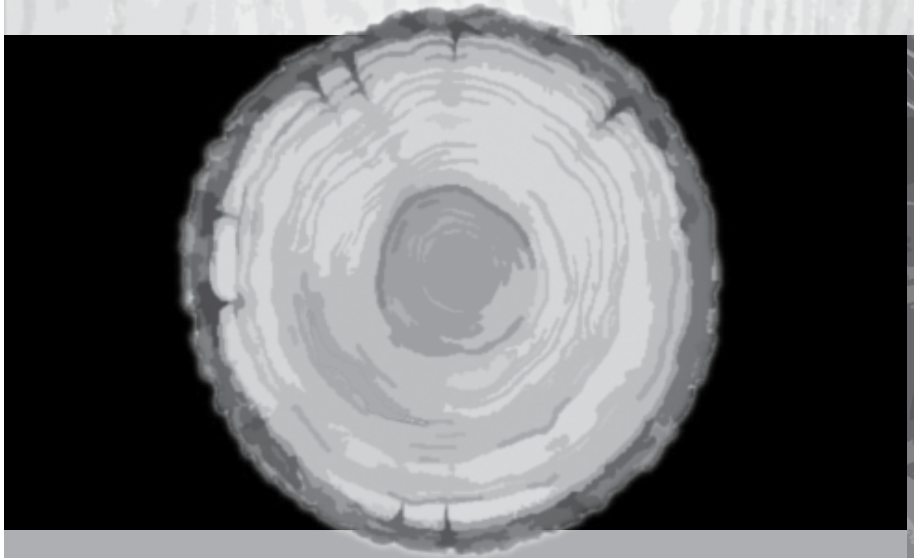
Progress Report for FY 2004

Center for Wood Utilization Research

at Oregon State University



Oregon State UNIVERSITY

Corvallis, OR 97331 • (541) 737-4257 • USDA Special Grant

Progress Report for
Fiscal Year 2004

Center for Wood Utilization Research

at Oregon State University

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Center for Wood Utilization Research

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Progress Report FY 2004

USDA CSREES Special Grant

Executive Summary

The USDA Special Grant for Wood Utilization Research (WUR) is focused on developing the science, technology, management approaches, and business practices that

- enhance the domestic and global competitiveness of the broad U.S. wood products industry
- maintain or expand sustainable and environmental acceptable forest operations and product manufacturing, and/or
- lead to more efficient use of renewable wood-based materials for the benefit of Americans.

Wood utilization research is critical to national needs because the U.S. is the world's largest consumer of wood products and the largest importer. The global competitiveness of our domestic industry is of strategic importance to provide jobs, especially in rural areas; reduce dependence on non-renewable materials; and sustain economic incentives for landowners to maintain private and public forests. The vast majority of U.S. wood product manufacturers are small- to medium-sized businesses. Oregon State University is part of a larger national program to address critical wood utilization research needs that vary across the U.S. and by discipline. Our principal focus is on the utilization of western species. This report summarizes grant activities for FY2004.

Twenty-nine active projects were supported by the USDA Special Grant to Oregon State University in 2004. Project research *generated 58 publications*, including *28 in peer-reviewed scientific journals*, and *7 graduate student theses*. Technology transfer continued at a high level of activity, with research results conveyed through *71 activities to scientists and practitioners* in industry, academe, and government agencies, as well as to policy and decision makers and the public.

Activities this year focused on important knowledge needs to extend the availability and utilization of domestic wood resources, improve our basic understanding of how wood is formed and degrades, and offer potential to enhance industry competitiveness. Several studies have improved the scientific basis for understanding and mitigating the impacts of timber harvesting activities on soil and water resources, thereby improving the knowledge base for rational forest management regulations that influence timber supply.

Research and development activities in wood science and manufacturing seek to develop new understandings of wood formation and biodegradation, reduce hazardous air emissions, and provide better product yields from available wood supplies. Key research results on the life cycle environmental costs of material selection are now being implemented into national standards and practices that inform consumers, architects and public policy makers. Pioneering work on sensor technology, on the performance of wood structures in earthquakes and on enhancing the durability of wood homes, will offer new economic development opportunities and safeguard public confidence in existing product use. Research on innovation and new product development helps the U.S. forest products industry understand how to remain competitive in the face of rising costs and increased foreign competition.

This Special Grant has enabled the University to leverage funding from the State of Oregon, industry, and other sources to develop intellectual capacity and provide operating funds for faculty and students. Support for graduate students is especially critical in the face of a looming shortage of well-trained

scientists, engineers, managers and teachers in the field. The Special Grant directly contributes to national and international research leadership in the cost-effective and environmentally sustainable use of wood.

Highlights of projects completed this year include the following:

- A study of precision forestry techniques evaluated applications of digital tools to capture and map data associated with harvest planning. Results illustrated costs, reliability efficiency, and accuracy compared with manual techniques. In some cases these tools can improve timber sale planning productivity substantially and thus add value along the wood supply chain.
- The development of an inexpensive and practical method for calculating stormwater discharge at culverts in small watersheds and a model to predict sediment discharge from a roaded watershed will contribute to the scientific basis for forest practice regulations that affect harvesting and transportation of logs on forest roads.
- Research on the physiology, patterns, and design criteria for heartwood formation suggests that we may be able to manipulate the durability of heartwood in some species by manipulating how the trees are grown. Durability is important for application such as shakes, shingles, fence posts, decks, hot tubs, and siding.
- This project provided basic engineering analysis and test data for log structure foundation attachment and lateral force resistance mechanisms of log walls. The information is now being referenced by the International Code Council as it drafts the first model code requirements for log building structures and is also being used by the log structures industry to justify designs for high seismic and wind requirements.
- Life cycle assessments of solid wood materials to determine net environmental and economic impacts of manufacturing and using wood building materials are now being implemented into national codes and standards.
- A collaborative research project modeled the environmental impacts of forest roads, including methodologies for predicting road segments prone to landslides, and developed a decision-support system methodology for managing environmental impacts while maintaining cost-effective transportation route access.
- An investigation into reducing emissions from wood drying by reducing the moisture variability prior to drying through effective sorting also found that some ionic liquids provide a good absorption media for pollutants and they can be cleaned and reused. An industrial process for removing pollutants could be developed based on absorption.
- The unification of various software modules for optimizing lumber production into a single computer program capable of modeling the sawing processes in the original versions. Together with the SAW-3D log sawing simulation software, it is now possible to explore processing options for log resources, especially small diameter material expected to be available from thinning sites.

One of the highlights of the OSU Special Grant Program has been the attention paid to the dissemination of new information through a variety of outlets and to different audiences. This high level of technology transfer is reflected in activities ranging from scientific conferences to workshops for landowners and manufacturers.

This report covers activities conducted under the following USDA/CSREES Special Grants:

01-34158-10625
02-34158-11903
03-34158-13892
04-34158-14679

Progress Reports

Improving Products and Processes to Enhance the Global Competitiveness of Oregon's Wood Products Industry

Softwood Grade Estimator for Inclusion in the CORY and SAW3D Simulation Programs

Charles C. Brunner, James W. Funck, James E. Reeb

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to develop a lumber grade estimator for the softwood appearance grades found in the Western Wood Products Association rules for factory lumber; (2) to incorporate the estimator into the board-sawing simulator CORY and the log-sawing simulator SAW3D

A C++ class structure compatible with the hardwood estimator and CORY programs has been developed, and the search algorithm for comparing cutting-areas has been coded and tested. The code to find cutting areas of different grades, e.g., No. 1 and No. 2 door cuttings, is being developed. Once this code is completed, the algorithm that determines a board's grade using the WWPA rules for factory grade lumber will be developed.

Innovation and New Product Development in the Global Forest Sector

Eric N. Hansen

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: (1) to develop a valid and reliable measure of innovation in the forest sector; (2) to assess current practices in innovation and new product development in the U.S. forest sector; (3) to determine the roles of market orientation and innovation in U.S. forest sector firm performance; (4) to develop case examples of successful new product introductions in the U.S. forest sector; (5) to assess current practices in innovation and new product development in Finland; (6) to assess current practices in innovation and new product development in the Chinese furniture industry

A study was completed investigating the innovation and new product development practices in the Chinese furniture industry. An ongoing qualitative project is assessing industry manager views of the nature of innovation in the forest sector. Interviews will be conducted in the U.S. West and Midwest. Data will be collected in early 2005 to develop a measure of industry innovativeness.

Durability of Wood-Based Composites Employed in Building Envelopes

Jeffrey J. Morrell, Robert J. Leichti

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to develop improved systems for assessing durability of water-resistant materials; (2) to assess the effects of various decay fungi on properties of wood-based composites; (3) to evaluate methods for nondestructive assessment of decay of wood-based composites

We have examined several methods for enhancing the durability of wood-based materials. The inherent water resistance of wood/plastic composites (WPCs) poses a challenge in laboratory decay studies traditionally used before field tests. We examined soil, agar, and vermiculite systems with three common wood decay fungi. Agar block tests were easiest to establish and gave results similar to those with traditional, but more labor-intensive, soil block tests. Effectiveness was improved primarily by placing the WPC in direct contact with the agar, which resulted in much more rapid moisture uptake. Moisture content (MC) was highly correlated with weight loss in all tests, suggesting that achieving rapid moisture uptake was the primary consideration for any test method. Our goal is to move this approach to an ASTM Standard.

We also have been examining moisture uptake patterns and the effects of this uptake on material properties in WPCs. Moisture uptake was extremely low in two commercial materials even after several months' immersion; there was no negative effect of repeated moisture cycling.

In trials of plywood and OSB, samples were wetted, then exposed to various decay fungi for up to 20 weeks. Moisture uptake was rapid in both materials and produced permanent losses in bending properties. Fungal growth was also noted, but the moisture effect tended to dominate material properties for most of the test period. Moisture intrusion appears to remain the primary damaging agent in traditional wood-based composites, although decay fungi have an effect after prolonged moisture exposure.

We also have explored the effects of wetting and fungal exposure on OSB/Douglas-fir cripple wall sections. Wood colonized by a decay fungus, *Postia placenta*, was placed at locations on the sill plates and wall between the OSB sheathing and the stud. Wall sections were then placed into pans containing water (replenished periodically) and MC of the frame was assessed over time. Fungal growth was evident at the end of 3 months, but there was no evidence of advanced decay. These results differ from those of our prior accelerated tests on OSB/Douglas-fir test sections and illustrate the effects of larger scale on test results. Full-scale tests comparing these materials (wetted alone and wetted plus fungal exposure) with similar non-watersoaked wall sections indicated that moisture uptake was the primary source of changes in properties. These tests continue.

We are trying to collaborate with researchers at the University of Tennessee who have NIR capabilities so that we can assess the relationship between changes in properties and NIR outputs. We expect to make much more progress on this objective in the coming year.

