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The Colville Study: Wood Utilization for Ecosystem Management

Preliminary Results of Study of Product Potential From Small-Diameter Stands

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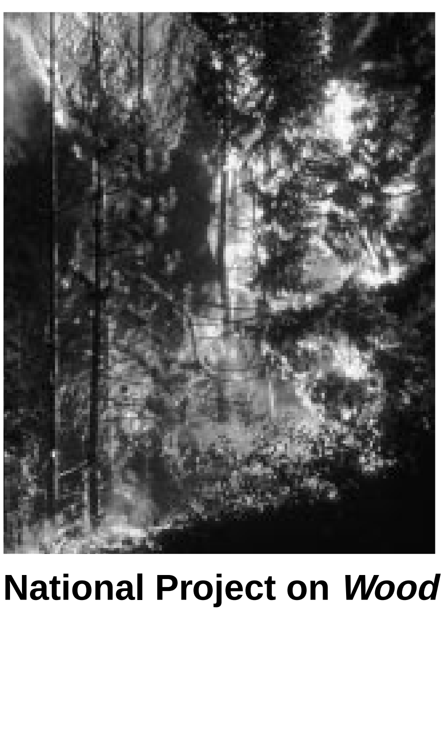

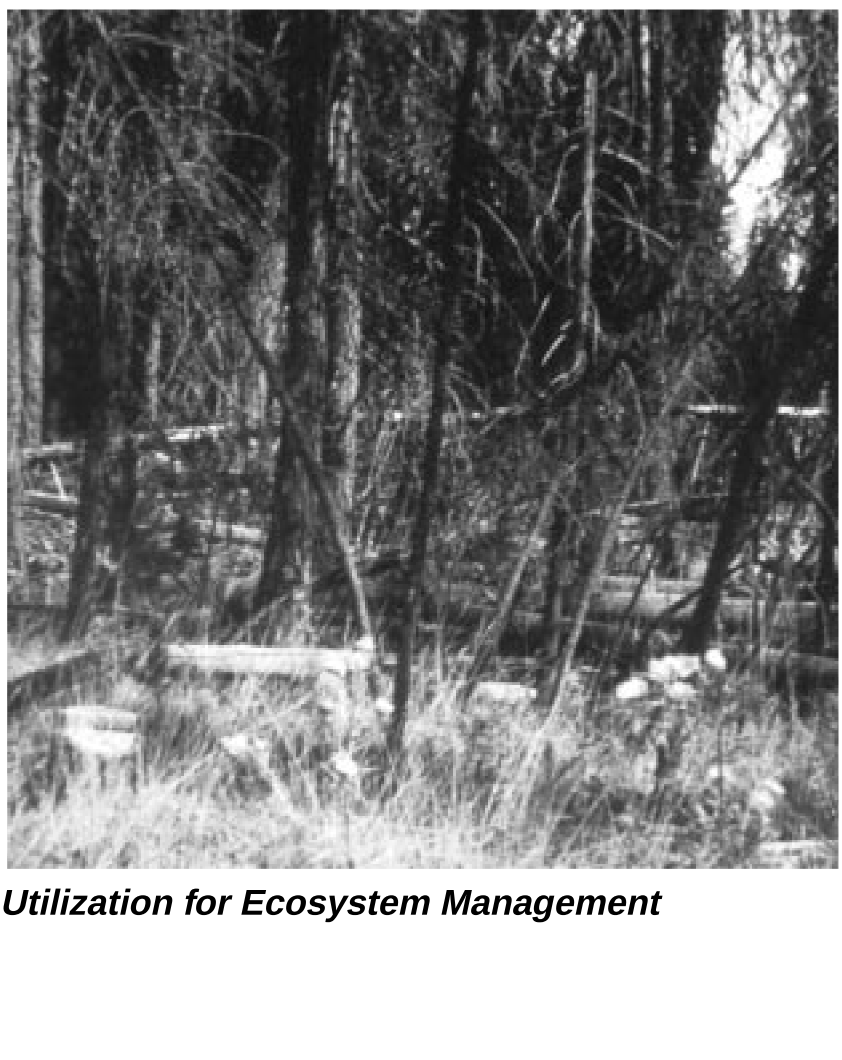

National Project on *Wood Utilization for Ecosystem Management*

Abstract

The Colville Study was developed in 1994 to identify and evaluate a series of management options for achieving ecosystem objectives in dense stands of small-diameter trees while also producing wood products. The Colville National Forest selected the Rocky II Timber Sale as an example of this type of stand that needed management to achieve the following goals: (1) create late successional forest structure, (2) decrease forest health risk from fire, insects, and disease, (3) improve wildlife habitat by providing large green trees and snags, and (4) improve stand aesthetics by decreasing stand density. The Colville Study was divided into four technical focus areas: Silviculture and Ecology, Forest Operations, Timber Conversion, and Economics. Results of each technical focus area indicate that (1) vegetative management activities are necessary to achieve the ecosystem goals, (2) there are alternative harvesting systems for removing the timber in an ecologically sound manner but costs need to be considered, (3) both species and material size are important in the recovery of wood products, and (4) financial analysis needs to incorporate all of these factors and many more to effectively evaluate the relative merchantability of different types of treatments.

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Introduction

The Colville Study was developed in 1994 to identify and evaluate a series of management options for achieving ecosystem objectives in dense stands of small-diameter trees while also producing wood products. These stands are common in forests of the Intermountain West and east of the crest of the Cascade Range in Oregon and Washington. Many of these stands originated after stand replacement fires, where natural regeneration was abundant and self-thinning was minimal. Traditionally, these stands have been marginal for economic operations and have been left alone while stands with larger trees have been harvested.

A recent survey of 110,000 acres (44,550 ha) of small-diameter stands conducted by the Colville National Forest (CNF) (Fig. 1) provided a good basis for considering various management options (Colville National Forest 1994). The CNF selected the Rocky II Timber Sale as an example of the type of stands that needed management to achieve the following goals:

- create late successional forest structure,
- decrease forest health risk from fire, insects, and disease,
- improve wildlife habitat by providing large green trees and snags, and
- improve stand aesthetics by decreasing stand density.

The stands on this sale were characterized by high densities of trees <9 in. (<22.9 cm) diameter at breast height (dbh), which commonly consisted of lodgepole pine (*Pinus contorta* Dougl. ex Loud), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), western larch (*Larix occidentalis* Nutt.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), often with a thick understory of grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) and western redcedar (*Thuja plicata* Donn ex. D. Donn).

Study Team

The Colville Study team originally consisted of researchers from the Pacific Northwest (PNW) Research Station and the Forest Products Laboratory of the USDA Forest Service and from Oregon State University in cooperation with the CNF. The study has been expanded to include a host of partners and cooperators, including Boise Cascade Corporation, Vaagen Brothers, Riley Creek Lumber Company, University of Washington, University of Idaho, Washington State University, and Idaho Panhandle National Forest. This study is part of a National Research Project on Wood Utilization for Ecosystem Management coordinated by the Forest Products Laboratory and funded in part under a Forest Service Five-Year Ecosystem Research Initiative (Skog and others 1995).

