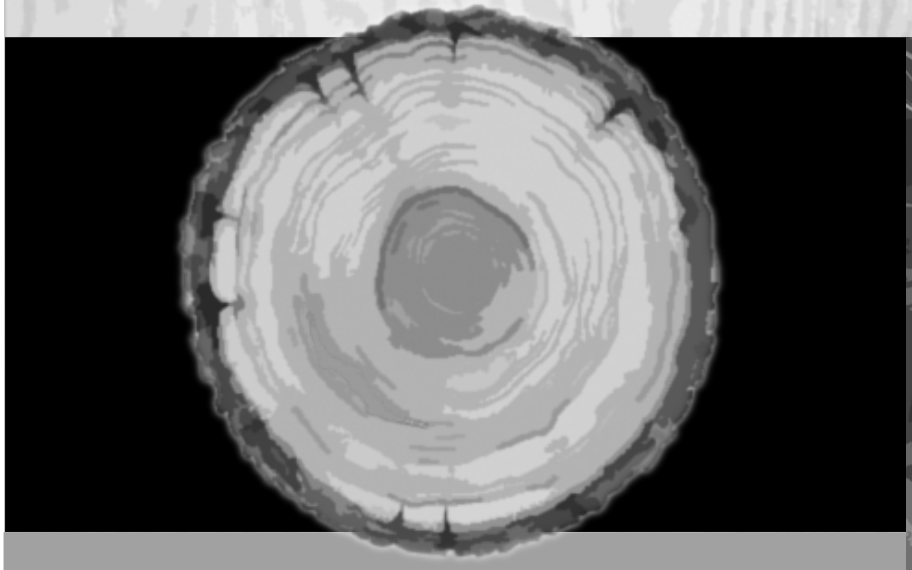
Progress Report for FY 2003

Center for Wood Utilization Research

at Oregon State University



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Progress Report for Fiscal Year 2003

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Oregon State University

Progress Report
FY 2003

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

- Will 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, and has a principal focus on the utilization of western species. This report summarizes grant activities for FY2003.

There were 26 *active projects* supported by the USDA Special Grant to Oregon State University in 2003. Project research *generated 74 separate publications*, including *30 in peer-reviewed scientific journals* and *7 graduate student theses*. Technology transfer continued at a high level of activity, with research results conveyed through *55 different 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, 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, reduce hazardous air emissions, and provide better product yields from available wood supplies. Key research on the life cycle environmental costs of material selection will inform consumers 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 US 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:

- Extended color machine vision systems were evaluated for use in classifying softwood species in an industrial environment. Techniques for using such data to make cutting decisions were developed. Preliminary tests showed that detecting subtle species differences is possible.
- A study of the effects of changing from a traditional manufacturing system to a cell-manufacturing system in a value-added wood products company demonstrated how discrete event simulation can be used to test system changes without disrupting production or large capital investments.
- A study on how decay fungi can selectively degrade wood lignin suggests a laccase/mediator system is the operational process for selected white rot fungi. This may indicate a practical way to improve paper making and reduce the environmental impact of traditional bleaching processes.
- Static and cyclic tests of wood shear walls subject to earthquake loading show that misplaced hold-down connections have unexpectedly severe negative effects on structural performance. Denser nail spacing may improve performance in some cases.
- Damage to trees during thinning was shown to have long-term negative effects on the future value of those trees. Inventory growth models may overestimate future harvest potential as a result.
- Major terpenoid compounds in the essential oil extracted from selected cedar species was shown to have potential as a bioactive agent against insects and microbes. These compounds were isolated and identified for further testing by the US Center for Disease Control.

One of the highlights of the OSU Special Grant Program has been the attention paid to the dissemination of new information using a variety of outlets. This high level of technology transfer is reflected in the over 55 different activities that targeted a variety of audiences, ranging from scientific conferences to workshops for landowners and manufacturers.

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

99-34158-8978

00-34158-8978

01-34158-10625

02-34158-11903

Progress Reports

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

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

James B. Wilson
Initiation Date: FY 01 Scheduled 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 or not the ATHENA™ model can be used to characterize the energy and environmental impacts associated with various management decisions; and (3) to investigate the effectiveness of life cycle analysis of assessing various processing alternatives for the forest products industry.

This work was done in conjunction with the CORRIM effort to document the environmental performance of wood. Two software packages were explored for assessing the environmental performance of wood building materials and their substitutes for residential construction. 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.

The two packages studied, ATHENA™ and SimaPro™, are complementary in their weaknesses and strengths and are an excellent combination to conduct life cycle inventory and life cycle assessments.

SimaPro was used to model two case studies: (1) the environmental impact of emission control devices in the manufacture of structural wood products and (2) the impact of switching energy sources. Use of a regenerative thermal oxidative (RTO) emission control device for a typical oriented stand board plant resulted in a 1,870% increase in the global warming potential, mainly from increased natural gas and electricity consumption. On the positive side, the Air Pollution Index decreased 98%. Although SimaPro could be used for tracking carbon through the various processes into wood buildings, making the calculations with a spreadsheet, based on SimaPro input/output data, was easier.

Using wood-based hogged fuel (biofuel) would provide significantly less global warming potential and more particulate emissions than would natural gas. The EPA considers the CO2 generated by the combustion of biofuel to be impact neutral because trees process CO2 into C for wood while releasing oxygen to the atmosphere. The ability of trees and wood buildings to store C significantly reduces its availability for making CO2, thus reducing global warming potential. The amount of carbon stored in U.S. housing is on the order of a billion tons. The more wood grown and more houses built, the greater the increase in amount of carbon stored and reduced global warming potential.

Planned research includes conducting sensitivity analysis of LCI processing models for plywood, OSB, LVL, I-joist, and glulam to explore means for reducing environmental impact of manufacture; examining substitution of materials in home construction; and refining SimaPro models to include LCA. Work to date will be included in CORRIM's phase I report.

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

Michael R. Milota
Initiation Date: FY 01 Scheduled 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; and (3) to develop the relationships between dryer emissions and other processing emissions, such as those from a press.

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Analysis of alternatives to current methods for VOC control indicated that absorption into a liquid might have potential for removing pollutants. Four ionic liquids were tested for liquid solubility of methanol and "-pinene. Methanol is highly soluble in all four, but pinene solubility is much less. Further research will tailor these ionic liquids to increase the solubility of pinene, and gas solubilities, a much more important parameter, will be determined.

Reducing moisture variability before drying through effective sorting reduces energy consumption, which is key to reducing emissions. We believe that the extractive content of the wood, which can be determined by near-infrared spectroscopy, is related to drying rate and moisture content variability. We characterized the near-infrared spectra to sort of hemlock lumber before and after drying. The spectral differences were inconclusive. We then ground samples for analysis by molecular beam mass spectrophotometry (yet to be done). The goal of this is to determine if there are differences in the specific compounds in the samples that would allow us to concentrate the analysis on the regions of the spectrum most affected by those compounds.