Improving Primary Production with New Technologies: Synthetic Rope Applications

John J. Garland, Stephen J. Pilkerton

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to assess the technologies and potential gains from using synthetic rope to replace wire rope in rigging applications for cable harvesting; (2) to develop and test suitable end connectors for synthetic rope and develop synthetic rope chokers to replace wire rope in harvesting operations; (3) to develop and test harvest systems for synthetic rope in applications to harvest small, underutilized material and biomass materials and for small-scale forest harvest operations; (4) to assess synthetic rope for running line applications for skylines, haulback, and mainlines: operating techniques and wear/damage assessments; (5) to develop a validated planning approach to replace wire rope with synthetic rope in cable logging applications by adding synthetic rope to LOGGERPC (OSU Forest Engineering Software) or as a stand-alone computer application

Two research cooperators are using synthetic ropes for skyline extensions on cable yarders. Initial indications are positive for application viability, economic benefit, and productivity enhancements. Two other cooperators are using synthetic ropes to rig intermediate supports and tail trees for improved access, environmental performance, and yarding productivity. Reaction from all four cooperators with respect to rigging uses has been positive. Additional logging contractors are implementing lift-tree rigging with synthetic ropes as a result of transfer activities to forester and harvesting audiences.

One synthetic choker design has been implemented successfully. This design will be scaled to an operational size for trial with a cooperator. An additional design is being considered as strength and durability of end connector technologies are evaluated.

Plans are being developed for two trials using synthetic ropes for harvesting underutilized, biomass, and nonmerchantable fiber. One trial will focus on harvesting of materials currently considered nonmerchantable and left during a commercial harvest operation. The second will evaluate small-scale forest harvesting as practiced by a nonindustrial private forestland owner.

In addition to the skyline trials, one active trial is evaluating the use of a synthetic rope as a mainline (line used to pull logs to a landing). Initial results indicate operational durability is equivalent to steel. Observed wear and damage suggest improvements to equipment (replacement of sheaves, line guides) with synthetic materials to improve durability.

Most of our efforts in the past 6 months have been in lab testing of stress/strain properties of synthetic rope to develop a measure for synthetic rope equivalent to the steel wire rope characteristics of A (cross-sectional area) and E (modulus of elasticity). We are working to determine this relationship empirically, as cross-sectional area is variable and modulus is undefined for synthetic ropes. Once this relationship has been determined, the use of synthetic rope in the cable-yarding payload-planning software LOGGERPC (OSU Forest Engineering Software) can be validated. A novel approach to this solution was discovered. Traditional testing required elevated end points and a supported load. The researchers implemented an "inverted skyline" in which the end points were anchored to the ground and the load was applied via an overhead crane. This approach was more

efficient for varying loading and diagnostics. Evaluation of the data from this approach is currently underway. A traditional loading approach is planned for validation of the "inverted skyline" results.

Future activities include several synthetic rope-use presentations in Washington, California, Idaho, and Oregon and a workshop for small woodland owners demonstrating use of synthetic chokers and winch lines for NIPF harvesting practices.

Improving the Planning, Scheduling, and Tracking of the Primary Forest Supply Chain

Kevin D. Boston

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: to develop (1) a framework for implementation of a supply chain management system for forest operations to improve profits and customer service by developing new planning, scheduling, and reporting tools to align harvest and distribution capacity so as to best meet customer demands; (2) new production forecasting tools that will support improved supply chain management

A heuristic algorithm has been developed to improve the efficiency of scheduling harvesting crews to units on an annual basis in order to improve the utilization of harvesting equipment and lower logging costs.

Development of a weekly log production scheduling model has been initiated, and cooperators are being sought to contribute data. The goal is to provide managers with a tool that will allow them to predict weekly log production better. This data can be used in the formulation of improved wood-flow plans that will improve the profitability of operations.

Adaptive Control of Bucking on Harvesters for Improved Wood Utilization

Glen E. Murphy

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to assess how well a sample of forest industry production controllers can use new sources of stem information to adaptively control bucking on harvesters in four pine stands and determine what decision rules they use; (2) to compare adaptive control by production controllers with existing adaptive control heuristics and develop new heuristics, objective functions, and constraint penalty functions; (3) to investigate which data sources are important (sources that are spatially related, temporally related, or most similar) and determine what weighting factors should be applied if combinations of data are used; (4) to determine how many stems are required in each new set of data to obtain acceptable results; (5) to determine the impact of harvester methods and measurement accuracy on overall success and variability in adaptive control; (6) to establish an intensively measured 25-acre plot in McDonald-Dunn Forest where every tree is spatially located for testing adaptive control heuristics in a mature Douglas-fir stand.

Ten forest industry workers were invited to participate in a log production control game (see Objective 1). The participants were asked to change relative prices or small-end diameter specifications for a specified number of log types. FASTBUCK was used to optimally buck stems to each controller's prices and specifications.

The adaptive control heuristic in FASTBUCK uses an objective function based on linear deviations from target yields (AD) with penalties for not achieving average minimum small-end diameter or product group goals. A recent Scandinavian publication suggested that an objective function based on squared deviations (AD^2) with penalties was superior to a linear function when using a near-optimal approach for meeting order book constraints. FASTBUCK was modified to incorporate that improvement. Fourteen substands within four stands were used to test the new algorithm. It was concluded that a linear deviation is sufficient when an adaptive price list is used to control bucking.

A 20-acre plot was established in a mature (70+ years) Douglas-fir. In FY04, every tree (>2700) was tagged, measured for DBH, and classified as hardwood or softwood and the spatial coordinates for over 600 trees were obtained. In 2005, New Zealand Forest Research scientists will test newly developed inventory tools and OSU will obtain detailed stem descriptions of every tree in the plot.

Stem data from one real-world and one artificially generated stand were used to determine how frequently, in terms of stems harvested, bucking parameters should be adaptively controlled to obtain acceptable bucking solutions. Updating frequency had no effect on meeting overall targets for one of the stands, but RMSE% decreased as updating frequency decreased. Data analysis for the second stand is still underway.

The use of data from mechanized harvesters to augment or replace preharvest inventory data was evaluated from the perspective of optimally matching wood to markets.

Data from four trials of harvester-based inventory systems in radiata pine plantations in Australia were gathered. A literature review on the tree measurement errors associated with preharvest inventory systems indicated that they may be no better than errors found in the recent Australian studies and in harvester measurements in New Zealand, Oregon, and Canada.

In 2005, the remaining 2000+ trees in the Extendo plot will be spatially located by ground surveying. The plot will be flown with LIDAR imagery in the winter. Data analysis will be completed on the effects of updating frequency when adaptively controlling bucking. Four pine stands and the Extendo Douglas-fir stand will be included.

Discovering New Knowledge for Future Opportunities and Benefits

Patterns and Mechanisms of Radial Water Movement in Live Sapwood

Barbara L. Gartner

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: (1) to categorize tree species on the extent to which their live wood permits radial water movement; (2) to characterize which anatomical features are associated with radial water transport; (3) to characterize the physiological and growth strategies associated with the low vs. high resistance to radial water transport in order to enable predictions beyond this dataset.

Conductivity and sap flow were higher in the outer than in the inner sapwood in all studied species: Douglas-fir, ponderosa pine, madrone, cottonwood, alder, and maple. The ratio of sap flow to conductivity often varied across the radius, however, implying that the axial gradient of tensions is not even from one radial location to the next. At 1 cm from the cambium, transpiration-induced axial tension was about twice as high as it was 4 cm from the cambium in Douglas-fir and about 10 times higher than it was 7 cm from the cambium in maple. The radial gradient indicates significant, measurable resistance to the radial transport of water. The gradient was 100 times higher in the longitudinal than the radial direction, suggesting that there is about 100 times higher flow longitudinally than radially. In Douglas-fir, conductivity was about 2800 times higher axially than radially, but the cell (tracheid) size was about 100 times longer than wide, again pointing to the different resistances to axial and radial flow. In alder and madrone, in contrast, the tension gradients were more constant across the radius. In these species, there appears to be little resistance to water movement in the radial direction.

In cottonwood, tension was higher in the inner sapwood than in the outer. Thus, either there was a higher driving force for water in the inner rings than the outer rings, or resistance for soil water was lower in the inner growth rings than in the outer. Neither explanation fits with current understanding of water relations in trees.

In ponderosa pine, outer sapwood produces about 60% of the stored water that is used at the end of the growing season, but it makes up about 40% of the sapwood volume. This shows again that sapwood cannot be considered as a homogeneous tissue for tree hydraulics.

We concluded a study on whether evergreen foliage stays connected hydraulically to the wood made in the same year. If so, this could explain why sap flow is often much higher a few growth rings inward from the cambium than in the very outer sapwood: the driving force for water transport would be higher in inner rings than outer, depending on the spatial and age distribution of the leaves. In four species, the foliage stayed attached to the wood made the same year, in eight species it did not, and in four species the pattern was too variable to categorize.

Investigation of Interfacial Adhesion of Wood-Plastic Composites

Kaichang Li

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objective: to investigate (1) methods of enhancing the interfacial adhesion between wood and plastics in wood-plastic composites (WPCs) and (2) the adhesion mechanisms. Two compatibilizer systems {stearic anhydride-PAE (polyaminoamide-epicholorohydrin) resins and a stearic anhydride-PMDI {poly[methylene(polyphenyl isocyanate)] system} will be developed and evaluated for their efficacy in enhancing the interfacial adhesion. Their compatibilization mechanisms will also be investigated.

We investigated a novel compatibilizer system: a combination of stearic anhydride and a paper wet-strength agent. The strength and stiffness of the resulting wood-PE composites depended on dosages of the paper wet-strength agent and stearic anhydride, and the weight ratio of the

paper wet-strength agent to stearic anhydride. This novel compatibilizer system gave higher strength than maleic anhydride-grafted PE, one of the most effective compatibilizers. A new extraction method was developed to remove PE from the wood-PE composites. Characterization of the extracted composites with FTIR showed that stearic anhydride covalently bonded to wood. The mechanisms by which this compatibilizer system improved the interfacial adhesion were extensively studied and are proposed as follows: the paper wet-strength agent strengthens wood, serving as a wood-binding domain; stearic anhydride forms entanglements with the PE matrix and covalent linkages with wood, serving as a PE-binding domain.

We developed another new compatibilizer system, N-vinyl formamide grafted polypropylene (VFPP) and polymeric methylene diphenyl diisocyanate (PMDI). This VFPP-PMDI compatibilizer system greatly increased the strength and stiffness of the resulting wood-PP composites and also greatly reduced the water adsorption of the resulting wood-PP composites.

We also studied effects of wood extractives on the interfacial adhesion between wood and PE. Removal of extractives from wood flour before mixing with PE greatly enhanced the strength and stiffness of the resulting wood-PE composites by improving the interfacial adhesion between wood and PE.

