 2. This mill capacity was based on

Table 1.—Constraints included in the four goal program alternatives for the basic solution and the sensitivity analysis for each processing center

	Basic solution alternative				Sensitivity analysis alternative			
	1	2	3	4	1	2	3	4
Timber supply								
Potential annual harvest								
Spruce-fir	X	X	X		X	X	X	
Lodgepole pine	X	X	X		X	X	X	
Ponderosa pine		X	X			X	X	
Ponderosa pine thinnings (special 5-year program)	X[1]				X[1]			
Ponderosa pine, dead <5 years	X	X[1]	X	X	X	X[1]	X	X
Ponderosa pine, dead >5 years (for firewood)	X	X	X	X	X	X	X	X
Current harvest level								
Spruce-fir				X				X
Lodgepole pine				X				X
Ponderosa pine				X				X
Mill capacity								
Current capacity	X	X	X		X	X	X	
Current production				X				X
Market constraint								
Volume marketed in 0-5 mile market area ≤10% of basic solution					X	X	X	X

[1]*This segment of the timber supply is given priority in harvesting and utilization. All of this segment that is economical to process into products must be utilized before other segments of the timber supply can be taken.*

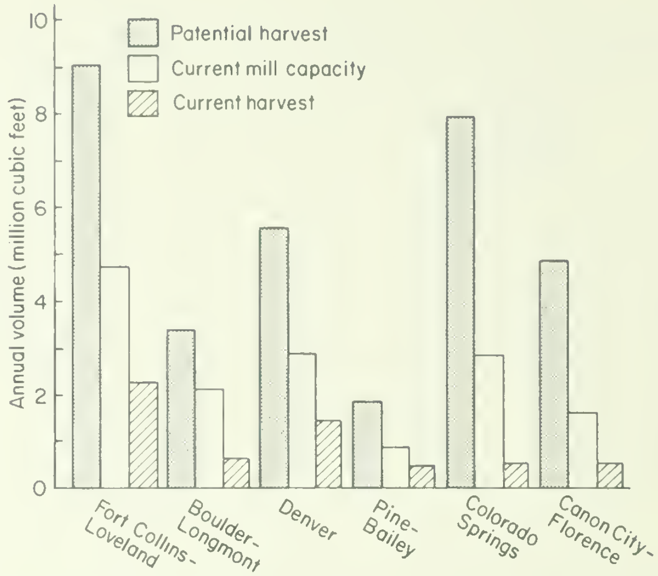

Figure 2.—Potential annual harvest, current mill capacity, and current annual harvest by timbershed.

operations as of 1976. There was a closure of one of the major mills in the Fort Collins-Loveland timbershed in 1979 which would reduce mill capacity there by about 2 million cubic feet. However, more timber is now being exported out of that timbershed for processing.

Potential annual harvest is far greater than existing forest products processing capacity for each of the tributary timbershed areas. Actual annual removals are well below the mill capacity for each of the timbersheds. The greatest difference between potential and actual annual harvest is in the Colorado Springs area, followed closely by the Fort Collins-Loveland area, then the Canon City-Florence area. The greatest difference between mill processing capacity and annual harvest is in the Fort Collins-Loveland area, followed by Colorado Springs and then Canon City-Florence.

Potential Products

The six potential Front Range products with the highest marginal values are shown in table 2. The highest value product per unit of volume is decorative paneling made from blue-stained wood of beetle-killed ponderosa pine. Four of the six processing centers were producing blue-stain paneling. Sawn timbers command high prices per unit of volume, and all processing centers except one are producing them. Fence posts are a high value product locally, but become uneconomic beyond 500 miles because of transportation costs and competition from other regions. The market volume for fenceposts within this economic area appears to be very high.

Utility poles are also a high value product, but only a small proportion of the resource is suitable for manufacture into this product. A recent study found that utility poles account for only 3% of the volume of pole and post products produced in Colorado (Betters et al. 1977). The fifth highest value product per unit of

Table 2.—Product values f.o.b. mill for highest value Front Range products

Product	Marginal value f.o.b. processing center[1]
	dollars per thousand cubic feet
Blue-stain paneling	2,119
Timbers	2,057
Fence posts	1,503
Utility poles	1,326
Beams	977
Finished boards	871

[1]*Marginal value is determined by deducting all costs (including stumpage harvesting, hauling, processing, overhead, and allowance for profit) from estimated sales value.*

output is beams which are used in construction of various kinds. The product ranking sixth in value per unit of output is finished boards (usually 1 inch in thickness). Twenty-one broad product classes were included in the analysis for this study. These combined with species classes and condition classes (whether live or dead when harvested) produced 57 product classes.

In recent years, particularly in fall 1979, there has been a dramatic increase in demand for and use of firewood along the Front Range. Most of this firewood has come from readily accessible dead timber and logging slash, although the USDA Forest Service has sold some live timber for commerical fuelwood. A recent survey of firewood use in the Denver metropolitan area by the Colorado State Forest Service found that more than 90% of the firewood used was being consumed by homes with fireplaces (Hostetler 1980). Firewood for use in stoves (less than 4% of total firewood consumed in the Denver metro area) is expected to increase in future years.

Goal Program Analysis

The solutions of the goal program for the four alternatives generally followed the same pattern among the six processing centers. Greatest annual returns were achieved by alternative 3 in every case. Alternative 1 provided the ponderosa pine sawtimber and poletimber supply that would be removed under an accelerated thinning program, but did not include the annual allowable cut foı ponderosa pine. The net returns were usually slightly lower than for alternatives 2 and 3 (fig. 3). Alternative 2 provided for annual potential cut of all species but required that recently killed ponderosa pine be given first priority for utilization. This strategy resulted in net returns that were usually greater than alterative 1, but always less than alternative 3. Alternative 4 constrained potential annual harvest to current harvest levels and also limited mill capacity to current production levels.

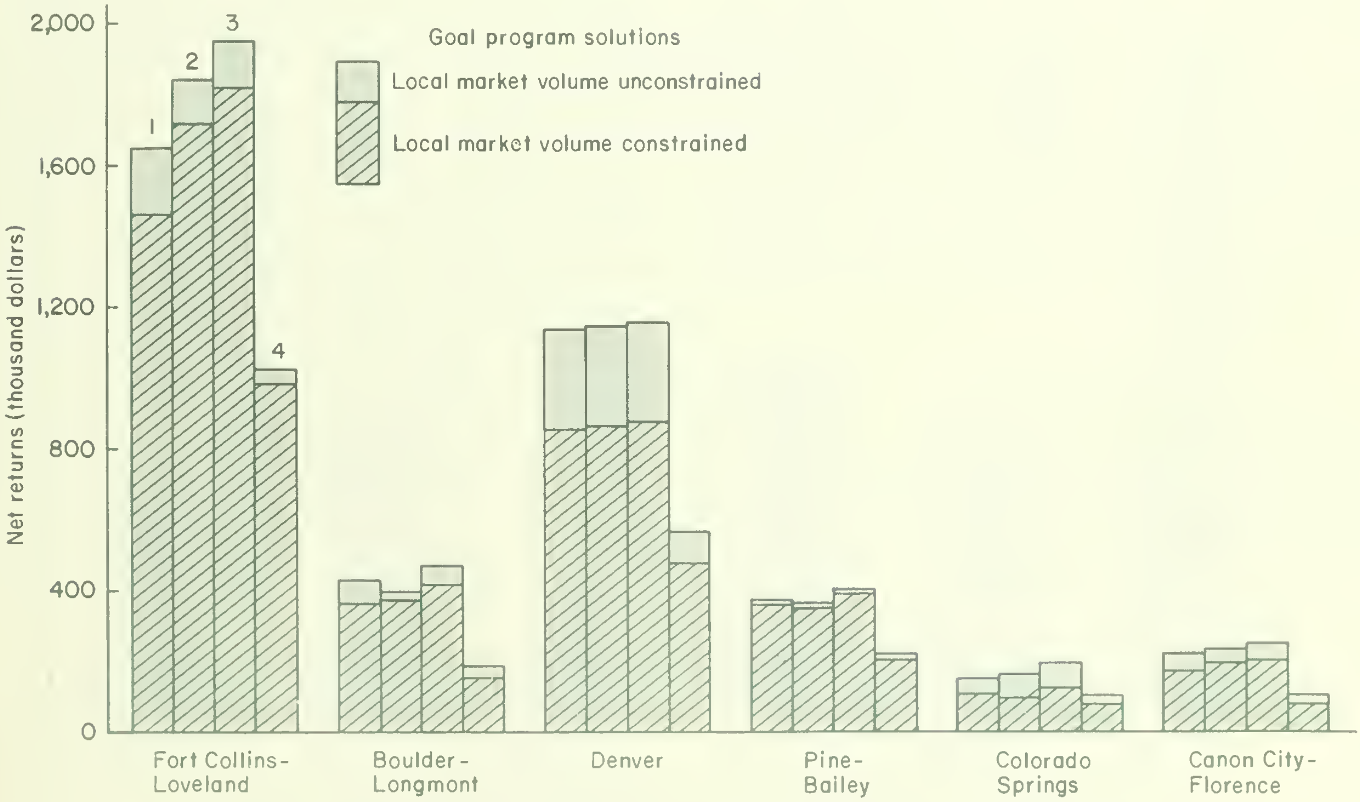

Figure 3.—Comparison of predicted returns to stumpage by the goal program for each alternative for each timbershed. (1) Priority to ponderosa pine thinnings; mill capacity; (2) priority to ponderosa pine dead less than 2 years; mill capacity; (3) priority to profits; mill capacity; (4) priority to profits; current mill production.

As a result, the net returns were far below that of the other three alternatives.

Because the goal programming sensitivity analyses limited the market for each product in the 0- to 5-mile marketing zone to 10% of the volume marketed there in the initial solution, there was a substantial decrease in returns for most processing centers for all alternatives. Net returns under the goal programming model cannot be compared with returns to stumpage under actual operation because this information is not known. However, the volume of timber harvested under the various assumptions of the model can be compared with the approximate volumes of actual timber utilization for each processing center (fig. 4). The actual timber harvest was approximately equal to the timber harvest level given for goal programming alternative 4 for all areas except Denver. For Denver, the predicted harvest volume was only 60% of the actual processed volume in 1976.

Conclusions

The results of the goal program indicate that special efforts to divert harvesting priorities to either thinning or removal of recently killed timber would have the most effect on residual values and volume of timber harvested in the Fort Collins-Loveland timbershed. Even with the constraints imposed by these special policies, optimum harvest levels predicted by the goal program are far in excess of actual removal levels (fig. 4). Institutional factors not included in the model appear to be limiting harvesting, processing, and marketing. When current harvest and processing levels are imposed in alternative 4, only the Denver timbershed has an actual processing level in excess of the model prediction.

The reason for this anomaly isn't clear, but it likely occurred because cost allowances for the model were too high, product prices for the model were too low, or entrepeneurs in the Denver area are operating at a lower profit and risk than provided in the model. Another possibility is that some of the local mills were importing timber from outside the timbershed.

Theoretically, actual harvest should be closer to mill capacity. The fact that it is not may be an indication that existing capacity is partially for different kinds of products. However, it may also be that the mill capacity figures used were too high, and/or that mills cannot get low cost timber sales. The goal program predicted that some shifts in product emphasis would be profitable.

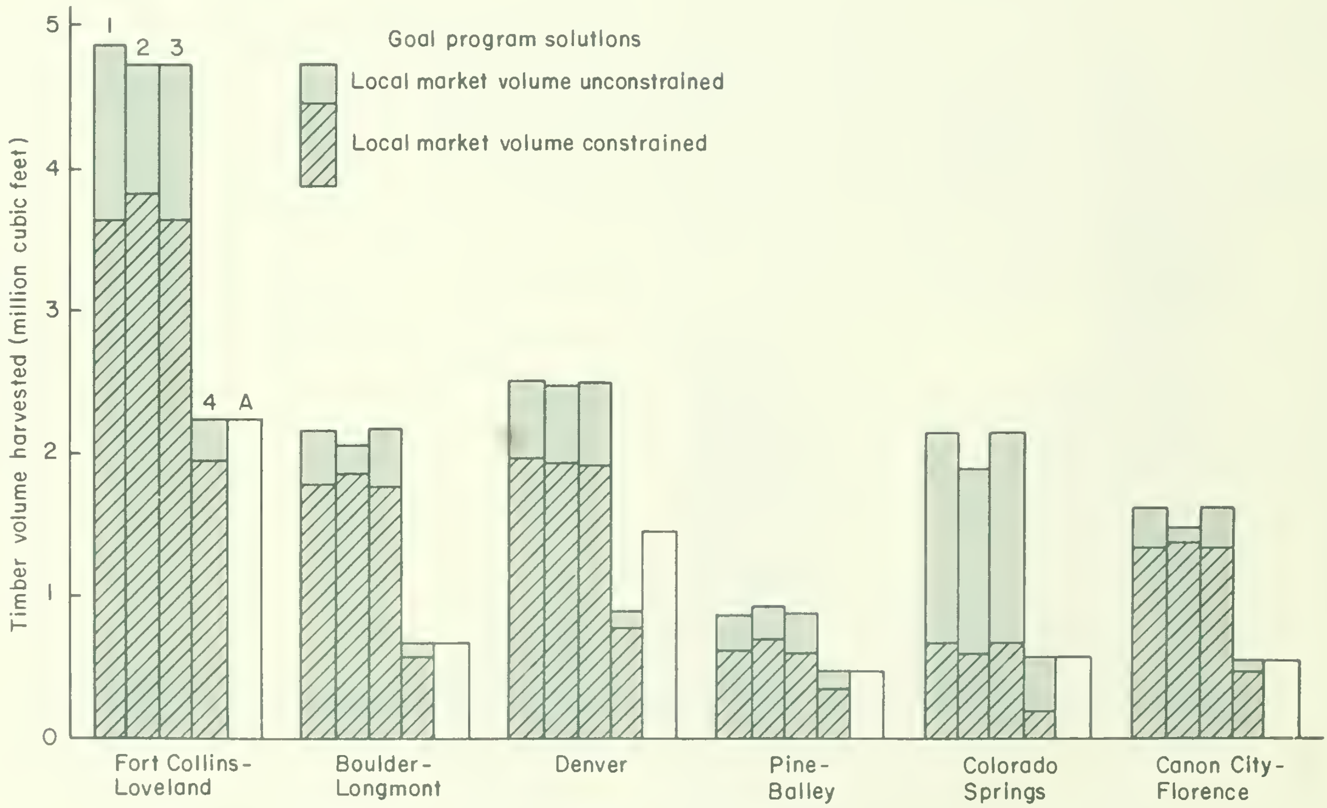

Figure 4.—Comparison of predicted timber volume harvested by the goal program for each alternative and estimated actual volume harvested for each timbershed. (1) Priority to ponderosa pine thinnings; mill capacity; (2) priority to ponderosa pine dead less than 2 years; mill capacity; (3) priority to profits; mill capacity; (4) priority to profits; current mill production; (A) estimated actual production—1976.

Ideally, the local annual production of forest products should equal potential annual removals from the tributary timbershed. This is difficult to achieve on a regular basis because of the uncertainty of demand for forest products from year to year and uncertainty about the amount of timber that may be available in any given year.

On the supply side, the amounts of timber from public land that can be made available annually for conversion into timber products are quite definitive. For private lands, however, there is in most cases no timber management plan specifying the amounts of timber that can be removed. However, based on experience from the South and the West, where local forest products industries processing capacity is high, most of the private landowners will sell timber under certain conditions. In areas where there are many owners with small acreages, timber sales need to be coordinated among owners to harvest timber economically.

There has been an increase in the number of low investment, small sawmills in some areas, largely as a result of a supply of beetle killed timber and interest by private owners in thinning timber for beetle control purposes. For example, the 1970 Colorado Forest Products Directory lists only one sawmill in Boulder county, but the 1977 version of this same Directory lists 12 sawmills or post and pole mills in this same county. However, the total production of these dozen operators was only about 30,000 board feet per day.

Marketing problems also have limited timber harvesting in the Front Range. The timber is not suitable for conventional manufacture into products for high volume markets such as framing for residential and light commercial construction. Instead, Front Range timber is manufactured into a variety of different products such as pallets, fencing, posts and poles, mine props, house logs, decorative paneling, and a variety of lumber items for general use (Colorado State Forest Service 1977). Individual sale volumes from mills to wholesalers are relatively small, making sales effort and expense per unit of product relatively high.

Because many of the existing Front Range lumber producers do not have planing equipment and do not produce and market grade stamped lumber, market opportunities are limited. In 1970, Colorado lumber producers exported more than 60% of annual production. Meanwhile, Colorado's annual consumption of lumber was 2.8 times annual production (Larson 1973). One or more centers which would concentrate lumber production from the small operators, and then plane, grade, and market it might prove to be successful.

National Forests

The less than potential harvest from National Forests in the Front Range results from several factors, including inadequate staff for timber sale preparation, policy changes, but probably most often, insufficient industry demand. It is not always clear when demand is satisfied. Some timber sales that are advertised may not be sold because industry perceives them to be uneconomic, even though, at the same time, some operators may need to purchase additional timber.

Where existing industry processing capacity is below potential annual harvest, no expansion in suitable industry processing capacity will be likely to occur unless industry is confident that long term potential harvest will be put up for sale. A trend in recent years in the central and southern Rocky Mountain National Forests has been a reduction in potential annual harvest due mainly to wilderness set-asides (USDA Forest Service 1979).

Other Forest Ownerships

Industry needs better information on the total local timber supply. Information on the potential annual harvest from private lands will be available only after timber management plans covering much of the private timber lands have been prepared. The Colorado State Forest Service has been attempting to develop a program for these private lands. If successful, this program would provide planned annual harvests from private forest lands which would benefit existing and future forest products industries.

Forest Industry

Much Front Range produced lumber is marketed as rough-sawn, and this and much of the surfaced lumber is never graded. An operation which would acquire rough lumber from the small operators, plane, grade, and market it could be valuable. The major requirement for such a firm is marketing expertise.

More definitive information about the kinds and grades of lumber sold locally in Colorado would benefit local firms, which now must import many wood products from states outside the area. Additional information on the volumes, sources, and kind and grade of lumber being handled by local wholesalers and retailers could be obtained by survey.

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Sampson, George R., David R. Betters, and Robert N. Brenner. 1980. Mountain pine beetle, timber management, and timber industry in Colorado's Front Range: Production and marketing alternatives. USDA Forest Service Resource Bulletin RM-3, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

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Keywords: Timber marketing, timber economics, *Pinus ponderosa*, *Dendroctonus ponderosae*

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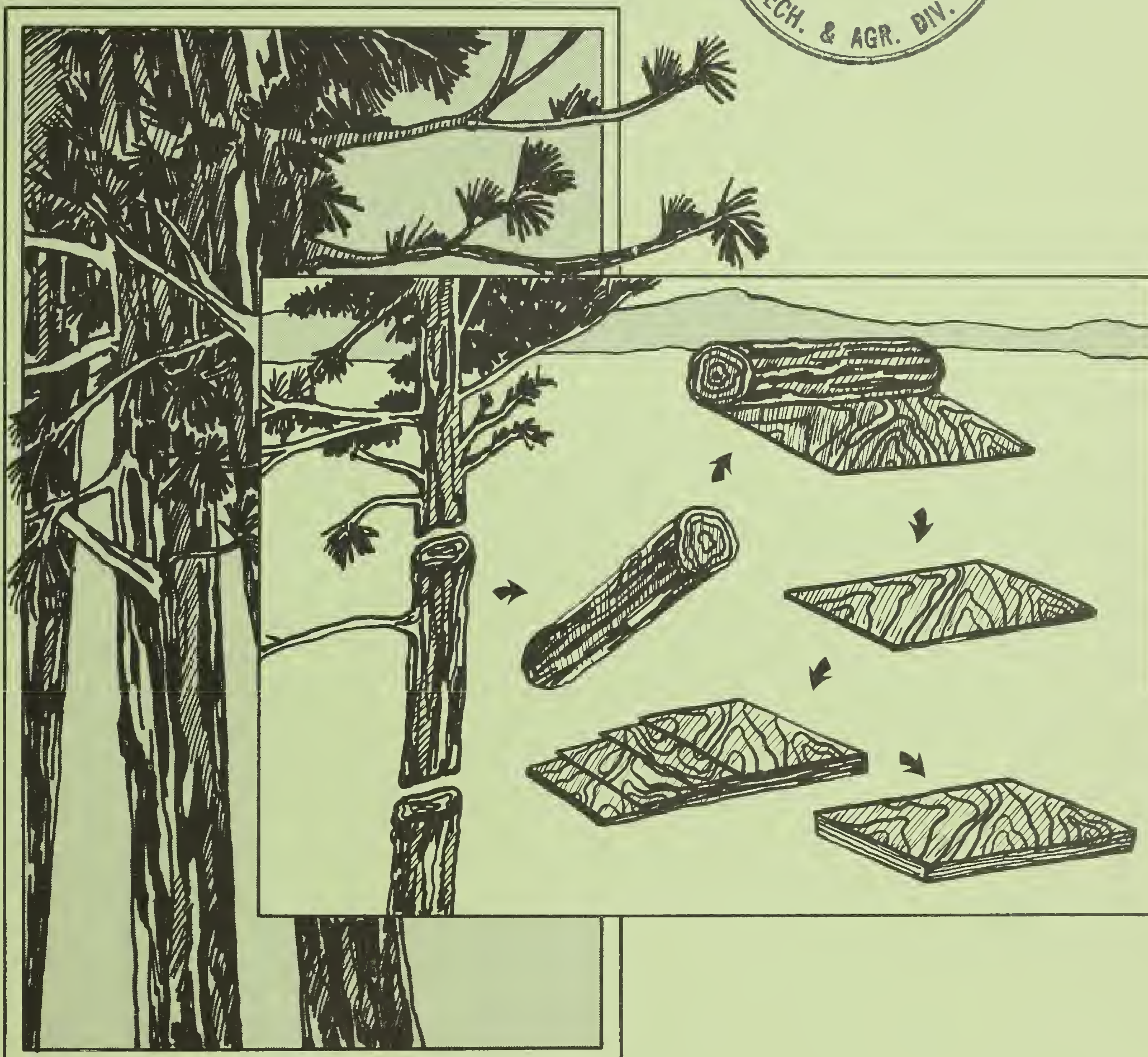
Potential for Producing Ponderosa Pine Plywood in the Black Hills

Dennis M. Donnelly and Harold E. Worth



Resource Bulletin RM-4
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

This study describes possible plywood production opportunities for Black Hills ponderosa pine in terms of kinds of plywood and advantageous market areas. The resource analysis examines current and future uses of the area's timber. Economic evaluation includes analyses of discounted cash flow and operating costs and revenues.

Acknowledgments

The resource section of this report is based in part on earlier work by Vern P. Yerkes, USDA Forest Service Southwest Region, and Richard O. Woodfin, USDA Forest Service Pacific Northwest Forest and Range Experiment Station, and their contributions are cited in the text. The economics section is based on a projection of investment and operating costs by F. E. Hahn, formerly with H. C. Mason and Associates. In addition, the authors thank the following people for their assistance: Robert G. Anderson (American Plywood Association), Richard F. Baldwin (Champion International Corporation), and James L. Bowyer (University of Minnesota).

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Contents

	Page
MANAGEMENT IMPLICATIONS	1
MARKETING	1
TIMBER RESOURCE	1
ECONOMICS	1
CONCLUSIONS	2
STUDY OBJECTIVES	2
MARKETS FOR BLACK HILLS PLYWOOD	2
U.S. PLYWOOD MARKET CHANGES	2
NATIONAL PLYWOOD OUTLOOK	3
End-Use Markets	3
End-Use Markets and Plywood Grades	3
PONDEROSA PINE PLYWOOD—POTENTIAL APPLICATIONS	3
Residential Construction	3
Industrial, Nonresidential, and Other Uses	4
MARKETING BLACK HILLS PLYWOOD	4
Production and Demand in Relation to Geography	4
Freight Rates	6
Market Potentials	7
TIMBER RESOURCES AND PLYWOOD	9
THE FOREST RESOURCE	12
Land	12
Growing Stock	12
RESOURCES FOR PLYWOOD	12
Current Utilization	12
10-Year Future Supply, 1977-1986	13
Availability for Plywood	14
The Second 10 Years, 1987-1996	15
QUALITY	15
Timber Sale Characteristics	15
Log Size Distribution	16
Product Characteristics	17
OPERATING ECONOMICS	18
ASSUMED OPERATING FORMAT	19
Plant Size	19
Plant Overview	19
Product Output	20
Economics	23
ALTERNATIVE OPERATING FORMATS	29
Effect on Break-even Price	29
Effect on Raw Material Need	29
LITERATURE CITED	31
APPENDIX	33
MARKETS	33
Plywood Properties Important in Marketing	33
Applications in Residential Construction	34
Some Industrial Applications	35
APA 303 Siding Specifications	35
TIMBER RESOURCE	36
Black Hills National Forest Timber Classes	36
Computation of Log Size Distribution	36
ECONOMICS	38
Computation of Veneer Recovery	39
Computation of Log Taper	39
Lumber and Residue Recovery	40
Bark Volume	40
Product Recovery for Index Log Volumes and Total Volume Required	40

Potential for Producing Ponderosa Pine Plywood in the Black Hills

Dennis M. Donnelly and Harold E. Worth

MANAGEMENT IMPLICATIONS

MARKETING

A major advantage of producing plywood in the Black Hills area of South Dakota and Wyoming is proximity to major markets. Plywood produced there could be delivered to Great Plains and upper Midwest markets at a freight cost lower than that from other major softwood plywood producing regions. Market potentials for softwood plywood in the United States are very strong for the foreseeable future. However, because ponderosa pine is not a well established plywood species, there is some question about the share of the market it can command. Because Black Hills ponderosa pine yields primarily C and D grade veneers, its utilization would be limited mainly to plywood products made from these grades, such as roof and wall sheathing, siding, or flooring. Other special plywood products for use in new residential, homeowner, nonresidential construction, and industrial markets seem promising also. Small volumes of B Patch and better veneer might be marketed as stock for products where appearance is of some importance, such as cabinets.

In addition, recent developments in performance standards for sheathing panels, including plywood, may have expanded market possibilities for woods such as ponderosa pine. Performance-rated sheathing panels are "designed, manufactured and identified for specific construction end uses" (American Plywood Association 1980). Such panels conform to "criteria for panel strength, stiffness, durability, stability and other properties relevant to the end-use." If structural criteria are met, panels can be made entirely from veneer faces bonded to a reconstituted wood core, or from reconstituted wood.

In the case of plywood manufactured from ponderosa pine in the Black Hills, the provisions of Product Standard 1-74 (American Plywood Association 1974) remain applicable. However, it is possible that such plywood could now obtain upgraded span ratings through testing for sheathing end-use applications. See the appendix for details about sheathing applications and span ratings. Plywood variables such as veneer thickness and orientation, along with inherent wood properties, would determine in part how well such panels meet the standards for performance-rated sheathing.

TIMBER RESOURCE

The Black Hills National Forest Timber Management Plan for the 10-year period ending in 1986 shows that enough timber of the required size[2] is available to support a plywood plant with an annual capacity of about 60-65 million square feet (MM ft^2), 3/8-inch basis. However, a very tentative projection for the following 10-year period indicates sawtimber volume from 1987 to 1996 may be about 23 million board feet less than volume for the current 10-year period—a 21% reduction. This reduction of volume in sawtimber size trees may mean a smaller potential supply of logs suitable for plywood.

The size of logs required for any potential plywood plant is roughly the same as for the established Black Hills lumber industry. The supply of timber of this size appears to be adequate to serve both the present industry and a new plywood plant until 1986. However, in the 10 years after 1986, reduced volumes of timber in this size class may not support both industries.

Estimated veneer block supply is concentrated largely in the 8- to 12-inch d.i.b.[3] range. A plywood plant would also have to deal with a substantial volume of logs smaller than 8 inches d.i.b. to utilize the tops of larger trees and any smaller trees purchased in multiproduct timber sales.

ECONOMICS

At early 1978 cost levels, the break-even price for 1,000 square feet of 1/2-inch C-D Interior plywood with external glue (C-D-X) sheathing, f.o.b. mill, was about $142. For a 20% rise in total costs, break-even price for 1/2-inch C-D-X sheathing rose 28%. Break-even price is also sensitive to other factors, to a lesser degree. In decreasing order of sensitivity, internal rate of return, log cost, labor cost, and energy cost are of greatest importance. All costs are those incurred before the plywood leaves the mill.

The economic aspects of plywood manufacture in the Black Hills area appear favorable except for the uncer-

[2]The "required size" in this report is assumed to be trees whose diameter at 4.5 feet above the ground (diameter at breast height) is 9 inches or greater. Diameters of the timber resource analyzed in this report are grouped into 2-inch classes for which the nominal diameter is the mid-value (e.g., the 10-inch d.b.h. class includes all trees whose diameter is between 9.0 and 10.9 inches.

[3]Usually the small end of the log is specified for the diameter inside bark (d.i.b.) measurement.

tainty surrounding supplies of logs for veneer. The analysis showed that under 1978 conditions, supplies of stumpage could be critical for both plywood and lumber. However, current total sawmill demand for stumpage has decreased significantly. It is possible that plywood manufacture would be economically attractive at this time.

CONCLUSIONS

The timber resource projected for harvest in the Black Hills area, during the next 15 years, is not adequate to support a plywood plant of economic size in addition to a sawmill industry of the size operating in early 1978. Under conditions existing at that time, competition for available sawtimber could be expected to intensify during the period, particularly after 1986. More recently, however, mill closures have resulted in substantial reductions in overall sawmill production, which could make plywood an attractive alternative for utilizing a potential surplus of sawtimber.

Markets do not appear to be a major problem, because the north-central part of the United States should provide good end-use outlets for plywood of the types that could be produced. Economic costs and returns would probably be favorable for a plywood producer at least until 1986, when the expected reduction in sawtimber volume could significantly increase competition and the cost of stumpage.

STUDY OBJECTIVES

The goal of this study was to evaluate marketing, timber resource and economic factors that determine whether plywood could be profitably manufactured in the Black Hills area of South Dakota and Wyoming. Specifically the study objectives were to:

1. Determine market potentials for selected plywood products that can be manufactured from Black Hills ponderosa pine.
2. Evaluate the timber resource of the Black Hills area in terms of its current utilization, its availability and suitability for veneer, and the log size classes available under current timber management plans.
3. Analyze the operating economics of a potential plywood plant/sawmill complex under several assumptions about product prices and plant costs.

MARKETS FOR BLACK HILLS PLYWOOD

U.S. PLYWOOD MARKET CHANGES

Since 1945, many new end uses have been developed for softwood plywood in the United States. The largest single use is structural sheathing for residential construction. In response to this increase in uses, the softwood plywood industry now has 10 times the production capacity of 30 years ago (Gregory 1972, Lambert 1977, U.S. Department of Commerce 1978a).

In 1950, the plywood industry manufactured about 2.7 billion square feet (MMM ft^2)[4] at a relative wholesale price index of 180 (1967 = 100). Until 1968, the plywood industry provided increasing supplies at decreasing relative prices because of efficiencies of scale, productivity gains, and increased industry competition (Gregory 1972). This relationship through the years until 1967 is shown in figure 1 by the steadily decreasing relative wholesale price index as production increased. However, starting in 1968, the relationship between relative wholesale price index and softwood plywood production became erratic because of several economic factors—primarily inflation, rising raw material costs and, especially, highly variable housing markets.

Production of sanded grades[5] was about 2.6 MMM ft^2 in 1976, 18% of total production (American Plywood Association 1977b). Production of specialty grades[6] was about 1.5 MMM ft^2 in 1976, 10% of total production. Production of sheathing grades[7] was about 10.7 MMM ft^2 in 1976, 72% of total production.

During the past 30 years, plywood, especially sheathing, has been substituted for lumber in housing

[4]All plywood production and volume figures in this report are based on 3/8-inch thickness unless otherwise noted.

[5]Sanded grades include B-D and better sanded grades (American Plywood Association 1974).

[6]Specialty grades include siding, and other specialty products like T 1-11, 303 sidings and overlays, and Plyron (American Plywood Association 1974).

[7]Sheathing grades include sheathing and touch sanded grades such as C-D-X, Underlayment, C-C, 2-4-1, Structural I and II, and C-D P & TS (American Plywood Association 1974).

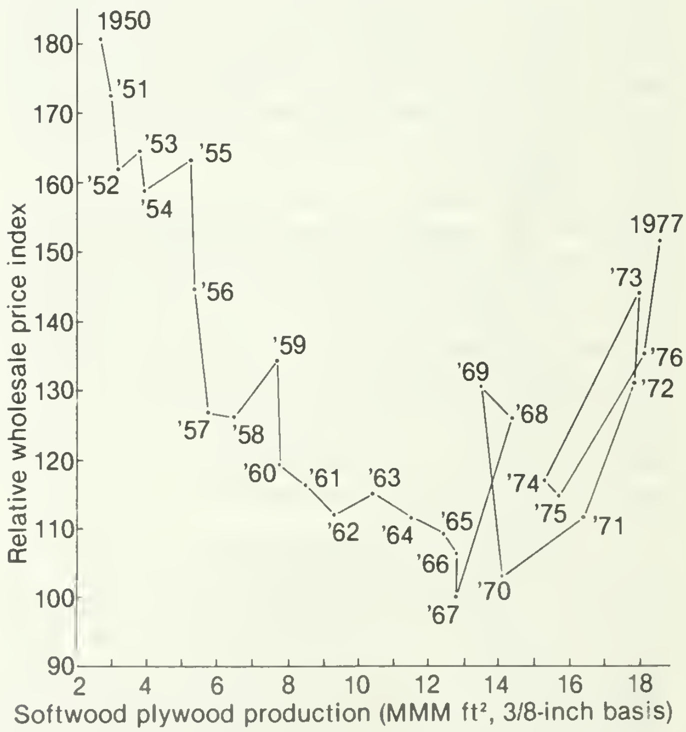

Figure 1.—Production of softwood plywood from 1950 to 1977 relative to its wholesale price index. Data Source: Phelps (1977), and U.S. Department of Commerce (1978b). Acknowledgement is made of the original form of this graph appearing in Gregory (1972).

construction. This shift accounts for the dominance of sheathing grades among all types of softwood plywood.

NATIONAL PLYWOOD OUTLOOK

Although the maturing plywood industry may not continue to experience the spectacular growth rate of the 25-year post-World War II period, industry sources expect continued expansion of production to meet increasing demand (Anderson 1977, Baldwin 1977). Housing growth is expected to continue to increase up to the late 1980's. However, wide cyclic swings may continue unless effective institutional means are adopted to even out production (Young 1978). New floor, foundation, and wall applications for plywood, such as the All Weather Wood Foundation or under-floor plenum heating-cooling systems, will probably strengthen plywood demand. Non-housing markets such as use by homeowners also are expected to create new plywood demand.[8]

Current (1980) plywood industry plant capacity,[8] based on 3-shift, 5-day operation, is estimated at 24.46 MMM ft². This current total capacity is slightly higher than a conservatively projected demand for the mid-1980's of about 22 MMM ft².

End-Use Markets

The five principal markets for softwood plywood, as defined by the American Plywood Association (APA) (Anderson 1977) are:

Residential construction.—Including single and multifamily homes, manufactured housing, and mobile homes.

Nonresidential construction.—Including most buildings not used as homes, such as commercial, industrial, and institutional buildings; hotels; motels; agricultural buildings; and applications such as barricades, signs, shoring, dams, bridges, and highways. Highrise apartment construction also is included in this end-use market.

Industrial.—Encompassing a wide variety of uses, such as manufactured products including furniture, fixtures, and toys. Pallets, crates, bins, and other containers, categorized as materials handling devices, are also included. The transportation industry uses plywood in truck bodies, cargo containers and liners, rail cars, ships, boats, and travel trailers. General industrial applications are for plant repair and maintenance, and for tools, jigs, and patterns.

Distribution (homeowner).—Including home repair and remodeling, home additions and alterations, and miscellaneous homeowner projects.

Miscellaneous.—The fifth market segment, including international markets, government and military markets, and any use not included in the other market sectors.

[8] *Personal communication from Robert G. Anderson, Marketing Group, American Plywood Association, Tacoma Wash.*

Of interest, is the projected change in demand for each of the five principal markets. Average growth or decline in each principal end-use market is indicated by a compound annual rate of demand change (table 1). For example, an estimated market share loss of 8.1% from 1977 to 1986 in the residential end-use market is taken up by market share gains in the other four end-use markets.

End-Use Markets and Plywood Grades

Some indication of future demand for individual plywood grades can be obtained by combining demand forecasts for end-use markets with information about plywood grades most used in those markets. Table 2 shows main segments of the five major plywood end-use markets along with plywood grades used predominantly in each market segment.

A Black Hills plywood plant, manufacturing panels with C and D grades of veneer, would have access to several market segments. Some degree of protection from market fluctuations would be afforded by this diversity.

Grades other than C-D-X that could be made from Black Hills ponderosa pine are Exterior C-C and Structural II C-C, C-C Plugged, and C-D; also Interior Structural II C-D, C-D Plugged, and Underlayment; also 2-4-1 and 2-4-1 T&G. These grades have wide application by market sector, as shown in table 2, and are relatively high in value; however, market demand is much smaller than for C-D or C-D-X grades.

In addition, new grade specifications for 303 siding may allow use of ponderosa pine for this product. Also, enough B Patch and better veneer can be recovered (Yerkes and Woodfin 1972) so that decorative panel products and cabinet grade plywood are production possibilities.

PONDEROSA PINE PLYWOOD—POTENTIAL APPLICATIONS

Ponderosa pine (*Pinus ponderosa* Laws.) is classified in U.S. Product Standard PS 1-74 as a Group 3 softwood plywood species (American Plywood Association 1974), based on stiffness and strength properties. Plywood characteristics and properties important in marketing and application are discussed in the appendix. Based on these characteristics and the APA classification, some of the uses for which ponderosa pine plywood should be suitable include sheathing, subflooring, underlayment, siding, soffits, signs, billboards, boxes, crates, movable partitions, interior paneling, and kitchen cabinets, furniture, fixtures, and decorative paneling. The following applications are discussed for each major end-use category that utilizes mostly C and D grades of veneer.

Residential Construction

Softwood plywood is primarily used in roof sheathing, subflooring, underlayment, combination flooring,

Table 1.—Comparison of demand and market share in plywood end-use markets[1]

Major end-use market	1977 demand	1986 estimated demand	Estimated average annual demand change 1977-1986	1977 market share	1986 estimated market share
	MMM ft^2		percent		
Residential	9.10	8.85	−0.28	46.8	38.7
Distribution (homeowner)	3.60	4.55	2.37	18.5	19.9
Industrial	3.00	4.10	3.17	15.4	17.9
Nonresidential	2.25	3.10	3.26	11.6	13.6
Other	1.50	2.25	4.14	7.7	9.8
Total	19.45	22.85	[2]1.62	100.0	100.0

[1]*Source: Anderson (1977).*
[2]*This figure is the average for all major end-use markets.*

wall sheathing, siding, and combination siding. These uses make up almost 90% of the plywood sold in the residential construction market. Most of the potential construction uses for ponderosa pine plywood are subject to local building codes, which establish the minimum physical requirements for a particular use. Applications must therefore be considered within requirements of building codes and other characteristics of the end use.

Industrial, Nonresidential, and Other Uses

The uses in the industrial market that were considered in this study are van interiors, boxes and crates, pallets, and air cargo containers—the total of which represents approximately 25% of the industrial market. However, there are many diverse end uses for softwood plywood in the industrial market, each requiring a unique set of physical properties. Unlike requirements for the residential construction market, characteristics other than strength and stiffness are important in many industrial uses of softwood plywood. For example, the weight of the material from which a container is made can be more significant than the material strength. Ponderosa pine could have an advantage over some other species used in plywood because of its combination of moderate strength and light weight. Because many uses in the industrial market require a face veneer of A or B grade, some Black Hills ponderosa pine plywood could fit these requirements.

The nonresidential construction market uses plywood in many ways, such as concrete forms and temporary structures.

Homeowner and miscellaneous uses would cover applications ranging from home remodeling to furniture. For structural use, ponderosa pine plywood would be subject to conditions similar to residential construction.

MARKETING BLACK HILLS PLYWOOD

Production and Demand in Relation to Geography

The distribution of plywood plants in the United States is shown in table 3. Plywood production in the South has risen dramatically since the first plant was established there in 1964. The number of plants has increased in the South and decreased in the Northwest. Although production capacity figures for some states and individual plants are available in the trade literature, estimates of total industry plant capacity from 1970 to 1978 are less certain. It is expected, however, that most future industry growth will occur in the South.

Relative volumes of plywood shipped from each producing region to various Rand McNally Major Trading Areas (Rand McNally and Company 1963) offer some insight into comparative advantages each region may have.

Shipment data on sheathing plywood for 1976 (American Plywood Association 1977b) indicate that shipments from producers in the South went to all but seven of 52 Rand McNally Major Trading Areas (including Alaska, Honolulu, and Export); shipments from producers in the West went to all Major Trading Areas; shipments from the producers Inland went to all but three Major Trading Areas (table 4). The regional pattern of shipments from the South is most apparent, while shipments from the West and Inland Regions appear to be more widely distributed.

Within the range of sheathing grades produced, certain producing regions manufacture a disproportionately large share of certain grades (table 5). The Inland Region, for example, shipped slightly less than 18% of the industry's sheathing production in 1976. However, of the total C-D Interior sheathing produced, the Inland

Table 2.—Softwood plywood applications by grade in major end use market segments[1]

	Panel use[2]	Residential					Nonresidential			Industrial				Distribution[3]		Miscellaneous[3]	
		Floor structures	Roof structures	Siding	Other residential uses	Mobile homes	Roof decks	Concrete forms	Other nonresidential uses	Material handling	Transportation equipment	Products made for sale	Plant repair, maintenance	Home modifications[4]	Other homeowner uses	International	Military and government
Engineered grades:																	
C-D, C-D-X	I	X	X		X	X	X	X	X	X	X	X	X	X		X	X
Structural I C-D	I					X	X				X		X				
Structural II C-D	I										X		X				
Underlayment	I	X			X	X			X				X	X		X	
T&G Underlayment[5]	I	X											X	X		X	
2-4-1	I	X			X		X		X				X				
C-D Plugged	I												X				
C-C	E								X	X	X		X			X	
Underlayment C-C Plugged	E	X											X	X		X	
C-C Plugged	E		X	X			X	X	X				X				
Structural I C-C	E					X	X				X		X				
B-B Plyform I & II	E							X					X				
Appearance grades:																	
N-N, N-A, N-B	I										X		X		X		
N-D	I										X		X		X		
A-A	I										X		X		X		
A-B	I										X		X		X		
A-D	I				X	X				X	X	X	X	X	X		X
B-B	I										X		X		X		
B-D	I										X		X		X		
A-A	E										X		X		X		
A-B	E										X		X		X		
A-C	E		X	X	X	X			X	X	X	X	X		X	X	X
B-B	E										X		X		X		
B-C	E		X	X	X		X	X	X	X	X	X	X	X	X	X	X
Specialty grades:																	
Decorative panels	I				X								X				
Plyron	I				X								X				
HDO	E							X				X	X				
MDO	E		X	X	X				X		X	X	X	X			
303 siding, T 1-11	E		X	X	X	X			X			X	X	X		X	X
Plyron	E												X				
Marine	E										X	X	X				

[1] *Sources: Anderson (1977), American Plywood Association (1976).*
[2] *Panel use: I = Interior, E = Exterior.*
[3] *Distribution is also called the homeowner market. For both Distribution and Miscellaneous market segments, almost all grades are in demand; only the principal grades are indicated.*
[4] *Includes home repairs, additions, alterations.*
[5] *T&G = Tongue and Groove.*

Table 3.—Distribution of North American softwood plywood plants for selected years[1]

Area	1970	1974	1976	1977	1978
South and Southeast					
Alabama	3	7	8	8	9
Arkansas	6	8	8	8	9
Florida	1	2	1	–	–
Georgia	5	5	7	5	6
Louisiana	10	11	13	13	13
Maryland	1	1	1	1	1
Mississippi	5	6	6	5	6
North Carolina	5	5	5	6	8
Oklahoma	–	1	1	1	1
South Carolina	1	2	2	3	4
Texas	7	7	9	7	9
Virginia	2	1	2	2	2
Total	46	56	63	59	68
Pacific Northwest and Coast					
California	16	17	23	16	13
Oregon	84	79	85	79	69
Washington	32	28	28	25	27
Total	132	124	136	120	109
Inland					
Idaho	5	4	5	5	5
Montana	5	5	7	6	5
Total	10	9	12	11	10
Other States[2]	4	3	4	2	2
Total U.S.	192	192	215	192	189
Total Canada	28	30	28	28	33
TOTAL NORTH AMERICA	220	222	243	220	222

[1]*Source: Directory of the Forest Products Industry for each year, published by Miller Freeman Publications, Inc., San Francisco, Calif.*

[2]*Number of softwood plywood plants in states not typically associated with any of the three recognized producing regions.*

Region shipped almost 96%, and of the total C-C Plugged Exterior sheathing produced, the Inland Region shipped almost 43%.

Freight Rates

Freight rates are a large factor in delivered price and, given a commodity type product like sheathing, can often determine where plywood is purchased. There are numerous market areas where a Black Hills producer might ship plywood with a freight advantage, or at least with a freight parity, compared to existing production centers.

Current freight regulations require plywood producers to separate the f.o.b. mill price from freight charges and permit customers to pay freight costs on the basis of actual weights. Consequently, ponderosa pine plywood,would have significant freight cost advantage over Douglas-fir or southern pine plywood due to its lighter weight.

Newcastle, Wyo., and Rapid City and Whitewood, S. Dak., were selected as representative Black Hills locations on which to base freight rate computations in this study. Of all other southern and western rail shipping points considered, one or more of the three Black Hills locations have the lowest rates to the following cities: Denver, Des Moines, Kansas City, Milwaukee, Minneapolis, Omaha, and Wichita. Freight rates to Chicago from the Black Hills locations were slightly higher than the lowest rate from the South, but remained competitive.

Of all truck shipping points considered, one or more of the three Black Hills locations have the lowest rates to the following cities: Chicago, Denver, Des Moines, Kansas City, Minneapolis, Omaha, and Wichita.

Table 7 shows how these truck and rail rates compare. In almost all cases, truck rates are highly competitive with rail; in a few instances they are lower. With the exception of Rapid City and Whitewood to Wichita and of Newcastle to Omaha, rail transport is less than $2.00 cheaper than truck transport. For

Table 4.—Shipments to major trade areas receiving 1% or more of total production from each producing region[1]

Southern		
Trade area destination	Amount shipped[2]	Percent of production from region
Charlotte	486,665	9.03
Atlanta/ Chattanooga	334,102	6.20
Chicago	293,543	5.45
Dallas/ Fort Worth	289,767	5.38
Memphis	238,737	4.43
Houston	234,824	4.36
Detroit/ Toledo	229,093	4.25
New York	203,471	3.78
Richmond/ Norfolk	198,767	3.69
Philadelphia	195,488	3.63
New Orleans	163,130	3.03
Washington/ Baltimore	153,333	2.85
St. Louis	149,583	2.78
Miami	143,574	2.66
Jacksonville	123,056	2.28
Birmingham	118,499	2.20
Kansas City	111,850	2.08
Cleveland	110,724	2.05
Milwaukee	110,320	2.05
Pittsburgh	105,464	1.96
Little Rock	104,171	1.93
Knoxville	95,807	1.78
San Antonio	94,103	1.76
Indianapolis	89,924	1.76
Tampa/ St. Petersburg	84,574	1.57
Cincinnati/ Dayton	83,974	1.56
Boston/ Providence	79,752	1.48
Des Moines/ Sioux City	68,994	1.28
Nashville	63,832	1.18
Shreveport	58,641	1.09
Oklahoma City	57,110	1.06
Columbus	53,622	1.00

Inland		
Trade area destination	Amount shipped[2]	Percent of production from region
Spokane	185,318	9.85
Salt Lake City	176,869	9.40
Denver	151,156	8.03
New York	131,522	6.99
Minneapolis/ St. Paul	127,871	6.79
Seattle	115,410	6.13
San Francisco/ Oakland	104,011	5.53
Boston/ Providence	76,779	4.08
Milwaukee	71,793	3.81
Export	65,978	3.51
Detroit/ Toledo	64,832	3.44
Philadelphia	63,046	3.35
Los Angeles	62,378	3.31
Portland	51,952	2.76
Des Moines/ Sioux City	34,627	1.84
Washington/ Baltimore	30,807	1.64
St. Louis	29,804	1.58
Buffalo/ Rochester	26,391	1.40
Kansas City	20,543	1.09
Omaha	19,635	1.04

Western		
Trade area destination	Amount shipped[2]	Percent of production from region
San Francisco/ Oakland	505,237	14.80
Portland	493,472	14.45
Los Angeles	482,389	14.13
Seattle	306,435	8.98
Export	247,908	7.26
New York	201,433	5.90
Chicago	127,535	3.74
Boston/ Providence	124,209	3.64
Phoenix	103,941	3.04
Minneapolis/ St. Paul	102,751	3.01
Salt Lake City	86,199	2.52
Milwaukee	76,331	2.24
Philadelphia	70,043	2.05
Detroit/ Toledo	54,635	1.60
Denver	51,843	1.52
Washington/ Baltimore	47,538	1.34
Kansas City	42,759	1.25
Spokane	42,447	1.24
Des Moines/ Sioux City	36,403	1.07

[1] *Data Source: American Plywood Association (1977b).*
[2] *In thousand square feet (M ft²), 3/8-inch basis.*

customers not located on rail sidings, any surcharge added to rail rates to cover truck delivery would likely overcome the slight cost advantage of rail shipment.

In the period since these figures were originally compiled (1977), several across-the-board, percentage freight rate increases have increased the rate advantage of Black Hills locations, compared to the Pacific Northwest and Southern Regions, when shipping to the Great Lakes States.

Market Potentials

Based on freight costs and trade patterns, the trade areas represented by the cities listed in table 7 probably comprise the prime potential market for a potential Black Hills plywood producer. Data for 1976, assembled in table 8, support the concept that plywood manufactured in the Black Hills can be marketed successfully in northern and central Great Plains, the upper Midwest, and the Great Lakes area.

Rough Grades

The total industry column in table 8 shows the proportion of total industry production of sheathing grades that was shipped to the prime Black Hills market area. For example, the total volume of sheathing that was shipped to the prime market area is about 1.75 MMM ft^2, 3/8-inch basis. This volume is about 16% of sheathing production of the entire plywood industry.

Table 5.—Distribution of 1976 sheathing plywood shipments by grade and producing region[1]

Sheathing plywood grade or group	Industry total production[2]	Percent of shipments from each region		
		Inland	Southern	Western
Interior				
C-D	56,161	95.71	0.47	3.82
C-D-X	7,350,432	15.64	55.54	28.83
Structural I & II	157,380	7.88	0.81	91.31
C-D Plugged	1,132	8.83	13.62	77.55
C-D-X Plugged	368,621	14.14	42.24	43.62
Underlayment	324	45.18	---	54.82
Underlayment Exterior glue	1,226,010	22.35	48.82	28.83
2-4-1	4,750	0.23	---	99.77
2-4-1-X	106,023	31.05	3.53	65.41
Miscellaneous	41,621	56.62	3.19	40.19
Total Interior	9,312,454	17.16	52.01	30.83
Exterior				
C-C	109,978	29.15	16.94	53.91
C-C Plugged	201,193	42.70	3.89	53.41
Total Exterior	311,172	37.91	8.50	53.48
Mill stamp	633,120	18.23	40.09	41.69
Rejects	397,876	11.31	63.55	25.13
TOTAL SHEATHING	10,684,622	17.62	50.43	31.95

[1]*Data source: American Plywood Association (1977b).*
[2]*In thousand square feet (M ft^2), 3/8-inch basis.*

Table 6.—Weight (pounds per M ft^2, surface area basis) for selected species, thicknesses, and constructions of sheathing plywood panels[1]

Nominal thickness	Number of double glue lines, typical panel construction[2]	Douglas-fir Coast	Douglas-fir Interior North	Western larch	Southern pine: Loblolly/ Shortleaf	Southern pine: Longleaf/ Slash	Ponderosa pine
5/16	1.0	928	918	997	966	1,103	777
3/8	1.0	1,105	1,093	1,188	1,151	1,315	924
1/2, 3 ply	1.0	1,459	1,443	1,569	1,521	1,739	1,218
1/2, 4 ply	1.5	1,480	1,465	1,590	1,542	1,761	1,239
1/2, 5 ply	2.0	1,501	1,486	1,612	1,563	1,782	1,260
5/8	2.0	1,855	1,836	1,993	1,933	2,207	1,554
3/4	2.0	2,209	2,186	2,375	2,302	2,631	1,848

[1]*Computed using wood density figures at 12% moisture (USDA Forest Products Laboratory 1974) and glue weight of 60 lb/M ft^2 of double glue line. Glue assumed to have 5/6 resin component with 65% solids and 1/6 hardener. Dried glue weight is 42.5 lb/M ft^2 of double glue line.*
[2]*From American Plywood Association (1974).*

Table 7.—Freight rates[1] (dollars per M ft[2]) for 1/2-inch, 4-ply sheathing from Black Hills points of origin to selected destinations representative of market trade areas (Rand McNally and Company 1963)

Destinations	Rapid City, S. Dak.		Whitewood, S. Dak.		Newcastle, Wyo.	
	Truck	Rail	Truck	Rail	Truck	Rail
Chicago[2]	19.08	17.22	20.07	17.72	18.71	18.21
Denver	10.53	9.66	10.53	10.66	8.80	9.29
Des Moines	14.12	12.02	14.99	13.51	14.99	14.99
Kansas City	15.49	14.99	15.86	15.49	16.48	14.99
Minneapolis	14.00	12.02	14.00	12.51	14.74	15.36
Omaha	12.64	11.15	13.75	11.77	14.00	11.77
Wichita[3]	16.35	11.52	15.49	11.89	15.49	14.99
Milwaukee[4]	—	16.97	—	17.35	—	17.97

[1]*Commodity rate for truck and rail transport, 1977 prices.*
[2]*Only one rail rate to Chicago lower than those shown was identified, $16.44 from Birmingham, Ala.*
[3]*Diboll, Tex., had a lower rail rate of $15.21 to Wichita.*
[4]*For comparison, Birmingham, Ala. had a rate of $17.97 to Milwaukee, equivalent to that for Newcastle, Wyo.*

Table 8 also shows the proportion of total industry production shipped to the prime market area from each major plywood region. For example, the Western and Southern Regions each shipped just under 14% of their total production to the prime market area in 1976. However, the Inland Region shipped about 29% of its production to the same trade areas. This relationship could be expected from comparing relative freight costs between regions.

Within each grade listed in table 8, the proportion shipped from each producing region reflects both freight cost influences and preferences in consuming regions for certain plywood types based on species or other wood characteristics. For example, of the total Underlayment volume shipped to the prime market area, the Inland Region supplied about 35%, the Southern Region about 47%, and the Western Region about 18%. Table 8 further indicates that several grades which could be produced in the Black Hills would have a good chance of market success in the eight trade areas of the prime market area. For example, plywood from Black Hills ponderosa pine could be manufactured in C-C, C-D, C-C Plugged, C-D Plugged, Underlayment, and 2-4-1 grades, with either interior or exterior glue. Even allowing for APA species group differences, ponderosa pine plywood in these grades would probably be acceptable.

Siding

Siding panels currently are manufactured from plywood species groups 1 through 4. As shown in table 8, the prime market area in 1976 received slightly less than 15% of all siding manufactured under the American Plywood Association's specifications for 303 siding products. Table 8 also shows that about 25% of siding made from species groups 2, 3, and 4 was shipped to the prime market area. Of this volume, virtually all (99.85%) 303 siding originated in the Western Region. Of the minute amount produced in the Inland Region, most (96%) was shipped to the prime market area.

Recently, the American Plywood Association revised its specifications for 303 siding (see appendix). Given the diversity of classes and grades defined in the new APA specifications, C grade veneer in the Black Hills could have increased technical potential for utilization in siding panels. Also, the prime market area for the Black Hills appears to accept enough 303 siding of all species groups for a market to be established for modest quantities of siding manufactured from Black Hills ponderosa pine.

TIMBER RESOURCES AND PLYWOOD

The Black Hills area is about 20,600 square miles of forested mountains located along the boundary between western South Dakota and northeastern Wyoming (U.S. Department of Agriculture and U.S. Department of Interior 1967). Surrounded by short grass prairie for at least 100 miles in all directions, the Black Hills is a uniquely isolated mix of federal, state, and private land (fig. 2). State land is largely concentrated in Custer State Park, located in the southeastern part of the Black Hills. Private land is scattered throughout the federal land, usually in small tracts.

To evaluate any proposed forest products venture, such as a plywood plant in the Black Hills, it is necessary to estimate the amount of timber required. Further, it is important to know how much material is available, what part of this material is used currently, and what part is suitable for the proposed product.

Table 8.—Quantity (square feet, 3/8-inch basis) of softwood plywood sheathing and siding shipped in 1976 from the three major producing regions to the prime market area for Black Hills production[1]

Plywood grade	Inland			Southern			Western			Total industry[2]	
	Quantity	Percent of total industry production shipped	Percent of regional production shipped	Quantity	Percent of total industry production shipped	Percent of regional production shipped	Quantity	Percent of total industry production shipped	Percent of regional production shipped	Quantity	Percent of total industry production shipped
SHEATHING											
Product standard sheathing											
Interior:											
C-D	17,393,038	97.67	32.36		--	--	414,787	2.33	19.33	17,807,825	31.71
C-D-X	343,884,670	29.27	29.92	509,168,100	43.33	12.47	321,981,349	27.40	15.20	1,175,034,119	15.99
Struc. I and II	1,570,433	53.78	12.66	219,872	7.53	17.16	1,129,558	38.69	0.79	2,919,863	1.86
C-D Plugged	16,000	49.34	16.02	11,307	34.87	7.34	5,120	15.79	0.58	32,427	2.87
C-D-X Plugged	16,586,055	30.41	31.82	27,786,853	50.95	17.84	10,169,172	18.64	6.32	54,542,080	14.80
Underlayment	143,616	100.00	98.08	--	--	--	--	--	--	143,616	44.31
Underlayment Exterior glue	120,122,950	35.09	43.83	161,679,888	47.23	27.01	60,490,545	17.67	17.12	342,293,383	27.92
2-4-1	--	--	--	--	--	--	265,824	100.00	5.61	265,824	5.60
2-4-1 Exterior Glue	1,111,296	29.26	3.38	--	--	--	2,686,368	70.74	3.87	3,797,664	3.58
Miscellaneous	1,806,570	94.95	7.67	--	--	--	96,000	5.05	0.57	1,902,570	4.57
Total Interior	502,634,628	31.44	31.45	698,866,020	43.71	14.43	397,238,723	24.85	13.84	1,598,739,271	17.17
Exterior:											
C-C	2,783,873	54.73	8.68	609,238	11.98	3.27	1,693,523	33.29	2.86	5,086,634	4.63
C-C Plugged	7,094,324	62.58	8.26	870,240	7.68	11.12	3,372,040	29.74	3.14	11,336,604	5.63
Total Exterior	9,878,197	60.15	8.37	1,479,478	9.01	5.59	5,065,563	30.84	3.04	16,423,238	5.28
Total product standard sheathing	512,512,825	31.73	29.86	700,345,498	43.36	14.38	402,304,286	24.91	13.24	1,615,162,609	16.78
Total mill stamp sheathing	32,426,097	28.59	26.83	20,243,352	17.85	7.62	60,765,858	53.57	12.98	113,435,307	17.11
Total rejects sheathing	3,871,056	14.86	8.60	19,156,334	73.54	7.58	3,022,067	11.60	3.02	26,049,457	6.55
TOTAL SHEATHING	548,809,978	31.28	29.16	739,755,184	42.16	13.75	466,092,211	26.56	13.65	1,754,657,373	16.42
SIDING											
Group 1	709,546	0.70	7.08	12,059,250	11.97	6.74	88,001,083	87.33	12.27	100,769,879	11.12
Group 2-4	117,493	0.15	96.13	--	--	--	78,293,922	99.85	25.15	78,411,415	25.18
TOTAL SIDING	827,039	0.46	8.15	12,059,250	6.73	6.74	166,295,005	92.81	16.16	179,181,294	14.71

[1]*The prime market area consists of the following trade areas: Chicago, Denver, Des Moines, Kansas City, Milwaukee, Minneapolis, Omaha, and Wichita.*
[2]*This is the quantity and proportion of all industry shipments to the prime market.*

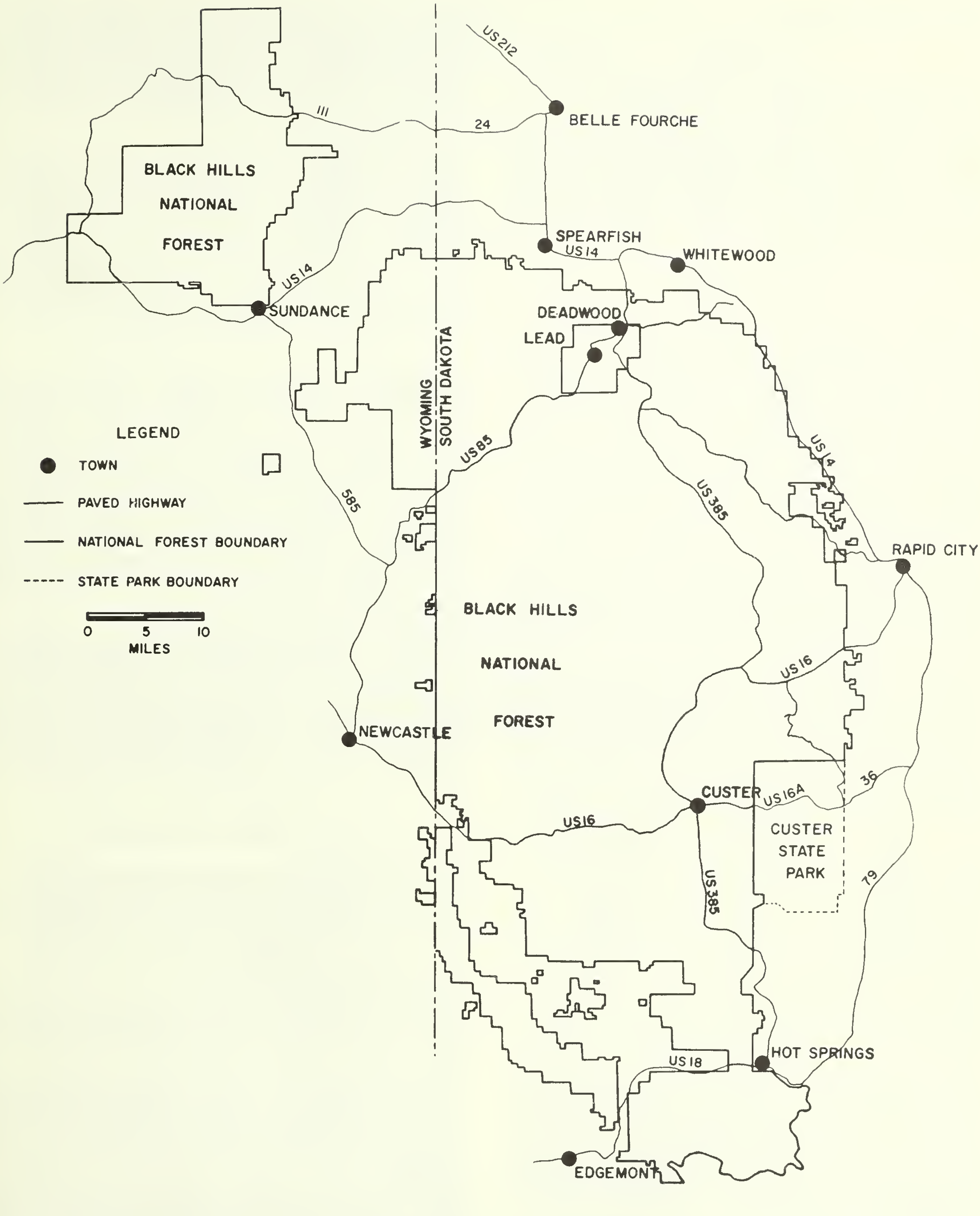

Figure 2.—Black Hills National Forest and adjacent area.

THE FOREST RESOURCE

Land

Total forest land area in all ownerships is about 2.1 million acres, and of this area, 1.9 million acres (88%) are classified as productive nonreserved forest land.[9] Of this productive nonreserved forest land, 1.1 million acres are in the Black Hills NF, 627,000 acres are in private ownership, and 131,000 acres are administered by state agencies and federal agencies other than USDA Forest Service.

Growing Stock

Ponderosa pine is the predominant species in the Black Hills, with minor amounts of white spruce (*Picea glauca*), aspen (*Populus tremuloides*), and other hardwoods present. Table 9 shows the distribution of growing stock among areas and timber types. Ponderosa pine is the only species considered in this study. Any small volumes of spruce harvested with pine would likely be processed for plywood with pine or sold for sawlogs. Major harvests of aspen are not planned, although small amounts may occasionally become available.

The Black Hills NF contains about 68% of the growing stock volume; private owners, 25%; and other public agencies, 7%. Sawlog volume in the Black Hills NF is also 68% of the total, with 27% on private lands and 5% in other holdings.

Nearly two-thirds of the ponderosa pine growing stock in diameter classes 5 inches d.b.h. and greater, on the Black Hills NF, have diameters between 5.0 and 8.9 inches. However, these diameter classes contain only about 22% of the net cubic foot volume. About half the cubic foot volume is in diameter classes from 9.0 to 14.9 inches. The complete distribution[10] is as follows:

D.b.h.	Live stems	Net volume
inches	*percent*	*percent*
5.0-8.9	65.2	21.9
9.0-14.9	29.9	49.6
15.0-20.9	4.5	23.9
21.0+	0.4	4.6

RESOURCES FOR PLYWOOD

Current Utilization

Sawmills are now the primary users of logs 8 inches d.b.h. and larger. A small volume (about 4%) of sawtimber size material is used for commercial poles (Setzer and Barrett 1977). Many sawmills are now equipped to saw logs smaller than those previously classified as sawlog size material. Sawmill output in the Black Hills is currently about 80% board lumber and about 20% dimension lumber.[11]

Estimated future sawmill requirements for sawtimber are based on past experience. Mill capacity figures are based on directories for the forest products industry in South Dakota and Wyoming (South Dakota Department of Game, Fish and Parks 1974, Wyoming Department of Economic Planning and Development 1974), as updated by unpublished data.[12] Based primarily on 1-shift operation, the estimated sawmill capacity in the Black Hills as of early 1978 was 200 million board feet lumber tally (MM fbm (LT)).

For a variety of reasons, sawmill production has been less in the past than suggested by the estimated capacity figures. Table 10 shows an effective capacity figure that estimates the degree to which sawmills have used their total capacity in utilizing the timber actually cut. The underutilization of production capacity indicated in table 10, together with the general lumber market conditions from 1972 to 1975, imply that in relatively poor years, production averaged only about 60-70% of total capacity. Effective capacity of 82% in 1974 indicates a relatively good year for Black Hills lumber producers.

Figures in table 10 suggest that a 75% effective capacity is a reasonable estimate of sawmill utilization for purposes of this analysis. Then, assuming a recovery factor[13] of 1.3, based on present USDA Forest Service Appraisal Guidelines, and assuming that these figures will hold for the next 10 years, the estimated log supply required to sustain sawmills at an average production level during this period is as follows:

200	MM fbm lumber tally current total capacity
×0.75	effective capacity proportion of total capacity
=150	MM fbm lumber tally effective capacity
÷1.3	MM fbm lumber tally/MM fbm log scale recovery factor
=115.4	MM fbm net log scale

Thus, the current estimated average annual sawmill requirement for timber is about 115 MM fbm (LS).

[9]Productive nonreserved forest land is defined as forest land capable of producing industrial wood crops. This requires a minimum growth rate of 20 cubic feet per acre per year, and the land must not be withdrawn from timber utilization because of statute or administrative regulation.

[10]These figures are based on data from computer program GROW that was used as part of the timber management process. The data were supplied by the Black Hills National Forest.

[11]Personal communication from F. P. Smedley, USDA Forest Service, Black Hills NF, Custer, S. Dak. (On file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.)

[12]Report of Black Hills Industry Mix Task Force. 1974. Unpublished report on file at Rocky Mountain Forest and Range Experiment Station.

[13]Recovery factor is the lumber output measured in foot board measure lumber tally (fbm (LT)) divided by the net log volume measured in board feet Scribner Decimal C log scale (fbm (LS)). All log volumes are given as net rather than gross, unless otherwise noted.

Table 9.—Total sawtimber and growing stock, Black Hills area, 1974

Forest type	South Dakota		Wyoming		Black Hills total	
	Sawtimber	Growing stock	Sawtimber	Growing stock	Sawtimber	Growing stock
	M fbm (LS)	*M ft³*	*M fbm (LS)*	*M ft³*	*M fbm (LS)*	*M ft³*
Ponderosa pine	5,212,922	1,542,243	2,141,742	644,683	7,354,664	2,186,926
White spruce	230,173	50,357	55,533	12,436	285,706	62,793
Hardwoods	133,251	39,388	115,518	57,309	248,769	96,697
Total	5,576,346	1,631,988	2,312,793	714,428	7,889,139	2,346,416

Table 10.—Estimates of available timber compared with effective capacity of Black Hills sawmills

Year	NF total cut all size classes[1]	NF total cut sawtimber[2]	All ownerships total cut sawtimber[3]	Mill capacity[4] lumber tally	Lumber recovery factor[5]	Mill capacity,[6] Scribner log scale	Effective capacity[7]
	MM fbm (LS)			*MM fbm (LT)*		*MM fbm (LS)*	*Percent*
1972	96.969	66.414	88.552	152.1	1.20	127.8	69.3
1973	89.170	61.073	81.430	152.1	1.19	127.8	63.7
1974	112.011	76.716	102.288	152.1	1.22	124.7	82.0
1975	76.796	52.598	70.130	152.1	1.49	102.1	68.7

[1]*Source: Black Hills NF Timber Management Plan 1977-1986.*
[2]*Board foot volume in all size classes multiplied by a factor of 0.6849, the proportion of sawtimber in 1974.*
[3]*Computed by dividing Black Hills NF sawtimber cut by 0.75 because this sawtimber was three-fourths of total cut.*
[4]*Source: Black Hills Task Force Report, 1974. In 1976, capacity increased by 30 MM fbm (LT), all in one mill.*
[5]*Source: USDA Forest Service, Rocky Mountain Region Appraisal Bulletins for the respective time periods.*
[6]*Computed by dividing lumber tally mill capacity by lumber recovery factor.*
[7]*Percentage of total sawmill capacity (net log scale—column 7) that was used in processing sawtimber from all ownerships (column 4).*

10-Year Future Supply, 1977-1986

The Black Hills NF plans to treat annually about 39,600 acres of forest land with a variety of silvicultural cuts. Most of this acreage is in the Standard Component[14] with the remainder in the Special Component.[15]

[14]*Standard Component is the component of the regulated, suitable, forested land on which crops of industrial wood can be grown and harvested with adequate protection of the forest resources under the usual provisions of the timber sale contract. This area includes stands of immature trees or areas not yet accessible, but which will be in the normal course of events. This area is capable of producing timber crops that have a reasonable probability of use, given the accessibility and economic conditions projected for a 10-year plan period, even though portions of the area may not be developed during this period.*

[15]*Special Component is the component of the regulated, forested land that is recognized in the multiple use plan as needing specially designed treatment of the timber resource to achieve landscape or other key resource objectives. For example, these are areas where timber management activities are informally delayed pending multiple use planning studies and management decisions, travel and water influence zones, peripheral portions of developed sites, and developed recreation areas.*

Harvest treatment in the Marginal Component[16] is not planned for the current 10-year period.

Under the 1977-1986 National Forest Timber Management Plan, programmed annual sawtimber harvest will be about 118 MM fbm (LS) from trees 8 inches d.b.h. or larger.[17] Planned utilization limits are to a 6-inch top. Trees 9 inches d.b.h. and larger are considered suitable for plywood because they can supply

[16]*Marginal Component is the component of the regulated, suitable, forested land that does not qualify as a standard or special components, primarily because of excessive development cost, low product values, or resource protection constraints. Included may be drainages requiring unusual logging techniques, such as helicopters, skyline logging systems; areas where harvesting is blocked until government constructed roads are in place; or areas supplying a particular product or particular species type not presently in demand. Also included is the backlog of nonstocked areas which would otherwise be classed as standard, but are in need of reforestation that cannot be accomplished with Knutson-Vandenberg funds.*

[17]*Timber Management Plan, Black Hills National Forest. 1977. Unpublished document on file at Rocky Mountain Forest and Range Experiment Station or available from Supervisor's Office, Black Hills NF, Custer, S. Dak.*

an 8-inch d.i.b. small end veneer log. Volume scheduled to be cut in trees 9 inches d.b.h. and larger is about 110.7 MM fbm (LS).

Timber harvested from non-national forest lands in South Dakota contributes significant amounts of roundwood. Estimated annual allowable harvest from these lands is about 57,290 cunits, with sawtimber amounting to about 15.6 MM fbm (LS).[18] Volume figures for Wyoming show an annual allowable cut of 22 MM fbm (LS) on private and other public land (U.S. Department of Agriculture and U.S. Department of Interior 1967). Past experience suggests that in both South Dakota and Wyoming, about half the allowable cut from non-national forest land will be harvested.

Timber available from state and private land in both states can be expected to range from a minimum of 19 MM fbm (LS), representing the historical level of actual cuts, to a maximum allowable cut of about 38 MM fbm (LS). These volumes in trees 9 inches d.b.h. and larger are an important potential resource in determining the timber volume available for plywood.

Availability for Plywood

A surplus sawtimber volume that may be available for plywood manufacture is estimated by deducting current sawtimber usage from total volumes that are available (table 11).

[18]*Personal communication from South Dakota Department of Fish, Game, and Parks, Division of Forestry. Figures from timber management plan for the period 1974-1984.*

Total estimated supply of sawtimber in the Black Hills available for forest products, is in a range of 137 to 156 MM fbm (LS), depending on volume cut from state and private lands. The supply in the Black Hills NF is divided into two parts: volume in trees equal to or greater than 9 inches d.b.h., and volume in trees less than 9 inches d.b.h. The supply of sawtimber from state and private land is assumed to be in trees 9 inches d.b.h. and larger.

In the use section of table 11, Black Hills NF volume in trees less than 9 inches d.b.h. is subtracted from total supply, because it is assumed trees smaller than 9 inches d.b.h. would not be suitable for plywood manufacture. When this volume is subtracted from the estimated total sawmill demand of 115 MM fbm (LS), the remaining 108 MM fbm (LS) of demand is in trees 9 inches d.b.h. and larger.

The 1977 sawmill usage of 108 MM fbm (LS) in trees 9 inches d.b.h. and larger is subtracted from 130 and 149 MM fbm (LS), respectively; so, the minimum volume available for plywood manufacture ranges from 22 to 41 MM fbm (LS). The computations shown are based on a relatively stable sawmill capacity and suggest that total wood volume available for plywood manufacture may not be as large as desirable. Any significant additions or reductions in total sawmill capacity would inversely alter the volume available for plywood manufacture.

Another factor that might further limit the availability of timber for plywood manufacture is the requirements of the Small Business Set Aside Program.[11] For the 5-year period ending December 31,

Table 11.—Computation of timber volume (MM fbm (LS)) available for plywood[1]

	Expected	Maximum
Supply of sawtimber		
USDA Forest Service		
⩾9 inches	111	111
<9 inches	+7	+7
Total Forest Service	118	118
State and private	+19	+38
Total, all ownerships	137	156
Use of sawtimber		
Sawmill (115 MM fbm (LS))		
<9 inches (7 MM fbm (LS))	−7	−7
	130	149
⩾9 inches (115-117 MM fbm (LS))	−108	−108
Volume available after satisfying estimated sawmill demand	22	41

[1]*Assumptions: (1) Entire Black Hills NF programmed harvest is available.*
(2) Sawmills are able, if not willing, to take material less than 9 inches d.b.h.
(3) State and private harvest is not less than half the allowable cut and does not exceed allowable cut.
(4) Total sawtimber volume is in trees 8 inches d.b.h. or larger.

1980, the Set Aside Program required preferential treatment of bids from small business on 67% of the sawtimber volume sold. In the next 5-year period the proportion of sawtimber allotted to small business set asides could increase or decrease slightly. However, the potential impact of the Set Aside Program would depend on the size of the firm operating a plywood plant.

In addition, a combination of existing Black Hills operators has announced plans to construct a waferboard plant in the Black Hills area (Forest Industries 1979). This plant is expected to utilize primarily small diameter roundwood not generally suitable for veneer blocks. There would not likely be much direct competition for timber between this waferboard plant and a plywood plant, with the possible exception of logs in the 8- to 10-inch d.i.b. range.

The Second 10 Years, 1987-1996

Under the non-declining, even-flow timber harvest policy of the USDA Forest Service, total cubic volume in the second decade of the Timber Management Plan is expected to be about the same as during the first decade. However, the proportion of sawtimber of larger sizes will probably decrease. The following tabulation shows the relation between sawtimber board foot volume and total cubic volume for the first two decades:[19]

Volume cut	Decade 1	Decade 2
Cubic-foot volume, M cunits, all size classes	364.14	363.14
Sawtimber volume, MM fbm (LS), trees 10-inch d.b.h. class and larger	110.67	87.61
Sawtimber volume, MM fbm (LS), trees 8-inch d.b.h. class and larger	117.99	Not available

Volume for trees 10 inches d.b.h. and larger is different for the two decades. Although total sawtimber volume includes trees down to 8 inches d.b.h., the assumption is that only trees 9 inches d.b.h. and greater (i.e., the 10-inch d.b.h. class using 2-inch d.b.h. classes) will be eligible for veneer blocks. Total sawtimber volume for the second decade is not available, but the figure pertinent to plywood manufacture is shown under decade 2 for sawtimber volume in trees in the 10-inch d.b.h. class and larger. Clearly, raw material for plywood would be less available in the second decade.

[19]*Sources: Timber Management Plan, Black Hills National Forest 1977-1986. Final Environmental Statement for Timber Management Plan, Appendix Q, Black Hills NF. Computer printed output from Program GROW used in Ram Run 37 for the Timber Management Plan, on file at Rocky Mountain Forest and Range Experiment Station.*

QUALITY

In addition to the gross amounts of raw material available, feasibility analyses must consider indicators of quality. In this study, the general aspects of quality were considered in terms of timber sale characteristics, log size distribution, and the main products available from Black Hills ponderosa pine.

Efficient plywood plant operation depends largely on having a favorable mix of log sizes available for manufacture; therefore, gross volumes alone do not adequately portray the suitability of the log supply. Estimates must be made of the material size likely to be in the plywood plant woodyard during a year of operation. The log mix that will actually be available to a plywood operation depends on a number of complex logistic factors and is somewhat indeterminate. However, for this study, a log mix was chosen to reflect the tree sizes most likely to be cut as part of the current 10-year Timber Management Plan.

Timber Sale Characteristics

The assumed characteristics of timber sales are based on the Black Hills NF Timber Management Plan. The current 10-year Timber Management Plan for the Black Hills NF, as well as the planning for later 10-year periods, is based on timber classes. Timber classes define growing stock by size, density, and species (USDA Forest Service 1977). Timber is classified as sawtimber trees (8 inches d.b.h. or larger), poletimber trees (5-7.9 inches d.b.h.), and seedling and sapling trees (less than 5 inches d.b.h.). Density of stands is ranked in terms of basal area classes: less than 60 square feet per acre, 60-119 square feet per acre, and 120 square feet per acre and greater. Species groups are ponderosa pine and mixed species. The mixed species group is further classified into pine-spruce, spruce-pine, pine-aspen, and aspen-pine subgroups, depending on the predominant timber type.

The current Plan calls for harvesting timber from 395,525 acres over a 10-year period ending in 1986. Thirteen timber classes are specified for harvest in this period (table 12). Each timber class and its silvicultural prescription is described in the appendix. Of the 13 timber classes, seven comprise almost 97% of the total acreage to be harvested in the current Timber Management Plan period. Thus, these seven classes will be encountered in timber sales to a much greater degree than the remaining six timber classes. These seven timber classes, therefore, were analyzed by proportion of trees in each 2-inch diameter class. From this analysis three major groups of timber classes were developed as shown in figure 3.

One group, timber classes P61 and P21, has mostly small trees 8 inches d.b.h. and smaller scheduled for harvest. This group is not of major interest for plywood production. Timber class P21, with trees in the 10-inch class, is considered a sawtimber stand, but note that the largest d.b.h. class is only 10 inches. Timber class

Table 12.—Timber class characteristics, Black Hills National Forest

Timber class designation[1]	Acres to be cut, 1977-1986	Basal area class[2]	Stand size class[3]	Dominant species[4]	Site index[5]
P21[6]	108,787	60-120	S	PP	55
PB1	73,492	60-120	S	PP	55
P31	68,813	120 +	S	PP	65
P61	48,104	120 +	P	PP	58
PA1	35,788	60 –	S	PP	52
SB1	35,774	120 +	S	PS	62
SC1	11,117	120 +	S	SP	75
WZS	5,150	120 +	S	SP	75
TZB	4,000	60-120	S	PP	60
TZN	1,500	60-120	S	PP	60
TZA	1,000	60-120	S	PP	60
N60	1,000	60-120	S	PP	55
NOR	1,000	n.d.	S	PP	55
Total	395,525				

[1]*Explained in appendix.*
[2]*120 + means 120 square feet or greater; 60 – means 60 square feet or less.*
[3]*S—sawtimber is predominant size; P—poletimber is predominant size.*
[4]*PP—ponderosa pine; PS—mixed ponderosa pine and spruce with pine dominant; SP—mixed ponderosa pine and spruce with spruce dominant.*
[5]*Site index—100-year base.*
[6]*Timber class P21 is classified by Black Hills NF as sawtimber. However, the largest diameter class represented is 10 inches. For the purposes of this study, it is classified in the poletimber group.*

P61 is classified as poletimber even though it has trees in the 8-inch class, which are considered sawtimber. Consequently, these two timber classes are referred to here as the poletimber group.

The second group, timber classes PA1 and PB1, contains trees in d.b.h. classes 12 inches and larger. Timber sales featuring these two timber classes would have raw material of highest value for a plywood plant. These timber classes are referred to as the sawtimber group.

The third group, timber classes SC1, SB1, and P31, has both pole and sawtimber diameter classes. These timber classes are called the all-size group. Sales having these timber classes would contain raw material of value for plywood but would also include tree diameter classes too small for plywood. Under the multiproduct sale format of the Black Hills NF, purchasers must buy all timber included in the sale, not just certain size classes. Utilizing these small trees poses a challenge for some sawmill operators in the Black Hills, and likely would similarly affect a plywood plant.

Having established the proportions of trees, a timber buyer for a plywood mill would likely give highest priority to the sawtimber group. Next in desirability would be sales featuring the all-size group. Finally, the buyer might consider the poletimber group because it does contain some 9- and 10-inch d.b.h. trees but would probably avoid sales featuring this group if at all possible.

As indicated in the previous discussion, these seven timber classes make up the vast majority of acreage in timber sales until 1986. Acreage for the three groups of timber classes is shown as follows:

Group (timber classes)	Acreage
Sawtimber (PB1, PA1)	109,280
All-size (P31, SB1, SC1)	115,704
Poletimber (P21, P61)	156,891

Acreage is roughly equal in the two groups most useful for plywood. Assuming sales in the poletimber group are of little interest, there is about an equal chance of encountering sales composed of the sawtimber and all-size groups, which together represent about 57% of the total area to be harvested under the current Timber Management Plan.

Log Size Distribution

An estimate of the distribution of log sizes that reasonably could be expected to come from each of the two groups of primary interest is extremely important in the operating economics of a plywood plant. The timber class with the largest acreage from each group was selected to represent the group—class P31 represents the all-size group, and timber class PB1 represents the sawtimber group.

Small end diameters inside bark (d.i.b.) for 8.5-foot veneer blocks were grouped into 1-inch d.i.b. classes for each timber class. Because the two timber class groups—sawtimber and all-size—had about equal acreage, the numbers of 8.5-foot veneer blocks in each d.i.b. class were averaged without weighting. It was assumed that, on an annual basis, a plywood plant would have access to a variety of sales from each timber class group, and that the d.i.b. distribution of veneer blocks would be similar to the computed values. A more complete discussion of methods involved in computing the veneer block distribution is contained in the appendix.

The curve for all 8.5-foot logs in figure 4 is a composite of proportions of logs from the all-size group and sawtimber group. Logs 4 and 5 inches d.i.b. come only from the all-size group. Logs 6 inches and larger come from both timber class groups. There are few logs less than 6 inches d.i.b. cut from large ponderosa pine trees because of the form of the upper bole.

The 6-inch division point also reflects a utilization limit prescribed by the Black Hills NF.[20] This limit specifies that sawtimber trees, those with d.b.h. 8 inches or larger, must be cut to a 6-inch d.i.b. top or less, provided the tree contains at least one 8-foot log. However, the utilization limits specify that poletimber trees, those with d.b.h. between 5 and 8 inches, must be cut to a 4-inch d.i.b. top or less, and must contain at least two "pieces" (logs) of 8.33 feet each (i.e., one log of 16.67 feet).

[20]*USDA Forest Service, Rocky Mountain Region. 1978. Supplement to the Forest Service Manual, Title 2400, Timber Management. R-2 Suppl. 236. Page 2451.22—3.*

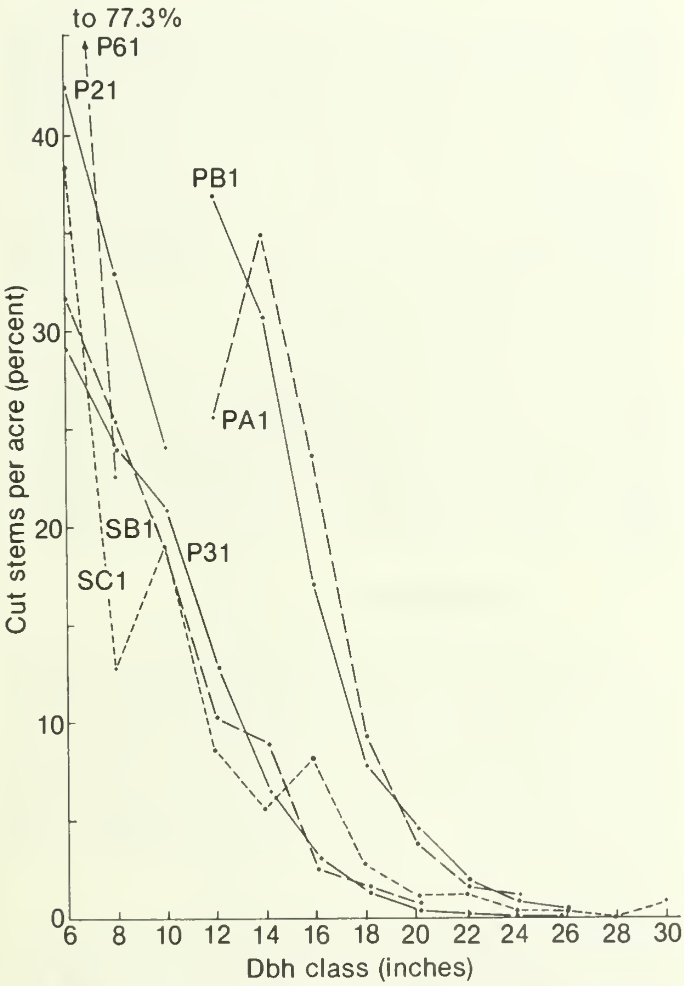

Figure 3.—Proportional distribution of trees in 2-inch d.b.h. classes for timber management tree classes on the Black Hills National Forest.

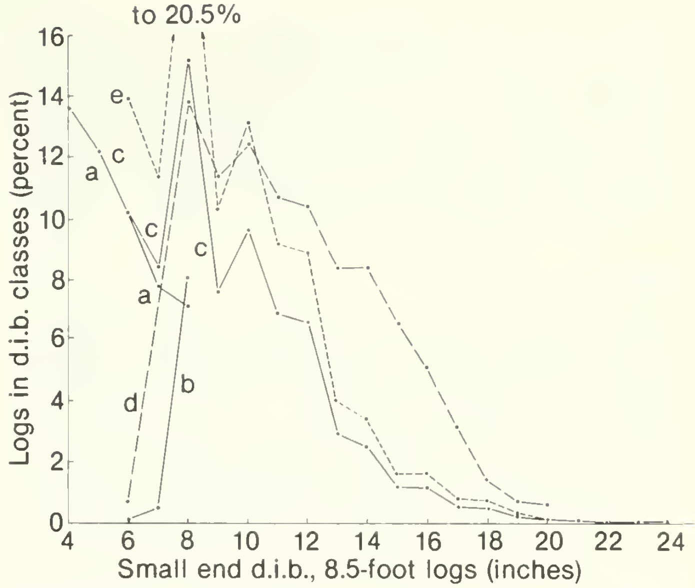

Figure 4.—Proportions of logs in 1-inch classes for small end, diameter inside bark (d.i.b.). Results based on tree distribution data from Black Hills National Forest timber classes PB1 and P31: a = logs ≤8 inches d.i.b. from small trees; b = logs ≤8 inches and less d.i.b. from large trees; c = logs in all d.i.b. classes from all trees; d = logs in study of veneer recovery (Yerkes and Woodfin 1972), ≥6 inches d.i.b. at the small end; e = logs in this study ≥6 inches d.i.b.

Note in figure 4 that both timber class groups contribute substantial numbers of 8-inch logs, and when combined, the proportion of logs in this d.i.b. class is the largest of all d.i.b. classes.

In d.i.b. classes larger than 8 inches, the proportion of logs decreases with an increase in diameter. Logs 20 inches d.i.b. or greater are few, but some can be expected.

Superimposed on figure 4 is the proportional distribution of small end d.i.b.'s for 8.5-foot veneer blocks measured by Yerkes and Woodfin (1972) in their veneer recovery study. Large logs are heavily represented, because large trees were deliberately included to insure an adequate number of peelable blocks in the sample. Logs processed in that veneer recovery study were 6 inches or larger, d.i.b., so comparable log sizes in this study are shown in figure 4.

Product Characteristics

Given the expected numbers of multiproduct timber sales offered by the Forest Service in the Black Hills, purchasers must expect that they will have to handle material that does not fit the mainstream of their operations. In the case of a projected plywood plant, this material would include logs too small for peeling, veneer block cores, and various kinds of residue, such as clipper trim, lily pads, or bark. To help estimate the amounts and kinds of products and by-products that would be generated, a general assessment of the characteristics of plywood, lumber, and residue product classes was made.

Veneer

The amounts and grades of veneer recoverable from Black Hills ponderosa pine are described in previous research (Yerkes and Woodfin 1972). Conclusions drawn from that research are:

1. A sample of 144 Black Hills ponderosa pine trees, from six d.b.h. classes, meeting defect criteria of the study, yielded veneer in a proportion of grades and sizes that was more than adequate to produce C-D grade, 3/8-inch, 3-ply plywood.
2. Trees in larger diameter classes yielded a higher percentage of veneer but lower percentages of C and better (C+) grades than trees in smaller diameter classes.
3. Larger diameter veneer blocks yielded slightly higher percentages of C+ grades than did smaller diameter blocks.
4. Blocks in lower tree positions yielded larger proportions of C+ grades of veneer than blocks in higher tree positions.
5. Recovery ratios appeared favorable for conversion of trees to plywood, except for trees and blocks of small diameters.[21]
6. More than enough full width sheets of C+ and D grades of veneer were recovered to provide one-piece face plies, even if all plywood that could have been produced in this study were 3/8-inch, 3-ply panels.
7. Knot size, as visually estimated on the veneer blocks, was a useful means of separating the blocks into two classes yielding significantly different proportions of C+ veneer.
8. Recovery data varied widely with all classes of trees and blocks. However, it is believed that any large sample of Black Hills trees in these diameters would give nearly the same veneer recovery as those in this study.

Lumber

Boards and dimension lumber, including studs, are the principal products now manufactured from Black Hills ponderosa pine. Because many plywood plants are associated with a sawmill, log allocation for use in lumber or plywood is influenced by product recovery and value. For purposes of this study, it was assumed that the associated sawmill would exist only as an auxillary to the plywood operation and would utilize only the logs that could not be profitably utilized in veneer.

The most recent lumber grade recovery study published for the Black Hills found a high proportion of the volume in Common grades of boards (Mueller and Kovner 1967). Log diameters in the study were typical of the Black Hills area—from 8 to 20 inches—and log grades were mostly Number 3 and Number 5. Approximately 75% of the lumber volume was about evenly divided between lumber grades 1 and 2 Common, 3 Common, and 4 Common. Lumber volume in grade 5 Common, as reported in the study, resulted only from downgrading of the higher grade lumber in the seasoning and surfacing operations. Some grade 5 Common lumber was discarded in the green state because it was considered unmerchantable.

The most likely lumber product from a plywood plant-sawmill complex will be 2- by 4-inch or possibly 2- by 6-inch dimension stock. However, no published data currently exist describing grade recovery of dimension products from Black Hills ponderosa pine.

Residue

Most residue from current sawmill operations in the Black Hills is underutilized. Some chips are shipped to pulp mills in the Great Lakes region. The market for salable residue, however, is sporadic. Another outlet for much of this residue could be particleboard, if this commodity were to be manufactured in the Black Hills (Markstrom et al. 1976). There is considerable interest in the Black Hills area in promoting some type of composition board plant. Such a facility could provide an outlet for mill residue and/or large volumes of small roundwood of less than 8 inches d.b.h.[11]

Another utilization opportunity in the Black Hills area is some type of composite panel product with veneer face plies over a particleboard core.[22] A product of this type could advantagously utilize C and D grade veneer for faces and backs while reducing the D grade veneer required for interior plies. Plant residues possibly could be utilized for the composition board core.

OPERATING ECONOMICS

Economic estimates in this section are necessarily based on a number of informed judgments, since no history of plywood production exists for the Black Hills. However, most economic factors are expected to be similar to those for plants of comparable size and type in other areas. This section is based on an economic analysis conducted within projected technology, and coupled with the previous assessment of markets and raw material conditions.[23]

[21] *"Small diameters" means trees of 9 and 10 inches d.b.h. and veneer blocks smaller than 9 inches d.i.b. When this cited research was done in 1968, the existing "state-of-the-art" in plywood manufacture made this statement generally true. However, recent advances in green end technology for small diameter blocks have made this constraint much less binding on raw material supply.*

[22] *Personal communication from R. F. Baldwin, Camden, Tex.*

[23] *Unless otherwise noted all cost estimates in this section are based on an engineering analysis, "Black Hills Plywood Study" by Frank Hahn, Senior Consultant, formerly with H. C. Mason and Associates, Inc. 1978. This analysis was performed under contract 43-82-FT-7-556.*

ASSUMED OPERATING FORMAT

Plant Size

The size of plywood plants that can operate economically has increased steadily over the years to spread rising fixed costs over greater plywood output. Figure 5 shows the production capacity distribution of U.S. softwood plywood plants in early 1977. The minimum capacity for an operating U.S. plant is about 40 MM ft² annually (3/8-inch basis).

The range of plant sizes that were considered in this study runs from about 40 to 70 MM ft² capacity, 3/8-inch basis. A smaller plant probably is not economical, and log volume is not available for a sufficient time to amortize a large plant. Capital equipment required under the assumed operating format is about the same for whichever plywood level is produced—40 MM or 70 MM ft². The largest difference in the two production capacities is the number of operating shifts per day and the resulting direct labor cost. Consequently, the only plant size discussed here is in the range of 60-70 MM ft² annual production.

Although no mills have been built in the last 10 years with less than 100 MM ft² capacity,[8] it should be noted that job counts, equipment, and variable operating costs for a plant with 70 MM ft² capacity are not much different than for a larger plant.[24]

[24]*Personal communication from R.F. Baldwin, Camden, Tex.*

Plant Overview

In the assumed operating format, logs are delivered from the woodyard to the debarker deck by front-end grapple loader. After debarking, logs are conveyed to the cut-off saw and cut to 102-inch blocks. Blocks of less than peelable diameter are diverted to a chipping headrig for stud manufacture.

Veneer blocks are sorted into several diameter classes, steamed,[25] and delivered to the lathe-charger system. The veneer green chain is close coupled with a veneer scanner triggering the clipper. Clipped, green veneer is manually pulled and stacked. The jet dryer has drying capacity (sections) proportional to plant capacity, plus two cooling sections. A patch and reclip system is used for veneer repair. Hand layup of dry veneer uses a spreader, prepress, press sequence.

Panels are trimmed, repaired (if product requires), bundled, palleted, and stored for shipment by truck or rail.

Wood waste in the form of short blocks, lily pads, slabs, edgings, bark, and fishtails is chipped and sold, or hogged to fuel a wood-fired boiler, depending on the relationship between energy needs and alternative outlets. Chips from the sawmill and plywood plant are sold in the most advantageous markets.

The associated sawmill produces mostly stud lumber from cores and logs not suitable for veneer. Lumber is sold kiln dried or rough green, depending on markets.

[25]*Conditioning logs in hot water vats instead of in steam tunnels is frequently preferred, but because of the possibility of water pollution problems, steam tunnels were assumed for the plant configuration.*

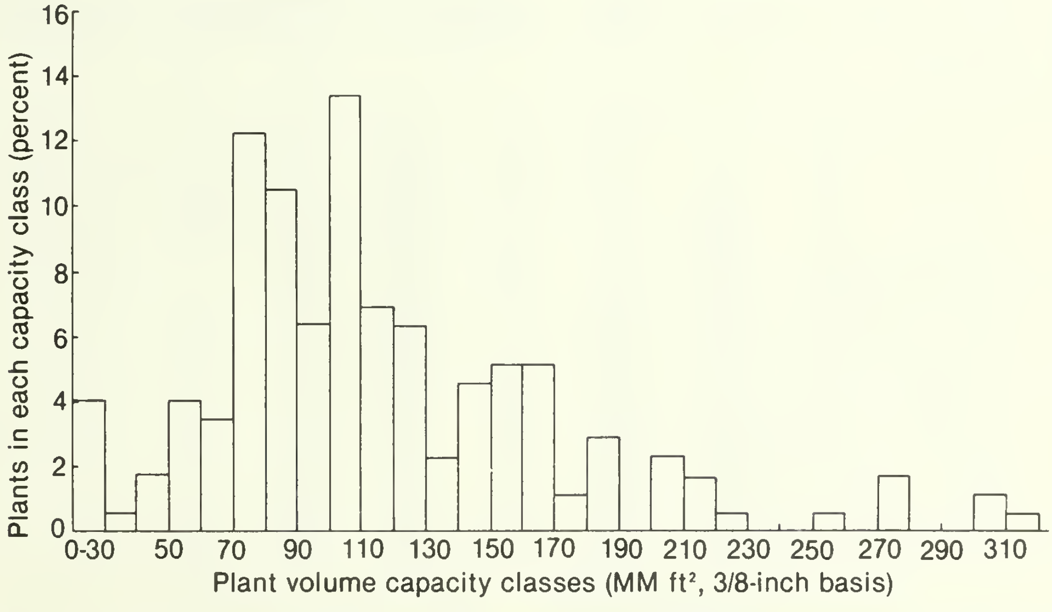

Figure 5.—Production capacity distribution of U.S. softwood plywood plants, 1977 (Forest Industries 1977).

Product Output

It might be assumed that all log sizes not suitable for peeling could be sold or traded to others, but such an arrangement does not conform to current industry patterns and therefore is not assured. It may be more realistic to assume that the plywood mill would be responsible for processing or otherwise disposing of all timber it purchased. If so, products likely to be produced are plywood (veneer), studs, chips, bark, and coarse and fine residues.

To estimate total volumes of these products, figures were compiled on expected recovery of each product, by diameter, for veneer blocks or stud logs. These recoveries were applied to the expected log size distribution and volume to estimate total product output.[26]

Veneer and Residue Recovery Per Log

Veneer yields by block diameter were computed by regression equations based on published material (Yerkes and Woodfin 1972, Woodfin 1973). This approach allows estimates of veneer recovery and residue generation for block diameters slightly larger than those listed in the reported research. Table 13 shows the material volume allocation for veneer blocks of various diameters, estimating total block volume, tangible loss volume, veneer shrinkage volume, and finally, green and dry veneer volumes for three target core sizes.[27] Tangible losses consist of round-up volume, end spur, and clipper loss. Details about the derivation of this table are found in the appendix.