The hazardous air pollutant emissions (methanol and formaldehyde) from white fir lumber were three times higher at a drying temperature of 240°F than at 180°F. Lower temperatures may help facilities with other HAP sources on site comply with Title 3 of the Clean Air Act. VOC emissions for ponderosa pine as a function of temperature and humidity in the kiln were also determined.

Smart Sensor System Technology for Improved Wood Utilization

Glen E. Murphy
Initiation Date: FY 02 Scheduled Completion Date: FY 05

Objectives: to evaluate and develop novel and superior sensing technologies for imaginative applications in managing production and costs, extracting maximum value from the forest, and improving utilization of the wood resource by (1) reviewing current developments in sensor system technologies that mimic human senses and identifying at least seven potential applications in forest-to-mill activities that could improve wood utilization; (2) assessing the costs and effectiveness of at least three promising sensor technologies; (3) determining how at least two of these technologies could best be linked with a memory function (smart sensors) to either reduce wastage, meet market needs for niche products, increase value recovery, or control costs; (4) developing methods and protocols for at least one smart sensor technology and establishing linkages with appropriate equipment manufacturers and suppliers.

Analyses were completed for three mechanized harvesting systems operating in the southeastern U.S. In FY02, four procedures for scanning on a mechanized harvester head were evaluated in economic terms, and break-even investment costs for new sensing technology were determined for radiata pine. The approaches incorporate aspects of the "smart" component of smart sensor systems. In FY 03 the analyses were expanded to include Douglas-fir and ponderosa pine.

Field data were collected on the length and diameter measurement accuracy of two mechanized harvesting systems using conventional measurement technology in ponderosa pine stands in Eastern Oregon. These measurements will serve as benchmarks for comparing new sensing technology. Discussions were undertaken late in FY 03 to collaborate with scientists from the New Zealand Forest Research Institute in gathering further benchmark data. This work will be carried out in FY 04.

Over 400 Douglas-fir wood discs were collected from 120 trees and 17 locations around Oregon. The wood discs were subsampled to provide material for assessing basic density (completed in FY 03), spiral grain (completed in FY 03), and extractives content (to be completed in FY 04). Chainsaw wood chips were also collected from all 400 discs. A preliminary analysis of 100 samples indicated that near-infrared (NIR) technology could be used to accurately predict basic density, but not spiral grain. Further work with NIR and chainsaw chips will be undertaken in FY 04.

Five adaptive control approaches to optimal bucking were evaluated using a computer program (*FASTBUCK*) written in FY 02 for optimally bucking a single stand of trees to meet order book constraints. This will allow more detailed testing of various smart sensor system approaches and adaptive control of bucking.

In 2004, we will carry out field work on value recovery and measurement accuracy of a mechanized harvesting system in New Zealand in collaboration with New Zealand scientists. In collaboration with researchers from the University of Idaho, we will finish

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the assessment of extractives content on the 400 Douglas-fir wood samples collected in FY 03. We also will develop NIR spectra for the 400 chainsaw chip samples and use these spectra to predict wood properties. We expect to determine what improvement in predictive ability can be made when location within-tree and other spatial information (e.g., elevation, aspect, land coordinates) are available.

Unification of the CORY Program Modules

Charles C. Brunner, James W. Funck, James E. Reeb
Initiation Date: FY 02 Scheduled 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, and (2) to develop a user-friendly interface for the unified version.

All previous two- and three-stage versions of the program have been converted into the object-oriented class structure developed for the new version of CORY. The new program has been verified by comparing its results with those of the original programs. The remaining tasks are to convert the Gilmore and Gomory algorithm for use with the fixed-width, fixed-length version of the program into the new structure and integrate it under the graphical-user interface.

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; and (6) to assess current practices in innovation and new product development in the Chinese furniture industry.

A North American study quantifying current innovation and new product development practices in the industry has been completed. An ongoing study is investigating the innovation and new product development practices in the Chinese furniture industry. This component will be completed in fall 2004. An ongoing qualitative project is assessing industry manager views of the nature of innovation in the forest sector. A project addressing objective (1) will be undertaken in summer 2004.

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 basis of the extent to which their live wood permits radial water movement; (2) to characterize which anatomical features are associated with radial water transport; and (3) to characterize the physiological and growth strategies associated with the low vs. high resistance to radial water transport, to enable predictions beyond this dataset.

Four individuals each of madrone, cottonwood, red alder, and bigleaf maple were instrumented with five sap-flow probes, each at a different radial position, for at least one week during the growing season. We then felled the trees and brought wood to the lab to enable us to do anatomical studies (just beginning) and to measure moisture content, wood density, and wood specific conductivity (all completed). The conductivity and sap flow data allow us to estimate the water potentials in the different growth rings, from which we can infer the radial resistance to water transport.

The results were more complicated than expected. In many cases the sap flow, conductivity, and moisture content trends were not monotonic, indicating either that there are problems with the data or that water transport in these hardwood species is much patchier than expected. This coming field season, we

are planning experiments to learn the extent of patchiness in moisture content, which should be a good surrogate for water transport (other factors being equal), and we will repeat the sap flow and conductivity measurements. Quite possibly this patchiness occurs; no studies have documented the spatial distribution of sap flow as thoroughly as we are planning.

A project was also conducted with coniferous species to learn how deeply the foliage of different ages is attached into the sapwood. If old foliage is attached deeply, this would help explain the published observation that flow is often higher about a centimeter inward from the cambium than near the cambium itself. We used 16 species, mostly from a nearby commercial nursery, in a common-garden setting. Species fell into four categories in terms of which growth rings needles of a given age were pulling water through. The longevity of a needle connection appeared more related to the tree's radial growth rate than to needle age.

Over this winter, we reanalyzed our previously collected data on ponderosa pine and Douglas-fir to characterize how much of the flow is axial and how much must be radial. This spring and summer we will also begin more work on water movement in stems, looking for where and when water is stored and released in radial positions.

Physiology, Patterns, and Design Criteria for Heartwood Formation

Barbara L. Gartner

Initiation Date: FY 01 Scheduled Completion Date: FY 04

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

Sapwood area does not appear to be determined on a basis of the need for water transport, and the volumetric respiration rate is lower in species with wider sapwood than in those with narrower sapwood, suggesting that the carbon budget for sapwood activities is more or less fixed.

A conceptual advance was proposed that the changes in wood properties across the radius are driven by hydraulic, rather than mechanical, needs. The four-fold increase in wood stiffness across the radius of a mature tree results from increased wood density and decreased microfibril angle. It has an extremely small effect on the overall increase in the stiffness of the stem as a structure, which is controlled more by the stem's geometry. In contrast, the four-fold increase in the tracheid length and the doubled tracheid diameter have an enormous effect on water transport, which in fact is necessary to meet the transpirational demands of large trees. This conceptual breakthrough (still a hypothesis) was made possible by this center-grant funded research.