Chemistry of Mill Residues for Increased and Improved Resource Recovery in Traditional Forest Products Operations

Joseph J. Karchesy

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to identify potentially useful chemicals, extracts, or chemical-based materials from traditional mill residues of a western sawmill, plywood, or wood composites operation; (2) over the long range, to provide traditional forest products operations with a means to increase the value of their resources and help support the main mill operations

The essential oil extracts of western juniper and Port-Orford cedar were studied by local lymph node and acute dermal initiation assay to define potential toxicity of these essential oils and woods and answer possible concerns about using the woods as animal bedding. Oil extracts from either species had no toxic effects and elicited neither a hypersensitivity reaction nor an acute skin irritation at the low concentrations to which animals bedded on these materials would be exposed.

The condensed tannin from Douglas-fir bark made a new type of wood adhesive when combined with polyethylenimine in joint research with members of the wood composite group in this department. This provides another potential avenue of utilization of Douglas-fir bark from mill residues. A new isoflavan-cinnamylphenol quinone-methide compound was discovered as the colorant in the imported wood species *Dalbergia congestiflora*. The terpenoids of several native plants that could be grown in agroforestry situations in Oregon were also investigated for new bioactive compounds. Mill residues from three heartwoods have shown significant toxicity towards the sudden oak death organism (*Phytophthora ramorum*); the active compounds are being identified.

Enhancing Engineering Applications for Wood and Wood-Based Products

Evaluation of Seismic Performance of Code-Prescribed, Wood-Frame Shear Walls

Rakesh Gupta

Collaborator: Thomas H. Miller, Department of Civil, Construction, and Environmental Engineering, Oregon State University

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: to evaluate the performance of code-prescribed, wood-frame shear walls under monotonic, cyclic, and real earthquake loads by (1) estimating variability in the response of shear walls, (2) evaluating the effect of anchorage—i.e., hold-downs (engineered walls) versus no hold-downs (prescriptive walls), (3) evaluating the effect of dead load, and (4) comparing the performance of shear walls under monotonic, cyclic, and dynamic loading conditions

In the last year, three wall treatments (fully anchored, partially anchored, and partially anchored with dead load) were tested under different loading conditions. Eight monotonic and eight cyclic tests were conducted on partially anchored walls. Two walls were tested for each of the fully anchored monotonic and cyclic tests, and two partially anchored walls were tested monotonically with

dead load, one with 10.68 kN (2400 lb) dead load and the other with 17.79 kN (4000 lb) dead load. The dead load tests provided a cursory understanding of the behavior of walls between the extremes of performance encountered by partially anchored and fully anchored walls.

Adding hold-downs to the wall dramatically changed the overall behavior and performance of the shear wall, producing a large increase in the load-carrying capacity, deformation capacity, and energy dissipation characteristics of the specimens. The most dramatic increase between partially anchored and fully anchored walls was in the energy dissipation parameter (E), which increased by factors of 8.66 and 6.39 for monotonic and cyclic tests, respectively. As expected, upeak was the only parameter to decrease between the partially anchored and fully anchored walls. Thus, the installation of hold-downs predictably reduces the uplift that the wall experiences at peak load. If the uplift is evaluated as a ratio of the uplift to the lateral displacement, this difference is even more significant. The average uplift rate for partially anchored walls was 0.72 mm per mm and 0.87 mm per mm for the monotonic and cyclic tests, respectively. The average uplift rate for fully anchored walls was 0.16 mm/mm and 0.15 mm/mm for the monotonic and cyclic tests, respectively.

Although the tests cannot be compared statistically because each wall treatment had only two fully anchored walls, the data showed trends similar to the partially anchored tests. The average value of P_{peak} for the cyclic tests was 7.7% lower than for the monotonic tests. Surprisingly, the differences between many of the other backbone parameters were much greater. The average value for Δ_{peak} was 32.8% lower for the cyclic tests than for the monotonic tests. Similarly, E decreased 43.3% between the monotonic and the cyclic tests.

In the next year, shear walls will be tested under actual earthquake loads as described in the original test matrix.

Evaluation of System Behavior of Three-Dimensional Wood Truss Assemblies

Rakesh Gupta

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objective: to provide a practical approach to analyzing three-dimensional light-frame wood truss assemblies by using commercially available structural analysis computer programs: specifically, to investigate and determine (1) a suitable design analog for a single truss, (2) a practical way to model two-way action of sheathing and composite action, (3) a suitable and practical joint model for assembly modeling, and (4) boundary condition (truss-to-wall connections) models to be employed in the assembly model.

After the 2-D truss design analogs were modeled, the individual trusses were connected to represent the actual 3-D roof assembly. Modeling a three-dimensional roof truss assembly included load-distributing elements and boundary conditions. Frame elements were used to simulate the roof sheathing as a load-distributing element in SAP2000 structural analysis software. A frame element was used here to keep the model simple and practical.

Sheathing beams will be modeled with a row of frame elements representing a row of roof sheathing and each row of roof sheathing elements representing a tributary width of roof sheathing. The sheathing beam element will be assigned the same thickness, tributary width, and modulus of elasticity (MOE) as the actual plywood sheathing. The major axis of a sheathing beam element is perpendicular to the truss top chord slope and the minor axis is parallel with the truss top chord. The use of sheathing beams rigidly connected to the truss top chord with no discontinuities between sheathing panels will also be investigated for modeling a 3-D truss assembly. A summary of our proposed 3-D assembly model is as follows: (1) Partial composite action is not included. (2) Sheathing beams are continuous and rigidly connected to truss top chords, with one sheathing beam representing a row of sheathing panels. (3) With respect to boundary conditions, pinned supports are located at the intersections of cross and end walls, and roller supports are present when trusses are located between cross and end walls.

The VIEW program was used to lay out entire T-shaped, L-shaped, and complex truss assemblies. VIEW provides geometry, loading conditions, material properties, and analyzes each truss individually. Then 3-D frame models of the T-shaped, L-shaped, and complex assemblies were generated for analysis in SAP2000.

Next year, assembly results from SAP2000 and VIEW will be compared in terms of maximum CSI values for each truss and their locations, deflections, and truss reactions. Based on these comparisons, the specific system effects will be described.

Assessing the Chemical-Mechanical Relations in Nailed Light-Frame Connections Subjected to Fungal Biodeterioration

Robert J. Leichti, Scott M. Kent

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: to determine changes in physical, mechanical, and chemical properties of aspen oriented-strand-board (OSB) sheathing after exposure to *Postia placenta* (brown rot) under ideal growth conditions for up to 30 weeks, specifically evaluating (1) the feasibility of using near-infrared (NIR) spectroscopy to predict the level of decay damage in terms of dowel-bearing strength, changes in specific gravity, and solubility in an aqueous solution of sodium hydroxide (NaOH); (2) the spatial density distribution of sound and decayed OSB as determined with x-ray densitometry.

The variability of the results in each incubation time group was relatively high, a combination of the variability inherent in the material and that associated with the rate of fungal growth. Samples were randomly selected during each harvest, and no attempt was made to sort samples based on the quantity of observed mycelium. This finding implies that prediction of time-to-failure due to fungal deterioration involves considerable uncertainty.

Two statistical models were developed to relate dowel-bearing strength to specific gravity. The first model used gross specific gravity of the OSB sample; the second used a zone of averaged specific gravity, determined using an x-ray densitometer, under the nail during the dowel-bearing test, averaged for a distance of half the nail diameter. A linear relationship fitted to the data gave coefficients of determination of 0.64 for the gross specific gravity and 0.81 for the averaged x-ray specific gravity. The slopes of the two models were not statistically distinguishable, but the unexplained variance was smaller for the second. This finding indicates that the dowel-bearing strength was affected by the local density of the material directly under the nail during the dowel-bearing test. Because the unexplained variation was only moderately reduced, other factors not addressed or measured in this experiment probably also affected the outcome.

The NIR spectra between 1300 and 2400 nm were used to create models for specific gravity, shear strength, dowel-bearing strength, and NaOH solubility. The prediction for specific gravity had the highest coefficient of determination, 0.90; the others ranged between 0.84 and 0.85. The NIR system used in this study can be used as a portable instrument with a self-contained light source that would enable in-situ evaluation of the sheathing in buildings.

Engineering Durability in Wood Structural Systems

Robert J. Leichti, David V. Rosowsky

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objective: to quantify selected effects of in-service deterioration on the performance of conventional wood frame and light commercial structures

This project is intended to investigate the vulnerability of the existing housing resource to potential hazard loadings. The basic design premise that connection details in light-frame construction do not change in capacity or energy dissipation characteristics is not necessarily true, especially if the connections have decayed or corroded, have been wetted or overloaded at some time; or have been subjected to other degradation. The general condition of nailed connections, metal-plate connection, and others in existing structures, however, is not known.

Municipal building departments in the Willamette Valley were requested to notify us of demolition permits for woodframe structures. Fifteen structures have been sampled; they were constructed from the early 1900s to 1970s, with most from the 1930–1950 era. One or more exterior wall sections, or at least selected studs with exterior sheathing still attached, are removed and brought to the laboratory, where the construction is documented and they are stored for testing (planned for early 2005). A large sample of nails has been removed from the structures so that bending-yield strength can be determined. Stud and sheathing materials (mostly plank sheathing) also have been sampled so that the embedment properties of these materials can be evaluated. This testing will also be conducted in the first half of 2005.

Load-deformation response of walls with "typical" decay patterns is being computed with Cyclic Analysis of Shear Walls (CASHEW) software. The analyses are for a wall section 2400 mm × 4800 mm, sheathed with two pieces of vertically oriented strandboard sheathing and nailed at 100 and 610 mm (edge and field) spacings. The modeling is conducted as a stochastic process that utilizes data from a previous experimental program that examined the progressive deterioration of nail connections subjected to biological deterioration. The computations will yield a family of response curves for a progressive decay condition that can be used in engineering assessment. We expect the computational work to be complete by the middle of 2005.

This project made it possible for the principal investigators to collaborate on a successful proposal to a university fund-

ing resource. The grant funds a seminar series of eight speakers on a wide range of durability issues durability engineering in wood-frame structures. The seminars are advertised and open to interested parties.

Smart Sensor System Technology for Improved Wood Utilization

Glen E. Murphy

Initiation Date: FY 02 Scheduled Completion Date: FY 05

Objectives: (1) to review current developments in sensor system technologies that mimic human senses and identify at least seven applications that could be expected to lead to improved wood utilization; (2) to assess the costs and effectiveness of at least three promising sensor technologies; (3) to determine how at least two of these technologies could best be linked with a memory function (smart sensors) to reduce waste, meet market needs for niche products, increase value recovery, or control costs; (4) to develop methods and protocols for at least one smart sensor technology and to establish linkages with equipment manufacturers and suppliers

In FY 03, over 400 Douglas-fir wood discs were collected from 120 trees and 17 locations around Oregon. The discs were subsampled to provide material for assessing basic density, spiral grain, and, possibly, extractives content. Chainsaw wood chips were also collected from all 400 discs. Preliminary analysis of 100 samples indicated that near-infrared (NIR) technology could be used to predict basic density accurately, but not spiral grain. In FY 04, NIR measurements were completed on the remaining wood chip samples. Analysis of the usefulness of NIR data for predicting basic density will be completed in FY 05. Extractives content of samples from the disks was to have been undertaken in collaboration with researchers from the University of Idaho. In FY 04, we were informed that the work was unlikely to be started until late 2005 or possibly 2006. Therefore, work on extractives content will not be completed in time for inclusion in this project.