Figure 1—Approximate location of Colville National Forest, the sawmill (Priest River, ID), the veneer plant (Kettle Falls, WA), and cooperating laboratories and universities.

Technical Focus Areas

The Colville Study is divided into four technical focus areas: Silviculture and Ecology, Forest Operations, Timber Conversion, and Economics.

Silviculture and Ecology

The objective of the Silviculture and Ecology technical focus area is to project the development of the selected small-diameter stands over 150 years under various silvicultural regimes. The resulting stand conditions are then evaluated to determine the extent to which the regimes improve wildlife habitat, increase structural diversity, and reduce the risk of insect and disease attack (Ryland 1996).

Stand exam data provided by the CNF were sorted into four hypothetical stand types by combining plots with similar overstory species:

- western larch/Douglas-fir
- western larch/lodgepole pine
- western redcedar
- mixed

On average, these stands had 5,300 trees/acre (tpa) (13,090 trees/ha (t/ha)) that were <4 in. (<10.2 cm) dbh; 290 tpa (717 t/ha) between 4 and 10 in. (10.2 and 25.4 cm) dbh; and 20 tpa (49 t/ha) >10 in. (>25.4 cm) dbh. The Inland Empire variant of the Forest Vegetation Simulator (FVS) was used to model the effects of no treatment and four silvicultural regimes over time in the hypothetical stands. The silvicultural regimes were (1) group selection, (2) single tree selection, (3) thinning, and (4) clearcut with green tree retention.

Not every prescription was applied to every stand. Rather, prescriptions were applied to stands where the initial conditions suggested that treatment might be feasible. Timber production was a secondary consideration for this project. The primary objectives were to speed development of healthy stands better able to support wildlife, to improve aesthetics, and to develop structural and biotic diversity. The timing and intensity of harvests were constrained to be reasonably cost-effective and practical to implement. Intolerant species were favored for retention and regeneration.

Criteria to judge the success of treatments were developed in accordance with the goals developed by CNF personnel and with regard to the Eastside Screening Process for timber sales in Forest Service Region 6 (R-6), the Eastside Forest Ecosystem Health Assessment (Everett and others 1994), and the CNF Forest Plan (USDA Forest Service 1988). The criteria were somewhat constrained by the types of output data available through the FVS. The following criteria were determined to be important:

- Stand structure—Stands should contain large-diameter early seral trees.
- Wildlife habitat—Stands should contain large-diameter (>16 in. (>40.6 cm) dbh) snags for cavity excavators, and average overstory height should be > 40 ft (> 12 m), with 60% crown cover for hiding and thermal cover for deer.
- Forest health—Site quality, host abundance, canopy structure, and total canopy cover are important factors for modeling risk of fire, insects, and disease.
- Stand aesthetics—Stands should maintain western larch for fall color, hardwoods for species diversity, and some areas with minimal visual evidence of vegetative management.

The modeling exercise illustrated that changes in the pattern and rate of stand development could be induced through silvicultural treatment to create desired ecological features and generate timber outputs.

The most evident change was in the development of large-diameter trees. Unthinned stands rarely had any 20-in. (50.8-cm) dbh trees, even after 150 years. Alternatively, thinning or other more intensive treatments resulted in a large number of 20-in. (50.8-cm) dbh trees within 50 years and several trees >30 in. (>76.2 cm) dbh within 100 years. These large-diameter trees could be killed or otherwise treated to encourage rapid development of snags or decay within green trees, thereby increasing cavity nesting habitat. The large trees are also valuable for timber. Thermal and hiding cover were maintained for white-tail deer (*Odocoileus virginianus*) in all scenarios. Without more intensive treatments, such as group selection or clearcutting, shifts in species composition toward more shade-tolerant species occurred, and shade-intolerant western larch was relatively difficult to maintain in the stand. In general, activities that improved individual tree vigor (e.g., thinning of existing stands, establishment of new vigorous trees) and encouraged the presence of intolerant, early seral species led to a lower risk rating for insects and disease. The simulations illustrate the effects of varying degrees of disturbance (Table 1) and suggest that meeting stated ecosystem objectives will require some form of intervention.

Table 1—Characteristics of western larch–Douglas-fir from Rocky Timber Sale for initial stand conditions and results of 50-, 100-, and 150-year simulations

Treatment[a]	Year	Trees >10 in./acre (>25.4 cm/ha)	Max dbh in. (cm)	No. of species	No. of canopy layers	Snags/acre (hectare)	Deer habitat[b]	Nesting habitat[b]	Insect/disease rating[c]
None	1991	27 (67)	17.9 (45.5)	8	5	0	Y	N	M/L/L
	2041	53 (131)	19.9 (50.5)	9	5	0	Y	N	M/M/L
	2091	64 (158)	19.9 (50.5)	9	6	0	Y	N	M/M/L
	2141	57 (141)	21.9 (55.6)	9	6	1 (2.47)	Y	N	M/M/L
Thinning	2041	110 (272)	19.9 (50.5)	7	6	1 (2.47)	Y	N	M/L/L
	2091	92 (227)	31.9 (81.0)	7	6	2 (4.94)	Y	N	M/M/L
	2141	90 (222)	35.9 (91.2)	6	6	5 (12.4)	Y	Y	M/M/L
CC–GTR	2041	21 (52)	29.9 (76.0)	8	5	0	Y	N	H/L/L
	2091	126 (311)	33.9 (86.1)	6	6	1 (2.47)	Y	N	M/M/L
	2141	114 (282)	37.9 (96.3)	5	6	3 (7.41)	Y	N	H/M/L
Group	2041	112 (277)	25.9 (65.8)	9	6	1 (2.47)	Y	N	H/M/L
selection	2091	115 (284)	31.9 (81.0)	6	6	3 (7.41)	Y	N	M/M/L
	2141	153 (378)	35.9 (91.2)	5	6	6 (14.8)	Y	Y	M/M/L

[a]CC–GTR is clearcut with green tree retention.
[b]Yes or no.
[c]Spruce budworm or Douglas-fir tussock moth/root disease/dwarf mistletoe ratings. L is low; M, medium; H, high.

Forest Operations

The objective of the Forest Operations technical focus area is to evaluate harvesting alternatives for various silvicultural prescriptions and to provide information on the costs and productivity of different harvesting systems. The CNF specified harvesting systems for various units on the Rocky II Timber Sale with the goals of (1) minimizing soil degradation in the forms of disturbance, compaction, and rutting, and (2) minimizing damage to the residual stand. Work was performed cooperatively by the PNW Research Station, the CNF, the University of Idaho, the University of Washington, and Vaagen Brothers (purchaser of the Rocky II Timber Sale).