[26] *The three possible outputs of this plywood complex—plywood panels, lumber, and residue—each have units of measure commonly associated with the product such as square feet, board feet lumber tally and ovendry tons, respectively. Logs, in turn, are commonly measured in board feet, Scribner Decimal C log scale, in the Black Hills. To achieve consistency in measurement this economic analysis is expressed in terms of cubic feet, with the corresponding volume measurements in the usual units shown as companion figures.*

Stud and Residue Recovery Per Log

There are no published data for stud recovery from Black Hills ponderosa pine logs. Consequently, stud recovery and residue generation was estimated by considering theoretical sawing diagrams for 8.5-foot stud logs.

It is assumed that three classes of logs based on log taper would be available to a sawmill auxiliary to the assumed plywood plant. First are logs without taper; that is, cores from the veneer lathe. Second are small logs with taper not greater than 1 inch per 8.5 feet. These logs tend to originate in trees smaller than 9 inches d.b.h., the lower limit set for trees with peelable blocks. Third are small logs that originate in the upper bole of trees cut for veneer blocks. Generally, these logs will have numerous large knots and severe taper resulting from the growth characteristics and stem form of Black Hills ponderosa pine. (See appendix sections, "Computation of Log Taper" and "Lumber and Residue Recovery.")

[27] *One way to increase veneer recovery is to install 4-foot core lathe equipment. However, the economic impact of this option was not analyzed in this study.*

Table 13.—Veneer block material allocation (cubic feet) by block diameter class (inches) and target core diameters[1]

Block diameter class	Total volume in one block (8.5 feet)	Loss volume	Veneer and core volume	Shrinkage volume	Target core diameters: 6 inches		5 inches		4 inches	
					Green	Dry	Green	Dry	Green	Dry
6	3.0828	1.0528	2.0300	0.0120	0.3611	0.3491	0.8710	0.8590	1.2883	1.2763
7	3.3054	1.0354	2.2700	0.0132	0.6011	0.5879	1.1110	1.0978	1.5283	1.5151
8	3.6120	1.1020	2.5100	0.0347	0.8411	0.8064	1.3510	1.3163	1.7683	1.7336
9	3.9925	1.2526	2.7399	0.0719	1.0710	0.9991	1.5809	1.5090	1.9982	1.9263
10	5.1558	1.4872	3.6686	0.1114	1.9997	1.8883	2.5096	2.3982	2.9269	2.8155
11	6.4031	1.8058	4.5973	0.1665	2.9284	2.7619	3.4383	3.2718	3.8556	3.6891
12	7.7344	2.2084	5.5260	0.2197	3.8571	3.6374	4.3670	4.1473	4.7843	4.5646
13	9.1497	2.6950	6.4547	0.2782	4.7858	4.5076	5.2957	5.0175	5.7130	5.4348
14	10.6490	3.2656	7.3834	0.3376	5.7145	5.3769	6.2244	5.8868	6.6417	6.3041
15	12.2323	3.9202	8.3121	0.3963	6.6432	6.2469	7.1531	6.7568	7.5704	7.1741
16	13.8996	4.6588	9.2408	0.4323	7.5719	7.1396	8.0818	7.6495	8.4991	8.0668
17	15.6509	5.4814	10.1695	0.5180	8.5006	7.9826	9.0105	8.4925	9.4278	8.9098
18	17.4862	6.3880	11.0982	0.5403	9.4293	8.8890	9.9392	9.3989	10.3565	9.8162
19	19.4005	7.3786	12.0269	0.6055	10.3580	9.7525	10.8679	10.2624	11.2852	10.6797
20	21.4088	8.4532	12.9556	0.6455	11.2867	10.6402	11.7966	11.1501	12.2139	11.5674
21	23.4961	9.6118	13.8843	0.7378	12.2154	11.4776	12.7253	11.9875	13.1426	12.4048
22	25.6674	10.8544	14.8130	0.8060	13.1441	12.3381	13.6540	12.8480	14.0713	13.2653
23	27.9227	12.1810	15.7417	0.8768	14.0728	13.1960	14.5827	13.7059	15.0000	14.1232
24	30.2620	13.5916	16.6704	0.9502	15.0015	14.0513	15.5114	14.5612	15.9287	14.9785

[1] *Discussion of the derivation of table values is found in the appendix. Four decimal places are carried here to insure that subsequent use of these figures will not introduce significant error caused by rounding.*

Table 14.—Theoretical 2- by 4-inch stud lumber and residue recovery from three classes of small diameter logs

Log class	Small end d.i.b. class	Total volume	Chips	Saw kerf	Lumber rough, green untrimmed	Trim	Lumber rough, green trimmed	Shrink	Planer, sander volume	Lumber dry, dressed	Nominal lumber tally	Number of pieces recovered
	inches	*cubic feet*									*fbm*	
Lathe cores (no taper)	4	0.742	0.377	--	0.365	0.021	0.344	0.024	0.028	0.292	5.333	1
	5	1.159	0.396	0.033	0.730	0.043	0.687	0.048	0.056	0.583	10.667	2
	6	1.669	0.517	0.066	1.086	0.064	1.022	0.072	0.084	0.866	16.000	3
Small tree logs (low taper)	4	0.950	0.585	--	0.365	0.021	0.344	0.024	0.028	0.292	5.333	1
	5	1.414	0.651	0.033	0.730	0.043	0.687	0.048	0.056	0.583	10.667	2
	6	1.970	0.808	0.066	1.096	0.064	1.032	0.072	0.084	0.876	16.000	3
	7	2.619	1.058	0.100	1.461	0.086	1.375	0.097	0.112	1.166	21.333	4
	8	3.361	1.004	0.166	2.191	0.129	2.062	0.145	0.168	1.749	32.000	6
Large tree logs (high taper)	6	2.883	1.721	0.066	1.096	0.064	1.032	0.072	0.084	0.876	16.000	3
	7	3.272	1.711	0.100	1.461	0.086	1.375	0.097	0.112	1.166	21.333	4
	8	3.811	1.444	0.166	2.191	0.129	2.062	0.145	0.168	1.749	32.000	6

Lathe cores.—For the veneer recovery study (Yerkes and Woodfin 1972), core size averaged close to 6 inches for all block diameters. However, current industry practice, especially in high-volume, small-log veneer plants, tends toward the 4-inch diameter target core size.

The core size decision not only affects veneer recovery, but also determines stud recovery. Table 14 shows the theoretical possibilities for lumber recovery from core logs in each diameter class and estimates of residues generated.

Low-taper logs.—As mentioned in the section on timber resources, logs in the 8-inch small end d.i.b. class will likely occur in greater proportion than other d.i.b. classes. The engineering analysis, however, recommends peeling only logs 9 inches and larger. This would mean allocating the largest proportionate log class, originating in both multiproduct and sawlog timber sales, to lumber manufacture. In turn, volumes of logs 9 inches and larger would need to be increased to maintain plywood production at capacity. Peeling 8-inch logs may increase operating costs, but this potential negative effect is less than that introduced by having to purchase significantly more stumpage. Also, making studs from the large volume of 8-inch logs would, in effect, require a sizable sawmill with an associated plywood plant. This runs counter to the original purpose of this study, which was to determine the feasibility of a plywood plant with a small sawmill added to upgrade utilization.

Table 14 lists stud lumber and residue recovery for 8.5-foot logs with d.i.b.'s from 4 to 8 inches. While the larger logs could yield lumber other than studs, considering a wider range of possibilities for this study would have obscured the main comparisons. The assumed sawn product, therefore, was restricted to stud lumber.

High taper logs.—Taper in these logs is much more variable, because the logs are cut from trees with a wide variety of diameters and heights. Assumptions for taper are as follows:

Log d.i.b. class	Taper per 8.5-foot log
inches	*inches*
6	3.4
7	2.6
8	2.0

Small end log diameters in table 14 range from 6 to 8 inches for this taper class. Few high taper logs should be less than 6 inches d.i.b., because they come from sawtimber size trees that have a 6-inch top utilization limit.

Bark Recovery

Bark volume was not computed on a per-log basis, as was done for veneer and lumber, because no published data were available to support such computations. Instead, data were used that estimate the bark produced per cubic foot of wood processed for each 4-inch diameter class (Krier and River 1968).

Complete computations for bark volume are given in the appendix section "Bark Volume." The basic approach was to segment the assumed log distribution into diameter classes compatible with those for which data were available. The result is that bark volume generated is 100 cubic feet for each group of 100 logs 8.5 feet in length distributed with respect to small end d.i.b., as previously assumed.

Log Distribution and Index Volumes

Tables 13 and 14 show how individual logs of each size class would contribute to product output, bark excepted. The essential question, then, is to determine whether the proportionate log size mix discussed earlier would yield sufficient veneer to support the plant target annual output of 62.5 MM ft², 3/8-inch basis.

To compute total requirements, a quantity called "index log volume" was defined. This index volume is for 100 logs with small end diameters distributed as in figure 4. For example, of the 100 logs, 15.2082 logs have diameters in the 8-inch class, 6.5903 logs have diameters in the 12-inch class, etc. Dealing with such precise decimal parts of logs is theoretical but will result in a more accurate estimate when transformed to a basis of total number of logs required annually.

The following part of the analysis is based on assumptions about future plywood management decisions with respect to the veneer block lower diameter limit and to the target core size.

Three levels each of block diameters and core diameters have been considered—9, 8, and 7 inches (d.i.b. small end) for veneer block lower size limit, and 6, 5, and 4 inches for target core size. The analysis for each of the nine combinations has been carried to the point of illustrating log volumes required and product volumes generated under each combination.

Complete tables for product and residue volumes are given in the appendix (tables A-4, A-5, A-6) for each of the nine combinations of veneer block size lower limit and target core diameter. Some of this information is summarized in figure 6 which shows how plywood and lumber volumes, obtained from an index log volume, will vary depending on the assumed combination of lower veneer block limit and core size. Note the relationship between plywood and lumber volumes. For example, peeling veneer blocks 9 inches and larger to a 6-inch core yielded the lowest cubic foot plywood volume but the highest cubic foot lumber volume per 100 index logs.

Total Product and Residue Volumes

The final step in analysis of estimated product output is to divide the index volumes based on log size distribution into the total volumes required to achieve an annual plywood production level of 62.5 MM ft², 3/8-inch basis, which is equivalent to 1,953,125 cubic feet or to 19.53 M cunits.[28] This assumed cubic volume of finished plywood can be traced back to the beginning of the production process to determine what volume of logs will supply the veneer volume required.

Figure 7 traces the flow of wood material through the plywood complex as conceived. Two primary flows are necessary to process all logs—one for plywood and one for lumber. In addition, veneer block cores enter the lumber flow.

As shown in figure 7, the 19.53 M cunits of finished plywood—banded, stacked, ready for shipment—is net of trim and other dry veneer loss incurred from veneer dryer output to shipping dock.

Two veneer recovery studies (Hunt and Woodfin 1970, Woodfin and Pong 1972), each found that approximately 16% of dry, untrimmed veneer is lost in the dry chain and panel layup. Losses at this step in plywood production are largely dependent on mill efficiency and production technology. Because two independent studies reported similar results, it was assumed that the proposed mill would experience a similar loss of 16%.

To provide the required plywood volume (62.5 MM ft², 3/8-inch basis), allowing for a dry veneer loss of 16%, the annual gross veneer volume from the dryer must be 2,325,149 cubic feet, or 23,250 cunits.

To produce 23,250 cunits of dry veneer annually requires an input log volume that depends on target core size and lower veneer block diameter limit. Total required log volume increases dramatically as target core size increases or as veneer block lower limit increases (fig. 8). Methods used to compute these alternative volumes are presented in the appendix.

An interesting consequence of decisions about the minimum block diameter and target core diameter is

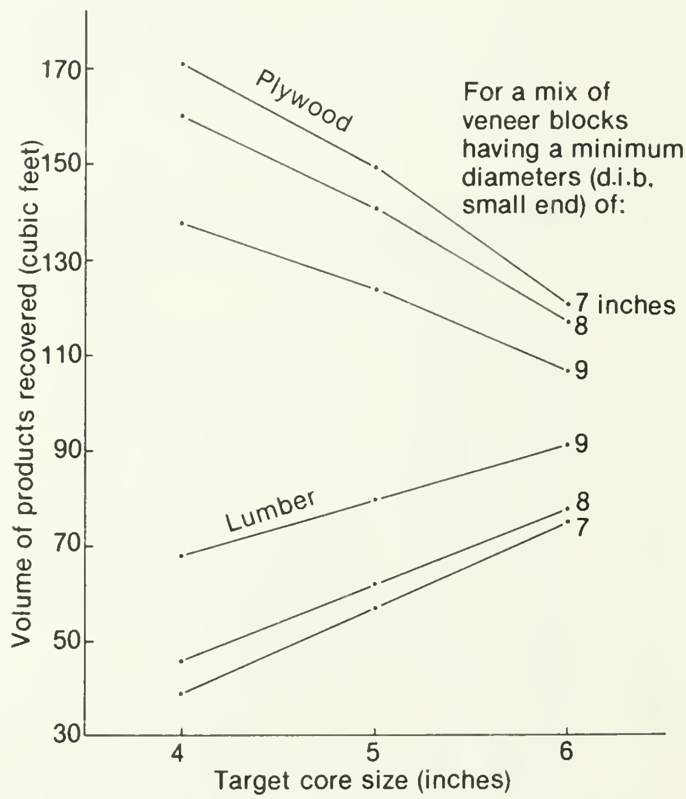

Figure 6.—Plywood and lumber product volume per 100 log index unit as a function of target core size and veneer block lower diameter limit.

[28]*One cunit is 100 cubic feet of wood; one M cunit is 100,000 cubic feet of wood. Although the cunit generally is used to measure roundwood products such as sawlogs or pulpwood, it is used here as a convenient, product-independent measure of solid volume.*

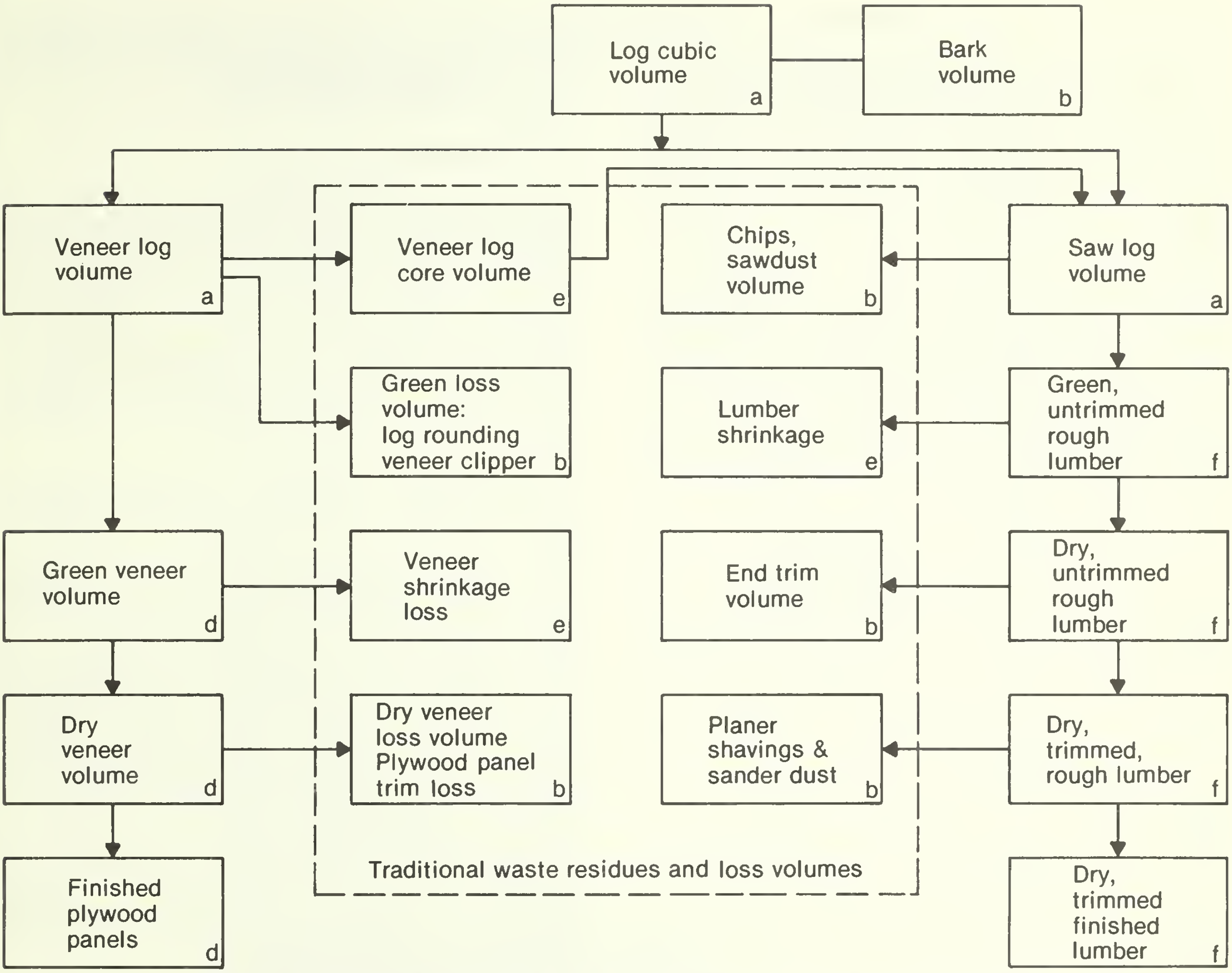

Figure 7.—Primary process steps and resulting intermediate products and by-products for plywood and lumber manufacture: (a) can also be measured in terms of board foot log rule volume; (b) traditional measurement unit is oven-dry tons (O.D.T.); (c) traditional measurement unit is a ratio-square foot, 3/8-inch basis, per board foot; (d) traditional measure unit is square feet, 3/8-inch basis; (e) has no traditional measurement unit; (f) traditional measurement unit is foot board measure, lumber tally basis (fbm (LT)).

the change in potential lumber output in the form of 2- by 4-inch studs. As the lower limit of veneer block diameters increases, lumber volume increases significantly. This happens because small logs not peeled must be disposed of at the sawmill. Product volumes for all nine combinations of target core sizes and veneer block lower limit can be computed from tables A-4, A-5, A-6. In figure 8, the distance between curves for total lumber and plywood volumes and total required wood volume represents residues of various kinds.

For the remainder of this analysis, plywood operations are based on peeling veneer blocks 8 inches and greater to a 4-inch target core. This assumption is an economic compromise between the two extreme combinations of 9-inch blocks to a 6-inch core and 7-inch blocks to a 4-inch core. It allocates to plywood the large supply of 8-inch logs and incorporates capabilities of modern plywood technology to peel blocks to a 4-inch core. Annual material requirements for the assumed management option are presented in table 15.

Economics

In this analysis, costs that are largely uncontrollable by plant management, such as log and energy costs, were separated for detailed analysis of their effects. For controllable costs it was assumed that the experience of producers with similarly configured plants in other areas was representative of the Black Hills. Some variation in labor cost can be expected with location, but most in-plant processing costs would be nearly the same whether the plant is located in South Dakota, Wyoming, or elsewhere. The engineering study mentioned previously supplied the basic data for in-plant costs.

The Cash Flow Analysis (CFA) Approach

A computer program was used to provide an analysis of discounted cash flows (Harpole 1978). The CFA computer program computes the after-tax value of investment cash flows over time. Results are presented in terms of present value of investment and internal rate of return. Also available is the total unit cost of production, or break-even price, under varying levels of input variables.

When analyzing cash flow with the CFA computer program, the only serious, but not insurmountable, limitation concerns units of measure for dealing with multiple products from the same facility. Because apportioning fixed and variable costs to several products was not practical in this case, a method was needed to realistically assign costs to plywood, lumber, and salable residues. The method used initially figures costs in units appropriate to each product and then converts these costs in terms of cost per cubic foot of wood equivalent. After analysis by the CFA program, prices and costs are then converted back into units characteristic of each product.

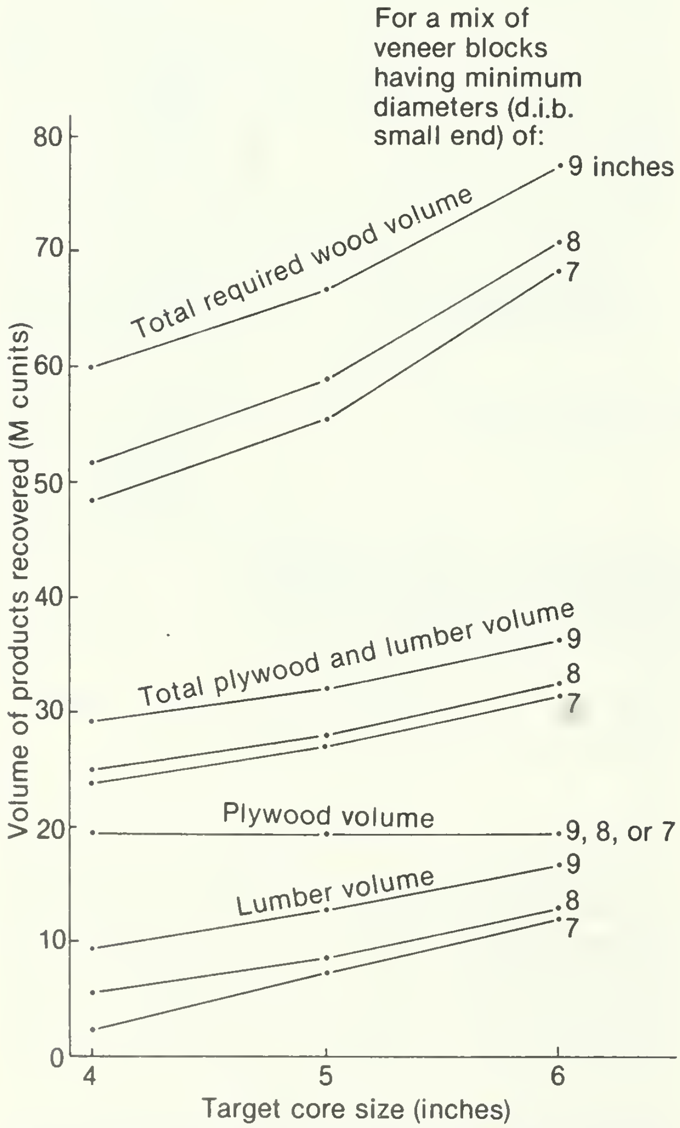

Figure 8.—Plywood and lumber volumes produced and total wood volume required on an annual basis. (Plywood is constant at 19,530 cunits, corresponding to 62.5 MM ft² (3/8-inch basis).

Cost of Operation

All costs are discussed in the order in which they are entered on the CFA program data sheet (Harpole 1978).

Selling expense.—The factor used represents the ratio of sales cost to gross sales, not an absolute value. The selling expense factor is assumed to remain constant for the analysis period.

Selling expense for plywood is composed of trade discounts of 5% and 3%, a 2% cash discount on invoiced amount, and a 3% sales cost allowance on invoiced amount. The resulting composite factor is 0.1246 or 12.46%.

Selling expense for lumber is composed of a 5% trade discount plus a 2% cash discount on invoiced amount. The resulting composite factor is 0.0690 or 6.9%.

No selling expense factor is assumed for salable residue, because any such costs in the Black Hills region are built into chip and residue contracts.

Because the CFA program does not accommodate individual product cost analyses in integrated operations, the above factors were combined in a weighted average to reflect overall product selling expense. Representative market prices and the assumed product outputs for plywood, lumber, and salable residue were combined to derive a sales cost factor of 0.1125 based on total gross sales of all products.

Working capital.—Typical sources and uses of working capital are accounts receivable, timber sale and road deposits, accounts payable, and raw material and operating costs invested in goods-in-process or in unsold finished products inventory.

For this analysis, it was conservatively assumed that working capital requirements are equivalent to about 2 months' or 40 working days' production. For a base working year of 242 days, the computed working capital factor is 0.1653.

Tax rate.—The federal income tax rate for this enterprise is assumed to be 48%. South Dakota and Wyoming do not impose state corporate income taxes.

Discount rate.—The expected rate of return on investment is represented in the analysis by assumed discount rates. These rates are used to determine the present value of future cash flows included in the break-even analysis. As part of the analysis to determine limits on plant operating parameters, the discount rate is varied from a minimum value of 6%, through an average value of 15%, to a maximum value of 25%.

Time span of CFA.—The time period considered in the CFA is 10 years, chosen for reasons explained in the paragraphs on depreciation.

Unit manufacturing costs.—For the plywood plant, these are variable costs, such as wood procurement costs and glue and chemical costs that vary directly with output; for the sawmill, only wood procurement

Table 15.—Annual material budget (cubic feet) for plywood complex[1]

Material type (product volume)	Material volume	
Total volume (wood + bark)		6,386,445
Minus: Bark volume		1,222,993
Total wood volume		5,163,452
Wood to plywood[2]		4,215,760
Minus: Green losses	1,287,079	
Lathe cores	501,419	1,788,498
Green veneer		2,427,262
Minus: Dryer shrink		102,108
Dry veneer		2,325,154
Minus: Trim & dry loss		372,024
Plywood (62.5 MM ft², 3/8-inch basis)		1,953,130
Wood to lumber (from logs)		947,693
Minus: Chips	469,579	
Saw kerf	23,342	492,921
Lumber, rough green untrimmed		454,772
Minus: End trim		26,629
Lumber, rough green trimmed		428,143
Minus: Drying shrink	29,991	
Planer, sander loss	34,869	64,860
Lumber, dry dressed (6,641,707 fbm)		363,283
Wood to lumber (from lathe cores)		501,419
Minus: Chips	254,867	
Saw kerf	—	254,867
Lumber, rough green untrimmed		246,552
Minus: End trim		14,197
Lumber, rough green trimmed		232,355
Minus: Drying shrink	16,188	
Planer, sander loss	18,929	35,118
Lumber, dry dressed (3,605,326 fbm)		197,237

[1]*Total values may be in error by 1 cubic foot because of rounding errors after multiplying index volumes (table A-5) by the "blow-up" factor (table A-7).*

[2]*Logs 8 inches and larger, d.i.b., peeled to a 4-inch core.*

costs vary directly with output. In an integrated operation, wood procurement cost is shared between plywood, lumber, and salable residue.

The CFA program used in this analysis considers only one product per computer run, but this limitation is not critical, because diverse outputs like plywood, lumber, and residue can be analyzed simultaneously when computed on a cubic foot product basis. Table 16 has unit cost data for various levels of log procurement cost. The final unit cost figure includes a charge of $23.20 per cunit of plywood for glue and chemicals, which translated into an equivalent of $9.87 per cunit of composite product output.

Other variable costs.—These costs are mixtures of fixed and variable elements, but are predominantly variable. Labor, energy, and utilities are examples of these costs. In this analysis "other variable cost" categories for year 1 are as follows:

Plywood	
Direct labor	$ 930,286
Operating supplies	48,750
Association dues	37,500
Power-electric (from commercial sources)	178,560
Power-steam (from residue fuels)	128,414
	1,323,510
Lumber, residue	128,668
Total of other variable costs	1,452,178

Fixed manufacturing costs.—Although regarded as constant regardless of output level, these costs can have some variable elements. However, for purposes of this analysis, they are considered joint costs dependent primarily on the rated capacity of the plywood/sawmill complex.

Costs in this category are maintenance, supplies and expenses, and mill supervision. Amounts for these fixed manufacturing costs are as follows:

Plywood	
Maintenance, supplies and expense	$103,125
Mill supervision	115,128
	218,253
Lumber	31,140
Total fixed manufacturing costs	249,393

Overhead costs.—Included are costs expected to vary as a constant proportion of facilities costs, such as insurance and taxes. Office and miscellaneous costs are also included in overhead costs.

Insurance is estimated to be 1.5% of total facilities capital investment. Taxes include ad valorem property taxes and other local assessments. Corporate income taxes are not considered here. Office costs are made up of staff salaries including the mill sales function, supplies, telephone, and travel expenses. Estimates of these costs are as follows:

Plywood	
Insurance	$297,284
Taxes, local	16,951
Office	74,852
Miscellaneous	10,000
	399,087
Lumber	308,436
Total overhead costs	707,523

Facilities costs.—These costs are made up of all investments necessary to provide physical resources for production. Items include costs for land, site preparation, buildings, engineering, processing machinery, mobile equipment, and other like expenses.

Table 17 shows the major capital expenditures necessary for the physical facilities. Included in addition to these costs are pre-start up charges for interest on capital during construction and for salaries of key personnel during the construction period.[29]

Physical facilities	$ 9,909,450
Interest on capital (15%)	1,486,418
Salaries	116,776
Total facilities costs	11,512,664

It was assumed that all mobile equipment would be replaced after 5 years of use. The original capital cost of $250,000 was increased to $367,332 to cover an inflation rate of 8% annually for 5 years.

Depreciation.—Depreciation charges account for expiration of fixed assets. Harpole (1978) has excerpted data from the 1971 Revenue Act to illustrate ranges in the time periods allowed for depreciation of various capital assets. Land improvements typically are allowed a 20-year depreciation period, and buildings are allowed 45- or 60-year depreciation periods depending on type of building. Processing equipment for primary and secondary manufacturing of plywood, lumber, and particleboard is allowed a depreciation period of 8 to 12 years with an average of 10 years.

[29]*These cost estimates as well as all others in this report are based on 1977 prices. A more recent estimate for cost of similar facilities, current as of mid-1979, is $20-25 million. Personal communication from R. F. Baldwin, Camden, Tex.*

Table 16.—Unit manufacturing costs (dollars) for Black Hills plywood, lumber, and chip mill

Stumpage cost (per M fbm (LS))	Stumpage cost[1] (per cunit, log scale)	Stumpage cost[2] (per cunit, plywood)	Stumpage cost plus glue and chemicals[3] (per cunit)	Unit cost[4] (per cunit of composite product)
130	57.85	153.04	176.24	75.002
110	48.95	129.50	152.70	64.982
90	40.05	105.95	129.15	54.962
70	31.15	82.41	105.61	44.943
50	22.25	58.86	82.06	34.922
30	13.35	35.32	58.52	24.903

[1]*Cost per M fbm (LS)* $\times$ *0.445* $\frac{\text{M fbm (LS)}}{\text{cunit, log scale}}$

[2]*Cost per cunit log scale* $\times$ *2.646* $\frac{\text{cunit, log scale}}{\text{cunit, plywood}}$

[3]*Cost per cunit plywood + $23.20/cunit for glue and chemicals = unit cost in terms of plywood cubic volume.*

[4]*Cost per cunit plywood* $\times$ *0.42556* $\frac{\text{cunit, plywood}}{\text{cunit, composite product}}$ *= unit cost in terms of total cubic volume of salable product.*

Table 17.—Capital investment (1977) (dollars) for plywood production facilities in the Black Hills (62.5 MM ft² annually, 3/8-inch basis)

Land	24,000
Site preparation	25,000
Foundations	411,200
Buildings	1,880,000
Utilities	1,948,000
Plant equipment and machinery	3,242,750
Miscellaneous and mobile equipment	250,000
Design and Engineering	412,000
Contingencies	750,000
Auxiliary sawmill, including kiln	966,000
Total facilities cost	9,909,450

Table 18 shows the flow of depreciation charges over the 10-year analysis period. In this analysis, site preparation, buildings, and mobile equipment were written off with straight line depreciation for the total period appropriate to each asset. Processing machinery is depreciated by the double declining balance method for the first 5 years, then switched to straight line depreciation for the remaining 5 years of its investment life. Accelerated depreciation in the early years of the capital investment assumes that benefits from the asset are greatest when it is new and that technical progress increases the risk of early obsolescence for machinery.

Investment tax credit.—This credit is incorporated into the feasibility analysis, because it is a currently available stimulus to investment. A credit of 10% of the cost of processing machinery and mobile equipment is shown below:

Plywood process equipment	$324,275
Lumber process equipment	75,300
Mobile equipment	25,000
Total investment tax credit	424,575

Rising costs.—The CFA computer program was modified to enable subsequent users to enter estimated changes in prices and costs into updates of the analysis. To allow for rising costs, the wholesale price index was selected as an indicator of general cost levels for industry. This index is available from the U.S. Department of Labor, Bureau of Labor Statistics, and is also tabulated in the series on demand and price situation for forest products published by the USDA Forest Service (Phelps 1977). The years 1967 to 1976 were chosen as the base period. During this period the Wholesale Price Index rose from 100 to 183. This increase is equivalent to a 6.95% compound annual interest rate. This rate was applied to estimated 1977 costs to compute future costs over the subsequent 10-year period.

Revenues

Cash revenue was projected from the sale of plywood, stud lumber, chips, and sawdust. While plywood revenues are the focal point of this report, economic feasibility also depends on sale of these other products.

Prices were assumed for lumber and salable residue, and then were used to determine the plywood price that would be needed to break even, with all costs considered. Lumber and residue prices were assumed to increase at a 7.2% annual rate based on data for 1967 to 1976 (Phelps 1977).

Base prices for 2- by 4-inch stud lumber were the average prevailing mill prices in 1977 and 1978. Chip and sawdust prices, oven dry (o.d.), were based on 1978 levels at rail loading points in the Black Hills. Base prices used were as follows:

Product and units	Product	Cubic volume price
	dollars/unit	*dollars/cunit*
2- by 4-inch stud lumber (M fbm (LT))	175.00	320.00
Chips, (o.d. tons)	17.50	21.00
Sawdust, (o.d. tons)	4.00	4.80

These cubic volume unit prices, multiplied by the cubic volume output of each respective product, give total revenue from all nonplywood production.

The typical definition of break-even point is that level of business operation where total revenues and total expenses are equal. Part of total expenses is the implicit alternative cost of capital and operating funds that could have been invested elsewhere. This alternative cost is covered by the specified rate of return. Thus, break-even plywood price, as used here, is the amount per thousand square feet required to make total revenue match total costs plus the specified rate of return.

One additional factor of importance in computing break-even plywood price is the mix of plywood grades and thicknesses. However, this price, as computed by the CFA program, must be in terms of dollars per hun-

Table 18.—Depreciation schedule (dollars) for plywood plant and associated auxiliary lumber/chip mill

Depreciable capital asset	Initial book value	Year 1	2	3	4	5	6-10
Site preparation[1]	25,000	1,250	1,250	1,250	1,250	1,250	1,250
Buildings—PW[2]	5,401,700	120,038	120,038	120,038	120,038	120,038	120,038
Buildings—LMCP[2]	213,000	4,733	4,733	4,733	4,733	4,733	4,733
Process machinery, PW[3]	3,242,750	648,550	518,840	415,072	332,058	265,646	
Book value,[4]	1,062,584						147,662
Process machinery, LMCP[3]	753,000	150,600	120,480	96,384	77,107	61,686	
Book value,[4]	246,743						34,289
Mobile equipment[5]							
Years 1-5	250,000	45,000	45,000	45,000	45,000	45,000	
Years 6-10[6]	367,332						66,120
Total depreciation		970,171	810,341	682,477	580,186	498,353	374,092

[1]*Straight line depreciation over 20 years with no salvage.*
[2]*Straight line depreciation over 45 years with no salvage; includes building, foundation, utilities, design and engineering, and contingencies. PW-Plywood mill. LMCP-Lumber/Chip mill.*
[3]*Double declining balance depreciation first 5 years, straight line depreciation last 5 years with salvage of 10% of initial 0 book value. Includes all in-plant machinery for each mill and installation.*
[4]*Remaining book value at beginning of last 5 years.*
[5]*Straight line depreciation over 5 years with 10% salvage.*
[6]*Cost is amount in year 0 inflated over 5 years at 8%.*

dred cubic feet of plywood, regardless of grade or thickness. Further analysis is needed to break down the composite cubic-foot price into a representative mix of plywood grades and thicknesses. In this study, the composite price was based on five thicknesses of C-D-X grade plywood. Although other grades of plywood were discussed as good production opportunities, only commodity grades were used for this economic analysis, because their market prices can be more accurately established. Any error resulting from this assumption would be on the conservative side. Output proportion and average mill price for the five thicknesses included in the analysis are shown below:

C-D-X thickness	Proportion of output	Assumed mill price
inch	*percent*	*dollars/M ft²*
5/16, 3 ply	1.2	160
3/8, 3 ply	13.9	164
1/2, 4 ply	68.7	223
5/8, 5 ply	12.8	263
3/4, 5 ply	3.4	327

These were used to establish the price spread between thicknesses in computing prices for individual plywood thicknesses.

Profitability

The values given in the preceding discussion of costs of operation are assumed to be base figures for the CFA. In addition, for the base run, log cost is assumed to be $70 per thousand board feet, Scribner log scale, and internal rate of return is 15%. CFA output for these assumed values is shown in table 19. As an example of how values in table 19 are computed, table 20 shows the flow of computations necessary to get an after-tax net cash flow of $2,199,782 for year 1.

Table 19 shows that the break-even unit price must average $180.48 per hundred cubic feet of composite product. Lumber mill value is assumed to be $175 per thousand board feet, and chip and sawdust mill value is assumed to be $17.50 and $4.00 per o.d. ton, respectively. Mill realization for 1/2-inch C-D-X sheathing must then be $141.41 per thousand square feet (M ft², surface area basis). Required mill realizations for the remaining C-D-X thicknesses are computed by applying market price spreads to the 1/2-inch C-D-X realization. Results are shown in the following tabulation:

C-D-X thickness	Price spread factor	Plywood mill realization
inch	*price, given thickness / price, 1/2-inch thickness*	*dollars/M ft², surface area basis*
5/16	0.717	101.46
3/8	0.735	104.00
1/2	1.000	141.41
5/8	1.179	166.77
3/4	1.466	207.36

To estimate market break-even prices, freight costs as shown in table 7 plus other handling charges must be added.

ALTERNATIVE OPERATING FORMATS

The preceding analysis portrayed operation of an integrated plywood plant, sawmill, and chip mill facility. All input and output factors described previously were set at values considered reasonable based on late 1977 and early 1978 price levels. Break-even prices computed under these circumstances indicated economic feasibility, given current market conditions. However, because market conditions in the forest products industry, and, therefore, production factors, vary widely over time, the effect on break-even prices of changes in selected input or output factors needs further investigation.

Effect on Break-even Price

Given the input factor values used in the previous sections, the effects of a change in various production costs and a change in stud price on the break-even price for plywood were computed (fig. 9). For example in A, an increase in labor cost of 20% would raise break-even price from about \$141 to about \$147 per thousand square feet area basis. The slope of the graph line for a specific factor indicates the sensitivity of break-even price to percent changes in the responsible factor—the steeper the slope, the greater the sensitivity.

In example B (fig. 9), the graph line for stud price shows that a 40% decrease from \$175 to \$105 per thousand board feet would result in a rise in break-even price for 1/2-inch C-D-X plywood to about \$152. Typically, however, the prices of sheathing plywood and studs move in the same direction at the same time, because they are complementary commodities in the housing construction materials market.

All relationships are linear except for changes in "Production below capacity." If the plant has to operate at 20% or 40% below capacity, for example, fixed costs are spread over lower output and, consequently, the break-even price must rise rapidly for revenues to cover expenses.

Total costs affect break-even price most dramatically and give a general idea of inflationary effects on a plant of this size. Because the capacity of this plant is the size of smaller plywood plants currently operating, fixed costs are a higher proportion of the total. Increases in general cost levels, therefore, can be expected to impact this plant more severely than a larger operation.

The relative lack of sensitivity of break-even price to energy costs is noteworthy. Energy costs are not as high as they otherwise might be, because it was assumed that the plant would depend on its own residue for process steam. Such residue was valued at current salable residue prices or at zero price depending on

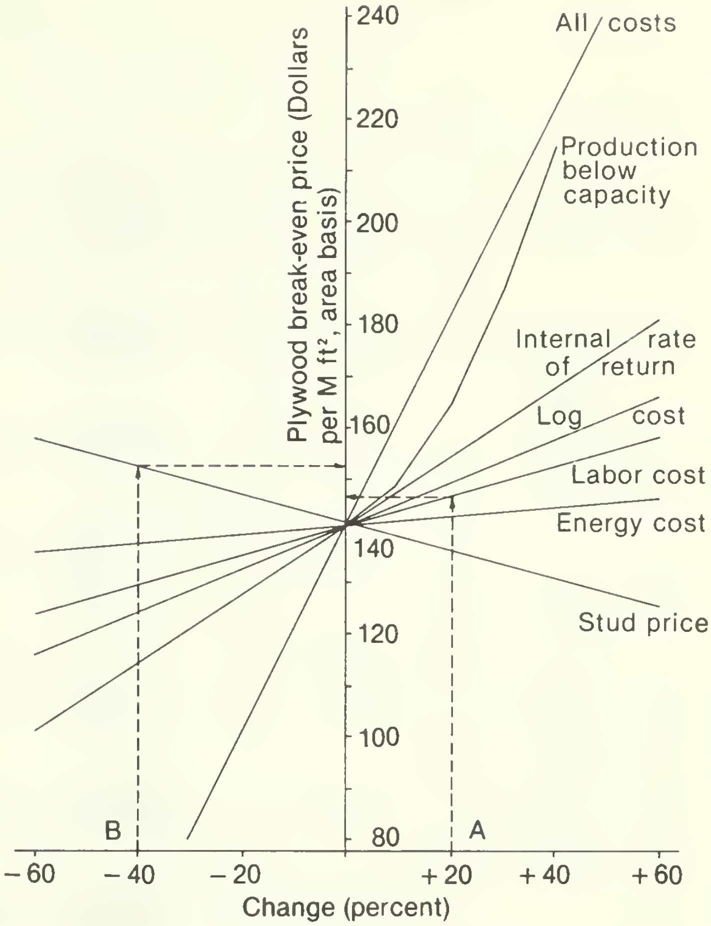

Figure 9.—Sensitivity of break-even price, 1/2-inch C-D-X plywood, area basis, to percent changes in selected cost and plant operation factors.

alternative uses. Therefore, although electricity is purchased commercially, total residue-based energy costs do not form a large proportion of total costs.

Effect on Raw Material Need

Although not discussed here in detail, log cost is sure to receive serious management attention. For this plant it was conservatively assumed that 8-inch and larger blocks would be peeled to a 4-inch core. Instead, management could decide, for example, to peel 7-inch, or even 6-inch and larger logs, to a 3-inch core. The rationale might be that because blocks of this size are generated from multiproduct sales, they might better go into plywood than lumber, and thus reduce the total mill log supply required to produce annually 62.5 MM ft² (3/8-inch basis) of plywood. In this case, rather than produce lumber as the only secondary product, cores might be treated with a suitable preservative and sold for fence posts. Logs not suitable for peeling might be sawn for lumber, or chipped for pulp or fuel, depending on relative needs and prices.

Table 19.—Discounted cash-flow analysis of assumed expense and revenue base values[1]

Initial investment—Year 0		Effective tax rate	0.4800	Original cash equity	$ 0	Variable costs/sales	=	0.5410
Facilities cost	$11,512,664	Borrowing rate	.0000	Ending value of equity	16,947,218	Fixed costs/sales	=	.1695
Working capital	722,112	Reinvestment rate	.0000	Facilities salvage value	6,468,008	Tax costs/sales	=	.1351
Total investment	12,234,776	Internal rate of return	.1500	Present value of investment (I = .1500)	3	After tax profit/sales	=	.1544

10-Year financial summary with break-even adjusted unit prices[2]

Year-end values	1	2	3	4	5	6	7	8	9	10
Unit sales	43,597	43,597	43,597	43,597	43,597	43,597	43,597	43,597	43,597	43,597
Unit price	$ 180.48	$ 193.48	$ 207.41	$ 222.34	$ 238.35	$ 255.51	$ 273.91	$ 293.63	$ 314.77	$ 337.43
Gross sales	7,868,534	8,435,068	9,042,393	9,693,445	10,391,373	11,139,552	11,941,600	12,801,395	13,723,095	14,711,158
Interest income or expense	0	0	0	0	0	0	0	0	0	0
Gross revenues	7,868,534	8,435,068	9,042,393	9,693,445	10,391,373	11,139,552	11,941,600	12,801,395	13,723,095	14,711,158
Variable manufacturing cost	1,959,399	2,095,578	2,241,220	2,396,985	2,563,575	2,741,744	2,932,295	3,136,090	3,354,048	3,587,154
Selling expense	885,210	948,945	1,017,269	1,090,513	1,169,029	1,253,200	1,343,430	1,440,157	1,543,848	1,655,005
Other variable cost	1,452,178	1,553,104	1,661,045	1,776,488	1,899,954	2,032,000	2,173,224	2,324,264	2,485,800	2,658,563
Total variable cost	4,296,787	4,597,627	4,919,535	5,263,985	5,632,559	6,026,944	6,448,950	6,900,510	7,383,696	7,900,723
Unit variable cost	98.56	105.46	112.84	120.74	129.19	138.24	147.92	158.28	169.36	181.22
Profit contribution	3,571,746	3,837,441	4,122,858	4,429,460	4,758,815	5,112,608	5,492,650	5,900,885	6,339,399	6,810,436
Fixed manufacturing cost	249,393	266,726	285,263	305,089	326,293	348,970	373,224	399,163	426,904	456,574
Overhead cost	707,523	756,696	809,286	865,532	925,686	990,021	1,058,828	1,132,416	1,211,119	1,295,292
Total fixed cost	956,916	1,023,422	1,094,549	1,170,621	1,251,979	1,338,991	1,432,051	1,531,579	1,638,023	1,751,866
Facilities cost	0	0	0	0	367,332	0	0	0	0	− 6,468,008
Working capital	50,187	53,675	57,405	61,395	65,662	70,225	75,106	80,326	85,908	− 1,322,001
Investment	50,187	53,675	57,405	61,395	432,994	70,225	75,106	80,326	85,908	− 7,790,009
Depreciation	970,171	810,341	682,477	580,186	498,353	374,092	374,092	374,092	374,092	374,092
After tax profit	1,279,798	1,041,913	1,219,833	1,392,900	1,564,411	1,767,753	1,916,984	2,077,511	2,250,188	2,435,928
After tax earnings	2,249,969	1,852,254	1,902,310	1,973,086	2,062,764	2,141,845	2,291,076	2,451,603	2,624,280	2,810,020
After tax net cash flow	2,199,782	1,798,579	1,844,904	1,911,691	1,629,770	2,071,620	2,215,970	2,371,278	2,538,371	10,600,029
Accumulated net cash flow (M dollars)	− 10,035.0	− 8,236.4	− 6,391.5	− 4,479.8	− 2,850.0	− 778.4	1,437.5	3,808.8	6,347.2	16,947.2

Internal rates of return—at adjusted input values

	80%	90%	100%	110%	120%
Unit sales	0.090	0.121	0.150	0.178	0.205
Unit price	.065	.109	.150	.189	.227
Unit variable cost	.201	.175	.150	.124	.098
Total fixed costs	.161	.155	.150	.145	.139
Facilities cost	.184	.165	.150	.137	.126

[1] *Investment tax credit of $424,575 considered.*
[2] *Figures in this table are reproduced from computer printout and are rounded off.*

Table 20.—Example of computations used in table 19

Unit sales, cunits		43,597
Unit price, dollars per cunit		(×) 180.48
Gross sales revenue		$7,868,534
Less: Variable manufacturing cost	$1,959,399	
Selling expense	885,210	
Other variable cost	1,452,178	
Total variable cost		(−) 4,296,787
Profit contribution (gross)		3,571,746
Less: Fixed manufacturing cost	249,393	
Overhead cost	707,523	
Total fixed cost	956,916	
Depreciation	970,171	
Total fixed cost (including depreciation)		(−) 1,927,087
Before tax profits		1,644,659
Tax allowance (1.00 - 0.48)		(×) 0.52
After tax profit		855,223
Plus: Investment credit		(+) 424,575
After tax profit (adjusted)		1,279,798
Plus: Depreciation		(+) 970,171
After tax earnings		2,249,969
Less: Working capital allowance		(−) 50,187
After tax net cash flow		2,199,782

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MARKETS

Plywood Properties Important in Marketing

Various plywood applications require different panel characteristics or different combinations of characteristics. The following summary describes some of the more important properties of sheathing and associated types of plywood related to particular end uses.[1]

Stiffness.—The ability of a panel to resist deformation in the plane of the panel results from the inherent elasticity of the wood and the panel thickness. Stiffness is of primary importance in such applications as roof sheathing, subflooring, combination floor, wall sheathing, boxes, pallets, and air cargo containers.

Bending strength.—The ability of a panel to support a load without breaking. This characteristic is significant in such applications as sheathing, subflooring, combination floor, wall sheathing, boxes, pallets, and air cargo containers.

Rigidity.—The ability of a panel to resist racking, or deformation "out-of-square." This property is important when the plywood is used as subflooring or wall sheathing and in boxes and pallets.

Weight.—Because panels manufactured from different species vary considerably in weight, this significantly affects ease of handling, dead loads of structures, and tare weight of packaging. Weight becomes important in uses such as roof sheathing, combination flooring, and air cargo containers.

Thermal insulation.—The ability of the material to restrict the flow of heat. This characteristic is particularly important for wall and roof sheathing.

Workability.—The ease with which various woods can be worked with hand or machine tools in such operations as sanding, sawing, grooving, etc. Workability of plywood is very significant when plywood is used in applications such as cabinets, boxes, and air cargo containers.

Fastening strength.—The ability of the plywood to hold mechanical fasteners, such as nails or screws. Fastener-holding capacity is important in all plywood applications but is especially critical in van linings, boxes, pallets, and air cargo containers.

Color.—The general appearance of a panel as to whether it is light or dark and the overall effect of the grain pattern caused by the growth rings. A light uniform color is usually considered to be desirable for plywood, even when it serves no specific functional purpose.

Integrity of surface.—The degree to which defects (knots, knotholes, bark pockets, and pitch pockets) are found in the face plies of plywood. This characteristic is most important when plywood is used for underlayment, combination floor, siding, combination siding, and van linings, where holes or voids in the surface may show through coatings or coverings or make the panel more subject to mechanical damage or weathering.

Surface hardness.—The resistance of the wood to abrasion and puncture. This property is significant in plywood used for underlayment, combination flooring, siding, combination siding, van lining, boxes, pallets, and air cargo containers.

Dimensional stability.—The ability of a panel to maintain the same dimensions through fluctuations in climate or moisture content. This property is most important for plywood used for underlayment, combination flooring, siding, and combination siding. Dimensional stability is slightly less important for roof sheathing, subflooring, wall sheathing, and van linings.

Weathering.—Warping and change in color, roughening, or checking of the surface caused by exposure to the elements. Because of plywood's exceptional dimensional stability, the problem of cupping and twisting from uneven stresses on the face and back of solid wood are largely eliminated. However, surface checking and roughening is often a problem. Good weathering characteristics are critical in siding and combination siding, but considerably less important in covered sheathing, boxes, pallets, and air cargo containers.

Painting quality.—This property reflects how well a material will take paint or stain and the frequency of maintenance required. Painting characteristics of plywood are similar but usually somewhat inferior to those of solid lumber of the same species. It is extremely important in considering the use of plywood for siding and combination siding, but not for sheathing and other "hidden" structural applications.

Gluing quality.—The ability of the wood to form good glue bonds with other structural elements over a wide range of glue types and gluing conditions. It is important in using plywood for subflooring, underlayment, and combination flooring.

Appearance.—The general visual characteristics of the plywood panel. Appearance plays an important role in utilization of panels for siding and combination siding.

Acoustical insulation.—The ability of the material to restrict sound from passing through it. It is an important consideration in selecting plywood panels for wall sheathing, siding, and combination siding.

[1]Information in the following titled paragraphs is taken from F. F. Wangaard et al. (1971). Potential markets for plywood made from Rocky Mountain ponderosa pine and Engelmann spruce. Unpublished Report, Department of Forest and Wood Science, Colorado State University, Fort Collins, Colo. (On file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.)

Applications in Residential Construction

Roof sheathing.—The most critical property of roof sheathing is stiffness. In this market, ponderosa pine plywood would compete mainly with plywood made from Douglas-fir and southern pine, which have the highest strength properties of any commercial softwood plywood species. Code standards for roof sheathing specify the minimum strength and stiffness required for a given span. In many cases, ponderosa pine plywood would be able to satisfy the minimum requirements and, at a given thickness, could be used interchangeably with Douglas-fir or southern pine, although its strength and stiffness may be less.[2] It is common practice for builders to use plywood roof sheathing thicker than required by building codes to provide an additional measure of stiffness desired by roofing applicators. Because thickness contributes more to stiffness than species, 1/2-inch ponderosa pine plywood roof sheathing may not only be acceptable under the code, but also about equally acceptable to builders when compared with Douglas-fir or southern pine. As an example, ponderosa pine 1/2-inch sheathing has an Identification Index[3] of 24/0, while 1/2-inch sheathing of Group 1 species like Douglas-fir has an Identification Index of 32/16. However, the most common roof joist spacing in light frame construction (housing) is 24 inches, no matter which plywood group is applied as sheathing. Subject to local building code restrictions and builder and consumer acceptance, ponderosa pine 1/2-inch plywood sheathing may be competitive with plywood sheathing of higher groups on an equal thickness basis.

Subflooring.—Stiffness and bending strength are the most important properties for subflooring, with rigidity, nail holding ability, dimensional stability, and gluing ability also rated as important characteristics. On the basis of physical properties, the suitability of species for subflooring follows the same general principles as for roof sheathing: Douglas-fir and southern pine have the highest ratings with ponderosa pine falling below western hemlock and above white fir and Englemann spruce. For a plywood species to be accepted in the flooring market, it must be suitable for spanning at least 16 inches, the most usual joist spacing. The APA has found that about 80% of plywood subfloors are 1/2-inch thick. Underlayment in double floor systems is usually 5/8-inch. However, the major trend in flooring systems has been toward concrete slabs and single layer wood floors instead of toward double floor systems.[4]

Underlayment.—It is important for underlayment plywood to have integrity of surface, surface hardness, dimensional stability, and gluing ability. Because floor coverings are applied directly to the underlayment, the face of the plywood must be free of voids and resistant to puncture. Veneer of C Plugged or better grade may be suitable for face plies in ponderosa pine underlayment. Also of importance is the contrast in hardness between early and late wood (grain pattern) which may show through thin flexible floor coverings. Ponderosa pine has less grain contrast than either Douglas-fir or southern pine and might be preferred for that reason.

Combination floor.—This application is often referred to as a single layer floor system because it is one sheet of plywood which serves the dual function of subfloor and underlayment. The important properties for this use are stiffness, bending strength, light weight, integrity of surface, surface hardness, and gluing ability. Although Douglas-fir is rated as the best species because of its stiffness, strength, and surface integrity, ponderosa pine of 5/8-inch thickness can be used over 16-inch spans. With more than 90% of the floor joists in single-family and multi-family homes having a 16-inch span, ponderosa pine plywood should be competitive in this market if it satisfies the other requirements for subflooring and underlayment.

Wall sheathing.—Physical requirements for wall sheathing are less demanding than for roof sheathing or flooring. As a result, the market potential for woods of lower strength and stiffness, such as ponderosa pine, is greater. Specifications for wall sheathing are established on the basis of minimum requirements for specific stud spacings. A 5/16-inch ponderosa pine panel carries an index of 16/0, well over the minimum 12/0 index required for 16-inch stud spacing. For 2- by 4-inch or 2- by 6-inch studs spaced 24 inches o.c.,[5] the panel identification index can range from 16/0 to 32/16, depending on panel thickness and construction.

Siding.—The most important properties for siding are integrity of surface, surface hardness, dimensional stability, weathering, painting ability, and appearance. Of the species considered in this study, white fir, Douglas-fir, spruce, and hemlock were rated as the most acceptable species. Appearance, which is prob-

[2]Personal communication from R. F. Baldwin, Camden Tex. As of midyear 1979, the Industry Standard Committee of the American Plywood Association were considering an amendment to Product Standard 1-74 (American Plywood Association 1974). The amendment allows marking 1/2-, 5/8-, and 3/4-inch C-C-X, C-D, and Structural panels of Group 3 woods with the same Identification Index (Reference footnote 3 in appendix) as Group 1 woods if they are manufactured 1/32-inch thicker than standard nominal thickness and if they have 1/6-inch thick minimum face and back plies. This amendment, if accepted, would assist acceptance of ponderosa pine plywood in applications where the Identification Index for sheathing panels is specified.

[3]Identification Index or Span Rating (American Plywood Association 1974) serves as an indicator of allowable roof and floor spans for which a particular plywood panel is mechanically suited. For example, in an Identification Index of 48/24, the 48 indicates that when used for roof sheathing, the panel may have supports spaced up to 48 inches apart, center to center; the 24 indicates that the panel may be used for structural floors with supports spaced up to 24 inches apart, center to center.

[4]Personal communication from Robert G. Anderson, Marketing Group, American Plywood Association, Tacoma, Wash., and personal communication from J. L. Bowyer, Department of Forest Products, College of Forestry, University of Minnesota, St. Paul, Minn.

[5]The distance from the center of one stud to the center of the next stud is 24 inches o.c. (on center). For more information on panel index and wall sheathing, read the American Plywood Association Tacoma, Wash., publications A30, Plywood Sheathing for Walls and Roofs, and W405, Mod 24 Building Guide. Application Data For 24-inch Framing.

ably the most important property, is almost entirely dependent on individual tastes, and an adequate rating system for appearance has not been established. It may be possible to develop a siding product from ponderosa pine plywood by taking advantage of the rustic appearance of knotty veneer. Two basic types of plywood siding offer either textured veneer surfaces for painting or staining or smooth medium density overlay faces (MDO grade) for painting. Any commercial softwood species is technically acceptable for plywood siding material, subject to proven durability under exterior exposure and appropriate surface treatment.

Combination siding.—This type of siding combines the important technical functions of both siding and sheathing. Although ponderosa pine is rated lower for this use than some other species because of its lower strength values, there are no standards or specifications which would restrict the use of ponderosa pine in single wall construction. A major reason for significant increases in demand for combination siding has been the modular home concept, where a single panel of plywood serving as both a sheathing and siding material can provide the additional stiffness required in transportable units. There is still a problem of gaining building code acceptance for the single wall system in some areas as well as convincing builders that a separate sheathing material is not necessary. These attitudes should change as the public becomes more aware of the technical acceptability of this system.

The ability of ponderosa pine to penetrate this market depends largely on the ingenuity of producers in developing attractive siding products.

Some Industrial Applications

Van interiors.—Although there are no standard specifications for plywood used as the interior lining of truck vans, most of the grades used are A-D, B-C, and A-C. Each van manufacturer establishes its own standards. In some cases, plywood is also used as a floor covering in vans. Important physical characteristics for van interiors are fastener holding capability and surface hardness. All plywoods are rated in approximately the same range for these properties.

Plywood overlaid with fiberglass or metal is being used more often in this application. This material is also important in the construction of marine cargo containers. Ponderosa pine plywood would be an excellent substrate for these overlays.

Because of the high grade surface veneer required, it might be difficult to sell ponderosa pine plywood that is not overlaid for interior lining material. However, a potential may exist for van lining because of the lighter weight of pine plywood.

Boxes and crates.—Ponderosa pine plywood belongs to a group of species with the following properties: lightness in weight, freedom from splitting when nailed, moderate nail holding capacity, and fairly soft (Anderson and Heebink 1964). One of the main reasons for using such plywood for boxes and crates is that it is stronger and more durable than lumber, but this advantage may be offset in some cases by the lower cost of lumber. Although penetration of plywood into the container market has been slow, it is increasing, and pine plywood could be in a particularly good position to supply an increasing proportion of this market.

Pallets.—Softwood plywood is increasingly used in pallet production, but substantial price differential over alternative materials largely limits its use to bin pallets and other specialized types. For example, an oak lumber pallet costs about one-third as much as a plywood pallet of comparable size and strength. Pallets, therefore, do not appear to offer a particularly promising market for ponderosa pine plywood, but the large size of the pallet industry means that ponderosa pine plywood might have specialized uses.

Air cargo containers.—Because light weight is a critical factor for this use, ponderosa pine plywood might be rated as one of the most suitable species. However, the American Plywood Association, after studying this application, feels that plywood does not have a good opportunity in this use.[6]

APA 303 Siding Specifications

APA siding is produced in four classes, based on number of panel face patches permitted, as shown below (American Plywood Association 1978a):

Class		Face patches
303-0	(Special Series)	none
303-6		6 maximum
303-18		18 maximum
303-30		30 maximum

Within each class there are provisions for different grades.

The characteristics of the four grades for the Special Series 303-0 class, which differ from those for the other three classes, are shown below (American Plywood Association 1978b):

Class and grade	Description
303-OC	Clear
303-OL	Overlaid (e.g., medium density overlaid siding)
303-NR	Natural rustic (e.g., permits open knotholes)
303-SR	Synthetic rustic (e.g., permits natural-defect shaped synthetic repairs)

Within each of the other three classes, the following three grades may be designated:

-W	Wood repairs only
-S	Synthetic repairs only
-S/W	Both wood and synthetic repairs

[6]*Personal communication from Robert G. Anderson, Marketing Group, American Plywood Association, Tacoma, Wash.*

Specifications for the APA "303" series siding include, but are not limited to, permissible levels for knots, knotholes, patches, splits, shims, and voids (American Plywood Association 1977a). The size and number of knots in C-grade ponderosa pine veneer may limit the class and grade of siding panels that could be manufactured in the Black Hills. However, APA "303-NR and -SR (rustic)" panels are permitted to have tight or pin knots up to 1 1/2-inches in maximum size and no limit in number. Also, APA "303-30-S and S/W" grades permit tight knots of 1 1/2 inches maximum, and pin knots of 3/8 inch maximum. Patches are permitted in all grades except "Special Series 303."

TIMBER RESOURCE

Black Hills National Forest Timber Classes

Timber classes specified in the current 10-year Timber Management Plan of the Black Hills NF are described below, along with a concise statement of the probable silvicultural treatment for each timber class.[7]

P21 is an uneven-aged stand of ponderosa pine sawtimber in the standard component with an inadequately stocked pine understory. This stand has 60 to 120 square feet of growing stock basal area. Enter this stand with the first cut of the three-cut shelterwood system to establish regeneration.

PB1 is a two-storied ponderosa pine stand in the standard component. This stand has 60-120 square feet of growing stock basal area. It has an adequately stocked sawtimber overstory and a fully stocked pine understory. The overstory will be removed in two cuts to minimize damage to the established understory. Because of the size of the understory, it is assigned a managed age of 10. The second cut (seed cut) will be made in the overstory.

P31 is an overstocked, uneven-aged stand of ponderosa pine sawtimber in the Standard Component. This stand has more than 120 square feet of growing stock basal area, which requires immediate entry. This entry will be by a multiproduct cut to reduce density. Trees will be cut from all diameter classes to a growing stock level (GSL) of 80.

P61 is an overstocked ponderosa pine poletimber stand in the Standard Component. This stand has in excess of 120 square feet of growing stock basal area. Enter this stand with an intermediate cut to a GSL of 80.

PA1 is a two-storied ponderosa pine stand in the Standard Component. This stand has less than 60 square feet of growing stock (all live trees ⩾5inches d.b.h.) basal area. It has a sparse sawtimber overstory age 150 and a fully stocked pine understory. The overstory will be removed in two cuts to minimize damage to the established understory. Because of the size of the understory, it is assigned a managed age of 10.

[7]*Timber Management Plan, Black Hills National Forest. 1977. Unpublished document on file at Rocky Mountain Forest and Range Experiment Station or available from Supervisor's Office, Black Hills NF, Custer, S. Dak.*

SC1/SB1: SC1 is a spruce-pine mix sawtimber stand in the Standard Component, and SB1 is a pine-spruce sawtimber stand in the Standard Component. Enter these stands, cutting in all size classes to a GSL of 90 to retain the uneven-aged character of these stands. GSL's of 120+ are acceptable, because beetle populations are not a problem in these stands.

WZS is a spruce-pine sawtimber stand in the Special Component. Cut in all size classes to a GSL of 90 to retain the uneven-aged character of this stand. GSL's of 120+ are acceptable, because beetle populations are not a problem in these stands.

TZB/TZN: TZB is an uneven-aged ponderosa pine sawtimber stand outside the Norbeck Wildlife Preserve Special Component. TZN is an uneven-aged ponderosa pine sawtimber stand within the Norbeck Special Component. These stands have adequately stocked understories which vary from 60 to 120 square feet of growing stock basal area. Intermediate cut to a GSL of 80.

TZA is an uneven-aged ponderosa pine sawtimber stand with an adequately stocked understory in the special component. This stand varies from 60 to 120 square feet of growing stock basal area. Intermediate cut to a GSL of 80.

N60 is an uneven-aged ponderosa pine sawtimber stand to be managed for wildlife habitat within the Norbeck Wildlife Preserve in the Special Component. This stand has 60-120 square feet of growing stock basal area. Enter this stand with an intermediate cut to a GSL of 60.

NOR is a two-storied ponderosa pine stand in the Norbeck Wildlife Preserve Special Component. It has an adequately stocked overstory and understory. The overstory will be removed in two cuts to minimize damage to the understory. The second cut (seed cut) will be made in the overstory.

Computation of Log Size Distribution

As mentioned in the main text, timber class P31 is representative of the all-size group of timber classes, and timber class PB1 is representative of the sawtimber group of timber classes. Each of these timber classes is composed of trees with a distinctive distribution of diameters (figure 3). If a tree height distribution is available or can be reasonably estimated, then the diameters of logs cut from such trees may be estimated by means of taper tables. This was essentially the process used here to estimate one possible distribution of veneer block diameters.

To start, construct a probable estimated tree height distribution based on stand type and mean height for each tree diameter class. Table A-1 shows the results for timber class P31, and table A-2 shows the same information for timber class PB1.

Relative tree height within a diameter class in a timber stand depends largely on the age structure of the stand. In contrast, relative tree height for cut trees in a harvested timber stand depends on the silvicul-

Table A-1.—Average tree heights and one possible distribution of estimated tree heights for timber class P31

Tree d.b.h. classes (2-inch classes)	Average tree height		Trees per acre	Tree heights in distribution[1]				
	feet[2]	*logs*[3]						
6	43.9	0.5	40.0000		0 (0.25)	0.5 (0.5)	1.0 (0.25)	
8	51.9	1.0	33.0000		0.5 (0.25)	1.0 (0.5)	1.5 (0.25)	
10	55.4	1.5	28.6591	0.5 (0.1)	1.0 (0.2)	1.5 (0.4)	2.0 (0.3)	
12	62.3	2.0	17.6607	1.0 (0.1)	1.5 (0.2)	2.0 (0.4)	2.5 (0.2)	3.0 (0.1)
14	66.8	2.5	9.1672	1.5 (0.1)	2.0 (0.2)	2.5 (0.4)	3.0 (0.2)	3.5 (0.1)
16	70.0	3.0	4.3085	2.0 (0.1)	2.5 (0.2)	3.0 (0.4)	3.5 (0.2)	4.0 (0.1)
18	76.6	3.5	2.1053	2.5 (0.1)	3.0 (0.2)	3.5 (0.4)	4.0 (0.2)	4.5 (0.1)
20	78.1	3.5	0.7068	2.5 (0.1)	3.0 (0.2)	3.5 (0.4)	4.0 (0.2)	4.5 (0.1)
22	85.0	4.0	0.3304	3.0 (0.1)	3.5 (0.2)	4.0 (0.4)	4.5 (0.2)	5.0 (0.1)
24	88.1	4.5	0.1222	3.5 (0.1)	4.0 (0.2)	4.5 (0.4)	5.0 (0.3)	
[4]26	88.0	4.5	0.0769					

[1]*Two numbers appears in each column. The first number, without parentheses, tells the number of 16-foot logs found in that tree d.b.h. class. The second number, within parentheses, tells what proportion of trees in the given d.b.h. class are assumed to have that number of 16-foot logs. For example, trees in the 10-inch d.b.h. class are assumed to have 40% of their number with 1.5 16-foot logs.*

[2]*Source: Computer program GROW printout. Information used as input to Black Hills NF Timber Management Plan, 1977-1986. On file, Rocky Mountain Forest and Range Experiment Station.*

[3]*Conversion from tree height in feet to tree height in merchantable 16-foot logs based on information in Van Deusen (1967).*

[4]*Taper information was not available for this diameter class. Effects of dropping this class are negligible.*

Table A-2.—Average tree heights and one possible distribution of estimated tree height for timber class PB1

Tree d.b.h. classes (2-inch classes)	Average tree height		Trees per acre	Tree heights in distribution[1]				
	feet[2]	*logs*[3]						
12	56.3	1.5	13.9867	0.5 (0.05)	1.0 (0.20)	1.5 (0.50)	2.0 (0.20)	2.5 (0.05)
14	61.9	2.0	11.6958		1.5 (0.25)	2.0 (0.50)	2.5 (0.20)	3.0 (0.05)
16	68.1	2.5	6.4858	1.5 (0.05)	2.0 (0.20)	2.5 (0.50)	3.0 (0.20)	3.5 (0.05)
18	72.2	3.0	2.9654	2.0 (0.05)	2.5 (0.20)	3.0 (0.50)	3.5 (0.20)	4.0 (0.05)
20	79.1	3.5	1.6948	2.5 (0.05)	3.0 (0.20)	3.5 (0.50)	4.0 (0.20)	4.5 (0.05)
22	83.7	4.0	0.7296	3.0 (0.05)	3.5 (0.20)	4.0 (0.50)	4.5 (0.20)	5.0 (0.05)
24	88.3	4.5	0.3106	3.5 (0.05)	4.0 (0.20)	4.5 (0.50)	5.0 (0.25)	
[4]26	93.3	5.0	0.1725					

[1]*Two numbers appears in each column. The first number, without parentheses, tells the number of 16-foot logs found in that tree d.b.h. class. The second number, within parentheses, tells what proportion of trees in the given d.b.h. class are assumed to have that number of 16-foot logs. For example, trees in the 10-inch d.b.h. class are assumed to have 40% of their number with 1.5 16-foot logs.*

[2]*Source: Computer program GROW printout. Information used as input to Black Hills NF Timber Management Plan, 1977-1986. On file, Rocky Mountain Forest and Range Experiment Station.*

[3]*Conversion from tree height in feet to tree height in merchantable 16-foot logs based on information in Van Deusen (1967).*

[4]*Taper information was not available for this diameter class. Effects of dropping this class are negligible.*

tural prescription for the stand and on the judgment of the timber cruiser in selecting trees to match the prescription.

Height data from about 400 trees from timber sales in the Black Hills NF suggests that distributions of cut tree height on that National Forest are approximately symmetric about the mean height for a particular tree diameter class. In addition, while data are not available, it is assumed that the distribution of tree heights within a diameter class is wider for an uneven-aged stand than for an even-aged stand. Thus, timber class P31, an uneven-aged stand, is given a wider distribution than timber class PB1, a two-storied, even-aged stand.

Based on the information in tables A-1 and A-2, the next step is to consult a taper table for the sawtimber trees (Woodfin 1960) and for the poletimber trees (Myers 1963). For each tree diameter and height combination, the taper table will supply data on number and small end diameter, inside bark, of veneer blocks, each 8.5 feet long, that can be bucked from the tree.

A tree from a given height and diameter class would supply veneer blocks in several small end d.i.b. classes, based on the taper tables cited above. When these numbers of veneer blocks are multiplied by trees per acre in the height and diameter class, the result is number of logs per acre, by small end d.i.b. class, from trees within the given height and diameter class. Then logs per acre in each d.i.b. class are summed for all tree height and diameter classes. The result is an estimate of the distribution, by small end d.i.b. class, of the veneer blocks and other logs that can be obtained from the timber class.

The d.i.b. distribution of logs from each timber class is weighted by the acreage of each timber class to arrive at an overall d.i.b. distribution of available logs. In this case, as stated in the main text, the acreage of timber classes P31 and PB1 are about equal, so the distributions from each timber class were merged with equal weights. The net result is an estimate of a likely distribution of small end d.i.b.'s shown in figure 4 for 8.5-foot logs.

ECONOMICS

Computation of Veneer Recovery

To estimate veneer recovery volumes and associated residue volumes, a set of relationships was developed to relate total veneer block volumes to published veneer recovery studies. The basic relationship is that volumes for all losses, such as roundup and clipper losses, volumes for green veneer, and volumes for the block core must sum to the total block volume. In addition, estimates for each volume component of the block must conform reasonably well with volumes reported in published recovery studies (Yerkes and Woodfin 1972, Woodfin 1973).

Residue Volume

Green residue volume results mainly from block roundup and from losses at the clipper. Roundup loss is mainly a function of tree form, log diameter, and resultant taper. Clipper loss can result from a wide variety of physical and biological factors that degrade green veneer. This loss volume is also a function of block diameter to the degree that some veneer degrade factors are functions of block size, or position in the tree. In addition, some good veneer occasionally is lost by clipper malfunction. Published loss data (Yerkes and Woodfin 1972) shown in figure A-1 suggest that a quadratic equation might fit the data. A linear regression analysis resulted in the equation

$$V_{\text{loss}} = 0.0420d^2 - 0.5634d + 2.912$$

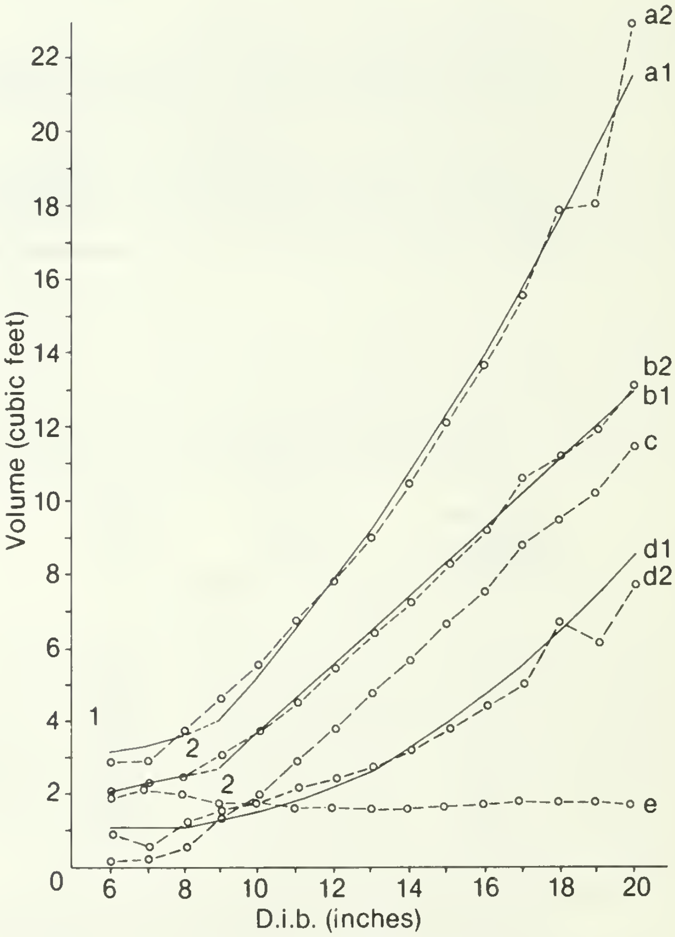

Figure A-1.—Veneer block component volumes by diameter class, Black Hills ponderosa pine (Yerkes and Woodfin 1972). Legend for the respective curves: a1 = sum of regressions for veneer, core, and loss volumes; a2 = data points for sum of veneer, core, and loss volumes; b1 = regression for veneer plus core volumes; b2 = data points for veneer plus core volumes; c = data points for veneer volume; d1 = regression for residue loss volume; d2 = data points for residue loss volume; e = data points for core volume. Dotted portion of lines a1 and b1 show break between two separate regressions.

where d is veneer block small end diameter inside bark[8] and V_{loss} is cubic foot volume lost.

Total of Veneer and Core Volume

This volume is the block volume net of all losses discussed above. Again, published recovery data were obtained from Yerkes and Woodfin (1972). The resulting regression equations are

$$V_{vc9+} = 0.9287d - 5.6184 \qquad d \geqslant 9 \text{ inches}$$

$$V_{vc6\text{-}8} = 0.2400d + 0.5900 \qquad d = 6,7,8 \text{ inches}$$

where V_{vc9+} is cubic foot volume in veneer (v) plus core (c) from blocks 9 inches and greater, and $V_{vc6\text{-}8}$ is cubic foot volume in veneer (v) plus core (c) from blocks 6 to 8 inches in diameter. The published data points for veneer and core (curve b2 in fig. A-1) show a distinct break between 8 and 9 inches. On each side of this break, the data points are almost linear. The simplest way to approximate these data points is by two linear equations for the block diameter ranges noted above.[9]

Total Volume

Total block volume is found by adding the respective volumes for losses and for veneer plus core, as computed by regression. Thus, total volume is completely accounted for and is expressed by the following equations:

$$V_{+9+} = 0.0420d^2 + 0.3653d - 2.6972 \qquad d \geqslant 9 \text{ inches}$$

$$V_{+6\text{-}8} = 0.0420d^2 - 0.3234d + 3.5112 \qquad d = 6,7,8 \text{ inches}$$

where d is veneer block small end diameter inside bark in inches and V_{+xx} is total veneer block cubic volume. An alternative method is to compute a regression equation for total veneer block volume as a function of block diameter. Data for this method would not be the sum of veneer, core, and residue; instead the data would be total block volume as reported by Yerkes and Woodfin (1972). This method, however, would lead to small discrepancies between total block volume computed by a regression formula and total block volume as the sum of the block component volumes. To be consistent total volume was computed on the basis of the sum of component volumes.

[8] *This regression and all following equations are based on published summaries of recovery data. The equations are used here as computational aids for analysis of the timber resource. As seen in figure A-1, the regressions generally fit the data points. The authors do not suggest that these equations are necessarily applicable beyond the analysis reported here.*

[9] *A single regression equation may fit these data points with a high coefficient of determination (r^2). However, such an equation would erroneously estimate volume for 8-inch veneer blocks. Because this size block is represented in the diameter distribution to a far greater extent than other diameters, this defect is serious. For this reason, two separate equations were used.*

Core Volume and Green Veneer Volume

Core volume is based on the formula for a cylinder. Length assumed is 8.5 feet for each veneer block. After allowing for the appropriate unit conversion factors the following equation results:

$$V_c = 0.046359d_c$$

where d_c is the target core diameter in inches, and V_c is cubic foot volume in the core. Target diameters used in this study and the corresponding volumes for veneer lathe cores are shown below.

Target core diameter	Core volume
inches	*cubic feet*
6	1.6689
5	1.1590
4	0.7417

Green veneer volume is computed by subtracting the respective core volume from the volume for green veneer and core.

Veneer Shrinkage and Dry Veneer Volume

Shrinkage volume is based on percent factors published by Woodfin (1973). The percent shrinkage of veneer by block diameter class is applied to the total block volume, computed as indicated above. The resultant cubic volume of shrinkage is then subtracted from each appropriate green veneer volume to arrive at the figure in table 13 for cubic volume of dry veneer.

Computation of Log Taper

Low-taper logs.—Work completed by Myers (1963) for ponderosa pine in the Southwest is the source of taper data for pole-sized trees that most closely resemble Black Hills ponderosa pine. Taper for 8-foot logs ranged from 0.4 to 1.9 inches, depending on diameter, tree height, and log position in the bole. Average taper for each 1-inch class of log diameter, inside bark, varies from 0.95 to 1.18 inches per 8-foot log. Average taper for all logs is 1.01 inch per 8-foot log. Based on the above information, it was assumed that taper in logs from poletimber trees averages 1 inch per 8.5-foot log.

High-taper logs.—As noted in the main text, these logs are bucked mostly from the top of the bole of sawtimber-sized trees. Taper data for ponderosa pine sawtimber trees in the Black Hills was compiled by Woodfin (1960). Analysis of these data reveal a wide variation in taper, as would be expected. When the data for 8.5-foot logs are aggregated by 1-inch small end d.i.b. classes, average taper is shown in the following tabulation:

Log small end diameter class	Taper per 8.5-foot log
inches	*inches*
6	3.4
7	2.6
8	2.0
9	1.8

These results are consistent with expectation. Six-inch logs are located in the rapidly tapering bole top. Logs of larger diameter would be located farther down the bole where taper is less than at the top.

Lumber and Residue Recovery

Smalian's formula, modified to reflect the assumed taper per 8.5-foot log, was used to compute total log volume. The resulting formula is:

$$V_L = 0.046359(d^2 + dt + 0.5t^2)$$

where V_L is log volume in cubic feet, d is log small end d.i.b. in inches, t is log taper in inches per 8.5 feet, and 0.046359 is the appropriate conversion factor for units computed as 0.005454 square feet per square inch × 8.5 feet. Six decimal places does not imply extreme accuracy, but rather, minimizes rounding error.

Dimension 2- by 4-inch lumber produced by the auxiliary sawmill with chipping headrig is assumed to have the following cross sectional dimensions, depending on its degree of manufacture:

Condition	Size
	inches
Rough, green	1.65×3.75
Rough, dry	1.59×3.63
Dressed, dry	1.50×3.50

Saw kerf, where it applies, is assumed to be 0.15 inch. Williston's (1976) recommended standard saw kerf of 0.125 inch was adjusted upward to assure a conservative estimate. Saw kerf sawdust volume is computed for the full log length of 8.5 feet because the 2- by 4-inch lumber is not yet trimmed to 8 feet.

Chip volume is the log volume net of rough green lumber and saw kerf volumes.

Trim volume is the 0.5 foot of ends trimmed to make an 8-foot long stud. Shrinkage is volume lost during the drying process. Planer shaving volume includes planer shavings plus sander dust. Both shrinkage and planer shaving volumes are based on changes in cross sectional dimension shown in the tabulation above.

Bark Volume

Bark volumes per cubic unit of roundwood volume were estimated using factors published by Krier and River (1968). These factors were given by 4-inch diameter classes for logs with diameters ranging from 7.6 to 35.5 inches. Because log diameter in the Black Hills is as small as 4 inches, the factor values were extrapolated to cover the entire range of Black Hills log sizes. Proportions of logs in each 4-inch diameter class were computed from data incorporated in figure 4. Assuming that log diameters are distributed as shown in the figure, the weighted average bark volume factor is computed as shown in table A-3.

The total volume of 100 index logs, defined in the main text, is 424.4980 cubic feet. Multiplying this volume by the weighted average bark factor (0.236724) results in a bark volume of 100.4889 cubic feet per 100 index logs.

Product Recovery for Index Log Volumes and Total Volume Required

Units of one hundred logs, each log 8.5 feet long, whose small end diameters are distributed as shown in figure 4, are estimated to provide the product volumes shown in tables A-4, A-5, and A-6.

Each table is organized to relate product recovery to three levels of target core diameter and to three levels of veneer block lower size limit. For example, the relationships illustrated in figure 6 are amplified in these tables. Lumber recovery from small logs shown in table A-5 depends only on choice of a lower diameter limit for veneer blocks, but lumber recovery from veneer block cores depends on both the lower veneer block diameter limit and on the target core size.

A most important question for the analysis of material flow is how many units of 100 index logs are required to support the plywood plant at the assumed capacity.

Dry veneer is used as the base product for computing volumes. The annual dry veneer requirement is 2,325,149 cubic feet. The column in table A-4 for dry veneer lists cubic volume per 100 index logs. For example, when peeling 8-inch and larger logs to a 4-inch core, the number of units of 100 index logs required is computed by dividing 2,325,149 cubic feet required per year by 191.03 cubic feet per 100 index logs. The result is that 12,172 units of 100 index logs are required annually. Similar results are shown in table A-7 for each of the nine combinations of veneer block lower diameter limit and target core size.

The numbers of index units in table A-7 are termed blow-up factors. When the appropriate blow-up factor is multiplied by index volumes from tables A-4, A-5, and A-6, the annual requirements for raw material can be determined, as well as the annual production volumes of the various products and residues. The annual material volume flow is shown in table 15 for the analysis presented in this report, assuming a target core size of 4 inches and veneer block lower limit of 8 inches.

Table A-3.—Computation of average bark volume factor weighted by proportions of log diameters

Midpoint, d.i.b. class	D.i.b. class range	Bark factor[1]	(×)	Percent of logs in d.i.b. class	(=)	Weighted bark factor
---- inches ----						
5	3.6-7.5	[2]0.260		36.0989		0.093857
9	7.6-11.5	.234		47.7529		.111742
13	11.6-15.5	.192		13.3195		.025573
17	15.6-19.5	.201		2.4870		.004999
21	19.6-23.5	.162		0.3250		.000526
25	23.6-27.5	.158		0.0168		.000026
Total weighted average bark factor						0.236724

[1]*Cubic feet of bark per cubic foot of wood in log volume. Source: Krier and River (1968).*
[2]*Estimated by extrapolation of tabulated values for the 9- to 25-inch d.i.b. classes.*

Table A-4.—Veneer and plywood recovery and losses per 100 index logs[1]

Target core diameter	Veneer block lower diameter limit	Total veneer log volume	Core volume	Tangible losses	Green veneer	Shrink	Dry veneer	Dry losses and panel trim	Cubic volume	Area volume (3/8-inch basis)
---- *inches* ----		---- *cubic feet* ----								*square feet*
4	9	291.4266	29.9157	88.9845	172.5264	7.8613	164.6648	26.3464	138.3184	4,426.1894
	8	346.3586	41.1956	105.7439	199.4191	8.3890	191.0297	30.5648	160.4649	5,134.8779
	7	373.9881	47.3954	114.3987	212.1940	8.4993	203.6943	32.5911	171.1032	5,475.3023
5	9	291.4266	46.7471	88.9845	155.6948	7.8613	147.8334	23.6532	124.1802	3,973.7620
	8	346.3586	64.3734	105.7439	176.2411	8.3890	167.8517	26.8562	140.9958	4,511.8620
	7	373.9881	74.0614	114.3987	185.5278	8.4992	177.0281	28.3244	148.7040	4,758.5236
6	9	291.4266	67.3134	88.9845	135.1285	7.8613	127.2672	20.3629	106.9043	3,420.9424
	8	346.3586	92.6944	105.7439	147.9201	8.3890	139.5311	22.3251	117.2060	3,750.5960
	7	373.9881	106.6446	114.3987	152.9446	8.4993	144.4453	23.1114	121.3339	3,882.6897

[1]*Four decimal places are carried here to insure that subsequent use of these figures will not introduce significant error caused by rounding.*

Table A-5.—Lumber and residue recovery and losses per 100 index logs for veneer block cores and for small logs sent directly to the lumber mill[1]

Target core diameter	Veneer block lower limit	Total core and log volume	Chips	Saw kerf	Lumber rough, green untrimmed	Trim	Lumber rough, green trimmed	Shrink	Planer, sander volume	Lumber dry, dressed	Nominal lumber tally	Number of pieces recovered
inches	inches	cubic feet									fbm	
4	9	29.9278	15.2059	--	14.7219	0.8470	13.8749	0.9680	1.1294	11.7775	215.1012	40.3340
	8	41.2123	20.9394	--	20.2729	1.1664	19.1065	1.3330	1.5552	16.2183	296.2066	55.5422
	7	47.4146	24.0907	--	23.3239	1.3419	21.9820	1.5336	1.7892	18.6591	340.7846	63.9011
5	9	46.7471	15.9723	1.3310	29.4438	1.7344	27.7095	1.9360	2.2587	23.5147	430.2428	80.6680
	8	64.3734	21.9947	1.8329	40.5458	2.3883	38.1575	2.6660	3.1104	32.3811	592.4686	111.0844
	7	74.0614	25.3048	2.1087	46.6478	2.7477	43.9001	3.0673	3.5785	37.2543	681.6330	127.8022
6	9	67.3174	20.8527	2.6620	43.8027	2.5814	41.2213	2.9040	3.3881	34.9262	645.3440	121.0020
	8	92.6999	28.7153	3.6658	60.3188	3.5547	56.7641	3.9990	4.6655	48.0995	888.6752	166.6266
	7	106.6509	33.0369	4.2175	69.3966	4.0897	65.3069	4.6009	5.3677	55.3384	1,022.4176	191.7033
Small logs[2]	9	132.5256	57.3990	4.4422	70.6843	4.1497	66.5346	4.6692	5.4198	56.4459	1,032.3321	193.5629
	8	77.8606	38.5797	1.9177	37.3632	2.1878	35.1753	2.4640	2.8648	29.8468	545.6697	102.3137
	7	50.5099	24.2775	1.0817	25.1507	1.4689	23.6817	1.6531	1.9286	20.1002	367.3472	68.8777

[1]*Four decimal places are carried here to insure that subsequent use of these figures will not introduce significant error caused by rounding.*
[2]*Recoveries from small logs do not depend on target core diameter, but do depend on the choice of a lower diameter limit for veneer blocks.*

Table A-6.—Lumber and residue recovery and losses per 100 index logs for veneer block cores and small logs combined[1]

Target core diameter	Veneer block lower limit	Total core or log	Chips	Saw kerf	Lumber rough, green untrimmed	Trim	Lumber rough, green trimmed	Shrink	Planer sander volume	Lumber dry, dressed	Nominal lumber tally	Number of pieces recovered
inches	inches	cubic feet									fbm	
4	9	162.4534	72.6049	4.4422	85.4062	4.9967	80.4095	5.6372	6.5492	68.2234	1,247.4333	233.8969
	8	119.0729	59.5191	1.9177	57.6361	3.3542	54.2818	3.7970	4.4200	46.0651	841.8763	157.8559
	7	97.9245	48.3682	1.0817	48.4746	2.8108	45.6637	3.1867	3.7178	38.7593	708.1321	132.7788
5	9	179.2727	73.3713	5.7732	100.1281	5.8841	94.2441	6.6052	7.6785	79.9606	1,462.5749	274.2309
	8	142.2340	60.5744	3.7506	77.9090	4.5761	73.3328	5.1300	5.9752	62.2279	1,138.1383	213.3975
	7	124.5713	49.5823	3.1904	71.7985	4.2166	67.5818	4.7204	5.5071	57.3545	1,048.9802	196.6799
6	9	199.8430	78.2517	7.1042	114.4870	6.7311	107.7559	7.5732	8.8079	91.3751	1,677.6761	314.5649
	8	170.5605	67.2950	5.5835	97.6820	5.7425	91.9394	6.4630	7.5303	77.9463	1,434.3449	268.9403
	7	157.1608	57.3144	5.2992	94.5473	5.5586	88.9886	6.2540	7.2963	75.4386	1,389.7648	260.5810

[1]*Four decimal places are carried here to insure that subsequent use of these figures will not introduce significant error caused by rounding.*

Table A-7.—Number of units of 100 index logs required to supply dry veneer required for capacity plywood plant operation

Veneer block lower limit (inches)	Target core size (inches)		
	6	5	4
9	18,269.8198	15,728.1698	14,120.4970
8	16,664.0183	13,852.3748	12,171.6613
7	16,097.0887	13,134.3265	11,414.8938

Donnelly, Dennis M., and Harold E. Worth. 1981. Potential for producing ponderosa pine plywood in the Black Hills. USDA Forest Service Resource Bulletin RM-4, 43p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

This study describes possible plywood production opportunities for Black Hills ponderosa pine in terms of kinds of plywood and advantageous market areas. The resource analysis examines current and future uses of the area's timber. Economic evaluation includes analyses of discounted cash flow and operating costs and revenues.

Keywords: *Pinus ponderosa*, plywood, forest products, Black Hills, ponderosa pine, markets, economics

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

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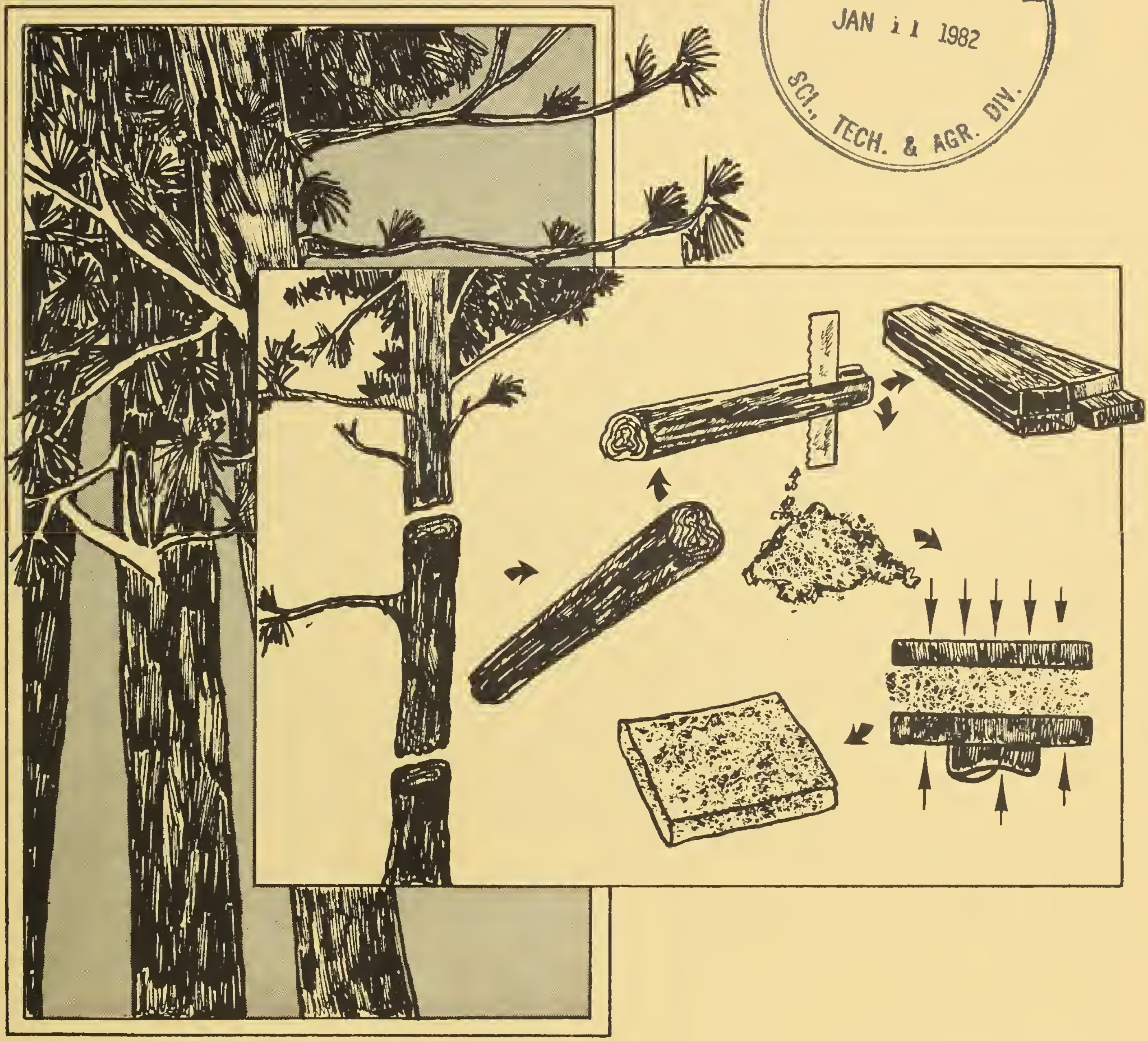
Economic Potentials for Particleboard Production in the Black Hills

Donald C. Markstrom and Harold E. Worth



Resource Bulletin RM-5
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Abstract

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard per year (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The plant would be capable of producing underlayment, mobile home decking, and industrial board, using mill residues as the main wood raw material, with the possibilities for supplementing these with a smaller fraction of forest residues. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area, because of the substantial freight cost advantage.

USDA Forest Service
Resource Bulletin RM-5

May 1981

Economic Potentials for Particleboard Production in the Black Hills

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CONTENTS

	Page
Management Implications	1
Introduction	1
Marketing Black Hills Particleboard	2
Competitive Factors	2
Distribution Channels	3
Current Consumption and Production Within Marketing Area	4
Projected Consumption	4
Availability and Cost of Wood Raw Materials	5
Plant Location	7
Manufacturing Process	8
Manufacturing Requirements and Costs	8
Capital Requirements and Costs	9
Operating Requirements and Costs	9
Feasibility Assessment	10
Literature Cited	14
Appendix A: Tables and Figures on Marketing of Particleboard	15
Appendix B: Tables and Figures on Manufacturing of Particleboard	20

Economic Potentials for Particleboard Production in the Black Hills

Donald C. Markstrom and Harold E. Worth

Management Implications

This paper is a discussion of the second of two studies of the potential for producing particleboard from ponderosa pine. This research is needed by prospective investors, wood plant managers with surpluses of raw material (residues), and land managers with an excess of small roundwood to help them assess the potential of producing particleboard from these materials. The conclusion of the first study (Markstrom et al. 1976) was that particleboard could be manufactured from ponderosa pine mill and logging residues to meet standard requirements for interior and exterior uses. This second study is an evaluation of marketing and manufacturing particleboard and produced the following conclusions:

Ponderosa pine is a preferred species for the manufacture of all types of particleboard, including industrial board, where surface characteristics are important for printing or overlaying.

Marketing factors and the wood raw material supply indicate that the manufacturing process should be designed to produce Type 1 particleboard for underlayment; mobile home decking; and industrial uses, such as furniture core, cabinets, door core, and general purpose stock. Type 1 particleboards are those made with urea-formaldehyde or equivalent bonding systems; Type 2 particleboards are those made with phenol-formaldehyde or equivalent bonding systems as defined in ANSI standard A208.1 for particleboard. Type 1 particleboard would be made from sawdust, planer shavings, coarse mill residues, and logging residues. Type 2 board may be produced if the process is modified. Bark would be used for fuel but not for particleboard furnish.

The north central United States appears to be a prime market area for Black Hills particleboard. Projected demand for the region is 993 million square feet (MM ft^2), 3/4-inch basis, by 1980 and 1.8 MMM ft^2 by 1990. Production within the region is projected to be 320 MM ft^2 by 1980—at least 673 MM ft^2 less than needed.

The Black Hills would have both lower rail and truck freight rates than the western and southern producing regions for shipments to Denver, Colo.; Des Moines, Iowa; Minneapolis, Minn.; and Omaha, Nebr., and lower truck freight rates to Chicago, Ill. Shipments destined for Chicago; Des Moines; Kansas City, Mo.; Milwaukee, Wisc.; Minneapolis; and Omaha could be shipped from the Black Hills at a freight advantage averaging $30 per M ft^2 over shipments from other western plants.

Analysis of three different sized plants for the Black Hills indicated that large economies of scale would result primarily from more efficient use of labor, overhead, and capital investment. The smallest plant projected—33 MM ft^2 per year—could not be expected to generate adequate earnings and would likely run into severe financial difficulties during weak market periods. The largest plant—100 MM ft^2 per year—could be expected to produce attractive financial returns, at typical levels of market price, and should have strong survival capacity in the soft markets that are to be expected based on past cyclical record of demand for particleboard.

This study was performed concurrently with a study on the economic potential of producing plywood in the Black Hills.

Introduction

The idea of producing particleboard in the Black Hills area of South Dakota and Wyoming is not new with potential plant investors, present wood plant managers, and land managers. Several factors have stimulated interest in particleboard manufacture. One factor stimulating this interest is the existence of a large surplus of raw materials (residues) from primary and secondary wood processing operations. Approximately 35% of the mill residue was utilized during 1971 with more than 60,000 tons of pulp chips shipped to Lake State pulpmills (South Dakota Department of Game, Fish and Parks 1974). Tightened burning restrictions make disposal of the excess residues a serious problem. Further, the cost of shipping pulp chips to the Lake States is rising rapidly and may threaten that market. A second factor stimulating interest in particleboard production is that this industry is more compatible with existing Black Hills industries than any other new forest-based industry. The particleboard industry would not compete with the sawmills for the sawtimber stumpage but would aid the sawmills in using their residues. A third factor is that particleboard could provide outlets for some of the small roundwood excess that needs to be harvested to improve management of the area's forests. The fourth factor is that use of these presently unutilized resources would enhance general economic conditions in the area.

The overall question is whether a Black Hills particleboard producer could derive sufficient advantage from his geographic location, available raw material, existing and/or foreseeable production techniques, production costs, or uniqueness of his products to compete under present or prospective industry conditions.

In a previous technical evaluation conducted in a laboratory, Markstrom et al. (1976) manufactured and tested different types of particleboard using Black Hills ponderosa pine sawmill and logging residues. Results indicated that Type 1 boards produced from Black Hills ponderosa pine would meet standard requirements for floor underlayment, D-2 mobile home decking, and coreboard and Type 2 boards for bracing, siding, combination siding-sheathing, and combination subfloor underlayment. Six different types of board with varying particle geometry and distribution and with different resin contents and board densities were tested.