We are working on several aspects of heartwood formation and expect to finish the analyses and writing within the year. We have manipulated stands of young Douglas-fir trees (control, severe pruning, or severe thinning) to learn whether environmental stresses affect the amount of heartwood extractives that are made. Similarly, we sampled western redcedar trees from an installation that had been manipulated a decade ago (thinned, fertilized, or both) to compare the quantity of heartwood extractives in the different manipulations.

Using stable isotope analysis, we have been testing whether the heartwood made in a given year is made with carbon acquired during that year, is acquired in the year the sapwood transitioning to heartwood was made, or is a mixture. This will help explain whether stored carbon in the sapwood is mobile (which implies that the amount of sapwood may affect carbon storage capacity) or not (which implies there's a window of time in which newly acquired carbon can be used). Either outcome has implications for how plants deal with risk.

Enhancing Engineering Applications for Wood and Wood-Based Materials

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. The studies seek to develop relationships between the levels of deterioration and the degradation in performance of wood materials, connections, and subassemblies. Analytical models will be developed that incorporate the degradation mechanism so that the effects on structural systems can be predicted and used to make rational engineering design and assessment decisions.

The first part of this project is to investigate the vulnerability of the existing housing resource to potential hazard loadings. The basic premise that connection details in light-frame construction do not change in capacity or energy dissipation characteristics is not necessarily true. The general condition of connections in existing structures is not known. Local building departments are being contacted to solicit access to buildings scheduled for demolition with the expectation that project personnel will remove selected connections and subassemblies from identified structures so they can be returned to the laboratory for testing in lateral loading. The process of connection and subassembly removal will become active during the summer 2004 construction season.

Corrosion in fasteners and connections, especially those in contact with preservative treated wood materials, is also an area of study. The new wood preservative chemicals are more corrosive to metal fasteners. This issue will surface as a significant durability issue in the future if preservative and fastener compatibilities are not addressed. The durability issue resulting from corrosion can be minimized with timely research.

Establishing Fundamental Structural Performance Characteristics of Log Structures

Robert J. Leichti
Initiation Date: FY 02 Scheduled 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. Specific objectives include (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, and (4) developing basic finite-element models that incorporate mechanical effects of wall mass, connection hardware, friction, and boundary conditions.

The experiments to evaluate the lateral force-resisting pathways in log structure foundation details used test specimens that represented two common construction details for sill log foundation anchorage: one with the sill log sitting on the floor diaphragm, and one with the sill log directly contacting 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 force-displacement curves showed an initial stiffness, slip, and post-slip stiffness. The hysteresis diagrams were open and boxy, demonstrating 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. Both connection details had capacities greater than required for Uniform Building Code seismic zone 4.

The finite-element models developed with various construction details were further improved by adding the weight of the logs. This caused some additional problems with numerical conversion because of the low stiffness of the force-displacement relationship during the slipping event and the many free edges in the models, such as door and window openings and wall edges. Thru-rod tension and tributary roof load are crucial to establishing normal forces that limit inter-log slip. Thru-rod hole size and foundation details also affected wall performance. Increased wall aspect ratio increased overall displacement more than any of the other variables. Window openings did not adversely affect wall performance because extra thru-rod hardware attendant to these features 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 extra thru-rod hardware.

In the future, a three-dimensional model should be developed with a testing program for verification. The three-dimensional model should incorporate the effect of the corners and the roof diaphragm.

Enhancing Engineering Applications for Wood and Wood-Based Materials

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

Objective: 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 at time intervals ranging from 0 to 30 weeks. The specific objectives included (1) evaluating the feasibility of near infrared (NIR) spectroscopy for predicting decay damage in terms of the dowel-bearing strength, changes in specific gravity, and solubility in an aqueous solution of sodium hydroxide (NaOH); and (2) evaluating the spatial density distribution of sound and decayed OSB with x-ray densitometry.

The variability of the test results in each incubation time group was relatively high. This variability was a combination of the inherent variability of the material and the variability associated with the rate of fungal growth. This finding implies that prediction of time-to-failure due to fungal deterioration involves considerable uncertainty.

Two statistical models were developed to relate the dowel-bearing strength with specific gravity. The first model used gross specific gravity of the OSB sample; the second model used a zone of averaged specific gravity under the nail during the dowel-bearing test. In both cases, a linear relationship was fitted to the data, giving coefficients of determination of 0.64 for the gross specific gravity and 0.81 for the averaged specific gravity. The slopes of the two models were not statistically distinguishable, but the unexplained variance was smaller for the second model. This finding indicates that the dowel-bearing strength was affected by the density of the material directly under the nail, but other significant factors not addressed in this experiment also affected the outcome. These influences may have included flake orientation, internal voids, and localized quality of the adhesive bonds.

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.

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. The specific objectives are as follows: (1) to investigate and determine a suitable design analog for a single truss; (2) to investigate and determine a practical way to model two-way action of sheathing and composite action; (3) to investigate and determine a suitable and practical joint model for assembly modeling; and (4) to investigate boundary condition (truss-to-wall connections) models to be employed in the assembly model.

A suitable design analog for a single truss was investigated. The proposed design analog provides simplicity and practicality for modeling 3-D light-frame truss assemblies and still can evaluate, with acceptable precision, the structural behavior of the roof truss assembly.

The study of joint modeling intends to offer a simple, practical way to model joint connectivity by considering all the joints in the truss either as pinned or rigid. This is convenient and simpler than including semi-rigid connections.

The heel joints are assumed to be rigid connections. The top and bottom chord members are continuous at the panel points. The webs are pin-connected to the chords. The ridge joint is also assumed to have a pinned connection. The slope in the top chord suddenly changes at the peak point. These assumptions are used in the current design practice, hereafter referred to as conventional design procedure (CDP). Although the connections actually behave nonlinearly, this study focuses on the service load range, so only linear behavior of the metal plate connectors will be considered. This approach offers tremendous advantages by reducing the level of complexity in modeling 3-D truss assemblies while providing acceptably accurate structural behavior.

Before the proposed design analog of a single truss is used to model the structural system behavior of a variety of light-frame wood truss assemblies, the structural response of the proposed design analog will be validated. Each two-dimensional truss model from the 3-D assembly is modeled and analyzed in SAP2000. The structural response of the individual trusses is compared with those of single trusses analyzed by VIEW, which represents the conventional design method (including semi-rigid heel joint). To match with the truss analyzed by the conventional design method, the same Fink trusses with the same loadings are used. The design analog will be adjusted as necessary until the main results (CSI values) match within 5%.

This approach for the analog is based on simplicity and practicality. Most importantly, the proposed assembly model should predict the structural behavior of three-dimensional light-frame roof truss assemblies with reasonable accuracy. The proposed analog will be used to model 3-D truss assemblies that will be further investigated in this study.