The spatial variation of spiral grain and wood density was analyzed for the wood disks. Spiral grain was not related to height within a tree, aspect or elevation. Wood density was weakly related to height within a tree, but not to elevation or aspect.

An algorithm was developed for optimally bucking stems into logs based on both internal and external quality features. The incorporation of internal properties into bucking algorithms is novel. The algorithm was implemented in Visual C++ and tested on a data set of over 3700 pine trees.

Field work on value recovery and measurement accuracy of a mechanized harvesting system was undertaken in radiata pine stands in New Zealand in collaboration with New Zealand scientists. The effects of measurement errors on value recovery were determined for harvesters working in ponderosa, loblolly, and radiata pine. The data sets used in the analysis came from eastern Oregon, southeastern U.S., and New Zealand.

Finally, current diameter-sensing systems measure over-bark diameters and have to predict under-bark diameters, since logs are sold based on under-bark specifications. The effects on value recovery of at least three different approaches to bark thickness predictions will be evaluated for use on mechanized harvesters/processors working in at least two species (Douglas-fir and radiata, ponderosa, or loblolly pine).

Extending the Timber Resource through Improved Harvesting, Transportation, and Manufacturing

Pushing the Limits: Production Economics and Impacts of Alternative Silvicultural Systems in the 21st Century

Loren D. Kellogg, Glen E. Murphy, Stephen H. Schoenholtz, Paul W. Adams, Kevin D. Boston

Initiation Date: FY 02 Scheduled Completion Date: FY 05

Objectives: (1) to determine the influence of four levels of intervention on production economics and tree damage in western Oregon stands and to identify how such interventions could be managed under a multiple entry scenario; (2) to determine how newly developed slash-bundling technology could be best integrated with "conventional" harvesting systems to remove small trees in high-fire-risk and unhealthy stands in Eastern Oregon and to assess the impacts of this technology on site sustainability; (3) to extend the operating season of eastern Oregon harvesting systems by developing economically viable and environmentally acceptable protocols and procedures for operating harvesting systems in winter and to com-

pare the impact on soil disturbance of an extended and a conventional season; (4) to assess the effect on production economics of different levels of market complexity for a cut-to-length, mechanized harvesting system operating in a Western and an Eastern Oregon stand; (5) to identify the long-term impacts on site productivity of soil disturbance caused by harvesting

A written research plan that examines both the scientific and operational aspects of alternative silviculture systems involving a range of harvest interventions under a multiple-entry scenario was completed on the OSU McDonald-Dunn College Forest in FY 2004.

A detailed research study to compare and contrast the capabilities of mechanical equipment configurations employed in different fuels reduction treatments throughout Oregon was completed in 2004. The study investigated soil disturbance, system productivity, owning and operating costs, system effectiveness within the fuels reduction treatment, and treatment effectiveness for altering future wildfire behavior. Study sites and cooperators are Boise Cascade Corp. in southwest Oregon and Confederated Tribes of the Warm Springs Reservation in central Oregon. Pretreatment measurements were completed on soils and vegetation, productivity studies were conducted, and parts of the post-treatment measurements were completed on all study sites.

Activities planned for 2005 include completing field data collection, compiling and analyzing data, and preparing manuscripts. Machine productivity observations will be used to establish relationships between the equipment configurations studied and site conditions. System productivity values will be analyzed and reported per unit area and volume removed. Detailed equipment owning and operating costs will also be determined for each treatment. Soil characteristic measurements will be used to determine the amount of disturbance generated from each forest harvesting activity. Fire behavior in the treated stands will be predicted with the Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS).

Long range planning was completed in 2004 for a more comprehensive assessment of fuels reduction alternatives and new wood utilization opportunities in eastern Oregon forests that are "at risk" of catastrophic wildfires. A Research Agreement was completed between Oregon State University and the Confederated Tribes that addresses science information needs in forest restoration focused on the integration of studies on equipment and operational systems, soil disturbance, wood utilization, and silviculture/fire management. Additional interest and in-kind support was obtained by the Sisters Ranger District on the Deschutes National Forest. This planning will be followed up in FY 2005 with the Confederated Tribes, the USDA Forest Service, and other collaborators.

We worked with personnel at the Sisters Ranger District on the Deschutes National Forest in Central Oregon to identify field study sites. Portions of the sites were logged under winter conditions (averaging 2–3 ft. snow pack) during the winter and early spring of 2004. Main skid trails were located and identified for further study after snowmelt. Areas to be harvested in 2005 under more typical circumstances have been identified and the operability is being discussed with the harvesting contractor. Measurements will be made when soil moisture is consistent (post snowmelt) and harvesting operations have concluded. The outcome is to characterize and compare relative site-level soil disturbance differences between winter ground-based logging over snow versus summer logging directly over soil.

Work started in FY 2004 on using new Multi-Dat technology developed by the Forest Engineering Institute of Canada (FERIC) and manufactured by GENEQ inc. of Montreal, QC, Canada for obtaining long-term productivity information useful for logging contractors. This work will be continued in FY 2005.

Additional work completed in FY 2004 included the modeling of road sediment yields reaching streams over 20 years in the foothills of the Oregon Coast Range. In the "clustered" scenario, all forest harvesting took place in the northern half of the forest. In the "dispersed" scenario, the same level of harvesting was allocated to the full forest estate. Three spatial modeling packages were used: SPECTRUM, to schedule the harvest settings over 150 years; NETWORK 2000, to determine which roads would be used during the first 20 years of harvest and how many truck loads would be transported over them; and SEDMODL2, to determine the road sediment yields likely to reach a stream. Concentrating the harvesting on half of the forest estate reduced total road sediment yields 36% when compared with dispersed harvesting.

Work continues to assess effects of contemporary harvesting operations on soil disturbance, decomposition, and nutrient availability as indicators of potential impacts on long-term soil productivity. The two sites, in western Oregon and western Washington, were subjected to intensive management of Douglas-fir by forest industry cooperators. *In situ* measurements of net nitrogen mineralization and decomposition are being assessed on (1) skid trails with visual evidence of compaction and mineral soils exposure; (2) skid trails containing logging debris; (3) low-distur-

bance areas between skid trails with low levels of logging debris; (4) low-disturbance areas between skid trails with high levels of logging debris; and (5) areas immediately adjacent to small slash piles on the two sites. At each site, replicated experiments are established to compare bole-only harvesting, whole-tree harvesting, and bole-only harvesting with creation of small debris piles on subsequent soil and stand productivity. Effects of logging treatments on extent of each disturbance class have been assessed. Preliminary results show that all logging treatments inhibited initial decomposition of conifer foliage assays relative to intact forest conditions. Furthermore, net nitrogen immobilization may be occurring during the initial months after logging in sampling areas adjacent to debris piles.

Improved Utilization of Wood and Reduced Energy Use during Lumber Processing through Effective Drying

Michael R. Milota

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: (1) to develop methods to make the model adapt to new process information; (2) to investigate methods to reduce energy consumption in lumber drying by modifying drying schedules and wood handling at the sawmill and planer; (3) to reduce the moisture content (MC) variability of dried lumber and increase lumber quality by optimal lumber processing

A model was developed that uses a commonly available spreadsheet program, Excel, to predict the final MC distribution of lumber coming out of a kiln. The inputs are kiln schedule (temperature, humidity, and air velocity), kiln configuration (lumber thickness, sticker thickness, stack height, width, and depth, and number of boards in a row), initial condition of the lumber (MC, temperature, specific gravity), and a characteristic drying curve for the species. The user can see results in a familiar format and can manipulate them for further analysis.

Mills can use the model to study the impacts of process changes. To date, the effects of fan reversals, kiln schedule, and presorting by board weight have been tested. The moisture variability in the dry lumber is strongly affected by the fan reversal times as shorter, more energy efficient schedules are used. Energy use during the kiln cycle can be reduced by reducing the venting (by keeping the vents closed at startup) and by using higher wet-bulb temperatures. Presorting hemlock by board weight was only marginally effective in reducing the final MC variability, although drying time was slightly reduced.

Science to Support Environmentally Responsible Wood Procurement

Development of Methodologies to Evaluate the Impact of Construction Practices, Materials, and Road Use on the Economic and Environmental Performance of Aggregate Forest Roads in the Oregon Coast Range

Kevin D. Boston, Marvin R. Pyles

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to implement the current aggregate road design methodologies from rural roads to determine their suitability for forest roads; (2) to test the potential for improved environmental performance by comparing the laboratory measures of subgrade and surface strength compacted at current field density and moisture conditions with properties at optimal density conditions; (3) to determine the changes in road shape based on road use and road strength.

Subgrade material has been collected from three road segments totaling approximately 2 miles. Ninety percent of the samples have been processed and classified according to both the Unified and AASHTO classification. Future work includes the completion of all laboratory tests by June 2005.

Planning for Fire-Killed Timber Salvage Considering Economic Values and Environmental Risks

John Sessions

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objective: to develop a decision support system to be used to assist managers in evaluating economic values and environmental risks associated with timber salvage in fire-prone forests

A forest growth-and-yield model simulator (SLOMO) has been modified to incorporate snag dynamics for SW Oregon forests. With this model, stands can be burned under a range of severities, and dead trees can be tracked over time. The effect of alternative timber salvage policies on wildlife can be estimated through the number of dead trees standing

over time by diameter class and species group. The next step will be to develop a regeneration module from the literature that will permit estimates of the time needed to regrow the forest to the size that provides green and dead wood suitable for mature forest wildlife habitat. This will permit evaluation of alternative salvage strategies, including slash treatment, on mature forest wildlife. One important policy examination will be to evaluate if harvesting smaller fire-killed trees with subsequent slash treatment immediately after fire, while leaving larger fire-killed trees, provides economic returns while lowering longer term fire risk to the new stand.

The Effect of Road Connectivity on Fine Sediment Delivery to Streams

Arne E. Skaugset III

Initiation Date: FY 02 Scheduled Completion Date: FY 05

Objectives: (1) to determine (a) a technically feasible, cost-effective method to measure the amount of fine sediment generated by individual road segments; (b) road and site characteristics, including those that influence surface runoff that affects the amount of fine sediment generated by individual road segments; (c) the amount and timing of sediment from connected road segments relative to the sediment load carried in the live stream where the road segment(s) are connected; (2) to model sediment production from individual road segments; (3) to compare the amount of fine sediment generated from connected road segments with the total basin sediment yield

This project is being conducted in the Oak Creek Watershed of the McDonald/Dunn Research Forest at Oregon State University. The watershed is instrumented with infrastructure dedicated to long-term monitoring of the hydrology and water quality. This infrastructure enables the investigation of forest roads and timber harvesting activities and their impacts on soil and water resources.