The Uniform, Basic, and National Building Codes are the model building codes used in marketing particleboard in the area. Products other than those specifically mentioned in these codes can be used by petitioning and obtaining approval from the organization governing the particular model code. The requestor must show suitability of the product by providing data and results from an independent testing agency (Applefield 1972). In addition to the building codes, which generally refer to the National Particleboard Association standards, the Federal Housing Authority, the General Services Administration, and the Department of Defense have specifications for particleboard use.

The objective of this study was to evaluate marketability of the particleboard, plant location within the Black Hills, type of plant and process characteristics, and plant investment and operating requirements and costs, including energy.

Marketing Black Hills Particleboard[2]

Competitive Factors

The chief product in competition with particleboard in most applications is plywood. Therefore, a careful analysis of the competitive relationship between the two is important. However, such an analysis is quite difficult because in many cases particleboard is not a direct substitute for plywood. Even when it is a substitute, the wide variety of thicknesses and types of both makes a comparison difficult. A comparison of wholesale price indices during the past 10-year period indicates that wholesale prices for all softwood plywood and plywood sheathing have risen, while prices for particleboard have been relatively stable (fig. 1). In contrast to wholesale prices, particleboard consumption has risen much faster than plywood consumption (fig. 2). A major factor in the rapid growth of particleboard consumption appears to be the lower price of particleboard relative to plywood. Growth in

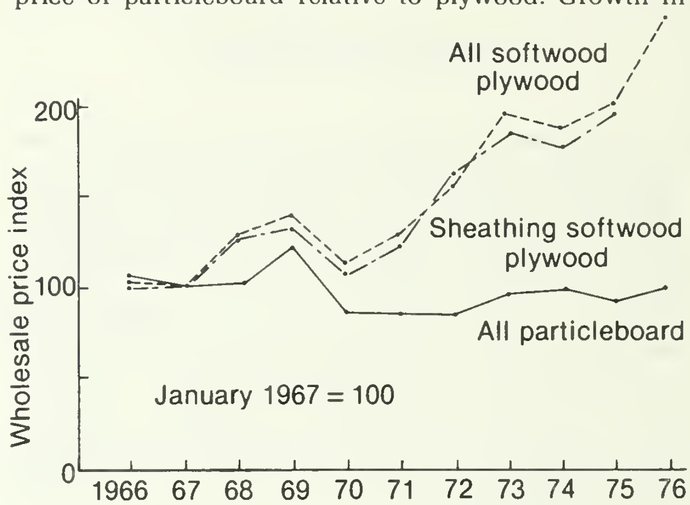

Figure 1.—Wholesale price index for particleboard and softwood plywood 1966-1976. (After U.S. Department of Agriculture Forest Service (1977)).

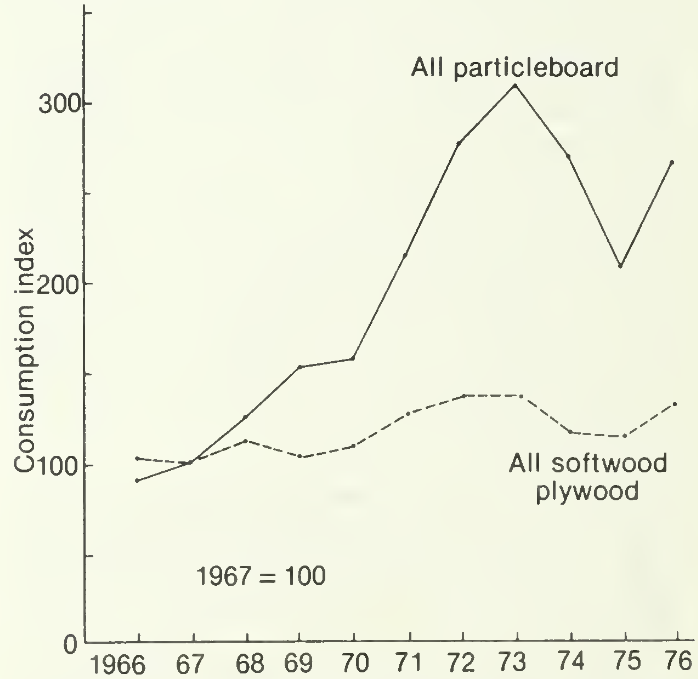

Figure 2.—Consumption index for particleboard and softwood plywood 1966-1976. (After U.S. Department of Agriculture, Forest Service (1977)).

[2]*The marketing portion of this paper is partially based on information from the following report: Wangaard, F. F., F. C. Shirley, R. S. Whaley, H. E. Troxell, and D. E. Eagan. 1972. Potential markets for particleboard produced in the Rocky Mountains—Phase II. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Technical Report Phase II. Rocky Mountain Forest and Range Experiment Station Research Agreement 16-229-CT, CSU Project 1473, 24 p.*

production capacity has continued to outrun demand even when demand has risen rapidly. New sources of raw material have been plentiful. It seems likely that the plywood industry, which depends on a more limited and fixed wood raw material base, will become less able to meet increasing levels of demand without consequent upheavals in price.

Unlike plywood, particleboard is available in sizes larger than 4- × 8-foot sheets and has uniformly smooth surface characteristics, especially important for floor underlayment, mobile home decking, shelving, unfinished furniture parts, and for material to be overlaid with wood veneers, vinyls, or printed for finished furniture or decorative wall paneling. However, particleboard has lower strength, higher weight, and greater vulnerability to breakage of corners and edges during rough handling.

Particleboard from some western species is generally more suitable for the manufacture of industrial particleboard products than particleboard from southern pine and most eastern hardwoods, which are consumed mainly by the underlayment and mobile home decking markets. Particleboard made from ponderosa pine generally represents the highest quality industrial and underlayment board on the market. Much of it can be used for sensitive industrial applications where surface characteristics are especially important.

Probably the most important single economic factor for a particleboard plant in the Black Hills is lower freight rates to major market areas compared to other producing areas. Delivered price often determines where a customer buys particleboard, especially commodity type boards. The delivered market price tends to be established by producers from the dominant producing region, this being the West Coast at present. The West Coast delivered price consists of the cost of manufacture, including an acceptable profit, plus the cost of transporation to the market area. The profitability for a plant in the Black Hills thus will be greatly affected by freight differentials between the Black Hills and the West Coast locations.

Railroad and common carrier truck freight rates from the Black Hills and other production locations to selected market locations are shown in tables A-1 and A-2. The production locations were selected on the basis of having production facilities that would be potentially competitive with a Black Hills plant in supplying the selected market locations. The market locations were selected because they use large volumes of particleboard but do not have nearby production facilities. Railroad rates were analyzed for shipments from nine production locations to fifteen market locations. Production locations were Whitewood, S. Dak.; Newcastle, Wyo.; Portland, Oreg.; Missoula, Mont.; Gaylord, Mich.; Crossett, Ark.; Birmingham, Ala.; Charlotte, N. C.; and Diboll, Tex.. Market locations were Boston, Mass.; Chicago; Denver; Des Moines; Detroit, Mich.; Kansas City; Milwaukee; Minneapolis; New York, N. Y.; Omaha; Philadelphia, Pa.; St. Louis, Mo.; Washington, D. C.; and Wichita, Kans. The two Black Hills locations have a rail freight advantage over the other producing locations to Denver, Des Moines, Minneapolis, and Omaha. Rail rates, although not as low as for products from the South or Midwest, are favorable to Chicago, Kansas City, and Milwaukee when compared to products from Portland and Missoula. The rail freight differential between the Black Hills and the West Coast to market areas are as follows:

Market location	Freight differential (West Coast rate minus Black Hills rate)
	dollars per M ft², 3/4-in basis
Chicago	33.07
Denver	17.25
Des Moines	38.52
Kansas City	32.77
Milwaukee	33.64
Minneapolis	33.06
Omaha	41.40

Even at market locations where South and Midwest producers have a freight advantage, an unfulfilled demand for particleboard in the market area should provide a potential outlet for Black Hills particleboard.

Particleboard producers often utilize truck transportation where no rail lines exist, where rail is inconvenient for the customer, where loads are small, or where truck rates are cheaper than rail rates. Truck rates were analyzed by us for shipments from six production locations to eight locations in the western portion of the market area. The production locations were Whitewood, S. Dak.; Newcastle, Wyo.; Portland; Missoula; Crossett, Ark.; and Diboll, Tex. The market locations were Chicago; Denver; Des Moines; Kansas City; Minneapolis; Omaha; St. Louis; and Witchita. The two Black Hills locations have truck freight rate advantage to Chicago, Denver, Des Moines, Minneapolis, and Omaha. These truck rates from the Black Hills are potentially competitive with the rail rates, especially if the receiving firm is not on a rail siding. The truck rates given in table A-2 are commodity rates as quoted by Motor Common Carrier, and may be higher than either proprietary carriers or negotiated contract arrangements.

Distribution Channels

Basically, markets for particleboard may be divided into two groups: construction and industrial. The structure of the construction market is essentially that of producer-wholesaler-retailer-end user, the latter being mostly building contractors. Smaller amounts are retailed to industrial firms and do-it-yourselfers.

Most of the particleboard for the industrial market, including mobile home decking, specialized furniture, partitions, and fixture stock, passes directly from the particleboard plant to the end user through an integrated distribution system of the manufacturer. Some particleboard plants cater exclusively to certain segments of the furniture industry. Figure 3 illustrates the major distribution channels for particleboard.

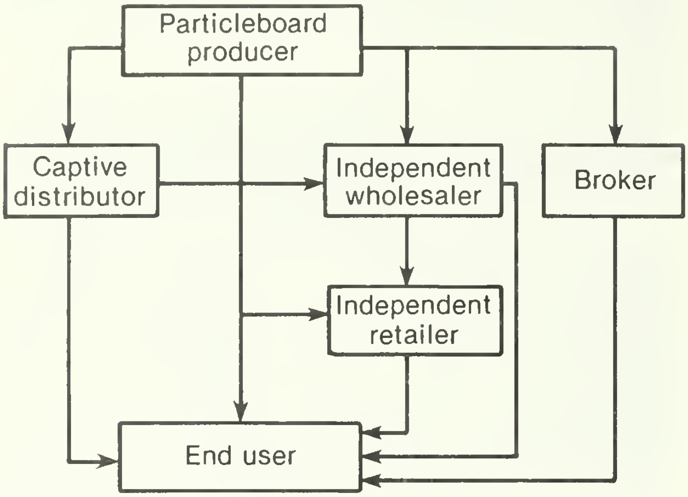

Figure 3.—Main distribution channels for particleboard.

Current Consumption and Production Within Market Area

The North Central Region of Indiana, Ohio, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North and South Dakota, Nebraska, and Kansas, as used by the Bureau of the Census, plus Colorado and Wyoming, is the prime market area for Black Hills particleboard, based on differences between volumes of production and consumption and the transportation advantage that Black Hills producers have in this area. The existing particleboard production capacity by state for 1980 within the market area is estimated to be (Dickerhoof and McKeever 1979):

State	Production capacity
	MM ft², 3/4-in basis
Colorado	0
Illinois	0
Indiana	24
Iowa	0
Kansas	0
Michigan	165
Minnesota	45
Missouri	0
Nebraska	0
North Dakota	0
Ohio	0
South Dakota	0
Wisconsin	86
Wyoming	0
Total	320

Projections made for this study indicate that demand will increase in the north central region from 993 MM ft^2 in 1980 to 1800 MM ft^2 in 1990 (table A-3). A 1980 deficit (consumption less production capacity) for the north central region of 673 MM ft^2 is probably a conservative estimate of the market potential for that area, since actual production seldom reaches the rated capacity of all the plants in the area.

Projected Consumption

Future consumption of particleboard was projected for end-use categories to determine the type of particleboard product that would find markets. Review of the literature indicated projections of consumption were available on a national basis but were not separated into different end-use categories and smaller market areas needed for this study (United States Department of Agriculture, Forest Service 1979). Consumption figures for different end-uses in the north central region were therefore projected for this study (table A-3).

Particleboard use figures for the north central region through 1990 were determined from national projections by us after making the following two assumptions: (1) There are no regional differences in the consumption and (2) the particleboard consumed in a region for a particular industry is proportional to the value of shipments of the finished products originating from that region. For example, if 20% of wood household furniture shipments originated in the north central region; it was assumed that 20% of the particleboard was consumed by the wood household furniture industry in the north central region.

National use projections in table A-4 were based by us on two growth factors: the projected growth of the particular industry using the particleboard, and the projected use of particleboard for each industry, measured in square feet per unit produced or in square feet per dollar value of shipments. Available growth and particleboard usage data for one- and two-family, multi-family, and mobile homes were used to project consumption of particleboard for these industries (table A-5). No reliable growth data could be found for the uses of nonresidential construction, repairs and remodeling, wood household furniture, wood office furniture, partitions and fixtures, recreational vehicles, modular homes, and general manufacturing. Consequently, the value of shipments for these industries was projected through 1990, assuming the value of shipments to be correlated with gross national product (fig. A-1, table A-6). Linear least square regression lines were fitted to the value of shipments and gross national data from 1958 to 1975. All gross national product and shipment values were deflated to 1958 prices in an effort to negate the effects of inflation. The pattern of the plotted data points indicated that straight lines fitted the data generally as well as curvilinear lines and would be useful to project the overall trend of shipment values.

The increased usage of particleboard by a particular industry was projected on the basis of published data or the authors' assumptions. The projected consumption in the north central region for the different end-uses is summarized below:

Residential Construction.—Particleboard use in the residential construction category, including single-family and multi-family in both the private and public sectors, will rise from 152 MM ft² during 1980 to 242 MM ft² during 1990. Particleboard in residential construction is used for underlayment, millwork, trim, shelving, and a limited amount of paneling. Further development of structural particleboard could increase the usage of particleboard significantly for roof sheathing or structural flooring.

Repairs and Remodeling.—The annual consumption of particleboard for repairs and remodeling is projected to increase from 81 MM ft² during 1980 to 142 MM ft² during 1990. The increase reflects large amounts of particleboard going into urban renewal projects. Also reflected is increased use of particleboard by homeowners for remodeling.

Nonresidential Construction.—This category represents all construction activity minus residential construction and repairs and remodeling. Increased use of particleboard per dollar of nonresidential construction activity is not expected to rise rapidly. The amount of particleboard consumed is expected to rise from 21 MM ft² to 33 MM ft² between 1980 and 1990.

Opportunities to use particleboard in nonresidential construction are few. Most floors in nonresidential buildings are concrete; thus, underlayment is unnecessary. Development of a reusable moisture resistant structural particleboard that could compete with plywood in concrete forms could cause substantial gains for particleboard.

Furniture and Fixtures.—This category includes wood household furniture, wood kitchen cabinets, metal household furniture, public building furniture, partitions, and fixtures (display cases, office partitions, etc.), and miscellaneous furniture and fixtures. The annual consumption of particleboard for furniture and fixtures is expected to increase from 451 MM ft² during 1980 to 909 MM ft² during 1990. This industry shows the greatest increase in particleboard consumption of all the industries. Growth of the industry is expected to remain vigorous.

General Manufacturing.—This category includes particleboard used in paper mill, foundries, luggage, prefabricated metal products, sporting goods, bird feeders, morticians' goods, musical instruments, games, and toys. The growth of particleboard in categories is expected to remain relatively high as new uses are found. The consumption is expected to rise from 74 MM ft² during 1980 to 157 MM ft² during 1990.

Mobile Homes.—A mobile home is defined as a housing unit for year-around living designed to be towed on its own chassis and to be connected to utilities, but lacking permanent foundation. Mobile homes in this study are defined as trailer coaches over 32 feet long and wider than 8 feet. The volume of particleboard used for mobile homes will remain at approximately 104 MM ft² from 1980 to 1990. This consumption represents a low increase in unit usage and a slight decrease in the number of new units during the period. The increase will be a result of increased mobile home size and the increasing use of particleboard in counter tops and cabinets.

Recreational Vehicles.—Recreational vehicles include trailer coaches less than 32 feet in length, campers for mounting on pick-up trucks, and self-contained motor homes. The growth of this industry is uncertain because of future motor fuel shortages. However, use of particleboard in these vehicles is projected to increase from approximately 9 MM ft² in 1980 to 20 MM ft² in 1990.

Modular Homes.—Modular homes are self-contained housing units built to meet existing code and standards for site-built homes. This definition eliminates mobile homes which do not normally meet codes and standards for permanent structures.

Particleboard is used mainly for combination subfloor-underlayment. Other uses include cabinets, doors, shelving, and counter tops. These uses of particleboard are expected to climb from 45 MM ft² in 1980 to about 92 MM ft² in 1990.

Availability and Cost of Wood Raw Materials

The availability and cost of wood raw materials for particleboard manufacture are important to the success of any particleboard manufacturing plant. Most particleboard on the market is manufactured from mill residues, largely in lumber and plywood manufacturing areas.

For the period 1977 to 1986, the estimated average annual volume of sawmill and logging residue potentially available at Black Hills production locations is 354.3 M ovendry (o.d.) tons (table 1), based on the potential yield of sawtimber from the Black Hills National Forest and an estimated allowable harvest of sawtimber from the area's state and private lands. The residues will drop to 243.5 M o.d. tons during the period 1987 to 1996, resulting from a decrease in projected sawtimber harvest on the Black Hills NF. The potential yield includes timber removed in silvicultural treatments in the Standard and Special components of the Black Hills National Forest. Logging residues include the upper stem portion beyond the minimum diameter for board foot measure, growing stock trees of less than sawtimber size destroyed during harvest, and portions of trees suitable for chips but culled as sawlogs because of crook.

About 225.1 M o.d. tons is potentially available annually at the eight sawmill centers in the area identified in table 2. This volume, a proportion of that shown in table 1, is based upon 13 mills operating at 80% of annual capacity—approximately 190 MM bf, lumber tally as during 1977. In the past, lumber production has not approached full mill capacity because of poor markets, inadequate returns, or other lack of

Table 1.—Annual volumes (M o.d. tons) of sawmill and logging residues potentially available during the time periods 1977-1986 and 1987-1996, based on the forest harvest estimates for the Black Hills NF and the allowable cut on the state, private, and other federal lands in the area

Time period Source	Sawmill residues[1] Sawdust	Shavings	Chippables	Logging residues chippable[2]	Total
1977-1986					
Black Hills NF	98.0	59.5	100.0	16.3	273.8
State, private, and other federal	28.8	17.5	29.4	4.8	80.5
Total	126.8	77.0	129.4	21.1	354.3
1987-1996					
Black Hills NF	58.3	35.5	59.5	9.7	163.0
State, private, and other federal	28.8	17.5	29.4	4.8	80.5
Total	87.1	53.0	88.9	14.5	243.5

[1]*The volume of sawmill residues was calculated from forest harvest estimates of the Black Hills NF and the allowable cut on state and private lands using residue factors by Landt and Woodfin (1964). The factors were .5663 tons per M fbm rough lumber tally for sawdust, .3442 for shavings, and .5782 for chippables. Rough lumber tally was assumed to equal net Scribner log scale times 1.25 for all trees with d.b.h. ≥9.0 inches. A conversion of 6.0 fbm, rough lumber tally, per net cubic foot was assumed for trees with d.b.h. 7.0-8.9 inches.*

[2]*The net cubic foot volume of logging residues was assumed to equal 4.72% of net cubic foot volume of sawlogs harvested (Setzer 1973). The o.d. weight per cubic foot for ponderosa pine wood residue was assumed to be 24 pounds (Markstrom and Yerkes 1972).*

Table 2.—Volume of sawmill and logging residues (M o.d. tons) potentially available at eight sawmill centers in the Black Hills[1]

Sawmill center	Estimated sawmill capacity	Sawmill residues[2] Sawdust	Shavings	Chippable	Logging residues chippable[3]	Total residues
	MM fbm (LT)[4]					
Spearfish, S. Dak.	35	[5]7.9	9.6	16.2	2.4	36.1
Hulett, Wyo.	20	9.0	5.5	9.3	1.4	25.2
Sturgis, S. Dak.	12	5.4	3.3	5.5	.8	15.0
Piedmont, S. Dak.	30	13.6	8.3	13.8	2.1	37.8
Hill City, S. Dak.	28	[5]6.4	7.7	13.0	1.9	29.0
Custer, S. Dak.	20	9.0	5.5	9.3	1.4	25.2
Newcastle, Wyo.	20	9.0	5.5	9.3	1.4	25.2
Whitewood, S. Dak.	25	11.4	6.9	11.6	1.7	31.6
Total	190	71.7	52.3	88.0	13.1	225.1

[1]*Sawmill production was assumed to be 80% of estimated capacity.*

[2]*The volume of sawmill residues was calculated using residue factors by Landt and Woodfin (1964). The factors were .5663 tons per M fbm rough lumber tally for sawdust, .3442 for shavings, and .5782 for chippables.*

[3]*The net cubic feet of logging residues was assumed to equal 4.72% of net cubic foot volume of sawlogs harvested (Setzer 1973). The o.d. weight per cubic foot for ponderosa pine wood residue was assumed to be 24 pounds (Markstrom and Yerkes 1972).*

[4]*LT = lumber tally*

[5]*Fifty percent of sawdust produced is used to generate steam at these plants.*

economic motivation. Ten of the above mills presently have chipping facilities for coarse sawmill residues and/or logging residues and have been marketing chips. The other three mills are also of a size and location that should give them potential for chipping.

The sources of residues in descending order are chippable sawmill residues, 39%; sawdust, 32%; shavings, 23%; and chippable logging residues, 6%. The highest concentration of residues is in the northeastern portion of the Black Hills, with Spearfish, Whitewood, Sturgis, and Piedmont, S. Dak., having a potential of 120.5 M o.d. tons or 54% of the total.

In computing the cost of materials, the manufacturer typically does not include stumpage and harvesting costs. If the residues have another use, such as pulpchips or hogged fuel, the manufacturer will include the appropriate opportunity cost in the analysis; otherwise, the only costs are further processing and hauling residues from the sawmill or plywood plant to the particleboard plant. Presently, 9 of the 13 mills are selling pulpchips to Lake States pulp mills. Further, two of the larger mills have installed wood residue fired boilers to heat the dry kilns and other mill buildings. Some mills sell minor amounts of slab and edgings for firewood and sawdust and shavings for livestock bedding.

The cost data in table 3 are based on the assumption that the value of pulpchips, f.o.b. railcar, to the sawmill operators averaged $21.00 per unit or $17.50 per o.d. ton. The value of sawdust and planer shavings loaded on chip vans at the sawmill was assumed to be $4.00 per o.d. ton. Estimating the cost of transporting chips, sawdust, and shavings from the sawmills to the particleboard plant assumed that a 10-unit chip van can be operated for $1.50 per loaded mile. At Whitewood, S. Dak., delivered cost of sawdust and shavings would range from $4.63 to $12.88 and chips from $15.50 to $26.38 per o.d. ton. At Newcastle, Wyo., sawdust and shavings cost ranges from $4.00 to $14.75 and chips from $17.50 to $28.25. The cost of these raw materials in terms of units of end product would, in addition, depend upon the type of maufacturing process, product, and the size of the facility. This aspect will be discussed later in the manufacturing cost section of the paper.

Plant Location

Two representative prospective plant locations are used in this analysis: Whitewood, S. Dak., and Newcastle, Wyo. Whitewood is on the northeastern edge and Newcastle on the west-central edge of the Black Hills area. The criteria for selection included existence and stability of the local timber industry, presence of transportation networks suitable for use by the forest products industries, and availability of community facilities.

Three forest-related industries are operating in or around Whitewood. These firms produce lumber, pulpwood, and treated posts and poles. Five sawmills within 21 miles of Whitewood have a total annual capacity of about 100 MM fbm. The town is within 1 mile of Interstate 90 and has rail service. Whitewood is near Spearfish, Sturgis, and Rapid City, S. Dak. These communities each have well established commercial, education, and other public service facilities as well as superior outdoor recreation opportunities for hunting, fishing, and hiking.

Newcastle has one major sawmill operating with the town. The community has a rail line, as well as U.S. Highways 14 and 85. It would have similar commercial,

Table 3.—Estimated cost of residues (dollars per o.d. ton) at the sawmill and delivered to particleboard plant locations at either Whitewood, S. Dak., or Newcastle, Wyo.

Place of delivery Origin of residues		Mileage[1]	Hauling cost[2]	Chip costs		Sawdust and shavings cost	
				Sawmill[3]	Plant	Sawmill	Plant
To Whitewood, S. Dak.							
From	Spearfish, S. Dak.	15	1.88	16.87	18.75	4.00	5.88
	Hulett, Wyo.	60	7.50	8.00	15.50	4.00	11.50
	Sturgis, S. Dak.	7	.88	17.50	18.38	4.00	4.88
	Piedmont, S. Dak.	21	2.63	17.50	20.13	4.00	6.63
	Hill City, S. Dak.	56	7.00	13.62	20.62	4.00	11.00
	Custer, S. Dak.	70	8.75	14.00	22.75	4.00	11.75
	Newcastle, Wyo.	71	8.88	17.50	26.38	4.00	12.88
	Whitewood, S. Dak.	5	.63	17.50	18.13	4.00	4.63
To Newcastle, Wyo.							
From	Spearfish, S. Dak.	66	8.25	16.87	25.12	4.00	12.25
	Hulett, Wyo.	83	10.38	8.00	18.38	4.00	14.38
	Sturgis, S. Dak.	70	8.75	17.50	26.25	4.00	12.75
	Piedmont, S. Dak.	86	10.75	17.50	28.25	4.00	14.75
	Hill City, S. Dak.	51	6.38	13.62	20.00	4.00	10.38
	Custer, S. Dak.	37	4.63	14.00	18.63	4.00	8.63
	Newcastle, Wyo.	0	0.00	17.50	17.50	4.00	4.00
	Whitewood, S. Dak.	71	8.88	17.50	26.38	4.00	12.88

[1] *Maps and Charts for Determining Distance in Hiway Miles, Household Carriers Bureau, 1973.*

[2] *The hauling cost assumes that a 10-unit van can be operated for $1.50 per loaded mile and one unit of sawmill residue equals 1.2 o.d. tons.*

[3] *The cost of chips at the sawmill assumes that chips are worth $17.50 per o.d. ton f.o.b. railcar in the Black Hills. Chip cost at the sawmills represents the difference between $17.50 and the handling and trucking costs to the rail sidings. Mileage and trucking costs per o.d. ton to rail sidings from sawmills without adjacent rail facilities are:*

Spearfish, S. Dak., to Jolly Siding, S. Dak.—5 miles and $.63,
Hulett, Wyo., to Whitewood, S. Dak.—60 miles and $9.50,
Hill City, S. Dak., to Rapid City, S. Dak.—31 miles and $3.88,
and Custer, S. Dak., to Hermosa, S. Dak.—28 miles and $3.50.

Trucking costs for the Hulett sawmills includes $2.00 per ton for unloading facilities.

educational, and public service facilities, and outdoor recreational opportunities as the communities in the Whitewood area.

Approximately 73 to 126 full-time employees would be needed, depending upon the size of the facility. The necessary professional and skilled workers for a particleboard plant could probably be attracted to either Whitewood or Newcastle.

Manufacturing Process

The manufacturing facilities described would be capable of producing particleboard for such construction uses as floor underlayment and mobile home decking and industrial uses including furniture core, cabinets, door core, and exterior board. The board product assumed is either three-layered or graduated with fiberous fines on the faces and coarser furnish in the core. The furnish would consist of planer shavings, ring cut flakes, and refined sawdust. Formaldehyde resin and wax would be the other contents of the board.

The process in general consists of the following: all wood raw materials are received on a truck scale and a truck dump unit; green material is conveyed to outside storage and piled with a radial stacker; dry material, such as planer shavings, is stored under a roof; the truck dump would be enclosed to minimize particulate emission.

Raw material feed bins would handle approximately 4-5 hours of plant flow. Planer shavings are screened with the fines passing directly to the dryer ovens. Coarser shavings are reduced in a ring type flaker. Sawdust is screened to remove large pieces prior to refining. Either double or single disc refiners mill the sawdust into fiber-like fine particles. Green chips are also reduced in ring type flakers. Magnets on conveyors eliminate tramp metal.

Each type of material is dried separately in dryers equipped with spark detectors and fire dumps. The material is then sent to the appropriate storage bins for face or core particles through interconnecting conveyors. Two blenders are required—one for the face layers and one for the core. Prior to blending, the material is measured by either scales or by density gages. This measuring system is connected to resin pumps that assure control of the resin and wax added, based on actual wood flow. The mat is formed either by three-layer or air-felting formers. The air-felting type of former gives better board surface characteristics with mill waste raw material. The mats would be handled on a conventional caul system.

The assumed presses are designed for fast closing and a specific pressure of 700-800 pounds per square inch. The entire caul handling and pressing system should have a press cycle of 3 minutes in order to manufacture thin (1/4-inch) panels at an efficient rate. The boards are passed through a cooler and stacked or sawed and stacked, depending on the plant size. The finishing section is equipped with 5-foot-wide belt sanders and a basic trim and cutup saw, with three saws on the first section and six to seven saws on the cross-cut or second section. A small cut-to-size saw is also provided.

A basic concern of this study was the availability of energy for a plant in the Black Hills. There appears to be plenty of wood waste such as bark in the area which can be delivered to a plant at a cost less than $10 per o.d. ton. Bark at this cost would generate heat at a lower cost per Btu than coal. Natural gas is available and therefore considered as a "control" fuel to supplement the dust burners. Because of the above considerations the fuel system was designed for use of the waste generated by the plant. Any shortage in these wastes to meet fuel requirements would be made up by purchasing bark or other wood residues from other plants.

The projected boilers are designed for burning dust and bark as well as coal and will supply steam for the "dry" dryers, presses, building heat, and resin and wax heating. The "dry" dryers handling the dry shavings are heated by steam heat/air exchangers to minimize the fire hazard. The "wet" dryers for drying the green material are fueled with direct fired dust and supplemented by boiler stack gases. These dryers also have auxiliary gas burners. The sized trim from the panels is hogged and screened to proper size for the dust burners. This material is then temporarily stored before being conveyed to the metering bins of the boiler and the "wet" dryers.

It is difficult to vary the amount of heat produced by a dust burner to accommodate moisture variations in the material to be dried. Such difficulties are overcome by supplementing the basic heat load provided by the dust burner with the auxiliary gas burners. This method requires about 10-15% of the total heat to be supplied by natural gas.

Cyclones and filters would keep particulate emission within the permissible standards. Bag houses are not recommended because of excessive fire hazard. Blue haze would be kept within acceptable standards because of low dryer temperatures (600-700° F) and keeping the salt content of the resin to a minimum. The effluent resulting from washing the blender and the containers and pipe lines to remove resin and wax will be treated in a lagoon.

The building would probably be a single-story steel type on a concrete slab, with insulated roof and wall panels. Fire protection would include building sprinklers, fire hydrants, and a fire pond or tank with pumping equipment.

Manufacturing Requirements and Costs

The total unit costs of manufacturing particleboard in the Black Hills were assessed using discounted cash flow analysis (DCFA) with the aid of a computer program (Harpole 1978). These unit production costs were computed in terms of per unit revenue required, f.o.b. the particleboard plant, to cover all operating costs, capital recovery requirements (depreciation), and return on the investment. The type of return on investment used in this study was internal rate of return (IRR). This value represents a single interest rate return to total investment where total investment is the sum of the investment requirements for facilities and working capital. The IRR is the interest earnings realized as after-tax profit in DCFA. This method of evaluating capital investments differs from the return on original investment method (ROI) where the average annual income after taxes and depreciation is divided by the original capital outlay.

Facilities costs and operating requirements and costs were projected by Columbia Engineering International Ltd. under contract. Estimates of wood costs were developed by the Forest Service. Figures B-1, B-2, and B-3, are layouts for three facilities with annual capacities of 33.5, 67.0, and 100.0 MM ft², 3/4-inch basis. All operating costs and revenue were assumed to increase at the rate of 5% per year.

Capital Requirements and Costs

Total capital requirements, including both facilities cost and working capital, ranged from $12,364,000 to $22,790,000 depending on the size and type of plant. Capital requirements in 1978 for facilities with annual production of 33.5, 67.0, and 100.0 MM ft² are summarized in tables B-1 through B-5. The press sizes considered for the 33.5-MM ft² facilities were 5- × 9-foot, 16-opening and 5- × 18-foot, 8-opening. The press size for the 67.0-MM ft² facility was 5- × 18-foot, 16-opening, and for the 100.0 MM ft² facility was 5- × 18-foot, 24-opening. Major components of the facilities cost were building and site development, equipment and installation, engineering and construction management, carrying interest and local sales tax on construction, pre-startup expenses, and a contingency allowance. The working capital needed was estimated to be equal to 2 months (16.7%) of annual manufacturing cost. The latter included raw material cost, process labor, administrative overhead, and factory overhead. Depending on size and type of plant, building and site development costs ranged from $1,760,000 to $3,572,000; equipment plus installation costs from $7,724,000 to $13,943,000 (tables B-2, B-3, and B-4). Engineering and construction management and the contingency allowance together are approximately 15% of the building and site development, equipment, and installation costs. Construction carrying interest and local sales tax together were about 7% of the total facilities costs. Pre-startup expenses include salaries of key plant operating personnel hired prior to plant startup to ensure the fastest possible build-up in plant output and sales (table B-5).

Operating Requirements and Costs

Operating requirements and costs are summarized in tables B-6 through B-10. The wood raw materials considered for the different sized facilities were:

Plant size	Wood raw material mix
MM ft² per year	
33.5	75% Day shavings 25% Green sawdust
	50% Dry shavings 50% Green sawdust
67.0	46% Dry shavings 54% Green sawdust
100.0	31% Shavings 43% Green sawdust 26% Green chips

Depending on the type and size of plant, the annual volume of dry shavings required would range from 26,663 to 49,290 o.d. tons, green sawdust from 13,316 to 68,370 o.d. tons, and green chips from 0 to 41,340 o.d. tons (table B-6). The average cost per o.d. ton of wood raw material delivered to plants at Whitewood and Newcastle ranged from $5.67 to $13.37, depending on the plant capacity and location and the wood raw material mix (table B-7).

The annual volume of resin would range from 4,003 tons for the 33.5-MM ft² plant to 11,950 tons for the 100-MM ft² plant, wax from 536 to 1,600 tons, and electricity from 14,658 to 26,241 MWh (table B-6). Energy requirements in the form of process steam for presses, "dry" dryers, and building heat and hot stack gases for the "wet" dryer are given in table B-8. Supply factors—dry trim and dust, green bark, and hot stack gas are also listed in table B-8. Natural gas would be used only if the bark is excessively wet because of rain or some other cause.

The estimated costs of resin, wax, electric power and fuel during 1978 were as follows:

Raw material	Cost
	dollars
Resin (per pound)	.13
Wax (per pound)	.14
Electric power (per kWh)	.02
Fuel	
Dry fine and trim (per o.d. ton)	0
Wet bark (per o.d. ton)	10.00
Natural gas (per M ft³)	1.69

The total number of full-time jobs would vary from 73 to 126 depending on the plant capacity (table B-9). Employment costs (3 shifts, 7 days per week) were based on a $16,000 cost per average man-year, including fringe benefits. The manning requirement are assumed to be at 77% of full requirements during the first year and at full level thereafter. Production is assumed to be at 46.7% during the first year, 98.8% during the second year, and 100.0% thereafter. The wages of the direct manufacturing employees are included as processing labor costs, maintenance and repair employees as factory overhead, and administration and sales employees as administrative overhead in the DCFA (table B-10). Factory overhead also includes costs of maintenance supplies and administrative overhead also the costs of office maintenance, travel expense, insurance, and local property and sale taxes.

Assumptions used in calculating break-even production costs were:

1. Investment tax credit—10% of the cost of processing equipment.
2. Selling cost—10% of the selling price to cover 5% sales commission, 2% cash discount, and a 3% bad debt allowance.
3. Tax rate—48% of taxable income for federal corporate income taxes. South Dakota and Wyoming do not have corporate income taxes.
4. Inflation rate—5% per year increase in costs and revenue.
5. Rate of return on investment—15% internal rate of return (15% IRR).
6. Economic life—10 years.

The method of depreciating capital assets is shown for the 100.0 MM ft² per year facility (table B-11). Land was not depreciated. Site preparation, buildings, mobile equipment, and miscellaneous were depreciated by the straight line method. Process machinery was depreciated using the double declining method for the first 5 years and the straight line method for the second 5 years.

The break-even unit production costs or plant prices ranged from \$173.46 per M ft² for the 100.0 MM ft² (5- × 18-foot, 24-opening) facility to \$241.19 per M ft² for the 33.5-MM ft² (5- × 18-foot, 8-opening) facility using 50% dry shavings and 50% green sawdust as the furnish (table 4). The itemized production costs in this table are expressed in terms of 1978 unit prices and are calculated from data of the DCFA computer program. For example, the proportion of the total variable cost to total sales over the 10-year period is 0.5531 (table B-12). This proportion value multiplied by the unit price for 1978 equals the total variable cost in table 4 for the 100.0 MM ft² facility. All itemized production costs in this table except that for raw materials were higher for the smaller than the larger plants. The higher raw material cost at the 100.0 MM ft² facility included higher cost pulp chips in the furnish because of insufficient supply of sawdust and shavings.

Year-end values are also projected by the DCFA program. These include unit sales, gross sales, gross revenue, raw material cost, administrative overhead, factory overhead, total fixed cost, working capital investment, depreciation, after-tax profit, after-tax earnings, after-tax net cash flow, and accumulated net cash flow (table B-12).

The plant selling price or total manufacturing cost, including internal rate of return, required for 6 levels of profitability—0, 5, 10, 15, 20, and 25% internal rate of return—was determined (table 5). The effects of both plant size and the market price upon profit become readily apparent. The break-even price at 0% internal rate of return indicates the survival capacity of the plant during periods of low market prices.

Feasibility Assessment

The assessment of feasibility assumes that the market price in the area served by a plant in the Black Hills will be established primarily by West Coast production. The product value at a Black Hills plant thus could be approximated as the West Coast price plus the freight advantage to the market areas. The average rail freight advantage of a Black Hills plant would be

Table 4.—Estimated production cost (dollars per M ft², 3/4-inch basis) at 15% internal rate of return for different particleboard facilities in the Black Hills, 1978

	Plant capacity (MM ft² per year)					
	33.5				67.0	100.0
	Wood raw material					
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
	Press size					
Cost category	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
Raw materials	60.92	60.93	60.96	60.96	61.09	63.98
Processing labor	24.51	24.51	24.51	24.51	18.38	14.61
Selling expense	22.89	23.88	23.14	24.12	18.72	17.35
Total variable costs	108.32	109.32	108.61	109.59	98.19	95.94
Fixed manufacturing cost	27.62	27.73	27.60	27.64	21.27	19.22
Depreciation	24.02	25.96	24.75	26.68	17.16	14.49
Taxes (Federal income)	31.15	34.32	31.83	34.99	22.91	19.87
After tax profit (15% IRR)	37.74	41.44	38.60	42.29	27.68	23.94
TOTAL COST/M ft²	228.85	238.77	231.19	241.19	187.21	173.46

about \$30.00 per M ft², to Chicago, Des Moines, Kansas City, Milwaukee, Minneapolis, and Omaha (table A-1).

The West Coast quarterly average price for 3/4-inch industrial board ranged from \$100 to \$183 f.o.b. plant from March 1976 through December 1978. An f.o.b.-plant value in the Black Hills would have ranged from \$130 to \$213 assuming a \$30 freight advantage for 3/4-inch thickness (fig. 4). The break-even total production costs (0% internal rate of return) for three different size facilities are shown by the three straight lines. Only the 67.0 and 100.0 MM ft² facilities would have yielded a positive rate of return over the entire three year period. The 33.5-MM ft² facility was profitable only during the latter portion of the period. The 1978 production costs were discounted 5% annually in estimating the other yearly production costs, reflecting inflation.

West Coast quarterly average price for 5/8-inch underlayment ranged from \$45 to \$175 f.o.b. plant from January 1973 through December 1978. An f.o.b. plant value in the Black Hills would have ranged from \$70 to \$200, assuming a \$25 freight advantage (fig. 5). Again, total production costs with 0% internal rate of return for three different size facilities are shown by the straight lines. Both the 67.0- and 100.0-MM ft² facilities would have shown minimum profits or losses from June 1974 to March 1977. The 33.5-MM ft² facility would have shown a consistent loss during the period. All three facilities showed profitability before and after this period. The 1978 production costs were discounted 5% annually to estimate the other yearly production cost, reflecting inflation.

The sensitivity of total unit production cost to changes in various operational costs and to reductions in plant output is important. The cost of adhesive and wax would probably be similar at most locations except for transportation to the plant. The wood, energy,

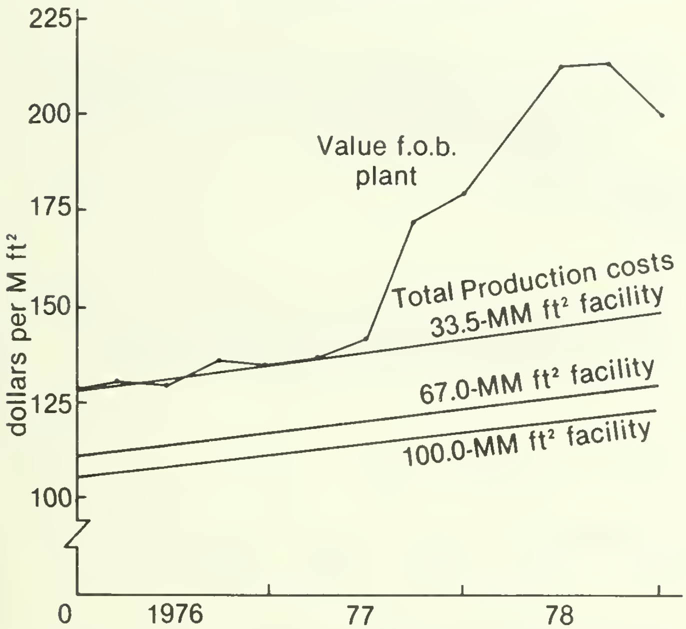

Figure 4.—Comparison of value f.o.b. plant with total production costs at 0% internal rate of return for 3/4-inch industrial particleboard produced in facilities of three different sizes.

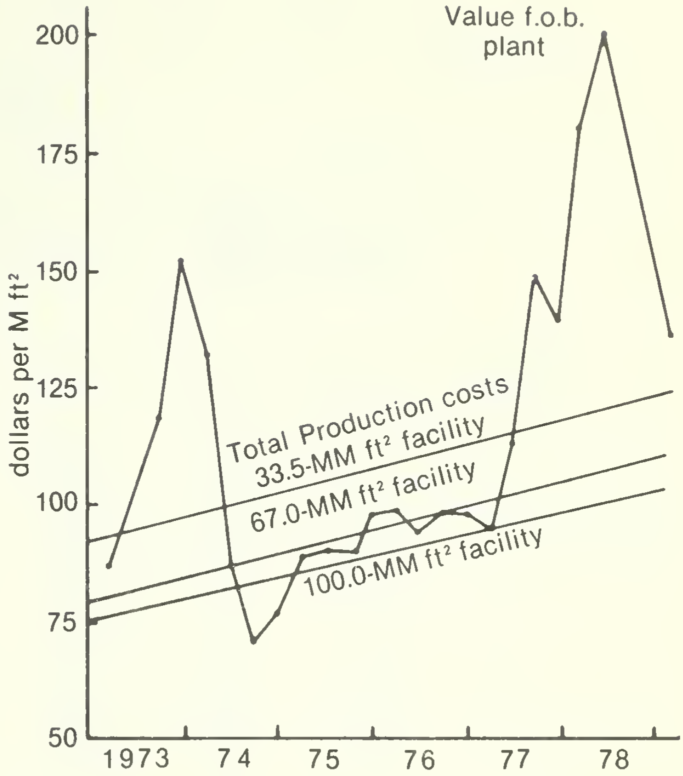

Figure 5.—Comparison of value f.o.b. plant with total production costs at 0% internal rate of return for 5/8-inch underlayment particleboard produced in facilities of three different sizes.

and salary costs, however, are more dependent on local supply and demand and would tend to vary more depending on plant location. Total production costs are not only affected directly by changes in the operational costs but also indirectly through associated changes in selling expense, after tax profit, taxes, and working capital. Sensitivity analyses indicated that total cost in dollars per million square feet, 3/4-inch basis, would be increased by:

1. \$1.85 for each \$1.00 per o.d. ton increase of wood cost for both the 67.0-MM ft² and 100.0-MM ft² facilities (fig. 6).
2. \$4.05 for the 67.0-MM ft² and \$3.05 for the 100-MM ft² facility for each 1 cent increase per kWh in electricity cost (fig. 7).
3. \$1.20 for the 67.0-MM ft² and \$1.63 for the 100-MM ft² facility for each \$1.00/thousand cubic feet increase of natural gas cost (fig. 8).
4. \$0.13 for the 67.0-MM ft² and \$0.16 for the 100-MM ft² facility for each \$1.00 per o.d. ton increase of bark cost (fig. 9).
5. \$1.93 for the 67.0-MM ft² and \$1.56 for the 100-MM ft² facility for each \$1000 per year increase of average salary including benefits (fig. 10).

It is apparent from the figures that total unit production costs changed linearly with the costs of the above resources. However, the unit production costs increased at an increasing rate with the reduction of plant output because of increasing unit fixed costs (fig. 11).

Table 5.—Estimated production cost (dollars per M ft², 3/4-inch basis) including internal rate of return or plant selling price[1] for different particleboard plants in the Black Hills operating at six levels of profitability or internal rates of return, 1978

	Plant capacity (MM ft² per year)					
	33.5				67.0	100.0
	Wood raw material					
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
	Press size					
Internal rate of return (percent)	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
0	[2]148.22	150.21	148.90	150.82	128.08	122.31
	123.52	125.18	124.08	125.68	106.73	101.93
5	171.68	176.00	172.88	177.12	145.33	137.28
	143.07	146.67	144.07	147.60	121.11	114.40
10	198.56	205.53	200.38	207.25	165.05	154.33
	165.47	171.28	166.98	172.71	137.54	128.61
15	228.85	238.77	231.39	241.19	187.21	173.46
	190.71	198.98	192.83	200.99	156.01	144.55
20	262.44	275.62	265.78	278.83	211.73	194.60
	218.70	229.68	221.48	232.36	176.44	162.17
25	299.14	315.86	303.37	319.95	238.48	217.63
	249.28	263.22	252.81	266.63	198.73	181.36

[1]*When internal rate of return is included in production costs, total production costs and plant selling price are equal.*
[2]*Upper costs are for 3/4-inch and lower for 5/8-inch thickness. The cost for 5/8-inch was estimated to be 83.3% of that for 3/4-inch, assuming costs to be proportional to thickness.*

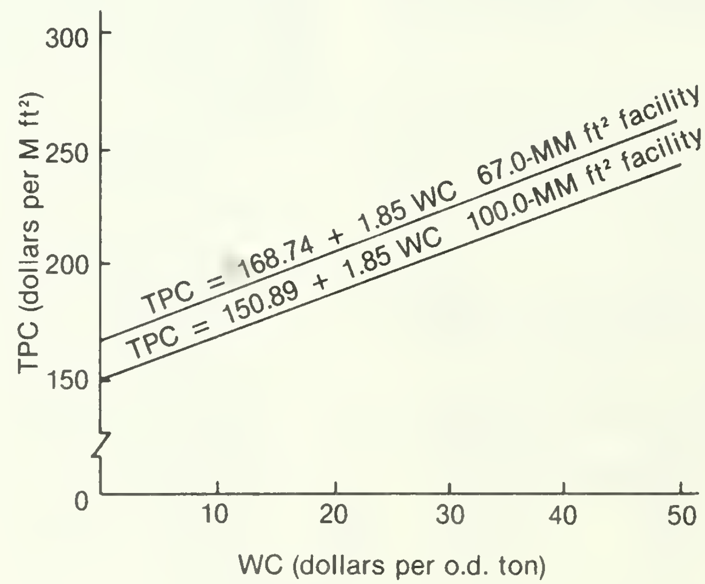

Figure 6.—The effect of wood cost (WC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15 % IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

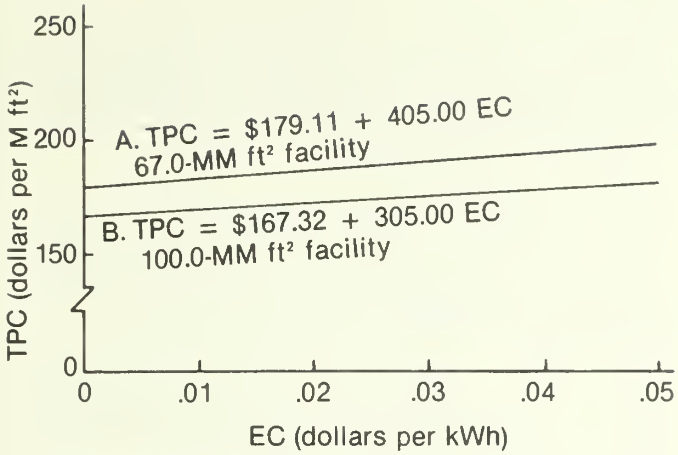

Figure 7.—Effects of electricity cost (EC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15 % IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

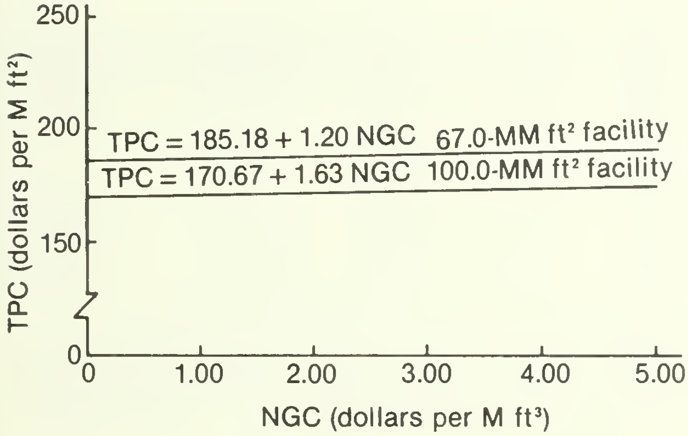

Figure 8.—Effects of natural gas cost (NGC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

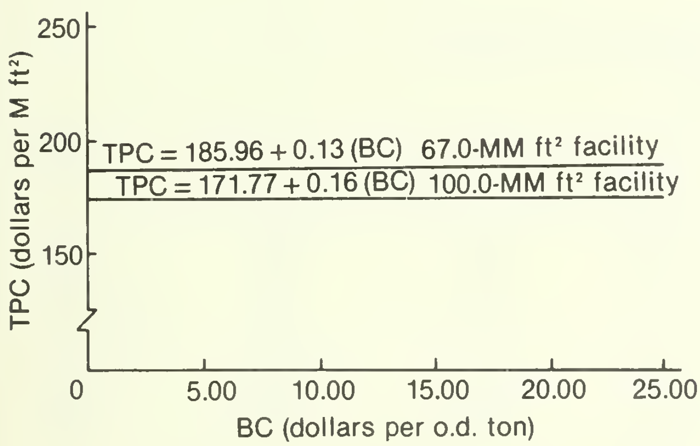

Figure 9.—Effect of bark cost (BC) or total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

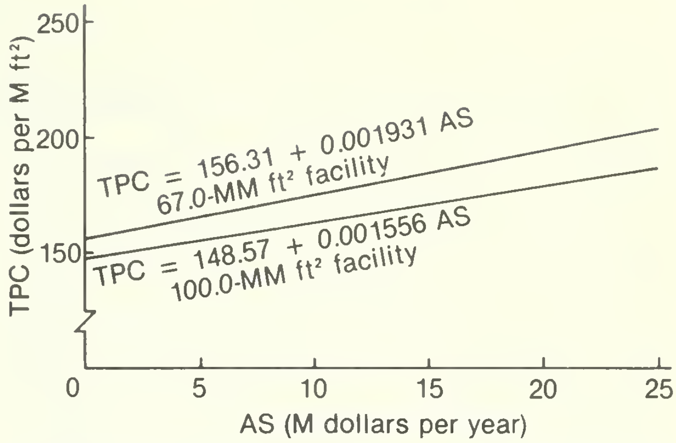

Figure 10—.Effect of average salary including benefits (AS) on total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

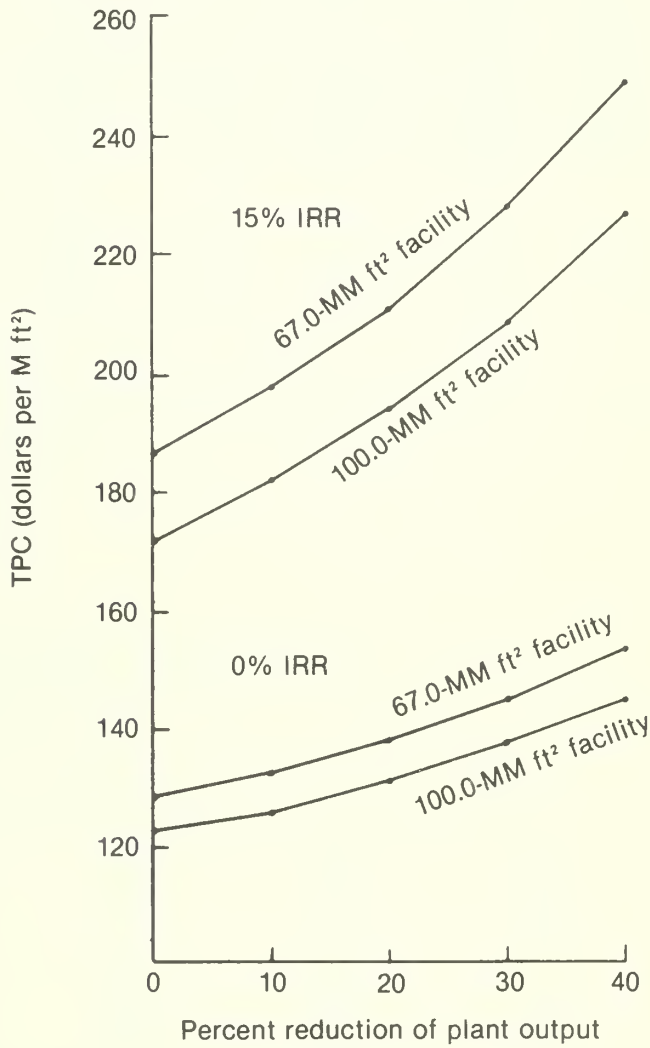

Figure 11.—Effects of reduced plant output on total production cost (TPC) with varying return to capital (0% and 15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

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Appendix A

Tables and Figures on Marketing of Particleboard

Table A-1.—Railroad freight rates (dollars per M ft², 3/4-in basis) for particleboard from production to market locations[1,2,3]

Market	Production locations								
	Whitewood, S. Dak.	Newcastle, Wyo.	Portland, Oreg.	Missoula, Mont.	Gaylord, Mich.	Crossett, Ark.	Birmingham, Ala.	Charlotte, N. C.	Diboll, Tex.
Boston	87.11	88.26	87.11	84.81	40.54	83.95	54.34	41.69	87.98
Chicago	41.11	42.26	75.33	72.74	23.29	41.98	35.94	41.98	52.90
Columbus	61.81	62.96	85.96	82.51	25.59	53.48	33.93	33.64	64.40
Denver	24.73	21.56	41.98	34.21	74.75	56.64	58.65	69.00	55.49
Des Moines	31.34	34.79	73.31	69.58	42.26	44.85	41.40	52.61	48.01
Detroit	61.54	62.68	85.10	81.65	18.69	59.51	38.24	38.81	70.44
Kansas City	35.94	34.79	68.71	65.55	50.31	35.94	38.53	52.33	39.96
Milwaukee	40.25	41.69	75.33	72.74	19.55	44.85	38.24	44.56	56.93
Minneapolis	29.04	35.65	68.71	65.55	39.96	52.61	48.59	57.21	59.23
New York	83.95	85.10	87.11	84.81	38.81	79.93	46.29	34.21	83.95
Omaha	27.31	27.31	68.71	65.55	50.31	44.85	44.85	56.64	47.73
Philadelphia	81.08	82.23	87.11	84.81	38.81	79.06	43.99	32.20	82.51
St. Louis	41.69	41.69	74.46	70.73	32.78	29.90	23.00	29.04	40.83
Washington, D.C.	79.64	80.79	87.11	84.81	37.95	73.60	26.45	18.69	79.93
Wichita	36.80	34.79	68.71	65.55	60.38	35.94	44.85	56.64	35.94

[1]*All values are based on 3/4-in thickness, 46 lb/ft³ or 2,875 lb/M ft².*
[2]*70,000-pound shipments.*
[3]*Freight rates were compiled by Mountain States Commerce and Traffice Services, Inc., Denver, Colo.—November 1977. These rates have been increased numerous times since then but have remained in about the same ratio.*

Table A-2.—Motor common carrier truckload freight rates (dollars per M ft², 3/4-in, basis) for particleboard from production to market locations[1,2,3]

Market locations	Production locations					
	Whitewood, S. Dak.	Newcastle, Wyo.	Portland, Oreg.	Missoula, Mont.	Crossett, Ark.	Diboll, Tex.
Chicago	46.58	43.41	82.51	72.45	44.56	52.04
Denver	24.44	20.41	54.34	43.70	60.95	52.04
Des Moines	34.79	34.79	81.65	71.30	41.11	43.99
Kansas City	36.80	38.24	91.43	70.15	30.48	33.35
Minneapolis	32.49	34.21	78.78	64.40	56.35	58.08
Omaha	31.91	32.49	82.51	69.00	46.86	41.98
St. Louis	49.16	46.29	82.51	72.45	28.45	37.09
Wichita	35.94	35.94	84.53	72.45	34.21	30.48

[1]*All values are based on 3/4-in thickness, 46 lb/ft³ or 2,875 lb/M ft².*
[2]*All rates are commodity rate.*
[3]*Freight rates were compiled by Mountain States Commerce and Traffic Services, Inc., Denver, Colorado—November 1977. These rates have been increased numerous times since then but have remained in about the same ratio.*

Table A-3.—North Central United States estimated consumption of particleboard, 1965-1990 (MM ft^2, 3/4-in basis)[1]

End use	1965	1970	1975	1980	1985	1990
Construction						
Residential						
1 and 2 family	27.1	56.3	85.0	136.5	187.3	228.8
Multi-family	8.4	8.9	14.3	15.1	13.5	12.7
Subtotal residential	35.5	65.2	99.3	151.6	200.8	241.5
Nonresidential	9.5	14.0	12.7	21.2	26.5	33.1
Repairs and remodeling	26.6	48.5	66.5	80.6	115.0	142.1
Subtotal construction	71.6	127.7	178.5	253.4	342.3	416.7
Industrial uses						
Furniture and fixtures						
Household furniture (wood)	39.2	74.7	125.3	217.5	316.5	455.7
Household furniture (metal)	10.5	18.7	24.3	36.9	47.7	58.8
Office furniture (wood)	1.2	4.1	8.0	13.0	19.0	26.3
Office furniture (metal)	.8	2.3	4.5	8.6	12.4	16.4
Public building furniture	7.4	13.8	22.1	35.1	45.8	59.2
Partitions and fixtures	24.4	45.4	74.4	128.5	187.2	269.1
Misc. furniture and fixtures	2.9	4.6	7.4	11.4	16.2	23.6
Subtotal furniture and fixtures	86.4	163.6	266.0	451.0	644.8	909.1
Mobile homes	4.1	65.0	96.3	103.8	98.9	103.8
Recreation vehicles	0.9	4.0	2.3	8.7	14.1	20.4
Modular homes	0.0	6.3	21.8	45.1	66.3	92.1
General manufacturing	16.6	23.3	41.8	74.4	113.2	156.8
Subtotal industrial	108.0	262.2	428.2	683.0	937.3	1282.2
Unknown[2]	10.6	23.4	36.4	56.3	76.8	101.5
TOTAL CONSUMPTION	190.2	413.3	643.1	992.7	1356.4	1800.4

[1] *The estimated proportion of the national particleboard consumption assigned to the north central region is based on the following percentages: single family homes, 25%; multi-family homes, 27%; nonresidential construction, 25%; repairs and remodeling, 25%; wood household furniture, 20%; metal household furniture, 25%; wood office furniture, 27%; metal office furniture, 53%; public building furniture, 43%; partitions and fixtures, 39%; miscellaneous furniture and fixtures, 20%; mobile homes, 29%; recreation vehicles, 39%; modular homes, 41%; and general manufacturing, 37%.*

[2] *Assumed to be 6% of the construction and industrial uses.*

Table A-4.—United States estimated consumption of particleboard, 1965-1990 (MM ft^2, 3/4-in basis)[1]

End use	1965	1970	1975	1980	1985	1990
Construction						
Residential						
1 and 2 family	108.5	225.0	340.0	546.0	749.0	915.0
Multi-family	31.2	33.0	53.0	56.0	50.0	47.0
Subtotal residential	139.7	258.0	393.0	602.0	799.0	962.0
Nonresidential	38.0	55.9	50.8	84.9	106.0	132.2
Repairs and remodeling	106.5	193.8	266.2	322.6	460.1	568.3
Subtotal construction	284.2	507.7	710.0	1009.5	1365.1	1662.5
Industrial uses						
Furniture and fixtures						
Household furniture (wood)[1]	196.0	373.6	626.5	1087.7	1582.6	2278.5
Household furniture (metal)	41.8	74.8	97.0	147.5	190.8	235.1
Office furniture (wood)	4.5	15.0	29.7	48.0	70.3	97.3
Office furniture (metal)	1.5	4.4	8.4	16.3	23.4	31.0
Public building furniture	17.1	32.0	51.3	81.6	106.5	137.6
Partitions and fixtures	62.5	116.3	190.8	329.6	480.1	689.9
Misc. furniture and fixtures	14.5	22.8	37.2	57.1	80.8	117.9
Subtotal furniture and fixtures	337.9	638.9	1040.9	1767.8	2534.5	3587.3
Mobile homes	14.2	224.0	332.0	358.0	341.0	358.0
Recreation vehicles	2.2	10.3	6.0	22.4	36.1	52.3
Modular homes	0.0	15.3	53.2	110.0	161.6	224.6
General manufacturing	45.0	63.0	113.0	201.0	306.0	423.9
Subtotal industrial	399.3	951.5	1545.1	2459.2	3379.2	4646.1
Unknown[2]	40.4	87.6	135.3	208.1	284.7	376.7
TOTAL CONSUMPTION	723.9	1546.8	[3]2390.4	3676.8	5029.0	6685.3

[1]*This classification includes wood kitchen cabinets and wood television and radio cabinets.*
[2]*Assumed to be 6% of the construction and industrial uses.*
[3]*Estimated 1975 particleboard production is 2,538.9 MM ft^2 (Current Industrial Reports 1975).*

Table A-5.—Estimated new productions (M units), particleboard consumption per unit (ft^2) and national consumption (MM ft^2, 3/4-in basis) of particleboard for one- and two-family homes to 1990

Year	New production[1]	Particleboard used per unit[1]	Total consumption
1970	900	250 + 5.3% per year	225
1975	1050	324 + 5.3% per year	340
1980	1300	420 + 3.5% per year	546
1985	1500	499 + 3.5% per year	749
1990	1550	590	915

[1]*U.S. Department of Agriculture, Forest Service (1973). The outlook for timber in the United States. Forest Resource Report 20. 367 p. Washington, D.C.*

Tab e A-6.—Estimated deflated value of shipments (MM dollars), particleboard consumption per dollar (ft²), and national consumption (MM ft², 3/4-in basis) of particleboard for wood household furniture to 1990[1]

Year	Value of shipments[2]	Particleboard used per dollar	Total consumption
1958	1382.2	.036 + 10.4% per year	[3]49.5
1963	1897.9	.059 + 21.4% per year	[4]112.7
1965	2250.6	.087 + 11.6% per year	[5]196.0
1970	2474.0	.151 + 11.6% per year	373.6
1972	3645.4	.188 + 3.0% per year	[6]685.1
1975	3056.2	.205 + 3.0% per year	626.5
1980	4570.2	.238 + 3.0% per year	1,087.7
1985	5734.2	.276 + 3.0% per year	1,582.6
1990	7120.2	.320	2,278.5

[1]*Includes wood television and radio cabinets—SIC 2517; and wood kitchen cabinets—SIC 2434.*

[2]*Calculated on basis of data from:*

Industry Profiles 1958-1969. SIC 2511, page 83, U.S. Department of Commerce.

Annual Survey of Manufacturers 1970-1971. U.S. Department of Commerce, Bureau of the Census.

Annual Survey of Manufacturers 1973. General Statistics for Industry Groups and Industries, M73(AS)-1, U.S. Department of Commerce, Bureau of the Census.

Annual Survey of Manufacturers 1974. General Statistics for Industry Groups and Industries, (Including Supplemental Labor Costs) M74(AS)-1, U.S. Department of Commerce, Bureau of the Census.

Annual Survey of Manufacturers 1975. Value of Product Shipments, M75(AS-2), U.S. Department of Commerce, Bureau of the Census.

GNP Values and Implicit Price Deflators, table B-1, page 171; and table B-3, page 174 of the Economic Report of the President, January 1976.

Wholesale Price Index for Furniture and Household Durables, table B-47, page 226, Economic Report of the President, January 1976.

Projected GNP and Implicit Price Deflator Values for 1980, 1985, and 1990 from Predicast, January 1977, Predicast, Inc.

[3]*U.S. Department of Commerce. 1966. Industry Statistics. 1963 Census of Manufacturers MC 63(2)-25A.*

[4]*U.S. Department of Commerce. 1971. Summary and Subject Statistics. 1967 Census of Manufacturers.*

[5]*U.S. Department of Agriculture, Forest Service 1969. Wood Used in Manufacturing Industries 1965. Statistical Bulletin No. 440, 91 p.*

[6]*U.S. Department of Commerce. 1976. Industry Statistics. 1972 Census of Manufacturers.*

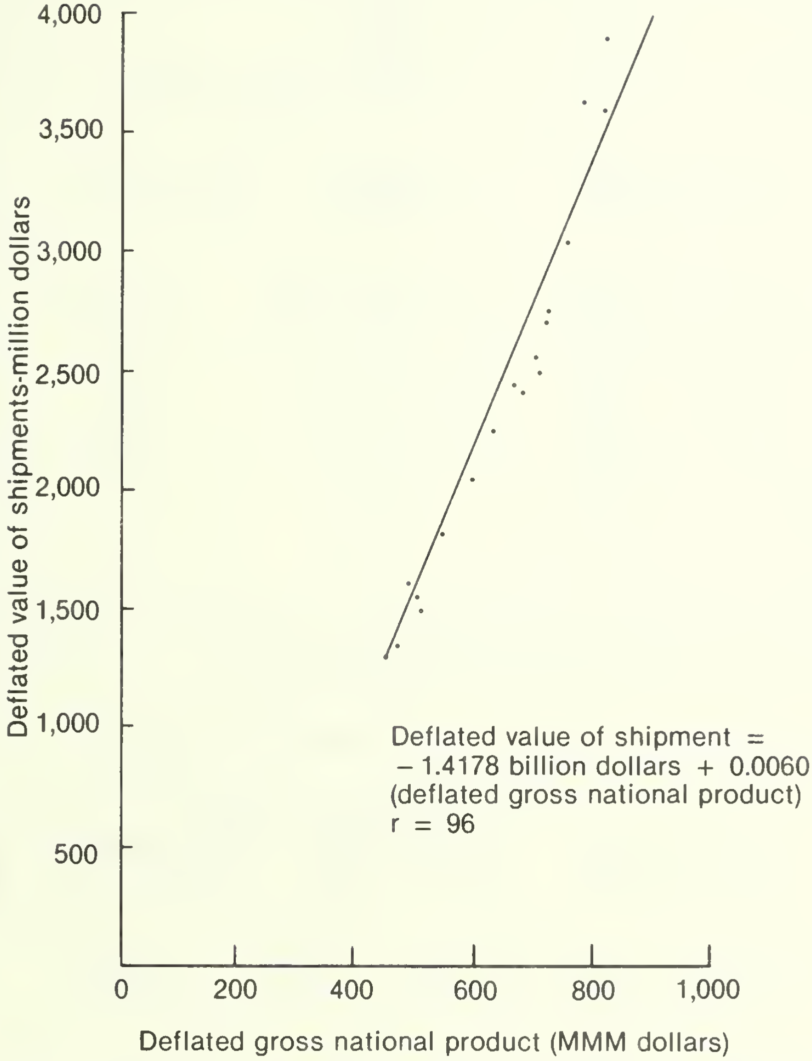

Figure A-1.—Scatter diagram and linear regression of deflated values for shipments of wood household furniture to deflated gross national product.

Appendix B

Tables and Figures on Manufacturing of Particleboard

Table B-1.—Estimated capital requirements (M dollars) for particleboard plants of different capacities in the Black Hills (1978)

	Plant capacity (MM ft² per year)					
	33.5				67.0	100.0
	Wood raw material					
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
	Press size					
Cost category	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
Facilities cost	11,955	13,148	12,278	13,470	17,160	21,803
Working capital	409	409	409	409	700	987
Total capital requirements	12,364	13,557	12,687	13,879	17,860	22,790

Table B-2.—Estimated facilities costs (M dollars) including pre-startup expenses for particleboard plants of different capacities in the Black Hills (1978)

	Plant capacity (MM ft² per year)					
	33.5				67.0	100.0
	Wood raw material					
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
	Press size					
Cost category	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
Building and site development	1,760	2,202	1,760	2,202	2,652	3,572
Equipment and installation	7,724	8,247	7,967	8,490	11,041	13,943
Engineering and construction management	755	827	786	858	1,070	1,325
Contingency allowance	661	724	687	750	937	1,160
Construction carrying interest and local sales tax on construction items	857	950	880	972	1,237	1,580
Pre-startup expenses	198	198	198	198	223	223
Total	11,955	13,148	12,278	13,470	17,160	21,803

Table B-3.—Estimated building, structures, site preparation, and land costs (dollars) for particleboard plants of different capacities in the Black Hills (1978)

Cost category	Plant capacity (MM ft^2 per year) 33.5		67.0	100.0
	Press size			
	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
Building area - square feet				
Raw material storage	14,000	14,000	16,000	20,000
Milling, drying, boiler	13.000	13,000	14,000	30,000
Blending and press line	30,000	40,000	40,000	45,000
Finishing and warehouse	31,000	45,000	62,000	87,000
Miscellaneous shops, offices, etc.	2,000	2,000	3,000	3,000
Total building area	90,000	114,000	135,000	185,000
Building costs - dollars				
Materials and labor[1]	1,430,000	1,802,000	2,137,000	2,912,000
Average cost per square foot	15.89	15.81	15.83	15.74
Site development - dollars				
Land purchase[2]	40,000	50,000	60,000	80,000
Site clearing and grading	50,000	60,000	85,000	100,000
Rail spur	20,000	30,000	40,000	60,000
Sewers and drainage	30,000	35,000	45,000	50,000
Fire loops, pumps, hydrants	75,000	90,000	110,000	130,000
Fire pond or tank	40,000	45,000	55,000	70,000
Roads and fencing	35,000	40,000	50,000	70,000
Miscellaneous outside slabs	20,000	30,000	45,000	70,000
Water well	20,000	20,000	25,000	30,000
Total site preparation	330,000	400,000	515,000	660,000
TOTAL BUILDING AND SITE	1,760,000	2,202,000	2,652,000	3,572,000

[1]*Prefabricated steel insulated buildings with slabs, footings, lighting, heating, sprinklers, and finishing.*
[2]*Land at $2000 per acre.*

Table B-4.—Estimated equipment and installation costs (M dollars) for particleboard plants of different capacities in the Black Hills (1978)

Equipment category	Plant capacity (MM ft² per year): 33.5				67.0	100.0
Wood raw material	75% Dry shavings, 25% Green sawdust		50% Dry shavings, 50% Green sawdust		46% Dry shavings, 54% Green sawdust	31% Dry shavings, 43% Green sawdust, 26% Green chips
Press size	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 9-foot 16-opening	5- × 18-foot 8-opening	5- × 18-foot 16-opening	5- × 18-foot 24-opening
Raw material receiving and storage	374	374	374	374	574	713
Milling and drying	1,069	1,069	1,207	1,207	1,809	2,629
Blending	451	451	451	451	583	701
Forming and pressing	3,005	3,395	3,005	3,395	4,195	5,305
Sanding and sawing	922	1,035	922	1,035	1,260	1,351
Boiler and fuel preparation	1,210	1,210	1,305	1,305	1,690	2,125
Auxiliary equipment	473	473	473	473	620	739
Subtotal processing equipment	7,504	8,007	7,737	8,240	10,731	13,563
Mobile equipment	70	70	70	70	110	140
Freight allowance	150	170	160	180	200	240
TOTAL EQUIPMENT AND INSTALLATION	7,724	8,247	7,967	8,490	11,041	13,943

Table B-5.—Estimated salaries (dollars) of key personnel during the pre-startup period for the 67.0- and 100.0-MM ft²-per-year particleboard plants in the Black Hills (1978)[1]

Key personnel	Pre-startup salary
General manager	66,000
Plant engineer	25,000
Plant superintendent	17,000
Technical director	14,000
Sales manager	14,000
Maintenance foreman	12,000
First shift foreman	9,000
Chief electrician	9,000
Chief millwright	9,000
Shift #1 key operators	32,000
Shift #2 key operators	16,000
Total	223,000

[1]*A total pre-startup cost of $198,000 for the 33.5-MM ft²-per-year plants excludes the salary of a plant engineer.*

Table B-6.—Estimated requirements for wood, chemicals, and electric power for particleboard plants of different capacities in the Black Hills

	Plant capacity (MM ft² per year)					
	33.5				67.0	100.0
	Wood raw material					
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
	Press size					
Requirement category	**5- × 9-foot 16-opening**	**5- × 18-foot 8-opening**	**5- × 9-foot 16-opening**	**5- × 18-foot 8-opening**	**5- × 18-foot 16-opening**	**5- × 18-foot 24-opening**
Daily production 325 days/year						
Thousand square feet (3/4-inch basis)	103.1	103.1	103.1	103.1	206.2	307.7
Thousand cubic meters[1] (m^3)	182.5	182.5	182.5	182.5	365.0	544.6
Tons[2]	141.8	141.8	141.8	141.8	283.5	423.1
Hourly production (22 hours/day)						
Square feet	4,686	4,686	4,686	4,686	9,373	13,986
Pounds	12,887	12,887	12,887	12,887	25,776	38,462
Wood requirements[3]						
Dry shavings						
Annual ovendry tons	39,948	39,948	26,633	26,633	49,004	49,290
Daily ovendry tons	122.92	122.92	81.95	81.95	150.78	151.66
Green sawdust						
Annual ovendry tons	13,316	13,316	26,633	26,633	57,526	68,370
Daily ovendry tons	40.97	40.97	81.95	81.95	177.00	210.37
Green chips						
Annual ovendry tons	—	—	—	—	—	41,340
Daily ovendry tons	—	—	—	—	—	127.2
Chemical requirements[4]						
Resin						
Annual (tons)	4,003	4,003	4,003	4,003	8,007	11,950
Daily (pounds)	24,641	24,641	24,641	24,641	49,274	73,540
Wax						
Annual (tons)	536	536	536	536	1,072	1,600
Daily (pounds)	3,299	3,299	3,299	3,299	6,598	9,846
Electrical power						
Connected horsepower	5,080	5,080	5,800	5,800	7,935	8,935
KW demand	2,450	2,450	2,780	2,780	3,800	4,280
Annual use megawatt hours	14,658	14,658	16,803	16,803	23,238	26,241
Daily use kilowatt hours	45,100	45,100	51,700	51,700	71,500	80,740

[1] 1,000 square feet of 3/4-inch board = 1.77 m^3.
[2] 1,000 square feet of 3/4-inch board = 1.375 tons.
[3] 1,000 square feet of 3/4-inch board requires 3,180 o.d. pounds of wood raw material.
[4] 1,000 square feet of 3/4-inch board requires 239 pounds of resin and 32 pounds of wax (7.0% resin and 0.9% wax content).

Table B-7.—Estimated availability and average cost of wood raw materials at Whitewood, S. Dak., and Newcastle, Wyo., from different sawmill locations in the Black Hills (1978)

	Plant capacity (MM ft² per year)							
	33.5				67.0		100.0	
	Wood raw material							
	75% Dry shavings 25% Green sawdust		50% Dry shavings 50% Green sawdust		46% Dry shavings 54% Green sawdust		31% Dry shavings 43% Green sawdust 26% Green chips	
	Particleboard plant location							
Sawmill location	Whitewood	Newcastle	Whitewood	Newcastle	Whitewood	Newcastle	Whitewood	Newcastle
	M o.d. tons							
Spearfish, S. Dak.	9.8	9.8	17.1	17.3	17.5	17.5	31.4	16.9
Hulett, Wyo.	5.6	5.6	—	—	11.8	11.8	23.1	23.1
Sturgis, S. Dak.	3.3	3.3	6.2	—	7.1	7.1	13.7	8.2
Piedmont, S. Dak.	8.4	8.4	16.2	—	17.7	17.7	20.8	20.8
Hill City, S. Dak.	8.0	8.0	—	14.0	14.1	14.1	13.4	26.4
Custer, S. Dak.	5.6	5.6	—	11.0	11.8	11.8	13.8	23.1
Newcastle, Wyo.	5.6	5.6	—	11.0	10.3	11.8	13.8	23.1
Whitewood, S. Dak.	7.0	7.0	13.8	—	16.2	14.7	29.0	17.4
Total	53.3	53.3	53.3	53.3	106.5	106.5	159.0	159.0
	dollars							
Average cost	8.48	11.47	5.67	9.31	8.49	11.46	11.00	13.37

Table B-8.—Estimated fuel requirements and sources for particleboard plants of different capacities in the Black Hills (1978)

Fuel requirement and source	Plant capacity (MM ft² per year) 33.5		67.0	100.0
	Wood raw material			
	75% Dry shavings 25% Green sawdust	50% Dry shavings 50% Green sawdust	46% Dry shavings 54% Green sawdust	31% Dry shavings 43% Green sawdust 26% Green chips
Requirements				
Process steam- (MM pounds[1])				
Annual	118	111	186	240
Daily	0.363	0.341	0.572	0.738
Wet dryers (MM Btu)				
Annual	50,700	101,075	218,725	416,650
Daily	156	311	673	1,282
Source				
Dry fuel from trim and dust generation- (o.d. tons[2])				
Annual	11,190	11,190	22,376	33,401
Daily	34.4	34.4	68.8	102.8
Bark-o.d. (tons equivalent[3])				
Annual	1,013	4,552	6,891	14,219
Daily	3.1	14.0	21.2	43.8
Hot stack gases (MM Btu)				
Annual	16,800	15,372	25,955	31,532
Daily	52	47	80	97
Natural gas (MM ft³)[4]				
Annual	9	42	68	139
Daily	.028	.129	.209	.428

[1]*One pound of steam = 1,333 Btu's.*
[2]*One ton of dry fuel from trim and dust = 16 million Btu's.*
[3]*One dry ton equivalent of wet bark = 12 million Btu's, assuming 75% of heat is recoverable as compared to dry fuel.*
[4]*Natural gas will only be used as a standby fuel. One cubic foot of natural gas = 1,000 Btu's.*

Table B-9.—Estimated employment (number of full-time equivalent jobs) for particleboard plants of different capacities (gross MM ft² per year) in the Black Hills

Type of job	Plant capacity 33.5	67.0	100.0
Manufacturing[1]			
Skilled	42	63	75
Unskilled	8	12	14
Maintenance and repair[2]	9	11	15
Administration and sales[3]	14	18	22
Total	73	104	126

[1]*Included in processing labor costs in the discounted cash flow analysis (DCFA) program.*
[2]*Included in factory overhead costs in the DCFA program.*
[3]*Included in administrative overhead costs in the DCFA program.*

Table B-10.—Estimated factory and administrative overhead costs (dollars) for particleboard plants of different capacities (gross MM ft² per year) in the Black Hills

	Plant capacity		
Overhead costs	**33.5**	**67.0**	**100.0**
Factory overhead			
Operating and maintenance supplies	$284,750	$536,000	$ 800,000
Maintenance labor	144,000	176,000	240,000
Total	428,750	712,000	1,040,000
Administrative overhead			
Salaries and payroll[1]	224,000	288,000	352,000
Office maintenance and travel expense	80,000	120,000	140,000
Insurance and taxes	150,000	234,500	300,000
Total	454,750	642,500	792,000

[1]*Including sales personnel salaries.*

Table B-11.—Depreciation (dollars) for a 100.0 MM ft² per year facility

	Year						
Capital assets	**[1]0**	**1**	**2**	**3**	**4**	**5**	**6-10**
Land	80,000			(Nondepreciable)			
Site preparation[2]	580,000	29,000	29,000	29,000	29,000	29,000	29,000
Buildings[3]	2,912,000	64,711	64,711	64,711	64,711	64,711	64,711
Process machinery[4]	13,800,000	2,484,000	1,987,200	1,589,760	1,271,810	1,017,450	813,950
Mobile equipment[5]							
1st 5 years	143,000	25,740	25,740	25,740	25,740	25,740	—
2nd 5 years	—	—	—	—	—	182,000	32,760
Miscellaneous[6]	4,288,000	378,720	378,720	378,720	378,720	378,720	378,720
Total	21,803,000	2,982,171	2,485,371	2,087,931	1,769,981	1,515,621	1,319,141

[1]*Values at time zero are costs of capital assets.*
[2]*Straight line depreciation over 20 years with no salvage value.*
[3]*Straight line depreciation over 45 years with no salvage value.*
[4]*Double declining depreciation over first 5 years, straight line over 6-10 years with salvage value 10% of initial cost.*
[5]*Straight line depreciation over 5 years with salvage value of 10% of original cost.*
[6]*Straight line depreciation over 10 years with salvage value of 12% of original cost.*

Table B-12.—Financial summary from the discounted cash flow analysis program with yearly unit sales (M ft², 3/4-inch basis), break-even prices, costs, depreciation, profits, earnings, and cash flow (dollars) for the 100 MM ft² particleboard facility in the Black Hills (1978)[1]

Year-end financial values	Year 1	2	3	4	5	6	7	8	9	10
Unit sales	46,700	98,800	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Unit price per M ft²	173.46	182.13	191.24	200.80	210.84	221.39	232.45	244.08	256.28	269.10
Gross sales	8,100,645	17,994,881	19,124,114	20,080,320	21,084,336	22,138,553	23,245,480	24,407,754	25,628,142	26,909,549
Interest income or expense	0	0	0	0	0	0	0	0	0	0
Gross revenue	8,100,645	17,994,881	19,124,114	20,080,320	21,084,336	22,138,553	23,245,480	24,407,754	25,628,142	26,909,549
Raw material cost	2,987,866	6,637,285	7,053,795	7,406,485	7,776,809	8,165,649	8,573,932	9,002,629	9,452,760	9,925,398
Processing labor	1,097,904	1,495,200	1,569,960	1,648,458	1,730,881	1,817,425	1,908,296	2,003,711	2,103,897	2,209,091
Selling expense	810,065	1,799,488	1,912,411	2,008,032	2,108,434	2,213,855	2,324,548	2,440,775	2,562,814	2,690,955
Total variable cost	4,895,835	9,931,973	10,536,166	11,062,975	11,616,123	12.196,930	12,806,776	13,447,115	14,119,471	14,825,444
Variable cost per M ft²	104.84	100.53	105.36	110.63	116.16	121.97	128.07	134.47	141.19	148.25
Profit contribution	3,204,811	8,062,907	8,587,948	9,017,345	9,468,212	9,941,623	10,438,704	10,960,639	11,508,671	12,084,105
Administrative overhead	792,000	831,600	873,108	916,839	962,681	1,010,815	1,061,356	1,114,424	1,170,145	1,228,652
Factory overhead	1,046,544	1,098,871	1,153,815	1,211,505	1,272,081	1,335,685	1,402,469	1,472,593	1,546,222	1,623,533
Total fixed cost	1,838,544	1,930,471	2,026,995	2,128,344	2,234,762	2,346,500	2,463,825	2,587,016	2,716,367	2,852,185
Facilities cost	0	0	0	0	182,000	0	0	0	0	−4,548,220
Working capital	689,912	97,985	88,774	93,213	97,873	102,767	107,905	113,301	118,966	−2,498,279
Investment	689,912	97,985	88,774	93,213	279,873	102,767	107,905	113,301	118,966	−7,046,499
Depreciation	2,982,171	2,485,371	2,087,931	1,769,981	1,515,621	1,319,141	1,319,141	1,319,141	1,319,141	1,319,141
After tax profit	−840,270	3,290,774	2,325,971	2,661,890	2,973,271	3,263,511	3,460,984	3,668,331	3,886,045	4,114,645
After tax earnings	2,141,901	5,776,145	4,413,902	4,431,871	4,488,892	4,582,652	4,780,125	4,987,472	5,205,186	5,433,786
After tax net cash flow	1,451,989	5,678,160	4,325,128	4,338,658	4,209,019	4,479,885	4,672,220	4,874,171	5,086,220	12,480,285
Accumulated net cash flow	−21,338.6M	−15,660.4M	−11,335.3M	−6,996.6M	−2,787.6M	1,692,3M	6,364.5M	11,238.6M	16,324.9M	28,805.2M

[1]*The program calculated variable costs to be 0.5531, fixed costs 0.1944, taxes 0.1145, and after tax profits 0.1380 of total sales during the 10-year period. The internal rate of return was 15%.*

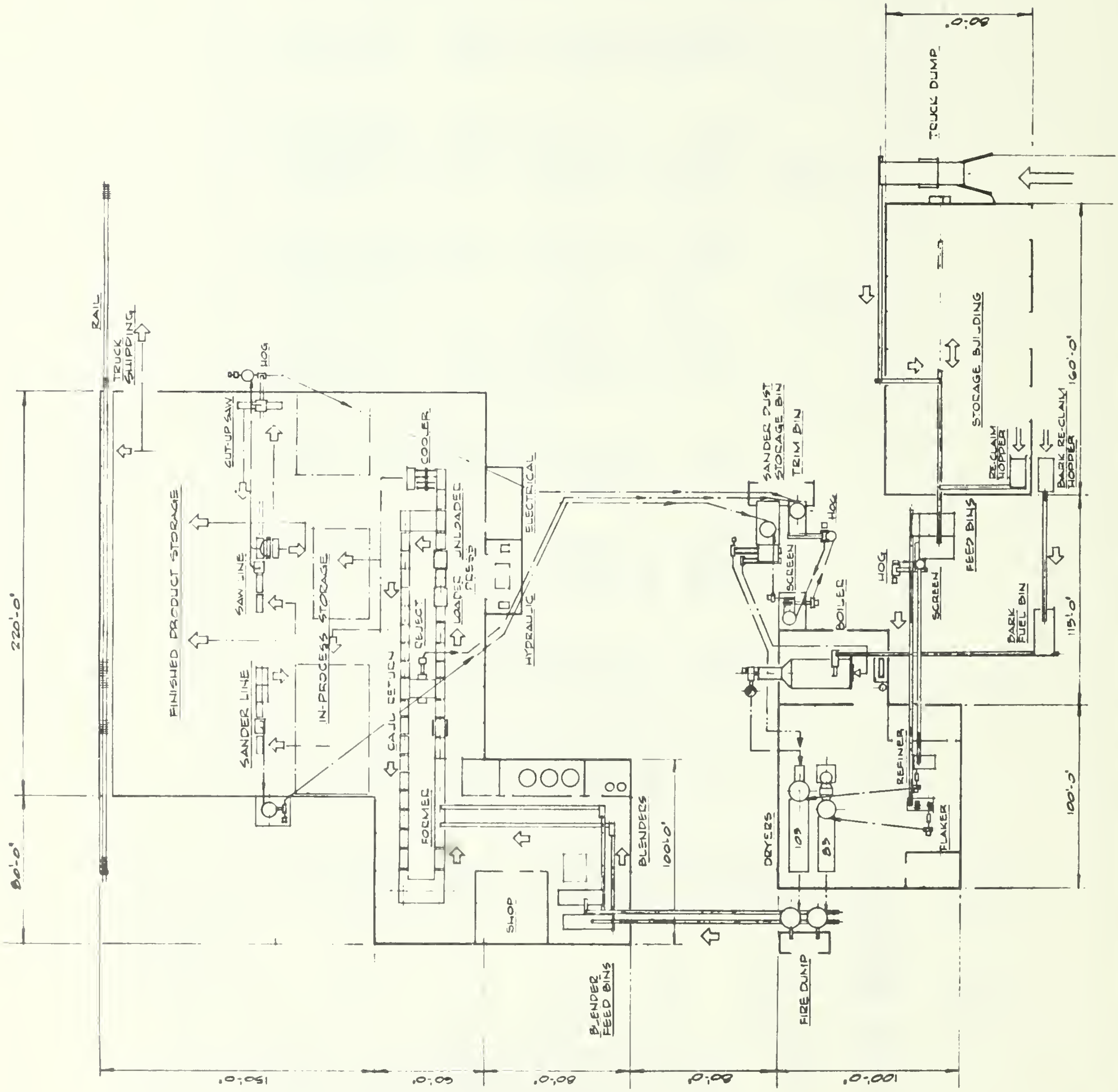

Figure B-1.—Plant and equipment layout for a 33.5-MM ft², 3/4-in-basis particleboard facility in the Black Hills.

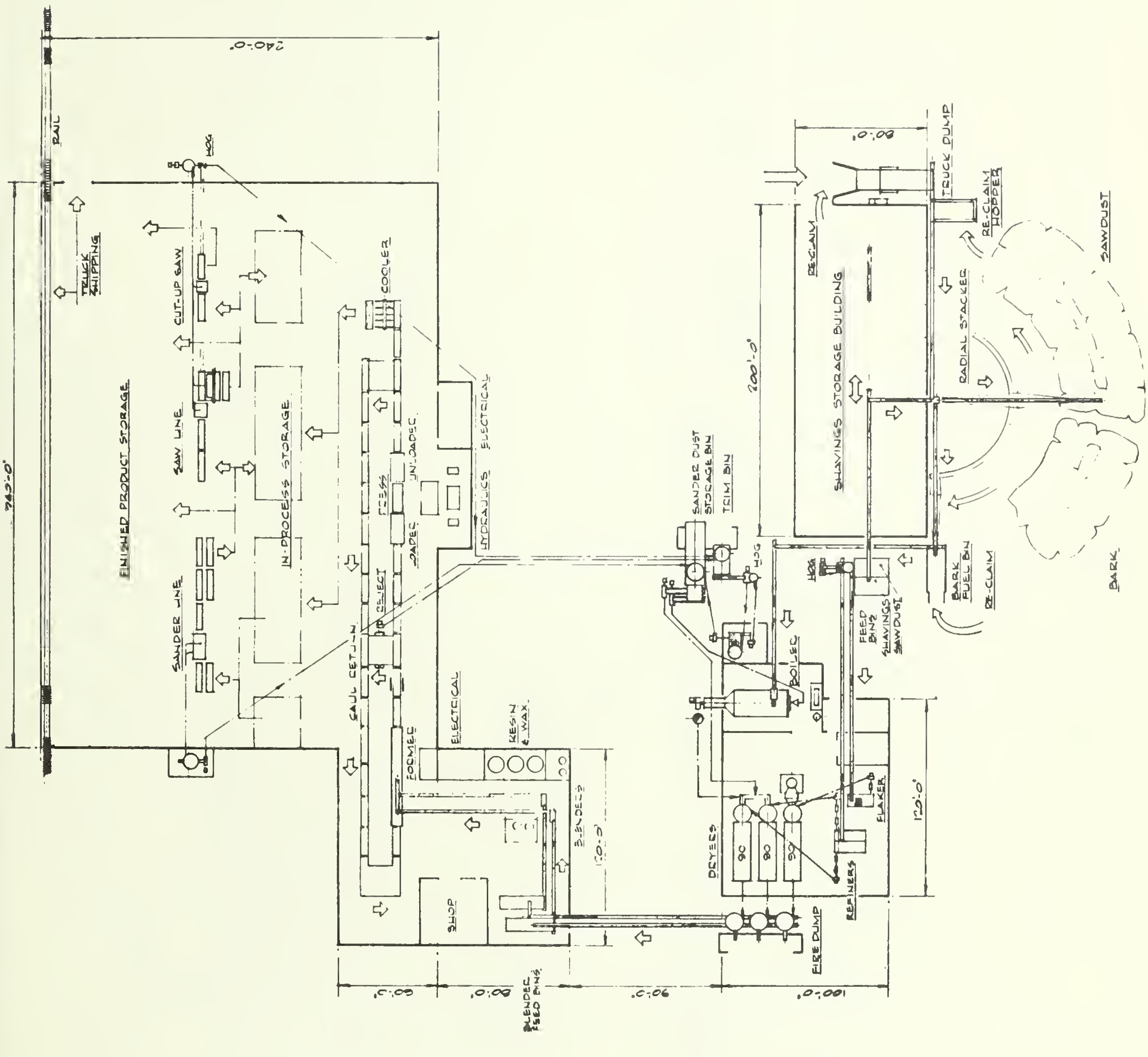

Figure B-2.—Plant and equipment layout for a 67.0-MM ft², 3/4-in-basis particleboard facility in the Black Hills.

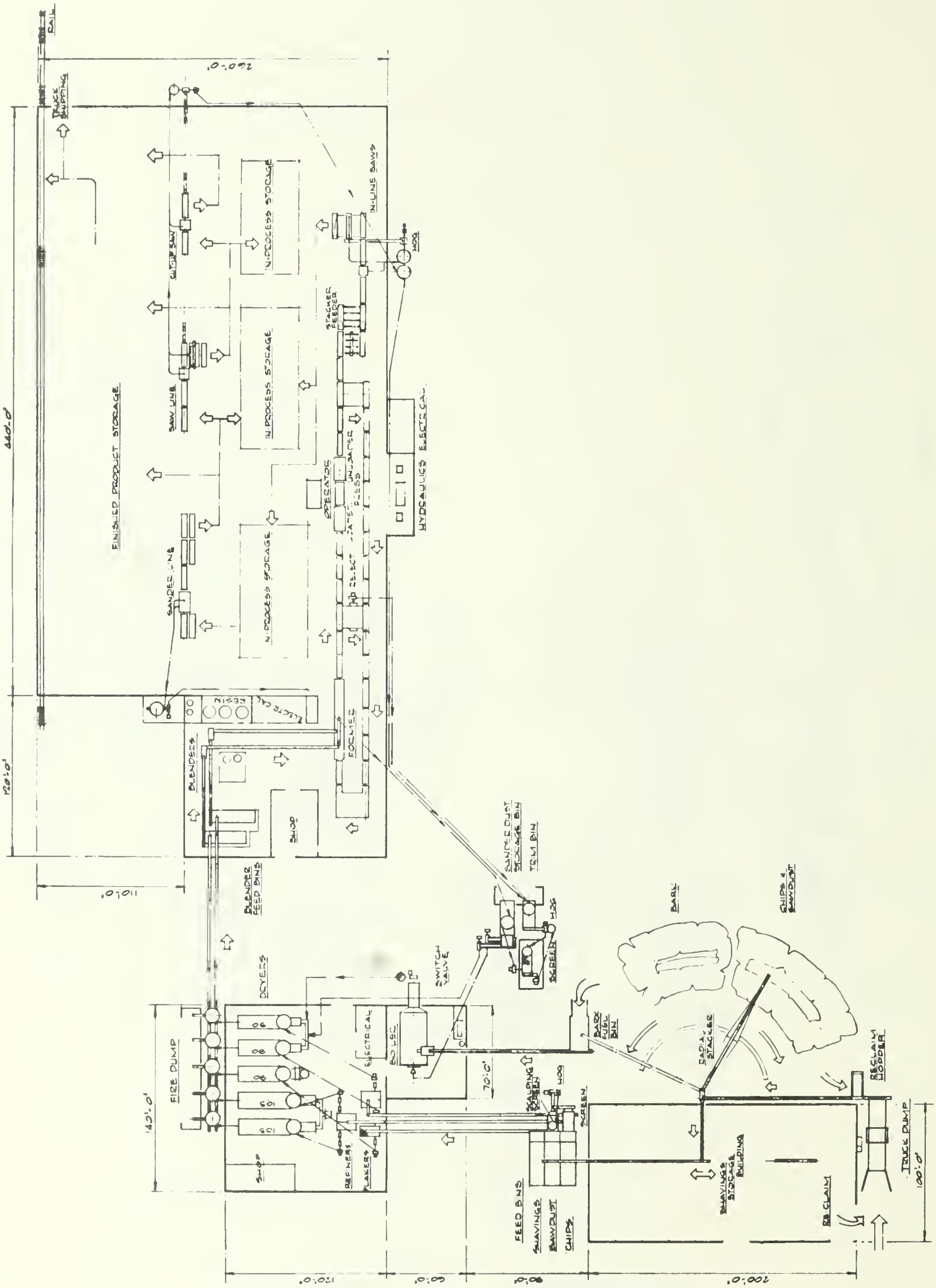

Figure B-3.—Plant and equipment layout for a 100.0-MM ft², 3/4-in-basis particleboard facility in the Black Hills.

Markstrom, Donald C. and Harold E. Worth. 1981. Economic potentials for particleboard production in the Black Hills. USDA Forest Service Resource Bulletin RM-5, 30 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area.

Keywords: Particleboard, forest products, *Pinus ponderosa*

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Wood Product Flows and Market Structure in the Rocky Mountain States

Dennis M. Donnelly
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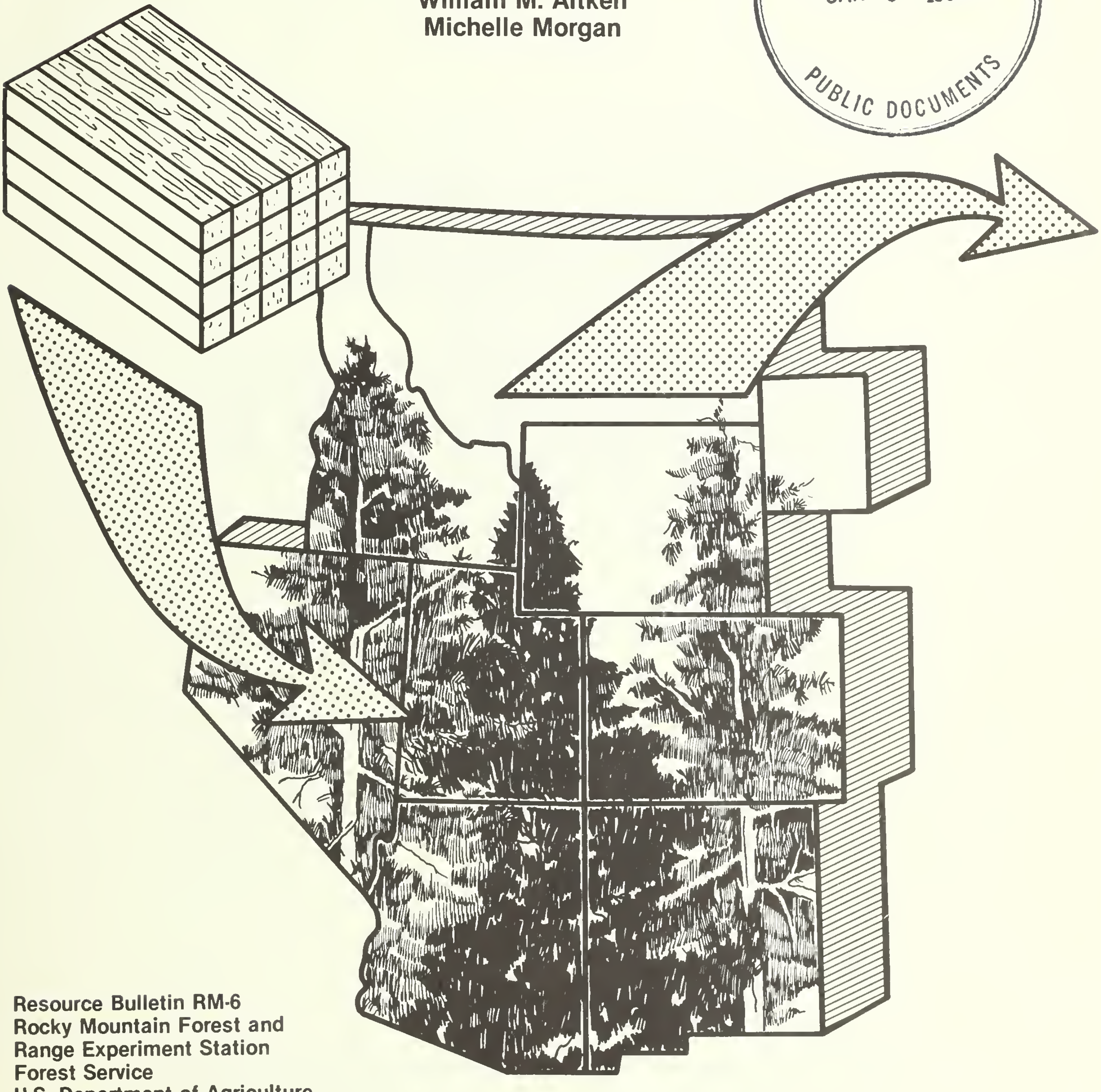
Michelle Morgan



Resource Bulletin RM-6
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Range Experiment Station
Forest Service
U.S. Department of Agriculture

Donnelly, Dennis M., Harold E. Worth, Ronald W. Hasty, William M. Aitken, and Michelle Morgan. 1983. Wood product flows and market structure in the Rocky Mountain states for manufactured wood products. USDA Forest Service Resource Bulletin RM-6, 15 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Central and southern Rocky Mountain states have enough harvestable timber to supply their own needs for many lumber classes, and potentially, for products such as plywood and particleboard. However, wood products continue to be imported in large volumes. Market channels, perceived quality differences, and relatively less product variety available locally contribute to this situation.