A "cut to length" (CLT) system was required on some units. This system processes the trees at the stump, thereby leaving nutrients on site for recycling and minimizing nutrient drain. The system also places limbs and needles on the path created by the harvester; this material acts as a cushion for the equipment and minimizes soil compaction during thinning. Since only processed logs are taken to the landing, most nutrients remain on the site, where they are well-distributed in the mat; the resulting fuels are compacted and present only a minor fire hazard after 1 or 2 years. McNeel and Ballard (1992) evaluated the impact of a CLT system in western Washington forests and found that less than 5% of the stand was negatively impacted. A low proportion of the sale area was used by equipment and compacted as trails (<7% heavily traveled and <14% lightly traveled), and the spacing between trails was a constant 82 ft (25 m). While there was some minor soil compaction in the trails, it was not enough to significantly affect tree growth.

Cut-to-length systems are expensive and the matter of cost is important. Can a CLT system operate profitably in small-diameter stands where the removed timber has low value? The harvester handles single stems in up to 1.5 min/stem depending on tree size, but only 34% of the time is actually spent processing. Barbour and others (1995) showed that changes in average stand diameter of as little as 0.5 in. (1.3 cm) can result in large differences in harvesting cost and wood product value.

Four units on the Rocky II Timber Sale were analyzed (Table 2). Predicted costs for harvester production based on these data are shown in Figure 2. The relationship depicted in Figure 2 shows that the cost of production for the harvester declined rapidly with increasing tree size for trees between about 6 in. (15.2 cm) dbh (0.2 tons (0.18 tonnes) per tree) and about 9.5 in. (24.1 cm) dbh (0.40 tons (0.36 tonnes) per tree). For practical purposes, the relationship becomes constant for trees larger than about 10 in. (25.4 cm) dbh.

This relationship has implications for the field forester. As average stand diameter drops below 10 in. (25.4 cm) dbh, potential buyers face increasing difficulty in operating profitably on sales when harvester–forwarder systems are specified. The exact point where operations become unprofitable in these stands depends on factors besides diameter, such as prevailing market conditions, stand characteristics and topography, sale lay-out, and species mix. The potential ecological advantages offered by alternative systems needs to be weighed against the increased costs associated with CLT systems.

Timber Conversion

The main objective of the Timber Conversion focus area is to explore the range of existing and potential products that can be manufactured from the small-diameter resource. Products evaluated included lumber, veneer, composites, pulp, and engineered products. Information on lumber and veneer volume recovery was developed for Douglas-fir, western larch, and lodgepole pine trees (8 to 14 in. (20.3 to 35.6 cm) dbh). Quality of both lumber and veneer was determined by visual and mechanical grading. Recovery of chips for pulping (mechanical and chemical processing) and of flakes for composites was established for the three species from several sources of material: (1) sawmill residuals, (2) tree tops and

Table 2—Summary of unit characteristics for harvested component for Rocky Timber Sale and estimated production and costs for harvester operation on thinning units

				Net weight				Cost (US$)	
Unit	Area (acres (ha))	Mean dbh (in. (cm))	Stand density (per acre (ha))	Tons (tonnes) per tree	Tons/acre (tonnes/ha)	Machine type[a]	Productivity (ton/MH[b] (tonne/MH))	Per MH	Per ton (tonne)
3	128 (51.8)	6.2 (15.7)	231 (571)	0.195	45.15	FMG 990	6.88 (6.24)	68.08	9.90 (8.98)
				(0.177)	(101.2)	KB1	8.89 (8.06)	54.66	6.08 (5.51)
12	47 (19.0)	7.2 (18.3)	145 (358)	0.230	33.35	FMG 990	6.83 (6.20)	68.08	9.97 (9.04)
				(0.209)	(74.76)	KB2	6.83 (6.20)	54.66	8.00 (7.26)
14	13 (5.3)	9.3 (23.6)	127 (314)	0.399	50.67	FMG 990	15.38 (13.9)	68.08	4.43 (4.02)
				(0.362)	(113.5)	KB2	14.65 (13.2)	54.66	3.73 (3.38)
18	81 (32.8)	6.6 (16.8)	198 (489)	0.270	54.05	KB1	8.80 (7.98)	54.66	6.21 (5.63)
				(0.245)	(121.2)	KB3	9.62 (8.72)	54.66	5.68 (5.15)

[a]FMG 990 is a harvester produced by the Forest Machine Group (FMG) in 1980s. KB1, KB2, KB3 are hybrid harvesters using a Kobelco 5142 type carrier (tracked excavator base) with a Keto 150 harvester head.
[b]MH is machine hour or 1 h of machine operation.

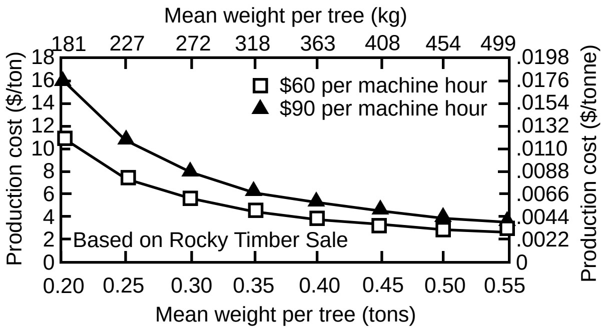

Figure 2—Harvester costs for thinning treatments on Rocky II Timber Sale.

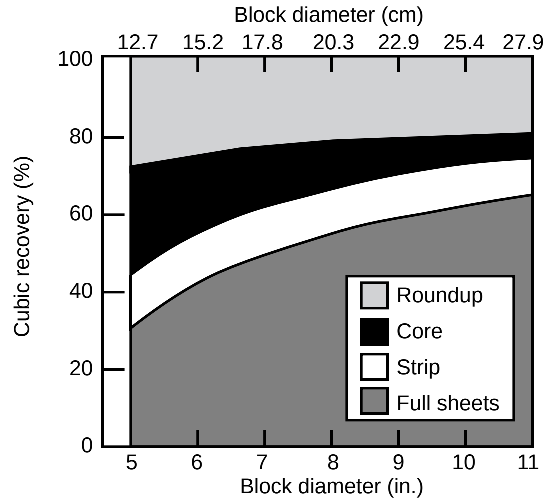

Figure 3—Distribution of products from processing of western larch blocks into veneer. Roundup is material lost to chips during rounding a conical log into a cylinder.

trees considered too small for lumber or veneer (<8 in. (<20.3 cm) dbh), and (3) logs generally considered unmerchantable for lumber and veneer (<5 in. (<12.7 cm)).

Several tree or log characteristics, in addition to size, are important in determining product quality and value. These characteristics include species, specific gravity, size and distribution of knots, taper, growth rate, and defect. Initial results showed significantly reduced specific gravity of Douglas-fir (15% to 20% less than established standards in the *Wood Handbook* (Forest Products Laboratory 1987)). These results have implications for the suitability of this wood for various products. For lumber and veneer, lower specific gravity indicates material with lower stiffness; for composites, it could indicate lower processing costs; and for pulp, it could result in different fiber properties.