Based on the proposed design analog, one truss (T-1 truss) from a T-shaped assembly was created. The CSI values for the T-1 truss, as analyzed by VIEW using the truss plate manufacturer's model and from SAP2000 using the proposed design analog, were compared. The maximum CSI occurred in the same truss top chord member 2, and the two values were very close. The maximum difference in CSI, a 6% increase, was in truss web member 11. Nevertheless, the CSI value was much less than 1.00 and is not a concern for truss designers. The minor differences are because the VIEW design analog is not exactly the same as our design analog and also has semi-rigid connections at heel joints, rather than rigid as in our proposed model.

Because of the symmetry of the T-1 truss, the deflections of panel points on the left and right sides were equal under VIEW (CDP) and SAP2000. All deflections were 5% higher with the SAP2000 model. The maximum deflection was still much lower than the serviceability requirement of the truss. Based on CSI values and deflections, our design analog thus is reasonably close to what is currently used by the industry.

Assemblies other than Finck trusses (L-shaped and complex assembly models) also include corner jack trusses and hip jack trusses. Almost all truss members had lower CSI values when analyzed with SAP2000 and the proposed model. The maximum CSI occurs in the same truss member, truss member 4, decreasing by about 12%. For other truss members, the CSI values decreased by <20%. The difference may be caused by the different design analog, especially at the heel joint. The change in CSI may seem to be large (about 20%) in this verification. However, previous studies have shown that "system effects" in the actual truss assembly may play a greater role in 3-D analysis. Effects due to the difference in truss design analog compared to these "system effects" may be reduced when the trusses are analyzed together in an assembly. Hence, this proposed design analog is deemed acceptable for 3-D analysis. Moreover, individual trusses in the L-shaped and complex assembly models provided close results in two-dimensional verification. The verification result for the L-shaped and complex assemblies shows that our design analog analyzed by SAP2000 can be used to represent actual trusses.

The following steps are planned for the next year:

Sheathing beams: The sheathing will be modeled as beams using frame elements. To simulate a relatively simple assembly model, the partial composite action will not be included in this study.

Truss-to-wall connection: The truss-to-wall connection for an actual roof truss assembly model should simulate the true connections between walls and trusses. Although single trusses often are designed for pin support at one end and roller support at the other, in reality the same type of hardware is used to connect trusses to the walls at both ends. Therefore, this study will assume pin support at both ends, along with horizontal and/or vertical springs to model out-of-plane movement of the wall. Various truss-to-wall connections will be tested to determine the spring properties.

Truss assembly analysis: The ultimate goal of this project is to provide a practical approach to model system behavior of 3-D light-frame wood truss assemblies using a commercially available structural analysis program, like SAP2000. Once the individual (or component) models, as described above, are developed and verified, three actual 3-D truss assemblies will be used to evaluate their system behavior.

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

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

Loren D. Kellogg, Michael G. Wing
Initiation Date: FY 01 Scheduled 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 with traditional methods; and (4) to seek partnerships with industrial and agency entities to explore the application of precision forestry techniques.

Field work will be conducted during two summers. Through partnerships with industry and forest agency operations, several field sites will be selected so that a mix of topography, silvicultural treatments, and forest types is represented during data collection. Initial field work will involve documenting the time and costs involved in a range of harvest planning and layout activities and manually collecting logging impacts that are typically monitored. This work will be replicated by the use of digital equipment, including a laser rangefinder, GPS, and GIS. The manual and digital survey techniques will be compared to determine the significance and size of differences between the methods.

Three study efforts were completed during the previous year. In the first study, 16 units (~1 ac) were used to evaluate different spatial data-collection instruments and techniques for measuring forested stand areas. 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 studies determined the overall efficiencies of each technique.

Time required to survey a patch and complete the office work varied substantially with the technique. Using the laser, digital compass, and Juniper data collector required the least time (17 min). The second most time-efficient technique was using the laser, digital compass, and the TDS data collector (19 min), followed by the string-box method (38 min), and GPS method (40 min). Average time for the total station was 54 min per patch; the longer average times were primarily due to instrument set-up time. Hourly labor and initial equipment costs were most significant in overall operating costs. The string box, manual compass, and clinometer method was approximately 6% less expensive than the laser method, but 48% more time was spent conducting the traverse of all the patches. The total station technique was 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 by traditional methods.

A second study compared two techniques for collecting terrain profile data and 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 with a traditional string box, clinometer, and hand-held compass; the second used an EDM device, digital compass, and digital data recorder. These methods were compared with the results from benchmark data collected by a digital total station. A time study determined the overall efficiencies of each technique. The corridor layout and profiling costs were lower for the string-box survey than the laser, likely because of different crew sizes. Small changes in the location/elevation of the critical terrain point resulted in substantial variations in payload calculations. 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.

In a third study, the accuracy and reliability of five commercially available digital range finders were compared with respect to measuring a distance course, traverse boundaries, and tree heights. In general, the highest-priced range finder performed most accurately and reliably. In several applications, however, some of the cheaper range finders outperformed more expensive instruments. Large measurement errors in several of our field-testing applications were detected. Potential users should identify their measurement and accuracy requirements before choosing a digital range finder.

Initial examination of GPS receivers will involve direct comparison of the horizontal and vertical accuracy of multiple GPS receivers, including at least one unit from each of the three broad categories of

GPS receiver quality grades. A measurement control course will be established by using a digital total station and placing semipermanent control points within 100 m (visible distance) of one another. The horizontal and vertical position of each control point, as recorded by the total station, will serve as comparison benchmarks against which to assess GPS measurements. Each GPS receiver will initially be stationed at a different monument and will collect measurements simultaneously with the other GPS receivers. After each control point measurement, the GPS receiver will be rotated to a different control point. This process will be replicated so that each GPS receiver will have at least one measurement at each control station. Study results will help foresters and other professionals choose a suitable GPS receiver.

Following the accuracy testing, a forestry field application of GPS receivers will be conducted. The field application will test the ability of mapping and resource grade GPS receivers to collect location data in a forested setting. Initial testing will involve GPS ability to locate features related to harvest operation layout and planning. Testing and evaluating the ability of GPS receivers to collect data required for timber harvesting should assist land managers in deciding whether to implement GPS in their planning.

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 a model for the mill dry end (from green sorter to planer) useful for training and research; (2) to determine methods to make the model adapt to new process information; (3) to investigate methods to reduce the energy consumption in lumber drying by modifying drying schedules and wood handling at the sawmill and planer; and (4) to reduce the moisture content variability of dried lumber and increase lumber quality by optimal lumber processing.

The source code for the deterministic drying model of Milota and Tschernitz (1994) was modified to communicate with Excel using Windows Open Database Connectivity (ODBC). To allow for model testing and for developing ways to adapt it to new process information, 16 charges of hemlock lumber were dried. The moisture content of each board was measured before and after drying. Each charge was graded by a certified lumber grader. The drying rate was measured throughout drying. These data will allow us to test if the model predicts a realistic final moisture content distribution and correctly predicts the average moisture content. The permeability of hemlock lumber was tested as a function of drying conditions and its variability was studied. Sorting lumber by permeability would be another way to reduce moisture content variability in softwood lumber.