Keywords: Wood products, forest products, markets, product distribution

USDA Forest Service
Resource Bulletin RM-6

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Wood Product Flows and Market Structure in the Rocky Mountain States

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Contents

	Page
MANAGEMENT IMPLICATIONS	1
INTRODUCTION	2
METHODS	2
VOLUME ESTIMATES	2
Lumber	3
Plywood	4
Posts and Poles	4
Pulp and Pulpwood	5
MARKET STRUCTURE	5
RESULTS	6
PRODUCT FLOWS	6
MARKET STRUCTURE	6
Channels of Distribution	6
Within CSRM States	6
Imports to CSRM States	7
Exports From CSRM States	7
Local Product Interaction with the Market	7
Mills	7
The Market Channel	7
DISCUSSION	9
PRODUCT FLOWS	9
Lumber	9
Plywood	9
Posts and Poles	10
Pulp and Pulpwood	10
MARKET STRUCTURE	11
CONCLUSIONS	11
LITERATURE CITED	13
APPENDIX	15

Wood Product Flows and Market Structure in the Rocky Mountain States

Dennis M. Donnelly, Harold E. Worth, Ronald W. Hasty, William M. Aitken, and Michelle Morgan

MANAGEMENT IMPLICATIONS

Forest resources of the Rocky Mountain states (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, South Dakota, Utah, and Wyoming) can be managed for a desired mix of multiple-use benefits only if there are economically viable opportunities for marketing the logs from timber harvest. At present (early 1983), such opportunities are limited.

Generally adverse economic circumstances in the national economy affect the timber industry. Also, disproportionately higher costs of harvesting and processing timber in the Rocky Mountains increase the economic risk of producing timber products in this region. Under these circumstances, the most feasible approach to improve timber utilization and marketing is to upgrade the value of existing products or to provide new higher value products. This has been successful in the Rocky Mountain states in several isolated instances. However, Rocky Mountain timber processors generally either depend on economies of scale in producing commodity products that are sold in highly competitive markets, or they produce small quantities of rough cut products sold in local markets as specialty items.

The study reported here indicated that expansion and diversification of outlets for Rocky Mountain timber could support needed resource management. However, to achieve a suitable relationship would require not only an increase in traditional production, but development of valuable new products as well. One approach in areas where large diversified firms are not typical would be to develop more secondary manufacturing operations that have potential for creating higher product values. Another possibility, that would take advantage of the region's expected growth in residential, commercial, and industrial construction,[4] is to concentrate on specialty products, for which market competition may be less severe. For example, ponderosa pine is well-suited for furniture, cabinets, or other products where "workability" is important. In addition, the relative ease of treating ponderosa pine with wood preservatives makes this species ideal for wood foundations, posts, and poles. Because of possible increases in underground mining in some Rocky Mountain states, mining requirements for timbers may offer a new area of expansion.[5,6] Composite panel products and laminated lumber products have been suggested as potential ways of increasing production and market penetration.[4] A recently completed study (Markstrom and Worth 1981) underscores favorable prospects for particleboard production in the Black Hills. Demand for firewood in the region is expected to continue to increase in the near future, providing additional outlets for small roundwood.

The region's forest products firms, especially small and medium sized operations, might strengthen their competitive position by considering the following marketing strategies:

1. Identify markets for, and produce, specialty products for which market volumes and prices are less volatile and for which local species can compete economically with imported products.
2. Gain expertise in direct marketing of products to retailers or industrial users, so that Central and Southern Rocky Mountain (CSRM) producers may advantageously ship their products to eastern markets.
3. Establish cooperative marketing strategies to offer more complete, good quality product lines.
4. Inform customers and others about the uses and advantages of CSRM products.

This bulletin describes what is known about forest product flows into, within, and out of the Rocky Mountain states. "Hard" data on flows are scarce, and filling in the gaps is an extremely costly and time-consuming task—an analysis that is beyond the scope of the resources available here. Given these limitations, and considering the importance of starting an analysis on this subject, it was decided to organize the available data to portray product flows as well as possible. Then product flows were estimated using projection, extrapolation, or ratio techniques, where it would enhance the understanding of flow patterns. Readers are cautioned that individual estimates should be used with awareness of their limitations, considering that data from most sources could not be verified and that some of the estimating procedures were subjective.

[4] *Brenner, R. N. et al. (1977). Production and marketing strategies for utilizing beetle-killed and associated Front Range timber. Department of Forest and Wood Sciences, Colorado State University, Fort Collins. [Unpublished report.]*

[5] *Smego, J., and D. R. Betters. (1979). Production and marketing alternatives for utilizing lodgepole pine in Colorado and Wyoming. Colorado State University Project No. 31-1470-2219, Department of Forest and Wood Sciences, Fort Collins. [Unpublished report.]*

[6] *However, timbers are in competition with other support materials such as steel rock bolts and even cinder blocks. Steel rock bolts apparently have a lower cost installed and offer less restriction to in-mine air flow. In addition, where wood is used in the central Rocky Mountain area, many "hard rock" mines use timbers of interior Douglas-fir from Idaho. Personal communication, April 8, 1982, from J. A. Fullenwider, State and Private Forestry, Rocky Mountain Region, USDA Forest Service, Lakewood, Colo.*

INTRODUCTION

Among the several reasons for owners and custodians of forest land to harvest timber, two are dominant for the central and southern Rocky Mountain states (CSRM).[7] First, harvesting trees is the primary means of manipulating forest vegetation to maintain or increase the multiple benefits from forest resources. Second, harvested timber provides raw material for industrial activity that helps meet national product requirements.

Timber harvesting is a significant element in the region's social and economic health and need not conflict with other environmental goals. However, to avoid damage to the region's sensitive ecosystems, timber harvesting must be carefully planned and executed. The higher costs associated with such harvesting are a challenge to economic operation, and ways must be found to cover these higher operating costs. The kinds of products produced, the efficiency with which they are produced and marketed, and the availability, and suitability of raw materials are the keys to economic wood product manufacture and to the future of forest land management in the Rocky Mountains.

Appropriate markets for manufactured wood products are essential to timber harvesting. Local markets in the CSRM states are presently served by a mix of locally produced and imported products. A common misperception about timber products manufactured in the Rocky Mountain states, especially lumber, is that they cannot compete on a quality basis with products manufactured in other western regions. The result is that numerous markets in the Rocky Mountain states, for a wide range of product types and grades, continue to be filled by imported products, even though local products could meet required performance standards. At the same time, significant volumes of timber products manufactured in the Rocky Mountains are exported to other regions.

There is a lack of current basic information related to forest product flows within the region although various aspects of marketing and production in the Rocky Mountain states have been analyzed and reported (Hutchison 1957, Williams 1964, Adair 1966, Wilson and Spencer 1967, Williams 1967, Yerkes et al. 1968, Setzer and Wilson 1970, Keegan 1980, Godfrey et al. 1980). Other forest product flow studies (Holland and Judge 1963, Bruce 1969) include information that covers more than the Rocky Mountain states. However, volumes of forest products, principally plywood and lumber, that are now produced and consumed may have changed significantly because of reductions in the number of active mills in the study region and because of major increases in regional population. Very little is known, and even less has been published, about these changes.

Information concerning local demand for products, by type and grade, would be especially helpful. For example, are exported products essentially different from imported ones? Are the region's products limited to production of lower grade, lower values types of products? Information about these topics and the reasons behind the current regional import/export balance would help to determine whether better use can be made of the region's timber resources.

The purpose of this study was to gather and organize available information about the volume of timber products moving into, through, and out of the Rocky Mountain states. Although many different kinds of wood products are consumed in the CSRM states, this study dealt primarily with major products that either are produced locally or are consumed in large volumes, such as lumber, plywood, posts and poles, and pulpwood. In addition to product volume, distribution of lumber and panel products in the CSRM states was investigated also.

Specific objectives of this study were (1) to estimate the volume of major timber products produced in, consumed in, imported into, and exported from the Rocky Mountain states, and (2) to describe the market structure for major softwood products in the CSRM states and to evaluate how local products fit this market structure.

METHODS

VOLUME ESTIMATES[8]

Wood product quantity estimates were based on a variety of secondary data sources, including published industry data, census reports, transportation statistics, etc. Because of the differing nature and quality of data sources, rigorous statistical analysis was not possible. Estimates given represent a summary of what is available from secondary sources, augmented by further projections and interpolations.

The major products considered were lumber, plywood, pulp, posts, and poles. The year 1976 was used as a base. Data were most readily available for those products and that year.

Figure 1 shows the basic conceptual relationships for lumber. Forest industries in the Rocky Mountain states, however, produce a wide variety of products from local species.[9] Each product may have one or more grades based on species, strength, appearance, and other technical wood properties. Product flow concepts for these other products are similar to those for lumber.

In this study, end uses were separated geographically into two categories—the Rocky Mountain states and elsewhere. Thus, products manufactured in the Rocky

[7] *In this report, the states of Arizona, New Mexico, Colorado, Wyoming, and the western portion of South Dakota are called the Central and Southern Rocky Mountain (CSRM) area.*

[8] *The reader should be aware that the geographic scope and method for the first objective differs from that for the second. For objective 1, available data and the desire for a sufficient scope pointed to inclusion of all Rocky Mountain states. For the second objective, however, forest type, available transportation, population distribution, and available resources indicated a somewhat more narrow scope—the central and southern Rocky Mountains.*

[9] *Predominant species are lodgepole and ponderosa pines and Engelmann spruce. To a lesser degree, other species are Douglas-fir (Inland), subalpine fir, and aspen.*

Mountain states either are consumed within the Rocky Mountain states or shipped outside the local area. Manufacturers from outside the Rocky Mountain states also ship products into the Rocky Mountain states.

Aggregated information on product volumes shipped into and shipped out of the region are not necessarily useful for product flow analysis. It is more important to analyze such shipments by product type and/or grade. For example, such analysis may reveal that certain products imported into the Rocky Mountain states are not generally available from local production.

Although this idea of product accounting is straightforward, collecting data for empirical analysis is difficult. Government agencies generally do not maintain consistent data series on regional flows of forest products. Industry trade associations sometimes publish or may be willing to share statistical data on product shipments, by region. The lumber and plywood industries have some relevant regional data, for example, but for other products, no such industry data exist.

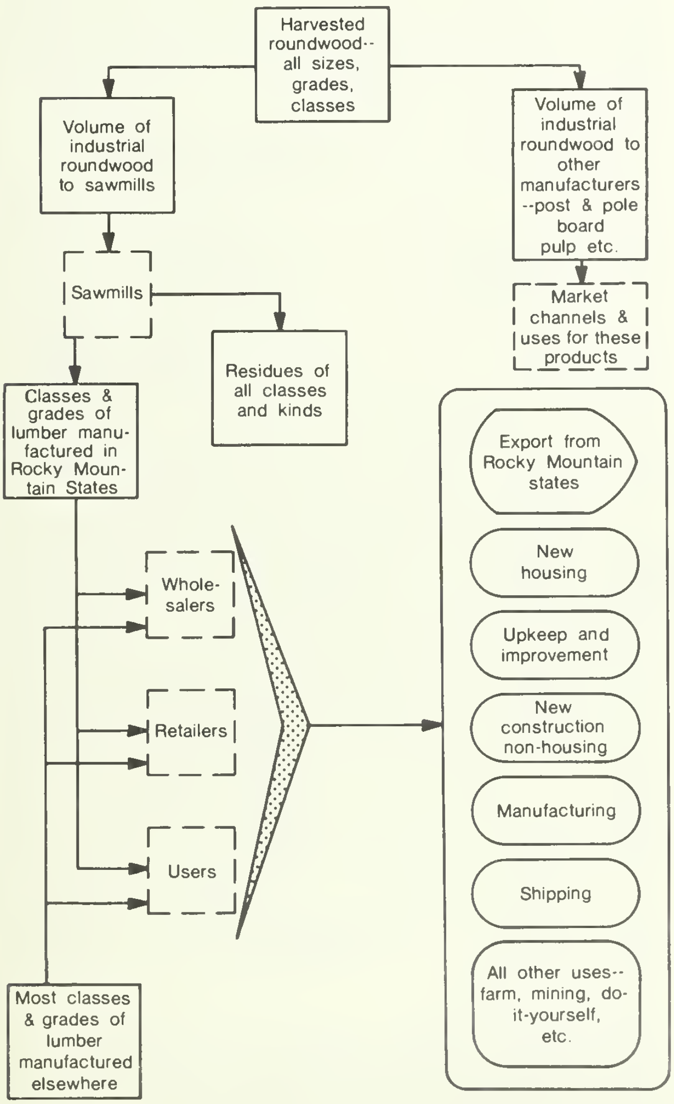

Figure 1.—How wood products flow through market channels.

Lumber

Production figures for lumber were available from a variety of sources (U.S. Department of Commerce 1977, Western Wood Products Association 1977). Consumption figures were calculated for each major use category using the methods of derivation described below.

New housing.—Separate figures were derived from existing information on volumes of lumber consumed in the four major classes of new housing, i.e., single family structures (USDA Forest Service 1970), two-unit structures (USDA Forest Service 1973), multi-unit structures (Wright and Reid 1972), and mobile homes (Dickerhoof 1978). By multiplying the per-unit consumption figure by the number of construction starts in each particular class (National Association of Home Builders 1978), total lumber use in that particular consumption category was estimated for the study region.

Manufacturing.—Lumber consumed in this category was estimated by taking the region's percentage of total United States value of shipments in the manufacturing industry (U.S. Bureau of the Census 1974a) and multiplying it by the figure for total volume of wood consumed nationally in the manufacturing industry (USDA Forest Service 1973).

Shipping.—The lumber consumption of this industry was estimated by the same procedure and from the same sources as used for the manufacturing industry.

New nonresidential construction.—The total volume of lumber consumed in the United States for new nonresidential construction (U.S. Department of Agriculture 1980) was multiplied by the region's percentage of total United states value of construction contracts (U.S. Bureau of the Census 1977a).

Residential upkeep and improvement.—Volume of lumber consumed in the Rocky Mountain area in this category was estimated by calculating the average number of persons per housing unit in the West and dividing the population of each state in the Rocky Mountain area (U.S. Bureau of the Census 1977b) by this figure. This procedure provides the estimated number of housing units in the Rocky Mountain area. The total volume of lumber consumed in residential upkeep and improvements (U.S. Department of Agriculture 1980) for the United States was multiplied by the percentage of residential housing in the study region to give a figure for lumber consumed in the study region.

All other uses.[10]—The total volume of lumber consumed in the United States in this category has been estimated by others (U.S. Department of Agriculture 1980), as has the total U.S. volume of lumber consumption for all U.S. consumption categories (U.S. Department of Agriculture 1980). The "all other uses" consumption in the U.S. can be expressed as a percentage of total U.S. lumber consumption in all categories. A total figure for lumber consumption in "all other uses" was estimated for the study region by assuming that the

[10]*All other uses include upkeep and improvement of nonresidential buildings and structures; mining; made-at-home projects, such as furniture and boats; made-on-the-job items, such as advertising and display structures; and a wide variety of other miscellaneous products and uses.*

Rocky Mountain region's percentage of "all other uses" lumber consumption, in relation to total CSRM lumber consumption, is the same as the national percentage.

Plywood

Softwood plywood production figures for the study region, available from two different sources (American Plywood Association 1977, Forest Industries 1977), were compared. Figures provided by the American Plywood Association (APA) (1977) represent shipment volumes for the Inland Region. The geographical boundaries for this region include the Rocky Mountain area and that portion of Washington and Oregon east of the Cascade Mountains. Because this latter area was not included in the Rocky Mountain study area boundaries, it was necessary to subtract the volume of softwood plywood produced in Washington and Oregon from the total volume given by the APA for the Inland Region to estimate production figures for the study region. The total shipment volume shown in the APA data differed substantially from the volume found by summing individual mill production volumes reported in Forest Industries (1977). This difference probably can be explained by the fact that APA can assess only the production of its member companies and must estimate production of nonmember mills. In contrast, Forest Industries questioned all individual mills. These figures may represent capacity instead of volume produced. The individual mill totals reported in Forest Industries (1977) were totalled in this analysis, because they were theoretically more complete. However, the data gathered by APA for their member mills may be more accurate for that segment of the industry.

Data to quantify volumes of softwood plywood imported into and exported from the study region were sketchy and hard to find. The 1972 Census of Transportation (U.S. Bureau of the Census 1974b) was not applicable because data were reported for regions whose boundaries did not conform to boundaries of the study region. In addition, forest products volumes were aggregated for groups that included several different products. Census figures for plywood were combined with millwork and prefabricated wood products, making the data inappropriate for estimating local plywood import and export totals. The APA's Geographical Analysis of Plywood Shipments (1977) provided reliable information for their member companies' shipments originally destined for the study region, but did not track shipments that were later diverted to destinations outside the study region, nor did it cover nonmember producers. To the extent that this occurred, volumes shipped to the region according to APA data would not equal the plywood consumed in the region. Therefore, the method and sources for calculating softwood plywood consumption were the same as described previously for lumber consumption.

Posts and Poles

Production figures on volumes of timber harvested for posts and poles (P&P) are available for 1976 from the USDA Forest Service for national forest (NF) lands.[11] Because similar production figures were not available for other commercial forest lands, estimates were derived by assuming that cutting patterns for all commercial forest lands were similar to those for national forests.[12] Thus, in order to estimate timber volume cut for posts and poles from all forest lands, the relationship between ratios of post and pole volume cut and acres of commercial forestland was used (U.S. Department of Agriculture 1980),

$$\frac{\text{Timber volume cut, P\&P, NF land}}{\text{Timber volume cut, P\&P, All forest land}} = \frac{\text{NF commercial timberland area}}{\text{All commercial timberland area}}$$

No allowance was made for timber harvested for poles that proved unsuitable during processing.

Post and pole consumption data for the study region were derived by multiplying the total acreage of farmland in the region (U.S. Bureau of the Census 1976) by the average post and pole consumption per acre in Colorado (Betters et al. 1977). The estimates derived were further subdivided into utility poles, barn poles, fence posts, and corral poles.

Product	**Volume consumed** *cubic feet*
Utility poles	2,302,629.6
Barn poles	530,956.2
Corral poles	1,241,384.8
Fence posts	2,824,776.2

This procedure assumes post and pole consumption per state was directly related to total farm acreage within that state but not related to average acreage per farm. It also assumes that there are no intraregional differences in the consumption of wood posts and poles.

The approach to estimating consumption of posts and poles could be much improved if data were available explicitly for each of the four classes of product noted previously. Consumption within each of the product classes responds to driving forces that are not comparable among all classes. Ideally, each class should be treated differently throughout the estimation procedure. For example, consumption of utility poles is hypothetically a direct function of population density and only indirectly a function of agricultural acreage. Further, agricultural consumption of fence posts varies by type of farm. Ranches would tend to use less posts per acre than would crop-livestock farms. Farms producing only field crops may likely tend to use even fewer posts per acre, regardless of size. In any case, data are not generally available from secondary sources to support this type of analysis.

[11] *Each Regional office of the USDA Forest Service issues quarterly reports titled, "Timber Cut and Sold, File No. 2490."*

[12] *We recognize this assumption may not be tenable. On the other hand, there is no evidence of which we are aware that indicates any other scenario. Estimates of production of posts and poles, indeed all forest products, would be useful research.*

No data were found on imports and exports of wood posts and poles from CSRM states to adjoining states. However, some Colorado respondents in at least one survey (Betters, et al. 1977) indicated that fence posts they acquired came from contiguous neighboring states including Oklahoma but excluding Utah, and from South Dakota, Idaho, and Montana. There may be a significant flow of fence posts between neighboring states within the Rocky Mountain area and to states in the Great Plains and western Midwest, but these flows, if they exist, are not discernible from existing secondary data.

Pulp and Pulpwood

The total volume of paper and board produced within the study region was calculated from published mill capacities and pulp production figures available for the three mills in the Rocky Mountain region (Pulp and Paper 1977). Volumes of wood (solid wood equivalent) necessary for the production of this volume of pulp were calculated using standard pulp conversion factors for the major western tree species[13] (Hartman et al. [no date]). Data about timber volumes cut for pulpwood production in the study region, for 1976, were available only for national forest lands.[11] To derive a figure for timber cut on all commercial forest land, it was necessary to make the gross assumption, as was done for posts and poles, that cutting patterns were similar for national forests and all other lands. A total figure for timber cut for pulpwood was found by computing the ratio of national forest commercial timberland to total commercial timberland (U.S. Department of Agriculture 1980) and then equating this figure to the ratio between timber cut for pulpwood on national forest land[11] and timber cut for pulpwood from all Rocky Mountain commercial forest land.

[13]*Interior Douglas-fir, ponderosa pine, western white pine, and western red cedar.*

Regional consumption figures for paper and board were derived by multiplying per capita consumption figures (Pulp and Paper 1977) by the population in each of the Rocky Mountain study states for 1976 (U.S. Bureau of the Census 1976). The volume of pulp products consumed in the Rocky Mountain region for 1976 was estimated by multiplying regional population (U.S. Bureau of the Census 1976) by the per capita consumption of pulp products in the United States for 1976 (U.S. Bureau of the Census 1977a). No export data were readily available for pulpwood. Import data were available for pulp and pulp mill products for 1972 (U.S. Bureau of the Census 1974a), but not for 1976.

MARKET STRUCTURE

Details of research to describe and evaluate market structure are described by Hasty et al.[14] After examining available secondary sources, they determined that primary data collection would be the most efficient method of obtaining the needed information.

Therefore, they collected information from as many firms as possible within forest products industry in the central and southern Rocky Mountains (Table 1). Data were obtained for major products moving into, through, and out of the CSRM states. Hasty and his associates focused on lumber and millwork, but particleboard and

[14]*Hasty, Ronald W., Michelle Morgan, and Ellen Sheeley. 1981. The market structure for major softwood products in the central and southern Rocky Mountain area. 81 p. Department of Marketing, Colorado State University. [Unpublished Report.]*

Table 1.—Description of the sample

Type of firm	Number of firms located	Number of inquiries mailed	Number of undelivered inquiries	Number of usable returns	Percent usable returns
Lumber Mills	242	242	31	46	21.8
Wholesalers	209	209	20	53	28.0
Retailers					
Lumber	310	260	[3]9	59	[3]25.6
Home Center	26	26		12	
Users					
Contractors[1]		100		17	
Building Material	87	87	[3]22	22	[3]21.9
Other	[2]76	76		14	

[1]*The number of contractors listed in various directories are in the hundreds. Hasty chose the sample to represent population proportions by state.*
[2]*Other users are defined as furniture manufacturers, cabinet manufacturers, pallet and crate manufacturers, and any miscellaneous responses.*
[3]*From both categories.*

plywood were also covered. The geographic area surveyed was western South Dakota, Wyoming, Colorado, New Mexico, and Arizona. Montana, Idaho, Nevada, and Utah, included in the analysis for volume estimates, were not considered here. Their inquiries were concerned with the attitudes toward CSRM wood products expressed by respondents in the major market distribution channels for these products.

RESULTS

PRODUCT FLOWS

These findings represent overall product flows as they were in 1976, based on estimates from available secondary data and such additional estimates as described. Detailed figures for lumber production and consumption, plywood consumption, post and pole consumption, and mill residues are shown in tables A-1 through A-5.

Table 2 shows the overall results of the product flow part of the study. This table covers lumber, plywood, and posts and poles. Pulp and paper is dealt with separately for reasons explained later. For each commodity, the volume produced plus the volume imported represents the total volume available for use in the Rocky Mountain states. This volume is reduced by the volume consumed plus the volume exported from the Rocky Mountain states.

In theory, there should be no surplus or deficit resulting from these calculations if all volumes are accountable. However, to the extent that secondary data were incomplete, there are inconsistencies in these results which are discussed later.

Table 2.—Summary of product flow data.

	Lumber	Plywood	Posts and Poles
	MMBF-LT[1]	*MM ft.², 3/8-inch basis*	*M ft³*
Produced	4,292	1,212	7,666
(+) Imported	2,808	823	
Total volume available	7,100	2,035	
Less:			
Consumed	2,264	1,481	6,900
Exported	3,018	947	
Total volume	5,282	2,428	
Surplus (+) or deficit (−), volume not accountable	1,818 (+)	393(−)	766 (+)

[1]*MMBF—LT-Million board feet, Lumber Tally.*

While it is logical to assume that the Rocky Mountain area might be self-sufficient with respect to lumber, and posts and poles, and to some small degree plywood, this assumption most certainly does not extend to pulp and paper products. With pulp and paper mills only in Arizona, Montana, and Idaho, the region likely exports large volumes of pulp and paper products of specific varieties manufactured in these states. Conversely, the region likely imports a wide variety of pulp and paper products in quantities proportional to populations and number of businesses. Thus, pulp and paper products are not expected to have balanced figures for import and export.

In 1976, the Rocky Mountain region consumed 3.1 million tons of paper and board products, while producing about 748 thousand tons of paper and board products. For pulp products, the region consumed an amount equivalent to 229 million cubic feet of timber. In turn, pulp mills in the region produced about 1.5 million tons of pulp, an amount equivalent to about 220 million cubic feet of timber. However, in the Rocky Mountain region only about 35 million cubic feet of timber actually was cut for pulp production. Thus, forest products residues or recycled material such as paper, rags, etc. went into pulp and amounted to about 185 million cubic feet of timber equivalent.

MARKET STRUCTURE[14]

Channels of Distribution

Within CSRM States

Producers in the central and southern Rocky Mountains sell their products to a variety of outlets in addition to consumer end users. Table 3 gives figures that indicate what proportion of dollar sales volume flows from one member of the market channel to another. For example, producers sell 31.5% of their dollar sales volume to lumber wholesalers, 10.3% to retailers, etc.

Wholesalers further distribute products purchased locally and from outside the CSRM area. For example, wholesalers who responded indicated that 57.9% of their dollar sales volume goes to retailers. One interesting sidelight is that wholesalers trade small volumes to other wholesalers, retailers trade to other retailers, and retailers also deal in small amounts with wholesalers.

Data on volume, quality, and quantity suggest that larger producers supplying major quantities of commodity products under industry quality standards generally market through wholesalers. However, fewer than 25% of the region's lumber producers who responded sell to wholesalers. The data suggest producers that sell directly to customers tend to produce selected categories of items for somewhat specialized markets. Examples are timbers for utilities and mines, common boards for household consumers, timbers and common boards for farm and ranch uses, and studs and timbers for contractors.

Table 3.—Flow of products from central and southern Rocky Mountain producers as a percentage of dollar sales volume

From: \ To:	Lumber Wholesaler	Retailer	Bldg. Contractors	Industry Manufacturers	Consumer and Other End Users
Producer	31.5	10.3	10.9	8.7	38.5
Lumber Wholesaler	4.5	57.9	9.7	18.1	9.9
Retailers	0.2	3.5	56.6	2.4	37.3

Imports to CSRM States

There are several ways products are imported into the CSRM area. Major volumes move from independent or affiliated mills to warehouse wholesalers, then to users or retailers in the CSRM states. Office wholesalers and brokers, who do not carry inventories, handle a large portion of the remaining business, selling to warehouse wholesalers and retailers. Retailers also purchase selected items directly from independent and affiliated mills outside the region. Item 1 in table 4 shows how many responding firms indicated they purchase some or all of their wood products from the CSRM area and how many said they buy no wood products from the CSRM area.

Exports from CSRM States

The majority of the wholesale and retail sales by the region's producers are to firms outside the CSRM area. Virtually all of the sales direct to end-users are to users in a CSRM state or, occasionally, an adjoining state. Wholesale transactions make up 30% of the total; retail sales, 10%; and direct sales, 60%.

Local Product Interaction with the Market

Mills

Of the forest product mills contacted, primarily producers of lumber, 85% indicated they market their products in the CSRM area, 11% indicated they market their products outside the CSRM area, and 2% indicated they market both in and out of the CSRM area.

Of those mills operators who indicated local marketing areas, 59% said their own primary product competition originated locally (i.e., elsewhere in the CSRM area). Thirty-one percent said their primary competition originated outside the CSRM area, and 10% said both areas. Lumber mills indicated that of all product classes they manufacture, light framing, studs, and timbers are the most susceptible to competition.

When asked why they thought competitive products are entering their market area, mill operators indicated two main groups of reasons. Forty-one percent said price differentials affected flow of competitive products. Thirty-three percent said specification of certain species by buyers affected flow of competitive products. Some mills gave both reasons in their responses. Price is straightforward when considered as a market motivation factor. However, the second perception, specification of certain species, is actually an overall indicator of a complex set of reasons having to do with perceived quality of product and service. Mill operators gave the following detailed responses when listing reasons why they feel competitive products are entering the CSRM area. The specific reasons are grouped into more inclusive categories.

Inclusive category	Specific reason	Percent giving this reason
I. Subjectivity	Preferences by buyers for certain species	19.6
	Bias against products produced locally	19.6
II. Availability	Quantity by grade or species	21.7
	Quantity by speed of service	6.5
III. Market channel	Established buying connections offering a wide range of products	19.6
	Local buyers affiliated with sole-source suppliers	13.0

The Market Channel

While the region's producing mills are the primary factor in overall market channels, secondary distributors also have an affect on, and perceptions about, CSRM products and their interactions with the market. Table 4 suggests why market channel members in the CSRM area make the decisions they do when consider-

Table 4.—Comparison of market channel members by selected attributes of the product buying decision. Numbers represent percentages of those who responded.

			Users	
	Wholesalers	Retailers	Manufacturers	Contractors
1. Purchase any wood products produced in the CSRM?				
Yes	72	63	77	47
No	25	32	17	24
Don't know	–	–	6	29
2. Decision to purchase based on:				
Price	55	42	43	24
Availability:				
By species	11	34	37	18
By grade	30	24	29	6
By speed of service	43	41	34	18
Quality	23	21	17	18
Market channel:				
Customer preference	11	7	11	12
Established business connections	30	34	46	29
3. Are some CSRM-produced products avoided?				
Yes	38	38	31	6
No	55	48	57	65
Don't know (DK) or No response (NR)	6NR, 2DK	14NR	12NR	35DK
4. Decision to avoid:				
Price	8	7	6	–
Not available:				
By needed quantity	8	4	9	–
By species	15	18	17	–
By grade	9	16	9	6
Product quality:				
Standards not met	19	23	26	6
Variation within grade	11	10	11	–
Does not meet building code	–	13	–	6
Market channel:				
Customer preference	9	7	–	–
Local buyers affiliated with sole-source suppliers	8	1	–	–

ing CSRM wood products. The first item shows the proportion of respective market channel members who said they purchase any wood products from the CSRM area.

For those market channel members who do purchase some products from the CSRM area, price and availability are important factors, as is the existence of established business connections. The positive effect of quality factors on the buying decision suggests that the quality of available products is at or above some acceptable standard set by each member of the market channel.

Although some products from the CSRM area are ordered by many members of the market channel, at least some products manufactured in the region are avoided by wholesalers, retailers, and manufacturers. Building contractors as a group seem not to consciously avoid CRSM products. However, for those members of the market channel who avoid at least some CSRM products, perceived quality and availability of local products are major factors influencing buying decisions. For example, availability of certain species seems important, as does compliance with standards for various products. For retailers in particular, one out of eight is concerned that products may not comply with standards set within building codes.

DISCUSSION

As indicated previously, the estimates and relationships depicted here, especially for product flow, should be interpreted cautiously. They are not precise measures of actual production and marketing levels. However, they may provide a reasonable insight into product flows in the Rocky Mountain region and, more specifically, in the CSRM area, until better production and market information is obtained.

PRODUCT FLOWS

Each of the major product groups in the CSRM states—lumber, plywood, posts and poles, and pulpwood and pulp—has its own particular flow pattern based on the nature of the product, comparative advantages of its manufacturing location, and sources of competing products.

Lumber

The volume of surplus lumber that was unaccounted for by the secondary data conceivably could be held in inventories within the region. However, this is probably not a realistic explanation considering the large amounts involved. One possible explanation is that data do not account for shipments originally destined for the study region that are diverted enroute to another location outside the study boundaries. If this is the situation, it would appear that the study area imports more lumber than actually occurs. However, the reverse could also occur (i.e., shipments destined for a location outside the study area could be diverted enroute to locations in the study region) with the result that imports would be undercounted. The first case is probably more likely because of the intricacies associated with the lumber marketing structure of the United States. For example, excess production in the Pacific Northwest and deficits in production in the Midwest and Northeast may cause lumber originally destined to the CSRM states to be transshipped further east instead. This activity would show more lumber imported to the Rocky Mountain states than is consumed.

A variation of the transshipment problem is temporary storage. Lumber destined for marketing areas inside the CSRM region may reach its initial destination but may be held there temporarily and then eventually reshipped to points outside the study area. Because this second shipment is not accounted for by available information, shipment data would tend to overestimate the actual volume of lumber used in the study region.

Lumber export data suggest that only about 30% of regional production was shipped to distributors inside the region. Of the 70% exported, the Midwest received the highest proportion (40.5%) (table A-2). The total export volume of 3017.8 MMBF, when related to the imports of 2,808.3 MMBF, indicates that regional production does not adequately serve the region's markets. This probably means that the region's products may not be sufficiently diversified to meet many of the region's requirements. This condition suggests there are limitations on the characteristics of Rocky Mountain raw materials as required for various specific uses. However, improved technology can help overcome many, if not most, of these limitations. Therefore, it appears that increased diversification of regional products is one way to improve the existing product-flow situation so that Rocky Mountain forests can supply more of the lumber products consumed in the region.

These interpretations are clearly speculative. Further research is needed on potential problems such as transshipment or product storage.

Plywood

Secondary data for plywood products indicated an unexplained negative regional flow amounting to 393 million square feet for 1976 (Table 2). It is unlikely that this figure represents volume pulled from existing regional inventories. However, a more probable explanation is a shipping destination problem similar to that encountered with lumber. That is, data used to compute regional imports and exports (American Plywood Association 1977) are based on original shipping documents at the producing mill. When a destination change occurs, as frequently happens for in-transit shipments, it is not reflected in APA records. In this study, there was no way to adjust product volumes to show such changes of destination while enroute.

Regardless of the actual flow of plywood products, in 1976, only Montana and Idaho of all the Rocky Mountain states produced plywood. This situation remains current. Therefore, it is not relevant or meaningful to discuss plywood flow under the same premises as for lumber. More explicitly, the relatively few plywood producers in the northern Rockies cannot realistically manufacture all the species, grades, and sizes required to satisfy plywood needs in the more populous central and southern Rockies, though certainly some plywood from the northern Rockies is shipped to the CSRM area.

If plywood manufacture is seriously considered in the CSRM states, some findings from past studies should be considered.[15]

1. Customers may perceive critical differences in essentially similar products because of tradition or product promotion, resulting in high demand for certain plywood, for example, Groups 1 and 2 species (Douglas-fir, hemlock) in plywood in lieu of Group 3 species (spruce, ponderosa pine). Also, building code requirements may strongly influence plywood grades demanded.
2. Major CSRM species such as Engelmann spruce or ponderosa pine are less familiar plywood species, in many cases, so distributors are not conditioned to accept these species.
3. Many wholesalers do not stock spruce or pine plywood and will only sell it if it can be shipped in carload or truckload lots directly to the retailer or contractor.
4. To be competitive in strength properties with west coast Douglas-fir or southern pine plywood (Group 1), ponderosa pine or Engelmann spruce plywood producers must increase panel thicknesses relative to Group 1 specifications. This increases material and operating costs to the point where substituting pine or spruce plywood for Douglas-fir may not be feasible. Gardiner (1972) found that more general market acceptance of ponderosa pine and Engelmann spruce plywood would be a prerequisite for expanding this industry in the CSRM states. He felt industrial markets were the most promising outlets for this type of plywood.

However, recent developments in standards for structural wood panel products have modified some of the differences between plywood panels based on species and also between plywood and composition wood panels (American Plywood Association 1981). For example, under these newer American Plywood Association guidelines, panels are manufactured to standards that give performance characteristics for certain end uses. Species is not a factor if the panel performs satisfactorily.

Posts and Poles

Data needed to determine production, consumption, import and export of wood posts and poles ranged from sketchy to nonexistent. In terms of production capacity, it appears that the region could be self-sufficient. However, posts and poles cross regional boundaries in both directions for a variety of reasons. For example, the region's ponderosa pine is easy to treat with wood preservatives and makes good fence posts and small poles. But, it is seldom suitable for the larger poles required for power transmission lines. Posts and poles generally are not shipped long distances. Producers find that the low product value of most posts and poles limits the transportation costs these products can absorb and still remain profitable.

Brenner et al.[4] and Betters et al. (1977) indicated that states directly east of the study region offer good potential market outlets for some of the region's post and pole products. They concluded that corral poles would have to be sold somewhere within a 200-mile radius of a producer's plant in the Front Range area to yield a profit. Barn poles could be marketed beyond 200 miles, but lose their profitability if shipped much farther. Fence posts could be marketed over at least a 900-mile radius and still generate a profit, meaning that they could be marketed as far away as Chicago.[4] This indicates that the Front Range area of Colorado has possibilities as a source of fence posts for large agricultural and urban markets outside the study region. As a general rule, then, posts and poles appear to offer good market potential in local situations.

Pulp and Pulpwood

The region's mills produce a quantity of pulp and paper roughly equivalent to the volume of pulp products consumed within the region. However, much of the region's paper production is exported, while regional needs are filled, in part, by imported products. This apparent anomaly is a result of differences between grades produced and grades used in the region, plus normal competitive trade factors.

Pulpwood constitutes only a fraction of the raw material required for the region's pulp production. An increasing portion of this requirement is met by sawmill residues (i.e., slabs, edgings, chips, sawdust). Because stumpage, harvesting, and some processing costs generally are not assigned to sawmill residues, these raw materials are preferred over pulpwood, which must absorb all production costs. Residues, therefore, usually can be hauled considerable distances before their transportation costs exceed the cost of pulpwood at the mill. A drawback to complete dependence on sawmill residues of pulp mills in the CSRM region is that volume required is typically greater than volume available within economic hauling range of the pulp mills. Also, availability of these residues varies with sawmill production, which rarely follows the same market cycles as pulp production. This leaves pulp mills vulnerable to raw material shortages, unless they have the flexibility of using roundwood as well as the preferred residues.

Little or no pulpwood or sawmill residues are imported into the CSRM region. However, for the past two decades, the CSRM region has exported to Lake States mills substantial volumes of both. Virtually all of the pulpwood and much of the sawmill residues exported has come from the Black Hills area. These shipments were made feasible by favorable freight rates originally

[15] *Unless otherwise noted the following material is taken from Wangaard, F. F., and R. S. Whaley. 1971. Potential markets for plywood made from Rocky Mountain ponderosa pine and Engelmann spruce. 93 p. Department of Forest and Wood Sciences, Colorado State University, Fort Collins, Colo. [Unpublished Report]*

negotiated between Black Hills operators and the railroads, beginning in 1958 (Chicago and Northwestern Railway Company 1964). Colorado and Wyoming operators also have shipped residues and, occasionally, pulpwood to these same markets. In recent years, rising freight rates have increasingly threatened the economic feasibility of these markets, with the result that shipments have decreased. Surpluses of small timber and sawmill residues are likely to grow in these CSRM areas as export markets decline. In 1974, before the recent increase in the use of wood for energy, it was estimated that unused, annual volumes of sawmill residues in the Black Hills alone amounted to 35.3 million cubic feet (table A-5).[16]

MARKET STRUCTURE

The forest products industry is essentially a commodity business. Products must be available on demand in economical purchase quantities that meet standard specifications at the lowest possible price. For the bulk of the industry's production, there is little opportunity for differentiation of the physical product except for certain species preferences that affect product choices. However, there are other ways to differentiate CSRM wood products. For example, packaging with weather resistant wrapping, reducing handling costs, and invoice systems would all contribute to defining a total product that is different than others.

Because wholesalers are the primary source of supply for retailers and manufacturers, and a significant source of material for contractors, they tend to determine which products flow through the distribution channels. This study found that many wholesalers avoid, or at least do not seek out, CSRM products. This situation may be understandable considering the nature of the commodity business. Because wholesalers desire convenience and avoid risk, they tend to purchase from just a few of the many possible sources in order to gain access to a complete product line in large quantities, at low prices, and with consistent quality. Additional factors in wholesalers' buying decisions that seem to work against CSRM products include preferences for species not available in the CSRM area, concerns about adequately dried lumber, and in some cases, building code restrictions.

Such factors can contribute to the situation noted earlier where some of the lumber products imported into the CSRM area seem to be identical to products shipped elsewhere from the CSRM area. Thus, CSRM wholesalers would order from elsewhere lumber products not readily available locally, for example select and finish grades or perhaps some sizes of structural dimension. Concurrently though, because of convenience and possibly bulk shipping cost factors, they order products from elsewhere that are available locally—for example, some grades of common boards and light framing lumber. In contrast, local producers satisfy only part of the local CSRM requirements for these products but ship significant volumes out of the CSRM area, usually east.

Retailers exercise less influence over the market because they usually purchase primarily from wholesalers. Their primary customers are contractors and household consumers, who have even less influence on commodity product choices.

CSRM mills recognize that they must compete for the bulk of the contractor, manufacturer, and consumer business through established wholesaler-retailer channels. While price competition with large Northwest and Inland Empire producers is a factor, quantity and quality control problems may be even more important than price in commodity markets. As an alternative to commodity products marketed through wholesale channels, a number of mills in the CSRM states also successfully developed direct local markets for specialty products. About 60% of the CSRM output goes to such markets. In addition, some CSRM mills are also reaching non-CSRM area markets directly, thereby creating stronger proprietary relationships with their customers.

CONCLUSIONS

Although the CSRM region now has more than enough harvestable timber to supply its own needs in many wood product classes, it continues to import significant quantities of lumber, plywood, and paper. This situation results, in part, from production deficits in some product categories. In other cases, market preferences and the market structure appear to discriminate against the region's products because of real or imagined differences in quality between local and imported items.

Brenner et al.[4] and Sampson et al. (1980) listed a number of reasons for the low level of production in 1977. Some of the problems they cite that face Colorado's wood products industry include (1) unsuitable product quality, (2) limited product variety in comparison to the total range of possible products required, (3) inability to maintain a steady flow of product, and (4) undetermined bias against Colorado products within the State. Although these problems were associated specifically with Colorado, they may be typical of the majority of the states in the study region, with the exception, perhaps, of Idaho and Montana.

With the region producing more lumber than was consumed in 1976, it might be expected that imports should have been small. Because this was not the case, it is probable that lumber manufactured in the region lacked the grade and product diversity required locally, resulting in the import of products not manufactured in the region (for example, higher quality boards[17]) and the export of local lumber products of types produced in excess of regional demands.[16]

[16]*Source material for this statement is found in five publications from the Forest Survey Research Work Unit at the Intermountain Forest and Range Experiment Station. They are Setzer and Throssell (1977a), Setzer and Barrett (1977a), Setzer and Shupe (1977), Setzer and Barrett (1977b), and Setzer and Throssell (1977b).*

[17]*Higher quality boards, in this case, refers to #1 and #2 Clear boards, Select and #1 and #2 Common boards.*

A possible method for improving local markets is greater product diversification. This may require efforts to upgrade products and to show local consumers that Rocky Mountain timber is not inferior to timber from other regions. Although not addressed in this study, further work could identify and evaluate beliefs about CSRM wood products held by consumers.

Certain marketing peculiarities exist for some states in the CSRM region. The two highest valued products produced in Colorado and Wyoming, planed boards and studs, are largely marketed in Illinois and Wisconsin, while timbers are shipped mainly to Kansas and Missouri. Other Colorado and Wyoming products are marketed mostly in these same four states. The reason for this appears to be that the higher value products can be shipped longer distances and still remain profitable, while lower valued products cannot support high transportation charges and must be marketed closer to their source. Rising prices for locally finished wood products may change this marketing pattern. Rising transportation costs could make local markets more appealing to the region's producers if these increases were not offset by higher product prices at more distant markets.[5]

Because the CSRM region contains no plywood production capacity, substantial quantities are imported. Unless potential producers are convinced that viable markets exist for plywood made from Engelmann spruce and ponderosa pine, for example in underlayment, sheathing, crates, boxes, etc., the current market structure for softwood plywood is likely to continue. Donnelly and Worth (1981) showed under what conditions plywood production is possible in the Black Hills area. These results could be adapted by further research to other locations in the CSRM states. In addition, there are other areas in the CSRM region where reconstituted wood products such as particleboard or composition board might be manufactured (Markstrom and Worth 1981).

The region's post and pole production has an importance greater than its volumes would indicate in relation to the total regional forest products output. Effective management of timber resources includes balanced utilization of sapling- and pole-sized timber as well as sawtimber. Because the region contains large areas of timber less than sawtimber size that needs stand improvement, management of such stands would result in reduction of stand overcrowding, stagnation, insect damage, and disease and yield large volumes of pole-sized timber. However, to achieve this goal, steps must be taken to improve the marketing opportunities for small timber (e.g. posts and poles).

Business techniques such as sales promotion and product diversification are needed to help expand regional and out-of-region trade (Betters et al. 1977). In particular, several positive steps would increase chances for better utilization of local wood species.[18]

[18] *Based on a personal communication August 23, 1982 from Vern P. Yerkes, Timber Staff, Southwestern Region, USDA Forest Service, Albuquerque, N. Mex.*

1. CSRM producers could combine to seek further acceptance of local species in the trades and the consumer marketplace through changes in unjustified code restrictions, tests and demonstrations of their products, and advertising and promotion carefully targeted on the most advantageous markets.
2. New products must be developed and tested in the marketplace.
3. Recognize the relatively favorable geographic position of CSRM producers with respect to populous Midwestern and other east-of-the-Rockies markets.

Because the region contains large supplies of small ponderosa and lodgepole pine roundwood, both excellent pulping species, it appears that pulp should be a forest product of great potential in the Rocky Mountain region. Now, the region does not completely utilize existing mill residues for pulp and, in some cases, exports pulpable raw materials because of a lack of local outlets. The region probably could support one or more additional pulp plants, as suggested previously in the Chicago and Northwestern Railway Company study (1964).

However, additional factors must be recognized that could hinder pulp development within the study region. For example, scattered sources of raw material may dictate pulping processes that do not require large production facilities to operate economically. Also, these processes must use little water, and be largely free of pollution. Therefore, it probably is not realistic to expect installation of a chemical pulping plant, for example, that must operate at a level of 1,000 tons or more a day to be profitable. Rather, other pulping processes, such as thermomechanical or chemimechanical, may offer considerable promise when related to the region's population and economic expansion. Another factor related to pollution in a technical sense, but which is probably more of an information problem, is social objection to the concept of pulp mills. This perception is based on historical pollution problems that can be largely controlled with modern pulp plants. However, social perception must be changed before serious attempts at pulp production are politically and socially possible.

In summary, production and distribution of forest products in the Rocky Mountains, and particularly the central and southern Rocky Mountains, could be made more efficient if local timber resources were utilized to better advantage. More attention should be focused on serving regional markets with regional production. Product upgrading and diversification are key factors in achieving this goal. Further attempts should be made to increase the competitiveness, and hence value, of products that are exported. To maximize economic efficiency, only those forest products that cannot realistically be produced in the region should be imported.

Finally, the findings of this study suggest that the competitive position of forest industry in the central and southern Rocky Mountains could benefit from research with several main emphases. One research theme should be to illustrate the explicit tradeoffs involved in providing specific levels of lumber moisture content. For example, because of favorable climatic conditions, yard drying of lumber is very attractive in the CSRM region. This process achieves substantial cost savings compared to kiln drying, but unless carefully controlled, yard drying may cause high marketing costs. A negative product bias related to occasional inadequately dried lumber may more than outweigh any technological cost savings associated with yard drying. Other research could explore the economic factors involved in a venture designed to channel commodity forest products from several local producers through a larger scale wholesale operation that could deal more effectively with large scale users. Research could further help identify specialty markets that would provide a buffer against the typically wide fluctuations in commodity markets.

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Agriculture—CSU, Fort Collins

Appendix

Table A-1.—Estimated consumption of lumber (in millions of board feet) by use, in the study region, 1976

End use	Volume consumed
Housing	
Single-unit structure	1,038.4
Two-unit structures	32.7
Multi-unit structures	146.6
Mobile homes	38.8
Manufacturing	130.0
Shipping	48.1
New nonresidential construction	257.4
Residential upkeep and improvements	288.5
All other uses	283.4
Total	2,263.9

Table A-2.—Estimated exports (in millions of board feet) of lumber from the study region, 1976

Receiving region	Volume exported	Percent of total RM production
California	130.4	3.0
Midwest	1,739.7	40.5
Northeast	395.3	7.8
South Central	333.8	9.2
Southeast	366.7	8.5
Export (outside U.S.)	51.9	1.2
Total	3,017.8	70.2

Table A-3.—Estimated imports of lumber (in millions of board feet) to the study region from other U.S. shipping regions, 1976[1]

hipping region	Volume exported
California	421.3
Oregon	1,659.4
Washington	727.6
Total	2,808.3

[1]*Data are not available for lumber imported from Canada to the CSRM area.*

Table A-4.—Estimated consumption of plywood (in million square feet, 3/8-inch basis) by end use, in the study region, 1976

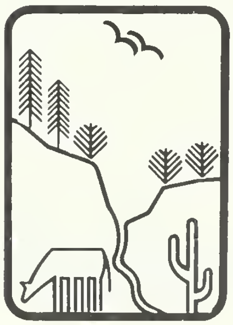
End use	Volume consumed
Housing	
Single-unit structures	713.4
Two-unit structures	18.8
Multi-unit structures	62.7
Mobile homes	7.7
Manufacturing	65.0
Shipping	5.1
New nonresidential construction	169.9
Residential upkeep and improvements	145.2
All other uses	293.8
Total	1,480.6

Table A-5.—Estimated volumes (in thousand cubic feet) of unused residue from sawmills in Arizona, Colorado, New Mexico, South Dakota, and Utah, 1974

	Unused bark	Residue coarse[1]	Fine[2]
Arizona	1,010	498	3,365
Colorado	3,853	2,070	4,285
New Mexico	3,264	2,543	5,109
South Dakota	1,801	416	1,677
Utah	1,547	2,179	1,715
Total	11,475	7,706	16,151

[1]*Material suitable for chipping, such as slabs, edging, and trimmings.*
[2]*Material such as sawdust and shavings.*

Rocky
Mountains



Southwest

Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

Timber Utilization and Marketing Alternatives for Colorado and Wyoming

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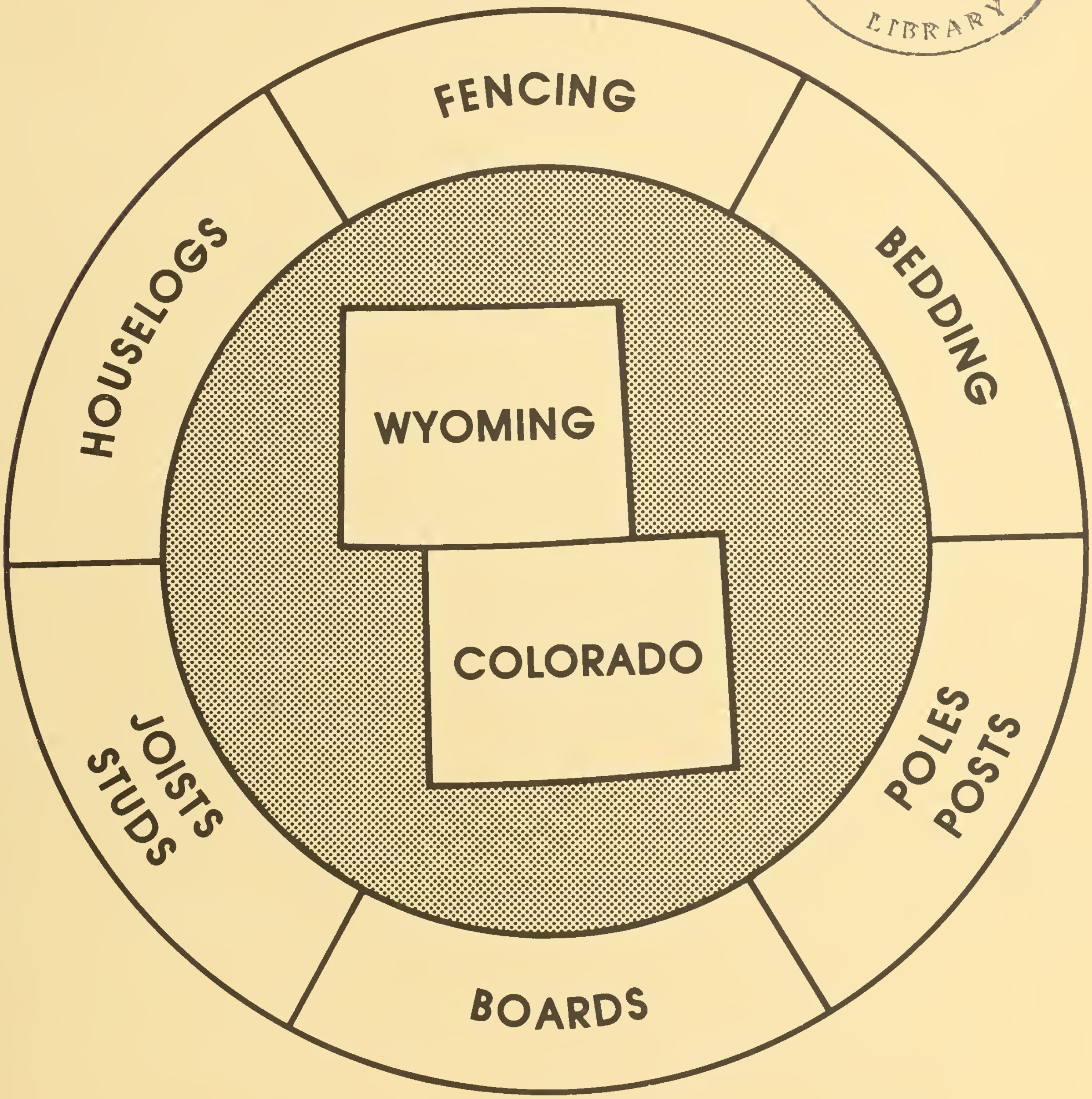

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Timber Utilization and Marketing Alternatives for Colorado and Wyoming

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Abstract

Profitable wood product mill operation in Colorado and Wyoming depends on market area, product, mill capacity, and characteristics of the available timber. This study shows how these factors affect timber marginal value and makes the connection between profitable wood products operations and the opportunities to manage woodlands.

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Timber Utilization and Marketing Alternatives for Colorado and Wyoming

James H. Smego, William E. Switzer, David R. Betters, Dennis M. Donnelly, and Harold E. Worth

MANAGEMENT IMPLICATIONS

This study found that improvements in wood product producers' end-product values would indirectly increase returns to stumpage and provide opportunities for desirable multiple-use management on forested lands. For example, the linear programming analysis showed that returns to stumpage in both Colorado and Wyoming were highest when mills produced a variety of both high- and low-valued products. With product diversification, producers potentially could receive higher net returns.

Wood products serving the coal industry and energy related markets are in demand as long as these outlets are active. However, such local markets are particularly volatile because of connections with international energy markets.

Finally, transportation rates are an important determinant of profitability. Thus, valuable products such as quality boards do not necessarily provide as much net return when shipped long distances as do other products shipped to closer markets.

If diverse products are marketed from Colorado and Wyoming mills, the possibility increases that over a wide geographic area, demand for stumpage will include all commercial tree sizes, not just sawtimber. To a certain degree, this situation now occurs widely, not only in Colorado and Wyoming, but also nationally, because of the demand for firewood as well as more traditional wood products.

The analyses discussed in this bulletin are based on 1977-79 data. These data portray and reflect economic conditions in the sawmill industry at that time.

Given these data, the intent of this bulletin is twofold. First, it presents an approach to analysis of markets, products, and mill operation that may be implemented under all circumstances. Second, the results demonstrated here are generally applicable over a wide range of economic conditions. For example, product diversification is a demonstrably good strategy at any time. Further, although 1977-79 economic conditions may never be reproduced exactly, those years are representative of generally "up-beat" conditions in the lumber industry. "Up-beat" conditions in forest products will periodically prevail again, just as will future downturns. Those working in forest products industry and in management of forest land, public or private, and who are well informed on a variety of economic conditions and possible responses, will surely be positioned well to guide their operations through future continuing business cycles, both the "up" parts and the "down."

INTRODUCTION

Harvesting timber consistent with environmental safeguards is one major goal of forest resource management. Timber harvesting also must be economically worthwhile. Realizing such opportunities is a common problem in Colorado and Wyoming.

Before the 1980-82 market slump and mill closures, Colorado and Wyoming had sufficient processing capacity to handle additional timber supplies, which could have been made available by changes in forest management activities. In this region, high harvesting costs and generally low product values have been an economic disincentive to more intensive management. However, higher returns to stumpage can be gained by harvesting in areas where the timber's marginal value is high. One way to gain high marginal value for timber is with diversified product lines that tend to give mills higher net returns for wood products because raw materials are more efficiently used.

Forest resource managers and timber processors in Colorado and Wyoming need to develop and examine alternative timber utilization strategies and pursue those that best meet their mutual objectives under expected market conditions. For management to be effective, the available timber supply must be in balance not only with consumer demand, but also with the capacity of nearby industry to process and market the species and volumes of wood available. These interdependent relationships make it essential that long-range forest management planning develop sound information and projections about the availability of raw materials over time. Concurrently, planning must consider other expected resource benefits, the product potentials of available timber, consumer demand, and end-product values. To demonstrate how this might be done, several alternative strategies are presented here. These alternatives are based on information available at the time the studies were completed, 1977-79. Since that time, a major economic recession has resulted in numerous sawmill closures and major declines in forecasted energy developments. Therefore, portions of this report should be interpreted as alternatives appropriate under much improved economic conditions. Considerable restructuring of the timber industry in Colorado and Wyoming is inevitable, because several former production facilities have been dismantled. Therefore, it seems to be a particularly good time to consider new production and marketing alternatives.

Background

Several USDA Forest Service sponsored studies, upon which this report is based, appraised the potential for increasing timber harvest and utilization of two major softwood timber species groups in Colorado and Wyoming—lodgepole pine (*Pinus contorta* Dougl.) and Engelmann spruce (*Picea engelmannii* Parry)—subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). Two studies[3] analyzed raw material supplies, mill capacities, and market demands for various wood products. A third study[4] analyzed several scenarios describing different levels of timber harvest, mill production, and market demand in order to examine a range of operating environments.

A companion study[5] examined the technical suitability of the same timber species for wood and fiber products. Many of the possible products identified were considered in the current study. Other related production and marketing studies dealt with beetle-killed ponderosa pine (*Pinus ponderosa*) in Colorado's Front Range (Sampson et al. 1980a, 1980b; Troxell et al. 1980).

Study Area

Subalpine forests are the largest and most economically valuable timber resource in Colorado and Wyoming. In Wyoming, lodgepole pine grows on about half of the commercial land in the subalpine zone. Spruce and fir are second in importance in land area, but they contain the largest volume of sawtimber, followed by lodgepole pine. In Colorado, spruce-fir occupies about one-third of the commercial forest land but contains nearly 70% of the subalpine sawtimber volume (Alexander 1974).

[3]Smego, James, Robert Brenner, and David R. Betters. 1978. Assessment of wood raw material and wood utilization potential for the lodgepole pine and spruce-fir timber types in Colorado and Wyoming. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colo. Rocky Mountain Forest and Range Experiment Station Cooperative Research Agreement 16-757-CA, CSU Project 31-1470-1470, 327 p.

Switzer, William and David R. Betters. 1980. Forest product production and marketing opportunities for utilizing the available timber resource in Colorado and Wyoming. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colo. Rocky Mountain Forest and Range Experiment Station Cooperative Research Agreement 16-869-CA, CSU Project 31-1470-2259, 153 p.

[4]Smego, James and David R. Betters. 1979. Production and marketing alternatives for utilizing lodgepole pine in Colorado and Wyoming. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colo. Rocky Mountain Forest and Range Experiment Station Cooperative Research Agreement 16-869-CA, CSU Project 31-1470-2219, 244 p.

[5]Lemaster, R. L., H. E. Troxell, and F. F. Wangaard. 1979. Assessment of wood raw materials and wood utilization potential for the lodgepole pine and spruce-fir types in Colorado and Wyoming. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colo. Rocky Mountain Forest and Range Experiment Station Cooperative Research Agreement 16-927-CA, CSU Project 2243, 79 p. + appendices.

The study area included virtually all the "commercial forest land"[6] in Colorado and Wyoming, excluding only the eastern slope of Colorado's Front Range and the Wyoming portion of the Black Hills. Lodgepole pine is predominant on 2.3 million acres of the study area. Another 2.2 million acres is mostly Engelmann spruce mixed with subalpine fir. In southwestern Colorado, where only a small amount of lodgepole pine grows, about 370,000 acres of ponderosa pine are classified as "commercial forest land." Most of the commercial timberland in both states (about 85%) is publicly owned.[7]

Study Objectives

The overall goal of this bulletin is to assess timber utilization and marketing opportunities as a key component of overall resource management strategies. To accomplish this, there are two specific objectives.

The first is to assess three elements that are key to utilizing the resource:

1. Levels of timber supply and mill residue and the identified influences on their future availability.
2. Levels of mill processing capacities in general, and of processing capacities for specific products.
3. Analysis of markets for existing and potential products to determine the most suitable geographic areas, possible market values, and lumber consumption levels.

The second objective is to develop several scenarios that describe the effects of changes in these three key elements.

METHODS

Definition of Concepts

Timbershed

A timbershed surrounding a processing center (see next section for definition) includes forest areas where local firms usually obtain timber. The key economic factor influencing timbershed boundaries is the cost of transporting logs from the woods to the mills, as evidenced by mills' past histories of procurement. Other related influences include the surrounding topography, the existing road system, size of timber sale, timber quality and volumes, and current market conditions.

[6]The USDA Forest Service defines "commercial forest land" as land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. Areas qualifying as commercial forest land are capable of producing more than 20 cubic feet of industrial wood per acre per year under management.

[7]This estimate is obtained using data contained in a report by the USDA Forest Service. 1978. Forest Statistics of the U.S., 1977. Washington, D.C. 133 p. For precise information, see Table 5, "Area of commercial timberland in the western United States by ownership, forest type, site class, section, and region, January 1, 1977."

Processing Center

A processing center is a location where major mill production capacity is located. Smaller mills may be scattered throughout the surrounding timbershed. Criteria for selecting processing centers are relatively large mill output levels, accessibility to large areas of timber, and good transportation facilities from woods to mill and mill to market.

Cluster

A cluster is two to four continguous processing centers combined for the purpose of marketing analyses. Clustering permits consolidation of figures, makes possible a broader use of available cost data, and avoids possible disclosure of proprietary information at certain processing centers. Figure 1 shows the five processing center clusters discussed in this study.

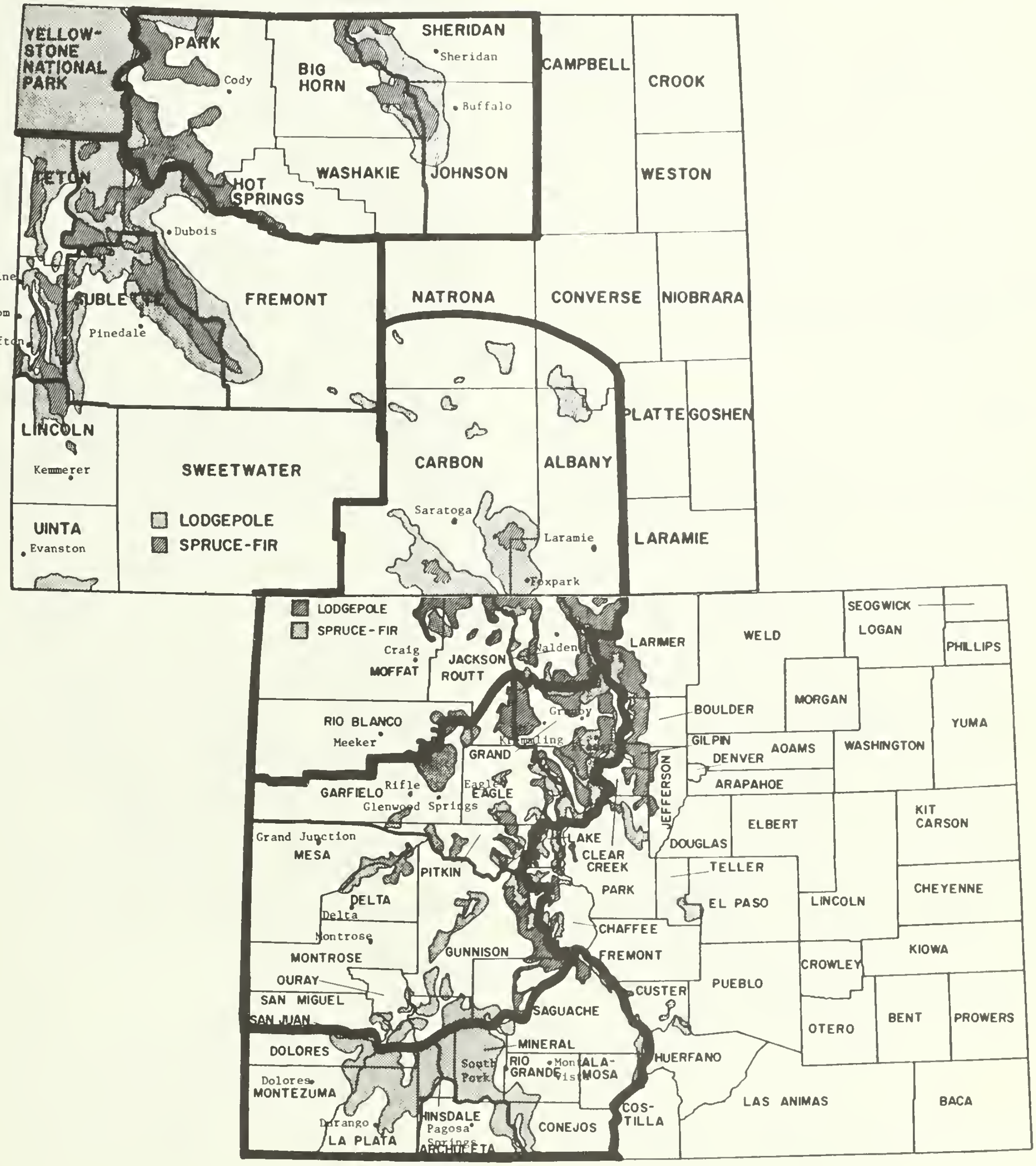

Figure 1.—Colorado and Wyoming Timber types, timbersheds, processing centers, and clusters of processing centers. In southern Colorado, light gray areas for species identification indicates ponderosa pine, not lodgepole pine.

Information and Data Obtained

Information is needed about both the supply of wood products from Colorado and Wyoming and the potential for consumption of those products.

Information was collected about existing and potential timber supplies, product lines, and mill production capacities, some of which is reported in this section even though results in general are discussed later. The study area was subdivided into 16 timbersheds or procurement areas, eight in each state (fig. 1).

The prime market area for Colorado and Wyoming wood products examined in these studies covers a large portion of the central United States, stretching from the Intermountain region and Southwest, north to Minnesota, south to Texas, and east to Ohio (fig. 2). Consumers in this area use large volumes of softwood products but are unable to obtain enough products from their local sources. In addition, these consumers are closer to the central Rocky Mountains than to other western, and in some cases southern, softwood producing areas.

Unless otherwise specified, the 1977 data reported in this study measured timber supply, production, and marketing activities and represents the most recent figures available at the time.

Timber Supply

Timber supply estimates (in thousand cubic feet, or MCF) were made from data provided by the USDA Forest Service, USDI Bureau of Land Management (BLM), and state forestry departments according to three size classes. Seedling-sapling trees are less than 5 inches d.b.h., poletimber trees are more than 5 inches d.b.h. but smaller than sawtimber, and sawtimber trees are softwoods greater than 9 inches d.b.h. and hardwoods greater than 11 inches d.b.h.

Assessments of the potential timber supply included only timber on commercial forest land. However, not all forest land classified as commercial is available for harvest. Commercial forest lands administered by the USDA Forest Service are further classified into "standard, special, marginal, and unregulated" components. "Standard" component lands are suitable and available for harvesting using normal silvicultural practices. "Special" component lands are suitable and available for timber production, but require the application of special silvicultural treatments to protect other resource values. Although "marginal" component lands are suitable for timber production, they are technically or economically unavailable at present, primarily because of excessive development costs associated with steep slopes, low product values, resource production constraints, or the absence of markets for the species or products available. "Marginal" lands also include a backlog of non-stocked areas needing reforestation. "Unregulated" lands are those lands not part of the harvest base and not included in allowable cut calculations.

Timber volumes and acreages were estimated for three harvest levels: programmed harvest, potential yield, and potential yield as affected by lands

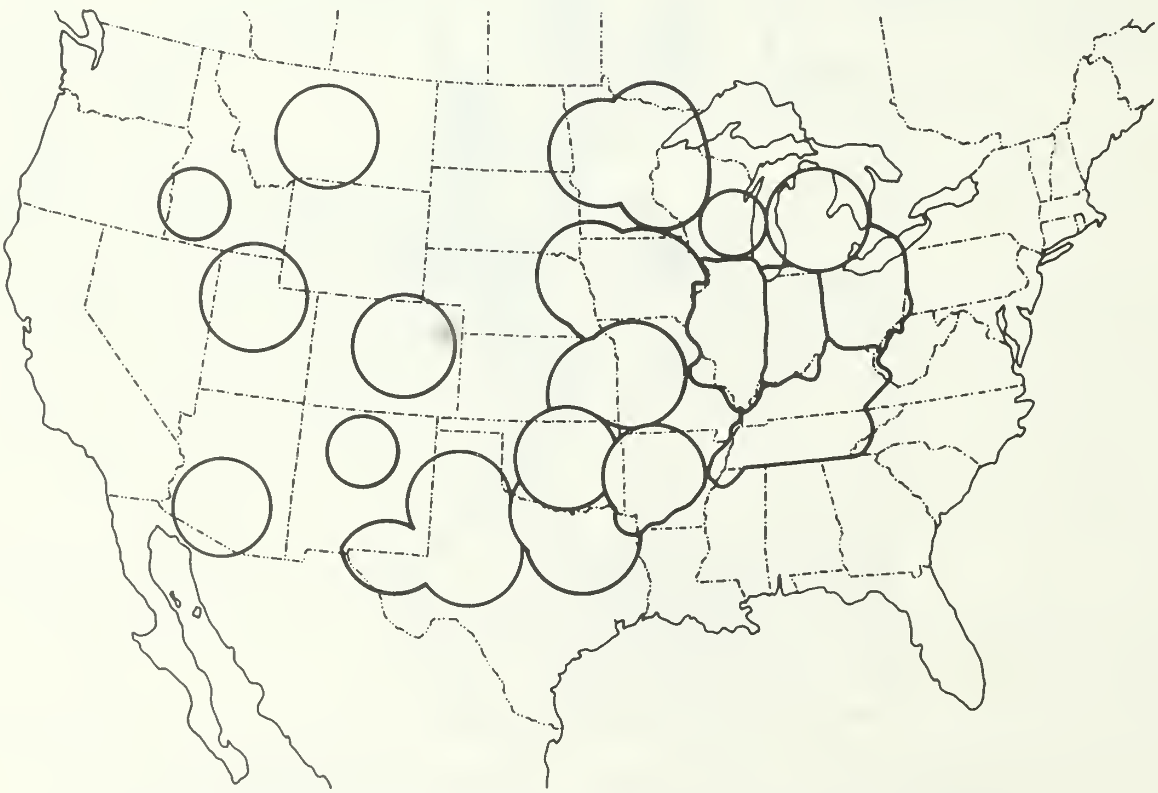

Figure 2.—Standard Metropolitan Statistical Areas that serve as loci of prime market area for Colorado-Wyoming wood products.

withdrawn from harvest during study for wilderness designation (RARE II). These categories used in USDA Forest Service management planning have been applied to all commercial forest lands in this study. "Programmed harvest" specifies the volume of timber being sold under current management plans on standard and special lands. "Potential yield" refers to the maximum level of harvest possible on a sustained-yield basis, including timber growing on marginal lands. "RARE II impacts on potential yield lands" indicates the amount acreage in standard and special components and the potential yield volumes affected by the exclusion of those areas being considered as set-asides for the national wilderness preservation system.

Data for the volumes and acreages of timber available, at each harvest level, in the five processing center clusters are summarized in table A-1 for Colorado and table A-2 for Wyoming. The original data available from USDA Forest Service management plans are classified according to their administrative areas. Therefore, the volume and acreage figures are adjusted to represent timbersheds defined on an economic basis. In the analysis portion of this study, these data helped estimate the future product potential of the timber supply.

Mill Production

The major products produced in the two states include rough and planed boards, dimension lumber, studs, timbers, houselogs, pallets, and fenceposts. Products produced in smaller quantities include railroad ties, utility poles, fencing, paneling, and firewood. Although no mills manufactured joists or particleboard, it is technically feasible with the available species of timber. Other new product possibilities include laminated beams, insulation board, fiberboard, and bedding, but market data about these products are not available for analysis in this study.

Various industry sources and state industry directories provided data for each processing center in Colorado and Wyoming.[8] For example each state traditionally publishes a directory of its forest product firms. These data described the products produced, mill capacities, and various production and marketing costs for 1977. Wherever possible, the information covered production levels by individual product lines.

Costs of stumpage, procurement, and product manufacturing are estimated from USDA Forest Service timber appraisal data.[9] Stumpage costs are represented by average costs per MCF for each species. Procurement costs include harvesting, clean-up, hauling, road building, and maintenance costs associated with timber sales. Manufacturing costs represent all costs of operating processing facilities. A profit and risk factor of 11%, frequently used by the USDA Forest Service, also applies in this analysis. Transportation costs to market vary according to the distance from the mill to various market points. Finally, handling costs cover the loading and unloading of freight at its origin and destination.

Market Area Evaluation

Wholesale market values for all products produced at each processing center were weighed against these cost figures. These values reflected competitive conditions in selected Standard Metropolitan Statistical Areas (SMSA).

Because SMSA's exhibit high levels of economic activity and population density, they also represent sites of major consumption of wood products. Groups of SMSA's are aggregated into market areas based on potential for lumber and other wood products consumption.

Several criteria helped identify SMSA's with good market potentials for Colorado and Wyoming wood products: (1) the largest markets, or SMSA's consuming the most wood products in the market area, (2) the most profitable markets for Colorado and Wyoming mills, (3) comparative advantages and disadvantages in shipping wood products to these markets, (4) trends in Colorado and Wyoming wood product consumption and production, and (5) potential increases in wood product consumption in Colorado and Wyoming resulting from coal-related energy development activities in the two states.

Demand for the region's wood products in each identified market area was assessed on the basis of the amount of lumber consumed in 1977 by the residential housing industry.[10] The 1977 consumption level was related to the number of new housing starts, as reported by the U.S. Census Bureau, multiplied by an estimate of the average amount of lumber used to build homes and apartments. Manufacturing, construction, and other non-housing consumption, which constitute a substantial part of the total, were not included because available information was difficult to associate with specific SMSA's. Thus, total consumption for each SMSA was under-estimated to the extent that non-housing uses are involved. According to the housing data, the demand for wood products appeared strongest (in descending order) in SMSA's within Illinois, Ohio, Arizona, and east Texas. Lesser demand (in descending order) existed in SMSA's in New Mexico, Arkansas, Idaho, and Montana.

Market Factor Analysis

The potential of SMSA's to serve as market areas for Colorado and Wyoming producers relates to several fac-

[8]A wide variety of resource and economic publications are published singly or in series by private, state, and federal organizations. Two sources of lists of such publications are Kallio and Dickerhoof (1979) and Donnelly (1980). Single copies of the latter paper are available from the author at USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colo. 80526.

[9]Each Regional Office of the USDA Forest Service compiles data about overall timber sale activity in its region. For example, data cover average costs, volumes produced, and stumpage prices among other items. These reports are filed generally under the designation 2400 which covers all phases of forest management including timber sales.

[10]At the time of the study this was the most current data available from the U.S. Census Bureau. While yearly consumption levels may change, the relative ranking of the SMSA's is normally the same each year.

tors that jointly affect profitability. These factors are net returns by market area, transportation costs, comparison of local and distant markets, and the possibility of local markets in the energy and mining industries.

Net Returns by Market Area.—To determine where Colorado and Wyoming mills could be competitive, this study estimated a product's profitability when distributed from the producer to a specific SMSA. The net return (dollar value per MCF of product remaining) is the value difference between product returns and all production costs, including transportation to market for each product line in each cluster. It appeared likely that mills could profitably market the particular product in the given market area when positive net returns are significantly large. Conversely, a large negative return indicated that a product would likely be unprofitable if marketed in the area.

Transportation Costs.—Another analysis estimated the advantages or disadvantages for Colorado and Wyoming producers when their transportation costs were compared with those of producers in adjacent states manufacturing similar products. The comparison measured truck and rail freight differences from five originating points to five key market destinations. Originating points included Colorado, Wyoming, Utah, Montana, and Idaho; and key market areas included Chicago, Ill.; Columbus, Ohio; Dallas, Tex.; Detroit, Mich.; and Phoenix, Ariz. According to published truck rates in 1978 and 1979, Colorado and Wyoming had a comparative advantage over other originating states to all of the five market areas except Phoenix, and Colorado had the advantage over Wyoming in all four instances (fig. 3). Recently, Colorado and Wyoming producers largely switched from rail to truck transportation because of favorable truck rates per unit of weight. In addition, wholesalers usually seem to incur fewer handling charges when shipping by truck, and were able to make faster and more frequent deliveries of smaller volumes.

Local and Distant Markets.—To analyze the potential of local markets, past trends in wood product production and consumption in Colorado and Wyoming were examined without forecasting trends into the future. Data came from past histories of local markets reported in wood products statistical yearbooks and U.S. Census Bureau reports. In Colorado, total lumber consumption was greater than production, with imports accounting for the difference (fig. 4). In Wyoming, total production was above both total consumption and housing unit consumption, making Wyoming a net exporter of lumber. Wyoming mills often find it more profitable to market their products out-of-state. In addition, Wyoming's production was much less erratic than Colorado's.

The Colorado-Wyoming, southern Colorado, and western Wyoming clusters have relied most heavily on the more distant markets, while the north-central Wyoming cluster has depended primarily on local market conditions. The wood products industry in Colorado and Wyoming has served primarily construction markets and, to a lesser extent, industrial markets. Mills have marketed the higher-valued products, such as joists and

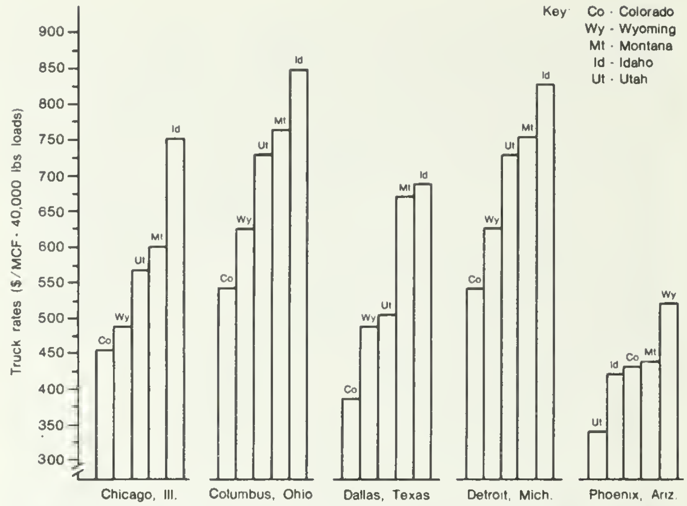

Figure 3.—Truck rates for lumber products to five key market areas.

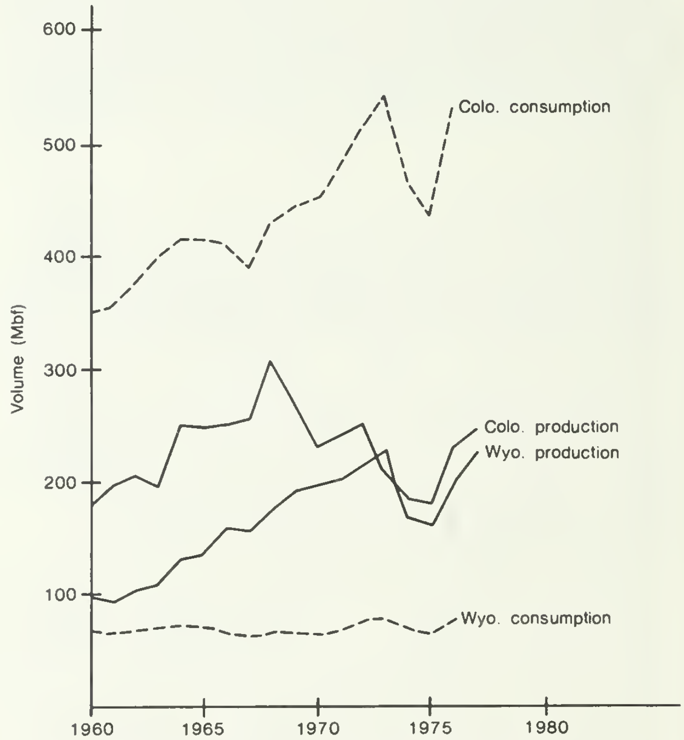

Figure 4.—Colorado and Wyoming lumber production and consumption. Source: Western Wood Products Association Statistical Yearbooks, 1977-1978. Consumption figures are based on the percentage of the total U.S. population in each state times total U.S. lumber consumption. Sources: U.S. Census Bureau and USDA Forest Service, Misc. Publ. 1357, "The Demand and Price Situation for Forest Products, 1976-1977."

studs used in housing construction, to the more distant markets located in the upper Midwest.[11] Because these market areas show no significant local manufacture of

[11] *Mills have traditionally marketed these products outside the two states. Besides profitability, there are other factors involved including a preference on the part of local lumber wholesalers to buy lumber from areas outside of Colorado and Wyoming. The reasons for this are difficult to assess and not part of this study to determine; however, they may involve species preferences, established connections for large orders, and preconceived concerns about product quality (Sampson et al. 1980b, Donnelly et al. 1983).*

such products, the demand for high-value softwood lumber has been strong, and market prices have been high enough to absorb freight charges. Conversely, lower-valued products, such as fencing, rough boards, and houselogs, have been profitable only if sold in nearby markets. Sales of these products often are made directly to end users, such as farmers and ranchers.

In addition, total production in Colorado and Wyoming has met only a fraction of the consumption requirements for the upper Midwest (Illinois and Wisconsin). The current 10% share[12] could possibly increase to 15% under potential-yield programs. The market share in the Great Plains states (Kansas and Missouri) amounted to about 4% of the area's consumption. Considering that present marketing practices emphasize out-of-state markets, local mills supplied about 6% of local (Colorado and Wyoming) consumption, but they could provide up to 15% under potential-yield programs.

Coal Mining Markets.—Local markets for certain products in Colorado and Wyoming could increase because of coal-related energy development activities in the two states. Direct implications for wood products markets stem from the potential use of wood for mine timbers and props in underground coal mines. The extent of this market is difficult to assess, and depends on mining practices used in developing additional mine capacity. Indirect potentials would stem from any increase in housing starts in local areas and the requirements for construction products these would generate. Using projected mining and housing estimates contained in BLM Environmental Impact Statements, lumber needs for housing units and coal developments were determined. Because almost all Colorado coal mines are underground, mine timbers, props, and beams have the greatest product potential. In Wyoming, however, coal is mined at the surface; therefore, need for timbers, props and beams is expected to be much less. Housing starts related to coal energy developments are expected to be significant in both states, with the anticipated housing starts in Wyoming more than twice that of Colorado if coal becomes a major, sustained energy source. However, the outlook for timber products sold to the coal mining industry is uncertain because of the highly volatile relationships the industry has with international prices for its product and for alternative energy sources.

Linear Programming Analysis

To determine the impacts of changed timber supply levels and increased local demand resulting from related energy development and population growth, this study examined several hypothetical models of the future, or scenarios, using linear programming. Considering different levels of timber supply and local market size, a linear programming analysis identified the most profitable mix of products that could be produced by each processing center and the best markets for those products.

The defined objective for the linear programming approach was to maximize net returns, or product profitability, by finding the best allocation of product mixes to markets. Constraints on the problem, which varied for each scenario, involved three limiting factors: (1) available raw materials supplies, described by grade (green #1, green #2, or deadwood)[13] and species; (2) mill capacities for various wood products; and (3) market consumption levels for various products.

Given these constraints, the program selected the products which gave the highest profit per unit of raw materials used, and the market areas where products had the highest net returns. The program limited the choice of product mixes to those manufactured by Colorado and Wyoming producers in 1977. However, it allowed quantities produced to vary within the limits of existing mill capacities. Because it was assumed that mills could not change technology in the short run to shift production from one product line to another, this study also examined shadow prices, or opportunity costs, and suggested where increasing production capacity would be most profitable. Products with high opportunity costs are products that would yield the most profit if constraints limiting production were relaxed and more of the product could be manufactured. The opportunity costs were calculated only for those products which the mills were presently capable, to some degree, of producing.

The linear programming analyses were done in two parts based on timber species. The first part analyzed opportunities and impacts in the four processing center clusters containing primarily spruce-fir and lodgepole pine. The second part studied the processing center cluster in southwestern Colorado containing predominantly spruce-fir and ponderosa pine.

In the analysis focused on spruce-fir and lodgepole pine, the scenarios represent a wide range of possible production levels, harvest levels, and market demands. "Current" refers to 1977-79 levels.

Scenario
1 Current mill production and current programmed harvest level.
2 Current mill production and potential-yield harvest level.
3 Current mill production and potential-yield harvest on all lands except RARE II wilderness areas.[14]

[12]*These percentages were based on the portion of Colorado and Wyoming lumber production shipped to those locations and the total lumber consumption in those states estimated from state housing start figures published by the U.S. Department of Commerce.*

[13]*These grades were derived by using USDA Forest Service timber sale appraisal data and mill information concerning the amount of resource material suitable to make certain products. For example, green #1 is the raw material suitable to make higher-valued products, such as boards. Green #2 is material suitable for products such as dimension lumber. Deadwood is to be used for firewood.*

[14]*RARE II wilderness areas refer to those lands now under Congressional review for wilderness designation and which are likely to be included in the wilderness system soon.*

4 Current mill production and potential-yield harvest on all lands except RARE II wilderness areas and further planning areas where defined.
5 Potential mill production and potential-yield harvest.
6 Potential mill production and potential-yield harvest on all lands except RARE II wilderness areas and further planning areas.
7 Potential mill production and potential-yield cut on all lands except RARE II wilderness areas and including new markets from local energy developments.

In the analysis focused on spruce-fir and ponderosa pine in southwestern Colorado, the scenarios remained basically the same, excluding only the RARE II areas under further planning mentioned in scenarios 4 and 6. Lack of merchantable timber in these RARE II areas will have negligible effect on the linear programming solutions.

Data for these models and the linear programming solutions are taken from the preliminary reports of this study.[3,4,5] Coefficients in the linear programs varied by product, market distance, or species, and were based on 1977 data, the most recent year for which data were available when this work was done.

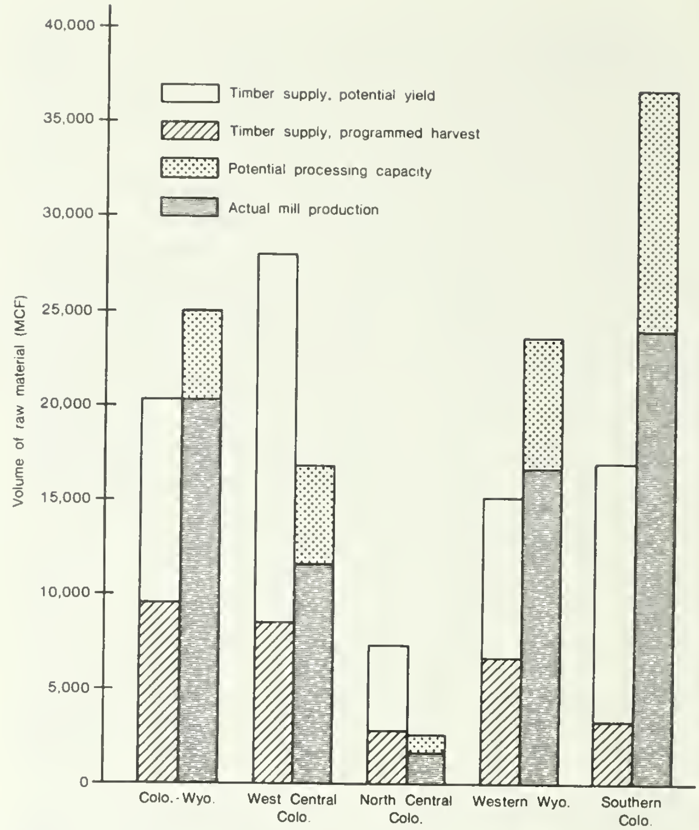

Figure 5.—Timber supply in 1977 compared to production capacity for selected clusters of processing centers. The actual and potential production capacities represent volumes necessary to produce dimension lumber, assuming a similar product mix for each cluster.

RESULTS AND DISCUSSION

The linear programming solutions describe several alternatives for timber management and wood products marketing. These alternatives indicate how changes in the timber supply, changes in market size because of energy development, and mill capacity restrictions affect net returns to mills and the optimal allocation of product mixes to markets. Because timber supply was the major limiting factor, the greatest opportunities for increasing net returns involve changing timber harvest levels.

Several opportunities exist for expanding timber supply from programmed harvest to the potential-yield level. Many Colorado and Wyoming producers did not manufacture products at full capacity and used only a small percentage of the timber that could have become available under potential-yield programs in their own timbersheds (fig. 5). For example, the southern Colorado and western Wyoming clusters had about one-third excess mill capacity, while the Colorado-Wyoming cluster had about one-fifth excess mill capacity. Because the potential mill capacity in these three clusters exceeded potential timber harvest levels, these clusters could readily take advantage of potential-yield programs; but the north-central Wyoming and west-central Colorado clusters would require additional mill expansion and investment to use mcre timber.

Figure 5 also shows that, in most clusters, timber volume cut in 1977 (roughly equivalent to mill production) was significantly greater than volume sold (programmed harvest) that year. Producers harvested timber sold to them in prior years to meet strong demand in products markets, particularly in housing. Thus, considering programmed harvest levels and available standing timber sold earlier, 1977 mill production figures were probably close to maximum.

Within each market cluster, the effects of RARE II wilderness restrictions on potential yields were minimal. The linear programs showed that, if the RARE II lands[14] were withdrawn from harvesting consideration, some processing centers with tight raw material supplies and with limited acres of standard- and special-component lands could become slightly more dependent on marginal lands for their timber supply, particularly in the Monte Vista-South Fork, Buffalo-Sheridan, Pinedale, Afton-Freedom-Alpine, and Evanston timbersheds. However, these impacts were limited to a few processing centers and were not characteristic of any entire market cluster.

Many opportunities also exist for directly improving producers' end-product values, thus, indirectly increasing returns to stumpage and providing opportunities for conducting additional multiple-use activities on forested lands. One way to increase returns to stumpage would be to concentrate timber harvests in areas where values of additional stumpage (opportunity costs) are high, indicating that market demand for raw materials exceeds supply (fig. 6). In Colorado and Wyoming, the analyses showed that returns to stumpage were highest where a variety of high- and low-valued products were produced. For both the Colorado-Wyoming and west-central Colorado clusters, recent killed deadwood was worth almost as much as green raw material because of limits on green material available, the product mixes produced, and large raw material requirements.

Returns were generally higher for spruce-fir than for lodgepole or ponderosa pine in all clusters, except the north-central Wyoming cluster. This difference in value was most significant in western Wyoming, where the product mix was dominated by studs, for which spruce is well suited. Lodgepole pine stumpage was worth the most in the Colorado-Wyoming cluster, and spruce-fir stumpage was worth the most in western Wyoming. Overall, the best immediate opportunities to increase stumpage returns, by as much as 50%, are in western Wyoming and southern Colorado under intensive timber management programs (table 1).

By changing the raw material or mill capacity levels in the linear programming models, it was possible to evaluate potential changes in stumpage prices. If additional raw material became available and mill capacities remained the same, stumpage prices should drop, especially if excess raw materials were used to manufacture lower-valued products. However, stumpage prices could rise if mills expanded production capacity or shifted production to higher-valued product mixes.

Using opportunity costs as a criterion for investment in timber management simultaneously considers the area's raw material market and manufacturing capabilities. This is different from traditional analysis of timber investments which have been based primarily on site productivity, using either present net worth or internal rate of return on a stand basis to assess investment possibilities. However, from an economic standpoint, it makes sense to initially make investments where the returns to stumpage are greatest and then schedule subsequent investments for other market clusters in decreasing order of stumpage value. Looking at this study's opportunity costs at the programmed-harvest level and at the margin, investments in the Colorado-Wyoming, western Wyoming, and southern Colorado clusters appear most worthwhile.

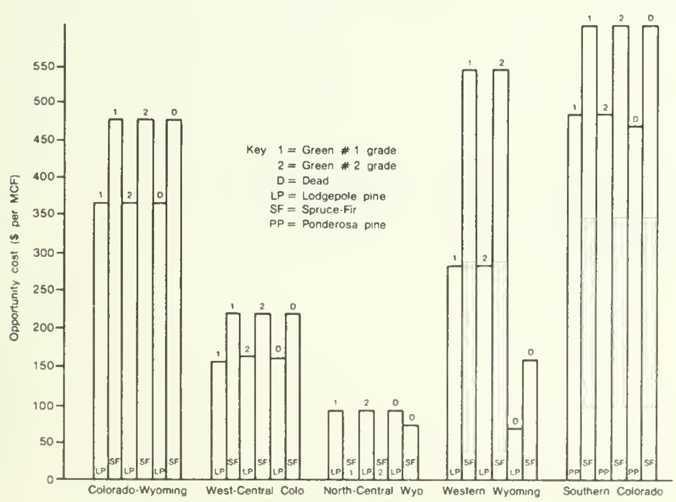

Figure 6.—Opportunity costs for stumpage.

The linear programming alternatives did not indicate a need to change product mixes, except where one or two products dominated production. In Colorado and Wyoming, producers were able to obtain higher net returns for wood products when they diversified their products lines (table 1). The Colorado-Wyoming cluster produced many product lines ranging from high to low values and, as a result, more completely used its raw materials. In contrast, the western Wyoming cluster produced large volumes of studs for which the raw material supply was limited. Consequently, mills in this cluster often used material for studs that also was suitable for other products.

The need for product diversification is important in Colorado and Wyoming, because there currently are no outlets for fiber-type uses, such as pulp and paper or composition board. Similarly, mills should diversify, because the high cost of timber extraction and, in some cases, restrictions on timber supply call for a high degree of efficiency in raw material utilization.

This study demonstrated that changes in local market size did not appreciably affect total production in the two states because production was not previously geared to satisfying demand in the market area. Regional growth in Colorado and Wyoming resulting from energy and other development may create requirements for timbers and housing materials in specific locations, with this demand probably exceeding local production, even under intensive timber management programs with all production being marketed locally. Only about 8% of the mine timbers needed to meet estimated 1977 coal-related energy development requirements were produced in the two states, primarily for Colorado's underground mines. Energy-related housing needs, if they should occur on a sustained basis, are much less for Colorado than Wyoming. Producers in the two states can meet approximately 50% of the expected increase in the Colorado demand for quantities of housing associated with energy development under the programmed harvest level. The west-central Colorado cluster is close to the area where local energy developments may occur and would experience low transportation charges. Local mills in this cluster could supply up to 85% of the energy-related housing needs under potential-yield programs if continuing energy development becomes economic in that area. Because Wyoming mills exported a large percentage of their production, they were able to meet only 7% of Wyoming's 1977 housing demand. However, with improved marketing and higher stumpages prices, local mills could supply a higher percentage of the need. In any case, producers that attempt to meet these housing demands could conceivably use all their capacity to satisfy local markets.

In the future, it seems clear that both states will continue to import wood products to meet their many needs. Economic efficiency, however, suggests the greatest possible utilization of local products be encouraged.

Table 1.—Comparison of residual values, excess mill capacity and excess raw material by market cluster for scenarios 1-7.