The total sediment yield for each road segment captured at the culverts was highly variable and ranged from 25 g up to approximately15 kg. Sediment from the road segments that yielded the most sediment was composed completely of coarse sediment that was captured in the geotextile sock. Conversely, sediment from the road segment that yielded the least amount of sediment was composed of only the finer "settleable" sediment and was all captured in the barrel. Cumulative runoff was a better predictor of the amount of sediment that a road segment would yield than any of the measured road and hillslope characteristics, including road grade and segment length. The hydrology of the road segments was quantified. As expected, the segment with the greatest runoff ratio also had the highest sediment yield.

The road and hillslope characteristics associated with the nine road segments studied were used as input variables for two models, WEPP:Road and SEDMODL2, that are used to predict the sediment yield from road segments. Average annual sediment yields were calculated and compared with actual erosion data. The relative rank of the road segments for predicted versus actual erosion was also compared. Neither model predicted the sediment yield from the road segments well. More importantly, neither model predicted the relative rank of the road segments. This latter finding is important because it is generally thought that they do consider the important road and hillslope characteristics that affect road sediment yield.

Two projects continue in the Oak Creek Watershed. One is an attempt to scale the impacts from individual road segments up to the scale of a small watershed. Two smaller watersheds within the Oak Creek Watershed have been intensively instrumented. One is forested with no roads; the second is forested but has a midslope road running across the top third of the watershed. Data analysis will include side-by-side comparisons with the unroaded watershed, as well as detailed process-level analysis of data from the roaded watershed.

A research project using data on discharge and sediment is beginning. The distributed discharge and sediment data from Oak Creek and the Oak Creek road network are being used to verify and calibrate a distributed physical hydrology model, DHSVM (Distributed Hydrology—Soil Vegetation Model).

The Design of Forest Roads to Minimize the Delivery of Fine Sediment While Transporting Logs during Wet Weather

Arne E. Skaugset III, Elizabeth M. Toman

Initiation Date: FY 04 Scheduled Completion Date: FY 06

Objectives: (1) to develop and test designs for aggregate pavement structures for low-volume forest roads that will minimize the generation of fine sediment from the road surface during active use in wet weather; (2) to investigate the relative role that aggregate quality (geology of the surface aggregate) plays in the generation of sediment from road surfaces during active use in wet weather; (3) to perform a benefit/cost analysis of the design alternatives, comparing the cost of the installed pavement aggregate surface with the savings in sediment from the road surface;

(4) to investigate the opportunity to use the road installations to investigate management strategies for roads during wet weather; (5) to use the data generated to verify, or perhaps modify, the coefficients used to predict the impacts of traffic on sediment yield used in SEDMODL and other models that predict the effects of traffic on the generation of sediment from low volume, aggregate surfaced roads

This year, funding has been used to create a research plan and solicit help from industry contacts and other researchers. In FY 2005, landowners in the Pacific Northwest will be invited to host an experimental installation. The pavement structures will be designed and constructed at each site. By the end of the year the pavement structures will be completed and ready for experimental testing.

Quantifying the Cumulative Effects of Timber Harvesting Adjacent to Perennial Nonfishbearing Streams on Water Quality

Arne E. Skaugset III

Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: (1) to determine (a) the on-site effects of harvesting adjacent to perennial, nonfishbearing streams on stream temperature and accelerated erosion; (b) the cumulative effects of harvesting adjacent to several perennial, nonfishbearing streams on stream temperature and accelerated erosion off-site in fish-bearing streams; (2) to identify and quantify the hydrologic processes and the magnitude of the processes responsible for propagating stream temperature and sediment effects downstream

This research project is part of the Hinkle Creek Paired Watershed Study. The overall goal is to determine the cumulative effects of contemporary forest practices on private industrial forestland on water quality, fisheries, and aquatic habitat. These effects include peak flows, stream temperature, fisheries, aquatic invertebrates, and amphibians on-site in perennial nonfishbearing streams, as well as off-site in fish-bearing streams.

The Hinkle Creek Paired Watershed Study is a nested, paired watershed study. The main study watershed has an area of 5,000 acres fairly evenly divided into the North and South Forks of Hinkle Creek. The South Fork will serve as the treated watershed in the paired watershed study. Six headwater watersheds, or small watersheds that are drained by perennial nonfishbearing streams, will also be set up as a paired watershed study. Two of these watersheds are in the North Fork and will act as controls; four are in the South Fork and will be treated.

Discharge, suspended sediment, and temperature will be measured on each of the small perennial nonfishbearing streams, as well as at the mouths of the North and South Forks of Hinkle Creek. For the four small watersheds that will be treated, the streams will be monitored at the downstream end of proposed harvest units. For the two small control watersheds, the measurements will be made at an accessible location that results in watershed areas comparable to the treated small watersheds.

For the first round of timber harvest in 2005, the timber will be harvested in the four small watersheds upstream of the streamgauging installations. The first year of data collection that includes discharge and suspended sediment in six headwater watersheds and two confluence locations and the fourth year of data collection that includes stream temperature at 45 locations throughout the watershed have been completed. These hydrologic data will function to calibrate the control watersheds (in the North Fork) and treatment watersheds (in the South Fork) and will be used to discern treatment impacts from contemporary forest practices.

Six storms during December, January, and late February to early March of the 2004 water year warranted further study because they carried significant and measurable sediment transport. These storms transported approximately two-thirds of the total annual sediment yield from these watersheds. Total annual sediment for the six small watersheds yield ranged from 747 kg/ha for Clay Creek to 201 kg/ha for Fenton Creek.

In order to investigate the processes responsible for propagating stream temperature downstream, a series of steady state, tracer dilution tests were carried out during the summer of 2004. The tracer dilution tests are used to quantify the amount and location of groundwater influx into streams during summer low flows.

Twelve scientists and resource managers from the Bureau of Land Management, U.S. Forest Service, Oregon Department of Environmental Quality, and a local private consultant attended a field tour at Hinkle Creek. Another 60 natural resource professionals toured as part of the Oregon Forest Resources Institute annual meeting. In October 2004, approximately 180 high school students and 20 adults from Roseburg High School spent the day as a part of the Hinkle Creek outreach program.

Termination Reports for Completed Projects

Applying Precision Forestry Techniques for Adding Value along the Wood Supply Chain

Loren D. Kellogg, Michael G. Wing

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to investigate and advance the use of precision forestry techniques to increase the efficiency of harvest planning, layout, and monitoring; (2) to document the efficiency of precision forestry techniques across different topographies, silvicultural treatments, and forest types; (3) to compare precision forestry techniques to traditional methods; (4) to seek partnerships with industrial and agency entities to explore the application of precision forestry techniques

In 2001, we examined using a laser rangefinder with a digital compass to capture and map data associated with harvest planning. The combination was effective in two typical field applications in helping locate and create spatial data for the traverse and profiles. This digital approach offers advantages over traditional data collection in that distance and direction information can be calculated quickly and accurately and distance measurements can be obtained without having to control sag or tension or adjust for uneven ground surfaces, as required with a measuring tape. The laser rangefinder calculated horizontal or slope distances almost instantly and could return several types of measurement, providing flexibility.

Research in 2002 added a global positioning system (GPS), digital total station, and string box to the laser rangefinder and compass. A study was designed to compare precision forestry techniques with manual survey techniques across a range of different topographic conditions, forest types, and silviculture treatments.

In 2003, sixteen (~1 ac) units were used to evaluate different spatial data-collection instruments and techniques. Unit boundaries were measured by three surveying techniques: (1) a string box, manual compass, and clinometer; (2) a laser, digital compass, and two digital data collectors; and (3) a global positioning system (GPS). The data were compared with a series of benchmarks established with a digital total station. Time required to survey a patch and complete the office work varied substantially by technique. Using the laser, digital compass, and Juniper data collector required the least time per patch (17 minutes). The second most time-efficient technique was using the laser, digital compass, and the TDS data collector (19 minutes), followed by the string-box method (38 minutes), and GPS method (40 minutes). Average time for the total station was 54 minutes per patch. The time, type of equipment, and crew size required to complete a traverse were used to calculate the variable cost of each survey method. Hourly labor and initial equipment costs were most significant in overall operating costs. The string box, manual compass, and clinometer method cost approximately 6% less than the laser method. Although the purchase price and labor costs with the string-box technique were lower, 48% more time was spent conducting the traverse of all the patches. The total station technique was the most expensive because of the larger crew and time required to clear sight lines. Using the digital instruments saved time, but performances were not always as effective as those achieved with traditional methods.

A second study compared two techniques for collecting terrain profile data, as well as assessing the associated costs and skyline design payloads for 20 logging corridors on the Siuslaw National Forest in western Oregon. The first technique used measurements made with a traditional string box, clinometer, and hand-held compass; the second employed an EDM device, digital compass, and digital data recorder. These methods were compared with the results obtained from benchmark data collected by a digital total station. The less labor-intensive and lower-cost string-box method provided data with accuracies similar to those produced by a total-station or laser method.

A third study assessed the accuracy and reliability of five commercially available digital range finders in measuring a distance course, traverse boundaries, and tree heights. In general, the highest-priced range finder we tested was more accurate and reliable than less expensive counterparts. In several applications, however, some of the lower-priced range finders outperformed more expensive instruments. The level of accuracy claimed by a range finder manufacturer was not met in at least one instance, and large

measurement errors in several of our field-testing applications were detected. Users should identify their measurement and accuracy requirements before choosing a digital range finder.

Research in the final year of the project (2004) involved rigorous GPS accuracy and reliability testing. Ten mapping and consumer grade GPSs were tested at several measurement courses, each in a different forest condition, in McDonald Forest. Even GPSs produced by the same manufacturer varied in mapping accuracy and reliability. Consumer grade GPSs (the most affordable) could determine reliable positions even under dense canopy, provided that multiple positions were recorded and averaged. With mapping grade GPSs, differential correction base station choice affected the accuracy of measurements between 1–3 m. Base stations located closer to GPS receivers did not always produce the most accurate results; research to examine the reasons for this continues.

This research demonstrated that digital technology for forested resource measurements can provide benefits over manual techniques, including increased efficiency, accuracy, and reliability of measurements. Limitations imposed by rugged terrain, thick canopy, dense understory, and inclement weather, however, can make using digital tools impractical or impossible. For some instruments, such as total stations, cost may also make digital tools impractical. Nonetheless, versatility and cost continue to improve as technology and market forces interact. Those measuring forest resources would be wise to use digital technologies when practical.