Energy could be reduced by treating wood with preservatives before drying. We tested a method for impregnating wood with copper and fluoride for preservative retention and leaching. Retention was highly variable, and the treatment did not diffuse to the center of the piece. Process modifications very likely would provide treatment levels adequate to allow the wood to be used in ground contact, but the leaching results indicated that the two chemicals are not chemically fixed in the wood and can leach into the environment.

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

John Sessions, Michael G. Wing
Initiation Date: FY 01 Scheduled Completion Date: FY 04

Objectives: (1) 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. The forest features a large, managed forest area that is dissected by steep terrain and has a well-developed road system. The forest staff have created spatial databases representing roads, stands, and a digital terrain model and are developing a 10-decade spatially defined harvest schedule. Spatial data from the forest will be made available for analysis. Log entry points for the road network will be taken from the 10-decade harvest plan. (2) Process the digital terrain model to associate transportation costs for all road segments within the road network. (3) Process a landslide model to rate the relative stability of all terrain within the forest. Entry points and destination points will be identified on the road network. All spatial data will be converted into a 10-m2 raster format. (4) Calculate transport and maintenance costs for each road segment on the network on the basis of road

section gradient. The relative stability of each segment's surrounding terrain will be used to calculate a stability cost for each segment. Heuristic optimization will be used to identify the system of routes between access and destination points under different goals or under multiple goals using goal weighting. Road system alternatives can be thus evaluated under different objectives. Road management alternatives, including closures, construction modifications, and replacement strategies, will be also be considered.

Research on the Analytical Hierarchy Process (AHP) explored the theoretical foundations of AHP and applied the AHP to a forest routing example. Overall, the 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. The AHP also requires users to make explicit values for decision-making and is particularly suited to quantifying cause and effect relationships based on professional judgment. AHP provides the decision maker with a great flexibility in formulating a problem. 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 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. The routing algorithm constraints were adjusted so that grades in excess of 20% would not be considered in final route creation. Routes were attempted that avoided 20% grades through the existing network and also through an unconstrained approach, where the entire landscape would be potentially available for transportation routes. Every route alternative included multiple grade values that exceeded 20%. Given that many parts of the existing route system have been used for log hauling, these results shed doubt on the reliability of the DEM that served as the basis for topographic representations.

Eliminating processing errors and rerunning the analysis with a USGS DEM of similar resolution gave a more likely explanation for the results, that is, a finer resolution DEM is needed to approximate road grade and terrain more reliably. The DEMs used were unable to accurately capture the lower gradients that should exist along the existing road network. These results encourage further investigations, including the use of finer resolution DEMs to model topographic surfaces for transportation routing.

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 implementing a supply chain management system for forest operations that will improve profits and customer service by developing new planning, scheduling, and reporting tools to align harvest and distribution capacity to best meet customer demands, and (2) new production forecasting tools to 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 that will improve the utilization of harvesting equipment and lower logging costs.

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

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 on production economics and tree damage in western Oregon stands of four levels of intervention (4-ac, 2-ac, and 1-ac clearcuts, all with thinning in between, and thinning only) and to identify how such interventions could be managed under a multiple entry scenario; (2) to determine how newly developed slash-bundling technology could best be 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 mechanized and cable harvesting systems in winter conditions and to compare the impact on soil disturbance of an extended versus 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 Oregon and an eastern Oregon stand; and (5) to identify the long-term impacts on site productivity of soil disturbance caused by harvesting operations by reassessing sites and trees first measured in the 1970s.

Work continued on the operational planning of various sizes and shapes of small clearcut openings in an uneven-aged forest management plan on the OSU McDonald-Dunn College Forest. A written research plan that examines the scientific and operational aspects of alternative silviculture systems was completed and presented to the College of Forestry Executive Committee.

Production studies, carried out in Finland, of slash-bundling systems were used as the basis for determining production rates for three levels of treatment (bundle and leave at stump, bundle and remove to roadside, bundle and transport to an energy plant) for five representative stand types in the western U.S. Slash was limited to trees <10 cm DBH and to the limbs and tops of larger trees removed in a conventional thinning operation. These simulated production rates were combined with constructed hourly costs to determine unit costs on a green-tonne and on a per-hectare basis. Per-hectare costs ranged from $250 for “bundle and leave” to $1090 for “bundle and transport.” Costs depended on forest type.

We also assessed the most problematic issues of forest fuel reduction faced by forest managers in the Pacific Northwest (PNW) through field visits. These visits, research experience, and the literature indicate a significant lack of information about mechanical forest fuels reduction systems. The largest deficiency is that of a consistent decision support system to help forest managers make accurate decisions about equipment selection, silvicultural treatment implications, and associated site disturbance within the context of forest fuels treatments. Three areas of mechanical fuels reduction systems need to be considered to establish an appropriate decision making framework: (1) conventional/commercial systems (feller-buncher/grapple skidder combinations); (2) nonconventional/ commercial systems (mobile in-woods chippers, and cable systems); and (3) noncommercial systems (masticating and mulching technologies for vegetation composition change only).

Planned activities for 2004 include completing a detailed research plan to investigate mechanical fuels reductions systems in these three categories. Preliminary field study sites will be confirmed in central, northeastern, and southern Oregon. Data collection will begin in the following areas: (1) soil disturbance, (2) operating costs per unit volume and area, (3) system productivity, (4) amount of fuel removed, and (5) biomass utilization applicability. Information from field studies will be combined with existing literature to construct a decision support framework outlining mechanical forest fuel reduction alternatives.

We will also conduct a comprehensive assessment of fuels reduction alternatives and forest restoration operational issues in eastern Oregon forests “at risk” of catastrophic wildfires. The assessment will be used to help develop a project proposal that addresses science information needs in forest restoration, focused on the integration of studies on equipment and operational systems, soil disturbance, and silviculture/fire management.

Field sites involving active timber sales during the winter of 2004 were located on the Deschutes National Forest. A study plan was completed to address both the operational and soil disturbance issues with logging systems over the snow compared with logging during the drier summer season. Shift-level data will be collected on equipment operating times and delays. Site-level soil disturbance data will be collected to compare winter and summer logging.

The effect of market complexity was evaluated for five species/market combinations in North America and New Zealand. The number of log-sorts was used as the surrogate for market complexity. Theoretical value recovery increases sharply when a few log-sorts are added, but flattens out as the total number of log-sorts exceeds five. The effect of the number of log-sorts on piece size and number of pieces handled, which affect production and costs, was inconsistent between species/market combinations.