Cluster	Residual	Excess mill capacity[1]	Excess raw material[1]
Scenario 1: Current mill production with programmed cut			
Colorado-Wyoming	$9,025,000	2,855	0
West-Central Colorado	4,161,700	418	0
North-Central Wyoming	914,170	0	878
Western Wyoming[2]	3,072,000	2,931	0
Southern Colorado	3,051,000	6,364	0
Scenario 2: Current mill production with potential yield			
Colorado-Wyoming	10,623,000	0	1,610
West-Central Colorado	4,776,700	0	16,354
North-Central Wyoming	1,003,400	0	4,871
Western Wyoming[2]	5,830,000	645	0
Southern Colorado	7,905,900	1,745	0
Scenario 3: Current mill production with potential yield less RARE II instant wilderness areas			
Colorado-Wyoming	10,540,000	0	208
West-Central Colorado	4,762,100	0	13,888
North-Central Colorado	1,003,300	0	4,863
Western-Wyoming[2]	5,732,800	716	0
Southern Colorado	7,849,800	1,830	0
Scenario 4: Current mill production with potential yield less RARE II instant wilderness and further planning areas			
Colorado-Wyoming	10,536,000	0	136
Western Wyoming[2]	5,627,000	791	0
Scenario 5: Potential mill capacity with potential yield			
Colorado-Wyoming	12,604,000	529	0
West-Central Colorado	6,814,500	0	11,912
North-Central Wyoming	1,388,600	0	4,199
Western Wyoming[2]	6,394,900	2,563	0
Southern Colorado	10,426,000	5,661	0
Scenario 6: Potential mill capacity with potential yield less RARE II instant wilderness and/or further planning areas			
Colorado-Wyoming	12,481,000	1,039	0
West-Central Colorado	6,799,900	0	9,446
North-Central Wyoming	1,388,500	0	4,190
Western Wyoming[2]	6,189,600	2,709	0
Southern Colorado	10,370,000	5,747	0
Scenario 7: Potential mill capacity with potential yield less RARE II instant wilderness areas with local energy impact markets			
Colorado-Wyoming	12,515,000	1,014	0
West-Central Colorado	6,841,000	0	9,447
North-Central Wyoming	1,388,500	0	4,190
Western Wyoming	6,296,300	2,634	0
Southern Colorado	10,370,000	5,747	0

[1]*Excess mill capacity is in terms of mcf product, and excess raw material is in terms of mcf raw material.*

[2]*Assumes all deadwood is utilized for firewood, and not other products.*

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Table A-1.—Summary of estimated areas and volumes for procurement areas in Colorado[1]

Processing center clusters	Colorado-Wyoming[2]				West-Central Colorado					
Processing centers	Walden		Craig-Meeker		Delta-Montrose		Eagle-Rifle-Glenwood Springs		Granby-Fraser-Kremmling	
	Acres	Mcf[3]	Acres	Mcf	Acres	Mcf	Acres	Mcf	Acres	Mcf
Living material										
Total sawtimber	90,116	212,199	134,931	260,717	394,794	844,537	146,154	321,711	187,876	465,377
Total poletimber	123,422	209,642	129,641	239,197	274,402	355,538	132,768	251,916	132,248	198,111
Total seedlings and saplings	26,089	6,056	40,957	9,094	54,071	11,778	37,948	5,156	50,474	12,529
Total living material	239,627	427,897	305,529	509,008	723,267	1,211,853	316,870	578,783	370,598	676,017
Dead material										
Sawtimber annual mortality	68,446	1,337	100,532	1,912	N/A	1,368	111,078	1,898	139,544	1,767
Poletimber annual mortality	59,247	835	80,307	1,115	N/A	874	60,412	766	72,836	875
Total dead material	127,693	2,172	180,839	3,027	N/A	2,242	171,490	2,664	212,380	2,551
Total non-CFL	15,176	N/A	47,584	N/A	377,440	N/A	153,150	N/A	189,391	N/A
Total potential yield	2,131	3,360	110,853	7,060	273,360	26,588	135,729	7,027	116,714	7,851
Total programmed allowable cut	1,346	1,374	5,773	2,714	5,200	3,946	20,099	3,508	22,738	3,472
Rare II impacts on potential yield										
Standard component	64,026	([4])	143,943	1228.8	127,339	182.0	123,400	1262.4	24,214	156.4
Special component	879		3,644	[5]8.0	64,617	30	12,709	8.0	58,744	414.4
Total standard & special	64,905	1643	147,587	2812.8	191,956	212	136,109	1270.4	82,958	570.8
Total gross area[6]	130,100		394,270		153,340		908,090		214,010	

Table A-1.—Summary of estimated areas and volumes for procurement areas in Colorado[1]—Continued

Processing center clusters	Southern Colorado					
Processing centers	South Fork Monte Vista		Durango-Dolores		Pagosa Springs	
	Acres	Mcf	Acres	Mcf	Acres	Mcf
Living material						
Total sawtimber	258,690	397,652	137,630	261,965	93,270	183,190
Total poletimber	88,960	79,669	72,003	122,683	43,133	80,877
Total seedlings and saplings	45,759	8,392	8,826	1,908	5,086	1,098
Total living material	393,409	485,713	218,459	386,556	141,489	265,165
Dead material						
Sawtimber annual mortality	N/A	330	N/A	935	N/A	539
Poletimber annual mortality	N/A	532	N/A	125	N/A	72
Total dead material		862		1,060		611
Total non-CFL	231,192	N/A	108,609	N/A	62,591	N/A
Total potential yield	53,690	7,721	100,435	8,790	73,255	5,422
Total allowable cut	5,900	3,990	N/A	1,226	N/A	366
Rare II impacts on potential yield						
Standard component	205,400	142	4,000	22	26,800	136
Special component	7,166	18	-0-	-0-	27,300	4
Total standard & special	212,566	160	4,000	22	54,100	140
Total gross area[6]	924,630		428,940		318,210	

[1]*Includes Forest Service, BLM, and state and private lands. This total includes raw material classifications where acreage or volumetric data were not available in summing values for a given procurement area. Therefore, the totals presented in this table are less than actual-on-the-ground resources. Further, data concerning volumes and acres come from several sources. Not all categories of data were available from each source. Thus, volume and acre figures must be considered independent and using them together, for example, to calculate a volume/acre/year figure, is not possible in many cases.*

[2]*The Colorado-Wyoming cluster includes processing centers and timbersheds that are in both states. See table A-2.*

[3]*Mcf - thousand cubic feet.*

[4]*Standard and special potential yield volumes not broken down by standard or special classifications.*

[5]*Includes additional standard and special volumes which could not be broken down into each component.*

[6]*Gross acres of RARE II areas within procurement area. At the time of this study the final environmental impact statement was not available and categorization of RARE II land was not completed. The figures presented here assume all areas specified in 1978 would be included in the wilderness system.*

Table A-2.—Summary of estimated areas and volumes for processing center timbersheds in Wyoming[1]

Processing center clusters	Colorado-Wyoming[2]				North Central Wyoming			
Processing centers	Laramie-Foxpark		Saratroga		Cody		Buffalo-Sheridan	
	Acres	Mcf[3]	Acres	Mcf	Acres	Mcf	Acres	Mcf
Living material								
Total sawtimber	142,457	185,265	127,705	240,939	87,320	169,492	116,185	200,874
Total poletimber	65,555	92,903	60,624	144,970	45,383	57,345	60,581	75,367
Total seeds and saps	19,797	1,066	18,749	547	27,802	5,670	29,819	11,250
Total living material	227,809	279,234	207,078	356,456	160,505	232,507	206,585	287,491
Dead material								
Sawtimber annual mortality	125,298	2,243	106,794	1,386	N/A	452	N/A	597
Poletimber annual mortality	63,639	587	48,758	1,555	N/A	278	N/A	330
Total dead material	188,937	2,830	155,552	2,941	N/A	730	N/A	927
Total non-CFL	47,455	N/A	32,902	N/A	258,353	N/A	83,199	N/A
Total potential yield	2,861	5,600	3,553	6,579	4,134	3,450	5,991	4,306
Total allowable cut	2,688	2,822	3,008	3,532	1,979	1,316	2,443	1,371
Rare II impacts on potential yield								
Standard component	38,375	90.0	79,890	188.0	20,505	56	97,350	128
Special component	6,332	26.0	2,480	6.0	31,738	64	95,691	109
Total standard & special	44,707	116.0	82,370	194.0	61.243	120	193,041	237
Total gross area[6]	289,980		203,620		665,209		419,470	

Table A-2.—Summary of estimated areas and volumes for processing center timbersheds in Wyoming[1]—Continued

Processing center clusters	Western Wyoming							
Processing centers	Dubois		Pinedale		Afton-Freedom Alpine		Evanston	
	Acres	Mcf	Acres	Mcf	Acres	Mcf	Acres	Mcf
Living material								
Total sawtimber	283,958	562,996	196,237	467,646	345,197	686,322	145,331	256,220
Total poletimber	55,129	19,444	92,557	26,993	166,625	78,719	109,187	37,069
Total seeds and saps	6,042	N/A	3,360	35	17,934	108	18,543	1,073
Total living material	345,129	582,440	292,154	494,674	529,756	765,149	273,061	294,362
Dead material								
Sawtimber annual mortality	N/A	4,273	N/A	4,489	N/A	7,593	N/A	1,756
Poletimber annual mortality	N/A	1,572	N/A	923	N/A	1,858	N/A	343
Total dead material	N/A	5,845	N/A	5,412	N/A	9,451	N/A	2,099
Total non-CFL	271,241	N/A	298,854	N/A	290,318	N/A	134,587	N/A
Total potential yield	18,736	4,349	1,719	3,181	4,395	13,630	1,303	1,834
Total allowable cut	18,602	2,708	1,714	1,950	5,805	2,052	1,737	1,728
Rare II impacts on potential yield								
Standard component	13,834	(4)	9,879	(4)	93,628	840.7	95,874	300
Special component	34,922		54,094		186,068	4157.9	52,773	38
Total standard & special	48,756	4,576	63,973	4,527	279,696	6591[5]	148,647	1,170[5]
Total gross area[6]	462,859		388,334		1,465,322		567,700	

[1]*Includes Forest Service, BLM, and state and private lands. This total includes raw material classifications where acreage or volumetric data were not available in summing values for a given procurement area. Therefore, the totals presented in this table are less than actual-on-the-ground resources. Further, data concerning volumes and acres come from several sources. Not all categories of data were available from each source. Thus, volume and acre figures must be considered independent, and using them together, for example, to calculate a volume/acre/year figure, is not possible in many cases.*

[2]*The Colorado-Wyoming cluster includes processing centers and timbersheds that are in both states. See table A-1.*

[3]*Mcf - thousand cubic feet.*

[4]*Standard and special potential yield volumes not broken down by standard or special classifications.*

[5]*Includes additional standard and special volumes which could not be broken down into each component.*

[6]*Gross acres of RARE II areas within procurement area. At the time of this study the final environmental impact statement was not available and categorization of RARE II land was not completed. The figures presented here assume all areas specified in 1978 would be included in the wilderness system.*

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Profitable wood product mill operation in Colorado and Wyoming depends on of market area, product, mill capacity, and characteristics of the available timber. This study shows how these factors affect marginal value and makes the connection between profitable wood products operations and the opportunities to manage woodlands.

Keywords: Utilization, marketing, forest products, Colorado, Wyoming.

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

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Opportunities for Timber Management and Wood Utilization of the Mixed Conifer Type in Arizona and New Mexico

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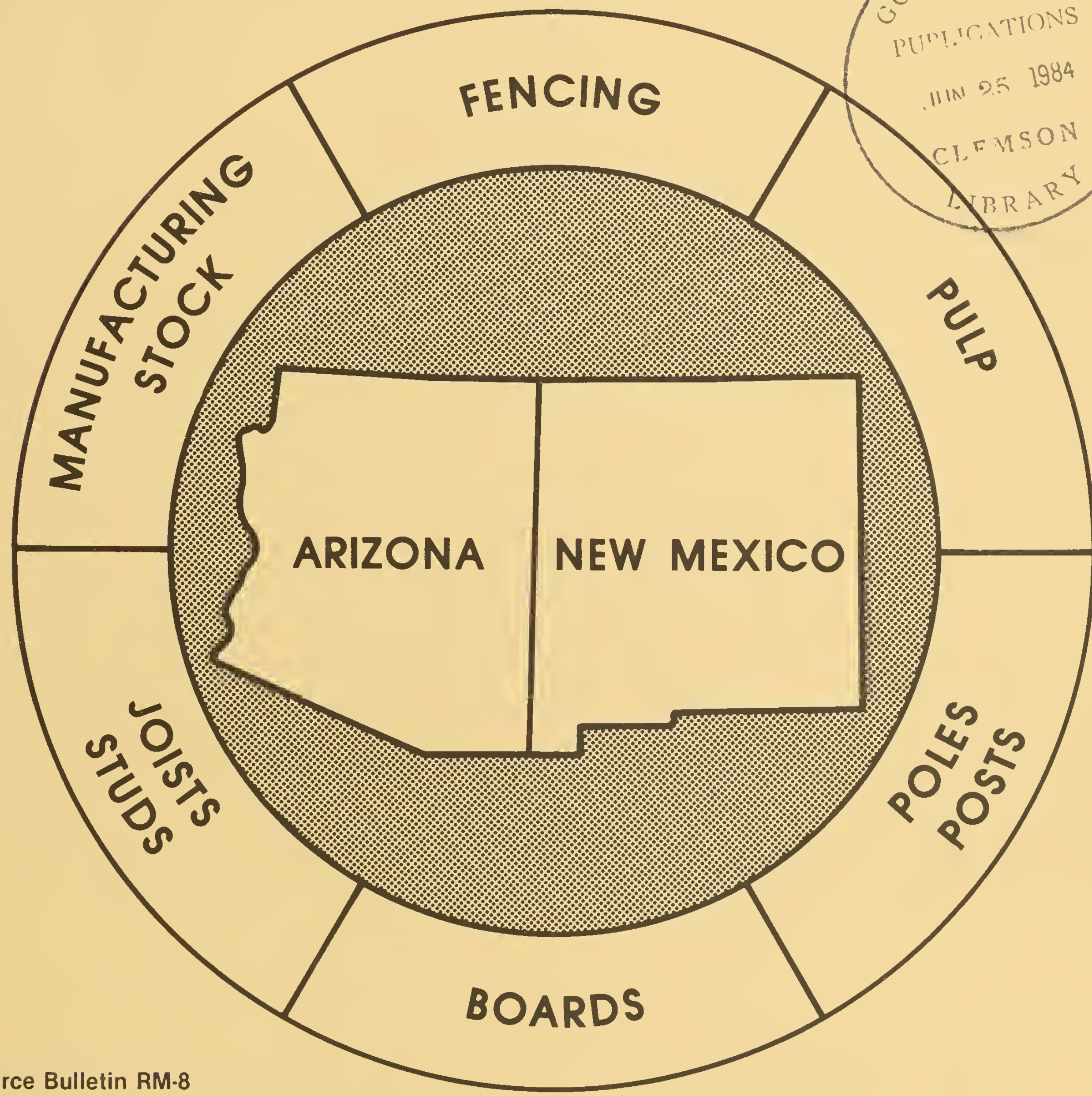

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Abstract

Production cost advantages favor Arizona mills, but marketing cost advantages favor New Mexico mills. Mills in both states can serve Chicago, Dallas, and Denver market areas with traditional and diverse new wood products. Forest management potential benefits from all increased utilization, resulting in better returns to the timber resource.

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Opportunities for Timber Management and Wood Utilization of the Mixed Conifer Type in Arizona and New Mexico[1]

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[1]This paper is based on a final report by David R. Betters, entitled "Opportunities for Increasing Harvest and Utilization of Mixed Conifers in Arizona and New Mexico." Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Fort Collins, Colo., Rocky Mountain Forest and Range Experiment Station Cooperative Research Agreement 80-130-CA, 313 p. Further details are available in this report.

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CONTENTS

	Page
MANAGEMENT IMPLICATIONS	1
INTRODUCTION	2
Mixed Conifer Resource	2
Wood Products and Markets	3
OBJECTIVES	3
METHODS	4
RESULTS AND DISCUSSION	5
Timbershed and Harvest Characteristics	5
Supply Costs and Schedules	8
Supply Costs	8
Mixed Conifer and Ponderosa Pine Sales	8
Comparison of Timbersheds	11
Supply Schedules	12
Products	14
Markets	15
LITERATURE CITED	16

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MANAGEMENT IMPLICATIONS

The structural lumber products now produced from mixed conifer forests generally have lower selling values (although not always less profit) than those produced from ponderosa pine. To help improve selling values, a more diverse set of products, for which the mixed conifer species are technically suited, might be manufactured with fairly low investment and production costs. This diversification has the potential to increase the overall selling value of mixed conifer logs, and at the same time, decrease the reliance now placed on the highly cyclical housing market, which contributes to depressed lumber prices over substantial periods of time. Successful development of such diversified product lines would require both aggressive marketing programs and careful mill production practices.

Selling values might be improved by shipping products to markets with the highest market prices and low transportation costs. Arizona and New Mexico processing centers have advantages because they are near to several of these prime market areas. They include the local in-state markets plus Chicago, Ill., Denver, Colo., and Dallas, Tex. Concentrating marketing efforts for traditional and new products in these market centers should help increase average selling values.

This study indicates that mixed conifer total production costs are generally the same as those for ponderosa pine within the same timbersheds. This is primarily a result of the mixed conifers' high volume per acre. However, the timber supply schedule, or cost per thousand board feet of logs delivered to the mill, is different for each timbershed largely because of the distribution of the timber and available road system. In the Eagar, Alamogordo, and Cuba timbersheds, mixed conifers are generally cheaper to procure than ponderosa pine; in Espanola and Albuquerque, the costs are about the same as ponderosa pine; and in Fredonia, mixed conifers are more expensive to procure. Both mixed conifer and ponderosa pine procurement costs are generally less for available volumes in the Arizona timbersheds; New Mexico timbersheds had higher procurement costs, which increased rapidly for additional volumes. The timbersheds ranked in order of overall procurement cost advantage for both ponderosa pine and mixed conifer are Fredonia, Eagar, Cuba/Espanola, Albuquerque/Alamogordo.

Timbersheds with lower costs offer better economic support for intensive management programs applicable to substantial portions of the timbersheds. When procurement costs are lower, the difference between selling value and cost (less stumpage) is larger, creating the opportunity to better manage and utilize mixed conifer timber.

Arizona timbersheds have advantages compared to those in New Mexico, because the mixed conifer timber is larger, has fewer defects, is a large part of timbershed timber volume, and most of the mixed conifer land, as well as total timbershed area, and may be harvested with standard logging techniques. These characteristics combine to make the Arizona wood utilization situation more favorable from a timber resource standpoint.

In northern New Mexico timbersheds, marginal land is prevalent (almost 50% of the CFL) with 10% to 35% of it occupied by mixed conifers. Therefore, expanding the harvest of mixed conifers would involve some logging on marginal land, using more expensive cable logging systems. Several incentives that could help mitigate the high costs of cable logging are (1) offering significant timber volumes in the sales and providing this volume over extended periods of time; (2) combining, where possible, cable logging with conventional logging; (3) applying cable systems only to areas with high volumes per acre and short logging distances; and (4) allowing a larger margin for profit and risk. Certain of these incentives are now being applied to timber sale offerings in the two states. Additionally, the advantages in terms of procurement costs and volumes available in certain zones within timbersheds could be used to identify the most economical areas for applying cable logging.

Actual timber harvest in most timbersheds has been declining but is still very close to the programmed cut in most timbersheds. Maintaining the present harvest level and, in particular, expanding this harvest to a potential yield level, would require production of diversified product lines which utilize smaller diameter materials. This is because realization of potential yield harvests would necessitate silvicultural treatments that include thinning, shelterwood, and selection methods. These methods usually result in some of the timber removed being smaller or of poorer quality. The Eagar timbershed, with the nearby pulpmill, now has the capability of handling smaller materials. Other processing centers could expand their capabilities along these lines by considering some of the new products mentioned later. Additionally, where timbersheds are near major population centers, such as the New Mexico timbersheds, fuelwood cutting by the public might help increase utilization of smaller-size timber and logging residues and help accomplish intensive timber management goals.

From a resource standpoint, the northern New Mexico timbersheds have the largest capability to increase harvest. In those timbersheds, the potential yield capability of federal and Indian lands is eight times more than the current programmed cut. Further, there is much state and private land in northern New Mexico which might add to this harvest availability. The possible harvest increase in other timbersheds is lower, primarily because they have less marginal land. Fredonia's annual harvest could increase by 50% and Alamogordo's 130% under a potential yield program. In all timbersheds, this level of management would allow for considerably expanded mill capacity, particularly in northern New Mexico. On the average, annual mill capacity could be increased by 15 to 30 million board feet at each processing center. The opportunities for expanded wood utilization are great, but only if mills diversify their production.

From a productivity standpoint, resource managers can increase forest growth considerably by intensive management of mixed conifer lands. From a timber investment standpoint, mixed conifer lands should offer a very cost efficient investment.

INTRODUCTION

Mixed conifer forests in Arizona and New Mexico provide many benefits that are based on timber, wildlife, water yield, range, and recreation. Increased production of such benefits relies, at least in part, on the ability to apply vegetation management practices that are economically justified. This in turn, usually requires economical use of the raw material as wood products. Within the two states, ponderosa pine is the predominant species utilized for wood products. Finding economic outlets for the timber is often more difficult when using mixed conifer species.

Compared to ponderosa pine, mixed conifer logs often have a higher level of defect and typically sell for lower prices. Sometimes logs are small and must be harvested on steep slopes. These problems tend to increase costs and decrease profit margins. Therefore, the wood utilization and marketing aspects of mixed conifer management should be analyzed for specific locations.

MIXED CONIFER RESOURCE

Mixed conifer forests typically contain Douglas fir (*Pseudotsuga menziesii* var. *glauca*), ponderosa pine (*Pinus ponderosa* and *Pinus ponderosa* var. *arizonica*), white fir (*Abies concolor*), Engelmann spruce (*Picea engelmannii*), aspen (*Populus tremuloides*), southwestern white pine (*Pinus strobiformis*), blue spruce (*Picea pungens*), and corkbark fir (*Abies lasiocarpa* and *Abies lasiocarpa* var. *arizonica*), often in that order of abundance. In some mixed conifer areas in the Southwest, one or more of these species may be absent (Jones 1974, Moir and Ludwig 1979).

Mixed conifer stands are scattered throughout the mountains of both Arizona and New Mexico, but are most extensive in the White Mountains and Mogollon and North Kaibab Plateaus in northcentral and mideastern Arizona, and the Sacramento, Sangre de Cristo, and Zuni mountains of southeastern and northcentral New Mexico (Moir and Ludwig 1979). Figure 1 illustrates the location of the mixed conifer forests in the two states.

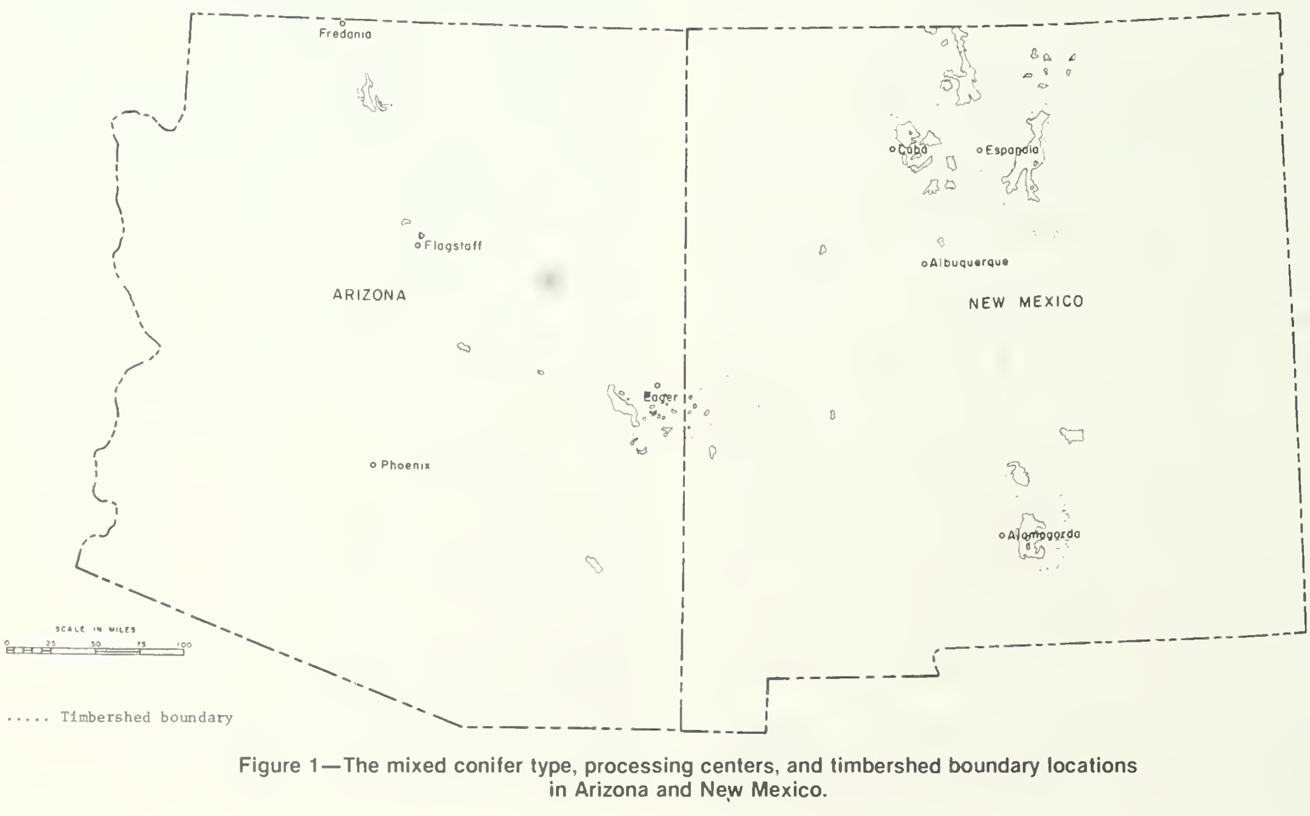


Figure 1—The mixed conifer type, processing centers, and timbershed boundary locations in Arizona and New Mexico.

This forest type is typically found between the ponderosa pine and spruce-fir types, at elevations of 8,000 to 10,000 feet. Because the stands are at higher elevations, they tend to receive more moisture, a critical growth factor in the Southwest. This additional moisture makes most mixed conifer sites more productive with a higher timber site index than for ponderosa pine.

Most mixed conifer forests are located on public or Indian ownerships. In Arizona, virtually all the mixed conifers are on either national forest land, in particular the Kaibab and Apache National Forests, or the White River Apache Reservation. In New Mexico, the mixed conifer type is principally on the Lincoln, Carson, and Santa Fe National Forests, and the Mescalero Apache Indian Reservation. Additionally, there are some mixed conifer stands on state and private lands in the northcentral part of the state.

Mixed conifers, excluding ponderosa pine, make up a larger portion of New Mexico's commercial timber volume than Arizona's — 37% compared to 18% (Green and Setzer 1974). Both states have fairly large areas of sawtimber-sized mixed conifers. In Arizona, about 97% of 309,000 acres of commercial forest land is sawtimber size. In New Mexico, about 86% of 1,667,000 acres of commercial forest land is classed as sawtimber (Green and Setzer 1974).

Most silvicultural prescriptions use the shelterwood or selection systems. Regionally, prescriptions often vary, because mixed conifers exhibit many different stand structures (Jones 1974) and have a variety of problems caused by insect, disease (particularly dwarf mistletoe), and windthrow. This variability in stands often results in a great deal of diversity in timber volume, size, and mix of species harvested.

WOOD PRODUCTS AND MARKETS

The wood products industry was one of the first established in the Southwest and continued to grow with the region until its production and employment peaked in the early 1960's (Setzer and Barrett 1977, Setzer and Throssell 1977). Since then, the number of wood product firms, employment, and lumber production have declined.

In the years after 1970, lumber production averaged 340 mmbf per year in Arizona and 250 mmbf per year in New Mexico (Western Wood Products Association 1980). The bulk of this lumber is produced by five fairly large firms — three in New Mexico and two in Arizona — whose mills are equipped with debarkers, bandsaws, gang saws, edgers, chippers, dry kilns, and planers. Most of these firms' mills are capable of producing at least 20 mmbf of graded lumber per year.

A pulp and paper mill in Snowflake, Ariz., produces newsprint and liner board (412 M tons per year), while in Albuquerque, N.Mex., an industrial particleboard plant has capacity of 42 million square feet per year. (Wood Industry of New Mexico 1979, Primary Wood Industries of Arizona 1978).

Sawmills in the two states share many characteristics but also exhibit several differences. Both Arizona's and New Mexico's sawmills are highly dependent on federal timber as a source of raw materials. Arizona and New Mexico sawmills obtain about 99% and 82%, respectively, of their timber from federal lands.[3] In other western states (excluding the West Coast), an average of only 74% of the timber harvest comes from federal sources.

New Mexico's sawmills use more mixed conifer species than Arizona's. Mixed conifer species comprise 35% of New Mexico's harvest compared to 13% of Arizona's. In both states, however, the bulk of each state's harvest is ponderosa pine (Western Wood Products Association 1980).

Mixed conifer species are most often the raw material for dimension stock. Ponderosa pine typically is sawn for shop and graded board lumber. Mills manufacture studs from both species groups. A few of the larger mills, and most of the smaller operations, produce one or more other products, including rough lumber, timbers, ties, viga poles,[4] fence post and poles, fuelwood, and houselogs. However, the total production of these products is small compared to that of graded lumber (Western Wood Products Association 1980). By-products, such as chips and sawdust, are normally sent to the pulp and paper mill, a particleboard plant (when economically feasible), or are burned at the sawmill to provide heat for the kilns.

Arizona mills market their products in other western states and in the Midwest. New Mexico's mills market to other western states and the southcentral states of Texas and Oklahoma. About 50% of the lumber is distributed through wholesalers, and another 30% is distributed directly to retailers. About 90% of the Arizona/New Mexico lumber is shipped by truck compared to an average of 65% for western sawmills in general. This is partly a result of the large "local" demand in nearby western and south central states. The relatively small volume of products shipped by rail is more economical when distance is greater than 900-1,000 miles one way.

OBJECTIVES

Because the forest products industry in the Southwest is oriented to lumber, only certain species and sizes of trees are sought for primary products. Mixed conifer forests, however, potentially may supply a wide variety of tree species and sizes. The goal then is to better match the types and kinds of wood fiber produced by forest management with wood products that southwestern forest products industry currently produces and other products that it could produce.

This study examines the economic and marketing aspects of the interaction between forest management

[3]*These figures are from the Western Wood Products Association Statistical Yearbook. The statistics include lands administered under the Bureau of Indian Affairs (BIA). Management and timber harvests on BIA lands are controlled by the respective Indian tribe, not the federal government.*

[4]*Viga poles are the roof joists employed in adobe style, southwestern Spanish American architecture. Viga poles may be decorative, functional, or both.*

and forest industry. It focuses on specific timbersheds and their associated wood products mills. The objectives of this study are:

1. to examine the mixed conifer timber supply with respect to quantity and location,
2. to determine the economic availability of the mixed conifer timber supply as it relates to timber size, product type, and harvest costs,
3. to identify the most promising markets for mixed conifer products from specific timbersheds and their associated mills.

METHODS

The first step in the analysis is to choose the location of processing centers. Locations considered for processing centers must be within 100 miles of mixed conifer forests and have an existing mill production capacity of at least 20 mmbf per year.[5] Because Fredonia and Eagar, Arizona, and Alamogordo, Albuquerque, Cuba and Espanola, N. Mex., match these criteria, they are the six processing centers analyzed in this study (fig. 1).

Because topographic features and transportation systems vary by location, each processing center has a unique wood procurement area or timbershed. Personnel from national forests, the Bureau of Indian Affairs, and mills helped establish the boundaries for each processing center's timbershed. The criteria used to establish boundaries included past procurement activities and the quantity of timber likely to be economically available in the foreseeable future. While the boundaries were selected to represent economic operating conditions, every effort was made to use boundaries compatible with existing inventory data, thus avoiding extrapolation or adjustment error. Finally, timbershed boundaries for certain processing centers overlapped. The areas were documented where overlap occurs, but each processing center was analyzed as a separate case study. Overlap between processing center timbersheds was especially noticeable in the north-central New Mexico area.

USDA Forest Service timber management plans and forest survey publications provided data concerning timber characteristics in each timbershed. Local resource managers familiar with each processing center and its associated timbershed helped to verify and expand the data. Timber resource information collected for each timbershed included the location and characteristics of the timber, both mixed conifer and other timber types, and past and present, actual and planned levels of harvest. This information was summarized in tables, and the locations of timber types were recorded and overlayed on U.S. Geological Survey state maps. In cases where the inventory and harvest data represented sites outside the timbershed area, the information was adjusted to fit the timbershed boundaries by prorating the figure based on that area applicable to the timbershed.

USDA Forest Service timber sale appraisal summaries furnished information for each timbershed about cost and other characteristics of recent timber sales. Most timber sale data are from the previous 5 years; but, in some instances, data from the past 7-8 years are included to develop an adequate sample size for both mixed conifer and ponderosa pine sales. All cost figures were adjusted to a common base year; then descriptive statistics were developed for each category of cost (e.g., logging) in the appraisal. A statistical "t" test helped determine if there were significant differences between various characteristics of mixed conifer and ponderosa pine sales within the timbershed. Two other statistical tests, a one-way analysis of variance and Tukey's multiple comparison, helped determine if there were significant differences in various cost categories between timbersheds.

Economic supply schedules for logs delivered to the mill deck were developed for mixed conifer, ponderosa pine, and the aggregate of the two, within each timbershed. The supply schedules constructed relate cost per unit volume and distance. Using the cost information for that timbershed, an average total procurement cost per thousand board feet, less hauling, roads and stumpage, was estimated for mixed conifer and ponderosa pine.[6] The types of roads encountered within a given distance from the mill affected estimates of hauling cost. On this basis, a hauling cost per thousand board feet was calculated for each 10-mile increment from the processing center. The volume of mixed conifer and ponderosa pine within that distance zone was estimated using the U.S. Geological Survey maps overlaid with the location of the timber types. A planimeter was used to estimate acreages within each distance zone; then a volume figure was derived for each timber type using the proportion that acreage represented of the total accessible or operable volume/acreage for the timbershed.

Once costs are well defined, the difference between wholesale lumber prices at the market and freight costs to the market will determine the most profitable market locations for each processing center. The larger the difference, the more profitable it would be to market the product in that area. Seven major market centers were selected for analysis. These markets are close to the Southwest and are considered economically feasible possibilities. An informal telephone inquiry provided estimates of wholesale lumber prices in these markets. Truck freight rates published by the Western Wood Products Association provided the basis to estimate freight costs from each processing center to each market area.

In order to identify potential new products manufactured from mixed conifer timber, a technical evaluation

[5]Certain Indian-owned mills satisfied these two criteria, but used only tribal timber as a source of timber supply. These mills were not considered as processing centers in this study. Further, mills that procured a large portion of their raw material outside the two states and/or actually operated at a much lower production level also were not considered.

[6]Road costs were not included, because they were extremely variable depending on the sale conditions. Stumpage was not included, because it is a function of the other costs. The appraisal process calculates stumpage as a residual value, or what is left after costs and a margin for profit and risk are subtracted from lumber selling value.

matched properties important for particular wood products with corresponding properties of mixed conifers. Most of the information for this evaluation came from published technical sources, but discussions with mill operators also provided suggestions for new products.

RESULTS AND DISCUSSION

TIMBERSHED AND HARVEST CHARACTERISTICS

Table 1 describes each timbershed's timber supply characteristics and reveals some differences as well as similarities between timbersheds. Timbersheds varied in their amount of commercial forest land (CFL), with northern New Mexico timbersheds having the largest acreages and Fredonia, Ariz. the smallest. However, the northern New Mexico timbersheds also have significant amounts of marginal component lands in the CFL base. If these lands are deleted and the standard or operable component acres are the only acres considered, there is much less variation among timbersheds. Thus, the operable acres, or acres available for harvest by conventional logging means, is reasonably the same in each timbershed.

In most timbersheds, the mixed conifer acreage ranges from 10% to 35% of the total marginal component acres. Only the Alamogordo timbershed and the Fredonia timbershed have a larger proportion of mixed conifer type on marginal lands. However, in both cases, the total marginal component acreage is rather small compared to the timbershed's total commercial forest land, and the majority of the mixed conifer acreage is located in the standard component.

Because most marginal component lands are on steep slopes, harvesting these acres normally requires cable logging, which costs more. Thus, increased harvest and utilization of mixed conifer and other timber types from marginal lands will require efficient use of cable logging systems. This is especially the case in northern New Mexico. Although cable systems are more expensive, the timber located on marginal component land is generally larger and has more volume per acre, particularly if it is mixed conifer. This can help to offset the higher costs; and if cable logging is combined with conventional logging sales, the mix can provide an economically viable harvest. This "sale mix" concept is now being applied in the Alamogordo and Eagar timbersheds.

Generally, the mixed conifer type makes up about 30% to 40% of the standard or operable sawtimber acreage and volume, respectively, in each timbershed. The only exception to this is Alamogordo, where approximately 50% and 70%, respectively, of the timbershed acreage and volume is comprised of mixed conifer. Ideally (with proper road and stand conditions), forest management would require the timber types harvested in each timbershed to be proportional to these figures. This is now the case in the Eagar and Alamogordo timbersheds—the proportion of species cut is close to the proportion of species available for harvest—but the remaining timbersheds should have a slightly higher portion of mixed conifer species in the harvest cut. In these other timbersheds about 15-25% of the present harvest is species other than ponderosa pine; this should probably be increased by about 10% to have the species cut correspond to available acreage and volumes of mixed conifer.

In all timbersheds, a large portion, averaging 45%, of the mixed conifer type is classed as Site I land (60 cubic feet or greater growth per acre per year). This percentage of productive land is normally greater than the mixed conifer type's percentage of total timbershed acreage. For example, in Fredonia the mixed conifer type represents 40% of the timbershed acres but more than 60% of the Site I acres; in Alamogordo it is 46% and 77%, respectively, of the timbershed and Site I acres. In other timbersheds, the differences in percentages are somewhat less, but only because those timbersheds have some spruce-fir acres that also tend to have higher site indices. Intensive timber management programs are likely to concentrate on more productive sites. This implies a larger portion of these treatments should be considered for mixed conifer sites.

The mixed conifer type is located in fairly large, continuous blocks in the Cuba, Alamogordo, and Fredonia timbersheds; whereas in the Albuquerque, Espanola and, especially, Eagar timbersheds, the acreage is scattered in blocks throughout the area. Blocks of mixed conifer are located fairly close to the Cuba processing center; at mid-distance in the timbershed tributary to Alamogordo; and more distance in the case of the Fredonia processing center. In the other timbersheds, as mentioned previously, the blocks of mixed conifer are in different subregions within the timbershed; and, therefore, distances vary from processing centers. Those differences make mixed conifer procurement, or hauling costs, vary depending on the timbershed.

All processing centers are heavily dependent on Forest Service timber. The only processing center not 90-100% dependent on Forest Service timber is Alamogordo, where approximately 50% of the harvest comes from the Mescalero Apache Indian Reservation; most of the remainder comes from the Forest Service lands. State and private lands generally have not been available for harvest in the recent past, although they represent a fairly large portion of acreage in the New Mexico timbersheds. Most private ownerships are small with traditionally heavy emphasis on recreational use, which is likely to continue. However, the extent of private acreage within New Mexico timbersheds indicates the potential for expanded harvest, if private landowners could be encouraged to manage their lands for multiple products, including recreation and timber.

In most cases, actual timber harvest is very close to the programmed cut (table 1). Fredonia is an exception. Although actual cut has been increasing in that timbershed, there appears to be an opportunity to expand the actual harvest by 8 million board feet per year in order to meet annual programmed harvest. In most timbersheds, the actual cut has declined slightly over the past 10 years. This is probably a result of general economic conditions and the weak housing market, rather than a

Table 1.—Timbershed characteristics[1]

	Fredonia Ariz.	Eagar Ariz.	Alamogordo[2] N. Mex.	Cuba[3] N. Mex.	Espanola[4] N. Mex.	Albuquerque N. Mex.
Total timbershed area (thousand acres, commercial forest land[5])	298.2	624.6	218.7 172.0 (BIA)	493.0	819.0	1138.0
Land class[6] (thousand acres)						
USFS						
Standard	273.0	520.7	206.8	248.0	343.4	450.4
Special	18.0	18.9	0.0	41.0	46.7	73.7
Marginal	7.2	86.1	11.9	212.7	317.5	457.2
State and private	0.3	N/A	99.0	293.4	293.4	82.8
BIA	0.0	0.0	172.0	0.0	0.0	0.0
Timber type[7] (thousand acres)						
Ponderosa pine	198.0	446.1	61.5	127.0	182.7	242.7
Mixed conifer	82.8	77.5	104.1	43.8	119.8	159.8
Spruce-fir	0.0	5.9	1.7	8.0	68.0	75.0
Aspen	14.0	10.3	8.0	N/A	N/A	N/A
Timber volumes[8] (mmbf)						
Sawtimber						
Ponderosa pine	438.2	1658.6	144.4	521.4	502.4	800.4
Mixed conifer	237.3	881.6	789.1	167.7	466.7	602.7
Spruce-fir	0.0	42.1	63.1	46.4	394.4	435.4
Aspen	N/A	159.9	84.8	N/A	N/A	N/A
Total	676.5	2742.2	1081.4	735.5	1492.7	1867.7
Timber harvest[9]						
Actual cut (mmbf/yr.), average of cut 1975-80, average change 1970-80	43.0, 0.8	55.0, −4.9	10.8, −0.1 18.4, −2.9 (BIA)	26.7, −2.0	36.0, −1.2	53.6, −1.9
Programmed cut (mmbf/yr.)	51.0	55.0	15.0 18.0 (BIA)	27.5	36.8	54.8
Potential yield (mmbf/yr.)	80.0	55.0	35.0	251.3	290.5	447.5
Fuelwood (thousand cords/yr.) average 1975-80, average change 1975-80						
Commercial	0.22, 0.01	5.1, 0.95	1.0, 0.09	5.8, N/A	4.6, N/A	8.5, N/A
Free use/nominal fee	2.2, 0.77	0.02, 0.02	10.2, 0.90 1.7, 0.18 (BIA)	17.0, −2.0	24.4, −0.71	37.8, −1.37
Processing capacity	35.0	50.0	20.0	25.0	25.0	20.0
Site class[10] (thousand acres, percentage of class)						
Site I						
Ponderosa pine	27.2, 37%	80.9, 51%	11.3, 15%	17.4, 6%	23.3, 6%	33.8, 6%
Mixed conifer	44.8, 61%	60.7, 38%	58.4, 77%	41.8, 30%	69.5, 30%	96.9, 30%
Spruce-fir	0.0, 0%	4.0, 3%	1.9, 2%	25.2, 71%	39.2, 71%	105.7, 71%
Aspen	1.5, 2%	13.4, 8%	4.3, 6%	N/A	N/A	N/A
Site II						
Ponderosa pine	27.2, 37%	323.9, 88%	42.6, 45%	43.6, 15%	55.7, 15%	84.5, 15%
Mixed conifer	26.8, 15%	39.9, 11%	46.1, 49%	51.4, 37%	85.7, 37%	119.6, 37%
Spruce-fir	0.0, 0%	21.0, 0.5%	0.9, 1%	8.2, 23%	28.8, 23%	34.2, 23%
Aspen	5.4, 3%	1.7, 0.5%	4.3, 5%	N/A	N/A	N/A
Site III						
Ponderosa pine	22.6, 53%	96.4, 91%	38.4, 86%	22.9, 79%	293.4, 79%	445.0, 79%
Mixed conifer	11.5, 27%	10.0, 9%	6.3, 14%	45.9, 33%	76.5, 23%	106.7, 23%
Spruce-fir	0.0, 0%	N/A	N/A	2.1, 6%	7.6, 6%	9.0, 6%
Aspen	8.5, 20%	N/A	N/A	N/A	N/A	N/A

[1]More detailed information is available in the Final Report, Opportunities for Increasing Harvest and Utilization of Mixed Conifers in Arizona and New Mexico, Cooperative Study, RM Agreement No. 80-130-CA, 1981. 313 p.

[2]All figures are for the Lincoln National Forest unless otherwise noted as BIA. Because the timber management plan for the Mescalero Apache Indian Reservation was not available, detailed volume information is not shown for BIA lands. However, on-site discussions with BIA officials indicated the Reservation's timber is about one-half mixed conifer and one-half ponderosa pine.

[3]Figures for the Cuba, Espanola, and Albuquerque timbersheds were estimated based on the portion of total Carson and Santa Fe National Forest acreage located in that timbershed. State and private CFL acreage figures for Cuba and Espanola are for Taos and Rio Arriba counties; Albuquerque includes Bernalillo, Sandoval, and Torrance counties. State and private figures are not included in volume available, because very little harvesting occurs on these lands. The Cuba timbershed contains 118,000 CFL acres it shares with Albuquerque; the Albuquerque timbershed contains 160,000 CFL acres that it shares with Cuba, and also contains 278,000 CFL acres it shares with Espanola; in addition, the Cuba timbershed also contains 160,000 CFL acres it shares with both Albuquerque and Espanola.

[4]Percentages for Sites I, II, and III for Carson National Forest were not available. Percentages for Santa Fe National Forest were used in the calculation. The acreage figures in each site index are based on total CFL acres.

[5]Commercial forest land (CFL) is that forested land capable of producing growth of at least 20 cubic feet per acre per year.

[6]Standard component lands are that portion of U.S. Forest Service CFL lands that are suitable and available for timber production and can be harvested under the usual provisions of a timber sale contract. Special component lands are that part of the U.S. Forest Service CFL that are suitable and available for timber production but require specially designed silvicultural treatments to achieve other key resource objectives. Marginal lands are USDA Forest Service CFL lands that are suitable for timber production but not currently available because of constraints associated with costs, product values, lack of market or resource needs. State and private lands are forested lands in those ownerships which fit the definition of CFL.

[7]Timber type class is based on the dominant tree species; if the species makes up more than 50% of the volume, the site is classed as that type. Mixed conifer have no one species that makes up 50% of the stand volume, and many of these have ponderosa pine in them. These are operable or standard component acres.

[8]Sawtimber are trees 9 inches d.b.h. and larger and volumes are calculated to a variable top diameter inside bark. Information concerning poletimber volumes are generally not available. N/A indicates the data are not available. These are operable or standard component acres.

[9]Actual cut is the actual amount of timber cut during a year. Programmed cut or harvest is the scheduled volume available for harvest in a fiscal year; it is based on potential yield considerations, funding and markets. Potential yield is the long-term sustainable harvest of the forest under a regulated management plan. The programmed harvest for Alamogordo is the combination of USFS and BIA allowable cuts; for Cuba, Espanola and Albuquerque, it involves a proration based on timbershed size and the Santa Fe and Carson National Forest harvest figures.

[10]Site Class I lands are capable of tree heights of 80 feet in 100 years or growth of 60 cubic feet per acre per year or greater; Site II 40 to 79 feet in height in 100 years or 40-60 cubic feet per acre per year; Site III less than 40 feet in height in 100 years or less than 40 cubic feet per acre per year. Figures for Eagar include some CFL acreage outside the timbershed.

reduction in available timber. Overall, there seems to be adequate capacity existing in processing centers to handle the present programmed harvest.

Potential yield varies considerably by timbershed, with the greatest opportunities for expanding harvest being in the northern New Mexico and Fredonia timbersheds (table 1). The northern New Mexico timbersheds, for example, could potentially harvest eight times more timber than programmed in the current cut. Attaining such harvest levels would require logging large acreages of marginal component lands and cutting smaller-sized material as part of a timbershed-wide intensive timber management program. Cable logging and increased utilization capacity capable of handling smaller-sized materials would be necessary.

Fredonia and Alamogordo have potential for increasing timber harvest by 60% and 130%, respectively, over the current programmed cut. These potential increases are less than those possible in the northern New Mexico timbersheds, because Fredonia and Alamogordo have substantially less marginal component lands. Most national forest lands in these timbersheds are standard or operable acreages. However, a potential yield program implemented in these timbersheds would require additional mill capacity (30 million board feet at Fredonia and 15 million board feet at Alamogordo) as well as the capability to handle smaller material.

Eagar is the only timbershed where programmed harvest is close to potential yield. Currently, the pulpwood market (Colorado Plateau Contract) in the Eagar timbershed area allows removal of smaller-sized material, resulting in more intensive timber management. In addition, there is some marginal component land which could, via cable logging, allow a further increase in the harvest level.[7]

Compared to other timbersheds, commercial and individual fuelwood harvest is much greater in New Mexico. In northern New Mexico, a fairly large number of "locally dependent" communities burn wood as a major alternative heat source. Additionally, there are commercial markets at winter ski areas and large population centers in the west Texas and Albuquerque, N. Mex. regions. Eagar and Fredonia have less fuelwood use, because the areas are fairly isolated and are some distance from major population centers. However, they also have experienced an increase in fuelwood harvest, which is likely to continue in the future, if fossil fuel prices remain at high levels compared to wood.

The area's national forests require permits for commercial and private cutting of fuelwood. Generally, the fuelwood is harvested from dead and downed material or from logging residues. In areas where a substantial fuelwood market exists, timber management/utilization might be improved by cutting 6-inch to 9-inch live timber for fuelwood as part of commercial thinning operations.

[7]The new national forest management plans were in the process of being completed at the time of this study, and the impact these plans would have on the level of harvests, both programmed and potential yield, was not known.

SUPPLY COSTS AND SCHEDULES

Supply Costs

Table 2 contains the results of the statistical analysis of each timbershed's timber sale appraisal data. The left side of the table shows, by timbershed, the mean or average values of various sale characteristics for both mixed conifer and ponderosa pine sales and a combined average for all sales. The right side illustrates the range in values for these same characteristics (for all sales combined) and indicates the results of a statistical analysis that tests for significant differences in the characteristics between timbersheds.

Mixed Conifer and Ponderosa Pine Sales

The sale size (acres) of individual mixed conifer and ponderosa pine sales is reasonably the same for most timbersheds. Eagar is the only exception; there ponderosa pine sales in the timbershed contain about five times more acres than mixed conifer sales. This probably occurs in the Eagar timbershed because the mixed conifer stands there tend to be of smaller acreage and scattered throughout the timbershed. However, even though the acreage of pine sales is five times larger in the Eagar timbershed, the total volume of pine sales is only twice that of the mixed conifer sales with no statistically significant difference. This is partly because mixed conifer stands have more volume per acre, resulting in a total mixed conifer sale volume much closer to the total pine sale volume. This is demonstrated also in the Alamogordo timbershed, where the additional volume per acre results in a mixed conifer sales volume that is three times larger than ponderosa pine (although not significantly different), even though the sale acreage sizes for the two species are reasonably similar. Other factors also influence the volume harvested including differences in silvicultural prescriptions.

One problem commonly associated with mixed conifer species is a high level of defect, particularly in New Mexico timbersheds. Another problem is lower lumber selling value. This too is reflected in the sale appraisal analysis, which shows mixed conifer lumber selling values (log scale) to be generally lower than ponderosa pine, and significantly lower in the Eagar and northern New Mexico timbersheds. Finally, mixed conifer sales typically have a heavier concentration of slash and added costs for lopping, piling, or scattering slash. In general, the appraisal analysis indicates some additional costs for slash disposal in mixed conifer sales, but these differences are not enough to create any marked difference in total production costs.[8]

[8] *There is, however, a good deal of variation in slash disposal costs, depending on the extent of USDA Forest Service participation in slash disposal, silvicultural prescriptions, yarding unutilized material and fire hazard reduction requirements, and fuelwood markets. Thus, the variation possible may be the major problem; the mean values discussed here do not reflect this situation. Given this range in values, slash disposal costs could definitely be a major cost in certain sales. Table 2 illustrates, by the width of the confidence intervals, the variation in slash piling costs.*

There are positive features related to mixed conifer utilization that tend to offset these problems. For example, compared to ponderosa pine sales, the mixed conifers sometimes have large diameters and generally have higher volume per acre. In certain cases, mixed conifer sales involve shorter hauls to the processing center. These factors can combine to help decrease overall production costs. This seems to be the case in the sales analyzed here, because total production costs are not significantly different between ponderosa pine and mixed conifer sales. The contention that total production costs are reasonably the same was supported, informally, by on-site discussions with the mill operators and Forest Service personnel at two of the processing centers. Depending on location, however, others estimated the logging costs to be 10-25% higher for mixed conifer timber. The appraisal analysis indicated that in the Fredonia and Alamogordo timbersheds, mixed conifer logging costs per thousand board feet are, in fact, about 10% higher, while the opposite is the case in Eagar and northern New Mexico timbersheds where mixed conifer logging costs are approximately 10% less than ponderosa pine, although not significantly different.

To determine whether mixed conifer sales were less "profitable" a comparison was made of total production costs (less stumpage) to lumber selling value—the higher the percentage of total costs to selling value, the less the margin for a net return. The results of this analysis (table 2) indicated that there were no statistically significant differences between ponderosa pine and mixed conifer sales. The mixed conifer sales averaged 4% less (percentage of total costs to selling value) than ponderosa pine sales in New Mexico — 73% compared to 77%. However, the opposite occurs in the Arizona timbersheds. There, the percentage averaged about 6% higher in mixed conifer sales — 71% compared to 65%. This, in part, is related to lower lumber selling values (Eagar) as well as longer hauling distances (Fredonia) for mixed conifer sales.

Sale appraisals specifically for cable logging were not available for either mixed conifer or ponderosa pine; therefore, cost estimates were collected through informal discussions with Forest Service personnel and loggers. Loggers currently using cable systems estimate the stump-to-truck costs to be about $40 per thousand board feet higher for cable logging. Forest Service personnel estimate these costs to be even greater—$80 per thousand board feet higher than the costs of conventional harvest methods. In all the timbersheds, this additional cost added to the current total production costs would result in a cost figure close to, and in some cases higher than, the selling value of the lumber. This would result in little, or no margin available to the mill for profit and risk, or no return to the timberseller for stumpage. Also, this cost-to-selling value comparison does not include roads, a likely component of cable logging sales that would further reduce the margin for a return to the mill or timber seller. Given these additional costs of cable logging, some incentives or innovations must be developed to make most cable sales economically feasible.

Table 2.—Timber sale characteristics and cost comparison[1]

	Comparison of mixed conifer to ponderosa pine within timbersheds				Comparison of all sales (mixed conifer and ponderosa pine) between timbersheds[2]	
	Fredonia Ariz. (F)	Eagar Ariz. (Ea)	Alamogordo N. Mex. (Ala)	Cuba (C) Espanola (Es) Albuquerque (Alb) N. Mex.	Distribution and confidence intervals (95%)	
Sale size (acres)					F	(4)
Mixed conifer	4,456.0	1,380.3	936.0	2,235.1	Ea	
Ponderosa pine	4,947.0	[3]6,747.8	1,060.0	2,459.9	Ala	
					C, Es, Alb	
Combined	4,702.0	3,332.0	977.3	2,332.8		
Sale volume (mbf)					F	(4)
Mixed conifer	17,054.0	6,115.6	4,914.7	5,973.1	Ea	
Ponderosa pine	17,104.0	13,480.0	1,912.7	6,818.0	Ala	
					C, Es, Alb	
Combined	17,079.0	8,793.0	3,914.0	6,340.4		
Average size (inches, dbh)					F	(4)
Mixed conifer	21.52	21.29	18.18	18.50	Ea	(4)
Ponderosa pine	21.78	21.13	15.83	17.10	Ala	
					C, Es, Alb	
Combined	21.65	21.23	17.40	17.80		
Average overrun (%)					F	(4)
Mixed conifer	24.0	29.2	29.0	33.6	Ea	
Ponderosa pine	28.1	31.0	35.3	37.2	Ala	
					C, Es, Alb	
Combined	25.8	29.9	31.1	35.2		
Selling value, lumber talley ($/mbf)					F	(4)
Mixed conifer	265.84	184.09	201.02	199.76	Ea	
Ponderosa pine	253.33	[3]265.42	213.81	232.21	Ala	
					C, Es, Alb	
Combined	259.58	214.39	205.87	213.87		
Selling value, log scale ($/mbf)					F	
Mixed conifer	319.80	304.10	302.04	294.86	Ea	
Ponderosa pine	332.47	[3]368.63	281.47	[3]337.94	Ala	
					C, Es, Alb	
Combined	326.14	327.56	295.18	313.59		
Average defect (%)					F	(4)
Mixed conifer	16.9	18.0	27.0	23.5	Ea	(4)
Ponderosa pine	[3]11.8	15.2	[3]17.1	[3]18.9	Ala	
					C, Es, Alb	
Combined	14.6	17.0	23.7	21.5		
Hauling distance (miles)					F	
Mixed conifer	46.6	30.0	19.3	Not tested	Ea	(4)
ponderosa pine	35.6	18.5	23.3		Ala	(4)
					Alb	
Combined	41.1	25.8	20.7	77 (ALB), 55 (Es)	Es	

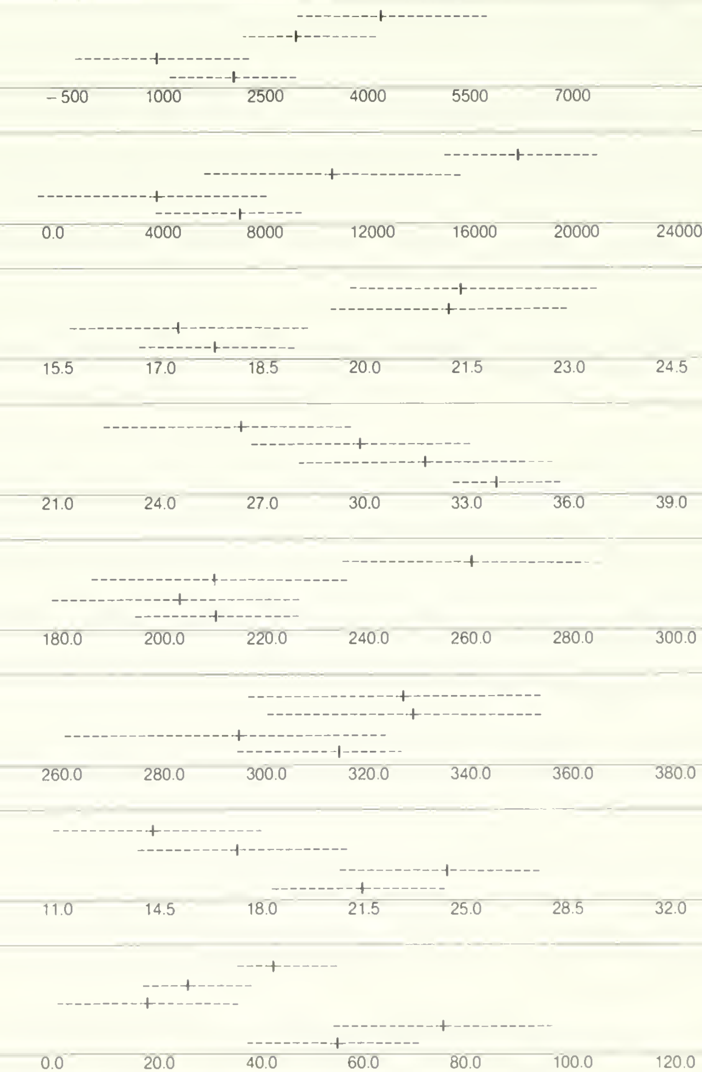
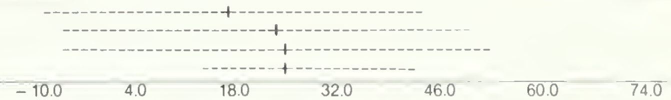
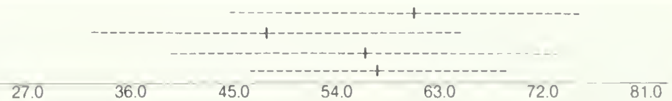
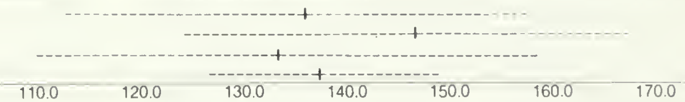
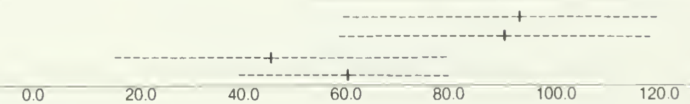
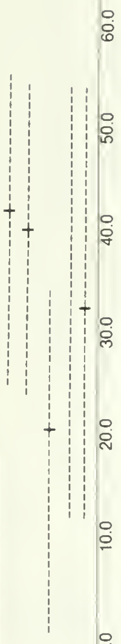
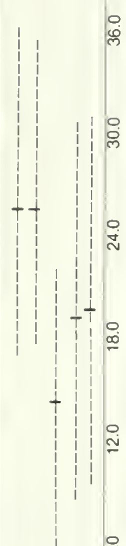
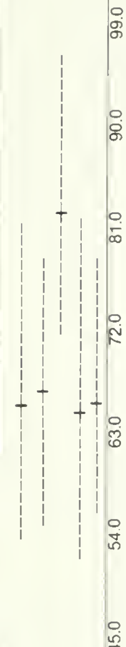


Table 2.—Timber sale characteristics and cost comparison[1]—Continued

	Comparison of mixed conifer to ponderosa pine within timbersheds				Comparison of all sales (mixed conifer and ponderosa pine) between timbersheds[2]
	Fredonia Ariz. (F)	Eagar Ariz. (Ea)	Alamogordo N. Mex. (Ala)	Cuba (C) Espanola (Es) Albuquerque (Alb) N. Mex.	Distribution and confidence intervals (95%)
Stump-to-truck cost ($/mbf)					 F, Ea, Ala, C, Es, Alb; – 10.0, 4.0, 18.0, 32.0, 46.0, 60.0, 74.0
Mixed conifer	35.46	34.20	49.89	41.38	
Ponderosa pine	32.38	38.19	43.10	45.28	
Combined	33.91	35.65	47.63	43.08	
Slash piling cost ($/acre)					 F, Ea, Ala, C, Es, Alb; 27.0, 36.0, 45.0, 54.0, 63.0, 72.0, 81.0
Mixed conifer	53.55	54.23	60.77	56.95	
Ponderosa pine	55.64	40.93	48.04	59.73	
Combined	54.60	48.91	56.53	58.08	
Environmental protection cost ($/mbf)					 F, Ea, Ala, C, Es, Alb; 7.0, 14.0, 21.0, 28.0, 35.0, 42.0, 49.0
Mixed conifer	18.65	17.78	31.00	11.47	
Ponderosa pine	16.17	30.44	39.82	16.33	
Combined	17.41	22.38	33.94	13.58	
Hauling cost ($/mbf)					 F, Ea, Ala, Alb, Es; 10.0, 15.0, 20.0, 25.0, 30.0, 35.0, 40.0
Mixed conifer	23.21	19.79	19.45	Not tested	
Ponderosa pine	16.45	21.28	15.69		
Combined	19.83	20.33	18.20	31.00 (Alb), 25.50 (Es)	
Lopping and scattering cost ($/mbf)					Insufficient data for test
Mixed conifer	10.84	25.02	41.66	33.96	
Ponderosa pine	22.74	22.86	6.98	16.75	
Combined	16.79	24.54	26.80	26.48	
Manufacturing cost ($/mbf)					 F, (Ea), (Ala, C, Es, Alb; 110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0
Mixed conifer	136.71	144.59	135.56	126.97	
Ponderosa pine	135.54	149.08	131.83	155.05	
Combined	136.13	146.22	134.41	139.18	
Total production cost without roads ($/mbf)					Individual components already tested
Mixed conifer	218.21	218.64	245.67	204.21	
Ponderosa pine	204.98	242.96	240.06	245.57	
Combined	211.59	230.80	242.86	222.19	
Average advertised rate ($/mbf)					 F, Ea, Ala, C, Es, Alb; 0.0, 20.0, 40.0, 60.0, 80.0, 100.0, 120.0
Mixed conifer	67.84	83.35	39.45	58.26	
Ponderosa pine	110.33	92.69	50.17	58.67	
Combined	89.09	86.75	43.02	58.44	

Average advertised rate (%) divided by total production costs					
Mixed conifer	33.6	41.5	16.9	32.0	
Ponderosa pine	54.3	38.9	22.3	29.0	
Combined	43.9	40.6	19.6	31.0	
Average advertised rate (%) divided by selling value					
Mixed conifer	20.6	27.0	12.5	19.0	
Ponderosa pine	31.6	24.5	17.1	17.0	
Combined	26.1	25.8	14.8	18.0	
Total production cost as a proportion of selling value (%)					
Mixed conifer	68.9	71.9	81.8	70.0	
Ponderosa pine	63.9	66.3	89.8	73.0	
Combined	66.4	69.7	85.8	71.5	

[1]*Sample size for Fredonia 10 observations; Eagar 11 observations; Alamogordo 9 observations; Cuba, Espanola, Albuquerque 23 observations. Because the timbersheds overlapped, Cuba, Espanola and Albuquerque sales were combined except for hauling distance and hauling costs. All selling values and costs are adjusted to 1980 base year. All costs per mbf are mbf log scale.*

[2]*Significant differences ($\alpha = 0.05$) exist for the following: sale size, F from Ala and C, Es, Alb; sale volume, F from Ala and C, Es, Alb; average size, F from Ala and C, Es, Alb and E from Ala and C, Es, Alb; average overrun, F from C, Es, Alb; selling value, F from Ala and C, Es, Alb; average defect, F from Ala and C, Es, Alb and E from Ala; hauling distance, E from C, Es, Alb and Ala from C, Es, Alb; environmental protection, F from Ala and Ala from C, Es, Alb.*

[3]*Indicates that a significant difference exists between the mean values using "Student" t-test, $\alpha = 0.05$.*

[4]*Indicates that a significant difference exists between the mean values and those not marked using a one-way analysis of variance F-test (0.05) and Tukey's multiple comparisons test.*

Comparison of Timbersheds

Table 2 reveals some interesting differences in the sale characteristics between the Arizona and New Mexico timbersheds. In general, the sale sizes, volumes, and timber diameter are all larger in the Arizona timbersheds; the Arizona timber also has fewer defects. Larger timber diameter and lower level of defect, for example, combine to provide for higher lumber selling values in Fredonia. Larger sale size and volumes are related, in part, to the lesser number of small business (SBA) set-asides in Arizona. Conversely, New Mexico timbersheds have more smaller acreage SBA sales. Overall, the typical wood utilization problems related to mixed conifer species seem to be less pronounced in Arizona than in the New Mexico timbersheds, and the situation in Arizona is more favorable from a lumber production/selling value standpoint.

Other sale characteristics relating to costs, such as manufacturing, slash disposal and stump-to-truck costs, do not seem to vary markedly between the timbersheds. In general, stump-to-truck, or logging costs, are about 16% of total production costs in Arizona, and about 19% in New Mexico's timbersheds. The only costs showing statistically significant differences were environmental protection costs, which were generally less expensive in the northern New Mexico timbersheds. Overall total unit costs averaged slightly less in Arizona timbersheds than in New Mexico. However, there was no statistically significant difference.

These sale characteristics combine to make the percentage of total cost to lumber selling value for both mixed conifer and ponderosa pine slightly more favorable in Arizona, averaging 68% there compared to 75% in New Mexico. Alamogordo had, by far, the least favorable situation, with costs making up 86% of selling value. None of these figures, however, were statistically different. The appraisal process compensates for the disadvantage of a lower cost-to-selling value percentage in the charge for stumpage. This process is designed to account for varying cost and price levels and to derive a fair return for the standing timber. In this case, stumpage rates charged for timber compensate for cost advantages in Arizona, and make up a larger percentage of both total cost and selling value in the Arizona timbersheds. When stumpage cost is added to the other production costs, the percentage of total cost (including stumpage) to selling value is similar in nearly all the timbersheds, about 90%. These percentage figures tend to reflect favorably on the effectiveness of the residual appraisal system. But more importantly, these figures suggest that in areas where stumpage makes up a larger percentage of cost, resource managers have the best opportunity to mitigate problems related to utilization by adjusting stumpage fees. Careful prescription and appraisal preparation is necessary to make the connection between wood utilization and timber management economically feasible. In areas where the proportion of costs to selling value is high, a relatively small increase in costs in any category could have the effect of making an already "marginal" operation infeasible.

Supply Schedules

Economic supply schedules based on costs were developed for each timbershed for ponderosa pine, mixed conifer, and the aggregate of the two timber types. These schedules are graphed in figures 2-4 and depict the relationship between procurement costs, including hauling costs, and available sawtimber volumes in each timbershed.[9] The schedules illustrate the differences between each timbershed's cost, volume, and distance characteristics, and serve to emphasize the importance of analyzing the mixed conifer supply situation on a site-specific basis. For example, given a certain procurement cost, each timbershed's supply schedule shows a different level of volume available. The schedules' graphs also vary in terms of their steepness in slope. If the supply schedule graph is steep, or more vertical (inelastic), additional volumes may be acquired, but only with substantial increases in procurement costs, whereas if the slope is less steep, or more horizontal (elastic), additional volumes can be procured with less cost increase.[10] The supply curve's slope depends on the

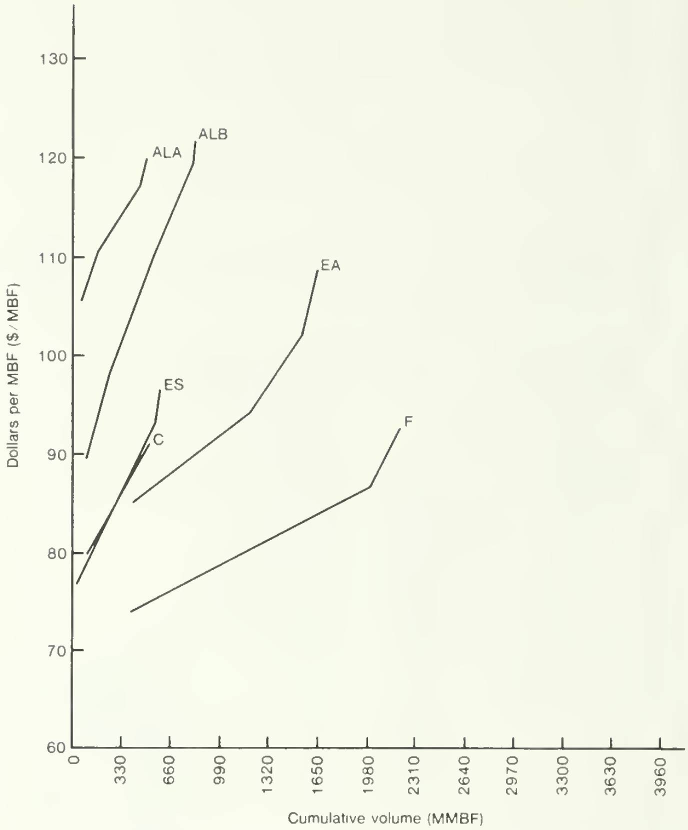


Figure 3—Ponderosa pine supply schedules.

distribution of timber volume and the location and type of roads within the timbershed; therefore, slope can vary over any portion of a supply schedule.

The timbershed supply schedules for mixed conifer and ponderosa pine all indicate an overall procurement cost advantage in the Arizona timbersheds. For example, all the available mixed conifer volume (fig. 2) and a large portion of the ponderosa pine volume (fig. 3) in the Eagar and Fredonia timbersheds can be procured at less cost per thousand board feet than the least costly volumes available in the Albuquerque and Alamogordo timbersheds. The schedules for New Mexico's timbersheds are also more inelastic than Arizona's, indicating that additional volumes are available, but only with proportionately larger increases in costs. However, this inelasticity means changes in costs (breakeven cost) will have less of an impact on total quantity procured in New Mexico and more of an impact on volumes removed in Arizona.[11]

Although total volumes available may be similar in certain timbersheds (e.g., the mixed conifer volume in Eagar, Fredonia and Alamogordo), their economic accessibility and, thus, availability for intensive management are quite different. For example, if a $90 breakeven cost per thousand board feet (logs to the mill deck) for mixed conifer logs is the maximum feasible procurement cost, then the total available volume in the Espanola, Cuba, Fredonia, and Eagar timbersheds could

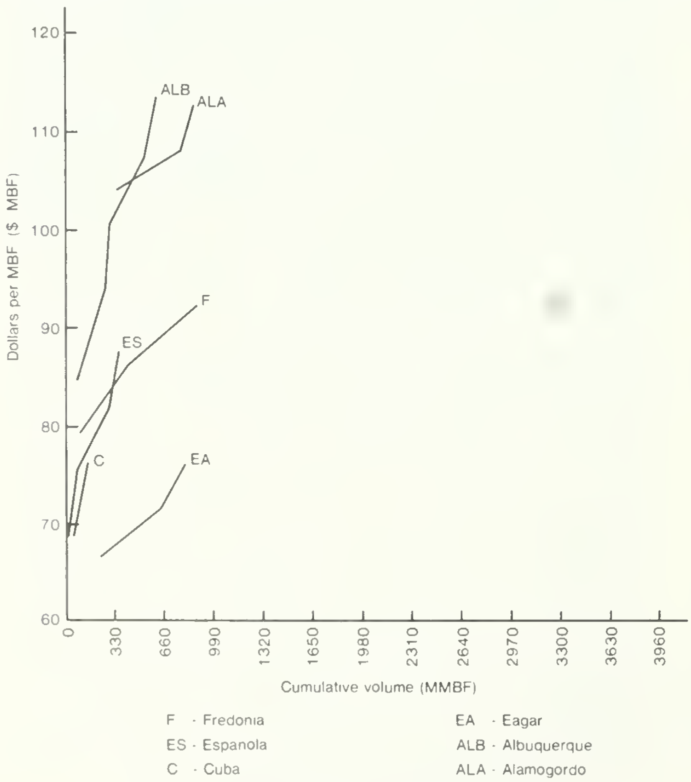


Figure 2—Mixed conifer supply schedules.

[9]*Available sawtimber volumes are volumes occurring on the standard component lands. These volumes are the only figures used in the supply schedules, because the procurement costs involve conventional logging methods, which apply to standard component lands only, not to marginal lands.*

[10]*Elasticity of supply is related to the slope but is not the same thing. The elasticity concept is defined as the relationship of a percentage change in price (or cost) to the percentage change in quantity (or volume) supplied. A portion of a supply schedule is said to be elastic when a given percentage change in cost results in a greater inverse percentage change in volume supplied. Supply is inelastic when a given percentage change in costs results in a smaller inverse percentage change in quantity supplied.*

[11]*These timbershed procurement costs are based on the average costs by timbershed. Therefore, they should reflect the harvesting conditions of the timbershed and the operational efficiency that exists in each separate case, given the appraisal data.*

be economically procured and be part of a timber management/wood utilization program. However, little or no mixed conifer volumes would be economically available at $90 per thousand board feet in the Albuquerque and Alamogordo timbersheds. These timbersheds could not be managed as part of such an intensive timber management program. Different breakeven costs per thousand board feet could be used with the supply schedule to assess their impacts on the procurement situation. The ponderosa pine/mixed conifer volume mix economically available would vary by timbershed, depending on the amount of this breakeven cost.

The supply schedules indicate that mixed conifer offers procurement cost advantages over ponderosa pine in Eagar, Alamogordo, and Cuba timbersheds. Mixed conifer is generally closer to the processing centers in these timbersheds. In the Espanola and Albuquerque timbersheds, the mixed conifer costs are generally the same as those for ponderosa pine. The only timbershed where ponderosa pine is cheaper to procure is Fredonia, where the ponderosa pine is closer to the processing center. Overall, from a procurement cost standpoint, mixed conifer sales are similar to ponderosa pine at most processing centers.

The overall timber supply situation for the timbersheds is shown in figure 4. Aggregating mixed conifers and ponderosa pine volumes changes the supply schedules dramatically, because each timber type's procurement cost per thousand board feet and volume location vary considerably within the timbershed. Figure 4 illustrates the overall cost advantage of the Arizona timbersheds and the additional available or operable volumes located there. For example, for any given procurement or break-even cost, more volume can be procured in the Arizona timbersheds. Fredonia and Cuba's supply schedules are almost linear, indicating a fairly uniform distribution of the aggregated timber volumes over the timbershed. Alamogordo and Albuquerque timbersheds have the least favorable procurement situation. They have higher overall procurement costs which rise rapidly for small increases in additional volumes. Decreases in lumber selling values or increases in production costs are likely to have more of an impact there, and to make intensive timber management more difficult economically in those timbersheds.

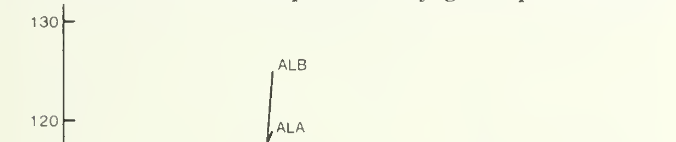


Figure 4—Combined ponderosa pine and mixed conifer supply schedules.

Figure 5 shows the relationship between procurement cost and distance in each timbershed. Albuquerque has the longest hauling distance; in fact, Albuquerque's hauling cost at 90 miles distance is close to the total procurement cost, logging plus hauling, in certain other timbersheds. The remaining timbersheds have similar hauling distances, but the distance for a specific breakeven cost varies markedly by timbershed. For example, again using $90 per thousand board feet as a breakeven cost, hauls in the Cuba timbershed would be about 30 miles distant from the processing center, but Albuquerque's would be 60 miles. This is primarily because of the road systems involved; Cuba has a much poorer road system, which results in higher haul costs even though the haul distance is rather short; whereas Albuquerque has an excellent road system, including a large portion of interstate roads. Generally, Cuba, Espanola, Fredonia and Eagar have similar supply schedules for cost versus distance. Alamogordo has a similar range in distances, but much higher costs per thousand board feet. Albuquerque has much longer hauls, and, therefore, greater overall costs per thousand board feet.

The different volumes available at various distances cause the slopes of individual supply schedules to change over the range of available volumes. For example, in figure 5, the slope of the supply schedule for mixed conifers at Fredonia first rises rapidly but then increases at a lesser rate for additional volumes. This is because most mixed conifer is further away, and in a particular distance zone (40-60 miles haul), much more volume is available. In this distance zone, total costs of procurement are spread out over more volume. Therefore, the incremental increase in procurement costs per thousand board feet become less, decreasing the slope. A similar explanation applies to cases where the curve shifts upward. However, in this case the volumes are declining, and total costs must be spread over less volume. Therefore, the marginal or incremental cost per thousand board feet increases. Many of the supply schedules increase in slope near the boundaries of the timbershed, where timber volumes tend to decline.

The fact that this rate of increase in marginal costs or costs per thousand board feet changes over the span of volumes available and over distance from the processing center illustrates an interesting phenomenon often overlooked in timber supply economics. Sales which are further from the processing center are likely to have higher procurement costs; but for a given increment in volume or distance, they are not likely to have the same rate of increase. This creates situations where procurement costs do not rise markedly over a given range of haul distances. For example, procurement costs for Albuquerque are not much different over an 80- to 100-mile interval in hauling distance. Although the magnitude of this phenomenon varies, it also occurs at various points in the timbersheds: 30-45 miles in Espanola; 40-50 miles in Fredonia; 40-60 miles in Eagar; 30-35 miles in Alamogordo (fig. 5). These distance zones indicate areas where intensive timber management and wood utilization may be relatively more feasible from a procurement cost standpoint.

PRODUCTS[12]

Traditionally, the principal wood products produced in Arizona and New Mexico have been structural type products, such as kiln- or air-dried dimension lumber and boards used in residential and industrial construction. Housing construction, in particular, has been a major market outlet for the lumber produced in the two states. However, during the past few years, the reduced housing market has contributed to decreased production. Coping with a poor housing market requires, in part, considering production of additional products that have other markets and more diversified end uses. Deciding whether a new product is profitable to produce depends on numerous criteria, including the capital investment required, market location and size, as well as the technical suitability of the available raw material.

[12] *This discussion relies heavily on written material in an addendum to the final report for this project prepared by Craig E. Shuler, wood technologist, Colorado State University entitled, "Technical Suitability of Product Development from Mixed Conifer in Arizona and New Mexico" 12 p.*

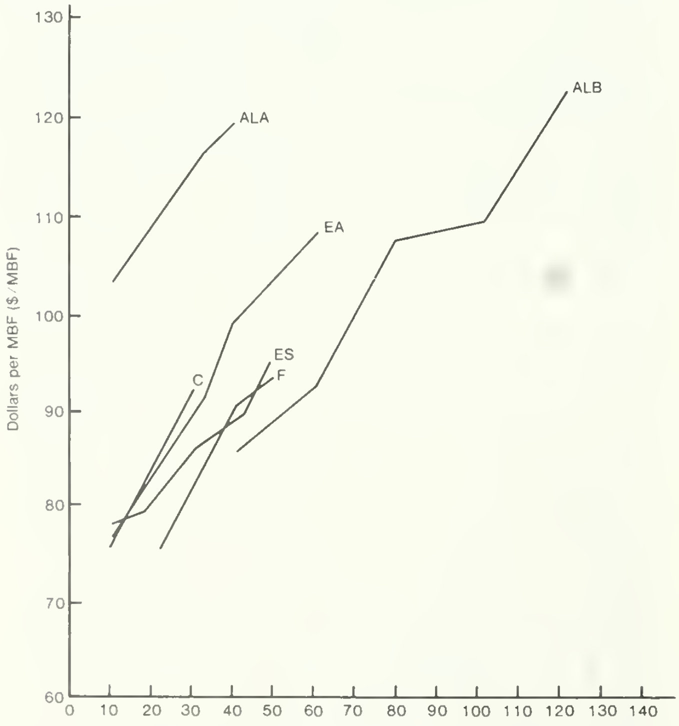


Figure 5—Variation of total procurement cost with distance for combined ponderosa pine and mixed conifer.

One of the major species of the mixed conifer type is Douglas-fir, which has greater strength properties than other species of the mixed conifer type. Therefore, it is the best suited of the mixed conifer species for structural applications and has been commonly used to produce dimension lumber for framing buildings. Another structural application which might expand this market would be manufacture of machine-rated lumber for use in trusses or concrete formwork. Additionally, the hardness of Douglas-fir could be used to advantage in development of flooring, either the typical tongue-and-groove material or patterned parquet-style "tiles." Various types of sawn timbers also offer possibilities. Timbers typically have diversified end uses, including railroad ties, decorative beams, decking, guardrail supports and mining and landscaping uses. These timbers also could be laminated such that only highly stressed regions of the member need higher quality or strength. Thus, species with lower strength ratings, such as Engelmann spruce, might also be used. Laminated dimension lumber for joists or planking might be manufactured from smaller size Douglas-fir logs as well as smaller logs of other species. Douglas-fir is also well suited for furniture framing, such as for waterbeds (a large, expanding industry), where high strength requirements are necessary. Finally, the species is technically suited for blocking material used to stabilize and steady truck and rail loads. Blocking material can generally be produced with basic sawmill equipment, although certain special cut-up saws may be required to shape blocking supports for items such as tanks and pipe.

White fir and ponderosa pine are lighter and generally not as strong as Douglas-fir, but have other favorable characteristics such as uniform to moderate texture, low shrinkage, ease in machinability, and ready acceptance of preservative treatments. Given these characteristics, these species can be used to produce shop lumber for remanufacture into speciality products, such as moulding, furniture stock, picture, door and window frames, and precut do-it-yourself kits. This additional processing results in considerable value added to the product line.

Pine is especially well suited for posts and poles, because it is easily treated with preservatives. Additionally, post and pole production is advantageous, because these products can be produced from smaller size logs which are less suitable for lumber. The uses of posts and poles are numerous and provide a wide range of market opportunities in ranching, urban decorative fencing, and housing (viga poles). Shakes and shingles have fairly low production costs and could have large local markets, particularly if they are treated with a fire retardant and preservative. Although pine does not have the natural resistance to decay as do some other species, this would not be of major importance for wood shingles applied locally in the dry conditions of the Southwest. Finally, solid wood siding is becoming more commonly used in housing designs. With some adjustment in sawing and planning patterns, most existing mills could use pine to satisfactorily produce this type of product.

Quaking aspen, for various reasons, has not been used extensively for producing wood products. However, its characteristics as a hardwood have gained considerable acceptance for producing pallet material. Aspen also has been the raw material for shingles, paneling, excelsior and specialized products such as matchsticks. All of these products can be produced at a fairly low cost and their production could probably be expanded. Pulp is also a possibility although there seems to be an adequate supply of preferred softwoods to satisfy the existing market.

All the mixed conifer species mentioned could be used for fuelwood; however, the present economic return for fuelwood is fairly small compared to that for wood products, such as graded lumber. In certain cases, particularly for mills near major population centers, poorer quality or smaller-sized material might be sold at the logging site, or at the mill and provide a profitable operation. Mills not wishing to sell fuelwood at retail could sell to commercial fuelwood vendors.

The products mentioned represent possibilities for wood products mills to expand the utilization of the mixed conifer species and, at the same time, reduce their reliance on the housing market. Most of the products would not result in "high volume" operations when compared to the levels expected for structural dimension and board products now manufactured. Instead, they would allow for limited production of items serving more diverse, specialized markets. As such, successful production of these wood products and improved utilization of a variety of mixed conifer species and log sizes would require establishing a comprehensive marketing and distribution system. At the mill, more careful grading, sorting, and sawing practices would also be necessary to produce different combinations of products.

MARKETS

Arizona and New Mexico mills could sell the wood products mentioned in the previous section in the same prime marketing areas they now serve. These areas include the two states themselves; the south-central states including Kansas, Oklahoma, and Texas; southern California; Colorado; and the midwest portion of the United States, including Illinois and Wisconsin. Within these states, there are large metropolitan growth centers that have a strong market demand for wood products. This is emphasized by U.S. Bureau of Census Construction reports which show Illinois, Texas, Colorado, and Arizona as among the top 10 lumber-consuming states. These markets are generally closer to Arizona and New Mexico producers than to producers in other western states and, in some cases, the southern softwood lumber-producing region. Tapping the market potential in these areas would require a more comprehensive marketing and sales effort to develop closer ties and better communication with builders, wholesalers, contractors, designers, and secondary manufacturers at the marketplace.

As was the case with timber procurement, certain processing centers have marketing cost advantages over others. In the case of markets, each processing center has different shipping costs to each major market area. Shipping cost advantages are particularly important to consider, because shipping charges are likely to increase as transportation costs, in general, continue to rise. To quantify this advantage for markets outside the two states, truck freight charges (for Arizona and New Mexico mills truck rates are generally the cheapest mode of transportation) were calculated for shipping from each processing center to seven market centers in the prime market areas: Chicago, Ill.; Denver, Colo.; Dallas and El Paso, Tex.; Oklahoma City, Okla.; Kansas City, Kans.; and Los Angeles, Calif. After comparing these truck freight charges, it was clear that New Mexico's processing centers had, in most cases, shipping cost advantages over the Arizona mills, ranging from about $10 to $20 per thousand board feet less. The only market center where Arizona mills had a shipping cost advantage was the Los Angeles market.

Given the processing centers and markets considered here, Alamogordo has the best overall advantage in terms of freight rates. This processing center has a fairly unique location in southeastern New Mexico, which allows a shipping cost advantage to the large Texas markets, as well as a close local market at Albuquerque. Alamogordo also has the same freight rates as other processing centers to markets in Colorado, as well as markets in the south-central and midwestern states.

Fredonia has the highest transport costs to its markets. This processing center is fairly isolated and some distance from most of the major market centers, except Los Angeles and the local market in Phoenix. Eagar is in a somewhat better location, because it is midway between two major local markets in Phoenix and Albuquerque and is somewhat closer than Fredonia to most of the other market centers. The remaining processing centers — Albuquerque, Espanola and Cuba — rank between Alamogordo and the Arizona mills in terms of freight cost advantage.

Unlike the timber supply situation where their procurement costs were greater, Alamogordo and Albuquerque processing centers seem to have cost advantages in terms of shipping products to prime market areas. This probably helps compensate for the less favorable timber supply situation and allows for a profitable operation, even though their total production costs are more than some other processing centers. These New Mexico processing centers probably can be more competitive in the market, and possibly may have a better opportunity to expand markets for traditional or new products. The production of new products is particularly important to these processing centers, because their timbersheds have both a large diversity in species available and generally smaller timber sizes that are not always suitable for traditional lumber products.

Transportation cost to market is not the only factor determining market profitability. Also critical is the product value at the market center. This product value is a function of each individual market center's supply and demand situation which can vary considerably among markets.

An analysis of wood product wholesale prices was made for representative lumber types at each market center. The results of this analysis indicated that lumber prices at Chicago, Denver, and Dallas were generally much higher than those in the other market centers. Prices quoted at these areas ranged from about $50 to $240 per thousand board feet higher than the other market centers. Generally, higher product quality brought larger price differences between centers.

Although a number of factors influence market potential, other things being equal, it seems that the product values indicate that the Chicago, Denver, and Dallas market centers are best for Arizona and New Mexico producers. Products produced from mixed conifer, as well as other species, would receive the greatest net return in these markets. Higher-valued products in particular, should be sent to these market centers. Lower-valued products would probably only be profitable if sold in nearby markets.

Given information about freight rates and lumber price at the market, it appears that New Mexico mills have an advantage over Arizona mills. Although Arizona mills would also find these same markets to be the most profitable, their shipping costs would generally be about $20 per thousand board feet more (in the case of shipping to Dallas and Chicago) than New Mexico mills.[13]

The overall comparative advantage of Southwest mills over certain other western states should be emphasized in any wood utilization program, particularly with wood products which already have lower selling values, such as some of the traditional mixed conifer products. Processing centers in both Arizona and New Mexico have unique opportunities in the growing market of the Southwest. Their comparative advantage in this market in terms of shipping costs will probably increase in the future. Wood products firms need to plan now to develop strategies to meet this expanding local market as well as selected markets in other states.

[13]*The differences in lumber prices ($50-$250) at the market centers are larger than the differences in the processing centers' freight costs ($10-$20). Thus, all processing centers would find it profitable to market in these areas, although some might find it more profitable than others. Additionally, the shipping cost may not be paid by the mill, because some lumber is purchased f.o.b. the mill by wholesalers. However, the value f.o.b. the mill is influenced by selling value at the market less freight costs. Therefore, the same markets as mentioned earlier should be the most profitable, even if the mills did not pay shipping charges directly.*

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

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United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**Resource Bulletin
RM-9**

Net Economic Value of Recreational Steelhead Fishing in Idaho

Dennis M. Donnelly
John B. Loomis
Cindy F. Sorg
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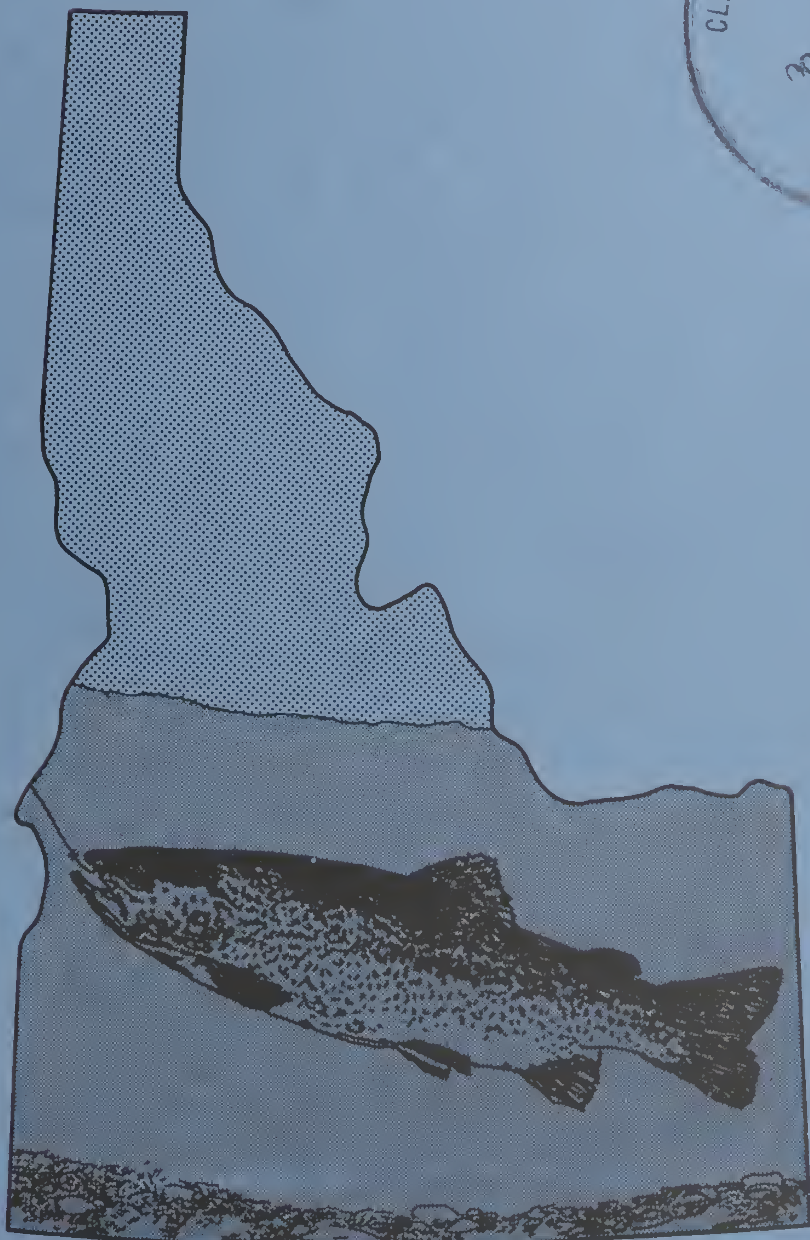

Abstract

Average willingness to pay in addition to actual expenditure for steelhead fishing in Idaho was estimated at $27.87 per trip with the Travel Cost Method and at $31.45 per trip with the Contingent Value Method. Willingness to pay was greater for increased catch or fish size. Average actual expenditure was $72 per trip.

Acknowledgement

This study was a cooperative effort of the Idaho Department of Fish and Game, the University of Idaho College of Forestry, Wildlife, and Range Sciences, the USDI's Bureau of Land Management and the Fish and Wildlife Service, the U.S. Department of the Army Corps of Engineers, and the USDA Forest Service.

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April 1985

Net Economic Value of Recreational Steelhead Fishing in Idaho

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Contents

	Page
MANAGEMENT IMPLICATIONS	1
INTRODUCTION	2
METHODOLOGY	2
Definition of Economic Value	2
Techniques for Measuring Net Willingness to Pay	2
Travel Cost Method	2
Contingent Value Method	3
SURVEY DESIGN AND IMPLEMENTATION	4
STATISTICAL ANALYSIS	5
Data Compilation	5
Regression Analysis	5
Calculation of TCM Benefits	6
RESULTS AND DISCUSSION	7
Contingent Value Method	7
Primary Purpose Trips	7
Multiple Purpose Trips	8
Travel Cost Method	9
Comparison of Idaho to Oregon TCM	11
Comparison of Idaho TCM and CVM Estimates	12
Application	12
Computation Based on Theory	12
An Approximation to Theory	13
Short Run Benefits	13
CONCLUSIONS	13
LITERATURE CITED	14
APPENDIX	16
Steelhead Survey Questionnaire	
Average and Marginal Consumer Surplus—Conditions of Equality	

Net Economic Value of Recreational Steelhead Fishing in Idaho

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Louis J. Nelson

MANAGEMENT IMPLICATIONS

Recreation associated with wildlife clearly has economic value. However, opinions on the nature and level of this economic value vary widely. This bulletin analyzes the value of steelhead fishing trips in Idaho, using both consumer surplus and expenditure as components of total value for consumptive use of the steelhead resource. Other types of value presumably exist for nonconsumptive uses.

Consumer surplus values generally are useful in analyses of the economic efficiency of resource allocation. An example is a decision about the relative economic efficiencies of two projects, such as improving natural steelhead habitat, or alternatively, easing the spawning run by construction of fish ladders. In contrast, expenditure data are useful for analyses about sectors of an economy, but are not appropriate or relevant for decisions involving the economic efficiency of resource allocation. Therefore, this analysis explicitly focuses on consumer surplus benefits (i.e., values useful in economic efficiency analyses), although some expenditure information is reported.

The estimated average net economic value (or consumer surplus) of a steelhead fishing trip in Idaho is $27.87. This is the value to both the angler and to society. This means that the average angler would be willing to pay an additional $28 per trip to continue to have these sites available for steelhead fishing in Idaho. This value was derived by the Travel Cost Method (TCM) — a demand curve estimating technique. The TCM statistically infers the amount that an average angler would bid if given the opportunity.

It is important for managers, analysts, planners, and others using this and the other information in this bulletin to note its exact nature. The value of a steelhead fishing experience on a per trip basis is a weighted average over all steelhead fishing sites in Idaho. The weighting is on the basis of number of trips to each site. Those sites with more visits, and consequently more consumer surplus, contribute relatively more weight to the average value.

The gross value is the sum of the consumer surplus value plus the expenditures. Thus, the gross consumptive value per trip is the sum of the efficiency value, $28, plus expenditures of $72 per trip, yielding a gross or total value of $100.

Appropriate consumer surplus trip values for a given decision context and scope can be converted to a value per 12-hour Wildlife and Fish User Day (WFUD). Converting trip values to a WFUD value is based on number of days fished per trip and the number of hours fished per day. The value of a WFUD of steelhead fishing is $30.

While the values just discussed are based on the TCM, the Contingent Value Method (CVM) also was used in the study to elicit "simulated market bids" from anglers. This CVM approach was used to measure the net economic value of the last trip by anglers taken during the 1982 steelhead season. The CVM value per trip was $31.45 for current conditions associated with steelhead fishing. This value per trip converts to $45.60 per WFUD for steelhead fishing.

Although the base values, as measured by TCM and CVM, are approximately the same, this correspondence does not necessarily apply to incremental changes. CVM surveys can be designed to measure base or incremental values or both. If there is an improvement in fishing opportunities to existing anglers, the net economic value in the short run, as measured by CVM, is typically less than the long-run value of improved steelhead fishing opportunities as measured by TCM. This is because analysis with the results of the TCM shows an increase in fishing trips of about 238% associated with the improvement, i.e., a 100% increase in fishing opportunities. Therefore, much of the benefits from a higher quality fishing experience would accrue to new anglers attracted by increased fishing quality. This result indicates that number of trips (i.e., participation) for steelhead fishing is sensitive to fishing quality, as measured by number of fish caught.

Readers are cautioned that, in general, economic theory shows that marginal values for the steelhead angling experiences are the theoretically correct values to use in decisionmaking concerning economic efficiency. There is at least one exception, noted by Mumy and Hanke (1975). The present study, however, estimates average value per trip, not marginal values. The reason these average values can be applied in analyses where only marginal values should be used is that the functional form of the demand curve used in this study has the unique property that, for consumer surplus, marginal value is equal to average value. (See the appendix for further details.) This property and result do not apply to most other functional forms.

A second caution concerns the geographic scope of analysis where the values shown in this bulletin are appropriate. Because the TCM value is a weighted average over all steelhead sites, the values could appropriately be used to evaluate the economic efficiency of management actions that uniformly affect all steelhead sites.

However, values for an entire region and values for any area of significantly different size are not measurements of the same geographic scope. To the extent that a management action affects selected fishing areas more than others, individual fishing site values, such as those in table 4, may be more appropriate than the overall values in this bulletin. However, an overall consumer surplus value, such as willingness to pay per trip, may be all that is available, and for efficiency analyses, these are more tenable than expenditure values.

Finally, caution is indicated when using fishing experience values in analyses that also incorporate values for other resources (e.g., timber or water). Direct comparisons of values between resources often is misleading, because the type of value (i.e., average or marginal), or its scope is either unknown or forgotten. For example, it would be generally incorrect to compare marginal consumer surplus values for steelhead fishing from a statewide study to average stumpage values for one forest area surrounded by other forest areas, all of which supply timber to local stumpage markets.

INTRODUCTION

The economic value of wildlife is used in land management planning by the USDA Forest Service and USDI Bureau of Land Management. Although the lands or habitats may be managed by the Federal Government, wildlife is managed by the states. Therefore, it is important to coordinate economic value of wildlife for federal plans affecting habitat so they are compatible with state plans for management of individual species.

This bulletin specifically examines the average net willingness to pay for steelhead (*Salmo gairdneri*) fishing,[3] and also provides a consistent set of dollar values that vary by steelhead fishing units. The purpose of this study was to produce theoretically correct values of average willingness to pay (in excess of current expenditures) acceptable to several federal agencies and the State of Idaho. In addition, this study served as a test of the cost effectiveness of using the Travel Cost Method (TCM) and the Contingent Value Method (CVM) for developing values useful for the 1990 Resources Planning Act (RPA) effort conducted by the USDA Forest Service.

METHODOLOGY

Definition of Economic Value

Economic value used in studies of economic efficiency is measured by the net amount in excess of their actual expenditures that consumers are willing to pay for a resource. Net willingness to pay is the standard measure of value in benefit-cost analysis performed by the U.S. Army Corps of Engineers, Bureau of Reclamation, and the Soil Conservation Service (U.S. Water Resources Council, 1979, 1983). Net willingness to pay is the basis of the values used by the U.S. Forest Service in its local and national planning efforts. The Bureau of Land Management applies willingness to pay measures as the value of all outputs in SAGERAM analysis.[4]

Use of actual expenditures by hunters and anglers is not appropriate for valuation of wildlife or other resources (Knetsch and Davis 1966). Expenditures are useful only for measuring the effect or impact on local economies of some resource management action.

[3]*The net economic value of general cold and warm water fishing is the subject of a separate manuscript by the authors.*

Techniques for Measuring Net Willingness to Pay

Dwyer et al. (1977), Knetsch and Davis (1966), the U.S. Water Resources Council (1979, 1983), and Walsh (1983) all recommended the Travel Cost Method (TCM) and the Contingent Value Method (CVM) as conceptually correct techniques for estimating users' net willingness to pay.

The TCM relies on variations in travel costs of recreationists to trace out the demand curve. The area under this demand curve but above actual travel costs is a measure (called consumer surplus) of net willingness to pay (Clawson and Knetsch 1966, Dwyer et al. 1977).

The CVM asks users directly to indicate their net willingness to pay. This willingness to pay is expressed in the form of bids for specified recreational conditions (Brookshire et al. 1980). Survey design is a critical factor in this method.

Travel Cost Method

This study constructed a Regional Travel Cost Model (RTCM) with trips per capita as the dependent variable. The traditional "per capita" specification was used to adjust for population differences between counties of visitor origin. As Brown et al. (1983) showed, trips per capita takes into account both the number of visits as a function of distance and also probability of visiting the site as a function of distance.

The list of possible independent variables include a surrogate for price (i.e., distance) and also fishing site characteristics, measures of substitutes, and demographic characteristics of fishermen. Given the constraints on length of the angler survey and the limitations on time for data analysis, a relatively simple RTCM was estimated. The basic model follows.

$$\frac{\text{Trips}_{ij}}{\text{Pop}_i} = b_o - b_1\text{DIST}_{ij} + b_2\text{QUALITY}_j - b_3\text{SUBS}_j + b_4\text{INCOME}_i \qquad [1]$$

where

DIST = round trip distance from county of residence, i, to fishing site j.

QUALITY = a measure of fishing quality at site j.

[4]*Bureau of Land Management. 1982. Final rangeland improvement policy. Washington Office Instruction Memorandum No. 83-27, dated October 15, 1982.*

SUBS = a measure of the cost and quality of substitute fishing sites relative to the one under consideration, i.e., site j.

INCOME = a measure of the ability of households in county of residence, i, to incur costs for recreation; serves as a proxy for other taste variables.

b_o to b_4 = coefficients to be estimated; the algebraic signs indicate the expected relationship of each independent variable with trips per capita.