Designing Hydrologically 'Transparent' Forest Roads for Timber Access: The Effect of Road Connectivity on Watershed Hydrology

Arne E. Skaugset III

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to determine road and site characteristics that influence the amount of runoff in road relief culverts on the scale of a complete watershed; (2) to determine the timing and magnitude of flows from the ditches of roads that are connected hydrologically to streams and to determine how the roads contribute to the timing and magnitude of stream flows at stream-crossing culverts; (3) to simulate the effect of hydrologically connected roads on watershed hydrology with a spatially distributed hydrologic model, DHSVM (Distributed Hydrology Soil Vegetation Model)

During the winters of 2002–2005, all of the water-level devices were installed and water-level data were collected throughout the watershed. These data included discharge at the mouth of the watershed, 24 stream crossing culverts, 74 road drainage culverts, and 17 flumes. Rainfall data were collected at the four tipping bucket rain gauges and data from the meteorological station were maintained.

Stream gauging and discharge calculation in small headwaters streams and at culverts can be difficult because of channel geometry. A single rating curve was desired that would be applied to all inlet-controlled culverts in the watershed. A method was developed to calculate discharge from water height at culverts in the Oak Creek Watershed. The calculated discharge values were validated by comparison to discharge values calculated from salt tracer-dilution tests and other commonly used empirical equations.

During the winter of 2001–2002, instantaneous peak flow and total runoff volumes were calculated at 58 of the 74 cross-drain culverts in the watershed. The distribution of the flow response was right-skewed in its frequency, indicating that most of the road runoff was contributed by a minority of the culverts. During the winters of 2002–2004, frequency distributions of observed values of instantaneous peak flows and total runoff volumes at cross-drain culverts in the watershed were also right-skewed. For four storms during 2002–2003, cumulative road runoff ranged from 13 to 25% of total quickflow at the watershed outlet. As storm size increased, percent of road runoff appeared to increase.

The GIS coverage for Oak Creek was used to calculate road and hillslope characteristics in the watershed. It was not possible to predict flow response at cross-drain culverts accurately based on commonly used independent watershed/road variables.

At 16 of the 24 stream-crossing culverts, ditch flow was measured in the road ditches draining to the stream-crossing culverts. Discharge hydrographs at the culvert inlet and in the road ditch just above the inlet were analyzed. Streamflow without the influence of the road was calculated by subtracting the measured flow in the ditch from the measured flow at the culvert inlet.

Peak flows in the ditches occurred before peak flows in the streams, resulting in increased stream flow on the rising limb of the stream hydrographs. The increases in the peak flow of the streams resulting from the ditch flows ranged from 0.0 to 11.3 l/s. Corresponding increases in total storm runoff ranged from 0 to 2,200 m3. This represents an increase in peak flow from 0 to 610% and an increase in total stream runoff of 0 to nearly 5,000%. Where the road intercepted subsurface flow, ditch flow increased stream peak flow 45% on average, compared with an average of

2% where the ditch flow consisted primarily of road surface runoff. The increases in peak flow and total storm runoff due to the road ditch were highly variable and could not be predicted using traditional topographic indicators.

The primary benefits from this study will be (a) development of an inexpensive and practical method for calculating discharge at culverts in small watersheds, (b) enhancement of the understanding of road segment hydrology and the impact on a watershed, (c) development of a model to predict sediment discharge from a roaded watershed, and (d) contributions to the scientific basis for forest practice regulations that affect harvesting and transportation of logs on forest roads.

Establishing Fundamental Structural Performance Characteristics of Log Structures

Robert J. Leichti

Initiation Date: FY 02 Completion Date: FY 04

Objective: to establish the basic performance data of log structures as affected by common construction details, with emphasis on lateral force pathways, specifically (1) establishing lateral force transfer mechanisms of log structures; (2) assessing the monotonic and reversed-cyclic shear capacity of log wall systems; (3) evaluating the interaction of the end and side walls as a result of their interconnection; (4) developing a set of basic finite-element models that incorporate mechanical effects of wall mass, connection hardware, friction, and boundary conditions

Log structures are constructed from round logs or manufactured timbers that are stacked vertically and have interlocking corners. Log shear walls are also bearing walls and resist lateral loading through a different mechanism than do light-frame walls. Light-frame and log walls also dissipate energy differently. The objective of part I of the project was to evaluate the lateral force resisting pathways in log structure foundation details, with a focus on seismic shear resistance provided by friction, anchor bolts, and through-rods. The experiments used test specimens that represented two common construction details for sill log foundation anchorage. One detail had the sill log sitting on the floor diaphragm; the other had the sill log in direct contact with the sill plate. Anchor bolts and thru-rods were included in both details. The coefficient of friction between the sill log and floor diaphragm was about 0.4.

The sill log-foundation details were loaded vertically to simulate wall and roof dead load and forced to move horizontally with a static and then with a fully reversed, cyclic, quasi-static test protocol. The tests were limited by actuator capacity, rather than capacity of the assemblies. The force-displacement curves showed an initial stiffness, slip, and post-slip stiffness. The hysteresis diagrams were open and boxy, showing that energy was dissipated by friction between the sill log and the floor diaphragm or sill plate. Initial and ultimate yield modes differed, depending on foundation details.

The base shear design requirement for a representative wall was calculated following the Uniform Building Code. Both connection details had capacities greater than required for Uniform Building Code seismic zone 4.

In part II of the project, a set of finite-element models was developed to conduct a parametric study of the effect of window and door openings, aspect ratio, and inter-log friction on wall stiffness and displacement. Test data for a log wall with manufactured logs were used to verify that the finite-element model was accurately predicting the log wall behavior. The finite-element models developed with various construction details were improved further by adding the weight of the logs. Some problems with numerical convergence occurred because of the low stiffness of the force-displacement relationship during the slipping event and the many free edges in the models, such as at door openings, wall edges, and window openings. Through-rod tension and tributary roof load are crucial to establishing normal forces that limit inter-log slip. Increased wall aspect ratio increased overall displacement more than any other study variable. Window openings did not adversely affect wall performance because extra thru-rod hardware compensated for the lost log-log friction. Door openings negatively affected initial stiffness, but not the other performance characteristics of the wall, also because of the extra through-rod hardware.

The foundation/anchorage systems for contemporary log structures appear to be adequate for lateral force resistance, and anchor bolts can be designed using the yield mode provisions of the *National Design Specification for Wood Construction*. Safety levels appear to parallel those for dowel-type connections used in wood construction. Finite-element models reproduced basic behavior of log wall systems and were extended to assess several common construction details, including through-rod tension, wall perforations, and through-rod hole size. Further studies are planned to examine the three-dimensional behavior of log structures as affected by wall interconnection and the roof diaphragm and to evaluate other inter-log connection hardware with respect to lateral force transfer and out-of-plane bending.

The log structures industry is a growing segment of the high-end wood building industry, and log structures are

being designed and constructed in areas at high seismic risk. The engineering information available to design engineers and log structure manufacturers, however, is limited in scope and technical quality. Engineering information pertaining to lateral force resistance, especially with respect to natural hazard loadings, is needed. This project provided basic engineering analysis and test data for log structure foundation attachment and lateral force resistance mechanisms of log walls. The information is being referenced by the International Code Council as it drafts the first model code requirements for log building structures and is also being used by the log structures industry to justify designs for high seismic and wind requirements.

Life Cycle and Costing Assessment to Determine Environmental and Economic Impacts of Manufacturing Wood Building Materials

James B. Wilson

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to assess the capability of ATHENA™ for modeling the life cycle performance of forest products manufactured in the U.S.; (2) to determine whether the ATHENA™ model can be used to characterize the energy and environmental impacts associated with various management decisions; (3) to investigate the effectiveness of life cycle analysis of assessing various processing alternatives for the forest products industry

Two software packages, ATHENA™ and SimaPro™, were explored for use in assessing the environmental performance of wood building materials and their substitutes for residential construction. SimaPro has good capabilities in areas of ATHENA's weaknesses and strengths, making them an excellent combination of programs to conduct life cycle inventory and life cycle assessments. The objective was to determine the most effective means of modeling the various process stages of wood from the forest through construction, use, and recycling or disposal. This work was done in conjunction with the CORRIM, Inc., effort to document the environmental performance of wood.

ATHENA was effective for modeling environmental performance of residential buildings, enabling the user to enter the design and list of building materials and providing output in environmental indices such as global warming potential, emissions, and solid waste, along with the embodied energy. The program relies on its library of building materials that includes wood, steel, concrete, and other construction materials, as well as doors, windows, etc. The user cannot modify or enter new life cycle inventory data for materials, model processes for producing materials, or use the program for economic analysis. CORRIM life cycle data for structural wood products such as plywood, OSB, LVL, glulam, and I-joists were entered into ATHENA software by their personnel.

SimaPro is excellent for modeling processes such as the growing and harvesting of trees and the processing of wood into building materials. The program has excellent databases of materials, chemicals, products, etc., for conducting life-cycle inventories of processes. The database is also updated on an availability basis. The program is not as convenient as ATHENA for modeling buildings, and the databases don't have the necessary building materials unless entered by the user. The program can be used for economic analysis, but it is much easier to do the economics in an Excel type spreadsheet. SimaPro can be used for the environmental indices, but the user needs to write the equations, since the indices provided are not suitable for the U.S. ATHENA and SimaPro software are useful for conducting sensitivity studies, such as the impact of substituting materials or making process changes, respectively. Calculations validated the results provided by both the ATHENA and SimaPro software.

SimaPro was used to assess the environmental impact of a wide range of product, process, and management scenarios. CORRIM data on harvesting, transportation, and product manufacturing were modeled to provide environmental performance data from the planting of trees through manufacturing for structural wood products of plywood, OSB, LVL, glulam, and I-joists. These models serve as a benchmark that can be used to measure performance enhancement resulting from management decision making. The models also were used to assess the impact due to specific management decisions. The impacts can be measured in specific emissions such as carbon dioxide, carbon monoxide, etc., or in terms of environmental performance indices such as global warming, energy, and emissions.

Methodology and models have been developed that will enable determination of the environmental impact of producing structural wood products; enable comparison of environmental performance of various materials; provide benchmark data that can be used for reducing environmental impact through optimization; and provide benchmark data for evaluating the performance of process changes such as fuel switching and selection of an emission control device. The data would also prove useful for material selection when considering impacts upon global

warming, energy use, conservation of resources, etc., and when making management and policy decisions for such issues as green certification, environmental policy, building standards, and preferred purchasing standards.

Meeting Timber Supply Goals through Improved Transportation Networks in Landslide Prone Terrain

John Sessions, Michael G. Wing

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to put data for the Elliott State Forest in the southern Oregon Coast Range into a GIS for initial inspection of forest terrain and current road status; (2) to process the digital terrain model to associate transportation costs for all road segments within the road network; (3) to process a landslide model to rate the relative stability of all terrain within the forest; (4) to calculate transport and maintenance costs for each road segment on the network, based on road section gradient

Initial research activities included developing a slope stability index and applying it to characterize the stability of roads. Spatial data layers representing roads, streams, culverts, and a digital terrain model (DTM) were obtained. The topographic index TOPMODEL was used to represent the hydrologic response of the study area to precipitation and incorporated the topographic index into a factor of safety (FS) equation. An FS was calculated for all roads within the Elliott State Forest and varied as expected, with road segments on ridge tops and in areas of mild slopes showing higher FSs (more stable). Combinations of large upslope contributing areas and high local slopes created lower factors of safety (less stable). These results demonstrated that a reliable FS could be created and applied without specialized software.