Veneer

Fifteen Douglas-fir and 19 western larch trees were selected for processing into veneer. The sample ranged from 8 to 14 in. (20.3 to 35.6 cm) dbh, and the average age was roughly 70 years. The trees were bucked tree-length to a 3-in.- (7.6-cm-) diameter top. Veneer blocks (102 in. (2.59 m) long) were manufactured from the tree-length logs up to a 5.5-in. (14-cm) small-end diameter, and the smaller tops were used for tests on composites. The blocks were marked for identification and then steamed in preparation for peeling. They were peeled into 0.164-in. (0.42-cm) veneer, which was color coded with dye to maintain the block identity. The veneer was dried, graded (C or D), tallied, bundled, and sent to Washington State University for testing for laminated veneer lumber (LVL).

Tree height is a significant factor in the production of veneer because it limits the number of blocks recoverable from a tree. To hold the blocks in the lathe, the logs must be 8.5 ft (2.6 m) long. In this mill, the smallest diameter block that could be transferred from the x–y charger to the lathe was 5.5 in. (14 cm). Since the Douglas-fir tree sample was on average 20 ft (6.1 m) shorter than the western larch sample, we recovered more blocks from western larch than Douglas-fir trees of the same diameter.

Veneer recovery (full sheet and strip) increased with block diameter (Fig. 3). For a given size block, no difference was found between Douglas-fir and western larch in the total recovery of veneer. However, more full sheets were produced from small-diameter western larch logs than from Douglas-fir. The core was a constant 3.9 in. (9.9 cm) in diameter; the proportion of the block volume remaining as core decreased as the block size increased. Because the veneer was graded for C and D grades only, the value per diameter followed the same pattern as that of veneer recovery. Results of mechanical testing for stiffness for LVL production are forthcoming.

Lumber

Twenty trees of each species (lodgepole pine, Douglas-fir, and western larch) were selected for processing into lumber. The logs were bucked into sawmill lengths and scaled for volume. They were then sawn into 1- and 2-in. (2.5- and 5-cm) lumber, 11% and 89% respectively.

There was no significant difference in volume recovery for the different species (Fig. 4). Value recovery based on visual lumber grades was quite different between the lodgepole pine and Douglas-fir–western larch samples (Fig. 5). The major difference was in the recovery of higher grade lumber—47% of the Douglas-fir–western larch sample was recovered as Select Structural and only 29% of the lodgepole pine sample. These differences are based on visual grading only. Differences in strength and stiffness related to specific gravity can be identified only by mechanical testing of each board.

Nondestructive and destructive testing of the lumber are being conducted by Washington State University. Additional testing of a subsample of the lumber will be conducted at Oregon State University to evaluate the potential of this resource for recovery of “cut-stock” or “fingerjoint” material (small, relatively clear material recovered during remanufacturing).

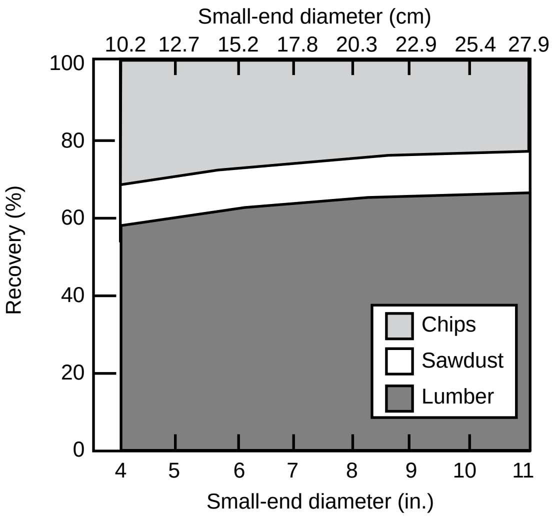

Figure 4—Distribution of products from sawing logs into lumber. Product recovery was not significantly different between species.

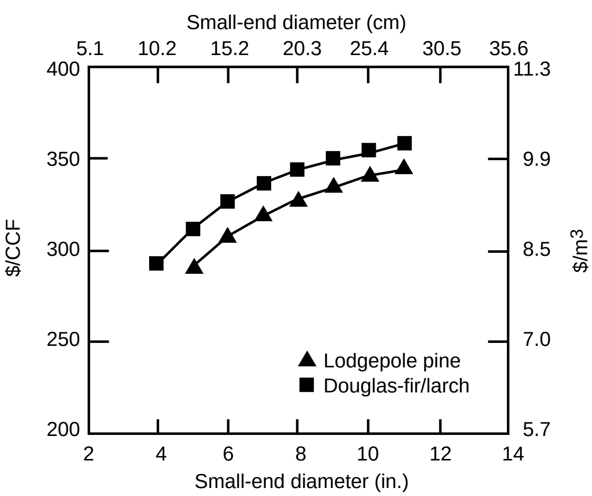

Figure 5—Gross value of lumber produced from Douglas-fir–western larch and lodgepole pine samples. Average difference of $25 per hundred cubic feet reflects higher grade produced from Douglas-fir sample.

Composites

Composites being tested include oriented strandboard (OSB), particleboard, and LVL. All the material was prepared and tested for basic properties (specific gravity, chemical composition, moisture content). The OSB and particleboard panels were made and tested for internal bonding, strength and stiffness, and differences between resource sources (sawmill residue, small tree tops, and small logs). Initial results indicated that all species and panel densities of OSB meet or exceed the standards set for O-2 panels. It would appear that panels from the small-diameter slow-grown resource could be manufactured with <37 lb/ft^3 (<593 kg/m^3) wood fiber or <3.5% resin and still

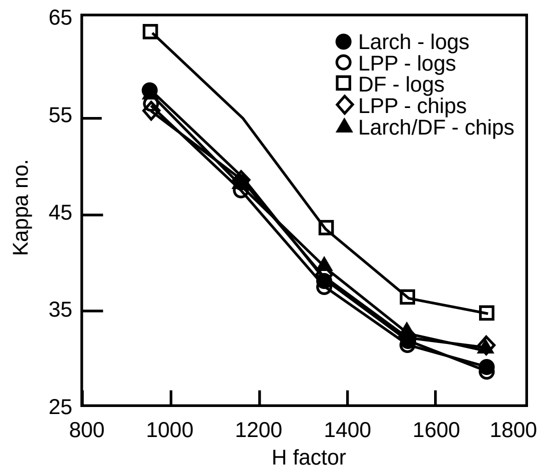

Figure 6—Douglas-fir (DF) submerchantable logs pulped significantly slower than did western larch or lodgepole pine (LPP) submerchantable logs or sawmill residue chips.

meet standards. This means that panels may be less expensive because less wood fiber and less high-cost resin would be used. Particleboard results showed that panels manufactured with <40 lb/ft^3 (<641 kg/m^3) wood fiber did not meet the standards. This result is consistent with that found in normal manufacturing. Additional analysis of species and material source differences is being conducted. Tests on LVL are ongoing at Washington State University.

Kraft Pulp

Results of kraft pulping to date suggest that this raw material source is important for pulp characteristics. Douglas-fir submerchantable logs pulped significantly slower than did western larch and lodgepole pine submerchantable logs or either sample of sawmill residual chips. This means that mills that pulp a high proportion of Douglas-fir submerchantable logs would experience measurably higher residual lignin contents for any cooking time than if pulping a resource primarily composed of any of the other raw material sources (Fig. 6).