Equation [1] specifies the per capita demand curve for the fishing sites in the region. By setting the quality measure at a value associated with a specific site, the general RTCM demand curve becomes the demand curve for that specific site. Therefore, recreation visitation patterns for all sites in the region can be modeled with one equation. Equation [1] states that trips per capita from origin i to site j is a function of the distance from origin i to site j, quality of site j, the substitute sites available to origin i, and the income of residents of origin i. Once the per capita demand curve for each origin-site combination is specified, a more aggregated demand curve is calculated. This aggregated demand curve for a site, the so-called "second-stage" demand curve, relates total trips to a site as a function of hypothetical added cost, as measured by distance. Once the hypothetical added distance is converted to travel costs (in dollars), the area under the second stage demand curve represents net willingness to pay. Willingness to pay is a net value, because only the hypothetical added cost is reflected in the second stage demand curve, not the original travel costs (Clawson and Knetsch 1966, Dwyer et al. 1977).

Finally, the total consumer surplus for all sites, as measured by net willingness to pay, can be converted to economic value per trip by dividing by the number of trips taken at zero added cost. Consumer surplus per day also may be computed by dividing consumer surplus per trip by estimated average days per trip for the recreationists sampled.

The estimate of net willingness to pay is the end result of a series of mathematical and statistical operations on the aggregated data. One item of interest about estimated net willingness to pay is the sensitivity of this estimate to variation within the travel cost data. This variation is evident in the standard error of the regression and in the computed statistical confidence interval associated with the estimate of each coefficient of the visits per capita regression model (i.e., the first stage demand curve).

Conceptually, this variation is carried through all the steps described previously, including formation of the second stage demand curve and the subsequent integration under it. Thus, it is logical to consider variation associated with estimated net willingness to pay per trip. However, the statistical properties of the confidence interval estimates of net willingness to pay are not yet completely developed.[5] Despite this, certain aspects of sensitivity may reveal information about the variability of benefit estimates. Specifically, for this research, a "sensitivity interval" was defined. This interval, for estimated benefits measured by willingness to pay, describes the upper and lower bounds of the benefit estimate when the regression coefficient of distance is varied to the upper and lower bounds of its confidence interval.

For example, the computer program that calculates benefits is run three times—once with the distance coefficient at its best unbiased level, once with it at the lower level of its 95% confidence interval, and once with the distance coefficient at the upper level of its 95% confidence interval. The three estimates of benefits related to steelhead fishing respectively indicate how benefits vary with respect to variation in the coefficient associated with distance. Distance was chosen specifically, because increased increments of this independent variable measure additional cost hypothetically incurred by anglers. Later in this bulletin, these sensitivity intervals are compared to the confidence intervals derived from contingent valuation. This comparison is not a statistical procedure; but it provides an indication of the relative ranges in estimates produced from each method.

Contingent Value Method (CVM)

The CVM is also known as the "direct method," because the interviewer directly asks the recreationists what they would be willing to pay to fish at a particular site. The object is to determine the net willingness to pay of an individual for fishing at a site, relative to some alternative site. The issue is not the value of fishing itself. An alternative typically valued involves the addition or elimination of one or more sites, not the elimination of fishing in general. While CVM relies on responses to hypothetical questions, research by Bishop and Heberlein (1979) and Brookshire et al. (1982) indicates that rather than overstatement of willingness to pay, CVM generally provides conservative estimates.

CVM is implemented with a bidding game approach. Researchers from the state of Idaho chose an "iterative" technique implemented by means of a telephone interview. The iterative technique involves repeatedly asking the person if he would pay successively higher and higher amounts of money. Once the person reaches the maximum amount he would pay, this final value is recorded.

Another aspect of presurvey design is to identify the appropriate "payment vehicle." That is, what payment mechanism is going to be used to elicit the money bid. One can use entrance fees, license fees, taxes, trip costs, or payment into a special fund. In this study, trip cost was used as the payment vehicle because it was fairly neutral and familiar to the respondents. The specific question format with the questionnaire is in the appendix.

One advantage of CVM over TCM is that the researcher can determine willingness to pay, not only for current conditions, but also for hypothetical changes in

[5] *Personal communication to Dennis M. Donnelly from Rudy M. King, Biometrician, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 80526.*

fishing quality. This study asked additional willingness to pay for doubling the number of fish caught (versus current catch) and doubling size of the fish (relative to current size). This provides important management information. Although the number of fishermen may or may not increase when fisheries improvements are made, fishery improvements appear to increase the value per day for those who do fish.

Another advantage of CVM is that the value per day associated with fishing on trips that were multipurpose or multidestination can still be estimated. With TCM, one can accurately value only trips for which the primary purpose and primary destination was for fishing. Therefore, this study was able to present the value of steelhead fishing for both types of trips.

The analysis of CVM results is straightforward. Generally the mean willingness to pay is calculated once outliers and protest bids are removed. It should be noted that question design is vital to obtaining a true CVM measure of value. Because CVM is based on a direct measure of value, a poor survey design will render useless results. This means including a protest mechanism in the survey. This mechanism allows differentiating between legitimate bids and bids made in protest to the survey itself, not to the resource in question.

Before calculating mean willingness to pay, the data must be screened to remove outliers. In this study, individual bids greater than \$100 were analyzed in conjunction with other data reported by individuals such as total days of fishing, total hours fished, and origin-destination information. A judgment then was made as to whether or not the bid was appropriate. For example, the likelihood is low that an angler would bid in excess of \$100 for a trip to an area where total length of stay was short. If an angler's bid did not fit the statistical properties of other bids in its range and was greater than \$100, it was discarded as suspect.

SURVEY DESIGN AND IMPLEMENTATION

The population sampled in the survey that preceded this study was anglers having an Idaho steelhead tag in 1982, including both residents and non-residents. The sampling rate was 1.69% or 427 individuals selected randomly. This is more than double the minimum sample size suggested by the U.S. Water Resources Council (1979).

The 427 anglers first received a letter of introduction from the University of Idaho's College of Forestry, Wildlife and Range Sciences. The letter indicated that someone from the University would be calling to collect the information requested, such as trips to the steelhead fishing units identified on an enclosed map (fig. 1). The map was included to help respondents identify locations or sites which were visited during 1982. Each individual then was asked to list his trips before he would be contacted by telephone, so that the answers could simply be read during the phone conversation. In that same telephone interview, additional questions were asked oriented to both TCM and CVM analyses.[6]

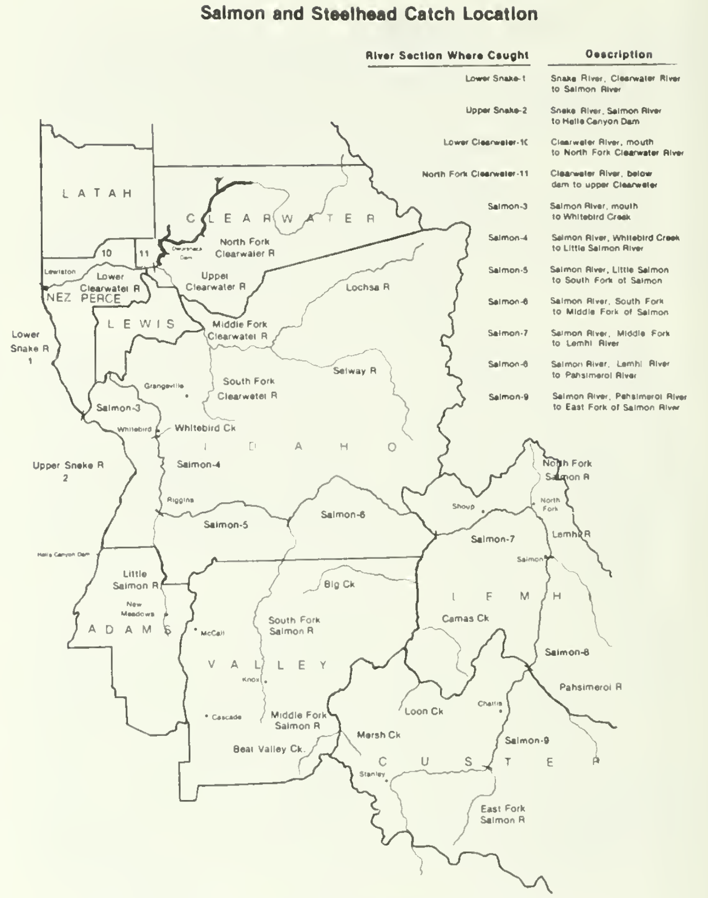


Figure 1.—Salmon and steelhead catch locations.

The survey was designed to determine trip information, such as number of people in each fishing party, fishing quality, and fish species sought. For the Travel Cost Model analyses, trips were screened to insure that fishing was the primary purpose and that the particular site was the primary destination. As explained previously, the intent was to eliminate from the TCM analyses visits that were not primarily for steelhead fishing. The bidding questions for CVM were asked with regard to the last trip to estimate the value of that trip regardless of whether its primary purpose was fishing.

The respondents were asked to report the round trip distance traveled to each site that was visited. This variable became the price variable. While Brown et al. (1983) noted that recall of distance may be in error, they also noted that use of zonal TCM minimizes the effect of the error on coefficient estimates. The reason is that by using the mean of reported distances, extreme responses are given less weight in the zonal method than in the individual observation approach.

[6] *Lloyd Oldenburg and Lou Nelson of the Idaho Department of Fish and Game, developed the combination mail and telephone surveys. The actual telephone survey was performed during the months of April and May 1983, by personnel at the University of Idaho under the supervision of Lou Nelson, then with the University of Idaho. This approach obtained a 100% response rate. For purposes of complete information, the text of the survey instrument is reproduced in the appendix.*

The usual alternative to relying on respondent's estimates is to compute distance as part of data analysis. This procedure depends on knowledge of respondent origin and site visited, and on supposition about the probable travel route. While this approach is potentially more accurate, it is also more time consuming and costly. And, in the absence of exact route information, these estimates may also include error. Thus, because one purpose of our approach to this study was to investigate cost-effective analysis techniques, the study design did not include computation of distance from maps or other exogenous information sources.

STATISTICAL ANALYSIS

Data Compilation

There were two basic phases to the analyses of the Idaho Steelhead data. First, the mean net willingness to pay (WTP) was determined from the CVM bid data. Because this required just a few days of total work, CVM is attractive as a methodology for rapid evaluation of wildlife benefits. In addition, the capability to value different situations including trips with multiple purposes and changed conditions is another asset of CVM.

Second, TCM analysis was initiated concurrently with the CVM analysis. The individual data cases were scanned to find data coding errors. To be able to derive visits per capita to a specific fishing site from a particular origin, the individual cases were grouped according to counties or, in some cases, county groups. Trips per capita for the sample from each county of visitor origin was calculated by dividing trips from a county by that county's population. Once the data were aggregated, measures of substitute site attractiveness and site quality were calculated. Past approaches used externally derived information about physical characteristics of the site under study and about substitute sites. Because this analysis was a prototype to evaluate the cost-effectiveness of TCM, substitute and quality measures were limited to those which could be derived from the data in the survey.

The substitute measure used in the final regressions was total fish catch at each of the alternative sites divided by that site's respective distance from a given origin. The numerator was taken as a measure of site quality to fishermen. The distance variable related to the cost of obtaining this level of fish catch. Therefore, the substitute measure was, in essence, fish per mile. For a given origin-fishing site combination, the substitute site was that fishing area, other than the one actually visited, that had the largest ratio of fish caught per mile traveled, compared to all other sites visited from that origin.

Several site quality measures were formulated to reflect fishing quality. Fish per hour, although the most logical candidate, proved to be statistically insignificant in all regression equations. Instead, total fish catch at the site was found to be statistically significant. This variable allows better identification of an individual site when using a Regional Travel Cost Model. The total fish catch variable can be used to estimate the economic efficiency benefits (in a Benefit-Cost sense) of any actions taken to increase total fish caught.

County per capita income also was tested as a variable, because economic theory indicated that it influenced the ability of county residents to purchase trips to a recreation site.

Regression Analysis

In the regression analysis, variables that were consistently insignificant were dropped from further consideration. Functional form, however, was not as easy to determine.

The model in equation [1], previously discussed, was the simplest formulation. In addition, several alternative models were proposed:

$$\ln(\text{Trips/pop}) = b_0 - b_1\text{DIST} + b_2\text{TOTFISH} - b_3\text{SUBS} \pm b_4\text{INC} \pm b_5(\text{INC})^2 \qquad [2]$$

$$\ln(\text{Trips/pop}) = b_0 - b_1\text{DIST} + b_2\text{TOTFISH} - b_3\ln(\text{SUBS}) \pm b_4\text{INC} \pm b_5(\text{INC})^2 \qquad [3]$$

$$(\text{Trips/pop})(\sqrt{\text{pop}}) = b_0\sqrt{\text{pop}} - b_1[\ln \text{Dist}](\sqrt{\text{pop}}) + b_2\,\text{TOTFISH}(\sqrt{\text{pop}}) - b_3\text{SUBS}(\sqrt{\text{pop}}) \pm b_4\,\text{INC}(\sqrt{\text{pop}}) \pm b_5(\text{INC})^2(\sqrt{\text{pop}}) \qquad [4]$$

where DIST = Round-trip distance from a particular county of residence to a particular fishing site.
TOTFISH = Total fish caught at the fishing site.
SUBS = The maximum of the ratios of TOTFISH for a given site under study to DIST from the origin under study to all the other sites visited from the origin under study.
INC = As defined earlier for income.

Equations [2] and [3] adopt the functional form that several economists have argued is most plausible. Ziemer et al. (1980), Vaughan and Russel (1982), and Strong (1983) contended that because of the pattern by which trips per capita fell off at higher distances, the natural log of visits per capita was preferred to either a linear functional form or natural log of distance as in equation [4]. Their point was that with these latter two functional forms negative visits would be predicted for a few high cost zones. They felt that negative visits were contrary to intuition which, therefore, provided credence for the natural log of visits per capita.

Income and income-squared was used, because Martin et al. (1974) found that income did not necessarily enter in a linear fashion. For example, an hypothesis is that increased income is associated with increased fishing activity, but perhaps the relationship is not linear. In addition, increases in income may allow nonparticipants to become anglers, thereby increasing overall use. However, income did not enter strongly into the analysis. Fishing may be a "normal good" for some and an "inferior good" for others. Goods for which purchases rise with income are "normal goods." Goods for which purchases fall as income rises are called "inferior goods." This latter term does not denote inferiority. Rather, it refers to a relationship between quantity demanded and income.

For a linear functional form, Bowes and Loomis (1980) argued that the unequal geographic sizes of population zones require a weighting factor that is the square root of population (equation [4]) to avoid heteroskedasticity (heterogeneous variances), thereby improving both benefit and use estimates. Vaughan and Russel (1982) and Strong (1983), however, showed that if the log of visits per capita is chosen as the functional form (equations [2] and [3]), the heteroskedasticity will be so greatly reduced that weighting by square root of population may be unnecessary.

In part, the choice of functional form depends on whether use or benefit estimation is the critical factor in the study's objectives. In this study, benefit estimation was most critical. However, the conclusions about functional form depend on characteristics of specific data bases. Several criteria important in deciding on the relevance of the regression were examined. First, the Regional Travel Cost Model was to estimate benefits accruing from an existing set of sites, not estimates of use at a new site. Therefore, goodness-of-fit of the model was tested according to the procedures developed by Rao and Miller (1965)[7] to determine whether the natural log of visits per capita or natural log of distance performed best. These test statistics indicated natural log of visits per capita was better. Second, examination of the residuals showed a random pattern well spread out in terms of positive and negative values and runs of sign. Finally, estimated visits were compared with actual visits. If estimated visits were fairly close to actual visits ($\pm$ 10%), the natural log of visits per capita was used instead of Bowes-Loomis weighting.

Calculation of TCM Benefits

To calculate benefits with distance as the price variable using the second stage demand curve approach, it is necessary to convert distance to dollars. Travel costs to a site consist of transportation costs and travel time costs. Travel time is included because, other things being equal, the longer it takes to get to a site the fewer visits will be made. That is, time is so often a limiting factor and acts as a deterrent to visiting more distant sites. Omission of travel time also biases the benefit estimates downwards (Cesario and Knetsch 1970, Wilman 1980).

[7] *The essential problem in comparing goodness of fit for two regressions like these with differing functional forms is that comparing the residual sums of squares to determine which has the lesser value is not valid, because the unit of measurement rather than the functional form is the operative factor in decreasing the sum of squares. However, by standardizing the variables so that variance does not change with measurement units, the two forms may be compared. The comparison of each equation's sum of squares is done by means of a nonparametric ratio test on the sums of squares. The test statistics follows a chi-square distribution with one degree of freedom (Box and Cox 1964). When the test statistic is greater than the chosen critical value, the null hypothesis that the two functions are empirically similar may be rejected.*

The value of travel time was set at one-third of the wage rate as prescribed by the U.S. Water Resources Council (1979, 1983). This is the mid-point of values of travel time that Cesario (1976) found in his review of the transportation planning literature. However, the use of one-third the wage rate is not necessarily intended to measure wages foregone during the time spent traveling, but instead, includes the deterrent effect of scarce time on the decision of which sites to visit. This study used the U.S. Department of Labor estimate of a median wage of $8.00 per hour because estimates of individual angler income were not collected. One-third of this is $2.67 per hour. For all anglers sampled, the average opportunity cost of time spent traveling was about $0.066 per mile. It would have been desirable to use the actual wage rate for steelhead anglers rather than this $8.00 average wage, because steelhead anglers may have different incomes than the national median.

This study computed transportation costs in three steps. First, mileage was converted to transportation cost on a per vehicle basis. This was done using variable automobile costs, such as gasoline. An intermediate vehicle size class was taken as typical and had a cost of 13.5 cents per mile in 1982 (U.S. Department of Transportation 1982). Second, with about 2.6 anglers per vehicle this standard cost per person was about $0.05 per mile. Figures for pickup trucks were not available.

Finally, the transportation cost also was estimated using the cost per mile reported by survey respondents for their last steelhead fishing trip rather than the cost per mile of $0.135 reported by the Department of Transportation (1982). Respondents reported their own share of transportation costs which, when divided by roundtrip miles, equaled $0.10 a mile. This may be a more appropriate value to use, because it is the price perceived by the respondent. That is, the quantity of trips consumed would probably be more closely related to the perceived cost rather than some standardized cost. Also, the Department of Transportation figure used for the standard cost reflected costs of suburban driving with an intermediate size car. Gas mileage on roads paralleling rivers for steelhead fishing may be somewhat different than for suburban travel. More important, if a larger vehicle were driven on these trips (allowing for the possibility for towing a trailer), it might raise the cost far above that of an intermediate size car. Increasing the transportation cost per mile from $0.05 to $0.10 increases total travel cost (including travel time) to approximately $0.16 per mile. Then the quantity of trips made is associated with a higher price per trip, which translates into a rightward shift in the upper portion of the second stage demand schedule. This shift results in an increase in total and, therefore, per trip consumer surplus, because the implication is that people are willing to pay for the same experience at an increased rate. Both standard and reported travel costs are used to provide the most useful information for valuation of Idaho steelhead fishing and to allow comparison to other studies.

The transportation cost and value of travel time are added for each increment in distance and for the amount of time required to travel that distance increment. This rescales the vertical axis of the second stage demand curve from miles to dollars of travel cost. The area under the second stage demand curve yields estimated consumer surplus for the sampled anglers. Dividing this quantity by trips yields mean consumer surplus per trip.

RESULTS AND DISCUSSION

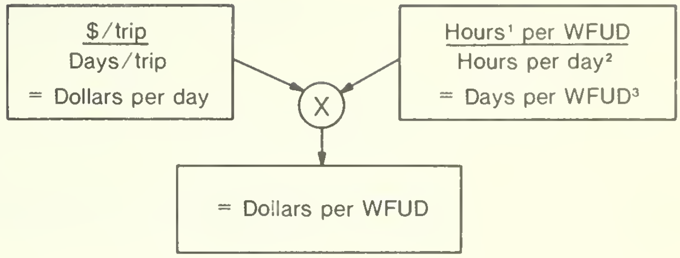
Contingent Value Method

Table 1 provides summary information about the population of steelhead anglers who were asked about their last trip in the CVM portion of the survey.

Primary Purpose Trips

Table 2 presents the dollar values for primary purpose and non-primary purpose trips. The data are for all sites. For primary purpose trips, steelhead anglers are willing to pay $31.45 per trip more than their current expenses rather than not visit their chosen site. This $31.45 is associated with 1.55 days of fishing per trip. The value per day is $20.29. On the basis of a 12-hour Wildlife and Fish User Day (WFUD), the value would be $45.50, because anglers fished 5.34 hours per day. The details of this computation are shown in fig. 2. In addition, anglers caught an average of 0.95 fish per day and fished 1.55 days each trip, so on the average, they caught 1.47 fish each trip. This yields an average value of $21.39 per fish harvested.

The estimates of fish caught per day from this survey are higher than reported in past Idaho Game and Fish Surveys. This may be because 1982 was a good year for



[1]Hours per WFUD - Defined as 12.

[2]Hour per day spent in the activity, in this case, fishing.

[3]WFUD - Wildlife and Fish User Day.

Figure 2.—Calculation of dollars per day and per WFUD.

steelhead fishing. Also past reports have spring-fall seasonal averages, whereas the estimates in this study were based on catch for the last trip. If actual fish catch per day were closer to lower historical levels, the value per fish harvested would be higher. However, one cannot simply divide the existing value per trip by the lower catch to calculate this new value per fish, because the value bid per trip in the CVM approach would fall if actual fish catch were lower.

Asking anglers about changed fishing conditions provides some economic values useful for fisheries management. If anglers were able to double number of steelhead caught, bids per trip increased from $31.45 to $41.36. Doubling the number of fish caught means increasing fish catch to nearly three per trip. So, to existing anglers, the $9.91 increase is the value per trip for catching twice the number of steelhead and, is equivalent to $6.74 per extra fish. Thus, if managers wish to consider

Table 1.—Survey Summary Statistic for CVM.

	Mean	Median	Minimum-maximum	Sample size
Distance (miles)	217.77	100.11	1.0 to 1000	481
Number of days fishing	1.55	1.09	.5 to 10.00	311
Number of hours fished per day	5.34	5.19	.5 to 12.0	311
Number of fish caught per day	.95	.50	0 to 12.0	263
Number of licensed anglers	2.63	2.36	1.00 to 8.00	311
Cost of travel	$33.15	15.38	0 to 700	338
Variable cost (food, tackle, etc.)	$33.86	14.85	0 to 700	338
Cost of accommodations	$12.73	[1].074	0 to 700	271

[1]*The median value is low because 236 out of 271 individuals reported zero cost for accommodations.*

Table 2.—Net willingness to pay and profile of steelhead anglers as estimated by CVM for their last trip

	Primary purpose	Non-primary purpose
Net willingness to pay (bid) for current conditions per trip	$31.45 [1]3.11 [2](258)	$45.71 26.38 (7)
Net willingness to pay in excess of bid for current conditions for double number of fish caught per trip[3]	$9.91 7.33 (257)	$11.43 6.70 (7)
Net willingness to pay in excess of bid for current conditions for 50% increase in fish size[3]	$7.69 1.19 (258)	$2.28 2.14 (7)
Days fishing on this trip	1.55 (311)	2.39 (8)
Hours fished per day on this trip	5.34 (311)	4.50 (8)
Fish caught per day on this trip	.95 (263)	2.57 (7)
Number of licensed anglers on this trip	2.63 (311)	3.75 (8)
Cost (travel, food, tackle, accommodations, etc.)	$72.21 (247)	$157.13 (8)

[1]*Standard error for each CVM mean bid is shown just beneath each bid.*

[2]*Of the 344 interviewed in CVM, 24 refused to put a dollar value on steelhead fishing. (Numbers in parenthesis are sample sizes.)*

[3]*To compute the total bid for each contingent change, add the amount bid for the change to the amount bid for current conditions. For example, the total bid for double the number of fish caught for primary purpose trips is $41.36 (=31.45 + 9.91).*

increasing fish populations, the value of extra fish caught may be helpful in establishing the associated economic benefits.

In addition, the net willingness to pay was worth $7.69 per trip for increasing the average size of steelhead by 50%. This benefit could be compared to the costs of managing for habitat conditions that would allow fish size to increase by 50%.

While the benefit estimates for primary purpose trips may appear low, the reader must keep in mind what is being measured. The benefits are net willingness to pay in excess of expenditures. Table 2 shows that the sum of net willingness to pay and cost (i.e., gross willingness to pay) is quite high—more than $100 per trip. Because of the high cost of trips associated with remoteness of certain segments of the Salmon River and other steelhead areas, the amount over cost anglers are willing and able to pay is lower than might be expected. However, the figure of $31 a trip translates to $20.29 per day, a value not too different from the willingness to pay value of $18.00 per day for ocean salmon/steelhead fishing reported by Crutchfield and Schelle (1978).

Table 3 provides values for the Clearwater River (Sections 10 and 11 in figure 1) and the Salmon River (Sections 3–9 in figure 1). Net willingness to pay for steelhead fishing in the Salmon River was higher, even though number of fish caught was similar for both rivers. The difference in value may partly relate to the resource setting in which the fishing takes place. Access for anglers to the Clearwater River is easier than for the Salmon River. Expenditures also were different, which may be useful for regional economic analysis. A later section discusses the 11 river segments studied.

Multiple Purpose Trips

Multiple purpose trips could not be analyzed using Travel Cost Method, because it would be incorrect to attribute the distance driven to the site as an indirect measure of price paid for fishing. The net willingness to pay for multiple purpose steelhead fishing trips using CVM was $45.71 per trip. This translates to $19.12 per day and to $51.00 per 12-hour WFUD. This group was not large. The sample showed that only 3% of steelhead anglers were fishing as part of a multiple purpose trip.

There are two possible reasons why multiple purpose trips had such high values. First, these values may not really be representative of such trips, because the sample was so small. Second, if the travel expenses were already incurred for other purposes (e.g., business, family), then the extra costs of steelhead fishing may

Table 3.—Net willingness to pay and profile of steelhead anglers as estimated by CVM for two rivers.

	Primary Purpose Trips	
	Clearwater	Salmon
Net willingness to pay (bid for current conditions per trip	$23.63 [1]3.86 [2](84)	$37.84 5.18 (123)
Net willingness to pay in excess of bid for current conditions for double number of fish caught per trip[3]	$7.64 1.31 (98)	$3.60 2.03 (126)
Net willingness to pay in excess of bid for current conditions for 50% increase in fish size[3]	$5.69 1.23 (99)	$9.63 2.14 (126)
Days fishing on this trip	1.20 (117)	1.81 (151)
Hours fished per day on this trip	5.30 (117)	5.33 (151)
Number of fish caught per day on this trip	0.89 (102)	0.95 (127)
Number of licensed anglers on this trip	2.42 (117)	2.71 (151)
Cost (travel, food, tackle, accommodations, etc.)	$38.68 (84)	$96.71 (123)

[1]*Standard error for each CVM mean bid is shown just beneath each bid.*
[2]*Sample size in parenthesis.*
[3]*To compute the total bid for each contingent change, add the amount bid for the change to the amount bid for current conditions. For example, the total bid for double the number of fish caught on the Clearwater is $31.27 (= 23.63 + 7.64).*

have been quite low. If this is the case, the net willingness to pay may be quite high, because the additional cost of steelhead fishing is minimal compared to the cost of the total trip.

Travel Cost Method

The regression equation used to calculate benefits is:

$$\begin{aligned} \ln(\text{trips/pop}) &= -7.60255 - 0.0058734(\text{DIST}) \\ (\text{"t" statistics}): &\quad (-28.909) \qquad (-9.839) \\ &\quad - 0.22482(\ln(\text{SUBS})) \\ &\quad\quad (-2.881) \\ &\quad + 0.021739(\text{TOTFISH}) \\ &\quad\quad (2.226) \end{aligned} \tag{5}$$

This equation is highly significant, with an F-value of 33.4. Both the F and the individual t statistics are all significant at the 99% level. The R^2 is 0.44.

The model specified in equation [5] is termed log-linear, because the dependent variable is transformed as shown and the independent variable associated with cost (i.e., distance) is not transformed. This transformation compresses the natural variation found in a completely linear model, resulting in an artificially high multiple correlation coefficient, R^2. Thus, it is not proper to compare a log-linear model to a linear model solely on the basis of R^2.

As discussed earlier, choice of functional form of the per capita demand equation was related to two factors. These were the Rao and Miller (1965) functional form test, and how well the log of visits per capita reduced heteroskedasticity. The Rao-Miller test indicated that log of visits per capita was preferred in terms of better data fit. The log of visits per capita minimized heteroskedasticity to the extent that estimated visits to the 11 sites were 1,811, while actual visits were 1,962. The estimated visits are within 10% of the actual. Because the main emphasis was on benefit estimation, this was deemed acceptable. In addition, the weighted linear regression resulted in neither substitutes nor quality (total fish) being statistically significant. When building a regional TCM for valuation of different sites, substitute and quality variables should be present in the equation, if possible, rather than deleting them to improve the use estimate another few percentage points.

Equation [5] does not contain an income variable because of a very high degree of multicollinearity between income and the substitute variable. The correlation coefficient of income and substitutes was 0.63 for natural log of substitutes and, 0.74 for untransformed substitutes. The effect of this multicollinearity when both income and substitutes were in the equation was to cause the sign on substitutes to change to positive, which is not plausible, given economic theory about the effect of substitutes on demand. As the quantity (fish-per-mile) of the best substitute site increases, visits per capita to the site under study are expected to decrease. When income was removed from the equation to eliminate multicollinearity (highly correlated independent variables), the sign of substitutes in fact became negative. The regression also was estimated including income but not substitutes. Including income resulted in estimated visits being about one-half of actual visits. In addition, the dollar values per trip derived from the second-stage demand curve were about $2 higher with income in and substitutes out. Given these empirical tests, substitutes were retained in the regression rather than income, because predicted visits were much closer to actual.

The per capita demand curve for steelhead fishing was used to derive a second stage demand curve for each of the 11 steelhead fishing sites. One of the advantages of a regional travel cost model is that one equation can be tailored to specific sites. In this case, the values of the variables for total fish and substitutes distinguish sites apart, so these were set at the appropriate numbers for each origin-site combination. Distance was set at its current value to calculate estimated visits at the mean distance anglers actually traveled from each origin. Then, 50-mile increments were successively added to distance until visits from a particular origin fell to 0.1, or until distance equaled the highest distance actually observed in the data. This maximum observed distance was a 1,000-mile round trip, which occurred in four cases. This distance limit was used as a cutoff point for incrementing distance, because visits per capita would never drop to zero with natural logs (Wennergren 1967, Smith and Kopp 1980). This rule yields a conservative estimate of the surplus, because it cuts off a portion of consumer surplus. However, in this application, the amount of consumer surplus lost was less than $100. In addition, use of this maximum distance implies an empirical boundary to the market area for steelhead fishing in Idaho.

Figure 3 illustrates the second stage demand curve for the most heavily visited site, site 10, the lower Clearwater River. Because the distance increment is computed over and above the current distance, the entire area under this curve (when distance is converted to dollars) is consumer surplus. A simple conversion of added distance to dollars cannot be made on the graph in figure 3, because the conversion of distance to travel cost for a given site incorporates differences in the number of anglers per vehicle from each origin visiting that site. The sample total consumer surplus is $18,070 using a standard cost per person per mile of $0.135. On a per trip basis the value is $19.12. Using the transportation cost reported by sampled anglers, the sample total consumer surplus is $25,617 yielding a consumer surplus per trip of $27.08.

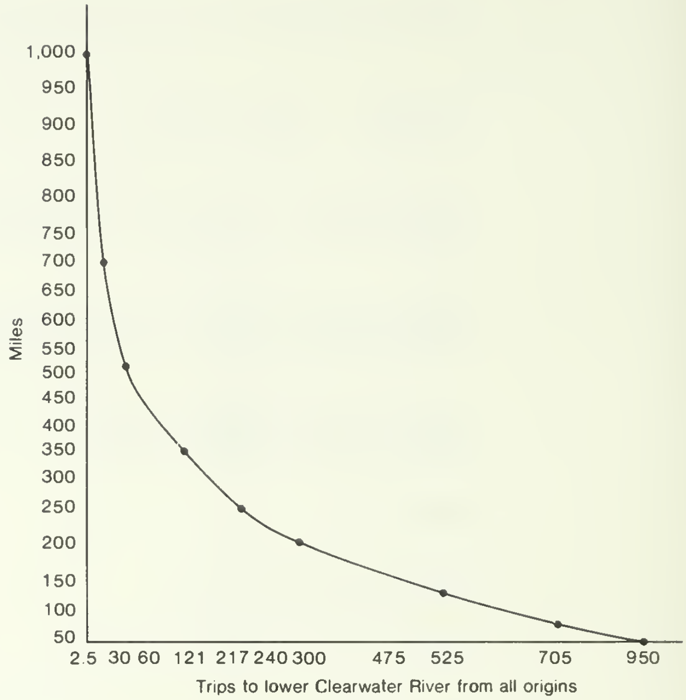


Figure 3.—Second stage demand curve for site 10, Lower Clearwater River.

Average steelhead values from the Travel Cost Method over all 11 sites combined are reported in the following tabulation:

	Standard cost *per mile*	**Reported cost** *per mile*
Net willingness to pay for current conditions per trip	$19.89	$27.87
Number of days fishing on this trip	1.95	1.95
Number of hours fished per day on this trip	5.76	5.76
Values per day	$10.20	$14.29
Value per 12-hour WFUD	$21.28	$29.77

Using a standard cost of $0.135 per mile, the value per trip is $19.89 with a sensitivity interval of $15.27 to $23.38. Using reported transportation cost of $0.26 per mile, the value per trip is $27.87 with a sensitivity interval of $23.12 to $34.82. Table 4 reports TCM values by site. Note, that the total consumer surplus for each of the 11 sites (the two bottom lines in Table 4), is generated by only 1.69% of users. To get a total value for the site, the sample value is expanded by the reciprocal of the sample rate (1/0.0169 = 59.11). Of course, each site's total value depends on the fact that it is part of a system of 10 other sites.

Converting the benefits per trip to benefits per day using estimated length of trip, yields $10.20 per day at the standard cost per mile and $14.29 at reported cost.

Table 4.—Steelhead Fishing Values Derived by CVM and TCM.[1]

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Travel Cost Method @ Standard Cost Per Mile											
Net willingness to pay for current conditions	$19.27	$20.44	$19.92	$18.89	$18.81	$19.68	$20.57	$23.88	$22.52	$19.12	$22.24
Travel Cost Method @ Reported Cost Per Mile											
Net willingness to pay	$26.60	$28.90	$27.88	$25.94	$25.78	$27.46	$29.27	$35.58	$33.00	$27.08	$32.40
Contingent Value Method[2]											
Net willingness to pay for current conditions	$27.83	$35.69	$10.96	$36.57	$25.83	$49.38	$50.98	$24.50	$27.50	$23.66	$19.00
	11.59	12.57	2.38	14.14	8.43	14.15	10.48	15.24	17.50	4.27	8.64
	(18)	(16)	(22)	(14)	(12)	(16)	(50)	(6)	(2)	(83)	(17)
Contingent Value Method											
Net willingness to pay for double number of fish caught	$34.18	$40.88	$18.86	$59.43	$30.50	$58.00	$65.98	$37.17	$42.50	$31.82	$23.18
	11.88	12.10	3.53	14.33	8.23	13.84	12.27	22.75	12.50	5.48	8.96
	(17)	(16)	(22)	(14)	(12)	(16)	(50)	(6)	(2)	(82)	(17)
Contingent Value Method											
Net willingness to pay for 50% increase in fish size	$35.88	$41.00	$16.68	$46.57	$32.08	$69.50	$59.06	$27.17	$32.50	$29.75	$22.06
	13.23	12.14	3.87	15.23	10.12	24.07	10.94	14.69	22.50	4.66	8.55
	(17)	(16)	(22)	(14)	(12)	(16)	(50)	(6)	(2)	(81)	(17)
Number of fishing days on this trip	1.64	1.50	1.15	1.71	1.81	1.81	2.23	1.57	1.50	1.19	1.24
	(22)	(21)	(26)	(19)	(16)	(18)	(57)	(7)	(2)	(99)	(17)
Number of hours fished/day on this trip	5.34	5.67	4.40	5.08	6.06	5.17	5.57	5.29	7.00	5.14	6.12
	(22)	(21)	(26)	(19)	(16)	(18)	(57)	(7)	(2)	(99)	(17)
Number of fish caught/day	.89	1.44	.56	.43	.50	1.75	1.14	.50	1.00	.91	.77
	(18)	(16)	(22)	(14)	(12)	(16)	(50)	(6)	(2)	(84)	(17)
Number of licensed anglers this trip	2.77	3.10	2.58	3.11	3.19	3.11	2.51	1.43	2.00	2.49	1.94
	(22)	(21)	(26)	(19)	(16)	(18)	(57)	(7)	(2)	(99)	(17)
Cost (travel, food, tackle, accommodations, etc.)	$68.24	$66.21	$43.86	$91.33	$145.27	$99.81	$104.09	$87.00	$51.50	$37.32	$36.58
	(21)	(19)	(21)	(15)	(15)	(16)	(43)	(6)	(2)	(71)	(12)
Sample total visits[1]	94	63	73	70	84	137	121	44	14	1,042	65
Total sample net willingness to pay at standard cost	$1,812	$1,287	$1,454	$1,322	$1,580	$2,696	$2,489	$1,050	$315	$19,923	$1,445
Total sample net willingness to pay at reported cost	$2,500	$1,820	$2,035	$1,815	$2,165	$3,762	$3,542	$1,565	$462	$28,217	$2,106

[1]*Sample size in parentheses.*
[2]*Standard error for each CVM mean is shown just beneath each bid.*

Converting these to a 12-hour Wildlife and Fish User Day (WFUD) basis using hours fished per day, yields $21.28 per WFUD for standard cost per mile and $29.77 per WFUD for reported cost per mile.

One use of the RegionaL TCM equation is to predict the change in visits if total fish harvest is increased. As an example, if total fish caught is doubled, the number of primary purpose trips would increase from 1,811 to 6,118.

Comparision of Idaho TCM to Oregon TCM

Generally, it may appear that the steelhead values are low compared to $45 per trip for salmon/steelhead values found by Brown et al. (1980) using TCM. However, the average round-trip distance traveled to steelhead fish in Idaho is 331 miles based on aggregated TCM data, whereas in Oregon it is much lower. The lower mileage in Oregon, and, therefore, the price paid, implies that, even with the same demand curve, greater net willingness to pay could be expected in Oregon. In addition, the equation in Brown et al. (1980) does not contain a substitute variable. Inclusion of such a variable would theoretically lower their benefit estimates somewhat. Recent work (Strong 1983) on steelhead fishing in Oregon, using a similar per capita TCM demand curve, yields a value of $22.95 per trip. This is between this study's two TCM estimates using standard and reported costs, respectively.

Comparison of Idaho TCM and CVM Estimates

The CVM value for a primary purpose trip is the appropriate CVM value for comparison to TCM values, because TCM is based on only primary purpose-primary destination trips. The mean value for CVM was $31.45, with a 95% confidence interval of $25.31 to $37.58. And, as reported earlier, when cost per mile is set at a standard cost, the TCM value per trip is $19.89 with a sensitivity interval of $15.27 to $23. When cost per mile is set at reported cost, the TCM value per trip is $27.87 with a sensitivity interval of $23.12 to $34.80.

Figure 4 shows how the sensitivity interval around the TCM value with reported cost overlaps the mean of CVM and vice versa. Thus, there appears to be no qualitative difference between the CVM value of $31.46 per trip and the TCM value of $27.87 per trip associated with actual reported cost per mile. The dollar value of $19.89 for TCM with standard cost per mile is lower than either the CVM or TCM value that are both based on reported cost per mile.

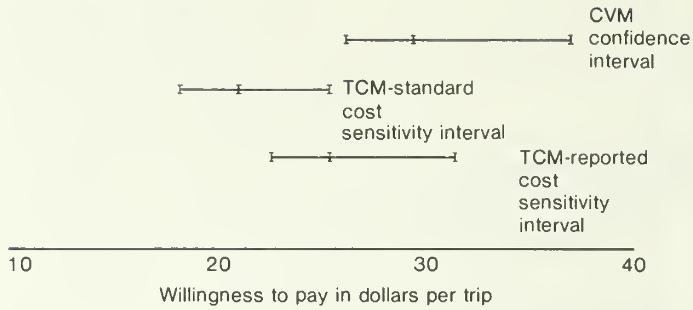
Comparison of TCM and CVM for the 11 individual sites shows a less consistent pattern. Using the TCM values associated with reported cost, the TCM and CVM values for site one and five are very close. For site 10, which received half the visits in the sample, the TCM values and the CVM values do not appear significantly different. For this most highly used site the two TCM values bracket the CVM values at about ±$4.00.

One reason the overall values for CVM are higher than those for TCM is that CVM values are for the anglers' last trip while TCM applies to all trips taken during the season. The key is that the distribution of trips across sites is slightly different in TCM and CVM. Making the distribution of trips more consistent between CVM and TCM may provide a more accurate way to compare TCM and CVM values per trip. For example, adjusting the distribution of CVM trips for sites 6, 7 and 10 to be more consistent with TCM trips and recalculating the overall mean CVM values for all 11 sites gives $25.63 per trip. This is almost identical to the TCM value of $27.87 using reported cost and much closer to the TCM values associated with standard cost.

Application

A comprehensive case study example that incorporates effects "with" and "without" the proposed management action, that goes into detail about benefit values and costs, and that considers discount rates and net present values is beyond the scope of this bulletin. However, some approaches to the use of these value estimates are illustrated here.

Suppose a combination of management practices in all steelhead areas is estimated by fisheries biologists to result in a doubling of the steelhead population (after a certain time lag).[8] The biologists further estimate that



[1] l - lower value of interval
m - mean value of interval
u - upper end of interval

Figure 4.—Comparison of confidence intervals for CVM to sensitivity intervals for TCM.

the doubling of the population would double the catch. Thus, over the course of time needed to increase the number of steelhead, the total harvest also increases. Increased harvest is a positive factor in equation [5], the demand curve for trips per capita discussed in this bulletin, because it is associated with increased visits to the fishing site. When the individual demand curves showing trips per capita to a site are summed over all origins to gve the overall demand curve for the fishing area, the consumer surplus benefits associated with more visits also increases.

Computation Based on Theory

Because total catch at a fish area is a demand curve shifter in this travel cost model, doubling this variable (because of the increased population of catchable steelhead) shifts the demand curve up and to the right. This can be seen as the shift from D1 to D2 in figure 5, and assumes that coefficients in the demand curve equation are stable over the range of such changes. The improvement in fishing over the long run will be translated (in TCM) into more trips taken by existing anglers and entry (or reentry) of new anglers because of the higher quality fishing experience. Based on the sample for this study, use of the per capita demand curve (equation [5]) and the benefits computation procedures described in this report show that current and new anglers would make an additional 4,307 trips per year (6,118–1,811) to Idaho steelhead areas.

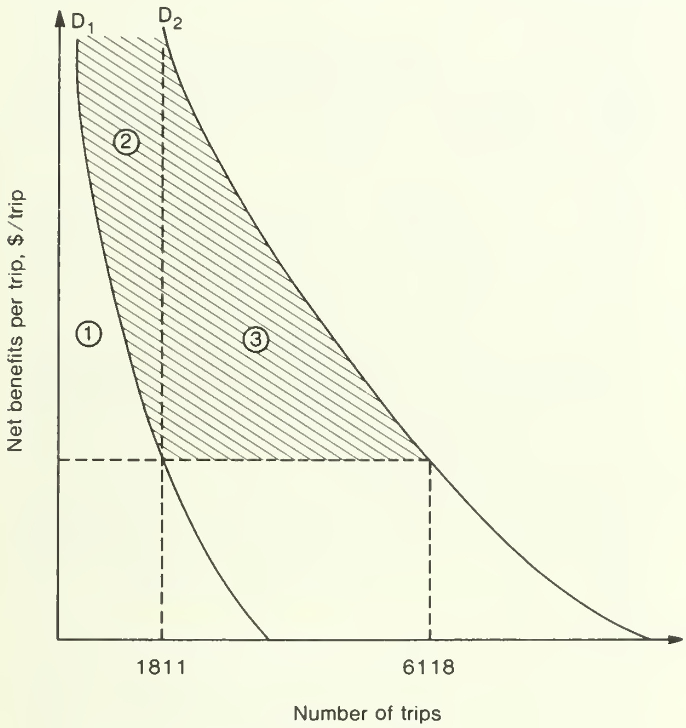
Long run value means the value once anglers have an opportunity to adjust their behavior (entry of new anglers and more trips by existing anglers). The theoretical measure of the net economic value of the additional 4,307 trips is equal to the shaded areas between the two demand curves (areas 2 and 3 in fig. 5). For the anglers in this sample (i.e., considering only those anglers sampled and not inflating the sample to the population of steelhead anglers fishing in Idaho), computation of the benefits shows they would be willing to pay an additional $117,751 for double fish catch. This is the long run sample value, which would be expanded by

[8] *Our example implies that changes may occur over several years. To keep the concepts clear, we have not considered present values and discounting. However, these effects may need consideration in actual practice.*

a factor of approximately 59 to apply to all steelhead anglers fishing in Idaho. This economic value of improved steelhead fishing (more than $6.9 million for all steelhead anglers if the improvement were made uniformly at every site in Idaho) would be compared to the net economic value of any foregone benefits of the management program and its cost. If the net economic value of what is gained (i.e., more than $6.9 million in the hypothetical example) is greater than what was lost, economic efficiency is improved.

An Approximation to Theory

Biologists often are able to translate the change in fisheries habitat or populations into an estimate of the increase in supply of fishing trips of constant quality. However, in field studies, it is often difficult for biologists to have access to the original TCM data, the TCM demand curve, and a computer program to calculate benefits of a quality induced change in net economic benefits. Thus, the correct way to compute the consumer surplus measure of value of such changes (i.e., to sum the additional consumer surplus generated by each successive additional trip), may not be technically feasible under field conditions. Despite this, based on results in this bulletin, the economic benefit of the added fishing



① Area 1 is the original estimate of consumer surplus.

② After the change, area 2 is the increased benefits estimated by CVM in the short run.

③ In the long run, areas 2 and 3 are the total increased benefits estimated by TCM.

Figure 5.—Relationship of benefits estimated by TCM and CVM for increases in fish catch.

trips can be approximated by multiplying the increase in number of trips times the marginal value per trip. The marginal value may be unavailable. Given that the geographic scope is comparable and appropriate, use of the average value in place of marginal value is possible, because the functional form of the demand curve used for steelhead fishing is such that the consumer surplus average value equals its marginal value. While this is the case for semi-log functional forms, as is discussed more fully in the appendix, it is not generally true for other functional forms. Mumy and Hanke (1975) analyzed a situation where an average value could correctly be used.[9] Figure 5 shows there is a demand for 4,307 additional trips. Taking this number of trips times the average net value (prior to the management change) of $27.87 per trip, yields $120,036. In this case, the approximation to the area between the demand curves is a good one (i.e., a computed value of $117,751 based on theory).

Short Run Benefits

Benefits of improved fish habitat do not necessarily flow only from more angler days in the long run. The increase in harvestable populations of fish may be received in the short run by current anglers. It may take several years before anglers believe the initial steelhead population change is permanent. It may take more time for informal information to spread from current anglers to potential anglers (those that are considering the sport and those that dropped out because fishing quality was not up to their expectations). As a result, the benefits of the improvement initially might be limited to current anglers. To estimate the value to current anglers, assuming no entry of new anglers, the analyst can use net economic values provided by the Contingent Value Method. In figure 5, this is area 2 between the demand curve and the vertical dashed line, showing that trips are held constant at the original level (1,811). In this steelhead study, anglers were asked in the CVM portion of the survey their willingness to pay for an increased probability of success that would result in double the number of fish caught. Mean responses of anglers indicated a total bid of $41.36 for the described increase. This is an increase of $9.91 over the bid for current conditions. Thus, the increase in net value in the short run would be about $18,000 (1,811 present trips × $9.91) for the sampled population.

CONCLUSIONS

TCM values using reported transport cost probably are more accurate in the case of steelhead fishing than a standard transport cost. Pickup trucks with campers and boat trailers are perceived by some as typical transport for many steelhead fishermen. Only the reported cost for these vehicles would reflect these higher costs.

[9]*John B. Loomis and John G. Hof expand on this theme in a forthcoming article, "A Note on the Comparability of Market and Nonmarket Valuations of Forest and Rangeland Outputs."*

The choice of which value, TCM or CVM, is better, is subjective. The TCM is representative of both spring and fall, whereas the CVM just represents fall fishing, because most anglers last trips were for fall fishing. Therefore, the value to use (TCM at reported cost or CVM) is the one that is most appropriate to the issue under study.

The Travel Cost and Contingent Value Methods used in this study each have advantages and disadvantages. The advantage of CVM is the ability to value not only primary purpose-primary destination trips but also multiple destination trips. For steelhead fishing in Idaho this is not a large advantage, because only 3% of the trips were not primarily for steelhead fishing. For other activities, this advantage may be more important. In addition, CVM provides reasonable values for changed conditions, such as doubling the number of fish or increasing fish size. There appears little trouble in getting people to participate in the bidding game. One limitation of CVM in this study was that it could reasonably be applied only to the last trip taken, because applying the bidding sequence to each trip would have doubled the length of the interview and involved greater difficulty in respondent recall. This limitation may not be too serious if the last trip is representative of the typical trips taken.

The primary advantages of TCM relate to its reliance on actual behavior and applicability to all trips taken during the season. Disadvantages relate to inability to value multiple purpose or multiple destination trips, and in selecting a value of travel time. TCM has the advantage of being able to predict how many additional trips (or with some additional calculations, fishermen), would be taken if the number of steelhead harvested doubled.

Perhaps the biggest practical disadvantage to the Travel Cost Method is the time it takes to construct a Regional Travel Cost Model (10–14 person days). The analysis work also involves use of several specialized computer programs designed to shorten the time necessary to aggregate individual data into zones, calculate substitute indices, calculate second stage demand curve, and benefits. If such programs are not available, then significant additional time is necessary.

In contrast, the CVM analysis of mean willingness to pay took about 1.5 person-days. Thus, if a survey must be performed to collect data for valuation, CVM is faster in terms of data compilation and statistical analysis. However, if origin-destination data already exist in the form of permits or license plate numbers, etc., then TCM would become a more cost-effective way to value recreational activities.

Each method yields consistent results. However, differing circumstances of application of results, of data availability, personnel, and time will determine which method is preferable.

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APPENDIX

Steelhead Survey Questionnaire

The survey of steelhead anglers fishing in Idaho was originated, developed, and administered by personnel from the Idaho Department of Fish and Game, and the University of Idaho Cooperative Wildlife Unit. In the interest of making complete information available, the text of the survey instrument is reproduced here with permission of the Idaho Department of Fish and Game.

SCRIPT FOR TELEPHONE INTERVIEW OF IDAHO STEELHEAD FISHERMEN
IDAHO DEPARTMENT OF FISH AND GAME

INTRODUCTION

HELLO, IS THIS THE RESIDENCE OF ______________________________?
first and last name

If yes. If no, → THE NUMBER I WAS CALLING IS ______________________________
telephone number

AND I AM TRYING TO CONTACT ______________________, SORRY I

BOTHERED YOU. (TERMINATE, CHECK NAME AND NUMBER.)

→ THIS IS ______________________ AT THE UNIVERSITY OF IDAHO. I
interviewer's name

AM CALLING FOR THE COLLEGE OF FORESTRY, WILDLIFE AND RANGE SCIENCES IN MOSCOW. WE ARE DOING A STUDY OF STEELHEAD FISHING IN IDAHO. WE ARE TRYING TO DETERMINE THE ECONOMIC VALUE OF IDAHO'S WILDLIFE. ______________________'S
first & last name

NAME WAS GIVEN TO US BY THE IDAHO DEPARTMENT OF FISH AND GAME. IS HE/SHE THERE? MAY I SPEAK TO HIM/HER?

1. Respondent is on the phone
2. Respondent is called to phone
3. No

WHEN MAY I CALL BACK TO REACH HIM/HER? __________ AND
date

__________ A.M./P.M. WOULD YOU TELL HIM/HER THAT I CALLED
time

AND THAT I WILL CALL BACK. THANK YOU.

→ THIS IS ______________________ AT THE UNIVERSITY OF IDAHO. I AM
interviewer's name

CALLING FOR THE COLLEGE OF FORESTRY, WILDLIFE AND RANGE SCIENCES IN MOSCOW. WE ARE DOING A STUDY OF STEELHEAD FISHING IN IDAHO. WE ARE TRYING TO DETERMINE THE ECONOMIC VALUE OF IDAHO'S WILDLIFE. YOUR NAME WAS OBTAINED FROM THE IDAHO DEPARTMENT OF FISH AND GAME'S LISTS OF LICENSE HOLDERS.

→ LAST WEEK WE SENT YOU A LETTER AND MAP THAT EXPLAINED A LITTLE ABOUT OUR STUDY. DID YOU RECEIVE IT?

yes

no → I AM SORRY YOURS DID NOT REACH YOU. IT WAS A BRIEF LETTER WE SENT SO THAT PEOPLE WOULD KNOW WE WOULD BE CALLING THEM.

1. DID YOU FISH FOR STEELHEAD IN IDAHO DURING 1982?

no THANK YOU FOR YOUR HELP. THAT IS ALL THE QUESTIONS THAT I HAVE FOR YOU.

yes

(skip this question if they did not receive the letter).

2. DID YOU HAVE TIME TO LIST ALL THE STEELHEAD FISHING TRIPS YOU TOOK DURING 1982 ON THE MAP WE SENT YOU?

yes WOULD YOU READ ME YOUR LIST OF FISHING AREA NAMES AND THE CORRESPONDING MAP UNIT NUMBERS.

RECORD LIST ON SEPARATE SHEET
go on to probes at bottom of page.

no

ON A PIECE OF PAPER, PREFERABLY THE ONE WE SENT TO YOU IN THE MAIL, LIST ALL THE STEELHEAD FISHING TRIPS YOU TOOK THIS PAST SEASON. A LIST OF GENERAL LOCATIONS IS FINE. OUR GOAL IS NOT TO FIND OUT YOUR SPECIAL SPOTS. IN ADDITION TO THIS LOCATION, IF YOU HAVE THE MAP WE SENT, PLEASE DETERMINE THE MAP UNIT WHERE YOU WENT ON EACH TRIP. PLEASE TAKE A MOMENT TO MAKE YOUR LIST OF FISHING AREAS AND CORRESPONDING MAP UNITS. IF YOU WENT TO ONE AREA MORE THAN ONCE, JUST LIST THE AREA AND NUMBER OF TRIPS.

Pause while he/she completes the list. Try to get them to make their own list. You may write the list if they do not have paper or refuse to write it out.

WOULD YOU READ ME YOUR LIST OF FISHING TRIPS.

NOTE 1. If an interviewee does not have a map, it is your duty to get enough information to assign a map unit number to each general location.

NOTE 2. Probe: DID YOU INCLUDE TRIPS YOU TOOK WITH YOUR FAMILY, VISITING RELATIVES, FRIENDS, OR PEOPLE YOU WORK WITH?

NOW THAT WE KNOW HOW MANY TRIPS AND IN WHAT MAP UNIT YOU TOOK THEM, I WOULD LIKE TO ASK YOU SOME MORE DETAILED QUESTIONS ABOUT EACH TRIP. IF

YOU MADE MORE THAN ONE TRIP TO AN AREA, PLEASE GIVE THE AVERAGE FOR THOSE TRIPS.

WAS THE PRIMARY PURPOSE OF YOUR TRIP TO ______________________________
general area

TO FISH FOR STEELHEAD?

yes

no → (terminate and start new area)

maybe → WOULD YOU HAVE VISITED THIS AREA IF STEELHEAD FISHING WAS NOT AVAILABLE?

yes → (terminate and start new area)

no

→ WAS THIS AREA THE PRIMARY DESTINATION OF THIS TRIP?

yes → (enter a "1")

no

maybe → WOULD YOU HAVE MADE THIS TRIP IF YOU COULD NOT HAVE VISITED THE AREA?

no

→ yes → HOW MANY DESTINATIONS DID YOU HAVE ON THIS TRIP?

______________ AREAS

WHAT WERE THOSE DESTINATIONS?

→ HOW MANY TRIPS DID YOU MAKE TO ______________________________
general area

DURING THE SPRING SEASON? ______________ TRIPS

HOW MANY TRIPS DURING THE FALL SEASON? ______________ TRIPS

DID YOU DRIVE THE ENTIRE DISTANCE TO ______________________________?
general area

yes → mode = 1

no → WHAT DIFFERENT TYPES OF TRANSPORTATION DID YOU USE?

small plane, airline, horse, car, jet boat, etc.

FOR YOUR TRIP TO ______________, WHAT WAS THE APPROXIMATE TOTAL DISTANCE YOU TRAVELED?

COUNTING YOURSELF, HOW MANY LICENSED ANGLERS WENT IN YOUR VEHICLE TO

______________? ______________anglers
general area

HOW MANY UNLICENSED CHILDREN FISHED? ______________________children

HOW MANY DAYS DID YOU FISH ON THIS TRIP TO ______________________________________?
general area

(TO NEAREST HALF DAY)

ON AVERAGE, HOW MANY HOURS PER DAY DID YOU FISH?

______________________hours

ON AVERAGE, HOW MANY DID YOU CATCH PER DAY INCLUDING THOSE YOU DID NOT KEEP? ______________________________

If this is the last area, go on to page 5.
If there are more areas, repeat from page 3 with other areas.

THAT IS ALL I NEED ABOUT THIS AREA, NOW I WOULD LIKE TO TALK ABOUT YOUR TRIPS TO ______________________________
general area

go back

NEXT, I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR LAST STEELHEAD FISHING TRIP IN 1982. WHAT AREA DID YOU VISIT ON YOUR MOST RECENT TRIP?

__________________ area

WAS THE PRIMARY PURPOSE OF YOUR TRIP TO ________________________ TO
general area

FISH FOR STEELHEAD?

yes

no

WAS THIS AREA THE PRIMARY DESTINATION OF THIS TRIP?

record response as follows:

If "Primary purpose?" is

	yes	no
yes	1	2
no	3	4

HOW MANY LICENSED ANGLERS WERE IN YOUR PARTY?

__________________________ people

HOW MANY DAYS DID YOU FISH ON THIS TRIP (TO NEAREST HALF DAY)?

__________________________ days

ON AVERAGE, HOW MANY HOURS DID YOU FISH EACH DAY?

________________________ hours

THE NEXT FEW QUESTIONS CONCERN THE AMOUNT OF MONEY THAT WAS YOUR SHARE OF THE AMOUNT SPENT ON THIS TRIP.

PLEASE ESTIMATE THE AMOUNT SPENT ON TRANSPORTATION ON THIS TRIP.

$ ________________________

PLEASE ESTIMATE THE AMOUNT SPENT ON FOOD, TACKLE, ETC. ON THIS TRIP.

$ ________________________

NOW, ESTIMATE THE AMOUNT SPENT ON ACCOMMODATIONS ON THIS TRIP.

$ ________________________

WAS THIS TRIP TO ________________________ WORTH MORE THAN YOU ACTUALLY SPENT?

no → STOP HERE

yes

→ NEXT, I WOULD LIKE TO ASK SOME HYPOTHETICAL QUESTIONS ABOUT THIS TRIP TO ________________________ (general area), ASSUME THAT THE TRIP BECAME MORE EXPENSIVE, PERHAPS DUE TO INCREASED TRAVEL COSTS OR SOMETHING, BUT THE GENERAL STEELHEAD FISHING CONDITIONS WERE UNCHANGED. YOU INDICATED THAT $ ________________________ WERE SPENT ON THIS TRIP FOR YOUR INDIVIDUAL USE.

WOULD YOU PAY $ ________________________ (20% of cost) MORE THAN YOUR CURRENT COST RATHER THAN NOT BE ABLE TO FISH FOR STEELHEAD AT THIS AREA?

PROTEST – WILL NOT ANSWER

RECORD WHY?

1. it's my right
2. my taxes already pay for it
3. no extra value
4. like to, but not able
5. refuse to put a dollar value

yes

no → work between 0 and 20% to find highest acceptable value.
split the difference in half until you reach nearest $1
(less than $10) or nearest $5 (greater than $10)

→ WOULD YOU PAY $ ______________ MORE THAN YOUR CURRENT COST RATHER THAN NOT

BE ABLE TO FISH FOR STEELHEAD AT THIS AREA.

yes

no → Work between 20 and 50% to find highest acceptable value.
split the difference in half until you reach nearest $1
(less than $10) or nearest $5 (greater than $10).

→ WOULD YOU PAY $ ______________ MORE THAN YOUR CURRENT COST RATHER THAN
100% of cost

NOT BE ABLE TO FISH FOR STEELHEAD AT THIS AREA?

yes

no → work between 50 and 100% to find highest acceptable value.
split the difference in half until you reach nearest $1 (less
than $10) or nearest $5 (greater than $10).

keep going until you receive a negative answer. Use 100$ increments.

work between last two bids to find highest acceptable value.

After last bid

IS THIS AMOUNT, $ ______________, WHAT YOU PERSONALLY WOULD PAY, NOT FOR ALL
bid

MEMBERS OF YOUR PARTY?

no → repeat bids for personal value

yes

→ HOW MANY STEELHEAD DID YOU CATCH ON THIS TRIP TO ______________?
general area

______________ fish

NOW SUPPOSE THAT INSTEAD OF ______________ STEELHEAD, YOU COULD CATCH
caught

______________ STEELHEAD. HOW MUCH, IF ANY, WOULD YOU INCREASE YOUR VALUE
double #

OF $______________?

$ ______________

NOW SUPPOSE, THAT THE SIZE OF FISH YOU CAUGHT INCREASED 50% (FOR EXAMPLE, FROM 8" TO 12". HOW MUCH, IF ANY, WOULD YOU INCREASE YOUR VALUE OF $ ______________?

$ ______________

THAT IS ALL THE QUESTIONS I HAVE FOR YOU. THANK YOU FOR TAKING THE TIME TO ANSWER THESE QUESTIONS. YOUR RESPONSES WILL BE VERY VALUABLE TO US.

GOODBYE.

Average and Marginal Consumer Surplus – Conditions of Equality

The objective of the proof is to show that average benefits are equal to marginal benefits in relation to the per capita (stage I) demand curve. The means to accomplish this is to derive the mathematical expression for the benefits in each case and to show these are equal. The conditions under which this is true are:

1. Demand relationships between visits per capita and price (cost of travel) can be validly modeled with a semi-log functional form such as

$$\ln(q) = a - bp \qquad [A1]$$

or equivalently,

$$q = e^{a-bp} \qquad [A2]$$

where q is quantity, in this case, visits per capita
p is price, in this case, travel cost
a is the intercept parameter
b is the slope parameter

2. The only shifting variables allowed in the equation affect the intercept. No slope shifting variables are in the equation.
3. A slight relaxation of condition 2 occurs if there are slope shifting variables but they do not change from the "before" to the "after" states.
4. Each origin is a price taker in that people from that origin may visit the site as many times as they desire at their current travel cost. Therefore, the supply curve facing a given origin is horizontal. Due to differences in location from the site, each origin faces a different horizontal supply curve.

The "Before" State

Figure A–1 shows the overall scope of the changes considered in the proof. At equilibrium in state 1 (i.e., the "before" state) the demand curve has a quantity intercept of e^{a_1} when price is zero. As price increases, quantity decreases and asymptotically approaches zero for very large p. For a price of p_1, visits per capita to a site from a specific origin are q_1.

Total benefits per capita that accrue to the presence of the site, given all other existing sites, are represented by the shaded area labeled CS_1 (consumer surplus in state 1). This area is found by integrating under the demand curve and above the price line p_1.

Let a small segment of the area dCS be

$$dCS = q\,dp \qquad [A3]$$

as shown in figure A–1.
Then

$$CS = \int dCS = \int_{p_1}^{p} q\,dp \qquad [A4]$$

The limits of integration define the lower boundary of the CS area, the p_1 price line, and the upper boundary of the CS area, the point where p goes to infinity and q goes to zero. In spite of these extreme values, it turns out the CS area is finite.

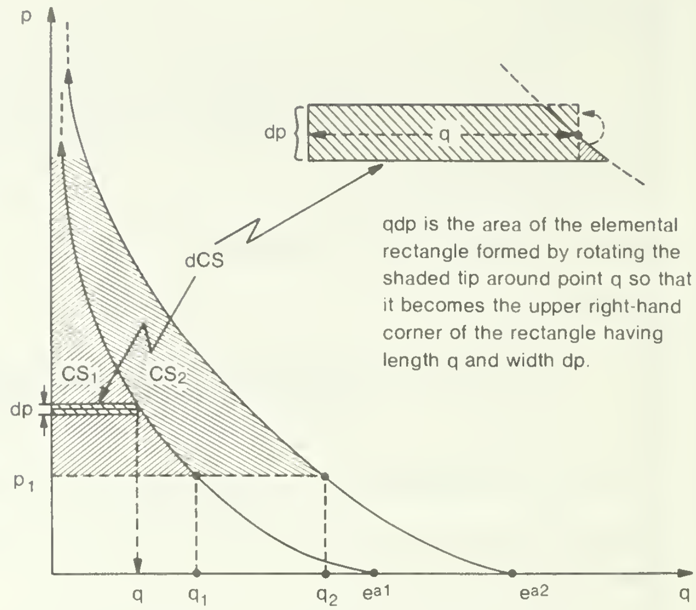

Figure A-1.—Changes in consumer surplus.

Substitute for q from equation [A2] in the integral in equation [A4] giving

$$CS_1 = \int_{p_1}^{p} e^{a_1 - b_1 p}\,dp \qquad [A5]$$

where the subscript 1 denotes state one ("before"). Continuing with the integration gives

$$CS_1 = e^{a_1}\int_{p_1}^{p} e^{-b_1 p}\,dp = -\frac{1}{b_1} e^{a_1 - b_1 p}\Big]_{p_1}^{p} \qquad [A6]$$

Evaluating the expression in [A6] at the limits of integration gives

$$CS_1 = \left(-\frac{1}{b_1} e^{a_1 - b_1 p}\right) - \left(-\frac{1}{b_1} e^{a_1 - b_1 p_1}\right) \qquad [A7]$$

$$CS_1 = \frac{1}{b_1}\left(e^{a_1 - b_1 p_1} - e^{a_1 - b_1 p}\right) \qquad [A8]$$

In order to include the entire area under the demand curve, let p (not p_1) become infinitely large ($\rightarrow \infty$). For large p

$$e^{a_1 - b_1 p} = q \rightarrow 0 \qquad [A9]$$

so that expression for CS in [A8] becomes

$$CS_1 = \frac{1}{b_1}\left(e^{a_1 - b_1 p_1}\right) = \frac{q_1}{b_1} \qquad [A10]$$

Average consumer surplus in state one per trip made (q_1) is

$$\overline{CS_1} = \frac{CS_1}{q_1} = \frac{1}{b_1} \left(e^{a_1 - b_1 p_1} \right) \frac{1}{q_1} \qquad [A11]$$

But $e^{a_1 - b_1 p_1}$ is q_1, so

$$\overline{CS_1} = \frac{1}{b_1} \qquad [A12]$$

Thus, average consumer surplus per trip in state one, the "before" state, is simply the inverse of the slope parameter from the demand equation, assuming the conditions previously stated are met.

The "After" State

Now, assume that managers of the recreational sites under consideration wish to increase the attractiveness of the specific site, for example, by increasing the number of animals or fish potentially harvestable. This new condition becomes the "after" state.

The new attractiveness at the site increases the intercept to e^{a_2}, but does not affect the slope coefficient b, as assumed, so $b_1 = b_2 = b$, (i.e., quality is an intercept shifter only). Using the result of the previous section, that, in general under the stated conditions,

$$CS = \frac{1}{b} \left(e^{a - bp} \right) = \frac{q}{b} \qquad [A13]$$

and placing the subscript (2) for the "after" state on the variables, total per capita consumer surplus for the "after" state is

$$CS_2 = \frac{1}{b_2} \left(e^{a_2 - b_2 p} \right) = \frac{q_2}{b_2} \qquad [A14]$$

Note that "after" average CS is also $\frac{1}{b_2} = \frac{1}{b}$.

The total change in consumer surplus from the "before" to the "after" state is

$$\Delta CS = CS_2 - CS_1 \qquad [A15]$$

$$\Delta CS = \frac{q_1}{b_2} - \frac{q_2}{b_1} \qquad [A16]$$

But, as noted, $b_2 = b_1 = b$, so

$$\Delta CS = \frac{q_2 - q_1}{b} \qquad [A17]$$

The marginal change per unit increase in trips is defined as

$$\frac{\Delta CS}{\Delta q} = \frac{\dfrac{q_2 - q_1}{b}}{q_2 - q_1} \qquad [A18]$$

So

$$\frac{\Delta CS}{\Delta q} = \frac{1}{b} \qquad [A19]$$

And since $b = b_1 = b_2$, combine the results of the derivation of "before" average consumer surplus and the derivation of the marginal consumer surplus caused by the change to the "after" state.

Thus,

$$\overline{CS_1} = \frac{1}{b} = \frac{\Delta CS}{\Delta q} = CS_{marg} = \overline{CS_2} \qquad [A20]$$

and the proof is complete given that the preceding conditions are met.

Note in the proof that the relationship in equation [A20] does not depend on the price level, even though figure A1 shows price unchanging. Neither do the key equations for "before" and "after" consumer surplus, equations [A10] and [A14], respectively. Under the stated conditions, there may or may not be a price change along with the demand curve shift. Regardless, it does not affect the equality between the "before" average consumer surplus and the "before" – to – "after" marginal change in consumer surplus. Moreover, the price may change in either direction without affecting the results.

GPO 846-592

Donnelly, Dennis M., John B. Loomis, and Cindy F. Sorg. 1984. Net economic value of recreational steelhead fishing in Idaho. USDA Forest Service Resource Bulletin RM–9, 23 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Willingness to pay in addition to actual expenditure for steelhead fishing in Idaho was estimated at $27.87 per trip with the Travel Cost Method and at $31.45 per trip with the Contingent Value Method. Willingness to pay was greater for increased catch or fish size. Average actual expenditure was $72 per trip.

Keywords: Steelhead fishing, economic value, travel cost method, contingent value method, recreation

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky
Mountains

Southwest

Great
Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

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Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**Resource Bulletin
RM-10**

Net Economic Value of Hunting Unique Species in Idaho: Bighorn Sheep, Mountain Goat, Moose, and Antelope

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Cindy F. Sorg
Lloyd Oldenburg

Abstract

The net economic value of hunting unique species in Idaho was estimated using the Travel Cost Method. The net willingness to pay per hunting permit was $239 for bighorn sheep, $360 for mountain goat, $113 for moose, and $73 for antelope.

Acknowledgements

Dr. Louis Nelson of the Idaho Department of Fish and Game provided valuable input. Helpful comments were also received from Terry Raettig and James McDivitt of the USDA Forest Service; Nancy Green, Robert Milton, and Stan Frazier of the USDI Bureau of Land Management; Richard Walsh of Colorado State University; and Debbie Gibbs, formerly with the Bureau of Reclamation.

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Net Economic Value of Hunting Unique Species in Idaho: Bighorn Sheep, Mountain Goat, Moose, and Antelope

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Contents

	Page
Management Implications	1
Introduction	2
Methodology	2
Definition of Economic Value	2
Travel Cost Method of Estimating Value	2
Statistical Analysis	4
Data Sources and Data Compilation	4
Calculation of TCM Benefits	5
Estimated Demand Equations	7
Benefit Estimates	8
Interpretation of Results: Average Versus Marginal in the Case of Lottery Rationing	12
Conclusions	13
Literature Cited	13
Appendix: Average and Marginal Consumer Surplus—Conditions of Equality	15

Net Economic Value of Hunting Unique Species in Idaho: Bighorn Sheep, Mountain Goat, Moose, and Antelope

John B. Loomis, Dennis M. Donnelly, Cindy F. Sorg, and Lloyd Oldenburg

Management Implications

This bulletin describes efforts to improve information available to federal agencies with regard to valuation of antelope, bighorn sheep, moose, and mountain goat hunting in Idaho. For these unique species, only a very limited number of permits are issued; in Idaho these are allocated by a random lottery. Thus, the conventional Travel Cost Method had to be modified to give estimates of the net economic value per permit and per day of hunting of these four unique species in Idaho.

This study did not estimate the "total economic value" (Randall and Stoll 1983) because the option and existence values of these unique species were not measured. Existence value reflects the net willingness to pay by hunters and nonhunters for the opportunity to know that these unique species exist. Budget constraints at both the Idaho Department of Fish and Game and the cooperating Federal agencies precluded estimation of option and existence values. The work of Brookshire et al. (1983) served as the basis for speculations later in this bulletin on what the existence value per permit might be to maintain the opportunity to know bighorn sheep exist in Idaho. In addition Brookshire et al. (1983) will be used to consider the likely benefits of nonconsumptive use of bighorn sheep. In their article this is expressed as option price, which is the sum of expected recreation benefits and option value. Option value is the net willingness to pay to maintain the opportunity to observe bighorn sheep in the future given the possibility of irreversibly losing the species.

To compare hunting values, which recur every year, against commodity values that are extracted only once or over long intervals, a technique such as discounting is used. By using an interest rate (called the "discount" rate), annual returns and irregular returns can be converted to a lump sum in today's values, called a "present value" or present worth. The 4% discount rate used in National Forest planning was the rate used here to calculate the present value of a hundred year flow of hunting benefits for these four species. Higher discount rates such as used by the U.S. Water Resources Council would lower the present value. This resulting value conservatively assumes that the per permit value does not rise in real terms over time. In addition, the 1985 RPA Program (USDA Forest Service 1984), Dwyer et al. (1977), and U.S. Water Resources Council (1979, 1983) require that the fees paid be included along with the net willingness to pay. This is because the fee paid is nothing more than a transfer of benefits from the recreationists to the government. Combining present value of hunting with the net present value of other resource benefits compatible with preservation of the species, such as option and existence values, would allow comparison to the net present value of resource activities not compatible with wildlife preservation (at least in the case where this is an all or nothing choice).

Mountain Goat Hunting.—The estimated net economic value of a mountain goat hunting permit is $360 or $90 per hunter day. In a typical hunt unit offering 3 permits per year, the annual hunting value is $1,080. Calculating the present value of a hundred year flow of mountain goat hunting benefits for a hunt unit with three permits yields $27,000. Including just the resident fee for mountain goat hunting raises the net annual value of a permit to $431. This yields a net present value for hunting of $32,325 for the average herd unit providing three hunting permits.

Bighorn Sheep Hunting.—The estimated net value of a bighorn sheep hunting permit is $239 or $28 per day. The net present value of bighorn sheep hunting in a typical unit offering five permits is approximately $30,000 (based on an annual value of $1,195). Including the resident hunting fee yields a net present value of $39,000. A rough approximation of the likely annual observer option price and existence values in Idaho for bighorn sheep is discussed later in the report. These later calculations serve to illustrate the relationship of hunting values to other benefits of a unique wildlife species.

Moose Hunting.—The net estimated present value to resident moose hunters for current conditions in a typical moose hunting area offering an average of four permits valued at $112 each is $11,200. Including the resident hunting fee results in a net present value of $18,300 for maintaining current opportunities in a typical moose hunting area. The value per day is $19.12. These moose hunting values are underestimates because of the effect the Idaho Department of Fish and Game's in-state-hunter-only rule has on the Travel Cost Method of estimating values.

Antelope Hunting.—The net present value to antelope hunters from maintaining a typical area offering 90 permits valued at the state average of $73 per permit is $165,950. Including the resident fee as part of the net benefit to society results in a net present value of $234,000 to hunters. The net economic value per hunter day is $38.58.

Managers are cautioned that site-specific values for individual hunt units are often more appropriate for project analyses than these state averages. Because of the reliance on a lottery to ration the few available permits among the many applicants, these site average values per permit also represent the marginal value of an additional permit (Mumy and Hanke 1975). This equivalence of marginal and average values will be discussed in detail later in this bulletin.

In all of these values the reader must keep in mind that this is the value for just two to three weeks of use of the species by hunters. If estimates of the option and existence values as well as nonconsumptive use values were added, this figure could easily be twice as large (Walsh et al. 1984). However, even the hunting values given here do provide a minimum value which can be compared to alternative uses of the habitat.

There are two benefits resulting from management that increases the populations of these animals. The most immediate effect is that success rate rises, and because success is a variable in our demand equations, willingness to pay of existing hunters rises. In the long run, higher animal populations allow for offering more permits to accommodate more hunters.

Introduction

The net economic values of antelope, bighorn sheep, moose, and mountain goat hunting have never been estimated in Idaho using the Travel Cost Method. Thus, the first objective of this research study was to quantify the net economic values of hunting these four unique species in Idaho, and to make this information available to the Idaho Department of Fish and Game, the Bureau of Land Management, USDA Forest Service, and conservation organizations. Inadequacy of previous simple Travel Cost Method approaches is one possible reason no one has previously quantified the net economic value of hunting these species in Idaho. Specifically, the simple Travel Cost Method will not work for these limited hunt species because of excess demand for permits at the current fee and travel cost. Based on the work of Loomis (1983) in Utah, the Travel Cost Method must be modified so it can be used with data from applications instead of actual trips taken. However, the permit applications in Utah were for a single site. No one has attempted to generalize the approach to a Regional Travel Cost Method, e.g., a multi-site system. Thus, a second research objective was to generalize the single-site Travel Cost Method adjustment and apply it to Idaho. By evaluating multiple sites it becomes possible to investigate the extent to which differences in site quality affect the demand for hunting these unique species.

Given the ability to evaluate quality, a third research objective was to statistically test how quality enters the Travel Cost Model. Traditionally, quality has entered as a demand shifter. Recent work by Vaughan and Russell (1982) suggests that quality also might enter as a slope shifter on the price variable. The same authors found that quality did enter as a slope variable as well as a shifter with regard to fishing. This paper will attempt to determine if the same result holds for activities such as mountain goat hunting.

The fourth major research objective relates to evaluation of these four species as part of the Idaho "prototype" study which is designed to test the cost effectiveness of combining state data with federally approved methods such as the Travel Cost Method to estimate the net economic values required by the 1990 Resources Planning Act (RPA) effort.

Methodology

Definition of Economic Value

For the purposes of Benefit Cost Analysis, Forest Planning Optimization (USFS FORPLAN), and Range-Wildlife Investments (BLM's SAGERAM), economic values for all outputs are defined in terms of net willingness to pay by the user. This is the correct value of forage to ranchers, the value of water to farmers and the value of wildlife to hunters. Net willingness to pay is the standard measure of value in benefit cost analyses performed by the U.S. Army Corps of Engineers, Bureau of Reclamation, and the Soil Conservation Service (U.S. Water Resources Council 1979, 1983). Net willingness to pay is the intended foundation of the Forest Service's RPA values. The Rangeland Investment Policy of the Bureau of Land Management stipulates willingness to pay as the value of all outputs in a SAGERAM analysis (BLM 1982).

User's gross willingness to pay is made up of two components. The first is the actual expenditure paid to engage in some activity (e.g., farming, ranching, or hunting). Expenditures are a cost to the user and are not appropriate for valuation of wildlife or any other resource (Knetsch and Davis 1966). Expenditures are primarily useful for measuring the effect or impact of some management action on local economies.

The second component of gross willingness to pay is known as "economic surplus." If there is a benefit remaining after all costs are paid then there is an economic surplus realized by the producer or consumers. Economists call the surplus accruing to producers "producer surplus" and the surplus accruing to consumers "consumer surplus." It is the change in producer or consumer surplus resulting from some management action that is the benefit or net economic value of that action. In the case of hunting, the surplus that is generated by maintaining population of the unique species is generally regarded as a consumer's surplus (Burt and Brewer 1971). In this report the term consumer surplus and net willingness to pay will be used interchangeably.

Travel Cost Method of Estimating Value

Dwyer et al. (1977), U.S. Water Resources Council (1979, 1983), Walsh (1983), and Knetsch and Davis (1966) all recommend the Travel Cost Method (TCM) as one of the two most commonly used, yet conceptually correct, methods for valuing recreation. The traditional Travel Cost Method relies on variations in travel costs of recreationists to trace out a demand curve; that is, the number of trips taken and the associated travel costs are taken as observations of equilibrium price-quantity points along a demand curve. Once the demand curve is estimated, the area above the expenditure but under the demand curve provides a measure of net willingness to pay (consumer surplus) for continued existence of that site. For the reader unfamiliar with the Travel Cost Method see Dwyer et al. (1977) or Clawson and Knetsch (1966).

One of the assumptions required by the traditional Travel Cost Method is that everyone wishing to enter the site at the current travel cost (price) is allowed to (Dwyer et al. 1977). This means there is no excess demand or no capacity constraint denying access to recreationists desiring to visit the site for a specific activity. In the case of hunting permits for bighorn sheep, antelope, moose, and mountain goat in Idaho this assumption is invalid. There are 10 to 100 applications for each permit, and only those hunters who have their applications selected by a random lottery actually may hunt at the site. As shown in Loomis (1983), actual visits do not serve as a measure of demand under these conditions. The correct measure of demand is the number of trips hunters would like to make at the current fee and travel cost, as given by the number of applications at each travel cost, i.e., the true price-quantity equilibrium.

Once the demand curve is estimated using applications, the long-run value (i.e., expected value of the lottery) of a permit can be arrived at. Use of the expected value or average value of a permit is consistent with the suggestion of Mumy and Hanke (1975) that when non-price rationing is used, marginal values equal average values because, without pricing (and particularly with a lottery), the ordering of consumers in terms of highest to lowest willingness to pay is destroyed. Only with pricing does the value of the next unit have a value lower than the previous one. For only with pricing are we assured users with the highest willingness to pay receive a good before users with lower willingness to pay (hereafter called "high valued user" and "low valued user"). Without pricing or with a random rationing system, the next unit could go to either a high or low valued user. Hence, the value of an additional unit should be calculated as an expected value of the probabilities of high and low valued users receiving the next unit. With a random assignment system, this turns out to be the average consumer surplus.

In this study a Regional (multi-site) Travel Cost Model was constructed. The dependent variable is applications per capita (instead of the traditional trips per capita). The "per capita" specification is used to adjust for differences in population sizes of counties of hunter origin. As Brown et al. (1983) have shown, the per capita specification takes into account not only the number of visits as a function of distance, but also the probability of visiting a given site (here, applying for a permit) as a function of distance.

The possible list of independent variables include hunt site quality variables such as harvest success and scenic value, measures of substitutes (if there are any), demographic characteristics of hunters, and a price variable. Because the analysis relied primarily on information that could be obtained from the hunter application form, a relatively simple Regional Travel Cost Model was estimated. The basic model was as follows:

$$A_{ij}/POP_i = B_o - B_1 DIST_{ij} + B_2 SUCES_j - B_3 SUBS_i + B_4 INC_i + B_5 NPERMT_j \quad [1]$$

where A_{ij} = applications from origin i for hunting in site j
POP_i = population of origin i
$DIST_{ij}$ = distance from origin i to site j
$SUCES_i$ = harvest or success rate at site j
$SUBS_i$ = substitute sites available to origin i
INC_i = per capita income of origin i
$NPERMT_j$ = probability of receiving a permit for site j (i.e., here, number of permits offered)
$B_o - B_5$ = coefficients to be estimated.

Equation [1] specifies a per capita demand curve for hunting sites in Idaho. Equation [1] states that the number of applications per capita from origin i to site j is a function of the distance from origin i to site j, quality of site j, the substitute sites available to origin i, the per capita income of residents in origin i, and the probability of obtaining a permit. By setting the quality or harvest measure at a value associated with a specific site, the Regional Travel Cost demand curve becomes the demand curve for the specific site. Thus, with one equation the researcher can model recreation use and benefits at all of the hunting areas for a particular species.

From the per capita demand curve, a second-stage demand curve is derived that plots total trips (here applications) to a site as a function of hypothetical added distance. Once the added distance is converted to dollars, the area under this second-stage demand curve represents net willingness to pay for the site under consideration. It is net willingness to pay because only the added distance or cost is reflected in the second-stage demand curve, not the original cost. The reader unfamiliar with this two stage process is encouraged to see Clawson and Knetsch (1966) or Dwyer et al. (1977). Lastly, the total site net economic value (net willingness to pay) can be converted to a net economic value per permit by dividing the estimated site net value by the number of applications received for that unit.

One advantage of statistical approaches to benefit estimation is that both a point estimate and the associated range of likely values can be derived. This range helps to establish a high and low boundary around the point estimated. This boundary conveys information to the decisionmaker about the accuracy of the point estimate. If a resource allocation decision remains unchanged as long as the value per day remains within this interval, then no more data need be collected for this species.

The traditional statistical range or interval, called "confidence interval," is a numerical range that encloses (with a certain probability, often 95% or 99%) the true parameter. Because empirical estimates of net willingness to pay (consumer surplus) are most sensitive to the price coefficient (here distance), the 95% confidence interval values of the distance coefficient were chosen to calculate the range of the per permit hunting values. This accounts only for the uncertainty surrounding the price (slope) coefficient and does not consider uncertainty surrounding estimates of the other slope coefficients nor the intercept term. For equations that use a linear functional form, the true confidence intervals around the benefit estimates are larger than our simple confidence intervals indicate. For the remainder of the report we will refer to these "price slope only" 95% confidence intervals as "sensitivity intervals." This term is used to describe the range in benefit estimates resulting from varying the distance coefficient from its lower 95% confidence value to its upper 95% confidence value. For the demand curves that use natural log of applications per capita, the appendix shows the average consumer surplus per permit is equal to the reciprocal of the price coefficient. For this functional form, our "price slopes only" confidence intervals are true statistical confidence intervals for average consumer surplus per permit.

Once identification of candidate variables has been accomplished, the issue of functional form and ordinary versus generalized least squares must be addressed. Based on past experience and several recent journal articles dealing with these issues, two basic model structures were considered:

$$\ln(A/POP) = B_0 - B_1DIST + B_2SUCES - B_3SUBS + B_4INC + B_5NPERMT \quad [2]$$

$$(A/POP)(\sqrt{POP}) = B_0(\sqrt{POP}) - B_1[(\ln DIST)\sqrt{POP}] + B_2SUCES(\sqrt{POP}) - B_3SUBS(\sqrt{POP}) + B_4INC(\sqrt{POP}) + B_5NPERMT(\sqrt{POP}) \quad [3]$$

where A = application
DIST = round-trip distance
SUCES = hunter success rate in percent
SUBS = substitute index (for antelope only)
INC = county per capita income
NPERMT = number of permits
POP = county population.

Equation [2] adopts a functional form that several economists have argued is most plausible. Ziemer et al. (1980), Vaughan et al. (1982), and Strong (1983) argue that because of the pattern by which trips per capita falls off at higher distances, the natural log of visits per capita is preferred to a simple linear form or even natural log of distance. Their point is that with either of these latter functional forms, negative visits are sometimes predicted for a few distant origins. These authors feel negative visits are counterintuitive, and this fact provides one factor supporting the log of visits (application in this study) per capita.

Bowes and Loomis (1980) argue the unequal sizes of population zones requires a square root of zone population weight to each variable to correct for the inherent heteroskedasticity of zonal TCM's. This weighting scheme corrects for heteroskedasticity and is equivalent to generalized least squares. The use of generalized least squares in this situation insures exact prediction of the total applications and less variance in the benefit estimates (Bowes and Loomis 1980). However, Vaughan and Russell (1982) and Strong (1983) show that if the log of visits per capita is chosen as the functional form, the heteroskedasticity may be so greatly reduced (but not eliminated) that weighting by square root of population may be unnecessary.

The choice of functional form and whether to use generalized or ordinary least squares is quite dependent on the data set one is analyzing. No one functional form is best for all data sets. The data will often inform the researcher as to which functional form is consistent with the behavior underlying the data. Whether the log functional form reduces heteroskedasticity sufficiently can be determined by comparing the estimated applications (from the equation) against the actual number of applications in the sample. If estimated applications are within 20% to 30% of actual applications, this may be acceptable if the researcher's primary interest is with benefit estimation. If estimated applications is greater than, say, 30% variance with actual applications or if use estimation is the primary interest of the researcher, then the generalized least squares approach, using weights suggested by Bowes and Loomis (1980), would be appropriate. Benefit estimation was the primary purpose of this study, and the functional form giving the smallest standard error on the distance variable (the one crucial to benefit estimation) will be chosen as long as the estimated applications is within 30% of actual applications. Otherwise the generalized least squares will be relied on. The choice will be discussed species by species in the results section.

Statistical Analysis

Data Sources and Data Compilation

The data necessary for travel cost modeling consist of applications (potential trips), distance, income, a measure of the probability of obtaining a permit, a substitute measure, and a quality measure. The data on number of potential trips from each county to each site were obtained from the limited hunt application form. On this form the hunter must state his or her address and herd unit desired. Thus, the origin-destination information was obtained without surveys. Per capita income was obtained from secondary Federal Government sources (Bureau of Census 1982). As a first approximation of quality, the percentage success rate in the unit was used. The probability of receiving a permit was taken as a direct function of the number of permits offered.

The distance from each origin to each site was calculated by the State of Idaho Department of Fish and Game. The Department used maps and their knowledge of travel routes to each herd unit to calculate the round-trip distance to each unit for each origin.

The data represent an entire census of limited hunt species applicants rather than a sample; i.e., all of the persons applying for a permit for a given species are included. This is necessary so that the true demand curve can be estimated. If the demand curve was just estimated on hunters receiving a permit, the true price and quantity relationship would be distorted by the random drawing or lottery. Loomis (1983) has shown that the distortions can be large. By estimating the demand curve reflecting what hunters would like to purchase at the current license fees and travel cost, this lottery-induced distortion is avoided and the efficiency of estimation improved.

For mountain goat, antelope, and bighorn sheep hunting the data reflect applications from hunters all over the country. Several applications were received from states on the west coast as well as the east coast. It is important to include these observations (assuming, as is likely for these species, that the trips would be primarily to visit the site applied for and to hunt the species applied for) because the variation in willingness to travel is used to infer a willingness to pay when utilizing the Travel Cost Method of estimating the demand curve. The definition of an origin or place of residence was expanded to include entire states or groups of states so that these observations could be included without having to add adjacent counties or states as separate zero observations.

In the case of moose hunting, Idaho state regulations prohibit out of state hunters from applying for a moose hunting permit, and therefore the data for moose hunting are limited to just in-state residents. This is likely to seriously bias the Travel Cost Method derived benefit estimates for moose hunting because the assumption is that all persons wishing to make a trip (here, applications) at every given distance are included in the sample (Dwyer et al. 1977). But, the in-state only rule eliminates from the sample hunters who would likely be willing to travel great distance for the opportunity to hunt moose in a wilderness setting provided in Idaho. Since the Travel Cost Method uses willingness to travel to infer willingness to pay, this in-state only rule will result in an underestimate of the additional willingness to pay by hunters living in Idaho. This underestimate is a direct result of the data incorrectly showing that no one is willing to travel from beyond the state boundary to visit these moose hunting sites. While there are sophisticated statistical routines to deal with truncated samples, they are difficult and expensive to use. Study constraints precluded any attempt to reestimate the demand curves using these special regression techniques. Therefore, it was decided to estimate the moose hunting equations knowing ahead of time they would be underestimates rather than estimate no value at all for moose hunting.

As explained below, a variable reflecting availability of substitute sites was seriously considered only for antelope hunting. The calculation of a substitute site variable utilized information on both quality of substitutes sites and distance (price) as to the substitute site. Quality was represented by hunting success in the unit. While other factors influence the desirability of an area, this was the primary variable on which information was available for all units at minimum computational costs. This quality measure was also used as a measure of attractiveness of substitute hunting sites. The form of the substitute index will be discussed in the Interpretation of Results section.

Based on discussion with an Idaho State Fish and Game biologist, it was determined that no substitute sites were available in Idaho for bighorn sheep hunting, moose hunting, or mountain goat hunting.[4] This seems to be a reasonable assumption for resident hunters since often times these species are not available in adjacent states. If the species is present many times few if any permits are allocated to nonresidents and even when permits are available, the nonresident permit fee (and travel distance) make adjacent states a very poor substitute. The lottery situation clearly indicates that there are no substitute sites within Idaho that can accommodate hunters interested in switching sites. In addition, substitutes are often used to find the added distance at which the hunters would switch to a substitute site. In the case of bighorn sheep, mountain goat, and moose, a hunter could not switch areas if the price got too high but would rather just go back into the pool of applicants for another site. It is unlikely that a hunter, after waiting several years to obtain a permit for one of these three species, would give up a certain permit and go back into a pool of applicants at the added prices for the next site (about $100–$200). For antelope, the proximity to Wyoming (with available nonresident permits) and the limited amount of excess demand (8,795 applicants for 2,435 permits, far less than for the other three species) makes substitutes more plausible.

County per capita income was also tested as a variable since economic theory indicates that it should influence purchases of trips to a recreation site. Hunter's income would have been preferable, but without a survey, that information was not available. Thus, a negative sign on the income variable is possible since per capita incomes on the west and east coasts were significantly higher than in Idaho. Due to the dominant effect of distance in reducing visits as one moves further away from the site, income and visits may be negatively correlated. This does not mean that as a given hunter's income rises he would not hunt more. The negative relationship may just be an artifact of income rising as distance from the site increases. Nonetheless, it was felt that income, when significant, should be included in the per capita demand curves.

Calculation of TCM Benefits

To calculate benefits from the second-stage demand curve with added distance as the price variable, the researcher must convert distance to dollars. Travel costs to a site consist of transportation costs and travel time costs. Travel time is included because, other things remaining equal, the longer it takes the hunter to get to a site, the fewer visits will be made. Thus time, because it is a limiting factor, acts as a deterrent to visiting more distant sites. Omission of travel time will bias the benefit estimates downward (Cesario and Knetsch 1970,

[4]Personal communication with Louis J. Nelson, Staff Biologist, Idaho Department of Fish and Game.

Wilman 1980). The U.S. Water Resources Council (1979, 1983) requires consideration of the effect of travel time in doing TCM studies. It is worth noting the Federal Highway Administration (1984) routinely includes the travel time saved as a benefit for improving highways much like recreation economists would of introducing a new site closer to recreationists. This is simply recognition that time is a resource that has an opportunity cost and saving time provides an economic efficiency benefit no different than saving gasoline.

The value of time was set at one-third of the wage rate as recommended by the U.S. Water Resources Council (1979, 1983). This is the mid-point of values of travel time that Cesario (1976) found in his review of the transportation planning literature. It must be kept in mind that the use of one-third the wage rate is not intended to measure the wages actually foregone during the time spent traveling, but rather the deterrent effect of scarce time on visiting more distant sites. This study used the U.S. Department of Labor's estimate of median wage rate in 1982 of $8.00 an hour. One-third of this amount is $2.67 per hour. On average, this yields about $0.066 per mile. This value per hour is about two-thirds the value used by the Federal Highway Administration (1984) in its highway studies. Without a survey, this approach of using average wage rates must suffice. While income of bighorn sheep or mountain goat hunters is likely above average, using a national average wage rate probably compensated for this. That is, since the national average wage rate is above wage rates found in Idaho, eastern Washington, and Oregon (where a large majority of the applications came from), the underestimate of the benefits due to travel time costs is probably not significant.

Evaluation of the transportation component of travel cost was more straightforward. The U.S. Water Resource Council suggests that variable vehicle costs be calculated from the U.S. Department of Transportation's "Cost of Owning and Operating a Motor Vehicle." Because there is no category for pickup trucks or four-wheel-drive vehicles, an intermediate size car was chosen as the best proxy to calculate what is termed in this report "standard" cost. For 1982 its variable cost was $0.135 per mile. Variable costs are used since we are interested in the incremental cost paid for this trip and by definition fixed costs are invariant to a decision of whether to take a trip or not.

It is likely that the cost per mile from this source may be an underestimate of the cost for such a highly specialized activity as big game hunting. Without survey data for bighorn sheep hunters, mountain goat hunters, and moose hunters, it was assumed that an approximation of the true cost of transportation to hunt these species might be the cost per mile reported by elk hunters. The reported cost per mile of deer hunting was taken as an approximation to the cost per mile of antelope hunting. These assumptions were discussed with Idaho Department of Fish and Game personnel to verify the reasonableness of such assumptions.[4] In this bulletin, the use of reported cost of elk hunters or deer hunters will be called "reported" cost. The reported cost per mile is generally higher because it reflects the operating cost of vehicles commonly used in big game hunting. In addition, the costs reflect the actual road conditions associated with big game hunting rather than "suburban" driving conditions associated with the Department of Transportation's estimates of costs per mile. The reported cost per mile for elk hunting is $0.31 per mile.[5] The cost per mile for deer hunting is $0.183 per mile.[6] The effect of using a higher reported cost per mile is to associate each quantity consumed with a higher price than if a lower standard cost per mile is used. If the cost per mile is higher, the "implied willingness to pay" at the margin for the last trip (as based on distance driven) is greater. This has the effect of an upward shift in the demand curve at every quantity. Thus, the net willingness to pay will be correspondingly higher. Estimates of net willingness to pay per permit will be displayed with both standard cost and reported cost to allow comparisons to other studies that may have used standard cost.

For hunting these species where acquisition of a permit is by lottery, the number of licensed hunters per vehicle is likely to be just one, especially for moose, bighorn sheep, and mountain goat where 3 to 10 permits is the common number per unit. Thus, the vehicle transportation costs are assumed to be borne completely by the single licensed hunter.

Once the transportation cost per mile and the value of travel time per mile is known, distance can be converted to dollars. When using a second-stage demand curve approach to calculating benefits, the added miles are then converted to price over and above costs using the sum of transportation costs and travel time. This rescales the vertical axis of the second-stage demand curve for each site from added distance to added dollars. The area under the second-stage demand curve reflects the net willingness to pay for the site in question. A separate second-stage demand curve is estimated for each site.

From this second-stage demand curve an average net willingness to pay for each permit can be calculated by dividing the total net willingness to pay by the number of applications. Since only a few of the many hundreds of applicants actually receive a permit, this average value is then multiplied by the actual number of permits offered in this area to get the net willingness to pay in a typical year. While Loomis (1982) shows that one could calculate the actual net willingness to pay associated with any outcome of the lottery, it is argued that this value may not reflect the long term average when only a few permits are drawn. The long-term value is better reflected in the expected value of the permit, which is equivalent under a random lottery to the average value of a permit.

Once this net willingness to pay or consumer surplus is calculated, it is necessary to add the hunting permit fee paid to obtain an estimate of the economic efficiency benefits to society from providing this opportunity (USDA Forest Service 1984; Dwyer et al. 1977; U.S. Water Resources Council 1979, 1983). The permit fee

[5]*Cindy Sorg, Net Economic Value of Elk Hunting in Idaho. Manuscript in preparation, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.*

[6]*Dennis Donnelly. Net Economic Value of Deer Hunting in Idaho. Manuscript in preparation. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.*

merely reflects a transfer of consumer surplus from the hunter to the government. No significant real resource costs are involved, merely a change in property rights. Had the hunter been able to obtain the permit without cost, he or she would have received just that much more consumer surplus. Having added the dollar amount of the hunting license to the net value per day, it is also important in benefit cost analysis to include the additional costs to both the federal, private, and state agencies in computing costs of some wildlife management action.

Estimated Demand Equations

The estimated regression equations provide statistically significant per capita demand curves for all four species. For all of these species, the process of testing significance of variables, choice of functional form, and choice of generalized versus ordinary least squares was the same. The model presented in equations [2] and [3], which contained all of the variables that theory indicates should be considered, were run using SPSS statistical package. Variables found to be insignificant or highly correlated to distance (such that multicollinearity was a problem) were dropped from subsequent runs. Even though theory indicated an *a priori* expectation of importance, the generality of consumer utility theory as applied to the Travel Cost Method could not be relied on to specify the form in which the variable entered. To see if candidate explanatory variables entered in a nonlinear fashion, the variable and the square of that variable were tried, as was the natural log of that variable.

The final parameters were estimated after removal of insignificant variables. The resulting equation was then checked for its capability to predict applications. Estimated applications (summed across sites) was compared to the actual number of applications in the data set. It was at this point that choice between functional form and generalized and ordinary least squares became apparent. For mountain goat hunting, the natural log of applications per capita was unable to significantly reduce the inherent heteroskedasticity of the unequal origin populations. This natural log of application per capita equations misestimated applications by 50%. The generalized least square model using natural log of distance estimated applications to within one of the actual number in the data set. Based on the substantial error in the ordinary least squares equation of applications per capita, the weighted regressions are used to calculate benefits for mountain goat. The natural log of visits per capita (ordinary least squares model) performed better than the generalized least squares model in estimating an equation for bighorn sheep hunting, antelope, and moose hunting.