Next, methods for predicting road segments prone to landslides were explored. We also examined the utility of combining the risk of surface erosion and hillslope failure to determine sedimentation risk from a road network in western Oregon. Data from two Oregon Department of Forestry 1996 Landslide Survey areas, Mapleton (Coast Range) and Vida (Cascade Range), were analyzed. A regression model of 30 randomly selected road segments that failed and 30 that did not was tested by a bootstrap method. The model correctly predicted road failure or nonfailure 71% of the time.

Work was initiated on a decision support system that considers landslide susceptibility, sedimentation, fish passage, and other factors to aid land managers in managing existing road networks. A key element was a method to prioritize forest road investments with the Analytic Hierarchy Process (AHP), a multi-criteria decision analysis technique by which problems can be structured hierarchically and preferences for solutions developed by pairwise comparisons between select attributes. After investment alternatives are prioritized, resources (i.e., time, personnel, budget) can be assigned to each alternative to provide an estimate of alternative cost. AHP provided flexibility in problem formulation and solution. One strength was its ability to accommodate different attribute types (numeric and categorical) and attribute values measured at different scales. AHP was particularly useful for formulating and determining solutions to forest engineering routing applications.

The use of DEM resolution for identifying transportation route alternatives was also examined. The goal was to develop an algorithm that identified transportation routes through the guidance of an objective function that weighted road grade and potential drainage area. A 9-m resolution DEM was used to create road grade and drainage area estimates, and the spatial distribution of alternate route solutions was examined. The 9-m DEM did not provide reliable road grade and landscape slope estimates; gradient estimations appeared to overestimate expected values. These results encouraged the use of finer resolution DEMs to model topographic surfaces for transportation routing purposes.

Research more closely examined AHP as a decision support tool for analyzing quantitative measures of environmental benefits for forested road activities. Two models were applied to schedule forest road maintenance and upgrade activities involving nonmonetary benefits. Model I used a linear objective function formulation that maximizes benefit subject to budgetary constraints. Model II used a nonlinear objective function equal to the sum of benefits divided by the sum of all costs in a period. The reduction in cost between the Model I (maximize benefit subject to budget constraints) and Model II (maximize a benefit-cost ratio) formulations was three to six times greater than the reduction in benefit for the same budget and time preference combination. The choice between these objective functions remains with the decision maker and involves tradeoffs between budget expenditures and minimizing environmental impacts. The AHP approach coupled with an optimization heuristic provides a flexible platform for scheduling activities that can be subject to both linear and nonlinear objectives and constraints and allows formulating and solving complex issues.

This research addressed a challenging agenda: to model the environmental impacts of forested roads and to develop a decision support system methodology for managing environmental impacts while maintaining transportation route access. The Analytical Hierarchy Process (AHP) was identified as a potential tool for quantifying environmental benefits and helping to organize a decision matrix that managers could use as a decision support system. AHP provides a flexible and accessible means of quantifying road impacts, with few limitations to the types and number of input parameters. Results from this study contribute to the scientific basis for assessing and mitigating the environmental consequences of forested road use in the timber supply chain.

Monitoring, Controlling, and Reducing the Airborne Emissions and Energy Use During Wood Processing

Michael R. Milota

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to develop the relationship between temperature, humidity, and airflow and the levels of volatile organic compound emissions from wood during drying; (2) to evaluate alternatives to RTOs (regenerative thermal oxidizers) for removing pollutants from dryer exhaust; (3) to develop the relationships between dryer emissions and other processing emissions, such as those from a press.

Nine additional ionic liquids were obtained and tested for their ability to absorb methanol and α-pinene from dry and wet air. Five (imidazolum-based cations with a PF6 anion) were not stable. The others are more promising, with trihexyl(tetradecyl)phosphonium-dicyanamide showing good absorption characteristics for the pollutants while being hydrophobic.

One key to reducing emissions is to reduce energy consumption by reducing the moisture variability prior to drying through effective sorting. We worked on correlating the near-infrared spectra from the surface of wet wood to drying behavior. In the past we had limited success using the entire spectrum, so chemical analysis (extraction followed by gas chromatography and mass spectrophotometry, and molecular beam mass spectrophotometer) was used to determine how better to correlate the drying data with the near-infrared spectrum. A previously written FORTRAN model was adapted to use Excel for the input and output so sorting scenarios can be simulated.

The past determination that hazardous air pollutant emissions (methanol and formaldehyde) from white fir lumber tripled when the drying temperature was 240 °F compared to 180 °F prompted further study on hemlock at temperatures ranging from 180 °F to 225 °F. These results also indicate a significant increase in emissions. These results will aid mills in determining if they are complying with the Clean Air Act reporting requirements and indicate that lower temperatures may help families with other HAP sources on site comply with Title 3 of the Clean Air Act.

This work produced a better understanding of how VOC and hazardous air pollutant (methanol and formaldehyde) emissions vary with dryer temperature. Emission levels for several western species were also determined, which will help mills to remain in compliance with emissions regulations. Mills may be able to use a lower dryer temperature to reduce hazardous air pollutant emissions significantly.

Evaluation of several alternatives to RTOs for removing pollutants from dryer exhaust indicated that adsorption onto polymeric beads followed by recycling of the beads, plasma discharge, and absorption into a liquid were viable alternatives. The adsorption process is hindered by deactivation of the beads over time. Plasma was being studied elsewhere. We determined that some ionic liquids provide a good absorption media for pollutants and they can be cleaned and reused. An industrial process for removing pollutants could be developed based on absorption.

Physiology, Patterns, and Design Criteria for Heartwood Formation

Barbara L. Gartner

Initiation Date: FY 01 Completion Date: FY 04

Objectives: (1) to elucidate the spatial and temporal patterns of permeability, respiration, storage, and mechanical properties within sapwood of woody plants; (2) to infer the plants' criteria for how much sapwood to maintain; (3) to infer the triggers for heartwood formation

In the coniferous species studied, permeability was higher in outer sapwood than in inner. The poor relationship between sapwood area (through which water flows) and leaf area (out of which water passes) shows that the amount of sapwood is not determined by a need for water transport. Respiration is inversely related to sapwood volume, suggesting that the carbon budget that woody plants spend on sapwood activities is more or less fixed.

Based on current research, I formulated a hypothesis, described in a book chapter, that the changes in wood properties across the radius are driven by hydraulic, rather than mechanical, needs. The increase in material stiffness across the radius has a minuscule effect on tree mechanics because most of the structure's stiffness is driven by tree radius to the fourth power, not tree material stiffness. In contrast, the 4-fold increase in the tracheid length and doubling of tracheid diameter affect water transport enormously as the tree matures.

Environment seems to affect durability in some cases and not in others. In Douglas-fir, the variation in growth rate caused by thinning coincided with variation in extractive concentration of heartwood produced during the same years. When young Douglas-fir trees were pruned or thinned, however, there was no effect on the extractives in their heartwood 1 year later. Much of the material converted into heartwood extractives is apparently produced the year that the growth ring is produced, not the year the growth ring converts into heartwood. Much of the stored materials may be unavailable to the tree for ordinary growth; they may be locked in the growth ring for use when heartwood extractives are made.

Analysis of 24 young western redcedars found no consistent effect of increasing growth rate on heartwood extractive contents. The methanol-soluble extractives were the most important for resistance against termite and fungal attack in western redcedar and Alaska cedar, but were not highly correlated with actual resistance to fungi or termites. There may be potential for influencing heartwood quality through silviculture, but we need to know more about the relationships between environmental factors and heartwood formation, and between heartwood variability and natural durability.

In many species, heartwood is very different from sapwood for many applications and even for the way it is optimally processed. If we can understand the production of heartwood and the factors that alter heartwood durability, we may be able to better predict the suitability of wood from different sites for different applications, and perhaps manipulate stands to improve heartwood durability.

This research shows that the common assumption that trees produce exactly the amount of sapwood needed to provide water for their leaves is invalid. Furthermore, in order to understand the biology of sapwood, one needs to look at outer, middle, and inner sapwood separately because their permeability and biological activity differ.

Finally, it shows that we may be able to manipulate the durability of heartwood in some species by manipulating how the trees are grown. Young individuals of durable species have much lower durability than old. Many of the durable species are being harvested at younger ages. If we can manipulate the stands to increase their heartwood durability, we may be able to continue using these species in applications for which durability is important, such as shakes, shingles, fence posts, decks, hot tubs, and siding.

Unification of the CORY Program Modules

Charles C. Brunner, James W. Funck, James E. Reeb

Initiation Date: FY 02 Completion Date: FY 04

Objectives: (1) to unify CORY's various modules into a single computer program capable of modeling the sawing processes in the original versions; (2) to develop a user-friendly interface for the unified version

All conversion programming has been completed and the user interface developed. The program is being used in studies of yields from hemlock and birch lumber. The new WinCORY program will facilitate yield studies exploring the effect of board cut-up strategies for various species of lumber. These studies can be helpful to industry in the economic decision-making process. In conjunction with the SAW-3D log sawing simulation, it can also help explore processing options for log resources, especially small diameter material expected to be available from thinning sites.

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Domec, J-C, ML Pruyn, and BL Gartner. 2004. Axial and radial profiles in xylem conductivity, water storage and native embolism in young and old-growth ponderosa pine trees. Proceedings, International Symposium on Wood Sciences, October 24–29, Montpellier, France.

Dunham, SM, J-C Domec, BL Gartner, FC Meinzer, and LM Ganio. 2004. Errors in extrapolating values of specific conductivity and vulnerability to embolism from branches to boles. Poster. Annual Meeting of the Ecological Society of America, August 1–6, Portland, OR.

Fallas-Cedeno, L, BL Gartner, and FC Meinzer. 2004. Radial gradients of axial sap flow and xylem tension in four species of hardwoods. Poster. Annual Meeting of the Ecological Society of America, August 1–6, Portland, OR.

Funck, JW, CC Brunner, DL Nicholls, KA Kilborn, and AM Brackley. 2004. The potential for producing higher value products from Alaska hemlock lumber. Technical forum poster presented at the 47th Annual Meeting of the Forest Products Society, June 28, Grand Rapids, MI.

Garland, JJ. 2004. Synthetic Rope in Logging. Weyerhaeuser Operations Managers, September 10, Skamania, WA.

Garland, JJ. 2004. Synthetic Rope for Forest Operations. Society of American Foresters Emerald Chapter, October 20, Eugene, OR..