Pulp yield also varied by raw material source (Table 3). The yield of lodgepole pine submerchantable logs at all Kappa numbers was about 2% higher than that of lodgepole pine sawmill residue chips. (Kappa number is an indirect measure of pulp lignin content.) This difference is great enough that a mill would realize measurable gains if a high proportion of this type of raw material were pulped over a long period. For example, at an equal Kappa number, the yield from lodgepole pine sawmill residual chips was 48% compared to 49% for small lodgepole pine logs (Fig. 7). About 2.08 tons (1.89 tonnes) of sawmill chips would be needed to produce a ton of paper but only 2.04 tons (1.85 tonnes) of small logs are needed. For a 1,000-ton (907-tonne)/day mill running 360 days/year, this represents a wood savings of 15,480 tons (14,043 tonnes) or about three-quarters of a million dollars at wood cost of $50/ton. The yield from western larch

Table 3—Yield of unscreened pulp obtained per unit of wood material for submerchantable logs and sawmill residual chips for three species at different H factors

		Pulp yield (%) for various H factors[a]				
Species	Source	954	1160	1349	1531	1708
Western larch–Douglas-fir	Sawmill chip residue	52.03	51.28	49.25	49.88	48.98
Western larch	Submerchantable logs	50.50	49.44	46.99	46.67	47.02
Douglas-fir	Submerchantable logs	53.07	51.83	49.31	48.65	48.18
Lodgepole pine	Sawmill chip residue	50.70	50.17	48.87	48.20	47.10
Lodgepole pine	Submerchantable logs	51.97	50.50	49.25	49.57	46.80

[a]H factor is a measure of amount of heat energy imparted to wood chips during pulping.

submerchantable logs was low enough at all Kappa numbers to be of concern if large amounts of this resource were included in the chip supply of a mill. If western larch submerchantable logs were compared to lodgepole pine submerchantable logs in the previous example, the added wood costs for using western larch would be $1.5 million per year.

Pulping results for small trees and results of handsheet tests (pulp quality) for all raw material sources are slated to be ready soon.

Thermomechanical Pulp

Thermomechanical pulps (TMPs) were prepared from five fiber sources: (1) mixed Douglas-fir–western larch sawmill residual chips, (2) lodgepole pine sawmill residual chips, (3) submerchantable Douglas-fir logs (small-end diameter <3.5 in. (<8.9 cm), (4) submerchantable western larch logs, and (5) submerchantable lodgepole pine logs. The sawmill residual chips represent the existing resource and were used as a control for comparison to the small-diameter resource. The results are presented as ratios of each variable for each species of submerchantable log to the corresponding sawmill residual chip source (Fig. 8). Each value is an average of four refiner runs, for a total of about 26.5 lb (12 kg) (ovendry) of raw material. Additional pulping work is in progress for small-diameter trees (<5 in. (<12.7 cm) dbh) and tops (large-end diameter <3.5 in. (<8.9 cm)), along with testing of handsheet properties.

The amount of energy consumed in thermomechanical pulping is important because energy is the largest operating cost associated with this type of pulping. Raw material sources that consume less energy are generally favored over those with higher energy consumption. However, low energy consumption is sometimes an indication of poor fiber integrity and may be associated with inferior handsheet properties. The Douglas-fir and western larch submerchantable logs consumed more energy than did the Douglas-fir–western larch sawmill residual chips. Energy consumption for the lodgepole pine submerchantable logs was only half that for the lodgepole pine sawmill residual chips. This difference is great enough to be of considerable interest to mills that produce these types of pulps.

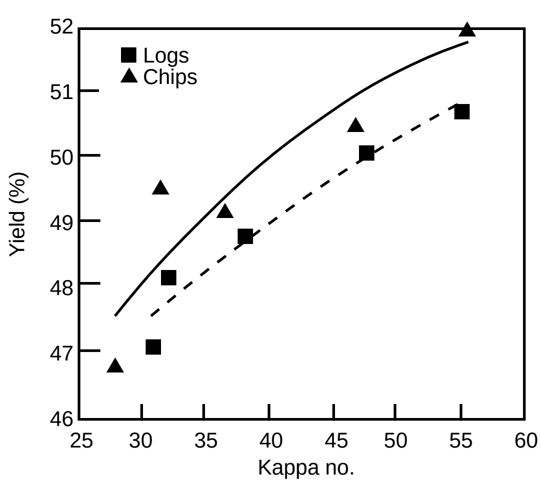

Figure 7—Lodgepole pine submerchantable logs had about 2% higher pulp yield than lodgepole pine sawmill residue.

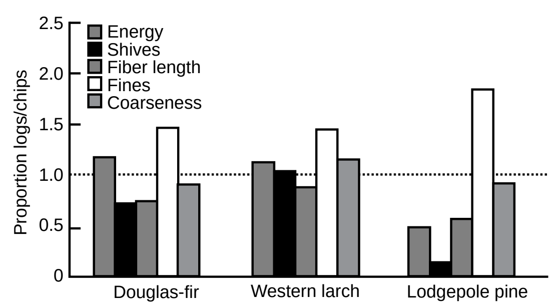

Figure 8—Ratio of submerchantable logs to sawmill residual chips of same species in thermomechanical pulping.

Material that is not completely fiberized in the refiner is called shives. Shives are undesirable in paper because they are visible and create inconsistencies in sheet appearance, and they are a source of tear initiation. Douglas-fir submerchantable logs produced about 72% as many shives as did the sawmill residual chips, and western larch submerchantable logs produced about 88% as many shives. Lodgepole pine submerchantable logs produced only about 15% as many shives as did the sawmill chips. This is also a favorable result, but it may be an indication of fragile fibers that broke down during the refining process.

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Grand Total $ 177

DBH	DF & Larch	Hem & Fir	Ponderosa	Lodgepole	Others	Dead PP	Dead other
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6	-30	-22	-34	-33	-33	0	0
8	22	-7	-34	-22	-30	6	0
10	58	-1	19	-22	-29	17	0
12	66	5	79	-22	-29	23	0
14	72	11	84	-22	-35	0	0
16	68	17	93	-22	-35	0	0
18	69	28	103	-13	-34	0	0
Totals	$ 293	$ 5	$ 277	$ -188	$ -257	$ 46	$ 0

Figure 11—Stand Table screen showing values for stand by tree dbh and species.

NET VALUE of Logs at Mill Yard ($/acre)							
STD124.STD--Status Quo							
Grand Total	$ 21,838						
Product	**DF & Larch**	**Hem & Fir**	**Ponderosa**	**Lodgepole**	**Other**	**Dead PP**	**Dead other**
Appearance & Commons	0	730	564	166	166	0	0
Appearance &Dimension	12,854	0	0	0	0	0	0
Visual Dimension	0	0	0	0	0	12	0
MSR Dimension	414	0	0	0	0	5	0
Veneer	4,706	2,196	0	0	0	8	0
Chips	13	6	0	0	0	3	0
Flakes	0	0	9	0	0	0	0
Energy	0	0	0	-1	-1	0	0
Total	$ 17,987	$ 2,932	$ 574	$ 166	$ 166	$ 28	$ 0

Figure 12—Log screen showing values for logs by product type and species.