Soil disturbance sites and trees first measured by OSU in the 1970s either could not be located or the trees had already been felled. Alternative sites were

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

sought. A suitable trial was located in New Zealand. The effect of harvesting-related soil disturbance (litter removal, topsoil removal, and compaction) on the productivity, log product yields, and economic potential of second-rotation *Pinus radiata* growing on clay loam was assessed 21 yr after planting and the results were projected to the expected harvest age of 28 yr. Relative to the controls, individual tree volumes at 21 yr were reduced by 10% in the plots where the litter had been removed and the topsoil had been compacted and by up to 43% in the plots where the topsoil had been removed and the subsoil compacted. The degree of compaction did not significantly affect individual tree volume in the plots where litter had been removed but did have a significant effect where the topsoil had been removed. Per tree economic potential was reduced more (up to 61% loss in value) than was individual tree volume, largely because of changes in log product yield distribution. Projecting tree growth to the end of the rotation at age 28 indicated that the impacts of soil disturbance on tree growth, economic potential, and log product yields are likely to be similar in relative terms to those found at age 21.

A second study has been established to assess effects of contemporary harvesting operations on soil disturbance, decomposition, and nutrient availability as indicators of potential impacts on long-term soil productivity. Soil bulk density and *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-disturbance 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 two sites. At each site, replicated experiments have been established to compare the effects on subsequent soil and stand productivity of (1) bole-only harvesting, (2) whole-tree harvesting, and (3) bole-only harvesting with creation of small debris piles. Treatments have been established and assessments of soil responses are ongoing.

Science to Support Environmentally Responsible Wood Procurement

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

Arne E. Skaugset III

Initiation Date: FY 01 Scheduled Completion Date: FY 04

Objectives: (1) to determine road and site characteristics that influence the amount of runoff in road relief culverts on a complete-watershed scale; (2) to determine the timing and size of flows from the ditches of roads that are connected hydrologically to streams and to determine how the roads contribute to the timing and size of stream flows at live-stream crossing culverts; and (3) to simulate the effect of hydrologically connected roads on watershed hydrology with a spatially distributed model, DHSVM (Distributed Hydrology Soil Vegetation Model).The project is being carried out in the Oak Creek Watershed of the McDonald-Dunn Forest of the College of Forestry at Oregon State University.

In the winter of 2002–2003, the water level devices were installed and water level data were collected throughout the watershed. Rainfall data were also collected at the four tipping-bucket rain gauges, and data from the micrometeorological station were maintained. During spring of 2003, an instrument shed was built to house the Turbidity Threshold System (TTS) equipment at the stream gauging station. An adjustable crane was built to allow turbidimeter and ISCO automatic water sampler intakes to be in the stream. This new equipment is online for the 2003–2004 winter. Flow hydrographs at the culvert inlet and in the road ditch just above the inlet were analyzed. Streamflow in the absence of the influence

of the road was calculated by subtracting the measured flow in the ditch from the measured flow at the culvert inlet.

The peak flows in the road ditches occurred before the peak flows in the streams. Peak flow increases ranged from 0% to 610%; total stream runoff increases ranged from 0% to nearly 5,000%. Where the road intercepted subsurface flow, ditch flow increased stream peak flow 45% on average, compared to an average of 2% where the ditch flow was primarily road surface runoff. The increases were highly variable and could not be predicted by using traditional topographic indicators.

Data collection will continue throughout the 2003–2004 winter. Much information has been gleaned about the hydrology of individual road segments. Next we will investigate how the hydrology of individual road segments comes together for the complete watershed. Several models, including the Distributed Hydrology Soil and Vegetation Model (DHSVM), will be used to model the hydrology of Oak Creek and the contribution of the road system thereto.

Funding for this project has been augmented by funds from the National Council for Air and Stream Improvement (NCASI) and a College of Forestry Innovative Grant. Data from this project are being augmented by stable isotope data funded by the Innovative Grant to see if stable isotopes can add insight into the understanding of the hydrology of roads and roaded watersheds.

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 method to measure the amount of fine sediment generated by individual road segments that is technically feasible and cost effective and allows effective collection of the needed data; (2) to determine road and site characteristics, including those influencing surface runoff that affect the amount of fine sediment generated by individual road segments; (3) given these characteristics, to model sediment production from individual road segments by using contemporary models SEDMODL and WEPP; (4) to determine 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; (5) 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 Oregon State University McDonald-Dunn Forest.

Discharge, turbidity, suspended sediment, electrical conductivity, and temperature are being continuously monitored at a stream gauging installation in Oak Creek. A micrometeorological station records air temperature, relative humidity, wind speed, and solar radiation continuously. Four tipping bucket rain gauges record rainfall amount and intensity throughout the watershed. A high-resolution (nominally 5-m) DEM of the watershed is available. All the roads and drainage structures have been georeferenced on the DEM and stored in a GIS. Geology, soils, and vegetation are available as layers in the GIS.

The 24 stream-crossing culverts and 74 drainage-relief culverts have either a capacitance rod or crest gauge installed to measure water level. Trapezoidal flumes are installed in the road ditches draining to the culvert inlets of 16 of the 24 stream-crossing culverts. A combination of geotextile socks and ISCO water samplers were installed on a subset of drainage relief culverts across a range of hydrologic response from the individual road segments. Total sediment yield for each drainage relief culvert was determined.

Road and hillslope characteristics, discharge, and rainfall will be correlated with the total sediment yield. Two of the models used most often to predict sediment yield from roads, WEPP and SEDMODL, will be run on the study road segments, and model output will be compared with actual sediment yield values. This will help determine the efficacy of these models for predicting chronic yield of fine sediment from roads.

Total sediment yield was highly variable. The data clearly show an extreme value right skew; thus, a majority of the sediment is coming from a minority of the culverts. The hydrology of the road segments shows the same distribution, meaning a majority of the water runs off a minority of the roads. It is too early to know if the nature of the sediment yield from the road segments overlays with the characterization of the road segments as having either ‘intermittent’ or ‘ephemeral’ hydrology.

Preliminary analysis suggests that the sediment yield from the road segments will correlate well with total runoff from the segments. Discharge appears to

be better correlated with total sediment yield than any of the other hillslope or road characteristics generally considered to control sediment yield from roads. Also, there are indications in the data that maximum 15-min rainfall intensity also correlates with some of the storm-total sediment yield. Analysis continues.

The preliminary analysis with WEPP shows that the model drastically overestimates sediment yield, often by several orders of magnitude. WEPP has not been able to place the road segments in their correct relative rank. Analysis will continue with WEPP and SEDMODL. Continued work will allow us to see if both our understanding and the efficacy of the models can improve.

The next project will concentrate on the stream-crossing culverts and the contribution of sediment from the road compared with the sediment regime of the streams and the watershed. An attempt will be made to put erosion from the roads into a watershed perspective.

Quantifying the Cumulative Effects of Timber Harvesting Adjacent to Perennial Non-Fish-Bearing Streams on Water Quality

Arne E. Skaugset III
Initiation Date: FY 03 Scheduled Completion Date: FY 05

Objectives: (1) to determine the on-site effects of harvesting adjacent to perennial non-fish-bearing streams on stream temperature and accelerated erosion; (2) to determine the cumulative effects of harvesting adjacent to several perennial non-fish-bearing streams on stream temperature and accelerated erosion off-site in fish-bearing streams; (3) to identify and quantify the hydrologic processes and the magnitude of the processes that are responsible for propagating stream temperature and sediment effects downstream.