Mountain Goat Hunting.—The mountain goat hunting demand equation is:

$$(A/POP) = 0.0000938 - 0.0000114[\ln(DIST)]$$
$$\text{T values} \quad (2.989) \qquad (-2.90)$$

The F ratio for this equation is 4.74, where variables are the same as defined earlier in equations [2] and [3], which indicates the overall equation is statistically significant at the 95% level. The distance coefficient is significant at the 99% level. The R^2 is not reported because its calculation assumes ordinary least squares estimation (more specifically, a column of 1's for the constant term) whereas this equation was estimated with generalized least squares to obtain an accurate use estimate. Generalized least squares was used because use of ordinary least squares with the natural log functional form did not adequately solve the inherent heteroskedasticity of the zonal data, and thus the ordinary least squares grossly mispredicted use. In addition, the natural log of visits per capita form did not result in any variables other than distance being significant (at similar levels of statistical significance) but the generalized least squares predicted far better. Therefore, the generalized least squares equation was selected for benefit estimation. It should be noted this equation does predict estimated trips equal to actual trips. Therefore, it does seem to represent the data fairly well, although it is disappointing that success, income, or number of permits were statistically insignificant. Several forms of the success variable were tried. The suggestion by Vaughan and Russell (1982) that success might act as an intercept and slope dummy was tried, but did not result in success being significant in combination (slope and intercept) or in the slope form only. Time did not permit testing the slope dummy on other species.

Moose Hunting.—The moose hunting demand equation estimates for residents is

$$\ln(A/POP) = -7.92 - 0.0032DIST + 0.033\ SUCES$$
$$(-12.9) \qquad (2.03)$$
$$-0.0002(SUCES)^2 + 0.0297NPERMT$$
$$(-1.788) \qquad (6.79)$$

The R^2 is 0.42 and the F ratio is 57.07. Here, the R^2 is the percentage variation in the log of applications per capita explained by the independent variables. The F ratio indicates the overall equation is significant at the 99% level. The distance and number of permit coefficients are significant at the 99% level. The success and success-squared variables are significant at the 95% and 90% level, respectively. The moose hunting per capita demand equation using the natural log functional form estimated applications within 25% of actual applications. While this may not be precise enough if one's goal is use forecasting, our main goal is benefit estimation. As such the natural log functional form yielded a substantially smaller standard error on distance and a significantly higher F value. Therefore, it was used in the next section to calculate benefits.

Bighorn Sheep Hunting.—The per capita or first-stage demand curve for bighorn sheep permit is:

$$\ln(A/POP) = -5.688 - 0.00141DIST + 0.01149SUCES$$
$$\text{T values} \qquad (-15.19) \qquad (1.966)$$
$$+ 0.0195NPERMT - .0006INC$$
$$(1.835 \qquad (-6.86)$$

The R^2 is 0.63 and the F ratio is 117.87. Here, R^2 is the percentage variation in the log of applications per capita explained by the independent variables. The F ratio indicates the overall equation is statistically significant at the 99% level of confidence. All variables other than number of permits are significant at the 95% level, while number of permits is significant at the 90% level. It is worth noting that the large T value on the distance coefficient (a result of the very small standard error on the distance coefficient) will translate into a benefit estimate with a very small variance. The negative sign on income results from the fact that as one moves further away from the bighorn sheep hunting sites (and in Idaho in general) county per capita income goes up. In future studies it may be desirable to use actual hunter income to see if this problem is avoided. For bighorn sheep hunting there was enough variation in success rate and number of permits that applications seem to be sufficiently sensitive to these variables. The bighorn sheep equation using the natural logs was a little disappointing in terms of use prediction capability. The equation predicted about a third more applications than were received. If use estimation was the primary concern, this degree of error might be of concern. In this case, use estimation is a minor concern because there is so much excess demand for a permit that any additional permits provided would be taken. The natural log functional form had a substantially smaller standard error on distance than the generalized least squares. For precision in benefit estimation the standard error on distance is of prime importance. In addition, the F value for the natural log equation was significantly higher than the F for the generalized least squares. Therefore, the natural log functional form was used to calculate benefits.

Antelope Hunting.—The antelope hunting TCM equation is:

$$\begin{aligned} \ln(A/POP) = {} & -6.2889816 - \underset{(-22.23)}{0.0032258DIST} \\ & + \underset{(4.055)}{0.019658SUCES} + \underset{(5.498)}{0.003285NPERMT} \\ & - \underset{(-2.34)}{0.0925SUBS} - \underset{(-5.545)}{0.0003759INC} \end{aligned}$$

T values

The overall equation is quite significant as judged by an F value of 186.2, which is significant well beyond the 99% level. The R^2 is 0.66, which is fairly high for cross-section regression. However, it must be emphasized this is the percentage of the explained variation in log of applications per capita rather than the percentage of variation in untransformed applications per capita on applications. The R^2 on actual applications is likely to be lower. This equation has a very small standard error on distance, which will translate into a tight 95% sensitivity interval on the benefit estimate. This equation has substitutes, quality, and number of permits as statistically significant variables exhibiting the theoretically correct sign. The unexpected negative sign on income is explained by the fact that the further one gets from rural Idaho the higher per capita income usually is.

A similar equation was estimated for antelope that used harvest and harvest divided by distance as the quality and substitute variable, respectively. This equation had a similar F value, R^2, and t statistics, but the sign on number of permits was negative.

In terms of accuracy of use estimation, the inclusion of the substitute term greatly improved the match between estimated and actual permits demanded. The number of actual applications was 8,795 and estimated number was 6,566. The estimated use is within 75% of the actual use level. While this may be too low if one's goal is solely use estimation, it is reasonably good for the purposes of benefit estimation. In addition, the use of generalized least squares to estimate the antelope regression did not result in the substitute variable having the theoretically correct sign. The incorrect sign on the substitute variable may result in overestimation of benefits. Avoiding overestimation of benefits was more important than improving use estimation.

This effect of inclusion of the substitute variable on benefit estimates will be discussed in the next section. Here we wish to briefly explain the construction of the substitute variables used in the antelope regression. This substitute term is modelled after Knetsch et al.'s (1976) measure. Their substitute term had attractiveness of the substitute site in the numerator and distance to the substitute site in the denominator. In our study attractiveness was related to success rate or harvest. Any site (k) was considered as substitute for site j if the ratio of success to distance from origin i to site k was greater for site k than site j's ratio. That is, site k would be a cost-effective substitute because it had a higher harvest per mile driven than the site under study (j). Therefore, both quality and cost (distance) of alternative sites were considered in determination of what sites were substitutes for others. The actual substitute measure was the sum of the indexes for all sites having a higher harvest or success rate per mile than the site under study. Because our research effort was generally limited to existing data, only sites applied for by at least one hunter from a given origin (county or county-state group) were considered as potential substitutes. This is a narrowing of the range of alternatives from that used by Knetsch et al. (1976). Study time limits did not allow for evaluating all possible substitutes. In addition, household production theory (Mendelsohn and Brown 1983) would suggest that only sites actually visited from an origin are efficient or on the "characteristic frontier" for that origin. Sites not visited from that origin may not be cost effective.

Benefit Estimates

The per capita or first-stage demand curves can be directly integrated by origin (below the demand curve but above the distance) to yield the total net willingness to pay (consumer surplus) for each site. Once the total is known, the average value per permit is easily calculated by dividing the total by number of applications. Alternatively, the per capita demand curve can be used to estimate a second-stage demand curve, the area under this is the total consumer surplus. This second-stage demand curve approach was adopted in this study. As Burt and Brewer (1971) showed, the two approaches yield identical results (other than rounding).

The first step in constructing the second-stage demand curve is to use the per capita demand curve to estimate the change in applications from each origin as distance is increased above the actual distance. This process is repeated by adding greater and greater distances (and recording the resulting applications) until applications from a given origin drop below one. Note that each site has its own unique second-stage demand curve as the number of applications, quality, and distance to the site are specific to each site. Thus, from one per capita demand curve the analyst can obtain unique second-stage demand curves for each of the sites by just setting the value of each of the independent variables at the level associated with the site of interest.

The second step in constructing the second-stage demand curve is to convert added distance to dollars. This conversion rescales the vertical axis of the demand curve to dollars. This conversion is made using the sum of transportation cost and value of travel time. As discussed earlier, the transportation cost was calculated using the "standard" cost from U.S. Department of Transportation and the "reported" cost from elk or deer hunting surveys in Idaho. The benefit estimates are higher when distance is converted to dollars using the higher reported cost rather than the standard cost because when reported cost is used each quantity of applications from each origin is associated with a higher gross willingness to pay (at the margin). The standard cost figure is reported as a benchmark to allow comparison to other studies and because the U.S. Water Resources Council suggests that this standard cost figure be used. However, for specialized activities where four-wheel-drive vehicles and camper-trailers are not uncommon, the reported cost figure is probably a more accurate reflection of gross willingness to pay.

Mountain Goat Hunting.—When distance is converted to dollars using standard cost per mile, the state average net willingness to pay for a permit is $193 (table 1). With an average of 4 days hunted per permit (according to the Idaho Department of Fish and Game[4]), this translates into $48 per day. Depending on the length of a hunting day, this could mean $70 to $90 per 12-hour Recreation Visitor Day (RVD). When distance is converted to dollars using the "reported cost" figure associated with elk hunting ($0.31 per mile), the net willingness to pay per permit is $360 (table 1), and the average value per day is $90.

These figures are net willingness to pay over and above all costs. Adding the resident permit fee of $71 for mountain goat hunting into the net willingness to pay per permit at reported cost yields $431. This raises the average value of a day to $108. This is the value to hunters only for hunting; it excludes nonhunting benefits such as observation or existence values. Even so, the net present value of maintaining mountain goat hunting in a typical management unit offering three permits is still $32,325 at 4% interest. At higher discount rates, the net present value would be lower.

These state average mountain goat hunting values are summarized in table 1 along with the state average values for other species. Because each herd unit has its own second-stage demand curve, each site will have its own unique total and average consumer surplus. Table 2 presents the average consumer surplus per permit for each of the mountain goat hunting areas. For evaluation of a specific project, the value of that specific site should be used to estimate benefits of an additional permit rather than the state average value.

Moose Hunting.—The benefit estimates for moose hunting were very conservative since the willingness to travel (i.e., willingness to pay) of nonresident hunters was excluded by the in-state only requirement for moose hunting applications. The state average net value per permit is $60 at standard cost. At the reported cost associated with elk hunting ($0.31 per mile), the net willingness to pay for a permit is $112.84. The 95% sensitivity interval around this $112.84 permit value is $97 to $133. A rough approximation of the impact of limiting moose hunting permits to resident hunters may be seen by comparing this benefit estimate to the net value of a mountain goat hunting permit. Excluding nonresidents could have the effect of reducing the estimated net willingness to pay by two-thirds. The per day net willingness to pay value (at reported cost) of a moose hunting permit is $19.12 based on an average of 5.9 days hunted per per-

Table 1.—Summary of Idaho average values per hunting permit and per day (not including license fees).

	Species			
	Bighorn sheep	Mountain goat	Moose	Antelope
Average days per permit	8.6	4	5.9	1.9
Standard cost				
Permit	$127.54	$193	$ 60.43	$59.21
Day	$ 14.83	$ 48	$ 10.24	$31.16
Reported cost				
Permit	$239.00	$360	$112.84	$73.31
Day	$ 27.80	$ 90	$ 19.12	$38.58
Permits (number)	127	43	173	2,435
Applications (number)	1,014	820	6,531	8,795

Table 2.—Mountain goat hunting permit values by combined herd unit at reported cost.

Combined herd unit	Average net WTP per permit	Net WTP + Resident fee[1]	Number of permits
4	$374	$445	2
9A-1	396	467	2
10-3	394	465	1
12	372	443	4
16	398	469	2
18	326	397	5
36A1-4	390	361	16
43 1-2	319	390	4
48 1-2	338	409	4
51	260	331	3

[1]*Resident fee = $71.*

Table 3.—Moose hunting permit values by herd unit at reported cost.

Combined herd unit	Average net WTP per permit	Net WTP + fee[1]	Number of permits
01 (1-4)	$111	$182	15
10	104	175	2
10A	108	179	2
12 (3-10)	110	181	31
15 (1-5)	109	180	19
16	111	182	4
16A	107	178	2
17 (1-2)	106	177	8
20 (1-2)	98	169	6
59	110	181	4
61 (1-3)	108	179	22
64	113	184	2
69 (1-2)	114	185	16
76 (1-6)	116	187	58

[1]*Fee = $71.*

mit.[4] Adding the license fee of $71 to the consumer surplus per permit yields a net economic value of $183.84 per permit. This translates to $31 per day. Depending on the number of hours hunted per day, the value per 12-hour Recreation Visitor Day would be between $40 and $50. Table 3 presents the average permit values associated with each moose hunting herd unit. These values do not include the license fee. These site-specific values (and the associated permit fee of $71) would often be more appropriate to use in National Forest or project level planning than the state average values.

The net present value to hunters of maintaining an area for moose hunting is $18,300 at 4%. This is the value to hunters flowing from use of the moose population for the brief hunting season and excludes observation-photographic values and existence values. Given the great public outcry over moose hunting in Maine (presumably by persons whose observer values and existence values were diminished by hunting of moose) one could expect these nonhunting values to easily be an order of magnitude larger than the hunting values.

Bighorn Sheep.—Using a standard cost per mile the estimated net willingness to pay for a bighorn sheep permit is $127.54 (table 1). With an average of 8.6 days hunted per permit,[4] this translates into a value of $14.83 per day. Probably a more accurate estimate of net willingness to pay is provided by rescaling the vertical axis of the demand curve using "reported cost." This yields a net willingness to pay of $239 per permit or $27.80 per day (table 1). The per day value is fairly low due to the substantial number of days hunted by each permittee. The 95% sensitivity interval is $204 to $278 per permit. When the hunting fee of $71 is added the net value or economic efficiency value of a permit is $310. Table 4 presents the site-specific average (and with a lottery, marginal) consumer surplus values for a permit. These numbers will often be more useful in National Forest and project level planning than the state average value.

Table 4.—Bighorn sheep hunting permit values by combined herd unit at reported cost.

Combined herd unit	Average net WTP per permit	Net WTP + Resident fee[1]	Number of permits
19	$246	$317	4
20	220	291	15
20A	234	305	15
21	223	294	5
26	230	301	15
27	249	320	38
28	236	307	17
41	244	315	2
42	238	309	9
50	241	312	7

[1]*Resident fee = $71.*

The net present value of bighorn sheep hunting in a typical unit offering five permits valued at $239 apiece is $29,875 (based on annual value of $1,195). Including the resident hunting fee as discussed above, yields a net present vlaue of $38,750 to hunters for maintaining existing areas for bighorn sheep hunting (and again assuming no real rise in relative value over time). A rough approximation of the observer option and existence values to big game hunters (again ignoring the existence and option values of other users) can be computed using the data of Brookshire et al. (1983). They estimate what potential Wyoming hunters would be willing to pay for the option to hunt or observe bighorn sheep in the future and their willingness to pay to know bighorn sheep exist. Using a survey of Wyoming hunters they calculate the annual observer option price of $34 (in 1982 dollars) per permit. For hunters willing to pay for preservation of bighorn sheep but who do not expect to see one in the wild, the annual existence value per permit is $11 (in 1982 dollars). Because these are values given by Wyoming big game hunters, they can at best be applied to Idaho big game hunters only. If we assume that the proportion of Idaho hunters falling into observer and existence categories is the same as in Wyoming, then 75% are potential observers and 25% receive existence values. The annual observer net willingness to pay for a typical bighorn sheep herd unit in Idaho is $216,325. (This figure is obtained by taking 75% of the Idaho big game hunters times the observer option price and then dividing by 30 bighorn sheep units). The annual existence net willingness to pay for a typical bighorn sheep herd unit is $23,191. (This figure is obtained by taking the remaining 25% of the Idaho big game hunters and multiplying by the mean existence value per permit and then dividing by 30 bighorn sheep units to get the value per unit). These calculations provide a measure of the average existence and observation values. Because these calculations provide the average willingness to pay for observer option value and existence value, they likely overstate the additional willingness to pay for the option of seeing one more bighorn sheep or knowing that one more bighorn sheep exists. Partly compensating for this upward bias in herd unit option prices and existence values, however, is the fact that observer and existence values for bighorn sheep in Idaho have been omitted for the nonhunting population in Idaho and other states.

While these observer option prices and existence values are at best rough approximations for Idaho bighorn sheep, they are likely accurate in their order of magnitude. These estimates do allow comparison of the hunter values to observe , and existence values for unique species such as bighorn sheep. The annual hunting values represent less than 1% of the annual viewer values and about 5% of the annual existence values of hunters. If available, the existence and viewer option prices to all users should be included when calculating the net present value of preserving an area for bighorn sheep. To be conservative in generalizing the Wyoming results, we will just include the viewer option price and existence values of hunters in Idaho in calculating the net present values of each herd unit. Summing the annual hunting values, observer option price and existence values for a typical herd unit to hunters only and then applying the 4% discount rate yields a net present value of about $6 million for each unit. This $6 million compares with $38,000 when only the hunting values are used. Accepting these approximations of option and existence values, the hunting values represent less than 1% of the total economic value of preserving these unique species.

Antelope Hunting.—At the standard cost per mile the state average net willingness to pay by antelope hunters is $59.21 per permit. This translates into a net willingness to pay of $31.16 per day as each permit involves slightly less than 2 days of hunting.[4] Adding the $31 tag fee results in a net value of $90 per permit or about $45 per day. Converting added miles to dollars using the reported cost associated with deer hunting ($0.183 per mile) yields a net willingness to pay of $73.31 per permit (table 1). Adding the license fee of $31 yields a value per permit of $104. This converts to a net value of $54 per day. The 95% sensitivity interval around the $73 permit value is $67 to $81. The figures for antelope are compared to other species in table 1. Table 5 presents the net willingness to pay values for each antelope hunting unit.

Table 5.—Antelope hunting benefits by herd unit at reported costs.

Combined herd unit	Average net WTP per permit	Net WTP + resident fee[1]	Number of permits
29 (1-6)	$71	$102	125
30	66	97	40
30A	69	100	100
36A1-2	61	92	50
37 (1-2)	67	98	175
37A	67	98	75
40	75	106	50
41	69	100	10
42 (1-2)	69	100	75
46	73	104	10
49	74	105	90
50 (1,2,3)	73	104	215
51 (1-4)	73	104	350
58 (1-2)	74	105	250
59 (1,2,3)	75	106	250
60 (1-2)	75	106	200
63 (1-2)	73	104	300
68	74	105	50

[1]*Resident fee = $31.*

The effect of including a substitute variable in the antelope demand equation was evaluated by comparing benefit estimates with and without a substitute variable. Converting added distance to dollars using standard cost per mile resulted in a net value of a permit of $59.21. This value reflects the presence of a substitute term. Estimating an equation identical to the antelope hunting demand curve except not including substitute yielded a consumer surplus value of $84.61 per permit at standard cost. This benefit estimate without a substitute term is about 40% higher than the estimate with substitutes. This reduction in value is often assumed to be the normal response to the inclusion of substitute sites. However, this reduction in benefits occurs primarily when the own price variable (here distance) and the omitted variable (here substitutes) are negatively correlated and the sign on substitutes is negative (Kmenta 1971). This is just one of two configurations for the relationship between substitutes and distance (Caulkins et al. 1985). If these two variables are positively correlated, the omission of substitutes would bias the benefit estimate downward. In the case of antelope hunting, the distance and substitute terms were negatively correlated. Thus, our estimate of net benefits was reduced when a substitute variable was added to the antelope hunting demand curve. What is even more striking is that the estimated number of applications from the equation without substitutes is larger than actual number of applications by a factor greater than 10. Apparently a large part of the misestimation of visits stemmed from omission of a substitute variable rather than heteroskedasticity.

The annual net willingness to pay from a typical area offering 90 antelope hunting permits is $6,598 and the net value (including fee) is $9,360 per year. To calculate present values this annual benefit stream is discounted at 4%, which yields a present value or worth for an average herd unit of $164,950. The present worth of the net economic value (including the license fee) is $234,000. Again it must be stressed that this is only the net willingness to pay of the hunters who get permits and assumes a zero value to hunters not getting a permit that year and to nonconsumptive users.

Interpretation of Results: Average Versus Marginal Values in the Case of Lottery Rationing

Both statewide and hunt unit average values have been presented. Each type of value is appropriate for a different decision context. If one is performing region-wide analysis, these state-wide numbers may be more useful than the site-specific numbers presented by species in tables 2, 3, 4, and 5. The hunt unit specific values may be more appropriate for valuation at the National Forest or project level than state average values. The numbers in these tables are site averages. These average values are also marginal values under the condition of non-price rationing such as a lottery (Mumy and Hanke 1975). Therefore, the analyst wishing to use these numbers can do so for analyzing both small changes involving a few permits or large changes involving elimination of big game hunting at the entire site. The reason that the average value equals the marginal under nonprice rationing is that without a pricing system (for example the limited hunt species lottery in Idaho) there is no way to insure that high valued hunters receive a permit before lower valued hunters. An additional permit offered could just as likely go to a low valued user before a high valued user. Thus the ordering of receipt of the good from high to low valued users implicit in the traditional demand curve is violated in a lottery situation. Therefore an additional permit does not necessarily go to the next highest valued user as it would under pricing. This being the case, the value of additional permits (i.e., the marginal value) is calculated as an expected value of the lottery. This expected value of an additional permit turns out to be the average value of a permit.

These values are for the hunting activity and it would be incorrect to calculate a value per animal from them. The value per animal may be misleading because the animal provides other benefits beyond just hunting.

Conclusions

This study demonstrates that the Regional Travel Cost Method approach can be generalized to use data from permit applications to estimate the value of hunting "limited hunt" species such as bighorn sheep or mountain goat. Thus, the findings of Loomis (1983) for the single-site Travel Cost Method appear valid for the multi-site Regional Travel Cost Method as well. For some of the unique species, the net value of a hunting permit is quite large. Mountain goat hunting in particular had a permit value of nearly $400 and a per day value of nearly $100.

The study also demonstrates that the number of applications by hunters for a specific unit is sensitive to the success rate or quality of that unit. This is encouraging in that it shows the Travel Cost Method is sensitive enough to pick up subtle factors influencing hunter behavior.

The cost effectiveness of implementing the Travel Cost Method with existing data was encouraging. About eight weeks total was the time required for one economist to estimate benefits from raw data on a tape for mountain goat, bighorn sheep, and moose hunting. An additional week's time was required to estimate benefits for antelope hunting because of the need to estimate regressions and calculate benefits with a substitute term. While these are not extremely fast times, they are faster than those expended with the large-scale models utilized in the past. The lower costs are largely attributable to the use of sort-aggregate programs in SPSS and Fortran programs to substitute indexes and second-stage demand curves.

Lastly, the values per day derived should be helpful to USDA Forest Service and Bureau of Land Management analysts as they attempt to evaluate the economic benefits of managing these wildlife species. The values can also serve to inform decisionmakers of the loss in economic benefits from reduction in hunting opportunities for these species. While the values do not represent the total economic value of these wildlife species to all persons, the net present value of hunting in most herd units is in the thousands of dollars annually. This value needs to be compared with the net values of other conflicting activities to see if a resource management action provides a gain or a loss in economic benefits to hunters keeping in mind that hunting benefits may represent as little as 1% of the total economic benefits of these unique species in Idaho.

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Appendix

Average and Marginal Consumer Surplus – Conditions of Equality

The objective of the proof is to show that average benefits are equal to marginal benefits in relation to the per capita (stage I) demand curve. The means to accomplish this is to derive the mathematical expression for the benefits in each case and to show these are equal. The conditions under which this is true are:

1. Demand relationships between visits per capita and price (cost of travel) can be validly modeled with a semi-log functional form such as

$$\ln(q) = a - bp \qquad [A1]$$

or equivalently,

$$q = e^{a-bp} \qquad [A2]$$

where q is quantity, in this case, visits per capita
p is price, in this case, travel cost
a is the intercept parameter
b is the slope parameter

2. The only shifting variables allowed in the equation affect the intercept. No slope shifting variables are in the equation.
3. A slight relaxation of condition 2 occurs if there are slope shifting variables but they do not change from the "before" to the "after" states.
4. Each origin is a price taker in that people from that origin may visit the site as many times as they desire at their current travel cost. Therefore, the supply curve facing a given origin is horizontal. Due to differences in location from the site, each origin faces a different horizontal supply curve.

The "Before" State

Figure A–1 shows the overall scope of the changes considered in the proof. At equilibrium in state 1 (i.e., the "before" state) the demand curve has a quantity intercept of e^{a_1} when price is zero. As price increases, quantity decreases and asymptotically approaches zero for very large p. For a price of p_1, visits per capita to a site from a specific origin are q_1.

Total benefits per capita that accrue to the presence of the site, given all other existing sites, are represented by the shaded area labeled CS_1 (consumer surplus in state 1). This area is found by integrating under the demand curve and above the price line p_1.

Let a small segment of the area, dCS, be

$$dCS = q\,dp \qquad [A3]$$

as shown in figure A–1.
Then

$$CS = dCS = \int_{p_1}^{p} q\,dp \qquad [A4]$$

The limits of integration define the lower boundary of the CS area, the p_1 price line, and the upper boundary of the CS area, the point where p goes to infinity and q goes to zero. In spite of these extreme values, it turns out the CS area is finite.

Substitute for q from equation [A2] in the integral in equation [A4] giving

$$CS_1 = \int_{p_1}^{p} e^{a_1 - b_1 p} dp \qquad [A5]$$

where the subscript 1 denotes state one ("before"). Continuing with the integration gives

$$CS_1 = e^{a_1} \int_{p_1}^{p} e^{-b_1 p} dp = -\frac{1}{b_1} e^{a_1 - b_1 p} \Big|_{p_1}^{p} \qquad [A6]$$

Evaluating the expression in [A6] at the limits of integration gives

$$CS_1 = -\left(\frac{1}{b_1} - e^{a_1 - b_1 p}\right) - \left(-\frac{1}{b_1} e^{a_1 - b_1 p_1}\right) \qquad [A7]$$

$$CS_1 = \frac{1}{b_1}\left(e^{a_1 - b_1 p_1} - e^{a_1 - b_1 p}\right) \qquad [A8]$$

In order to include the entire area under the demand curve, let p (not p_1) become infinitely large, $(\rightarrow\infty)$. For large p

$$e^{a_1 - b_1 p} = q \rightarrow 0 \qquad [A9]$$

so that the expression for CS in [A8] becomes

$$CS_1 = \frac{1}{b_1} e^{a_1 - b_1 p_1} = \frac{q_1}{b_1} \qquad [A10]$$

Average consumer surplus in state one per trip made (q_1) is

$$\overline{CS}_1 = \frac{CS_1}{q_1} = \frac{1}{b_1} e^{a_1 - b_1 p_1} \frac{1}{q_1} \qquad [A11]$$

But $\qquad e^{a_1 - b_1 p_1}$ is $q_1 \qquad$ [A12]

So $\qquad CS_1 = \dfrac{1}{b_1}$

Thus, average consumer surplus per trip in state one, the "before" state, is simply the inverse of the slope parameter from the demand equation, assuming the conditions previously stated are met.

The "After" State

Now, assume that managers of the recreational sites under consideration wish to increase the attractiveness of the specific site, for example, by increasing the number of animals or fish potentially harvestable. This new condition becomes the "after" state.

The new attractiveness at the site increases the intercept to e^{a_2}, but does not affect the slope coefficient b, as assumed, so $b_1 = b_2 = b$, (i.e., quality is an intercept shifter only). Using the result of the previous section, that, in general under the stated conditions,

$$CS = \frac{1}{b} e^{a-bp} = \frac{q}{b} \qquad [A13]$$

and placing the subscript (2) for the "after" state on the variables, total per capita consumer surplus for the "after" state is

$$CS_2 = \frac{1}{b_2} e^{a_2 - b_2 p} = \frac{q_2}{b_2} \quad \text{[A14]}$$

Note that "after" average CS is also $\frac{1}{b_2} = \frac{1}{b}$.

The total change in consumer surplus from the "before" to the "after" state is

$$\Delta\ CS = CS_2 - CS_1 \quad \text{[A15]}$$

$$\Delta\ CS = \frac{q_1}{b_2} - \frac{q_2}{b_1} \quad \text{[A16]}$$

But, as noted, $b_2 = b_1 = b$, so

$$\Delta\ CS = \frac{q_2 - q_1}{b} \quad \text{[A17]}$$

The marginal change per unit increase in trips is defined as

$$\frac{\Delta CS}{\Delta q} = \frac{\frac{q_2 - q_1}{b}}{q_2 - q_1} \quad \text{[A18]}$$

So

$$\frac{\Delta CS}{\Delta q} = \frac{1}{b} \quad \text{[A19]}$$

And since $b = b_1 = b_2$, combine the results of the derivation of "before" average consumer surplus and the derivation of the marginal consumer surplus caused by the change to the "after" state.

Thus,

$$\overline{CS}_1 = \frac{1}{b} = \frac{\Delta CS}{\Delta q} = CS_{marg} = \overline{CS}_2 \quad \text{[A20]}$$

and the proof is complete given that the preceding conditions are met.

Note in the proof that the relationship in equation [A20] does not depend on the price level, even though figure 6 shows price unchanging. Neither do the key equations for "before" and "after" consumer surplus, equation [A10] and [A14], respectively. Under the stated conditions, there may or may not be a price change along with the demand curve shift. Regardless, it does not affect the equality between the "before" average consumer surplus and the "before" – to – "after" marginal change in consumer surplus. Moreover, the price may change in either direction without affecting the results.

Loomis, John B., Dennis M. Donnelly, Cindy F. Sorg, and Lloyd Oldenburg. 1985. The net economic value of hunting unique species in Idaho: Bighorn sheep, mountain goat, moose and antelope. USDA Forest Service Resource Bulletin RM-10, 16 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

The net economic value of hunting unique species in Idaho was estimated using the Travel Cost Method. The net willingness to pay per hunting permit was $239 for bighorn sheep, $360 for mountain goat, $113 for moose, and $73 for antelope.

Keywords: Valuation, big game, Idaho, economic values

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Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
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Net Economic Value of Cold and Warm Water Fishing in Idaho

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Abstract

Net willingness to pay for cold and warm water fishing in Idaho was estimated at $42.93 and $42.18 per trip, respectively, with the Travel Cost Method, and at $22.52 and $16.35 per trip, respectively, with the Contingent Value Method. Willingness to pay was greater for increased catch or fish size.

Acknowledgement

This study was a cooperative effort of the Idaho Department of Fish and Game, the University of Idaho College of Forestry, Wildlife, and Range Sciences, the USDI's Bureau of Land Management and the Fish and Wildlife Service, and the USDA Forest Service.

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Contents

	Page
MANAGEMENT IMPLICATIONS	1
INTRODUCTION	1
METHODOLOGY	2
Definition of Economic Value	2
Techniques for Measuring Net Willingness to Pay	2
Travel Cost Method (TCM)	2
Contingent Value Method (CVM)	3
SURVEY DESIGN AND IMPLEMENTATION	4
STATISTICAL ANALYSIS	4
Data Compilation	4
Regression Analysis	6
Calculation of TCM Benefits	6
RESULTS	7
Contingent Value Method	7
Primary Purpose Trips	7
Non-Primary Purpose Trips	7
Travel Cost Method	12
Comparison to Other TCM Studies	14
Comparison of TCM Values to CVM Values	14
Application	14
CONCLUSIONS AND RECOMMENDATIONS	15
LITERATURE CITED	16
APPENDIX 1	18
Average and Marginal Consumer Surplus—Conditions of Equality	18
APPENDIX 2	21
Script for Telephone Interview of Idaho Fishermen	21

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MANAGEMENT IMPLICATIONS

That recreation associated with wildlife has economic value is obvious. However, estimates of what constitutes this value vary widely by species and by state. In part, this is due to the different definitions and estimation techniques used by wildlife biologists, economists, and resource managers. This bulletin uses results from a state-wide survey in Idaho to estimate the values of cold and warm water and mixed species fishing, using both consumer surplus and expenditures as components of total value for consumptive use of the resource.

The net economic value (consumer surplus) of a cold water fishing trip to the angler and to the Nation is $42.93. This means the typical angler would be willing to pay an additional $43 per trip over and above current expenditures. The gross value is the sum of the $37 of expenditures (transportation, lodging, food, tackle) plus the consumer surplus of $43 which equals $80 per trip. For warm water fishing the net economic value per trip is $42, and the expenditures were $24 per trip; therefore, the gross economic value is $66 per trip. These values are state averages from which one can derive per day or per Recreation Visitor Day (RVD) values. It is important to note the exact nature of the net values reported in this bulletin. These state average values of cold and warm water fishing are weighted averages over all fishing sites in Idaho. The weighting is on the basis of number of trips to each site. Those sites with more visits, and consequently more consumer surplus, contribute relatively more weight to the average value.

Actual forest planning or project-related analyses (e.g., environmental assessments) should use the individual site values, reported in tables 4 and 5, rather than the state average. Theoretically, marginal values rather than average are the correct values to use in decisionmaking concerning economic efficiency. Due to the statistical properties (e.g., functional form) of the demand curve estimated for cold and warm water fishing, the individual site average value per trip equals the marginal consumer surplus per trip. That is, the additional net value to the angler and society of another trip is equal to the average value of a trip. These average values can thus be applied where marginal values are appropriate because the functional form chosen for the demand curve has the unique property that consumer surplus marginal and average values are equal. (See Appendix 1 for a discussion and proof.)

If the decisionmaker is evaluating the economic benefits of alternative investments in fisheries management, then the net value of $43 for cold water and $42 for warm water fishing is the appropriate value to use per trip. These values can be converted to a 12-hour RVD for use in FORPLAN or Benefit Cost Analyses. Converting trip values to RVD values based on number of days per trip and hours fished per day yields $63.87 per RVD for cold water fishing and $63.26 per RVD for warm water fishing.

These net economic values were derived by a demand curve estimating technique called the Travel Cost Method (TCM). This approach statistically infers the bid that anglers would make if given the opportunity to express willingness to pay. The Contingent Value Method (CVM) was also used in the study to elicit simulated market bids from anglers. This approach was used to measure the value of the last trip taken during the year. The per trip values were $22.52 for cold water fishing and $16.35 for warm water fishing. These convert to a net economic value per RVD of $37.75 for cold water fishing and $33.08 per RVD for warm water fishing.

Although angler expenditures are useful for evaluating the impact on communities dependent upon tourism, they are not a measure of net economic value. Much like the harvesting and transportation expenditures of logging contractors, angler expenditures can be used in Input-Output models such as IMPLAN or BREAM to calculate the multiplier effects of expenditures on local income and employment.

INTRODUCTION

The economic value of wildlife as measured from the National or economic efficiency view is used in Federal land management planning by the USDA Forest Service and USDI Bureau of Land Management. While the land or habitat may be managed by the Federal government, the wildlife is property of the State. Coordination of economic value is necessary if Federal plans affecting habitat are to be compatible with the state plans for management of individual species.

Specifically, this bulletin analyzes the net willingness to pay for cold water and warm water fishing. The value of steelhead fishing is analyzed in a separate bulletin (Donnelly et al. 1985). Federal agencies and the State of Idaho will have a consistent set of dollar values which vary by the type of fishing (cold, warm, and mixed) and by site. These numbers may serve as the basis of discussions on value of wildlife in National Forest planning, BLM range-wildlife investments and Forest Service Resource Planning Act (RPA) assessments.

The underlying premise of this study was that by using data from a survey reviewed by all parties, using methodologies acceptable to all parties, and applying standard statistical techniques, all parties would reach consensus on resulting dollar values. In addition, this study served as a test of the cost effectiveness of using the Travel Cost Method and the Contingent Value Method for developing values for the 1990 RPA assessments.

METHODOLOGY

Definition of Economic Value

Economic values for all outputs are defined in terms of net willingness to pay (amount in excess of actual expenditures) by users. This is the value of forage to ranchers from ranch budgets, the value of water to farmers, and the value of wildlife to hunters-anglers.

Net willingness to pay is the standard measure of value in Benefit-Cost Analysis performed by the U.S. Army Corps of Engineers, Bureau of Reclamation, and the Soil Conservation Service (U.S. Water Resources Council, 1979, 1983). Net willingness to pay is the basis of the Resources Planning Act values used by the USDA Forest Service in National Forest Planning. The Rangeland Investment Policy of the Bureau of Land Management stipulates willingness to pay as the measure of value of all outputs in SAGERAM analysis (Bureau of Land Management 1982).

Use of actual angler expenditures is not appropriate for valuation of wildlife nor for valuation of other resources (Knetsch and Davis 1966). Expenditures are only useful for measuring the effect or impact on local economies of some resource management action.

Techniques for Measuring Net Willingness to Pay

Dwyer et al. (1977), the U.S. Water Resources Council (1979, 1983), Walsh (1983), and Knetsch and Davis (1966) all recommend the Travel Cost Method (TCM) and the Contingent Value Method (CVM) as conceptually correct techniques for empirically estimating users' net willingness to pay.

The TCM relies on variations in travel costs of recreationists to trace out the demand curve. The area under this demand curve but above actual travel costs is a measure (called consumer surplus) of net willingness to pay. For readers unfamiliar with TCM see Clawson and Knetsch (1966), or Dwyer et al. (1977).

The CVM asks users directly to state their net willingness to pay for current or proposed conditions. Since it is a direct measure of consumer surplus, survey design is a critical factor in this method.

Travel Cost Method (TCM)

In this study a Regional Travel Cost Model (RTCM) was constructed. The dependent variable, i.e., the variable we are trying to predict and explain, is trips per capita. The traditional "per capita" specification was used to adjust for population differences between counties of visitor origin. As Brown et al. (1983) show, trips per capita accounts for both the number of visits as a function of distance and also probability of visiting the site as a function of distance. Alternatively, population could be incorporated as an independent variable (Knetsch et al. 1976).

The list of possible independent variables includes a surrogate for price (i.e., distance), fishing site characteristics, measures of substitutes, and the demographic characteristics of anglers. Given the constraints on length of the angler survey, measurement of several site-specific characteristics was precluded; therefore a relatively simple RTCM was estimated.

The basic model is:

$$\frac{\text{Trips}_{ij}}{\text{Pop}_i} = b_0 - b_1\text{Dist}_{ij} + b_2\text{Quality}_j - b_3\text{Subs}_{ik} \pm b_4\text{Income}_i \qquad [1]$$

where Dist = round trip distance in miles from county residence (i) to fishing site (j).

Quality = a measure of fishing quality at the site; e.g., fish caught per trip, fish caught per hour, or hours fishing per day.

Subs = a measure of the cost and quality of substitute fishing sites (k) to origin i relative to the one under consideration, i.e., site j.

Income = a measure of ability of county i households to incur costs for recreation and a proxy for other taste variables.

$b_0 - b_4$ = coefficients to be estimated.

Equation [1] specifies the per capita demand curve for the fishing sites in the region. By setting the quality measure at a value associated with a specific site, the general RTCM demand curve becomes the demand curve for that specific site. Thus, with one equation one can model recreation visitation patterns for all sites in the region. Equation [1] states that trips per capita from origin i to site j is a function of the distance from origin i to site j, the quality at site j, the substitute sites k available to origin i and the income of residents of origin i.

From a per capita demand curve a second stage demand curve can be calculated for a specific site. This second stage demand curve plots total trips to a site as a function of hypothetical added distance. Once the added distance is converted to travel costs (in dollars), the area under the second stage demand curve represents net willingness to pay. It is net willingness to pay, the willingness to pay over and above the travel costs actually incurred. (Clawson and Knetsch 1966, Dwyer et al.

1977). Finally, the total site consumer surplus can be converted to net economic value per day by dividing by the number of trips and then dividing this figure by days per trip.

The estimate of net willingness to pay is the end result of a series of mathematical and statistical operations on the aggregated data. One item of interest about estimated net willingness to pay is the sensitivity this estimate exhibits in response to variation within the travel cost model. This variation is initially seen in the computed statistical confidence interval associated with the estimate of each coefficient of the visits per capita regression model. Conceptually, this variation is carried through all the steps described above, including formation of the second stage demand curve and the subsequent integration under it. Thus, it is logical to talk about variation associated with estimated net willingness to pay.

However, the exact statistical properties of the confidence interval estimates of net willingness to pay are not yet completely developed.[4] Despite this, certain aspects of sensitivity may reveal information about the variability of benefit estimates. Specifically for this research a "sensitivity interval" was defined. This interval is for estimated benefits measured by willingness to pay and describes what are the upper and lower bounds of the benefit estimate when the regression coefficient of distance is varied to the upper and lower bounds of its confidence interval.

For example, the computer program that computes benefits is run three times once with the distance coefficient at its best unbiased level, once with it at the lower level of its 95% confidence interval, and once with the distance coefficient at the upper level of its 95% confidence interval.

The three estimates of benefits indicate how benefits vary with respect to variation in the coefficient associated with distance. Distance is chosen specifically because increased increments of this independent variable measure additional cost hypothetically incurred by anglers. Later in this report, these sensitivity intervals are compared to the confidence intervals derived from the contingent value method. This comparison is not a statistical procedure per se, but it does provide an indication of the relative ranges in estimates produced from each method. Because of the functional form of the demand curve used in this study, sensitivity intervals on average trip values are likely to be good approximations of true trip value confidence intervals.

Contingent Value Method (CVM)

The CVM is also known as the "direct method" since the interviewer directly asks the recreationists what they would be willing to pay to fish at this particular site. The object is to determine each individual's net willingness to pay for fishing at a site relative to all alternative sites. The issue is not the value of fishing itself. The survey design can also involve elimination or addition of one or more fishing sites, not the elimination of fishing in general.

There are several ways to ask the bidding game question. Because a telephone interview was to be used, the iterative technique was chosen. The iterative technique involves repeatedly asking if the person would pay successively higher and higher amounts of money. Once the person reaches the maximum amount he or she would pay, then this final value is recorded.

Another aspect of survey design is to determine the appropriate "payment vehicle." That is, how is the money bid going to be paid. One can use entrance fees, license fees, taxes, trip costs, or payment into a special fund. In this study, trip cost was used as the payment vehicle because it was fairly neutral and familiar to the respondents. Entrance or license fees may provide an emotional reaction biasing answers, in that an individual bid reflects bias toward the payment vehicle used and not the value of the resource of interest. In order to identify individuals who are responding negatively to the payment vehicle or the survey itself, the survey should include a protest mechanism. By allowing individuals to identify bias toward the payment vehicle or survey, these responses can be excluded from data analysis. The specific question asked is shown in the questionnaire which is reproduced in Appendix 2.

The analyses of CVM results is quite straightforward when analysis is based on a sound survey. Generally, the mean willingness to pay is calculated after removing protest bids and identifying outliers.

One advantage of CVM over TCM is the researcher can estimate willingness to pay not only for current conditions but also for hypothetical changes in fishing quality. In this study we asked additional willingness to pay for doubling the number of fish caught (versus current catch) and doubling size of the fish (relative to current size). This provides some important management information. Often times the number of fishermen may not increase when fisheries improvements are made. But fishery improvements appear to increase the value per day.

Another advantage of CVM is that the value per day associated with fishing on trips that were multi-purpose or multi-destination can still be estimated. With TCM, one can accurately value only trips for which the primary purpose and primary destination was for fishing. Thus in this study we will be able to estimate the value of cold water and warm water fishing for both primary and nonprimary purpose trips.

One criticism of CVM is the hypothetical nature of the value derived because it is not based on actual observed behavior. Research by Bishop and Heberlein (1979) and Brookshire et al. (1982) indicates that rather than an overstatement of willingness to pay, CVM generally provides conservative estimates of willingness to pay.

[4]Personal communication from Rudy King, Biometrician, Rocky Mountain Forest and Range Experiment Station, to Dennis Donnelly, October 3, 1983.

SURVEY DESIGN AND IMPLEMENTATION

The population sampling frame for this study was resident and nonresident anglers having an Idaho fishing license in 1982. The sampling rate for residents was 0.6% or 1,758 Idaho residents. A total of 194 nonresidents were sampled. The sampling rate for nonresidents varied by license type, varying from 0.34% for season nonresident to 0.104% for one day nonresident license holders. This inadvertent nonresident undersampling was adjusted for in the data set by increasing the number of trips for the undersampled populations until the sampling percentages were equal. Since data were later aggregated, this adjustment technique was deemed acceptable. Only nonresident sampling needed adjustment. The overall sample provided information on 14,552 cold water fishing trips, 4,481 mixed species fishing trips and 1,771 warm water fishing trips. Only for warm water fishing was the number of trips so small as to make individual site estimates unreliable. In displaying benefit estimates, warmwater sites were grouped together by areas to partially overcome this problem.

The 1,952 fishermen were first mailed a letter of introduction from the University of Idaho's College of Forestry, Wildlife and Range Sciences. Included with the letter was a map identifying the fishing units in Idaho (see fig. 1). The map was included to assist the respondents in determining the locations or sites which were visited during 1982. The letter indicated that someone from the University would be calling to collect fishing information requested in the letter. The individuals were asked to list their trips ahead of time, so that their answers could simply be read back over the phone. Additional questions were asked during the telephone interview (see questionnaire in Appendix 2). The actual telephone survey was performed by personnel at the University of Idaho during the months of February and March 1983. The data collected reflected trips taken for the entire 1982 fishing season. This approach proved quite successful in obtaining a response rate of 99%, with only 19 nonresponses out of the 1,952 persons contacted.

The survey collected trip information, party size, fishing quality, and fish species sought. For the Travel Cost Model analyses, trips were screened to insure that fishing was the primary purpose and that visitation of that particular site was the primary destination of a trip. The intent was to eliminate from the TCM analyses multi-destination and multi-purpose visits that were not dependent on the availability of fishing. The respondents were asked to report the round trip distance traveled to each site that was visited. This variable became the price variable for the TCM analysis. The number of days fished on the trip and the number of hours fished per day were also elicited from the respondent. This information will be used to convert TCM and CVM dollar values to 12 hour RVD values as required for Forest Service analyses. Since the questionnaire did ask for trip information for the previous year, accuracy of respondent recall is of concern. However, the use of zone averages tends to minimize the statistical effects of recall error on coefficient estimates (Brown et al. 1983). Future research may be able to provide some insights on the accuracy of annual recreation surveys.

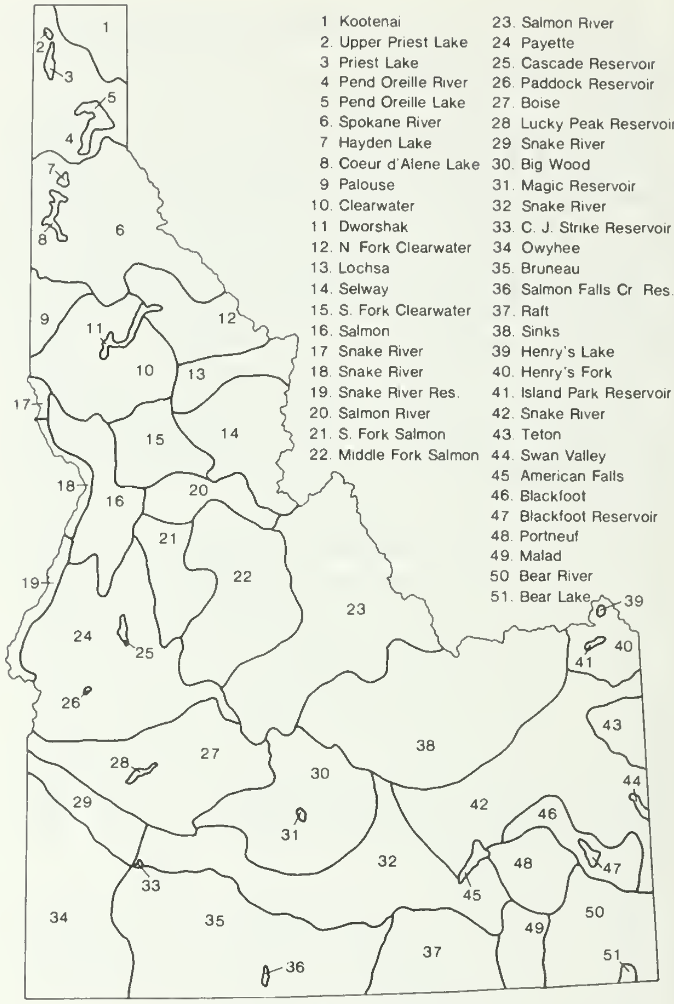

Figure 1.—Idaho fishing areas.

The CVM bidding questions were asked with regard to the last trip to estimate the value of this trip regardless of whether it was a primary or non-primary purpose fishing trip. Calculation of mean bids from CVM were separated by primary and non-primary purpose. The primary purpose bids could then be compared to TCM estimates.

The fish species sought was also recorded so that TCM and CVM values for cold water and warm water fishing could be calculated separately.

STATISTICAL ANALYSIS

Data Compilation

There were two basic phases to the analyses of the Idaho fishing data. First, an analysis of mean net willingness to pay from the CVM was performed after outliers were removed. Possible outliers included those bids over $100. For each bid over $100, the individual case was screened for length of trip, site visited, hours fished and whether the trip was a primary purpose. Based on these variables, a subjective decision was made as to the validity of the bid. For any species less than three percent of the sample was removed as high bid outliers. The minimal time required in calculating CVM derived net willingness to pay values makes CVM attractive as a methodology for rapid valuation of wildlife benefits. In addition, the capability to value all wildlife use whether primary purpose or not is another asset.

Concurrently with the CVM analysis, the TCM analysis was begun. Data were separated by cold water and warm water fishing trips. Mixed species fishing trips were appended to both the cold water and warm water data sets because mixed fishing involved both species and statistical tests indicated mixed fishing was similar to both groups (test from Kmenta 1971; p. 373). The hypothesis tested the possibility that the coefficients of the cold water fishing regression may not be different from those of mixed species fishing. Therefore, the null hypothesis was that the coefficients were not different across the regressions. The mixed species data set was appended to the cold and warm water data sets only to aid in estimating the per capita demand curve. Since the primary purpose of the study was not to estimate total site consumer surplus but rather average consumer surplus per trip there is no double counting of mixed species fishing benefits. As will be discussed in Results section, the average consumer surplus for mixed species fishing at each site is estimated by its own second stage demand curve which is derived from the pooled per capita curve.

The next step was to aggregate the individual cases into counties or in some cases, county groups. By dividing county populations into trips from a county, trips per capita from each county of visitor origin could be calculated. Once the data were aggregated, measures of substitute site attractiveness and site quality were calculated. Past approaches used exogenous information on physical characteristics of the site under study and substitute sites. Since this analysis was, in many respects, a prototype analysis to evaluate the cost-effectiveness of TCM, substitute and quality measures were limited to those which could be derived from the data contained in the survey.

Several site quality measures were formulated to reflect fishing quality and were statistically evaluated. Fish per hour seemed the most logical candidate but this rate variable proved to be statistically insignificant in all regression equations. Considered next was a measure of total fish catch at the site by individuals in our survey. The hypothesis here was the more fish taken out of a site, the greater the word-of-mouth information on fishing success and hence, the higher the visitation rate. The total fish caught variable was statistically significant for both cold and warmwater regressions.[5] This is fortunate for several reasons. First, this variable allows better identification of an individual site when using the RTCM. Second, it is a management relevant variable. That is, the State Department of Game and Fish can influence total fish caught through habitat management, stocking programs and fishing regulations. The total fish catch variable can be used to estimate the economic efficiency benefits (in a benefit-cost sense) of any of the Game and Fish actions taken to increase total fish caught. That is, because fish harvest is a demand curve shifter, the marginal benefits of any management action that changes fish harvest can be calculated as the area between the old and new demand curves (Freeman 1979).

Incorporation of a variable to reflect substitute recreation opportunities followed the basic approach of Knetsch et al. (1976). Their substitute measure reflects the price of substitute sites, quality of substitute sites and availability of such sites. The price of substitute sites is given by the distance from the origin i to the alternative site k . The quality of substitutes is approximated in this study by the total number of fish harvested at the alternative sites k. A substitute index is calculated by dividing harvest at alternative site k by distance from origin i to site k. This ratio is essentially a measure of the cost effectiveness of site k to recreationists in origin i. Specifically the ratio can be thought of as fish harvested per mile of driving. Any site k having a fish per mile greater than the fish per mile of the site under study, becomes a cost-effective substitute. To account for the degree of availability of these substitutes for a given origin-site combination, the substitute index is the sum of these substitute ratios for all alternative site k's having a ratio greater than the ratio for origin i - site j.

Mathematically,

$$S = \frac{H_k}{D_{ik}} \sum \text{for all } \frac{H_k}{D_{ik}} > \frac{H_j}{D_{ij}}$$

where
H = harvest
D = distance
j = site being studied
k = potential substitute site for site j.

The greater the number of alternative sites that are more cost-effective than the site j visited, the larger this substitute index is for j. The larger the value of the substitute index, other things remaining equal, the lower visits per capita ought to be to site j from origin i. Therefore, one would normally expect a negative sign on the substitute term. In this study, consideration of substitute sites was limited to alternative sites visited by any person coming from a given origin. Statistical estimation would not allow evaluation of the price to every site that a person could conceivably visit. This adopts the approach of Mendelsohn and Brown (1983) which relies on the Household Production theory view that observed behavior of visitation traces out an efficient recreation characteristic frontier where the key characteristic here is harvest. Thus, sites not actually visited by any persons from a given origin are assumed not to be cost-effective substitutes. This clearly narrows the range of sites possibly considered as substitutes. Whether this narrowing is empirically important cannot be determined without a case study comparing the Mendelsohn and Brown (1983) approach and the full substitute approach.

[5] *Use of total fish harvest avoided statistical problems that Meyer et al. (1983) found when they used fish harvest per capita. Since the dependent variable in their model was visits per capita the two terms appeared to have interacted in a way that biased the estimates of the other coefficients. Personal communication with William G. Brown, February 1984.*

County per capita income was also tested as a variable because economic theory indicates that it would influence the ability of county residents to purchase trips to a recreation site. In economics, goods for which purchases rise with income are classified as "normal goods." Goods that have purchases fall as income rises are called "inferior goods." This latter term does not imply inferior in quality or in any social sense. Rather it refers to a relationship between quantity demanded and income. Hamburger is often considered an "inferior good" to many consumers because we observe as income rises, that less hamburger (and more steaks) are bought.

Regression Analysis

In regression analysis the determination of which of the potential variables in the full model to retain depends on their statistical significance. Variables that were consistently insignificant were generally dropped from further consideration. The issue of functional form was not so straightforward. The model in equation [1] discussed previously was the simplest form.

In addition, several alternative specifications were proposed:

$$\ln(\text{trips/pop}) = b_0 - b_1\text{Dist} + b_2\text{Totfish} - b_3\text{Subs} \pm b_4\text{Inc} \pm b_5(\text{Inc})^2 \quad [2]$$

$$\ln(\text{trips/pop}) = b_0 - b_1\text{Dist} + b_2\text{Totfish} - b_3 \ln \text{Subs} \pm b_4\text{Inc} \pm b_5(\text{Inc})^2 \quad [3]$$

$$(\text{trips/pop}) \,.\, (\sqrt{\text{pop}}) = \sqrt{\text{pop}}\; b_0 - b_1[1\text{nDist}](\sqrt{\text{pop}}) + b_2\text{Totfish}\,(\sqrt{\text{pop}}) - b_3\text{Subs}\,(\sqrt{\text{pop}}) \pm b_4\text{Inc}\,(\sqrt{\text{pop}}) \pm b_5\,(\text{Inc})^2\,(\sqrt{\text{pop}}) \quad [4]$$

Equation [2] and [3] adopt the functional form that several economists have argued is most plausible. Ziemer et al. (1980), Vaughan and Russell (1982), and Strong (1983) contend that given the pattern by which trips per capita falls off at higher distances, the natural log of visits per capita is preferred to either a linear functional form or natural log of distance as in equation [4]. Their point is that with either two of these latter functional forms negative visits will be predicted for a few high cost zones; negative visits is counter intuitive and thus provides credence for the natural log of visits per capita.

With an untransformed dependent variable, Bowes and Loomis (1980) contend that the unequal sizes of population zones require a square root of population weighting factor (eq. [4]) to correct for heteroskedasticity and thus improve both benefit and use estimates. Vaughan and Russell (1982) and Strong (1983) show that if the log of visits per capita is chosen as the functional form (equations [2] or [3]), the heteroskedasticity will be so greatly reduced that the weighting by square root of a population may be unnecessary.

Which specification works best depends on the specific data base. The approach taken in this study was twofold. First, a Regional Travel Cost Model was being developed for estimating benefits at an existing set of sites, not for use estimation at a new site. Therefore, we used an econometric test suggested by Rao and Miller (1965) to determine whether the natural log of visits per capita or natural log of distance performed best. The hypothesis tested to determine the form of the dependent variable to use involved comparing the residual sum of squares between two specifications of the dependent variable. The test of the form of the dependent variable considered the chi-squared distribution. The null hypothesis tested whether the two functions (visits per capita and log of visits per capita) were empirically equivalent. The null hypothesis was rejected indicating the log of visits per capita better fit the data. Next, estimated visits were compared with actual visits. If estimated visits were fairly close to actual visits ($\pm$ 20%), the natural log of visits per capita was adopted rather than Bowes-Loomis weighting (which does provide exact prediction of actual sampled visits). This settlement of the trade-off depends on whether use or benefit estimation is the critical factor in one's study objectives. In this study, benefit estimation was most critical.

Income and income squared were used in the regression equation because income does not necessarily enter in a linear fashion (Martin et al. 1974). For example, as income increases we may increase our fishing activity. However, further increases in income do not always result in proportional (i.e., linear) increases in fishing. That is, if income doubles fishing may not double. If income doubles, cruises in the Caribbean may be substituted for more reservoir fishing.

Calculation of TCM Benefits

To calculate benefits with distance as the price variable using the second stage demand curve approach it is necessary to convert distance to dollars. Travel cost to a site consists of transportation costs and travel time costs. Travel time is included because other things remaining equal, the longer it takes to get to a site the fewer visits will be made. That is, time, because it is often a limiting factor, acts as a deterrent to visiting more distant sites. As is well known, omission of travel time will bias the benefit estimates downward (Cesario and Knetsch 1970, Wilman 1980). The U.S. Water Resources Council (1979, 1983) requires consideration of travel time in performing TCM studies.

In this study, round trip mileage driven was converted to transportation costs using three steps. First, mileage was converted to transportation cost on a per vehicle basis. This was done using variable automobile costs as listed by the U.S. Department of Transportation's (1982) Cost of Owning and Operating Automobiles and Vans. Based on the number of persons per vehicle and the fact that a large number of fishing trips were overnight camping trips, it was likely that many persons may have used an intermediate size car. While some anglers may have gone in compact cars, others may balance this by going in large cars, pickups trucks, or vans. Thus, the intermediate size car was taken as typical. This had a cost of \$0.135 per mile in 1982 (U.S. Department of Transportation 1982). Interestingly enough, dividing transportation costs reported by respondents by their round-trip miles yields a cost per mile of \$0.126 and \$0.129 for warm water and cold water fishing, respectively. Therefore, $0.135 was used in this analysis. Benefit estimates using the lower cost per mile would be trivially smaller.

The value of travel time was set at one-third of the wage rate as per the U.S. Water Resources Council (1979, 1983). This is the mid-point of values for travel time that Cesario (1976) found in his review of the transportation planning literature. However, the use of one-third the wage rate is not necessarily intended to measure wages foregone during the time spent traveling, but rather the deterrent effect of scarce time on which sites to visit. In this study, the U.S. Department of Labor's estimate of a median wage of $8.00 an hour was used. One-third of this is $2.67 per hour.

For each increment of distance or added miles, the transportation cost and value of travel time for that added distance is added together. This rescales the vertical axis of the second stage demand curve from miles to dollars. The area under the second stage demand curve yields estimated site consumer surplus for the sampled anglers. Dividing sample consumer surplus by sampled trips yields consumer surplus per trip to that site.

RESULTS

Contingent Value Method

Primary Purpose Trips

Table 1 presents the dollar values for primary purpose and non-primary (multiple) purpose trips. The value in brackets in table 1 reflects the mean bid with high bid outliers removed. Unfortunately there is no standard procedure for determining what is a high bid outlier. Initially, all bids over $100 per trip were screened as potential high bid outliers. To determine if the bid was an outlier, trip length in days and hours of fishing per day were screened. If trip length was very short or hours fished minimal, the bid was subjectively removed as a high bid outlier. For example, a bid of $240 for double fish caught by a person on a one-day trip was considered a high bid outlier. Because no individual income data were collected, it was difficult to tell if such a bid was within the angler's ability to pay. In the primary trip category, the mixed species fishing values were most affected by excluding one or more high bid outliers. There were also several high bid outliers on the more hypothetical questions such as "doubling fish caught" and 50% increase in fish size. Since these questions were more hypothetical than the current condition questions, this may be expected. The following discussion is based on the bracketed values.

For primary purpose trips, coldwater anglers are willing to pay $22.52 per trip more than their current expenses rather than not visit this site. This $22.52 is associated with 1.58 days per trip. The value per day is $14.25. On a 12-hour Recreation Visitor Day basis, the value would be $37.75 since there was a mean of 4.53 hours fished per day.

For warm water fishing, anglers were willing to pay $16.35 per trip more than their current expenses rather than not visit the site. This $16.35 is associated with 1.36 days per trip. This represents $12.02 per day. With 4.36 hours fished per day, this translates to $33.08 per 12-hour RVD. Fishing for both warm water and cold water species at the same site had a net willingness to pay of $17.61 per trip. This translates to $28.90 per 12-hour RVD.

The results for doubling number of fish caught and 50% increase in fish size provide some economic values useful for fisheries management. The bids per trip increased from $22.52 to $31.87 if number of cold water fish caught (but not necessary kept) doubled. This value of extra fish caught may be helpful in establishing the economic benefits of greater fish populations. For warm water fishing the increase in value for doubling the number of fish caught is $7.91. For increasing fish size, net willingness to pay increases even more per trip. The net willingness to pay for increasing by 50% the size of coldwater fish species caught was worth $12.78 per trip. For warmwater species, increasing fish size by 50% was worth $9.81 per trip; for mixed fishing, it was worth $9.23 per trip. Desirable increases in fish size could be accomplished by holding fish at a hatchery until they are larger or implementing a catch and release program for fish under a certain size. The additional benefits of larger fish could be compared to the costs of managing to produce larger fish.

Non-Primary (Multiple) Purpose Trips

Multiple purpose trips were defined as trips where fishing was not the major reason for visiting a site and/or visiting this particular site was not the primary destination of the trip. These trips could not be analyzed using the Travel Cost Method because it would be incorrect to attribute the distance driven to the site as an indirect measure of price paid for fishing. The net willingness to pay for multiple purpose cold water fishing trips was $39.71 per trip. This translates to $21.01 per day and to $68.70 per 12-hour RVD. For warm water fishing, the value of these non-primary purpose trips is $19.36 or $11.39 per day. This translates to $37.86 per 12-hour RVD. Mixed fishing trips had a value of $50.98 or $24.03 per day. Per 12-hour RVD this value is $75.75.

The multiple purpose users contribute important benefits to the cold water and mixed sites. About 20% of cold water anglers visiting these Idaho sites were on non-primary purpose trips. The same is true for mixed species anglers. For warmwater fishing, non-primary purpose trips contributed about 12% to the value of these sites.

Table 2 represents average dollar values per trip based on combining coldwater fishing with mixed and warmwater fishing with mixed. These values may be useful for fisheries that support both types of species. Note the bracketed values presented in table 2 represent values when the high bid outliers are removed. Thus, the numbers in brackets in table 2 can be compared to the numbers in brackets in table 1.

Table 3 reports values for each of the coldwater fishing sites. Table 4 reports values for warmwater fishing regions; these regions were formed to account for the

Table 1.—CVM values[1] for cold, warm, and mixed water fishing
(sample size in parentheses)

	Cold Water Fishing		Warm Water Fishing		Mixed Fishing	
	Primary Purpose					
Net willingness to pay for current conditions	$24.77 (776)	[$22.52][2] (769)	$17.72 (79)	[$16.35][3] (78)	$22.15 (141)	[$17.61] (137)
Net willingness to pay for double number of fish caught	$32.47 (774)	[$31.87] (768)	$27.53 (78)	[$24.26] (76)	$29.21 (140)	[$23.18] (138)
Net willingness to pay for 50% increase in fish size	$38.03 (773)	[$35.30] (762)	$27.52 (79)	[$26.16] (77)	$33.41 (139)	[$26.84] (136)
Number of fish caught on trip	5.00 (795)		9.79 (84)		6.89 (142)	
Number of days fished on trip	1.58 (980)		1.36 (113)		1.53 (181)	
Hours fished per day	4.53 (980)		4.36 (113)		4.78 (181)	
Value per day for current conditions	$14.25		$12.02		$11.51	
Value per 12-hour RVD for current conditions	$37.75		$33.08		$28.90	
Cost (travel, food, tackle, accommodations	$37.05 (963)		$24.62 (111)		$35.06 (179)	
	Multiple Purpose					
Net willingness to pay for current conditions	$42.73 (201)	[$39.71] (198)	$19.36 (11)		$80.71 (42)	[$50.98] (41)
Net willingness to pay for double number of fish caught	$58.44 (200)	[$51.03] (198)	$22.45 (11)		$106.00 (42)	[$58.59] (41)
Net willingness to pay for 50% increase in fish size	$64.31 (200)	[$53.88] (197)	$28.45 (11)		$112.78 (41)	[$64.61] (40)
Number of fish caught on trip	7.39 (203)		7.00 (12)		4.82 (45)	
Number of days fished on trip	1.89 (256)		1.70 (15)		2.12 (56)	
Hours fished per day	3.67 (255)		3.61 (13)		3.81 (56)	
Value per day for current conditions	$21.01		$11.39		$24.05	
Value per 12-hour RVD for current condition	$68.70		$37.86		$75.75	
Cost (travel, food, tackle, accommodations)	$66.27 (253)		$30.93 (14)		$57.07 (56)	

[1] *Bracketed values have outliers removed.*
[2] *95% confidence interval: $19.95 to $25.08.*
[3] *95% confidence interval: $10.36 to $22.34.*

Table 2.—CVM values[1] for cold/mixed water fishing and warm/mixed water fishing (sample size in parentheses).

	Cold/mixed water fishing		Warm/mixed water fishing	
	Single Purpose			
Net willingness to pay for current conditions	$24.36 (917)	[$21.77][2] (906)	$20.56 (220)	[$17.15][3] (215)
Net willingness to pay for double number of fish caught	$31.96 (914)	[$30.83] (905)	$28.61 (219)	[$25.68] (214)
Net willingness to pay for 50% increase in fish size	$37.31 (912)	[$34.22] (898)	$31.30 (217)	[$26.80] (212)
Number of fish caught on trip	5.29 (937)		7.97 (226)	
Number of days fished on trip	1.57 (1161)		1.47 (294)	
Hours fished per day	4.57 (1161)		4.62 (294)	
Value per day for current conditions	$13.86		$11.67	
Value per 12-hour RVD for current conditions	$36.39		$30.31	
Cost (travel, food, tackle, accommodations.	$36.74 (1142)		$31.06 (290)	
	Multiple Purpose			
Net willingness to pay for current conditions	$49.29 (243)	[$44.12] (242)	$67.98 (53)	[$44.29] (52)
Net willingness to pay for double number of fish caught	$66.66 (242)	[$61.49] (242)	$88.66 (53)	[$50.94] (52)
Net willingness to pay for 50% increase in fish size	$72.66 (241)	[$63.42] (240)	$94.19 (52)	[56.94] (51)
Number of fish caught on trip	6.92 (248)		5.28 (57)	
Number of days fished on trip	1.93 (312)		2.03 (71)	
Hours fished per day	3.70 (311)		3.77 (69)	
Value per day for current conditions	$22.86		$21.82	
Value per 12-hour RVD for current conditions	$74.14		$69.45	
Cost (travel, food, tackle, accommodations	$64.60 (309)		$51.84 (70)	

[1] *Bracketed values have outliers removed.*
[2] *95% confidence interval: $19.43 to $24.12.*
[3] *95% confidence interval: $12.92 to $21.39.*

Table 3.—TCM and CVM values derived for coldwater fishing at designated sites in Idaho (sample size in parentheses)

Site	TCM	Contingent Value Method (CVM)							
	Net WTP for current conditions	Net WTP for current conditions	Net WTP for double no. of fish caught	Net WTP for 50% increase in fish size	No. of fish caught on last trip	No. of days fished on last trip	Hours fished per day	No. of licensed anglers	Cost (travel, food, tackle, accommodations)
1	$36.70	$5.00 (7)	$6.57 (7)	$8.29 (7)	4.71 (7)	.85 (10)	3.45 (10)	1.80 (10)	$7.90 (10)
2	$41.83	$5.00 (2)	$5.00 (2)	$9.00 (2)	2.00 (2)	1.67 (3)	2.17 (3)	2.33 (3)	$4.33 (3)
3	$32.92	$71.50 (4)	$71.50 (4)	$130.25 (4)	4.50 (4)	1.90 (5)	4.60 (5)	1.80 (5)	$19.20 (5)
4	$41.99	$6.78 (9)	$10.67 (9)	$13.44 (9)	3.44 (9)	1.00 (9)	3.94 (9)	3.00 (9)	$15.89 (9)
5	$38.99	$24.52 (25)	$39.64 (25)	$40.72 (25)	2.93 (27)	1.58 (33)	6.00 (33)	2.55 (33)	$38.53 (32)
6	$39.66	$20.58 (40)	$24.90 (40)	$30.25 (40)	5.14 (42)	1.40 (48)	3.28 (48)	2.35 (46)	$26.28 (47)
7	$46.16	$6.00 (8)	$8.71 (7)	$5.43 (7)	3.13 (8)	.90 (9)	3.67 (9)	2.11 (9)	$6.44 (9)
8	$36.20	$8.11 (19)	$13.00 (19)	$10.50 (18)	10.74 (19)	.91 (21)	4.00 (21)	2.14 (21)	$19.67 (21)
9	$40.97	$6.40 (5)	$8.40 (5)	$8.80 (5)	2.40 (5)	1.17 (6)	4.42 (6)	3.17 (6)	$5.00 (6)
10	$36.27	$14.98 (41)	$22.07 (41)	$25.93 (41)	2.51 (41)	.97 (48)	5.40 (48)	2.40 (48)	$16.11 (47)
11	$35.38	$24.50 (6)	$27.00 (6)	$32.33 (6)	8.50 (6)	2.13 (8)	5.69 (8)	2.50 (8)	$43.86 (7)
12	$38.45	$24.09 (11)	$26.82 (11)	$30.73 (11)	4.73 (11)	1.29 (12)	4.92 (12)	1.92 (12)	$40.33 (12)
13	$32.63	$59.33 (3)	$62.67 (3)	$62.67 (3)	43.67 (3)	2.96 (5)	4.90 (5)	3.20 (5)	$47.00 (5)
14	$27.38	$10.00 (1)	$10.00 (1)	$10.00 (1)	10.00 (1)	2.00 (1)	4.00 (1)	2.00 (1)	$20.00 (1)
15	$36.56	$21.50 (8)	$23.38 (8)	$24.00 (8)	6.38 (8)	1.81 (11)	3.36 (11)	3.09 (11)	$25.18 (11)
16	$36.08	$44.33 (24)	$51.00 (24)	$56.92 (24)	2.35 (29)	1.74 (31)	4.59 (34)	2.15 (34)	$49.62 (34)
17	$35.54	$15.80 (5)	$24.20 (5)	$28.20 (5)	.60 (12)	1.50 (12)	6.04 (12)	2.17 (12)	$26.67 (12)
18	$51.55	$128.75 (4)	$135.00 (4)	$136.25 (4)	1.25 (4)	2.25 (4)	5.00 (4)	3.00 (4)	$135.00 (4)
19	$40.17	$10.00 (4)	$27.50 (4)	$28.75 (4)	1.33 (3)	1.25 (4)	7.63 (4)	1.75 (4)	$24.25 (4)
20	$37.55	$62.33 (6)	$99.00 (6)	$113.00 (5)	9.00 (5)	3.44 (8)	5.38 (8)	3.25 (8)	$72.29 (7)
21	$51.96	$50.00 (2)	$50.00 (2)	$52.50 (2)	8.50 (2)	7.00 (2)	4.00 (2)	1.50 (2)	$100.00 (2)

Table 3.—TCM and CVM values derived for coldwater fishing at designated sites in Idaho (sample size in parentheses)—Continued

Site	TCM	Contingent Value Method (CVM)							
	Net WTP for current conditions	Net WTP for current conditions	Net WTP for double no. of fish caught	Net WTP for 50% increase in fish size	No. of fish caught on last trip	No. of days fished on last trip	Hours fished per day	No. of licensed anglers	Cost (travel, food, tackle, accommodations)
22	$34.37	$70.11 (9)	$82.33 (9)	$83.22 (9)	7.89 (9)	3.17 (11)	4.09 (11)	3.27 (11)	$166.27 (11)
23	$42.57	$37.21 (44)	$52.84 (44)	$60.21 (44)	4.11 (46)	2.02 (54)	4.56 (54)	2.32 (54)	$68.42 (50)
24	$37.37	$26.79 (38)	$33.42 (38)	$39 .79 (38)	5.45 (38)	2.01 (46)	4.45 (46)	2.61 (46)	$37.33 (46)
25	$34.44	$18.33 (21)	$29.67 (21)	$32.86 (21)	7.58 (24)	1.95 (28)	5.54 (28)	3.00 (28)	$38.39 (28)
26	$42.41	$15.00 (1)	$16.00 (1)	$16.00 (1)	6.00 (1)	1.00 (1)	3.00 (1)	2.00 (1)	$2.00 (1)
27	$41.65	$17.50 (48)	$23.04 (48)	$27.56 (48)	7.22 (49)	1.61 (63)	4.30 (63)	2.32 (63)	$34.81 (63)
28	$42.41	$9.56 (16)	$11.06 (16)	$13.25 (16)	9.18 (17)	.96 (21)	4.19 (21)	2.33 (21)	$23.81 (21)
29	$37.72	$15.40 (5)	$21.40 (5)	$21.40 (5)	.80 (5)	1.38 (6)	4.50 (6)	2.17 (6)	$32.00 (6)
30	$62.00	$21.79 (29)	$25.72 (29)	$29.93 (29)	5.46 (28)	1.66 (34)	4.07 (34)	2.53 (34)	$34.18 (34)
31	$35.15	$18.44 (23)	$21.48 (23)	$25.57 (23)	3.61 (23)	1.39 (29)	5.07 (29)	2.66 (29)	$30.25 (28)
32	$42.56	$13.85 (27)	$19.26 (27)	$27.11 (27)	6.54 (28)	1.03 (42)	4.11 (42)	2.62 (42)	$17.20 (41)
33	$37.43	$24.50 (4)	$12.67 (3)	$11.00 (3)	2.00 (4)	1.00 (7)	3.93 (7)	2.57 (7)	$16.86 (7)
34	$34.31	$12.50 (2)	$15.00 (2)	$20.00 (2)	6.00 (2)	1.00 (2)	2.50 (2)	1.50 (2)	$23.50 (2)
35	$38.28	$26.54 (13)	$25.83 (12)	$37.62 (13)	5.71 (14)	1.21 (18)	5.61 (18)	3.22 (18)	$28.00 (18)
36	$37.85	$12.00 (10)	$15.56 (9)	$16.44 (9)	3.00 (10)	1.08 (13)	4.63 (13)	2.62 (13)	$14.54 (13)
37	$38.47	$22.20 (5)	$22.20 (5)	$35.60 (5)	4.20 (5)	1.20 (5)	3.40 (5)	2.60 (5)	$32.00 (5)
38	$34.17	$27.39 (28)	$37.82 (28)	$40.71 (28)	5.93 (28)	2.09 (33)	3.97 (33)	3.03 (33)	$46.27 (33)
39	$32.61	$42.50 (6)	$66.33 (6)	$50.83 (6)	4.50 (8)	3.33 (12)	5.08 (12)	3.17 (12)	$127.33 (12)
39	$32.61	$42.50 (6)	$66.33 (6)	$50.83 (6)	4.50 (8)	3.33 (12)	5.08 (12)	3.17 (12)	$127.33 (12)
40	$36.80	$26.87 (15)	$32.27 (15)	$40.87 (15)	6.38 (16)	2.22 (19)	4.08 (19)	2.26 (3)	$44.94 (18)
41	$36.87	$36.46 (11)	$64.55 (11)	$57.09 (11)	3.00 (11)	3.46 (11)	5.73 (11)	3.10 (10)	$69.64 (11)

Table 3.—TCM and CVM values derived for coldwater fishing at designated sites in Idaho (sample size in parentheses)—Continued

Site	TCM	Contingent Value Method (CVM)							
	Net WTP for current conditions	Net WTP for current conditions	Net WTP for double no. of fish caught	Net WTP for 50% increase in fish size	No. of fish caught on last trip	No. of days fished on last trip	Hours fished per day	No. of licensed anglers	Cost (travel, food, tackle, accommodations)
42	$42.25	$14.07 (62)	$21.69 (62)	$26.10 (62)	3.71 (63)	1.14 (76)	4.38 (75)	2.54 (76)	$21.12 (73)
43	$42.03	$61.50 (12)	$66.42 (12)	$82.50 (12)	5.25 (12)	1.43 (13)	5.23 (13)	3.00 (13)	$31.00 (13)
44	$42.48	$11.08 (12)	$16.00 (12)	$18.17 (12)	3.42 (12)	1.37 (18)	4.53 (18)	3.17 (18)	$30.77 (17)
45	$35.49	$13.00 (15)	$21.73 (15)	$23.60 (15)	2.75 (16)	1.28 (18)	4.83 (18)	2.72 (18)	$19.61 (18)
46	$32.84	$16.50 (14)	$20.71 (14)	$23.29 (14)	4.15 (13)	1.35 (17)	4.22 (18)	2.17 (18)	$25.83 (18)
47	$33.12	$12.67 (21)	$18.57 (21)	$18.52 (21)	4.29 (21)	2.22 (29)	5.01 (29)	3.21 (29)	$44.57 (28)
48	$38.24	$18.62 (13)	$29.42 (12)	$30.25 (12)	3.54 (13)	.92 (17)	4.07 (17)	2.82 (17)	$20.59 (17)
49	$35.97	$22.86 (14)	$23.23 (13)	$27.46 (13)	3.07 (14)	1.22 (16)	4.34 (16)	2.44 (16)	$26.27 (15)
50	$36.83	$10.08 (12)	$14.83 (12)	$18.00 (12)	4.42 (12)	1.06 (16)	3.53 (16)	2.38 (16)	$19.13 (16)
51	$30.11	$12.50 (2)	$22.50 (2)	$27.50 (2)	5.00 (2)	1.00 (2)	3.25 (2)	3.00 (2)	$20.00 (2)

small sample size in the warmwater fishing data which prevented estimates on an individual site basis for warmwater fishing.

Travel Cost Method

As discussed earlier, choice of functional form of the per capita demand equation was related to two factors. These were the Rao and Miller (1965) functional form tests and how well the log of visits per capita reduced heteroskedasticity. The Rao and Miller (1965) test indicated that log of visits per capita was preferable in terms of better fit of the data. In addition, the weighted regression resulted in neither substitutes nor quality being statistically significant. The log of visits per capita did minimize heteroskedasticity to the extent that estimated visits to the 51 sites for cold water and mixed fishermen were 19,116 while actual visits were 19,033. Estimated visits over all 51 sites were within 1.0% of actual visits. Since the main emphasis was on benefit estimation, this is acceptable. The difference between actual and estimated use for any individual site is likely to be greater than 1% and caution should be observed in using individual site averages as compared to State averages. For warm water fishing, the estimated visits were 5,710 while actual visits were 6,262. This was within 10%. The regression equation estimated using cold/mixed water fishing is given in equation [5]. This regression equation was used to calculate benefits for cold water fishing and cold/mixed water fishing.

$$\begin{aligned} \ln(\text{trips/pop}) = & -10.712 \; -.00322\text{Dist} \; +.00345\text{Totfish} \quad [5] \\ (\text{t statistics}) \quad & (-6.23) \quad (-15.13) \quad (5.61) \\ & -0.00000239(\text{Totfish})^2 \; -0.015\ln(\text{Sub}) \\ & (-4.37) \quad (-1.04) \\ & +0.00134\text{Inc} \; - \; 0.00000015(\text{Inc})^2 \\ & (2.48) \quad (-3.54) \end{aligned}$$

The estimated regression equation using warm/mixed data is:

$$\begin{aligned} \ln(\text{trips/pop}) = & -12.647 \; -.002750\text{Dist} + .00477\text{Totfish} \\ (\text{t statistics}) \quad & (-4.05) \quad (-8.14) \quad (3.99) \\ & -0.00000402(\text{Totfish})^2 \; -0.0259\ln(\text{Sub}) \\ & (-2.68) \quad (-1.13) \\ & +0.1937\text{Inc} \; -0.000000204(\text{Inc})^2 \\ & (1.97) \quad (-2.66) \end{aligned}$$

The equations are highly significant overall with an F-value of 83 on cold water and 32 on warm water. The overall F and the individual t statistics on distance and

Table 4.—CVM and TCM values for warm/mixed water fishing by site grouping[1] (sample size)

Site grouping	A	B	C	D	E	F	G
TCM							
Net willingness to pay for current conditions	$50.55	$43.17	$41.12	$45.60	—[2]	$40.19	$37.91
CVM							
Net willingness to pay for current conditions	$10.20 (41)	$23.87 (15)	$18.96 (105)	$12.87 (15)	$27.00 (5)	$9.31 (13)	$12.86 (14)
Net willingness to pay for double number of fish caught	$16.10 (41)	$29.50 (14)	$24.93 (104)	$17.20 (15)	$30.40 (5)	$15.00 (13)	$19.71 (14)
Net willingness to pay for 50% increase in fish size	$17.85 (40)	$29.13 (15)	$28.95 (102)	$18.93 (15)	$27.80 (5)	$25.15 (13)	$23.57 (14)
Number of fish caught on this trip	9.02 (43)	8.13 (15)	8.32 (108)	7.69 (16)	2.20 (5)	5.15 (13)	8.80 (15)
Number of days fished on this trip	1.38 (61)	1.74 (19)	1.45 (137)	1.72 (18)	2.17 (9)	.82 (16)	1.45 (19)
Hours fished per day	4.57 (61)	4.13 (19)	4.69 (137)	4.43 (18)	4.33 (9)	4.40 (16)	5.06 (19)
Number of licensed anglers	2.49 (61)	2.95 (19)	2.68 (136)	2.22 (18)	2.56 (9)	2.88 (16)	3.47 (19)
Cost (travel, food, tackle, and accommodations)	$23.03 (61)	$28.79 (19)	$29.54 (137)	$31.39 (18)	$86.67 (9)	$12.00 (17)	$39.58 (19)

[1] *Warmwater groupings of fishing areas: A—2, 3, 4, 5, 6, 7, and 8; B—9, 10, 11, 16, 17, and 18; C—19, 24, 25, 26, 27, 28, 29, 33, and 34; D—30, 31, 32, 35, and 36;E—38, 39, 40, 41, and 43; F—42, 44, 46, and 47; G—37, 45, 48, 49, 50, 51.*

[2] *No TCM values recorded for these areas.*

quality are significant at the 99% level. The small standard error on distance for both warm water and cold water fishing provides a relatively small sensitivity interval around the benefit estimates. The R^2 was 0.40 for cold water fishing and 0.36 for warm water fishing. The t statistic on substitutes is not statistically significant at standard levels. However, given the theoretical importance of substitutes, omission would bias the distance coefficient. The advantages of leaving in this theoretically significant variable is greater than the cost of omitting it from a statistical standpoint (Kelejion and Oates 1974).

Distance to cost-effective substitutes and distance to the site under study have a very low but positive correlation. What this positive correlation implies is that as one moves away from the site j under study, one also becomes further away from substitute sites. Failure to include a substitute term under these conditions will overstate benefit estimates (Caulkins et al. 1985). Given this spatial pattern, the slope coefficient on the demand curve will be too price inelastic due to failure to account for distant users. The reason there is relatively little drop off in visits per capita from more distant zones is not solely price insensitivity but rather fewer substitutes available. Correcting for substitutes flattens out the demand curve in this case. This has the effect of reducing the benefit estimates (average and total consumer surplus).

The per capita demand curves were used to arrive at a second stage demand curve for each fishing site. This was done by setting the values of total fish at that site's value and setting income at that origin's value. Then distance was set at its current value for a given origin to calculate estimated visits per capita at current distance. Visits per capita were then multiplied by the origins population to calculate visits from the origin. Next, 200 mile increments were successively added to distance until the maximum observed distance in the sample was reached or visits from that origin fell to less than one. This takes into account the market area and provides an upper limit for integration which is necessary with the log of visits per capita functional form. This procedure of using highest observed distance as an upper limit was first used by Wennergren (1967) and since then by others (Smith and Kopp 1980). This rule yields a conservative estimate of the surplus because it cuts off some of the consumer surplus. In this application the amount of consumer surplus lost was about 70 cents a trip for warm water fishing.

The average economic efficiency TCM benefits for all sites is given in table 5. The average TCM cold water fishing values are $42.93 per trip or $25.55 per day. On

Table 5.—Average cold, cold/mixed, warm and warm/mixed values from Travel Cost Method.

	Cold water fishing	Cold/mixed water fishing	Warm/mixed water fishing	Warm water fishing
Net willingness to pay for current conditions per trip.	$42.93[1]	$39.43[2]	$42.44[3]	$42.18[4]
Number of days fishing on this trip	1.68	1.58	1.56	1.61
Number of hours fished per day on this trip	4.8	4.8	5.06	5.0
Value per day	$25.55	$24.96	$27.21	$26.36
Value per 12-hour RVD	$63.87	$62.40	$64.53	$63.26

[1] *95% Sensitivity Interval: $38.13 to $48.84*
[2] *95% Sensitivity Interval: $32.56 to $41.40*
[3] *95% Sensitivity Interval: $34.25 to $54.54*
[4] *95% Sensitivity Interval: $35.08 to $55.86*

a 12-hour RVD basis this is $63.87 per day. The value of mixed species fishing that is similar to cold water fishing (or cold water species dominant) is $39.43 per trip. For mixed fish species fishing that is similar to warm water fishing (or warm water fish species dominant) the value is $42.44. Warm water fishing values are $42.18 per trip or $26.36 per day. Putting this on a 12-hour RVD basis yields $63.26 for warm water fishing. The cold water fishing values for each of 51 sites can be found in table 3. The small sample sizes precluded calculating warm water fishing values by site; these values are shown by fishing regions in table 4.

Comparison to Other TCM Studies

The Idaho cold water fishing value of $25.55 per day is similar to the value of $19.49 per day found by Vaughan and Russell (1982) as a national average. It is also similar to the updated value of $22.39 per day estimated by Martin et al. (1974). Recent unpublished work by Miller and Hay[6] using the USFWS National Survey of Fishing, Hunting, and Wildlife Associated Recreation estimated a value of $24.00 per day for cold water fishing in Idaho. This value is almost identical to the State average estimated in this report.

Comparison of TCM Values to CVM Values

The appropriate CVM values to compare to TCM are CVM values for primary purpose trips. The CVM values are generally lower than TCM for both warm water and cold water fishing. One possible reason is that the CVM bids are for the angler's last trip while the TCM applies to all trips that year. If the last trip is not quite typical of all trips taken, the values would differ. Unlike hunting which has a very short season and a bag limit of one animal, people can take numerous fishing trips over the year. As such, the last trip of the year may be worth less at the margin than the first trip of the year. Since CVM is based on this last trip it may reflect a marginal value to the individual that could be below the average consumer surplus over all trips (Gum et al. 1983).

[6] *Personal communication with Dr. John Miller, University of Utah, Salt Lake City.*

Use of confidence intervals for CVM and sensitivity intervals for TCM can assist in this comparison of CVM and TCM values. In this comparison the edited CVM values (reported in the brackets of table 1) for cold and warm water fishing are used. For cold water fishing the CVM value per trip was $22.52 with a 95% confidence interval of $19.55 to $25.08. The TCM value for cold water fishng was $42.93 per trip with a 95% sensitivity interval of $38.13 to $48.84 per trip.

Comparison of warm water fishing trip values shows CVM with a mean of $16.35 and 95% confidence interval of $10.36 to $22.34. The TCM trip values for warm water fishing had a mean of $42.18 with a 95% sensitivity interval of $35.08 and $55.86 per trip.

These confidence intervals seem to indicate the CVM values are lower than the TCM ones. This is similar to what Miller and Hay found in the USFWS National Survey of Fishing and Hunting.

Application

To evaluate the benefits of a possible fisheries management action the net economic value per RVD should be utilized. As a simple example, suppose the fisheries biologist estimates that fish populations would double if streambank improvements were made along riparian areas. The biologist, recreation planner, and economist could then translate this doubling in fish population into an increase in fish available for harvest. Once the increase in fish available for harvest is known, the theoretically correct way to calculate the additional long run benefits of this change is to use this new level of harvest as a demand curve shifter. When fish harvest goes up, the demand increases. This can be seen in figure 2 as the shift from D_1 to D_2. The improvement in quality will be translated (in the TCM) into existing anglers taking more trips and non-anglers entering (or reentering) fishing to become anglers due to the higher quality. The theoretically correct benefits of the increase in quality is equal to the shaded area between the demand curves. This is the long run value since we have allowed for entry of new anglers in response to the improvement in quality. Discussion of how to calculate the initial short run value of the change will be discussed below in conjunction with information about application of the Contingent Valuation Method.

In field studies it has been difficult for biologists to have access to the original TCM data, per capita demand curves for each site and a computer program to calculate benefits with quality-induced demand shifts. Often the biologist will be able to translate the increase in fish populations to an increase in supply of fishing trips. The economic benefit of the added fishing trips that there is a demand for can be approximated by multiplying the increase in trips times the average net value per trip. If there is a demand for an additional 300 fishing trips per year at a value of $42 per trip this would yield annual benefits of $12,600. In this case the approximation to the area between the demand curves is valid since the functional form of the demand curve is such that the average value equals the marginal value. This is not always the case, as is discussed in Appendix 1. This benefit would be compared to the annualized economic costs of stream improvements in riparian areas. These costs may take the form of water diversions, streambank stabilization or planting of vegetation. If the anglers' net willingness to pay (as revealed by the $12,600) for the additional fishing trips is greater than the annualized cost of stream improvements, then economic efficiency is improved by investing in stream improvements in riparian areas.

Evaluations of benefits of increased fish populations do not necessarily flow only from more angler days. In the short run, an increase in harvestable fish may be received by current anglers. For example, it may be several years before anglers believe this increase is a permanent change and for word of mouth to spread the news that fishing has improved. As a result, the benefits of higher harvests initially are obtained by current anglers only. To estimate the increase in value to current users we rely on Contingent Value questions asked in the survey. By increasing fish population, the demand

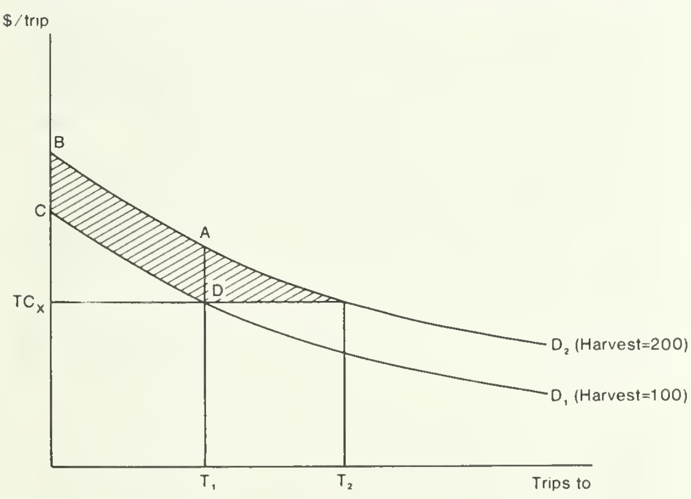

Figure 2.—Site demand curve for cold water fishing.

curve for the fishery resources shifts up to the right, leading to a higher value per day. These added benefits or marginal benefits can be calculated by taking the area between these two demand curves while holding number of trips constant. Such increases in value per trip are obtained directly from the bidding question. This study showed the value per trip would rise by about $8 if the number of coldwater fish caught doubled. If the size of the fish caught increased by 50% the value per trip rose by about $13 per trip. For warm water fishing these values are $8 more for double number of fish and $10 more for a 50% increase in size of fish. In terms of figure 2, the benefits being calculated here represent just the area between the demand curves for the current 700 trips (area ABCD). Continuing our example, if when fish populations double, fish harvest to existing anglers also doubles, then the CVM values can be used to calculate the area ABCD. Doubling harvest would, according to our CVM results, increase the value of the existing 700 trips by about $8 per trip. This results in an increased value of $5,600 for doubling fish harvest to existing anglers. This, however, represents only about half the total long run benefits when existing anglers take more trips and new anglers begin to visit this site.

These added values can be very useful in evaluating changes in fishing regulations or resource actions that will change the number of fish harvested or the size of fish caught. Decisions made by integrating these economic values into project analyses of timber sales, grazing allotment management, right of way design and fish restoration investments are likely to result in increases in net public benefits as compared to current undervaluation of fisheries values.

CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to derive recreational values for fishing using data collected by the Idaho Department of Fish and Game. The Travel Cost and Contingent Value Methods were applied in accordance with the U.S. Water Resources Council Principle and Guidelines (1983) and accepted professional practices. A Regional Travel Cost Model was constructed. The per capita demand curve included statistically significant variables on distance, income, quality and substitutes.

Both the Travel Cost and Contingent Value Methods had advantages and disadvantages in this study. The advantage of CVM was the ability to value not only primary purpose-primary destination trips but also secondary purpose or multi-destination trips. For cold and warm water fishing this is a large advantage since over 20% of the trips were not primarily for fishing. In addition, CVM provided values for doubling the number of fish caught or increasing fish size. There appeared little trouble in getting people to participate in the bidding game. One limitation of CVM was that it could reasonably be applied only to the last trip because applying the bidding sequence to each trip would have more than doubled the length of the interview and caused respondent fatigue.

The primary advantage of TCM relates to its reliance on actual behavior and applicability to all trips taken during the season. However, the disadvantages relate to inability to value multi-purpose or multi-destination trips and in selecting a value of travel time. The multi-destination or multi-purpose problem is not a serious shortcoming but is of some concern as TCM cannot value 20% of the trips taken to these 51 sites. The Regional or Multi-Site TCM, as applied in this study, has the advantage of being able to predict how many additional trips (or with some additional calculations, anglers) would be taken if the number of cold and warm water fish harvested doubled.

Perhaps the biggest practical disadvantage of TCM is the time it takes to construct and apply a Regional Travel Cost Model. A total of 40 work days (by two economists) were needed in this study to apply TCM. This time estimate involves economists familiar with mechanics of TCM, regression analysis, and computers. TCM, as applied in this study, also involved use of several specialized computer programs designed to shorten the time necessary to aggregate individual data into zones, calculate substitute indices, calculate second stage demand curves, and calculate benefits. These programs will be documented and made available to others in the future.

By contrast, the CVM analysis of mean willingness to pay takes relatively little time. Thus, if a survey must be performed to collect data for valuation, CVM is quite a bit faster in terms of data compilation and statistical analysis. However, if origin-destination data already exist in the form of permits or license plate numbers, then TCM would become a more cost-effective way to value recreation activities. In conclusion, no method is superior in all cases but both yield fairly consistent, although not identical results.

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Appendix 1

Average and Marginal Consumer Surplus—Conditions of Equality

This appendix discusses the issues of average versus marginal values in the context of application of study results to forest planning and project studies (e.g., environmental assessments). To correctly apply our study results the analyst should know how the change in demand for trips to this site is occurring. One possible way is due to population growth in the counties surrounding the site under study. Another way results from management actions taken by an agency changing the demand for wildlife recreation by changing site characteristics (e.g., harvest) or site location (e.g., travel cost or price) to some counties of recreationists origin. Population changes and changes in site characteristics are reflected in our TCM demand curves as a shift in the second stage demand curve. The area between the "with and without" condition demand curves is the appropriate measure of the change in net economic value or economic welfare as measured from the standpoint of economic efficiency (Freeman 1979). In the case of a reduction in travel cost to the site due to an addition of a new site closer to at least one county of origin the change in consumer surplus due to the price change reflects recreationists willingness to pay or the net economic value of such a change (Burt and Brewer 1971).

The area between the "with and without" TCM demand curve provides an estimate of the long run economic benefits of the change in, say site quality, due to some management action. This is termed long run because in the TCM model the change in quality will be translated into a change in number of trips taken by existing visitors to this site as well as entry of new recreationists due to the added incentive to visit this site due to improved quality. The reason that trips increases is that if the recreationist was in consumer equilibrium before the change, the improvement in site quality will throw the consumer out of equilibrium. That is the marginal utility of another trip is now higher and the price of another trip has not changed, so the marginal utility per dollar of visiting this site another time is now higher than alternative uses of that income. Therefore the consumer "reoptimizes" his or her consumer bundle and continues to take more trips to the site until they drive the marginal utility per dollar into equilibrium with all other goods.

In addition to being able to calculate benefits, the TCM demand curves simultaneously provide an estimate of the change in trips (which could be converted to the change in RVDs) associated with the change in site characteristics, change in population or a change in site location. This may be of value in addition to the change in benefits. For example, the change in trips times the recreationists expenditures would be useful in IMPLAN or other input-output models to estimate the local economic impacts.

The area between two CVM derived demand curves derived in our survey, represent just the short run benefits of the increased quality. By short run benefits we mean the increase in value to the existing recreationists taking their current number of trips only. This is represented by taking the area between the two demand curves but only up to the current quantity of trips taken. Thus, it is short run since, the way we asked the question, we get the added value of existing trips due to improved harvest quality but do not allow for the recreationist to get to the new equilibrium number of trips associated with higher quality. CVM questionnaires can be designed to ask individuals how number of trips would change based on a change in quality.

To carry out this theoretically correct application of our results the analyst would need access to the raw data (containing current travel cost, county population and current value of site characteristics) and a program to calculate the second-stage demand curve. At the present time it is not envisioned that many potential field users of this informatin would have access to the data and computer program. Until the benefits program is made easier to use or a program is maintained for each species, it would be difficult for field persons to actually shift the demand curves and recalculate benefits.

The question often posed in field studies is "Given that I have this change in trips or RVDs, what is the value that I should multiply these trips by to get the correct estimate of benefits?" The temptation is to use the average consumer surplus per trip or RVD times the change in trips or RVDs to calculate the change in benefit. The question is really about how good or bad is this procedure as an approximation to the theoretically correct area between the demand curves? Vaughan and Russell (1982) have shown that the goodness of this approximation depends on the functional form of the demand curve from which the average consumer surplus was estimated. If the demand curve is linear, Vaughan and Russell (1982) show that multiplying the original average consumer surplus times the change in trips will understate the true benefits by at least 50 percent. If the demand curve is a double log, then this procedure will over or understate the true benefits depending on the price elasticity of the double log function.

The demand curves estimated in this study generally use the natural log of visits per capita as the dependent variable and untransformed distance as the price variable. This is known as a semi-log model. In the semi-log model the average consumer surplus equals the marginal consumer surplus. That is the net benefits of another trip (due to an increase in population, increase in site quality or reduction in travel cost) is equal to the average consumer surplus. The proof is as follows:

The objective of the proof is to show that average benefits are equal to marginal benefits in relation to the per capita (stage I) demand curve. The means to accomplish this is to derive the mathematical expression for the benefits in each case and to show these are equal. The conditions under which this is true are:

1. Demand relationships between visits per capita and price (cost of travel) can be validly modeled with a semi-log functional form such as

$$\ln(q) = a - bp \qquad [A1]$$

or equivalently,

$$q = e^{a-bp} \qquad [A2]$$

where q is quantity, in this case, visits per capita

p is price, in this case, travel cost
a is the intercept parameter
b is the slope parameter

2. The only shifting variables allowed in the equation affect the intercept. No slope shifting variables are in the equation.

3. A slight relaxation of condition 2 occurs if there are slope shifting variables but they do not change from the "before" to the "after" states.

4. Each origin is a price taker in that people from that origin may visit the site as many times as they desire at their current travel cost. Therefore, the supply curve facing a given origin is horizontal. Due to differences in location from the site, each origin faces a different horizontal supply curve.