Every cell in the Project screen is tied to a set of more detailed tables. Figure 10 shows the summary information on important cost and revenue components for a single cell in the Project screen. Figure 11 shows the net value at the stumpage level broken down by species and diameter. These calculations involve some arbitrary cost allocations, which requires that these results be used with caution. The results do not indicate the financial cutoff point for including or excluding stand components in the harvest; they do indicate the relative value of stand components. Adding or removing stand components can be accurately analyzed by making additional simulations. Figure 12 shows the net value of logs at the mill by the type of product and species.

Conclusions

Although this paper presents only the preliminary results from each of the four technical focus areas in the Colville Study, we are beginning to see some significant trends and relationships. Results of the Silviculture and Ecology modeling exercise illustrate the effects of varying degrees of disturbance and suggest that meeting stated ecosystem objectives will require some form of intervention. Results of Forest Operations show that the harvester–forwarder system can remove wood while leaving important material on the site and reducing the soil compaction as compared to a more conventional system. However, depending on market conditions, as average stand diameter drops below 10 in. (25 cm), potential buyers face increasing difficulty in operating profitably on sales when harvester–forwarder systems are specified. Results from the Timber Conversion focus area indicate that both species and type of raw material resource (small trees, submerchantable logs, and sawmill residue) are important in determining the recovery and value of some manufactured products. Significant differences were found in the grade yield of lumber (yield of Douglas-fir–western larch was much greater than that of lodgepole pine), in the yield of kraft pulp (yield of lodgepole pine submerchantable logs was better than that of sawmill residuals and yield of Douglas-fir–western larch submerchantable logs was worse than that of sawmill residuals), and in the yield and quality of thermomechanical pulp (TMP) (yield of lodgepole pine submerchantable logs was worse than that of sawmill residues). Little differences were found in visually graded veneer, lumber yield, production of oriented strandboard (OSB), or production of TMP from Douglas-fir–western larch samples.

Continuing studies of paper quality, additional composites, and mechanically tested lumber and veneer will provide more information about the potential for the small-diameter resource. The key to providing this information in a “user-friendly” format in the financial analysis package is being developed in the Economics focus area. FEEMA will be the tool that allows timber planners and others to evaluate the financial feasibility of alternative actions designed to achieve ecological goals.

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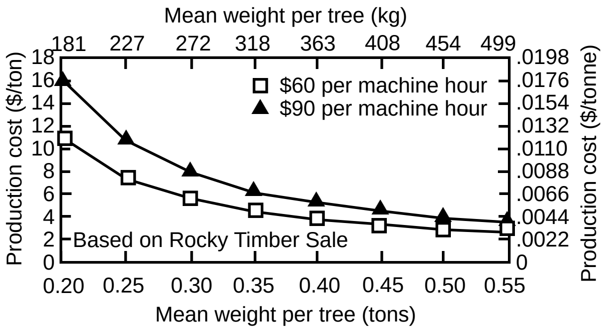


Figure 2—Harvester costs for thinning treatments on Rocky II Timber Sale.

trees considered too small for lumber or veneer (<8 in. (<20.3 cm) dbh), and (3) logs generally considered unmerchantable for lumber and veneer (<5 in. (<12.7 cm)).

Several tree or log characteristics, in addition to size, are important in determining product quality and value. These characteristics include species, specific gravity, size and distribution of knots, taper, growth rate, and defect. Initial results showed significantly reduced specific gravity of Douglas-fir (15% to 20% less than established standards in the *Wood Handbook* (Forest Products Laboratory 1987)). These results have implications for the suitability of this wood for various products. For lumber and veneer, lower specific gravity indicates material with lower stiffness; for composites, it could indicate lower processing costs; and for pulp, it could result in different fiber properties.

Veneer

Fifteen Douglas-fir and 19 western larch trees were selected for processing into veneer. The sample ranged from 8 to 14 in. (20.3 to 35.6 cm) dbh, and the average age was roughly 70 years. The trees were bucked tree-length to a 3-in.- (7.6-cm-) diameter top. Veneer blocks (102 in. (2.59 m) long) were manufactured from the tree-length logs up to a 5.5-in. (14-cm) small-end diameter, and the smaller tops were used for tests on composites. The blocks were marked for identification and then steamed in preparation for peeling. They were peeled into 0.164-in. (0.42-cm) veneer, which was color coded with dye to maintain the block identity. The veneer was dried, graded (C or D), tallied, bundled, and sent to Washington State University for testing for laminated veneer lumber (LVL).

Tree height is a significant factor in the production of veneer because it limits the number of blocks recoverable from a tree. To hold the blocks in the lathe, the logs must be 8.5 ft (2.6 m) long. In this mill, the smallest diameter block that could be transferred from the x–y charger to the lathe was 5.5 in. (14 cm). Since the Douglas-fir tree sample was on average 20 ft (6.1 m) shorter than the western larch sample, we recovered more blocks from western larch than Douglas-fir trees of the same diameter.

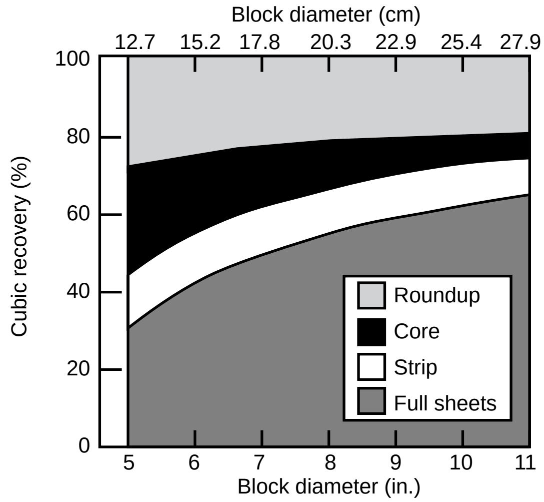


Figure 3—Distribution of products from processing of western larch blocks into veneer. Roundup is material lost to chips during rounding a conical log into a cylinder.

Veneer recovery (full sheet and strip) increased with block diameter (Fig. 3). For a given size block, no difference was found between Douglas-fir and western larch in the total recovery of veneer. However, more full sheets were produced from small-diameter western larch logs than from Douglas-fir. The core was a constant 3.9 in. (9.9 cm) in diameter; the proportion of the block volume remaining as core decreased as the block size increased. Because the veneer was graded for C and D grades only, the value per diameter followed the same pattern as that of veneer recovery. Results of mechanical testing for stiffness for LVL production are forthcoming.

Lumber

Twenty trees of each species (lodgepole pine, Douglas-fir, and western larch) were selected for processing into lumber. The logs were bucked into sawmill lengths and scaled for volume. They were then sawn into 1- and 2-in. (2.5- and 5-cm) lumber, 11% and 89% respectively.