This project is part of the Hinkle Creek Paired Watershed Study. The 5,000-ac main study watershed is fairly evenly divided into the North and South Forks of Hinkle Creek. Roseburg Forest Products has set the North Fork aside for 10 yr to act as a control. The South Fork will serve as the treated watershed.

Six headwater watersheds, or small watersheds that are drained by perennial non-fish-bearing streams, will also be set up as a paired watershed study. Two of these watersheds, in the North Fork, will act as controls; the four small watersheds in the South Fork will be treated. Discharge, suspended sediment, and temperature will be measured on each of the small perennial, non-fish-bearing streams, as well as at the mouths of the North and South Forks. For the watersheds to be treated, the streams will be monitored at the downstream end of proposed harvest units. For the control watersheds, the measurements will be made at an accessible location that results in watershed areas comparable to the treated small watersheds.

The treatment planned for the treated watershed is to harvest timber using contemporary forest practices. For the first round of timber harvest in 2005, the timber will be harvested in the four small study headwater watersheds upstream of the stream gauging installations. For two of the study watersheds, current forest practices will be used to harvest the timber, and no formal buffer strip will be prescribed. For the other two streams, a buffer strip of nonmerchantable overstory material will be prescribed. The treatment prescribed for each study watershed will be randomly assigned.

USGS personnel under contract have installed all of the hardware needed to measure discharge and water quality at the six 1st-order streams and at the confluence of the North and South Forks and currently are responsible for collecting stage data, downloading and maintaining the data records, creating and maintaining the stage-discharge relationship, converting stage to discharge, and storing and maintaining the long-term record of discharge at the confluence of the tributaries.

The Turbidity Threshold System (TTS) developed by the Redwood Sciences Laboratory of the Pacific Southwest Forest and Range Experiment Station is being used to measure and record discharge at the remaining six 1st-order streams and the water quality parameters at all eight study sites. For discharge at the six 1st-order streams, the needed hardware consisted of prefabricated fiberglass Montana flumes, Campbell Scientific data loggers (CR-10X), and pressure transducers to measure water level (stage). At all eight study locations, turbidimeters and probes were used to measure temperature and electrical conductance. ISCO water samplers were purchased for each site to allow remote collection of individual water samples. At all eight study sites, an instrument shed was constructed to house the hardware. The

purchase and installation of all of the hardware was made possible by a $250,000 grant from the Oregon Watershed Enhancement Board (OWEB).

The TTS continuously tracks stage, turbidity, electrical conductivity, and temperature. Using those input parameters, decisions are made by the program in the CR10X regarding when to optimally take water samples with the ISCO for later analysis. All eight systems were up and collecting data before any storms occurred.

In addition to the stream gauging equipment, a micrometeorological station has been installed at the approximate centroid of the watersheds. The weather station collects rainfall intensity, wind speed, solar radiation, air temperature, and relative humidity.

The Hinkle Creek Paired Watershed Study is currently scheduled to last until 2011. The TTS stations at the six 1st-order streams and at the confluence of the North and South Forks will be operated and maintained for the duration of the study. In addition, 45 thermistors will be deployed every summer to investigate the response of stream temperature, on a watershed scale, to timber harvest.

A weighing rain gauge (or rain gauges) needs to be installed, accompanied by snow lysimeters to measure the amount of snowfall and the timing of the delivery of snowmelt to the soil. Snow could be a significant part of the hydrology of Hinkle, and the degree of significance needs to be known. A measurable portion of the treatment effect on the hydrology of Hinkle Creek will be due to interception loss. A number of throughfall gauges will be installed in the vicinity of the micrometeorological station to quantify this component of the hydrologic cycle in Hinkle Creek. The influence of snow will have to be included in these installations.

The importance of subsurface seepage from the hillslope to the stream and hyporheic exchange processes needs to be studied with regard to in-stream processes and their effects on aquatic habitat and biota. Research will be initiated in the near future to investigate the magnitude of these processes and their specific location in the watershed.

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 assist managers in evaluating economic values and environmental risks associated with timber salvage in fire-prone forests.

A decision-support system for considering economic values and environmental risks of harvesting fire-killed timber is needed. Within the federal agencies responsible for managing forest lands, there is no integrated process for calculating the costs and benefits of timber salvage at the landscape, state, national, or international level. Nor is there a system available to the Oregon Board of Forestry or to the College of Forestry, which provides advice to the Governor. In addition to the value of the dead and dying trees, there is the question of ecological recovery and the time lost to return forests to their desired future condition, the substitution of salvaged fire-killed timber for green standing timber, and the effects on local jobs, communities, timber imports and exports, and carbon storage.

We developed a decision support system for evaluating the value of fire-killed timber as a function of time since fire and yarding distance and applied it to timber salvage by helicopter, using data from the 2002 Biscuit Fire. Deterioration of fire-killed trees was simulated over time by using data from the literature, bucking decisions were made considering recoverable log value, and logging costs were estimated. The window of opportunity for economic salvage by helicopter was very short. The window of opportunity for salvage by lower cost harvesting systems was longer, but the environmental disturbance would be larger. Preliminary evaluation of interactions between timber salvage strategies and wildlife are underway. Alternative strategies for timber salvage to recover value, provide deadwood for wildlife habitat, and hasten return of the future forest to provide for future wildlife habitat will be evaluated.

Termination Reports for Completed Projects

Extended-Color Imaging System for Wood Surface Feature Identification

Charles C. Brunner, David A. Butler, James W. Funck
Initiation Date: FY 00 Completion Date: FY 03

Objectives: to determine the operational parameters for a prototype extended color-imaging system for wood surface features and develop and test a prototype.

The components for an extended-color system were identified. Techniques for employing image data from such a system were further developed and refined from the principal investigators' earlier research. Unfortunately, the prototype system was never built or tested due to the expected retirement of one principal investigator and the untimely health problems of another.

Identifying wood-surface features has proven to be a difficult task with conventional color video systems. Extended-color cameras that use different (and usually more) information channels or "colors" than the standard red, green, and blue have the potential to improve image data for surface-feature classification. Image data from approximately 350 to 1100 nm is possible, which includes information outside the visible range (400 to 700 nm). Preliminary work suggests that classifying surface-features with subtle differences is possible, as well as classifying some softwood species in an industrial environment.

Improvement and Innovation in Forest Products Manufacturing

James E. Reeb
Initiation Date: FY 00 Completion Date: FY 03

Objective: to identify the critical elements required for improving the manufacturing processes in a value-added forest products firm.