The "Before" State

Figure A1 shows the overall scope of the changes considered in the proof. At equilibrium in state 1, i.e., the "before" state, the demand curve has a quantity intercept of e^{a_1} when price is zero. As price increases, quantity decreases and asymptotically approaches zero for very large p. For a price of p_1, visits per capita to a site from a specific origin are q_1.

Total benefits per capita that accrue to the presence of the site, given all other existing sites, are represented by the shaded area labeled CS_1 (consumer surplus in state 1). This area is found by integrating under the demand curve and above the price line p_1.

Let a small segment of the area, dCS, be

$$dCS = q\,dp \qquad [A3]$$

as shown in figure A1.

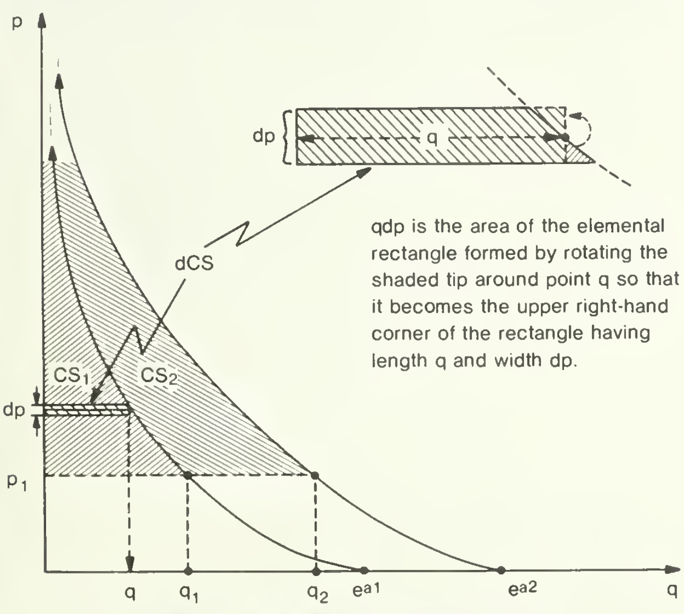

Figure A1.—Changes in consumer surplus.

Then

$$CS = \int dCS = \int_{p_1}^{p} q\,dp \qquad [A4]$$

The limits of integration define the lower boundary of the CS area, the p_1 price line, and the upper boundary of the CS area, the point where p goes to infinity and q goes to zero. In spite of these extreme values, it turns out the CS area is finite.

Substitute for q from equation [A2] in the integral in equation [A4] giving

$$CS_1 = \int_{p_1}^{p} e^{a_1 - b_1 p} dp \qquad [A5]$$

where the subscript 1 denotes state one ("before"). Continuing with the integration gives

$$CS_1 = e^{a_1} \int_{p_1}^{p} e^{-b_1 p} dp = -\frac{1}{b_1} e^{a_1 - b_1 p} \int_{p_1}^{p} \qquad [A6]$$

Evaluating the expression in [A6] at the limits of integration gives

$$CS_1 = \left(-\frac{1}{b_1} - e^{a_1 - b_1 p}\right) - \left(-\frac{1}{b_1} e^{a_1 - b_1 p_1}\right) \qquad [A7]$$

$$CS_1 = \frac{1}{b_1}\left(e^{a_1 - b_1 p_1} - e^{a_1 - b_1 p}\right) \qquad [A8]$$

In order to include the entire area under the demand curve, let p (not p_1) become infinitely large, (∞). For large p

$$e^{a_1 - b_1 p} = q \rightarrow 0 \qquad [A9]$$

so that the expression for CS in [A8] becomes

$$CS_1 = \frac{1}{b_1}\left(e^{a_1} - {}^{b_1 p_1}\right) = \frac{q_1}{b_1} \qquad [A10]$$

Average consumer surplus in state one per trip made (q_1) is

$$\overline{CS_1} = \frac{CS_1}{q_1} = \frac{1}{b_1}\left(e^{a_1 - b_1 p_1} \frac{1}{q_1}\right) \qquad [A11]$$

But

$$e^{a_1 - b_1 p_1} \text{ is } q_1, \qquad [A12]$$

So

$$CS_1 = \frac{1}{b_1}$$

Thus, average consumer surplus per trip in state one, the "before" state, is simply the inverse of the slope parameter from the demand equation, assuming the conditions previously stated are met.

The "After" State

Now assume that managers of the recreational sites under consideration wish to increase the attractiveness of the specific site, for example, by increasing the number of animals or fish potentially harvestable. This new condition becomes the "after" state.

The new attractiveness at the site increases the intercept to e^{a_2}, but does not affect the slope coefficient b, as we have assumed, so $b_1 = b_2 = b$, (i.e., quality is an intercept shifter only). Using the result of the previous section, that, in general under the stated conditions,

$$CS = \frac{1}{b}\left(e^{a-bp}\right) = \frac{q}{b} \qquad [A13]$$

and placing the subscript (2) for the "after" state on the variables, total per capita consumer surplus for the "after" state is

$$CS_2 = \frac{1}{b_2}\left(e^{a_2 - b_2 p}\right) = \frac{q_2}{b_2} \qquad [A14]$$

Note that "after" average CS is also $\frac{1}{b_2} = \frac{1}{b}$.

The total change in consumer surplus from the "before" to the "after" state is

$$\Delta CS = CS_2 - CS_1 \qquad [A15]$$

$$\Delta CS = \frac{q_1}{b_2} - \frac{q_2}{b_1} \qquad [A16]$$

But, as noted, $b_2 = b_1 = b$

So

$$\Delta CS = \frac{q_2 - q_1}{b} \qquad [A17]$$

The marginal change per unit increase in trips is defined as

$$\frac{\Delta CS}{\Delta q} = \frac{\frac{q_2 - q_1}{b}}{q_2 - q_1} \qquad [A18]$$

So

$$\frac{\Delta CS}{\Delta q} = \frac{1}{b} \qquad [A19]$$

And since $b = b_1 = b_2$, combine the results of the derivation of "before" average consumer surplus and the derivation of the marginal consumer surplus caused by the change to the "after" state.

Thus,

$$\overline{CS_1} = \frac{1}{b} = \frac{\Delta CS}{\Delta q} = CS_{marg} = \overline{CS_2} \qquad [A20]$$

and the proof is complete given that the preceding conditions are met.

Note in the proof that the relationship in equation [A20] does not depend on the price level even though figure A shows price unchanging. Neither do the key equations for "before" and "after" consumer surplus, equation [A10] and [A14], respectively. Under the stated conditions, there may or may not be a price change along with the demand curve shift. Regardless, it does not affect the equality between the "before" average consumer surplus and the "before" – to – "after" marginal change in consumer surplus. Moreover, the price may change in either direction without affecting the results.

Therefore, with this functional form multiplying the average consumer surplus of a trip or RVD times the change in trips or RVDs due to one of the three factors discussed above will result in an exact estimate of the area between the demand curve associated with that change in trips or RVDs. This is a result specific to this functional form. Therefore, if the field analyst has an idea of change in trips associated with some management action, one can calculate an estimate of the change in economic efficiency benefits associated with that change in days without having to shift the second-stage demand curve.

APPENDIX 2
Script for Telephone Interview of Idaho Fishermen

INTRODUCTION

HELLO, IS THIS THE RESIDENCE OF ______________________ ?
first and last name

If yes. *If no.* THE NUMBER I WAS CALLING IS ______________________
telephone number

AND I AM TRYING TO CONTACT ______________________ .
first and last name

SORRY I BOTHERED YOU. (TERMINATE. CHECK NAME AND NUMBER.)

→ THIS IS ______________________ AT THE UNIVERSITY OF IDAHO. I
interviewer's name

AM CALLING FROM THE COLLEGE OF FORESTRY, WILDLIFE AND RANGE SCIENCES IN MOSCOW. WE ARE DOING A STUDY OF FISHING IN IDAHO. WE ARE TRYING TO DETERMINE THE ECONOMIC VALUE OF IDAHO'S WILDLIFE. ______________________'s
first and last name

NAME WAS GIVEN TO US BY THE IDAHO DEPARTMENT OF FISH AND GAME. IS HE/SHE THERE? MAY I SPEAK TO HIM/HER?

1. *Respondent is on the phone*
2. *Respondent is called to phone*
3. *no*

WHEN MAY I CALL BACK TO REACH HIM/HER? ______________ AND
date

______________ A.M./P.M. WOULD YOU TELL HIM/HER THAT I CALLED
time

AND THAT I WILL CALL BACK. THANK YOU.

→ THIS IS ______________________ AT THE UNIVERSITY OF IDAHO. I AM CALLING FROM
interviewer's name

THE COLLEGE OF FORESTRY, WILDLIFE AND RANGE SCIENCES IN MOSCOW. WE ARE DOING A STUDY OF FISHING IN IDAHO. WE ARE TRYING TO DETERMINE THE ECONOMIC VALUE OF IDAHO'S WILDLIFE. YOUR NAME WAS OBTAINED FROM THE IDAHO DEPARTMENT OF FISH AND GAME'S LISTS OF LICENSE HOLDERS.

→ LAST WEEK WE SENT YOU A LETTER AND MAP THAT EXPLAINED A LITTLE ABOUT OUR STUDY. DID YOU RECEIVE IT?

yes

no → I AM SORRY YOURS DID NOT REACH YOU. IT WAS A BRIEF LETTER WE SENT SO THAT PEOPLE WOULD KNOW WE WOULD BE CALLING THEM.

→ 1. DID YOU FISH IN IDAHO THIS SEASON?

no → THANK YOU FOR YOUR HELP. THAT IS ALL THE QUESTIONS THAT I HAVE FOR YOU.

yes
↓
(SKIP THIS QUESTION IF THEY DID NOT RECEIVE THE LETTER)

2. DID YOU HAVE TIME TO LIST ALL THE FISHING TRIPS YOU TOOK THIS SEASON ON THE MAP WE SENT YOU?

yes → WOULD YOU READ ME YOUR LIST OF FISHING AREA NAMES AND THE CORRESPONDING MAP UNIT NUMBERS.

RECORD LIST ON SEPARATE SHEET
go on to page 4

no
↓
ON A PIECE OF PAPER, PREFERABLY THE ONE WE SENT TO YOU IN THE MAIL, LIST ALL THE FISHING TRIPS YOU TOOK THIS PAST SEASON. A LIST OF GENERAL LOCATIONS IS FINE. OUR GOAL IS NOT TO FIND OUT YOUR SPECIAL SPOTS. IN ADDITION TO THIS LOCATION, IF YOU HAVE THE MAP WE SENT, PLEASE DETERMINE THE MAP UNIT WHERE YOU WENT ON EACH TRIP. PLEASE TAKE A MOMENT TO MAKE YOUR LIST OF FISHING AREAS AND CORRESPONDING MAP UNITS. IF YOU WENT TO ONE AREA MORE THAN ONCE, JUST LIST THE AREA AND NUMBER OF TRIPS. LIST TRIPS FOR DIFFERENT TYPES OF FISH SEPARATELY.

PAUSE WHILE HE/SHE COMPLETES THE LIST. TRY TO GET THEM TO MAKE THEIR OWN LIST. YOU MAY WRITE THE LIST IF THEY DO NOT HAVE PAPER OR REFUSE TO WRITE IT OUT.

WOULD YOU READ ME YOUR LIST OF FISHING TRIPS.

NOTE 1. *IF AN INTERVIEWEE DOES NOT HAVE A MAP, IT IS YOUR DUTY TO GET ENOUGH INFORMATION TO ASSIGN A MAP UNIT NUMBER TO EACH GENERAL LOCATION.*

NOTE 2. *PROBE:* DID YOU INCLUDE TRIPS YOU TOOK WITH YOUR FAMILY, VISITING RELATIVES, FRIENDS, OR PEOPLE YOU WORK WITH?

NOW THAT WE KNOW HOW MANY TRIPS AND IN WHAT MAP UNIT YOU TOOK THEM, I WOULD LIKE TO ASK YOU SOME MORE DETAILED QUESTIONS ABOUT EACH TRIP. IF YOU MADE MORE THAN ONE TRIP TO AN AREA, PLEASE GIVE THE AVERAGE FOR THOSE TRIPS.

WAS THE PRIMARY PURPOSE OF YOUR TRIP TO ______________________
general area

TO FISH?

yes

no → *(TERMINATE AND START NEW AREA)*

maybe → WOULD YOU HAVE VISITED THIS AREA IF FISHING WAS NOT AVAILABLE?

yes → *(TERMINATE AND START NEW AREA)*

no

→ WAS THIS AREA THE PRIMARY DESTINATION OF THIS TRIP?

yes → *(ENTER A "1")*

no

maybe → WOULD YOU HAVE MADE THIS TRIP IF YOU COULD NOT HAVE VISITED THE AREA?

no

yes → HOW MANY DESTINATIONS DID YOU HAVE ON THIS TRIP?

____________________ AREAS

WHAT WERE THOSE DESTINATIONS?

→ HOW MANY TRIPS DID YOU MAKE TO ____________________ ?
general area

____________________ TRIPS

DID YOU DRIVE THE ENTIRE DISTANCE TO ____________________ ?
general area

yes → *mode* = 1

no → WHAT DIFFERENT TYPES OF TRANSPORTATION DID YOU USE?
small plane, airline, horse, car, jet boat, etc.

FOR YOUR TRIP TO ____________________, WHAT WAS THE APPROXIMATE
general area

TOTAL DISTANCE YOU TRAVELED? ____________________ miles

COUNTING YOURSELF, HOW MANY LICENSED ANGLERS WENT IN YOUR VEHICLE TO ____________________ ? ____________________ anglers
general area

HOW MANY UNLICENSED CHILDREN FISHED? ____________________ children

HOW MANY DAYS DID YOU FISH ON THIS TRIP TO ____________________ ?
general area

(TO NEAREST HALF DAY)

ON AVERAGE, HOW MANY HOURS PER DAY DID YOU FISH?

____________________ hours

WHAT WAS THE PRIMARY TYPE OF FISH YOU WERE TRYING TO CATCH?

1. *coldwater (trout) in mountain streams*
2. *coldwater in alpine lakes*
3. *coldwater in lowland lakes and reservoirs*
4. *landlocked salmon*
5. *warmwater - panfish*
6. *warmwater - bass, walleye*
7. *sturgeon*
8. *steelhead*
9. *mixed (any two or more of above)*
0. *warmwater - other*

ON AVERAGE, HOW MANY DID YOU CATCH (NOT KEEP)?

____________________ fish

If this is the last area, go on to page 6.
If there are more areas, repeat from page 4 with other areas.

THAT IS ALL I NEED ABOUT THIS AREA. NOW I WOULD LIKE TO TALK ABOUT YOUR

TRIPS TO ____________________ .
general area

GO BACK

NEXT, I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR MOST RECENT FISHING TRIP. WHAT AREA DID YOU VISIT ON YOUR MOST RECENT TRIP?

____________________ area

HOW MANY LICENSED ANGLERS WERE IN YOUR PARTY?

____________________ people

HOW MANY DAYS DID YOU FISH ON THIS TRIP (TO NEAREST HALF DAY)?

____________________ days

ON AVERAGE, HOW MANY HOURS DID YOU FISH EACH DAY?

____________________ hours

WHAT WAS THE PRIMARY TYPE OF FISH YOU WERE TRYING TO CATCH?

1. *coldwater (trout) in mountain streams*
2. *coldwater in alpine lakes*
3. *coldwater in lowland lakes and reservoirs*
4. *landlocked salmon*
5. *warmwater - panfish*
6. *warmwater - bass, walleye*
7. *sturgeon*
8. *steelhead*
9. *mixed (any two or more of above)*
0. *warmwater - other*

THE NEXT FEW QUESTIONS CONCERN THE AMOUNT OF MONEY THAT WAS YOUR SHARE OF THE AMOUNT SPENT ON THIS TRIP.

PLEASE ESTIMATE THE AMOUNT SPENT ON TRANSPORTATION ON THIS TRIP.

$ ______________

PLEASE ESTIMATE THE AMOUNT SPENT ON FOOD, TACKLE, ETC. ON THIS TRIP

$ ______________

NOW, ESTIMATE THE AMOUNT SPENT ON ACCOMMODATIONS ON THIS TRIP.

$ ______________

WAS THIS TRIP TO ____________________ (general area) WORTH MORE THAN YOU ACTUALLY SPENT?

no —— *STOP HERE*

yes

→ NEXT, I WOULD LIKE TO ASK SOME HYPOTHETICAL QUESTIONS ABOUT THIS TRIP TO ____________________ (general area). ASSUME THAT THE TRIP BECAME MORE EXPENSIVE, PERHAPS DUE TO INCREASED TRAVEL COSTS OR SOMETHING, BUT THE GENERAL FISHING CONDITIONS WERE UNCHANGED. YOU INDICATED THAT $ ____________ WERE SPENT ON THIS TRIP FOR YOUR INDIVIDUAL USE.

WOULD YOU PAY $ __________ (20% of cost) MORE THAN YOUR CURRENT COST RATHER THAN NOT BE ABLE TO FISH AT THIS AREA?

PROTEST - WILL NOT ANSWER

RECORD WHY?

1. *it's my right*
2. *my taxes already pay for it*
3. *no extra value*
4. *like to, but not able*
5. *refuse to put a dollar value*

yes

no ——→ *work between 0 and 20% to find highest acceptable value. split the difference in half until you reach nearest $1 (less than $10) or nearest $5 (greater than $10)*

→ WOULD YOU PAY $ __________ (50% of cost) MORE THAN YOUR CURRENT COST RATHER THAN NOT BE ABLE TO FISH AT THIS AREA?

yes

no → *work between 20 and 50% to final highest acceptable value. split the difference in half until you reach nearest $1 (less than $10) or nearest $5 (greater than $10).*

WOULD YOU PAY $ ________ MORE THAN YOUR CURRENT COST RATHER THAN NOT
100% of cost

BE ABLE TO FISH AT THIS AREA?

yes

no → *work between 50 and 100% to find highest acceptable value. split the difference in half until you reach nearest $1 (less than $10) or nearest $5 (greater than $10).*

keep going until you receive a negative answer. Use 100% increments.

work between last two bids to find highest acceptable value.

After last bid

IS THIS AMOUNT, $________, WHAT YOU PERSONALLY WOULD PAY, NOT FOR ALL
bid

MEMBERS OF YOUR PARTY?

no → repeat bids for personal value

yes

HOW MANY FISH DID YOU CATCH ON THIS TRIP TO ____________________ ?
general area

________ fish

NOW, SUPPOSE THAT INSTEAD OF ________ FISH, YOU COULD CATCH ________
\# caught double #

FISH. HOW MUCH, IF ANY, WOULD YOU INCREASE YOUR BID OF $ ________ ?

$________

NOW, SUPPOSE, THAT THE SIZE OF FISH YOU CAUGHT INCREASED 50% (FOR EXAMPLE, FROM 8" TO 12"). HOW MUCH, IF ANY, WOULD YOU INCREASE YOUR BID OF $ ________ ?

$________

THAT IS ALL THE QUESTIONS I HAVE FOR YOU. THANK YOU FOR TAKING THE TIME TO ANSWER THESE QUESTIONS. YOUR RESPONSES WILL BE VERY VALUABLE TO US.

GOOD-BYE.

Sorg, Cindy F., John B. Loomis, Dennis M. Donnelly, George L. Peterson, and Louis J. Nelson. 1985. The net economic value of cold and warm water fishing in Idaho. USDA Forest Service Resource Bulletin RM-11, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Net willingness to pay for cold and warm water fishing in Idaho was estimated at $42.93 and $42.18, respectively, with the Travel Cost Method, and at $22.52 and $16.35 per trip, respectively, with the Contingent Value Method. Willingness to pay was greater for increased catch or fish size.

Keywords: Cold water fishing, warm water fishing, economic value, travel cost method, contingent value method.

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Rocky
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Rocky Mountain Forest and Range Experiment Station

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*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526

United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**Resource Bulletin
RM-12**

Net Economic Value of Elk Hunting in Idaho

Cindy F. Sorg and Louis J. Nelson

Abstract

Net willingness to pay in addition to actual expenditure for elk hunting in Idaho was estimated at $63.17 per trip and $99.82 per trip using a standard cost per mile travel cost method and a reported cost per mile travel cost method, respectively. Using the contingent value method, the values for the 1982 and 1983 elk hunting seasons were $51.84 per trip and $92.54 per trip, respectively. Willingness to pay was greater for double number of elk seen on a trip. Methods, results, and applications are fully described.

Acknowledgements

This study was a cooperative effort of the Idaho Department of Fish and Game; the University of Idaho College of Forestry, Wildlife, and Range Sciences; the USDI's Bureau of Land Management and the Fish and Wildlife Service; and the USDA Forest Service.

USDA Forest Service
Resource Bulletin RM-12

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The Net Economic Value of Elk Hunting in Idaho

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Contents

	Page
MANAGEMENT IMPLICATIONS	1
INTRODUCTION	2
METHODOLOGY	2
Definition of Economic Value	2
Techniques for Measuring Net Willingness to Pay	2
Travel Cost Method (TCM)	3
Contingent Value Method (CVM)	3
SURVEY DESIGN AND IMPLEMENTATION	4
STATISTICAL ANALYSIS	5
Travel Cost Method	5
Regression Analysis	5
Calculation of TCM Benefits	6
Contingent Value Method	6
RESULTS AND DISCUSSION	7
Travel Cost Method	7
Contingent Value Method	9
Comparison of TCM and CVM Values	9
Comparison to Other Elk Studies	11
Applications	15
CONCLUSIONS	15
LITERATURE CITED	16
APPENDIX	18
Marginal vs. Average Values	18
Sensitivity Intervals	20
Elk Hunting Survey Questionnaire	21

Net Economic Value of Elk Hunting in Idaho

Cindy F. Sorg and Louis J. Nelson

MANAGEMENT IMPLICATIONS

Wildlife-related recreation clearly has value, but estimates of this value are difficult to establish. This is partly because of different definitions of economic value and widespread misunderstanding of economic terminology. This bulletin analyzes the value of elk hunting in Idaho, using both estimates of consumer surplus (net willingness to pay of the user) and expenditure as components of total value for consumptive use of the elk resource. Other types of value exist for nonconsumptive use.

In analyses of the economic efficiency of resource allocation, consumer surplus values generally are useful, whereas expenditure data are inappropriate or irrelevant, although they are useful for analyses about sectors of an economy. This bulletin explicitly focuses on economic surplus benefits (useful in economic efficiency analyses), although some expenditure data are reported.

Benefit-cost analyses and federal and state wildlife planning programs, such as the USDA Forest Service's FORPLAN and the BLM's SAGERAM, involve determining whether the benefits of implementing a project exceed the costs of the project. When the net willingness to pay of the gainers exceeds the net willingness to pay of the losers, once all costs have been removed, then the investment is economically efficient or the benefit-cost ratio is greater than 1. For a project like a controlled burn to improve elk summer forage, the gains might include increased hunting opportunities because of increased elk population and the losses might include forfeiting another species that requires old-growth vegetation, decreased timber activity, or restricted cattle grazing.

In 1982, the net economic value of an Idaho elk hunting trip to the hunter and to the Nation was estimated to be $99.82 (table 3). This means the typical hunter would be willing to pay an additional $100.00 per trip. The gross value is the sum of $76.00 of expenditures (transportation, lodging, food, ammunition) plus the consumer surplus of $100.00, which equals $176.00 per trip. This value is a state average from which can be derived per day or per Wildlife and Fish User Day (WFUD) values. Because of the statistical properties (functional form) of the demand curve estimated for elk hunting, the average value equals the marginal value of another trip. That is, the additional net value to the hunter and society of another trip is equal to the average value of a trip. This result holds only because of the specific functional form used in this study. It should be noted that the marginal value is the appropriate economic efficiency measure. The reason these average values can be applied in analyses where only marginal values should be used is because the functional form of the demand curve used in this study has the unique property that for consumer surplus, marginal value is equal to average value. (See the appendix for a discussion and proof.)

If the decisionmaker is evaluating the economic benefits of alternative investments in elk management, then the net value of $99.82 is the appropriate value to use per trip. This value can be converted to a 12-hour WFUD for use in FORPLAN or benefit-cost analyses. Converting the trip value to a WFUD based on number of days per trip and hours hunted per day yields $59.87 per WFUD.

The values given above were derived by a demand curve estimation technique called the Travel Cost Method (TCM). This approach statistically infers the bid that hunters would make if given the opportunity to express willingness to pay.

The Contingent Value Method (CVM) was also used in the study to elicit simulated market bids from hunters. This approach was used to measure the value of each trip taken during the season and is, therefore, theoretically equivalent to TCM. The CVM estimate per trip is respectively, $51.84 and $92.54 for the 1982 and 1983 hunting seasons (table 4). These convert to a net economic value per WFUD of $31.06 for 1982 and $36.31 for 1983. For 1983, the CVM portion of the survey also elicited bids from respondents regarding willingness to pay if they could expect to see double the number of elk per hunting trip; the value per trip was $56.85 greater than for existing conditions.

The geographic scope of analysis where the values given above are appropriate should be noted. The values are a weighted average across all sites and as such may not adequately reflect specific site characteristics. Values generated for a given scope, such as a management hunt unit, may not be appropriate for an area of different scope, such as a herd unit. However, an overall consumer surplus value, such as willingness to pay per trip, may be all that is available, and for efficiency analyses, these are more tenable than expenditure values.

Two additional points of clarification are necessary in reference to economic values. The above example extends only to expenditure and consumer surplus values as they relate to the hunting aspect of recreation value. Option, existence, or bequest values (nonconsumptive values) were not considered. To date, no study has addressed the total value framework of any component of a wildlife resource. Further, only general elk hunting license holders were sampled. The hunting values generated by limited hunt license holders are not included in these values estimates. In 1983, 37,800 individuals applied for a limited hunt permit while only 7,600 permits were issued; therefore, the hunting values reported may be an underestimate of total recreational hunting values.

INTRODUCTION

Elk are Idaho's premium big game species. They provide over half as many hunter days of recreation as do the more abundant deer. Idaho is one of only six states in the U.S. where general elk hunting is allowed. In 1981, elk populations statewide were 90,325 and provided 416,660 hunters days and a total harvest of 8,165. As habitat is lost to development and demand for elk hunting increases, careful land use decisions must be made. These decisions must be based on the best available biologic and economic data.

The economic value of wildlife as measured from the national or economic efficiency view is used in federal land management planning by the USDA Forest Service and USDI Bureau of Land Management. While the land or habitat is managed at the federal level, the wildlife itself is property of the state. Coordination of economic value of wildlife is necessary if federal plans affecting habitat are to be compatible with the state plans for management of individual species.

To promote a consensus on the economic value of elk hunting in the State of Idaho, several federal agencies (USDA Forest Service, USDI Bureau of Land Management, and USDI Fish and Wildlife Service) joined with the Idaho Department of Fish and Game to empirically estimate the value of consumptive recreational use of elk in Idaho.

Specifically, the net willingness to pay for elk hunting was analyzed in this report. This provides a consistent set of dollar values that can be used by federal agencies and the State of Idaho for the state and hunt units within the state. These values may serve as the basis of discussion on value of wildlife in national forest planning, BLM range-wildlife investments, Resource Planning Act evaluations of the Forest Service, and on feasibility studies of investments to enhance elk hunting in the State of Idaho.

In addition, this study served as a test of the cost effectiveness of using the Travel Cost Method and the Contingent Value Method for developing resources Planning Act (RPA) values for the 1990 RPA to be conducted by the Forest Service.

METHODOLOGY

Definition of Economic Value

Wildlife resources provide many different values. Each of these values is a component of total value. These component values, which include recreational, option, existence, bequest, and commercial values, can perhaps be best conceptualized in what has been called by Randall and Stoll (1983) a "total value framework" (fig. 1). Each of the values within this framework applies to consumptive uses (hunting, fishing, trapping, etc.) and nonconsumptive uses (observation, photography, etc.) of wildlife resources.

Recreational economic value is the recreationist's willingness to pay over and above the current expenditures for a recreation experience. Option value is willingness

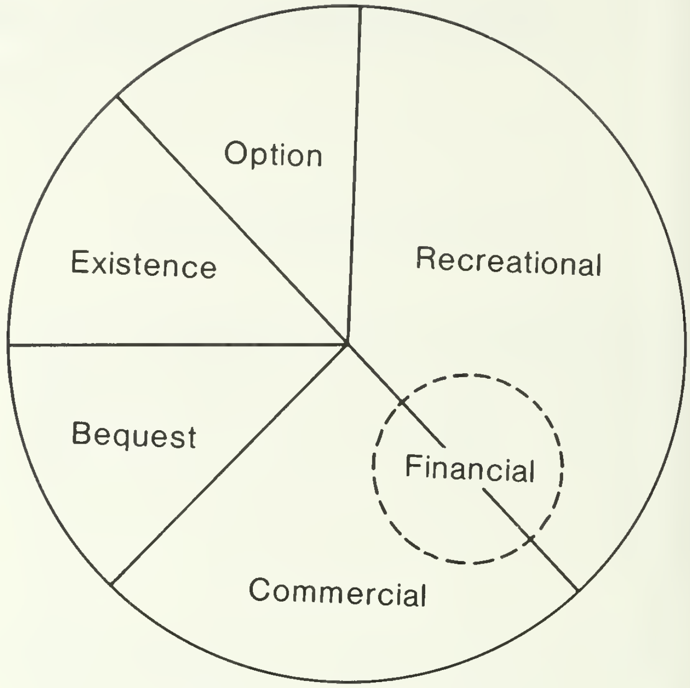

Figure 1.—Total value of wildlife

to pay to maintain a resource so that it is available to use in the future. Existence value is the economic benefit received from simply knowing wildlife exists regardless of one's use. Bequest value is an extension of existence value since it is willingness to pay to provide wildlife resources for future generations.

Expenditure values are often quantified in terms of gross expenditures and are a component of both recreational and commercial values. Expenditures are important from the standpoint of local economies, but do not represent the total economic value of wildlife. Hunters' expenditures can be used to calculate the multiplier effects of expenditures on local income and employment. While important locally, expenditures do not represent the economic value of wildlife from an economic efficiency standpoint. The demand curve in figure 2 illustrates the difference between expenditures and consumer surplus. Consider the elk hunter who has the above demand curve which shows the number of trips the hunter would take when faced with alternative travel costs (i.e., alternative prices). From this curve, if travel costs are $25, the hunter will take 3 hunting trips. Therefore, total expenditures equal $75 (3 × $25) and consumer surplus equals the area above expenditures or $112.50. The $75 provides information on community and multiplier impacts of these expenditures while the $112.50 represents the economic value used in benefit-cost analysis.

Techniques for Measuring Net Willingness to Pay

Dwyer et al. (1977), the U.S. Water Resources Council (1979, 1983), Walsh (1983), and Knetsch and Davis (1966) all recommend the Travel Cost Method (TCM) and the Contingent Value Method (CVM) as conceptually correct techniques for empirically estimating users' net willingness to pay. The TCM assumes that travel costs can be used as a proxy for price to derive a demand curve. The CVM asks users directly to indicate their willingness to pay, expressed in the form of "bids" for specified recreational conditions (Bradford 1970, Brookshire et al. 1980).

Travel Cost Method (TCM)

The basic premise of TCM is that per capita visitation of a recreation site will decrease as distance to the site and time costs of travel to the site increase. In this study, a Regional Travel Cost Model (RTCM) was constructed. By grouping individuals based on county (or state) of origin, travel costs (and distance) within each county/state zone are approximately constant across all individuals. The dependent variable is trips per capita. Use of the per capita specification adjusts for population differences between counties of visitor origin. As Brown et al. (1983) show, trips per capita takes into account both the number of visits as a function of distance and also

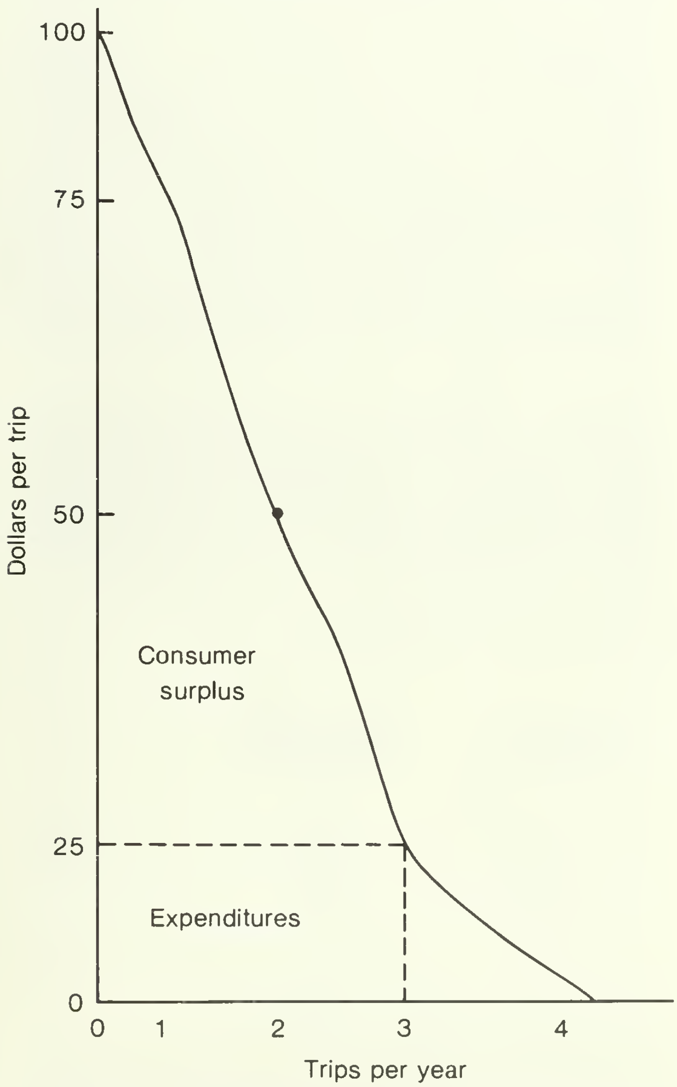

Figure 2.—Hypothetical demand curve for elk hunting

probability of visiting the site as a function of distance. Regression analysis is utilized to estimate a function for visitation rates based on distance, socioeconomic data, and site quality changes. Johnson et al. (1981) described a general functional form:

$$V_{ij} = \alpha_o + \alpha_1 D_{ij} + \alpha_2 S_{ij} + \sum_k \beta_k E_{ki} + \Sigma \gamma_1 Q_{1j} \qquad [1]$$

where:

- V_{ij} = annual per capita visits to hunting site j from origin i
- D_{ij} = distance from origin i to site j
- S_{ij} = recreation hunting opportunities available to population of i as alternatives to site j (substitute sites)
- E = demographic/socioeconomic variables for origin i
- Q = variables of recreation hunting quality at j.

Equation [1] specifies the per capita demand curve for the hunting sites in the region. By setting the quality measure at a value associated with a specific site, the general RTCM demand curve becomes the demand curve for that specific site. Thus, with one equation recreation visitation patterns for all sites in the region can be modeled. From the per capita demand curve a more aggregated second stage demand curve is calculated. This second stage demand curve plots total trips to a site as a function of hypothetical added distances. Once the hypothetical added distance is converted to travel costs (in dollars), the area under the second stage demand curve represents net willingness to pay. It is net willingness to pay because only the hypothetical added cost is reflected in the second stage demand curve, not the original travel costs (Clawson and Knetsch 1966, Dwyer et al. 1977).

Contingent Value Method (CVM)

Contingent Value Method techniques are most commonly referred to as bidding games. Unlike the familiar market situation where people alter consumption in response to price changes, bidding games can determine respondents' willingness to pay for current conditions and also for hypothetical changes in conditions. Usually the individual is responding to a discrete quality rather than a quantity change in a nonmarket good; e.g., indicating how much seeing wildlife would add to the value of a backpacking trip.

Contingent valuation was first used by Davis (1964). A questionnaire must be designed to present individuals with a well-defined good so that all individuals are responding to the same situation if bids are to be aggregated across participants. Also, if respondents are not fully aware of current conditions or the ramifications of a proposed change, the resulting bids are unreliable. Because hunting is an activity familiar to participants, clearly defining the good is less difficult. However, the survey must explicitly state the area of hunting affected, i.e., value associated with a particular site with all other sites still available, not value of all elk hunting in the state.

Another aspect of survey design is to identify the appropriate "payment vehicle." That is, what payment mechanism is going to be used to elicit the money bid. Possible payment vehicles include entrance fees, license fees, taxes, trip costs or payment into a special fund. In this study, trip cost was used as the payment vehicle since it is fairly neutral and familiar to the respondents and is not likely to elicit a protest bid.

As indicated above, questionnaire design is vital to obtaining a true CVM measure of value. Whereas TCM is an indirect measure of value, CVM is based on a direct measure of value and, therefore, a poor survey design will render useless results. While CVM relies on responses to hypothetical questions, research by Bishop and Heberlein (1979) and Brookshire et al. (1982) indicates that rather than an overstatement of willingness to pay, CVM generally provides conservative estimates.

SURVEY DESIGN AND IMPLEMENTATION

The population sampled for this study was resident and nonresident elk hunters having a general elk hunting license. Limited elk hunt permit-holders were not sampled. The sampling rate for 1983 was 2.1% or 1,629 individuals selected randomly. Table 1 presents the breakdown of the 1983 sampling rate. The economic data were collected in conjunction with the Idaho Department of Fish and Game yearly Big Game Harvest Survey (see appendix). The telephone survey, implemented in January and February 1983, collected information related to the 1982 elk hunting season. Using the same Harvest Survey, muzzle-loader and archery hunters were sampled two weeks after rifle hunters. Stamps permitting muzzle-loader or archery hunting are sold for both elk and deer general hunt permits without a separate stamp issued for each species. Therefore, no data is available on the proportion of elk muzzle-loader or archery tag-holders surveyed. The overall percentage of deer and elk muzzle-loader and archery tag-holders is presented in table 1. The CVM portion of the survey was repeated in February 1984; it collected information on the 1983 elk hunting season.

The survey was designed to collect information on elk hunting trips made during the hunting season,[3] e.g., hunt unit visited, number of animals seen, and number of licensed hunters in party. For the Travel Cost Model analyses, trips were screened to insure hunting was the primary purpose and that visitation of that particular site was the primary destination of the trip. The intent was to eliminate from the TCM analyses multidestination and multipurpose visits that were not dependent on the availability of hunting. The CVM bidding question was asked for each trip to estimate the value of each trip made during the hunting season.

In the CVM portion of the survey on the 1982 season, respondents were asked if the trip was worth more to them than they actually paid. If they gave a specific amount, this value was recorded. When the respondent was hesitant to express a value, the interviewer increased the value in increments of 10% until a maximum was reached. This final value was recorded. This method of eliciting bids combines the open-end and the iterative bidding procedures. When the respondent could not put a dollar value on the worth of the trip or indicated an infinite value, the bid was not used in data analysis. If the respondent said the trip was not worth more, no protest question was asked. As a result some of the zero bids used in data analysis represent a protest against the question and not a zero value of the elk hunting resource.

The CVM portion of the survey was repeated in 1984 for the 1983 hunting season in order to implement a single bidding technique. In this survey respondents were asked if the trip was worth more. If they responded yes, an iterative bidding technique starting with a 25% increment was implemented. The value was increased in increments of 10% until the final bid was elicited and recorded. This later survey included a protest question

[3] *The questionnaire related to economic data, developed by Lou Nelson and Lloyd Oldenburg of the Idaho Department of Fish and Game, was implemented in conjunction with the Big Game Harvest Survey. The economic portion of the survey was revised using feedback provided by John Hof, Thomas Hoekstra, Terry Raettig, Wendall Beardsley, and Cindy Sorg of the USDA Forest Service and John Loomis of the USDI Fish and Wildlife Service. A copy of the survey of big game hunting units is contained in the appendix.*

Table 1.—Sampling rate for economic survey of elk hunting in Idaho, 1983.

Tag type	Number sold	Number of hunters contacted	Percent of tag holders surveyed
Rifle resident	50,240	11,112	2.21
Resident Panhandle	14,625	323	2.21
Senior resident	3,708	5	.14
Nonresident	7,301	159	2.18
Nonresident Panhandle	1,119	30	2.50
All elk[1]	77,073	1,629	2.11
Archery elk	15,594	42	1.58
Muzzle-loader	6,791	255	3.76

[1]*Figures do not include archery or muzzle-loader hunters.*

to allow for differentiating between legitimate zero bids, which were recorded, and zero bids made in protest to the survey itself, which were not used. In addition, this later survey asked willingness to pay for double number of elk seen.

For both years, information on the number of days hunted on this trip and the number of hours hunted per day was also recorded. This was used to convert TCM and CVM dollar values to a value per day and also a value per 12-hour WFUD.

Confidence intervals around the TCM estimate of net willingness to pay cannot be estimated directly because of aggregation and statistical operations applied to the data. The appendix shows a method by which sensitivity intervals can be estimated around the TCM distance coefficient of net willingness to pay. For a complete discussion of the Travel Cost Method, refer to Clawson and Knetsch (1966) or Dwyer et al. (1977).

STATISTICAL ANALYSIS

Travel Cost Method

Analysis of the travel cost data progressed in the following manner. To be able to derive visits per capita, the individual cases were grouped according to counties or in some cases county groups. Within the state of Idaho and bordering counties, county-level specification was used. For bordering states with nonbordering counties, county groups were developed. Beyond this level, state and state groups were specified. By dividing population into trips for a state or county group, trips per capita from each group of visitor origin could be calculated. Mean per capita income was also calculated for each group. Once the data were aggregated, measures of substitute site attractiveness and site quality were calculated using data collected in the survey or data contained in the harvest report.

Several site quality measures were formulated to reflect hunting quality.[4] Total harvest in 1981 was used as the significant variable in the regression analysis because it was felt many hunters would plan 1982 elk hunting trips based on success in the 1981 hunting season. Total harvest in an area may be considered a measure of possible success at a site and, therefore, a reflection of quality at a site.

Two methods for measuring substitute sites were tested, both modeled after Knetsch et al. (1976). Their substitute term has attractiveness of substitute site in the numerator and distance to the substitute site in the denominator. In this study, attractiveness was correlated with total harvest. Any site K was considered a substitute for site J if the ratio of harvest to distance from origin L to site K was greater for site K than site J's ratio. That is, site K would be a cost-effective substitute because it had a higher harvest per mile driven than the site J under study. Therefore, both quality and cost (distance) of alternative sites were considered in determination of what sites were substitutes for others. The first substitute considered only that site with the highest ratio relative to the site in question. That is, the most effective substitute site J relative to the given site K.

The second substitute measure was the sum of the quality index for all sites having a higher harvest per mile than the site under study. Because analysis was limited to data collected in the survey, only sites with actual visits by at least one hunter were considered as potential substitutes.

No measure of substitutes was found significant in the regression analysis, indicating benefit estimates are an overestimate or underestimate of consumer surplus. The magnitude of the effect on value estimation that results from not including a substitute measure is not known. As discussed in Caulkins et al. (1983), there are two possible effects of not including a substitute term. If the substitute and distance variables are positively correlated, the omission of substitutes would bias the benefit estimate downward whereas the value estimate would be biased upward. The sign of the bias on the value estimate is not known.

Mean per capita personal income for county/state groups was also tested as a variable because economic theory indicates income influences ability to purchase trips to a recreation site. Income entered strongly into the analysis with a negative coefficient, possibly indicating elk hunting is an inferior good. This term does not imply inferior in quality or in any social sense; it merely refers to the relationship between quantity demanded and income. Without specific income and hunting preference data for each respondent, it is not possible to determine the degree, if at all, to which elk hunting can be considered an "inferior good" relative to other more expensive and time-consuming recreational activities such as bighorn sheep or mountain goat hunting.[5] It is also possible that as income rises, a different form of elk hunting is demanded, such as limited hunt permits in remote areas that involve a longer hunt using more specialized and expensive equipment.

Regression Analysis

In performing the regression analysis, choices regarding functional form and inclusion of variables became obvious as the analysis progressed. The variables that were consistently insignificant were generally dropped from further consideration. The issue of functional form is not so easy to determine. Several models are proposed in the literature.

Ziemer et al. (1980), Vaughan and Russell (1982), and Strong (1983) argue that because of the pattern by which trips per capita falls off at greater distances, the natural log of visits per capita is preferred to either a linear func-

[4]*Those site quality variables tested but found to be insignificant in regression analysis included total animals seen, hunters per square mile in 1981, harvest per square mile, total animals seen per day, average number of days hunted, average number of hours hunted, and hunter days per square mile.*

[5]*Goods for which purchases rise with income are "normal goods." Goods for which purchases fall as income rises are called "inferior goods."*

tional form or natural log of distance. Their point is that either of the latter two functional forms will predict negative visits for a few high-cost origins. Negative visits are contrary to intuition and, thus, the natural log of visits per capita functional form is preferable.

Bowes and Loomis (1980) argue that unequal sizes of population groups require a weighting factor that is the square root of population to avoid heteroskedasticity (heterogeneous variances), thereby improving both benefit and use estimates. Vaughan and Russell (1982) and Strong (1983) show that if the log of visits per capita is chosen as the functional form, heteroskedasticity will be so greatly reduced that weighting by square root of population may be unnecessary.

Both methods were tested in this study. A judgment criterion involved comparing estimated visits to actual sampled visits. If estimated visits were fairly close to actual visits, the natural log of visits per capita was used rather than Bowes-Loomis weighting, which provides exact use estimation of predicted visits and sampled visits. The settlement of this trade-off depends on whether use or benefit estimation is the critical factor of the study objective. In this study, benefit estimation was most critical.

Calculation of TCM Benefits

To calculate benefits with distance as the price variable using the second stage demand curve approach, distance must be converted to dollars. Travel costs to a site consist of transportation costs and travel time costs. Travel time is included because, other things remaining equal, the longer it takes to get to a site, the fewer visits will be made. That is, time, because it is often a limiting factor, acts as a deterrent to visiting more distant sites. Omission of travel time will bias the benefit estimates downward (Cesario and Knetsch 1970, Wilman 1980).

The value of travel time was set at one-third of the wage rate as prescribed by the U.S. Water Resources Council (1979, 1983). This is the mid-point of values of travel time that Cesario (1976) found in his review of the transportation planning literature. However, the use of one-third the wage rate is not necessarily intended to measure wages forgone during the time spent traveling, but rather the deterrent effect of scarce time on which hunt units to visit. Because direct data on hunter income were not collected, this study used the U.S. Department of Labor's estimate of a median wage of $8.00 per hour. One-third of this is $2.67 per hour, so an average opportunity cost of time spent traveling was about $0.67 per mile.

Conversion of round-trip mileage to transportation costs progressed in three steps. First, mileage was converted to transportation cost on a per vehicle basis using the variable automobile costs from the U.S. Department of Transportation (1982). An intermediate-size car class was taken as typical, at a cost of $0.135 per mile in 1982. A mileage figure for pickup trucks was not reported. Second, with approximately 2.7 hunters per vehicle, this standard cost per person was approximately $0.05 per mile.

Finally, the transportation cost also was estimated using the cost per mile reported by survey respondents rather than the standard cost per mile of $0.135. Respondents reported their own trip transportation costs which, when divided by round-trip distance, equaled approximately $0.313 per mile or $0.12 per mile per hunter. This may be a more appropriate value to use because it is the price perceived by the respondent. That is, the quantity of trips consumed would probably be more closely related to the perceived cost rather than some standardized cost. Additionally, the Department of Transportation figure used reflected costs of suburban driving with an intermediate size car. Elk hunting may often involve use of a four-wheel-drive pickup, often with a camper shell. Roads traveled would rarely resemble suburban driving. These considerations would raise the transportation costs above that of an intermediate-size car. The net effect is to now associate the quantity of trips made with a higher price per trip ($0.05 vs. $0.12), which translates into a rightward shift in the upper portion of the second stage demand schedule. This shift results in an increase in total and, therefore, per trip consumer surplus. To provide the most useful information for valuation of Idaho elk hunting and to allow comparison to other studies, net willingness to pay is calculated and presented in the results using both standardized and reported cost. For a given increment in distance or added miles, the transportation cost and value of travel time for the amount of time required to travel that distance increment is added together. This rescales the vertical axis of the second stage demand curve from miles to dollars. The area under the second stage demand curve yields estimated consumer surplus for the sample.

Contingent Value Method

The mean net willingness to pay was calculated once missing values, outliers, and infinite bids were removed. Consider first the data collected in 1983 for the 1982 hunting season. When asked if a trip was worth more, 88.8% indicated yes. Any bid greater than $1,000 was screened as a possible outlier. This involved looking at the respondent's origin, hunt unit visited, number of hours hunted, and number of days hunted. Based on these variables, a subjective decision was made as to the validity of the bid. Of the seven bids over $1,000, three were judged to be invalid. These bids were more than $6,000 for a two-day trip. The bids reported in the results section may be an underestimate of true value because 39.5% of respondents placed an infinite value on elk hunting at the site they hunted. If these individuals could have been questioned further and a value elicited, the result may have been to increase the overall mean. Further, for elk hunting in Wyoming, Sorg (1982) found a significant difference between initial bids and final iterative bids, indicating those bids obtained without using the iterative bidding procedure may be an underestimate of true value.

A CVM iterative bidding technique was used in 1984 to collect willingness to pay information for the 1983 elk hunting season. No outliers were found for willingness to pay for current conditions or willingness to pay for double the number of elk seen per trip. The trip was worth more to 91.5% of the respondents. In addition, use of an iterative bidding procedure resulted in only 6% of the respondents placing an infinite bid on hunting at the site in question. The willingness to pay bids reported for the 1983 season are, therefore, more reliable.

Data collected on number of animals seen on the trip were used to segregate individual bids into groups; in this study, bids were separated into the following groups: 0 elk, 0–5, 5–10, 10–15, 15–20, 20–30, 30–40, 40–50, 50–100, and more than 100 elk. This gave an indication as to whether bids vary by number of elk seen.

RESULTS AND DISCUSSION

Table 2 presents a summary profile of the data collected in the hunter survey for the TCM and CVM analyses. These mean values will be used in discussions and tables throughout the remainder of the report to convert net willingness to pay per trip to standard accounting measures such as net willingness to pay per day or per WFUD.

Figure 3 presents an elk hunt unit map that shows the type of season available in each hunt unit. This map will prove useful when differentiating values across units. For example, in the Panhandle area a general rifle permit allows hunting for both antlered and nonantlered elk. All other areas in the state allow antlered hunting only. Also notice the units that permit only archery hunts. The values for these sites as compared to general rifle season may prove useful to management.

Travel Cost Method

As discussed earlier, choice of functional form of the per capita demand equation was related to how well the log of visits per capita reduced heteroskedasticity. The weighted regression equation resulted in neither substitutes nor quality measures being statistically significant. The log of visits per capita did minimize heteroskedasticity to the extent that estimated visits to the hunting units were 2,851 while actual visits were 3,636. The estimated visits were within 25% of the actual. For building a Regional Travel Cost Model for valuation of different hunt areas, it may be more important to have quality and income variables present in the equation rather than to sacrifice them to improve the use estimate.

The regression equation used to calculate benefits for elk hunting is given in equation [2]:

$$\begin{array}{lll} \ln(\text{Trpcap}) = -3.1102 & -0.0016\text{Dist} & \\ \text{“t” statistics } (-7.13) & (-24.12) & \\ -0.0009924\text{Inc} & +0.001049\text{Tharv} & [2] \\ (-14.09) & (3.45) & \end{array}$$

where

Trpcap = total trips per capita
Dist = round-trip distance in miles
Inc = county (group) mean per capita income
Tharv = total harvest in hunt unit for 1981.

This equation is highly significant overall with an F-value of 398.33 and an R^2 value of 0.69.

The model specified in equation [2] is termed log-linear because the dependent variable is transformed as shown and the independent variable associated with cost, i.e., distance, is not transformed.

As discussed earlier, no measure of substitute sites was found significant in the regression analysis. While total harvest in 1981 proved significant in measuring quality at a particular unit, a measure of this variable does not provide a measure of what constitutes a substitute unit. For example, two equally distant units with the same total harvest may not be substitutes because one has a much later season or one does not have a developed camping area. Therefore, while total harvest does play a significant role in measuring quality at a unit, it does not show how hunters substitute across sites. Data outside this set may provide this information. Variables that could provide a measure of substitutes may include geographic characteristics, family tradition, or remoteness. Without a measure of substitute units, the values reported here are an overestimate or underestimate of elk hunting consumer surplus. How much of an overestimate or underestimate is not known. The TCM

Table 2.—Elk hunter profile.

	1983		1984	
	Mean	Sample Size	Mean	Sample Size
Number of elk seen per trip	4.50	3862	8.98	335
Number of hunters per vehicle	2.70	3860	3.12	424
Number of days hunted per trip	2.84	3862	4.10	426
Number of hours hunted per day	7.05	3862	7.46	426
Round-trip distance	244.16	3862	—	—
Total expenditures	$76.47	3862	—	—
Dollars spent on travel	$37.73	3862	$92.33	423
Dollars spent on food	$22.47	3862	$84.02	406
Dollars spent on accommodations[1]	$42.60	102	$86.22	56
Dollars spent on guides[1]	$1026.68	57	—	—

[1]*Only those people using the service entered into calculation of the mean.*

Figure 3.—Map of Idaho elk hunting units showing season permit types for 1983

values can be compared to the CVM values as an indication of the direction and magnitude of the bias. If the 1982 and 1983 seasons are similar, the 1983 CVM values may be the most representative because they were collected using standard methodology. The sensitivity intervals discussed below provide a range of values to consider.

The resulting per capita demand curve was used to derive a second stage demand curve for each elk hunting unit. The second stage demand curve was calculated for each hunt unit using the total harvest in 1981 as the quality measure and mean county (group) per capita income. Successive 100-mile increments were added to the distance variable until visits per capita from a particular origin were reduced to 0.1 or until distance equaled the highest regularly observed distance in the data. The highest regularly observed distance was a 5,000-mile round-trip from Florida. This occurred in five cases. This distance limit was used as a cutoff because, with natural log of visits per capita, visits would never drop to zero. This procedure of using highest observed distance as an upper limit was used first by Wennergren (1967) and since then by others (Smith and Kopp 1980). This rule yields a conservative estimate of the surplus because it cuts off a portion of consumer surplus; however, in this application only five areas had an added distance greater than 5,000 and therefore little consumer surplus was lost.

Figure 4 illustrates the second stage demand curve for the most heavily visited unit, unit 4, in the Panhandle region. Because the distance increment is over and above current distance, the entire area under this curve (when distance is converted to dollars) is consumer surplus. A simple conversion of the added distance to dollars cannot be made on the graph because the conversion of

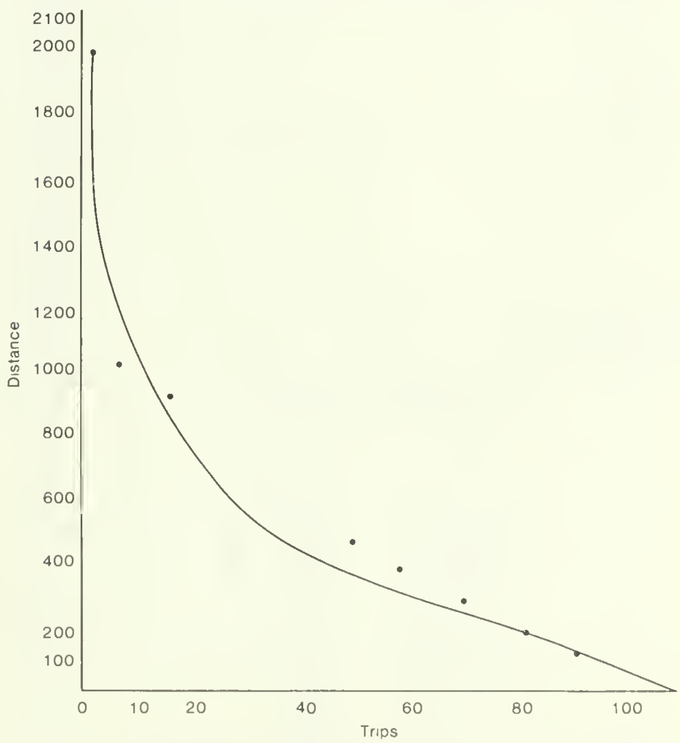

Figure 4.—Second stage demand curve for unit 4, Panhandle region

distance to travel cost for a given site was made origin by origin to account for differences in the number of hunters per vehicle. The unit total consumer surplus of those 2.1% individuals sampled is $7,327.79 using the standard cost of $0.135 per mile. Putting this on a per trip basis gives a value of $64.90. With the reported transportation cost of $0.313 per mile, the unit consumer surplus of those 2.1% sampled is $11,472.22, yielding a consumer surplus per trip of $101.61.

Table 3 reports average TCM values over all hunting units. These values represent the average value for an elk hunting trip to an average unit in the state, not the average value for elk hunting in the state as a whole (i.e., the value of a trip to an average unit with all other units available).

Contingent Value Method

Table 4 reports average CVM values over all hunt units. As with the average TCM value, the CVM average state value is willingness to pay for an average unit in the state with all other units available, not average willingness to pay for elk hunting in the state as a whole. If the elk hunting seasons for 1982 and 1983 are nearly identical, the difference in trip values can be explained by the open-ended iterative technique and high infinite bid response rate found in 1982. Alternatively, changes in management or increased hunting success or improved quality in the 1983 elk hunting season may be reflected in the 1983 value. On a per day basis, the values are much closer. Because no major changes were made in elk season management, it is assumed that differences in techniques and infinite bid response rates account for the discrepancies. As a result, the 1983 values are more theoretically correct.

In addition to asking a willingness to pay for current conditions, the survey for the 1983 season asked willingness to pay if the individual could expect to see double the number of elk per trip. Respondents indicated a willingness to pay $149.39 per trip for doubling the number of elk seen. This is a useful tool to management. Even though elk hunters can only bag one animal, they still prefer to see more elk per trip. Perhaps seeing more elk gives more choice as to which one to kill or merely adds to the trip enjoyment.

To show a trend in willingness to pay bids, hunters were grouped according to number of elk seen per trip. These bids are shown on table 5. In general as number of elk seen increased, willingness to pay also increased. This is especially true for 0–15 elk and generally true for more than 15 elk. Hunters may have a threshold of the number of elk they would like to see on a trip, and may not be willing to pay more above this threshold. Obviously the threshold level varies across hunters, but the general trend shown in table 5 should be useful to managers.

Comparison of TCM and CVM Values

Comparison of TCM and CVM values will focus on trip values to allow comparison of state average values and

Table 3.—Average elk hunting values from the Travel Cost Method.

	Standard cost per mile[1]	Reported cost per mile[2]
Net willingness to pay per trip for current conditions	[3]$63.17	[4]$99.82
Number of days hunting per trip	2.84	2.84
Net willingness to pay per day for current conditions	$22.26	$35.18
Number of hours hunted per day	7.05	7.05
Net willingness to pay per WFUD for current conditions	$37.88	$59.87
Expenditures per trip	$76.47	$76.47

[1]*Standard cost per mile of $0.135.*
[2]*Reported cost per mile of $0.313.*
[3]*Sensitivity interval: $57.86 to $69.40.*
[4]*Sensitivity interval: $89.67 to $111.52.*

Table 4.—Average elk hunting values from the Contingent Value Method.

	1982	1983
Net willingness to pay per trip for current conditions	$52.84[1]	$92.54[2]
Number of days hunting per trip	2.84	4.10
Net willingness to pay per day for current conditions	$18.25	$22.57
Number of hours hunted per day	7.05	7.46
Net willingness to pay per WFUD for current conditions	$31.06	$36.31
Number of animals per trip	—	8.98
Net willingness to pay per trip for double number of elk seen	—	$149.39

[1]*95% Confidence interval: $45.44 to $58.24.*
[2]*95% Confidence interval: $72.31 to $112.78.*

Table 5.—CVM average elk hunting values based on number of elk seen per trip. (Numer of respondents in parentheses)

Number of elk seen per trip	Net Willingness to pay per trip 1983		1984	
0	$ 29.24	(735)	$ 49.88	(86)
1-5	52.02	(554)	70.19	(133)
6-10	$ 65.12	(199)	130.85	(41)
11-15	104.86	(91)	191.82	(22)
16-20	93.64	(36)	120.91	(11)
21-30	113.75	(36)	193.85	(13)
31-40	204.69	(13)	181.79	(14)
41-50	76.67	(15)	139.29	(7)
51-100	321.89	(9)	578.57	(7)
>100	156.40	(5)	1000.00	(1)

region average values. Figure 5 presents a graphic comparison of the mean state TCM and CVM values and their associated sensitivity and confidence intervals. The mean 1983 CVM willingness to pay value for the 1982 season is $51.84 with a 95% confidence interval from $45.44 to $58.24. The mean 1983 CVM willingness to pay value is $92.54 with a 95% confidence interval from $72.31 to $112.78. The mean TCM willingness to pay using standard cost is $63.17 with a sensitivity interval of $57.86 to $69.40. Using reported cost, the mean TCM willingness to pay is $99.82 with a sensitivity interval of $89.67 to $111.52. The reported cost TCM sensitivity interval crosses the 1984 CVM confidence interval indicating the two measures are comparable.

Collection of the 1982 CVM data utilized a combination of open-ended and iterative survey design. While not conclusive, studies (Rahmatian 1982 and Sorg 1982) indicate use of an open-ended survey format may result in an underestimate of maximum willingness to pay. The results of the 1983 survey substantiate this conclusion. Also, in reference to the 1982 season CVM survey design, a disproportionately larger number of respondents (39.5%) indicated an infinite bid and, therefore, were not included in estimating the overall mean willingness to pay. Only 6% placed infinite bids in 1983. The combination of noniterative and infinite bids may have resulted in the 1982 CVM value being an underestimate of true willingness to pay. The 1983 CVM values are more theoretically correct.

An important variable in the TCM regression analysis is a substitute site term. This variable shows the effect on a particular site value when there are other sites that could be visited in place of that site. For some hunting activities, such as bighorn sheep, there may not be substitute sites or substitute site may be so few that their effect on value is negligible. In the case of the Idaho elk hunting where there are at least 40 other sites available as alternatives to a particular site, not including a substitute term in the regression may result in an overestimate or underestimation of value. Several substitute variables were tested; however, none was found significant in the regression analysis. As a result, the TCM reported cost values may be an overestimate or underestimate of willingness to pay.[6] However, in this study TCM and CVM values are theoretically equivalent; therefore, the values measured by each should be similar. This is the case, based on confidence and sensitivity interval comparisons, which indicates omission of the substitute term has not greatly biased TCM value estimation.

Table 6 reports TCM and CVM values by region, area, and unit, as defined by Idaho Department of Fish and Game Elk Species Management Plan (1980).[7] The value for each unit is conditioned by the fact that it is part of a system of all other units. That is, the value at one unit is contingent on the availability of all other units. When comparing across units, it is more reliable to compare

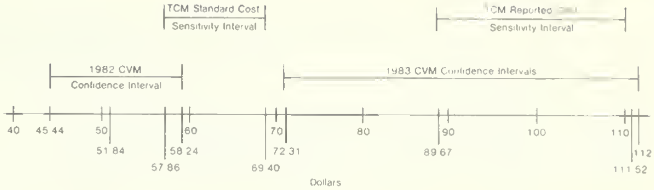

Figure 5.—Comparison of TCM and CVM dollar value estimates for elk hunting

across areas or regions rather than individual units because, at the individual unit level, unit-specific data has a smaller sample size and, therefore, a larger degree of error. For example, the two regions with the highest TCM values are regions 1 and 6. Region 1 is the only region with an either sex hunt and, as the results indicate, this a more highly valued resource.

CVM values by hunt unit, area, and region in table 6 show that for 1982, region 6 has the highest value, followed by region 2. For 1982, regions 3 and 2 have the highest values.

Human population centers are located in the southwest portion of the state, therefore the most accessible hunting is located in region 3. The close proximity to human populations while still not within these centers translates into a highly valued resource. Because the cost of obtaining the resource is low, benefits are high. A more remote elk hunting resource is found in region 2. The remoteness of this region may be more important to some hunters; therefore, the high value reflects this factor rather than the accessibility factor.

Comparison to Other Elk Studies

Hansen[8] (1977) utilized CVM to derive the value of elk hunting in a region comprising Idaho, western Wyoming, Utah, and Nevada. Data were taken from the 1975 U.S. Fish and Wildlife Service Hunting and Fishing Survey. The mail survey format was noniterative and open-ended. Respondents were asked how much more they would be willing to spend before not engaging in elk hunting. A value of $22.63 per visitor day is reported. Adjusted to 1982 this value is $36.37. Except for the mail format, the survey technique used by Hansen is similar to this study. Hansen's value is lower; however, it is a regional value that includes Utah and Nevada. If elk hunting in Idaho is of higher quality when compared to Utah and Nevada, the difference in values is explained. Further, use of a noniterative bid format may account for the lower value.

Sorg (1982) measured the value of elk hunting in Wyoming utilizing CVM. The survey was in-person iterative and asked willingness to pay additional expenditures before forgoing elk hunting at the hunt unit in question. A value of $92.00 per day for resident hunters is reported. This value is similar to the reported cost TCM value and the 1983 CVM value and slightly larger than the 1982 CVM value. This would indicate Wyoming and Idaho offer a similar resource or attract a similar

[6] *It should be noted that this discussion has no effect on the choice between reported and standard cost per mile, which is a separate issue.*

[7] *Idaho Department of Fish and Game. 1980. Elk, 1981–1985. Species Management Plan. 91 p.*

[8] *Hansen, Christopher. 1977. A report on the value of wildlife. Intermountain Region, U.S. Forest Service, Ogden, Utah. December 1.*

Table 6.—Average elk hunting values from TCM and CVM by region, area, and unit. (Sample size in parentheses)

Hunting site—Area Unit	Travel Cost Method		Contingent Value Method			Average total cost/hunter-trip						Average no./hunter-trip			
	Standard cost/mile NWTP	Reported cost/mile NWTP	1983 NWTP for current conditions	1984 NWTP for current conditions	1984 NWTP for double no. elk seen	Total cost	Travel	Food	Motel	Guide	Sample size	Elk seen/ trip	Hunters/ vehicle	Days hunting	Hours/day hunting
REGION 1															
Area 1															
1	$57.57	$86.50	$27.38 (21)	$38.00 (5)	$57.00 (5)	$16.49	$10.86	$5.63	–	–	99	0.82	1.78	2.25	5.10
2	51.28	78.28	0 (4)	–	–	12.42	9.63	2.79	–	–	19	3.11	2.56	2.74	5.32
3	56.32	91.60	11.33 (43)	26.11 (9)	28.88 (9)	21.58	16.08	5.50	–	–	78	1.35	2.55	2.45	7.00
5	39.10	59.34	33.00 (1)	23.33 (3)	60.00 (3)	34.54	15.36	19.18	–	–	11	2.82	3.00	1.64	6.18
Total	54.26	83.29	15.87 (69)	29.12 (17)	42.65 (17)	18.99	12.95	6.04	–	–	207	1.34	2.21	2.34	5.89
Area 2															
4	64.90	101.61	21.21 (225)	87.71 (24)	103.96 (24)	30.51	17.62	12.83	28.00 (1)	–	456	1.39	2.71	2.15	6.66
6	62.82	95.24	21.21 (102)	122.22 (18)	152.77 (18)	29.85	18.74	11.04	20.00 (1)	–	289	0.88	2.78	2.26	6.47
7	69.22	117.69	69.98 (45)	133.33 (12)	270.61 (11)	105.27	54.69	45.13	75.00 (1)	350.00 (1)	78	2.45	3.21	5.06	7.26
9	82.57	60.96	286.38 (8)	–	–	186.77	71.77	61.15	–	700.00 (1)	13	3.31	3.23	5.54	6.77
Total	68.36	109.54	32.57 (380)	109.35 (54)	155.58 (53)	39.68	22.31	15.97	41.00 (3)	525.00 (2)	836	1.34	2.79	2.51	6.65
TOTAL	66.55	106.16	30.00 (449)	90.14 (71)	128.43 (70)	35.67	20.45	14.00	41.00 (3)	525.00 (2)	1043	1.34	2.67	2.48	6.50
REGION 2															
Area 1															
8	48.04	74.53	14.73 (96)	–	–	14.30	10.65	3.65	–	–	170	0.67	2.30	1.57	7.19
8–A	37.84	60.96	21.76 (37)	9.44 (9)	36.57 (9)	24.35	15.36	8.99	–	–	108	1.90	2.21	1.95	6.57
9–A	97.73	183.89	38.00 (2)	–	–	258.34	151.67	106.67	–	–	3	4.33	2.33	4.33	5.67
10	57.21	84.27	57.84 (141)	172.67 (30)	239.50 (30)	84.73	40.53	22.88	29.50 (14)	1055.37 (7)	366	5.56	2.88	3.18	6.53
10–A	67.58	107.12	13.71 (45)	33.75 (4)	122.50 (4)	29.33	18.91	10.42	–	–	114	2.48	2.50	2.01	6.78
12	63.93	103.30	326.31 (42)	60.00 (16)	87.80 (15)	286.64	109.63	68.29	34.90 (10)	959.71 (7)	65	8.31	2.91	6.17	7.31
15	53.29	83.73	46.49 (69)	97.50 (10)	151.00 (10)	65.14	35.96	18.42	56.80 (5)	852.50 (2)	185	5.11	2.66	2.91	7.09
16	64.97	102.26	153.55 (11)	85.00 (4)	127.50 (4)	207.05	91.39	42.89	15.50 (2)	930.50 (2)	26	4.23	3.00	4.27	7.27
Total	60.69	95.11	66.97 (443)	105.14 (73)	157.01 (72)	73.54	35.75	19.71	34.74 (31)	981.85 (18)	1037	4.09	2.64	2.83	6.84
Area 2															
11–A	58.15	80.24	29.50 (2)	40.00 (1)	50.00 (1)	18.86	11.07	7.79	–	–	14	1.43	1.57	1.57	2.79
Area 3															
16–A	45.20	61.83	130.36 (11)	125.00 (4)	200.00 (4)	453.94	91.39	42.89	16.00 (3)	676.67 (3)	18	4.23	3.00	4.27	7.27
17	48.82	71.12	297.77 (31)	175.33 (15)	302.33 (15)	665.02	247.02	139.05	24.58 (12)	1013.55 (11)	41	4.76	3.51	7.37	8.20
19	55.01	83.05	68.20 (5)	50.00 (1)	75.00 (1)	162.90	105.80	49.10	80.00 (1)	–	10	5.00	2.70	5.20	8.10
20	54.42	84.94	148.57 (7)	610.00 (3)	1110.00 (3)	383.51	149.38	99.13	80.00 (1)	500.00 (2)	8	7.25	3.25	12.13	6.63
Total	54.43	76.80	223.07 (54)	217.83 (23)	380.00 (23)	512.31	216.66	113.94	29.59 (17)	886.25 (16)	77	5.71	3.34	7.13	7.91
TOTAL	57.83	86.76	83.72 (499)	129.50 (109)	204.91 (108)	103.42	47.79	25.99	32.92 (48)	936.86 (34)	1128	4.17	2.67	3.12	6.86

Table 6.—Average elk hunting values from TCM and CVM by region, area, and unit.—Continued

Hunting site— Area Unit	Travel Cost Method: Standard cost/mile NWTP	Travel Cost Method: Reported cost/mile NWTP	Contingent Value Method: 1983 NWTP for current conditions	Contingent Value Method: 1984 NWTP for current conditions	Contingent Value Method: 1984 NWTP for double no. elk seen	Average total cost/hunter-trip: Total cost	Average total cost/hunter-trip: Travel	Average total cost/hunter-trip: Food	Average total cost/hunter-trip: Motel	Average total cost/hunter-trip: Guide	Sample size	Average no./hunter-trip: Elk seen/ trip	Average no./hunter-trip: Hunters/ vehicle	Average no./hunter-trip: Days hunting	Average no./hunter-trip: Hours/day hunting
REGION 3															
Area 1															
19-A	56.55	92.86	42.61 (18)	105.00 (4)	130.00 (4)	64.82	40.27	24.55	-	-	33	2.09	2.82	3.61	6.94
20-A	61.46	96.74	296.00 (15)	705.00 (6)	1126.67 (6)	882.33	276.86	115.57	50.77 (9)	1228.88 (8)	21	11.38	3.00	6.52	8.86
25	59.23	96.41	32.84 (37)	125.00 (4)	135.00 (4)	53.57	31.80	21.39	25.00 (1)	-	66	1.64	2.50	2.59	7.41
26	44.53	65.16	313.70 (10)	56.67 (6)	245.00 (6)	412.69	111.50	52.81	37.00 (2)	1950.00 (2)	16	25.81	3.19	7.69	7.69
Total	57.09	90.24	119.49 (80)	274.50 (20)	464.50 (20)	226.52	81.07	40.40	84.42 (12)	1373.10 (10)	136	6.10	2.74	4.04	7.55
Area 2															
22	87.17	157.05	13.96 (27)	42.00 (5)	56.00 (5)	57.40	34.82	22.58	-	-	33	3.18	2.33	2.49	7.06
23	51.78	80.46	32.70 (10)	162.50 (4)	362.00 (4)	34.89	16.89	18.00	-	-	26	6.39	3.00	2.81	7.73
24	58.16	91.78	30.14 (36)	36.00 (5)	104.00 (5)	42.49	23.49	18.35	21.00 (2)	-	65	3.92	2.62	2.37	6.86
31	64.54	102.56	12.25 (4)	-	-	46.66	31.83	14.83	-	-	6	2.67	2.50	3.00	8.00
32-A	64.40	107.35	13.40 (5)	41.67 (3)	83.33 (3)	28.91	17.23	11.68	-	-	22	2.77	2.23	2.09	6.77
33	69.21	116.53	41.73 (11)	25.00 (3)	35.00 (3)	39.48	22.91	16.57	-	-	21	2.76	2.71	3.48	8.00
34	75.46	131.46	18.67 (6)	230.00 (5)	249.00 (5)	63.63	44.13	19.50	-	-	16	7.13	2.50	3.56	7.81
35	48.41	67.02	72.33 (3)	75.00 (2)	130.00 (2)	177.33	96.33	56.00	75.00 (1)	-	3	0.33	3.00	4.67	6.00
39	59.64	94.59	45.78 (37)	63.33 (9)	101.11 (9)	35.34	20.68	14.66	-	-	87	4.67	2.47	2.21	7.49
Total	65.98	109.35	31.56 (139)	86.39 (36)	153.33 (36)	42.77	24.95	17.40	39.00 (3)	-	279	4.24	2.55	2.54	7.31
TOTAL	62.77	102.44	63.68 (219)	155.83 (54)	273.70 (54)	102.99	43.34	24.94	75.33 (15)	1373.10 (10)	415	4.85	2.61	3.03	7.39
REGION 4															
Area 2															
(48)	0	0	6.00 (1)	-	-	6.00	3.00	3.00	-	-	1	0	1.00	1.00	10.00
Area 3															
(49)	55.85	85.44	1.00 (1)	-	-	13.00	8.00	5.00	-	-	1	0	3.00	1.00	5.00
Area 4															
45	46.27	76.95	-	-	-	30.00	20.00	10.00	-	-	1	0	2.00	2.00	7.00
52	48.49	75.31	20.43 (7)	-	-	23.57	8.57	15.00	-	-	7	38.86	2.86	1.86	7.00
TOTAL	50.10	78.32	16.67 (9)	-	-	21.40	9.10	12.30	-	-	10	27.20	2.60	1.70	7.10
REGION 5															
Area 2															
66-A	50.68	72.10	148.00 (7)	30.00 (4)	52.50 (4)	123.20	75.50	47.70	-	-	10	5.70	3.90	4.10	8.00
76	48.76	81.35	8.75 (4)	22.50 (4)	36.25 (4)	25.27	16.40	8.87	-	-	15	2.33	1.80	1.27	5.27
75	57.19	92.13	40.88 (25)	10.00 (2)	43.50 (2)	30.46	20.33	10.13	-	-	39	3.26	2.77	1.54	7.36
77	56.92	84.22	19.00 (7)	10.00 (1)	20.00 (1)	12.23	7.36	4.87	-	-	31	1.84	5.13	1.26	7.36
78	34.51	50.68	525.00 (1)	43.33 (3)	43.33 (3)	51.86	23.29	28.57	-	-	7	6.29	2.57	4.14	7.14
TOTAL	53.26	81.55	62.52 (44)	24.69 (16)	38.56 (16)	34.71	21.42	13.29	-	-	102	3.14	3.44	1.84	7.10

Table 6.—Average elk hunting values from TCM and CVM by region, area, and unit.—Continued

Hunting site—Area Unit	Travel Cost Method		Contingent Value Method			Average total cost/hunter-trip						Average no./hunter-trip			
	Standard cost/mile NWTP	Reported cost/mile NWTP	1983 NWTP for current conditions	1984 NWTP for current conditions	1984 NWTP for double no. elk seen	Total cost	Travel	Food	Motel	Guide	Sample size	Elk seen/ trip	Hunters/ vehicle	Days hunting	Hours/day hunting
			REGION 6												
Area 1															
21	53.21	82.68	141.11 (9)	71.88 (8)	90.63 (8)	124.03	67.31	48.59	130.00 (2)	–	32	12.28	2.41	3.94	3.69
21-A	72.90	126.02	99.80 (10)	134.00 (5)	154.00 (5)	86.72	44.23	25.71	20.00 (1)	500.00 (1)	31	6.00	2.81	3.65	7.42
28	50.93	79.14	43.11 (27)	30.00 (5)	30.00 (5)	58.49	32.56	20.12	110.33 (3)	–	57	3.79	2.14	2.67	6.68
36	63.69	106.60	485.00 (31)	283.33 (3)	373.00 (3)	87.00	50.91	35.83	14.00 (1)	–	54	2.48	2.32	3.54	7.98
36-B	55.45	83.13	202.00 (10)	43.75 (8)	56.25 (8)	80.77	48.07	31.22	40.00 (1)	–	27	2.67	2.44	3.74	8.00
Total	60.44	98.25	235.48 (87)	89.48 (29)	110.86 (29)	83.93	46.91	31.23	83.13 (8)	500.00 (1)	201	4.98	2.37	3.40	7.32
Area 2															
29	38.49	63.65	–	0 (1)	0 (1)	28.33	17.33	11.00	–	–	6	0	2.83	4.83	2.33
30	44.35	73.69	7.20 (5)	50.00 (1)	150.00 (1)	58.22	37.78	20.44	–	–	9	8.00	2.78	3.11	6.33
50	81.14	134.94	–	–	–	295.00	157.00	93.00	45.00 (1)	–	1	3.00	2.00	1.00	10.00
Total	70.13	116.59	7.20 (5)	17.50 (6)	54.17 (6)	61.81	37.56	21.44	45.00 (1)		16	4.69	2.75	3.63	5.06
Area 4															
27	50.88	79.16	292.38 (24)	58.33 (6)	64.33 (5)	215.62	80.49	30.59	27.20 (5)	1037.50 (4)	41	3.46	2.68	3.73	8.20
51	69.02	119.20	31.57 (7)	–	–	72.33	47.33	25.00	–	–	9	9.22	2.44	3.11	7.56
58	54.53	81.41	–	55.00 (2)	232.50 (2)	155.50	68.00	87.50	–	–	2	18.50	3.00	4.50	8.00
59	82.74	147.54	49.11 (9)	0 (1)	0 (1)	55.00	36.10	18.90	–	–	29	10.48	2.41	1.79	8.69
59-A	54.60	86.76	–	41.25 (4)	102.50 (4)	110.00	75.00	35.00	–	–	2	19.00	2.50	4.00	9.00
Total	61.49	101.52	41.44 (16)	39.29 (7)	125.00 (7)	66.12	41.88	24.24	–	–	42	11.00	2.45	2.31	8.43
Area 5															
60	62.74	93.25	27.20 (44)	60.63 (24)	93.54 (24)	68.84	39.52	29.16	7.00 (2)	–	88	5.82	2.81	2.61	7.48
61	61.52	97.05	44.60 (165)	35.50 (30)	72.33 (30)	62.00	38.19	23.24	34.60 (5)	–	302	11.42	2.68	2.63	8.02
62-A	59.66	100.04	30.25 (12)	46.00 (5)	68.00 (5)	77.00	48.41	27.50	24.00 (1)	–	22	9.86	3.41	3.00	7.86
Total	62.21	94.69	40.36 (221)	46.61 (59)	80.59 (59)	64.26	39.02	24.73	26.38 (8)		412	10.14	2.74	2.64	7.90
Area 6															
62	62.07	99.42	11.50 (8)	5.00 (2)	12.50 (2)	52.84	27.69	24.36	22.00 (1)	–	13	4.00	3.54	2.62	7.85
64	62.94	96.83	6.33 (6)	10.00 (2)	25.00 (2)	24.18	16.47	7.71	–	–	17	1.53	3.00	1.41	7.24
65	70.47	117.13	170.00 (2)	5.00 (3)	5.00 (3)	70.29	49.29	21.00	–	–	7	6.00	3.00	2.86	8.14
67	61.63	95.50	40.08 (13)	11.00 (5)	42.00 (5)	47.28	29.36	17.92	–	–	25	6.36	2.88	2.16	7.64
Total	63.75	100.93	34.17 (29)	8.33 (12)	25.00 (12)	44.71	27.73	16.63	22.00 (1)	–	62	4.50	3.07	2.13	7.63
Area 7															
66	93.10	164.28	53.35 (48)	41.43 (14)	84.64 (14)	88.43	37.33	30.74	33.33 (3)	825.00 (2)	84	7.43	2.99	2.70	7.01
69	59.40	94.47	42.00 (18)	20.00 (3)	38.33 (3)	48.78	27.97	20.81	–	–	32	7.47	2.91	2.56	7.44
Total	88.66	155.07	50.26 (66)	37.65 (17)	76.47 (17)	77.49	34.75	28.00	33.33 (3)	825.00 (2)	116	7.44	2.97	2.66	7.13
TOTAL	67.91	110.42	92.48 (448)	46.73 (133)	78.96 (132)	76.09	41.48	26.25	45.35 (26)	900.00 (7)	890	7.87	2.69	2.83	7.64

hunter population. Hypotheses could be formulated and tested in each state. If similarities were found, it might then be possible to extrapolate this data to other states offering a similar resource.

Applications

To evaluate the economic efficiency of multiple-use trade-offs associated with elk habitat, the net economic value per WFUD should be utilized. As a simple example, suppose the wildlife biologist estimates that elk populations would double if habitat improvements were made in a portion of the state. Further, assume there is a demand for additional elk hunting opportunities. The biologist, recreation planner, and economist could then translate this doubling in elk populations to an increase in elk available for harvest. Once the increase in elk available for harvest is known, the theoretically correct way to calculate the additional long-run benefits of this change is to use this new level of available harvest as a shift in the demand curve. When the number of elk available for harvest increases, it is assumed that the demand curve shifts. This can be seen in figure 6 as the shift from D_1 to D_2. The increase in number of elk will be translated (in TCM) into existing hunters taking more trips and the nonhunters entering (or reentering) to become hunters because of the increased quantity. The theoretically correct benefits of these additional 500 trips (and hence an estimate of the change in benefits due to improved quality) is equal to the shaded area between the demand curves. This value is a long-run value because allowance was made for entry of new hunters in response to the increase in elk numbers. The assumption is made that congestion will not be a factor that causes benefits to decrease.

In field studies it is often difficult for biologists to have access to the original data, per capita demand curves for each site, and a program to calculate benefits with quality-induced demand shifts. Often the biologist will be able to translate the increase in population into an increase in supply of hunting trips. The economic benefit of the added trips that there is a demand for can be approximated by multiplying the increase in trips by the average net value per trip. For figure 6, suppose there are an additional 500 elk hunting trips per year. This 500 elk trips at a net willingness to pay of $100.00 per trip would yield annual benefits of $50,000. This would be compared to the economic costs of implementing habitat improvements. These costs may take the form of prescribed burns, restricted timbering, or reduced cattle grazing.

If the hunters' net willingness to pay (as revealed hypothetically by the $50,000) for the additional hunting trips is greater than the costs associated with habitat improvements, economic efficiency is improved by the management action.

Evaluations of benefits of increased elk populations do not necessarily flow only from more hunter days. In the short run, an increase in harvestable elk may benefit current hunters only. CVM questions asked in the survey can be used to estimate the increase in value to current users. By increasing elk populations, the demand curve for the elk resource shifts up to the right, leading to a higher value per day. These added benefits or marginal benefits can be calculated by taking the area between these two demand curves, holding number of trips constant. In terms of figure 6, the benefits being calculated here represents just the area between the demand curves for the current 500 trips (area ABCD). Continuing this example, if when elk populations double, the number of elk seen by existing hunters also doubles, then the CVM values can be used to calculate the area ABCD. Doubling the number of elk seen, would, according to the CVM results, increase the value of the existing 500 trips by about $57.00 per trip. This results in an increased value of $28,500 for doubling elk seen by existing hunters. However, this represents a little more than half the total long-run benefits.

These added values can be useful in evaluating changes in elk harvest regulations or resource actions that will change the total number of elk harvested or the type of elk harvested. Decisions made by integrating the economic values into project analyses of timber sales, grazing allotment management, right-of-way design, and habitat restoration investments will result in a more equitable use of valuable resources.

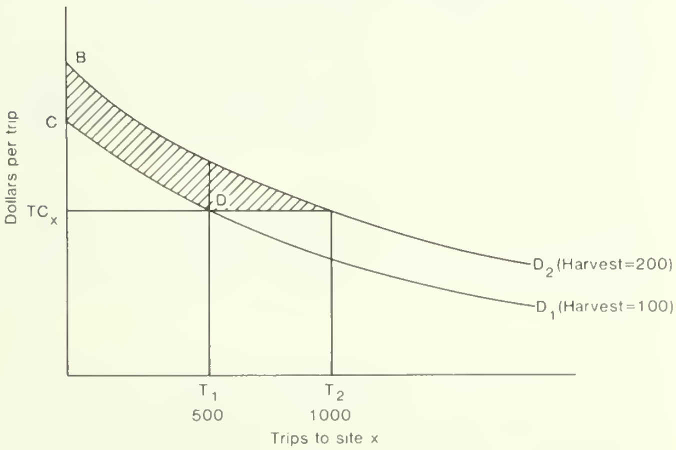

Figure 6.—Site demand curve for elk hunting

CONCLUSIONS

In deriving recreational values for elk hunting in Idaho, both methods used in this study—the Travel Cost Method and the Contingent Value Method—were based on the entire hunting season; therefore, it is possible to compare results. The study showed that, if the 1982 and 1983 elk hunting seasons are similar, then the average CVM value of a trip for 1983 ($92.54) is nearly identical to the reported cost TCM value ($99.82).

The TCM values using reported transportation costs are probably more accurate in the case of elk hunting than the standard cost TCM value ($63.17). Suburban driving in a mid-size car is reflected in the standard transport cost; however, in the case of elk hunting, pickup trucks on dirt roads may be more typical. The reported cost for these vehicles would reflect these higher costs while the standard cost would not.

With TCM, substitute sites may be statistically significant variables, as shown by regression analysis. In this study, the RTCM per capita demand curve included statistically significant variables on distance, income, and site quality; however, no tested measure of substitute sites was found significant.

Both TCM and CVM have advantages and disadvantages when used in this study. The main advantages of CVM include the ease of data analysis for calculating the mean willingness to pay and ability to value discrete changes in the resource setting. Data analysis based on CVM is often straightforward and involves little analysis time. This, however, assumes a solid questionnaire design that specifies an appropriate payment vehicle, incorporates a protest mechanism, and presents individuals with a realistic, carefully designed situation on which to bid. Although not a factor in this elk hunting study, managers are often faced with valuing recreation that is nonprimary purpose and nonprimary destination in that individuals visit a location in conjunction with other locations. In such cases, TCM cannot be implemented and CVM offers the best method to value these users. Additionally, managers may want to know the effect of incremental quality changes on recreation value. If several quality alternatives are feasible, CVM can be easily implemented to measure the benefit of alternative scenarios. The primary disadvantages of CVM are not only the necessity to have the expertise to design an appropriate questionnaire, but the cost of collecting an adequate sample.

The primary advantages of TCM relate to its reliance on actual behavior and the ability to use existing data. A major criticism of CVM relates to the hypothetical nature of the survey, and as a result TCM is often more desirable. Often cost prohibits collection of extensive primary data; therefore, if origin-destination data already exist in the form of permits or license plates numbers, etc., then TCM would become more cost-effective than CVM in valuing recreation activities.

Perhaps the biggest practical disadvantage of TCM is the time it takes to construct a Regional Travel Cost Model. Data aggregation, computing additional variables, selecting variables for regression, and selection of the value of travel time is time-consuming. Once a statistically significant regression is found, calculation of a second stage demand curve and sensitivity intervals involves little additional work. However, it involves specialized computer programs. Thus, benefit estimation involves more time, computer knowledge, and statistical expertise than is necessary for CVM.

Choice of CVM or TCM involves many considerations: type of user to be sampled, availability of secondary data, expertise in questionnaire design, statistical and computer knowledge, and the research budget, to name a few. No method is superior in all cases; for each case, a determination will need to be made as to which method is preferable.

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APPENDIX

Marginal and Average Consumer Surplus—Conditions of Equality

The objective of the proof is to show that average benefits are equal to marginal benefits in relation to the per capita (stage I) demand curve. The means to accomplish this is to derive the mathematical expression for the benefits in each case and to show these are equal. The conditions under which this is true are:

1. Demand relationships between visits per capita and price (cost of travel) can be validly modeled with a semi-log functional form such as

$$\ln(q) = a - bp \qquad [A1]$$

or equivalently,

$$q = e^{a-bp} \qquad [A2]$$

where q is quantity, in this case, visits per capita
p is price, in this case, travel cost
a is the intercept parameter
b is the slope parameter

2. The only shifting variables allowed in the equation affect the intercept. No slope shifting variables are in the equation.
3. A slight relaxation of condition 2 occurs if there are slope shifting variables but they do not change from the "before" to the "after" states.
4. Each origin is a price taker in that people from that origin may visit the site as many times as they desire at their current travel cost. Therefore, the supply curve facing a given origin is horizontal. Due to differences in location from the site, each origin faces a different horizontal supply curve.

The "Before" State

Figure A-1 shows the overall scope of the changes considered in the proof. At equilibrium in state 1, i.e., the "before" state, the demand curve has a quantity intercept of e^{a_1} when price is zero. As price increases, quantity decreases and asymptotically approaches zero for very large p. For a price of p_1, visits per capita to a site from a specific origin are q_1.

Total benefits per capita that accrue to the presence of the site, given all other existing sites, are represented by the shaded area labeled CS_1 (consumer surplus in state 1). This area is found by integrating under the demand curve and above the price line p_1.

Let a small segment of the area, dCS, be

$$dCS = q\,dp \qquad [A3]$$

as shown in figure x.

Then

$$CS = dCS = \int_{p_i}^{p} q\,dp \qquad [A4]$$

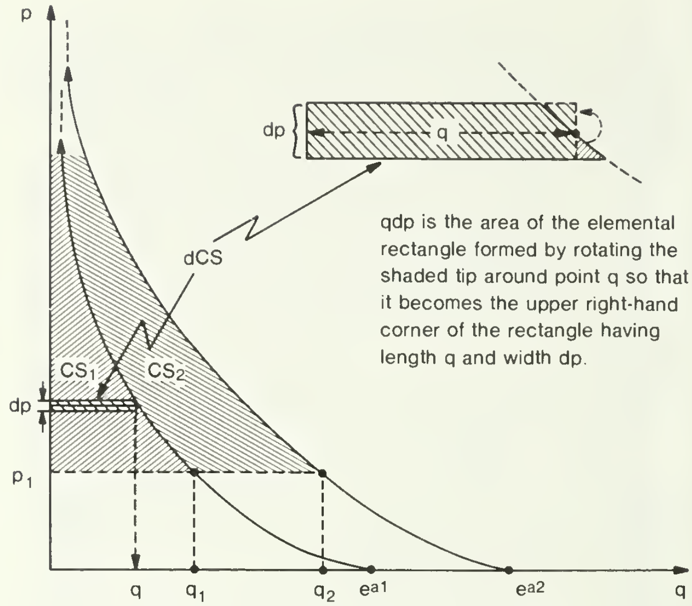

Figure A-1.—Changes in consumer surplus.

The limits of integration define the lower boundary of the CS area, the p_1 price line, and the upper boundary of the CS area, the point where p goes to infinity and q goes to zero. In spite of these extreme values, it turns out the CS area is finite.

Substitute for q from equation [A2] in the integral in equation [A4] giving

$$CS_1 = \int_{p_i}^{p} e^{a_1 - b_1 p}\,dp \qquad [A5]$$

where the subscript 1 denotes state one ("before"). Continuing with the integration gives

$$CS_1 = e^{a_1} \int_{p_1}^{p} e^{-b_1 p} dp = -\frac{1}{b_1} e^{a_1 - b_1 p} \Big]_{p_1}^{p} \qquad [A6]$$

Evaluating the expression in [A6] at the limits of integration gives

$$CS = -\left(\frac{1}{b_1} e^{a_1 - b_1 p}\right) - \left(-\frac{1}{b_1} e^{a_1 - b_1 p_1}\right) \qquad [A7]$$

$$CS_1 = \frac{1}{b_1}\left(e^{a_1 - b_1 o_1} - e^{a_1 - b_1 p}\right) \qquad [A8]$$

In order to include the entire area under the demand curve, let p (not p_1) become infinitely large, ($\rightarrow \infty$). For large p

$$e^{a_1 - b_1 p} = q \rightarrow 0 \qquad [A9]$$

so that the expression for CS in [A8] becomes

$$CS_1 = \frac{1}{b_1}\left(e^{a_{21} - b_1 p_1}\right) = \frac{q_1}{b_1} \qquad [A10]$$

Average consumer surplus in state one per trip made (q_1) is

$$\overline{CS}_1 = \frac{CS_1}{q_1} = \frac{1}{b_1}\left(e^{a_1 - b_1p_1}\right)\frac{1}{q_1} \qquad [A11]$$

But $e^{a_1 - b_1p_1}$ is q_1, so [A12]

$$CS_1 = \frac{1}{b_1}$$

Thus, average consumer surplus per trip in state one, the "before" state, is simply the inverse of the slope parameter from the demand equation, assuming the conditions previously stated are met.

The "After" State

Now assume that managers of the recreational sites under consideration wish to increase the attractiveness of the specific site, for example, by increasing the number of animals or fish potentially harvestable. This new condition becomes the "after" state.

The new attractiveness at the site increases the intercept to e^{a_2}, but does not affect the slope coefficient b, as we have assumed, so $b_1 = b_2 = b$, (i.e., quality is an intercept shifter only). Using the result of the previous section, that, in general under the stated conditions,

$$CS = \frac{1}{b}\left(e^{a-bp}\right) = \frac{q}{b} \qquad [A13]$$

and placing the subscript (2) for the "after" state on the variables, total per capita consumer surplus for the "after" state is

$$CS_2 = \frac{1}{b_2}\left(e^{a_2 - b_2p}\right) = \frac{q_2}{b_2} \qquad [A14]$$

Note that "after" average CS is also $\frac{1}{b_2} = \frac{1}{b}$.

The total change in consumer surplus from the "before" to the "after" state is

$$\Delta CS = CS_2\ CS_1 \qquad [A15]$$

$$\Delta CS = \frac{q_1}{b_2} - \frac{q_2}{b_1} \qquad [A16]$$

But, as noted, $b_2 = b_1 = b$, so

$$\Delta CS = \frac{q_2 - q_1}{b} \qquad [A17]$$

The marginal change per unit increase in trips is defined as

$$\frac{\Delta CS}{\Delta q} = \frac{\frac{q_2 2_1}{b}}{q_2 - q_1} \qquad [A18]$$

So

$$\frac{\Delta CS}{\Delta q} = \frac{1}{b} \qquad [A19]$$

And since $b = b_1 = b_2$, combine the results of the derivation of "before" average consumer surplus and the derivation of the marginal consumer surplus caused by the change to the "after" state.

Thus,

$$\overline{CS}_1 = \frac{1}{b} = \frac{\Delta CS}{\Delta q} = CS_{marg} = \overline{CS}_2 \qquad [A20]$$

and the proof is complete given that the preceding conditions are met.

Note in the proof that the relationship in equation [A20] does not depend on the price level even though figure x shows price unchanging. Neither do the key equations for "before" and "after" consumer surplus, equation [A10] and [A14], respectively. Under the stated conditions, there may or may not be a price change along with the demand curve shift. Regardless, it does not affect the equality between the "before" average consumer surplus and the "before" - to - "after" marginal change in consumer surplus. Moreover, the price may change in either direction without affecting the results.

Therefore, with this functional form multiplying the average consumer surplus of a trip or WFUD by the change in trips or WFUDs due to one of the three factors discussed above will result in an exact estimate of the area between the demand curve associated with that change in trips or WFUDs. This is a result specific to this functional form. Therefore, if the field analyst has an idea of change in trips associated with some management action, the analyst can calculate an estimate of the change in economic efficiency benefits associated with that change in days without having to shift the second stage demand curve.

Sensitivity Intervals

The estimate of net willingness to pay is the end result of a series of mathematical and statistical operations on the aggregated data. One item of interest about estimated net willingness to pay is the sensitivity of this estimate to variation within the travel cost data. This variation is initially seen in the computed statistical confidence interval associated with the estimate of each coefficient of the visit-per-capita regression model.

Conceptually, this variation is carried through all the steps described previously, including formation of the second stage demand curve and the subsequent integration under it. Thus, it is logical to talk about variation associated with estimated net willingness to pay.

However, the confidence interval estimates of net willingness to pay are not yet completely developed. Despite this, certain aspects of sensitivity may reveal information about the variability of benefit estimates. Specifically, for this research, a "sensitivity interval" was defined. This interval, for estimated benefits measured by willingness to pay, describes the upper and lower bounds of the benefit estimate when the regression coefficient of distance is varied to the upper and lower bounds of its confidence interval.

For example, the computer program that calculates benefits is run three times—once with the distance coefficient at its best unbiased level, once with it at the lower level of its 95% confidence interval, and once with the distance coefficient at the upper level of its 95% confidence interval. The three estimates of benefits related to elk hunting respectively indicate how benefits vary with respect to variation in the coefficient associated with distance. Distance was chosen specifically because increased increments of this independent variable measure additional cost hypothetically incurred by hunters. In this bulletin, these sensitivity intervals are compared to the confidence intervals derived from the contingent valuation. This comparison is not a statistical procedure, but it provides an indication of the relative ranges in estimates produced from each method.

Elk Hunting Survey Questionnaire

Tag Type ____________
Tag No. ____________

Continue if this person did hunt ____________ in 1982

In addition to getting hunter success, the Department and the University of Idaho are asking a sample of hunters to answer questions to help determine the value of Idaho's ____________
elk, deer

Can you please tell me how many ____________ hunting trips you made and to what units ____________ in 1982?

Unit No.	Drainage or general area	Counting yourself, no. people in your vehicle with ____ tags.
1.		
2.		
3.		

Now, I would like some specific information about each trip:

(Ask separately about each trip even if to some area more than once.)

Did you visit more than one unit on your trip (or 1st, 2nd, 3rd trip) to unit ______. If so, how many other units (list) __________ __________ __________ __________ .

Did you drive the entire distance to where you went hunting in unit ______? Total distance traveled round trip __________.

If no, what different type of transportation did you use?

car small plane airline horses jet boat back pack other

____

How many days did you hunt on this trip to unit (to nearest ½ day) ____________ and average number of hours spent hunting per day ____________.

Now, please estimate the total amount you spent on this trip for:

Transportation ____________________

Food ____________________

Motel-hotel ____________________

Guide Services ____________________

Do you feel this trip to unit ______ was worth more than you actually spent __________?

(If no, stop - if yes, go on to next question)

One final question about this trip:

The cost of everything is increasing. How much would the trip cost have to rise above what you spent this year before you would not hunt ____________ in unit ____________ again? $ ____________.

Sorg, Cindy F., and Louis J. Nelson. 1986. Net economic value of elk hunting in Idaho. USDA Forest Service Resource Bulletin RM–12, 21 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Net willingness to pay for elk hunting in Idaho was estimated at $63.17 per trip and $99.82 per trip using a standard cost per mile travel cost method and a reported cost per mile travel cost method, respectively. Using the contingent value method, the values for the 1982 and 1983 elk hunting seasons were $51.84 per trip and $92.54 per trip, respectively. Willingness to pay was greater for double the number of elk seen on a trip. Methods, results, and applications are fully described.

Keywords: Travel Cost Method, Contingent Value Method, elk hunting, Idaho, economic efficiency, expenditures

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Rocky
Mountains

Southwest

Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526