There was no significant difference in volume recovery for the different species (Fig. 4). Value recovery based on visual lumber grades was quite different between the lodgepole pine and Douglas-fir–western larch samples (Fig. 5). The major difference was in the recovery of higher grade lumber—47% of the Douglas-fir–western larch sample was recovered as Select Structural and only 29% of the lodgepole pine sample. These differences are based on visual grading only. Differences in strength and stiffness related to specific gravity can be identified only by mechanical testing of each board.

Nondestructive and destructive testing of the lumber are being conducted by Washington State University. Additional testing of a subsample of the lumber will be conducted at Oregon State University to evaluate the potential of this resource for recovery of “cut-stock” or “fingerjoint” material (small, relatively clear material recovered during remanufacturing).

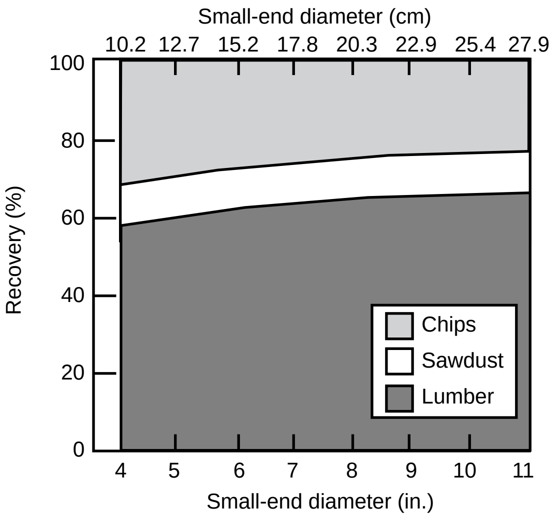


Figure 4—Distribution of products from sawing logs into lumber. Product recovery was not significantly different between species.

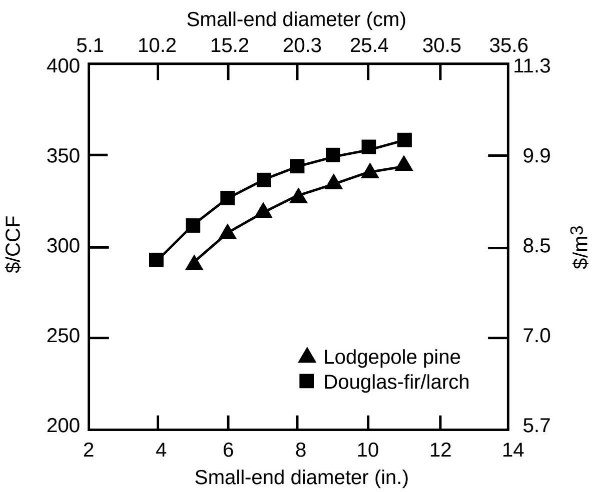


Figure 5—Gross value of lumber produced from Douglas-fir–western larch and lodgepole pine samples. Average difference of $25 per hundred cubic feet reflects higher grade produced from Douglas-fir sample.

Composites

Composites being tested include oriented strandboard (OSB), particleboard, and LVL. All the material was prepared and tested for basic properties (specific gravity, chemical composition, moisture content). The OSB and particleboard panels were made and tested for internal bonding, strength and stiffness, and differences between resource sources (sawmill residue, small tree tops, and small logs). Initial results indicated that all species and panel densities of OSB meet or exceed the standards set for O-2 panels. It would appear that panels from the small-diameter slow-grown resource could be manufactured with <37 lb/ft^3 (<593 kg/m^3) wood fiber or <3.5% resin and still meet standards. This means that panels may be less expensive because less wood fiber and less high-cost resin would be used. Particleboard results showed that panels manufactured with <40 lb/ft^3 (<641 kg/m^3) wood fiber did not meet the standards. This result is consistent with that found in normal manufacturing. Additional analysis of species and material source differences is being conducted. Tests on LVL are ongoing at Washington State University.

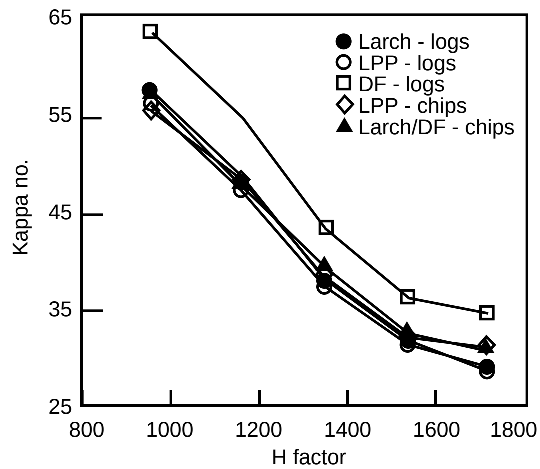


Figure 6—Douglas-fir (DF) submerchantable logs pulped significantly slower than did western larch or lodgepole pine (LPP) submerchantable logs or sawmill residue chips.

Kraft Pulp

Results of kraft pulping to date suggest that this raw material source is important for pulp characteristics. Douglas-fir submerchantable logs pulped significantly slower than did western larch and lodgepole pine submerchantable logs or either sample of sawmill residual chips. This means that mills that pulp a high proportion of Douglas-fir submerchantable logs would experience measurably higher residual lignin contents for any cooking time than if pulping a resource primarily composed of any of the other raw material sources (Fig. 6).

Pulp yield also varied by raw material source (Table 3). The yield of lodgepole pine submerchantable logs at all Kappa numbers was about 2% higher than that of lodgepole pine sawmill residue chips. (Kappa number is an indirect measure of pulp lignin content.) This difference is great enough that a mill would realize measurable gains if a high proportion of this type of raw material were pulped over a long period. For example, at an equal Kappa number, the yield from lodgepole pine sawmill residual chips was 48% compared to 49% for small lodgepole pine logs (Fig. 7). About 2.08 tons (1.89 tonnes) of sawmill chips would be needed to produce a ton of paper but only 2.04 tons (1.85 tonnes) of small logs are needed. For a 1,000-ton (907-tonne)/day mill running 360 days/year, this represents a wood savings of 15,480 tons (14,043 tonnes) or about three-quarters of a million dollars at wood cost of $50/ton. The yield from western larch

Table 3—Yield of unscreened pulp obtained per unit of wood material for submerchantable logs and sawmill residual chips for three species at different H factors

		Pulp yield (%) for various H factors[a]				
Species	Source	954	1160	1349	1531	1708
Western larch–Douglas-fir	Sawmill chip residue	52.03	51.28	49.25	49.88	48.98
Western larch	Submerchantable logs	50.50	49.44	46.99	46.67	47.02
Douglas-fir	Submerchantable logs	53.07	51.83	49.31	48.65	48.18
Lodgepole pine	Sawmill chip residue	50.70	50.17	48.87	48.20	47.10
Lodgepole pine	Submerchantable logs	51.97	50.50	49.25	49.57	46.80

[a]H factor is a measure of amount of heat energy imparted to wood chips during pulping.

submerchantable logs was low enough at all Kappa numbers to be of concern if large amounts of this resource were included in the chip supply of a mill. If western larch submerchantable logs were compared to lodgepole pine submerchantable logs in the previous example, the added wood costs for using western larch would be $1.5 million per year.