Gartner, BL, J-C Domec, FC Meinzer, and D Woodruff. 2004. Gradients of xylem water tension across Douglas-fir trunks: Deducing patterns and causes. Proceedings, International Symposium on Wood Sciences, October 24–29, Montpellier, France.

Gartner, BL, D Newton, and R McKinley. 2004. Producing wood of specific quality for designated end uses. Invited Talk, Symposium on Intensive Plantation Forestry in the Pacific Northwest: Assessment of Future Potential and Economic, Environmental and Social Implications, January 20–22, Portland, OR.

Geng, Y, K Li, and J Simonsen. 2004. Further investigation of polyaminoamide-epichlorohydrin/stearic anhydride compatibilizer system for wood-polyethylene composites. Progress in Woodfiber-Plastic Composites Conference 2004, May 10–11, Toronto, Canada.

Gupta, R, and P Limkatanyoo. 2004. An integrated approach to include system effects in wood assemblies. Oral Paper Presentation, 8th World Conference on Timber Engineering, Lahti, Finland.

Gupta, R, P Seaders, K White, TH Miller and M Clauson. 2004. Performance of Wood Shear Walls Under Actual Earthquake Records. Joint Meeting of Structural Engineers Association of Oregon and Wood Design Education Committee (FPS), January, Corvallis, OR.

Hansen, E. 2004. Can innovation help wood products companies compete? Wood Moulding and Millwork Producers Association and Annual Meeting, August 3–6, Long Beach, CA.

Hansen, E. 2004. Industry evolution: Implications to the forest sector. Keynote Address. EU COST30 Seminar, October 27–31, Yundola, Bulgaria.

Hansen, E. 2004. Innovating to maintain competitiveness. SAF/SFRC Spring Symposium. The Future of Wood Products: It's All About Innovation, April 21–22, Gainesville, FL

Hansen, E. 2004. Marketing and new product development. SmallWood 2004. Creating Solutions for Using Small Trees, May 18–21, Sacramento, CA.

Hansen, E. 2004. Worked with Drs. Ewald Rametsteiner and Anssi Niskanen to successfully propose a parallel main session at the IUFRO World Congress in Brisbane, Australia, summer 2005. Innovation and entrepreneurship: Rural economic development and industry competitiveness.

Hansen, E, and R Anderson. 2004. Innovation in the sawmilling sector. Thirty-Second Annual Wood Technology Clinic and Trade Show, March 17–19, Portland, OR, (30/2).

Ice, GG, A Skaugset, and A Simmons. 2004. *Calculating the Area and Cost of Riparian Management Zones. Presentation at the AWRA Conference, Riparian Ecosystems and Buffers: Multi-Scale Structure, Function, and Management*, June 28–30, Olympic Valley, CA.

Kellogg, LD. 2004. FE 371. Harvest Process Engineering. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Kellogg, LD. 2004. FE 471. Harvesting Management. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Kellogg, LD. 2004. Wildfires in the West: Logging Methods and Harvest Planning. Presentation, 21st Annual Forest Engineering Conference, March 2–3, Moscow, ID.

Kellogg, LD. 2004. Seminar presentations at the Taiwan Forestry Research Institute, November 5, Taipei, Taiwan: Sustainable Forestry Through Active Management: Experiences from the Pacific Northwest Region of the USA; Stand Density Management Operation on Steep Terrain; and Wildfires in the Western Region of the USA: Fuels Reduction and Salvage Logging.

Kellogg, LD, CT Davis, and MC Bolding. 2004. Forest fuel reduction: Commercial and non-commercial approaches. Poster presented at the 2004 Oregon Logging Conference, Eugene, OR.

Kellogg, LD, MC Bolding, and CT Davis. 2004. Integrated forest operations research in the Pacific Northwest: Creating viable options for sustainable forest management. Poster presentations: 27th Annual Council on Forest Engineering Meeting, April 28, Hot Springs, Arkansas; 2004 Oregon Society of American Foresters Annual Meeting, May 6, Ashland, OR; 2004 International Mountain Logging Conference, June 14, Vancouver, British Columbia, Canada.

Leichti, RJ. 2004. Biodeterioration effects on nailed connections. Presentation, 8th World Conference on Timber Engineering, June 13–17, Lahti, Finland.

Li, K. 2004. Di-block copolymers as wood-polyethylene compatibilizers: Development and compatibilization mechanisms. Progress in Woodfiber-Plastic Composites Conference 2004, May 10–11, Toronto, Canada.

Lippke, B, J Bowyer, D Briggs, J Perez-Garcia, and J Wilson. 2004. Life Cycle Assessment of Materials in Residential Construction: How Wood Products Stack Up. Talk and Abstract, Forest Products Society Annual Meeting, June 29, Grand Rapids, MI.

Marshall, HD, K Boston, and GE Murphy. 2004. Modeling the effect of measurement error on optimal bucking. Paper presented at INFORMS Conference, October, Denver, CO.

Maton, C, and BL Gartner. 2004. Longevity of needle-to-stem xylem connections in conifers: Patterns and potential causes. Proceedings, International Symposium on Wood Sciences, October 24–29, Montpellier, France.

Meehan, NA, SH Schoenholtz, and TB Harrington. 2004. Early response to post-harvest woody debris manipulation and competing vegetation control in western Oregon and Washington. Poster presented at the Soil Science Society of America Annual Meetings, Division S-7, October 31–November 4, Seattle, WA.

Meehan, NA, SH Schoenholtz, and TB Harrington. 2004. Initial responses of decomposition and nitrogen mineralization to woody debris manipulation and competing vegetation control in intensively-managed Douglas-fir plantations. Poster presented at Productivity of Western Forests: A Forest Products Focus Conference, September 20–23, Kamilche, WA.

Murphy, GE. 2004. Mechanization and value recovery: Worldwide experiences. Paper presented at the Production Forestry Workshop, EXPOCORMA Conference, November, Concepci\n, Chile.

Murphy, GE. 2004. Pre-harvest inventory versus harvester-based inventory methods. Paper presented at the Production Forestry Workshop, EXPOCORMA Conference, November, Concepci\, Chile.

Murphy, GE, and P Adams. 2004. Harvest planning to sustain value along the forest-to-mill supply chain. Presentation at the Productivity of Western Forests: A Forest Products Focus Conference, September 20–23, Kamilche, WA.

Peterson, P, C Bolstad, and C Marbet. 2004. Modeling Sediment in Runoff from Forest Roads: A GIS Based Empirical Approach. Seminar and subsequent discussion hosted by Department of Forest Engineering and Arne Skaugset and lab, November 12.

Pilkerton, S. 2004. Synthetic Rope Use for Guying and Anchoring. Western Region Meeting of the Council on Forest Engineering, November 12, Corvallis, OR. 65 participants.

Puettmann, M, and J Wilson. 2004. Forest to Product: Cradle-to-Gate Life Cycle Inventories of Structural Wood Products. Talk and Abstract, Society of Environmental Toxicology and Chemistry Fourth World Congress, November 15, Portland, OR.

Renninger, H, AT Grotta, and BL Gartner. 2004. Correlation of latewood formation with leader growth in Douglas-fir saplings. Poster. Annual Meeting of the Ecological Society of America, August 1-6, Portland, OR.

Saputra, H, J Simonsen, and K Li. 2004. Effect of extractives on wood-plastic composites. Progress in Woodfiber-Plas-

tic Composites Conference 2004, May 10–11, Toronto, Canada.

Simmons, A. 2004. Trip to the Oak Creek Watershed outlet. Presentation to the College of Forestry Fernhopper Day Tour, May 15, approximately 80 people.

Simmons, AN, and AE Skaugset. 2004. Total Runoff from Roads as an Index for Potential Changes in Watershed Hydrology. Eos Trans. AGU 85(47), Fall Meet. Suppl., Abstract H51d-1182.

Simmons, A, and A Skaugset. 2004. Trip to the Oak Creek Watershed. Presentation to the Gibbet Hill Fellows/ Richard Strachan, October 14, approximately 15 people in attendance.

Skaugset, A, J Amann, J Appt, K. Ellingson, A Simmons, and E Toman. 2004. The Hydrology of Forest Roads & Roaded Watersheds: The Oak Creek Study. Poster and abstract presentation at the Oregon Logging Conference, Lane County Convention Center and Fairgrounds, February 25–28, Eugene, OR.

Skaugset, AE, and EM Toman. 2004. Designing Forest Roads to Minimize Turbid Runoff During Wet Weather Hauling. Department of Forest Engineering, Oregon State University, Corvallis. 13 p.

Toman, EM. 2004. Forest Road Hydrology: The Influence of Forest Roads on Stream Flow at Stream Crossings. Seminar presented in Department of Forest Engineering for Master's Defense, April 30.

Toman, EM. 2004. Proposed Research: Designing Forest Roads to Minimize Turbid Runoff During Wet Weather Hauling. Committee Program Meeting, December 3, Department of Forest Engineering, Oregon State University, Corvallis.

Toman, EM. 2004. The Influence of Forest Road Runoff at Stream Crossings Culverts. Seminar presented to the Department of Forest Engineering, February.

Toman, EM, and AE Skaugset. 2004. Increases in Stream Flow at Stream Crossings on Forest Roads in Western Oregon, USA. Eos Trans. AGU 85(47), Fall Meet. Suppl., Abstract H51D-1181.

Wilson, J. 2004. Determining the Cost of Drying Lumber: The Role of Energy Plays in This Cost. Talk. Lumber Drying Course. Oregon State University, December 2, Corvallis.

Wilson, J. 2004. Life Cycle Assessment of Wood Use in Residential Construction. Talk and Abstract, Society of Environmental Toxicology and Chemistry Fourth World Congress, November 15, Portland, OR.

Wilson, J, and M Puettmann. 2004. Product Life-Cycle Inventories: Process and Fuel Alternatives as a Means to Reduce Green House Gas. Talk and Abstract, Forest Products Society 58th Annual Meeting, June 29, Grand Rapids, MI.

Wimer, JA. 2004. Synthetic Rope Use for Guying and Anchoring. Western Region Meeting of the Council on Forest Engineering, December 17, Arcata, CA. 50 participants.

Wing, MG. 2004. FE 308. Forest Surveying. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2004. FE 357. GIS and Forest Engineering Applications. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2004. GIS Applications for Logging Planning, March 30–31, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2004. Introduction to GIS Applications in Natural Resources with ArcGIS, December 9–10, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2004. Introduction to GIS Applications in Natural Resources with ArcView 8.3, February 12–13, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2004. Introduction to GIS Applications in Natural Resources with ArcView 8.3, May 6–7, College of Forestry, Oregon State University, Corvallis.

Wing, MG and A Eklund. 2004. Affordable GPS Accuracy and Reliability. Educational Session, GIS in Action 2004 Conference, May 12, Portland, OR.

Zhang, C, K. Li, and J Simonsen. 2004. A new compatibilizer system for wood-polypropylene composites. Progress in Woodfiber-Plastic Composites Conference 2004, May 10–11, Toronto, Canada.