Pulping results for small trees and results of handsheet tests (pulp quality) for all raw material sources are slated to be ready soon.

Thermomechanical Pulp

Thermomechanical pulps (TMPs) were prepared from five fiber sources: (1) mixed Douglas-fir–western larch sawmill residual chips, (2) lodgepole pine sawmill residual chips, (3) submerchantable Douglas-fir logs (small-end diameter <3.5 in. (<8.9 cm), (4) submerchantable western larch logs, and (5) submerchantable lodgepole pine logs. The sawmill residual chips represent the existing resource and were used as a control for comparison to the small-diameter resource. The results are presented as ratios of each variable for each species of submerchantable log to the corresponding sawmill residual chip source (Fig. 8). Each value is an average of four refiner runs, for a total of about 26.5 lb (12 kg) (ovendry) of raw material. Additional pulping work is in progress for small-diameter trees (<5 in. (<12.7 cm) dbh) and tops (large-end diameter <3.5 in. (<8.9 cm)), along with testing of handsheet properties.

The amount of energy consumed in thermomechanical pulping is important because energy is the largest operating cost associated with this type of pulping. Raw material sources that consume less energy are generally favored over those with higher energy consumption. However, low energy consumption is sometimes an indication of poor fiber integrity and may be associated with inferior handsheet properties. The Douglas-fir and western larch submerchantable logs consumed more energy than did the Douglas-fir–western larch sawmill residual chips. Energy consumption for the lodgepole pine submerchantable logs was only half that for the lodgepole pine sawmill residual chips. This difference is great enough to be of considerable interest to mills that produce these types of pulps.

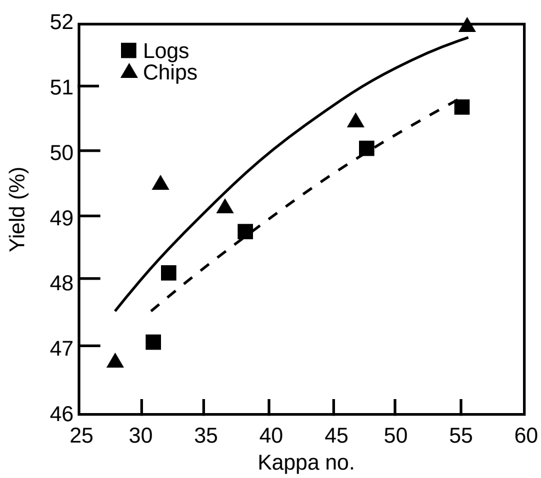
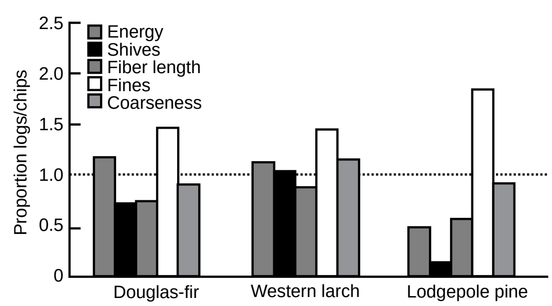


Figure 7—Lodgepole pine submerchantable logs had about 2% higher pulp yield than lodgepole pine sawmill residue.



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6	-30	-22	-34	-33	-33	0	0
8	22	-7	-34	-22	-30	6	0
10	58	-1	19	-22	-29	17	0
12	66	5	79	-22	-29	23	0
14	72	11	84	-22	-35	0	0
16	68	17	93	-22	-35	0	0
18	69	28	103	-13	-34	0	0
Totals	$ 293	$ 5	$ 277	$ -188	$ -257	$ 46	$ 0

Figure 11—Stand Table screen showing values for stand by tree dbh and species.

NET VALUE of Logs at Mill Yard ($/acre)

STD124.STD--Status Quo

Grand Total $ 21,838

Product	DF & Larch	Hem & Fir	Ponderosa	Lodgepole	Other	Dead PP	Dead other
Appearance & Commons	0	730	564	166	166	0	0
Appearance &Dimension	12,854	0	0	0	0	0	0
Visual Dimension	0	0	0	0	0	12	0
MSR Dimension	414	0	0	0	0	5	0
Veneer	4,706	2,196	0	0	0	8	0
Chips	13	6	0	0	0	3	0
Flakes	0	0	9	0	0	0	0
Energy	0	0	0	-1	-1	0	0
Total	$ 17,987	$ 2,932	$ 574	$ 166	$ 166	$ 28	$ 0

Figure 12—Log screen showing values for logs by product type and species.

Every cell in the Project screen is tied to a set of more detailed tables. Figure 10 shows the summary information on important cost and revenue components for a single cell in the Project screen. Figure 11 shows the net value at the stumpage level broken down by species and diameter. These calculations involve some arbitrary cost allocations, which requires that these results be used with caution. The results do not indicate the financial cutoff point for including or excluding stand components in the harvest; they do indicate the relative value of stand components. Adding or removing stand components can be accurately analyzed by making additional simulations. Figure 12 shows the net value of logs at the mill by the type of product and species.

Conclusions

Although this paper presents only the preliminary results from each of the four technical focus areas in the Colville Study, we are beginning to see some significant trends and relationships. Results of the Silviculture and Ecology modeling exercise illustrate the effects of varying degrees of disturbance and suggest that meeting stated ecosystem objectives will require some form of intervention. Results of Forest Operations show that the harvester–forwarder system can remove wood while leaving important material on the site and reducing the soil compaction as compared to a more conventional system. However, depending on market conditions, as average stand diameter drops below 10 in. (25 cm), potential buyers face increasing difficulty in operating profitably on sales when harvester–forwarder systems are specified. Results from the Timber Conversion focus area indicate that both species and type of raw material resource (small trees, submerchantable logs, and sawmill residue) are important in determining the recovery and value of some manufactured products. Significant differences were found in the grade yield of lumber (yield of Douglas-fir–western larch was much greater than that of lodgepole pine), in the yield of kraft pulp (yield of lodgepole pine submerchantable logs was better than that of sawmill residuals and yield of Douglas-fir–western larch submerchantable logs was worse than that of sawmill residuals), and in the yield and quality of thermomechanical pulp (TMP) (yield of lodgepole pine submerchantable logs was worse than that of sawmill residues). Little differences were found in visually graded veneer, lumber yield, production of oriented strandboard (OSB), or production of TMP from Douglas-fir–western larch samples.

Continuing studies of paper quality, additional composites, and mechanically tested lumber and veneer will provide more information about the potential for the small-diameter resource. The key to providing this information in a "user-friendly" format in the financial analysis package is being developed in the Economics focus area. FEEMA will be the tool that allows timber planners and others to evaluate the financial feasibility of alternative actions designed to achieve ecological goals.

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