This research studied the effects of changing from a traditional manufacturing system to a cell manufacturing system in a value-added wood products company. Discrete event simulation was used to describe the current system and the proposed new systems. Parts were separated into 11-part families that shared similar processing requirements, 2 of which were the best candidates to be manufactured in a manufacturing cell. Two cell layouts were simulated, a subcell layout and a single U-cell layout. A separate simulation studied the effect of adding an additional CNC router to the system. The variables analyzed for each part family in the system were work-in-process (WIP), lead time, value-added/non-value-added (VA/NVA) time ratio, and batch sizes. In each case, different cell layout, WIP, and lead time decreased from the current traditional manufacturing system. The ratio of VA/NVA time increased. When batch sizes were reduced, WIP and lead time decreased for each of the different cell scenarios and the ratio of VA/NVA time increased. The most efficient process resulted with single piece flow through a two-person cell.

This research illustrates how wood products firms can use discrete event simulation to test the effects of introducing new technology (employee redeployment, machine, product) on their systems without making large capital investments or risking damage to their present systems. Vast potential exists to improve manufacturing efficiency and customer satisfaction by adopting lean manufacturing methods.

Mechanistic Study of Fungal Degradation of Lignin

Kaichang Li
Initiation Date: FY 00 Completion Date: FY 03

Objective: to learn how white-rot fungi can selectively and efficiently degrade lignin in wood. More specific objectives were to identify and characterize laccase, a key lignin-degrading enzyme, from a newly isolated white-rot fungus, *Trichophyton rubrum*, and elucidate structural requirements for laccase-mediators.

We purified and characterized two lignin-degrading enzymes, laccase and manganese peroxidase (MnP), from two newly isolated fungal strains *T. rubrum* LKY-7 and *T. rubrum* LSK-27. Degradation of pine, yellow poplar, and sweet gum by three fungi *(Pycnoporus cinnabarinus*, *T. rubrum* LKY-7, and *T. rubrum* LSK-27) were also investigated in detail. Degradation of pine flour by the three fungi for three months resulted in increased condensed phenolic OH

group and carboxylic acid group content, decreased guaiacyl phenolic OH content, and little change of aliphatic OH groups in lignin. *P. cinnabarinus* could degrade nonphenolic lignin, although it secretes laccase as a lignin-degrading enzyme and laccase alone is unable to degrade nonphenolic lignin substructures. This suggested that *P. cinnabarinus* uses a laccase/mediator system for lignin degradation. We investigated structural requirements for an effective mediator and the effect of chemical properties, such as redox potential of a mediator, on the efficacy of a laccase/mediator system in degradation of lignin. New, effective mediators were developed and evaluated for degradation of lignin in unbleached kraft pulps. MnP requires hydrogen peroxide for its activity, but is also inactivated by high concentrations of hydrogen peroxide. We have studied the mechanism of this inactivation and have also investigated mediators that could enhance MnP's pulp-bleaching ability.

Degradation of wood in the forest, caused mainly by fungi, is a key process in the global carbon cycle. White-rot fungi are of special interest because they are the only microorganisms able to degrade lignin efficiently. Production of white paper (a process for selective removal of lignin from wood) requires harsh conditions and may result in environmental pollution. Fungal degradation of lignin is efficient and environmentally safe. Study on fungal degradation of lignin may have significant implications for improving papermaking and reducing the risk of environmental pollution. Our results provided a much better understanding of the mechanisms by which white-rot fungi degrade lignin. Our study of a laccase/mediator system also has great implications for development of an environmentally friendly pulp bleaching technique.

Performance of Wood Shearwalls Under Actual Dynamic Records

Rakesh Gupta, Thomas H. Miller
Initiation Date: FY 00 Completion Date: FY 03

Objectives: to (1) understand the behavior of shearwalls under various actual dynamic loading records, (2) compare the behavior of shearwalls under standard static tests to their behavior after subjection to actual earthquake and hurricane loading records, and (3) compare the behavior of shearwalls under cyclic loadings to the behavior of shearwalls under actual random dynamic loading records.

During the study, the objectives were revised in order to obtain information needed to proceed with the original objectives. The revisions were (1) evaluating the effect of reference displacement on wall behavior and assessing damage accumulation under fully reversed cyclic loading using the CUREE (Consortium of Universities for Research in Earthquake Engineering) test protocol, and (2) determining the effect of misplaced holddowns on the static and cyclic behavior of wood shear walls.

The first objective was achieved by conducting tests on identical 2440- x 2440-mm (8- x 8-ft) wall specimens constructed of Douglas-fir studs and oriented strand board panels fastened to the framing with pneumatically driven annular ring shank nails. The CUREE cyclic test protocol for ordinary ground motions was used to study the racking response of the wood shear walls. Four sets of tests (two wall specimens for each) were conducted with four reference displacements. Reference displacement influenced wall strength by up to 15%; there was little or no effect on stiffness and area under the backbone curve. A trend of increasing strength and ultimate displacement with increased reference displacement was observed for the first three sets of tests but did not hold for the tests with the largest reference displacement. Additional tests using a segmented version of the CUREE protocol allowed correlation of visible damage and stiffness degradation to imposed drifts. Although visible damage was minimal at drifts as high as 1%, a 52% reduction in secant stiffness occurred. In general, significant softening of the wall could occur with only minimal signs of visible damage to the sheathing fasteners. These results could help in the development of a standard test protocol for cyclic testing of wood shear walls and in post-earthquake damage assessment of wood-frame houses.

The second objective was achieved by testing three shearwall configurations: wall type 1 (control) had hold-downs at the ends of the wall; wall type 2 had one hold-down misplaced to the first interior stud; wall type 3 had a misplaced hold-down with additional nailing applied to the stud attached to the misplaced hold-down. Two wall specimens for each configuration were tested under both static and cyclic loading conditions, for a total of four tests per configuration. The CUREE protocol was used for all cyclic tests.

Misplaced hold-downs reduced strength and absorbed energy. Strength values of wall type 2 specimens were 42% lower under static loading and 35% lower under cyclic loading than in wall type 1, much higher than the 17% strength loss anticipated because of the reduced effective wall width. Wall type 3 specimens reached an average strength 21% lower than wall type 1 under static loading and 19% lower under cyclic loading, closer to the anticipated strength loss. Additional nailing had little effect on the initial stiffness of walls with misplaced hold-downs. Denser nail spacing significantly increased the amount of energy absorbed by the shear walls with misplaced hold-downs. Wall type 3 specimens tested under both

cyclic and static protocols absorbed nearly 36% more energy than wall type 2 specimens. Failure mode for the control walls was in the form of nail withdrawal from the center stud. Hold-down misplacement to the first interior stud (wall type 2) shifted the nail failure away from the center stud. Wall type 2 specimens had nail withdrawal primarily from the stud attached to the misplaced hold-down. With denser nailing to the stud attached to the misplaced hold-down, nail failure shifted back to the center stud (wall type 3). In wall types 2 and 3, the frame was significantly deformed by vertical deflection of the unrestrained portion of the sill plate.

The static and cyclic test results show that undetected misplaced hold-downs have unexpectedly severe detrimental effects on the structural performance of wood shear walls. Application of denser nail spacing can help to regain strength.

Spatial and Economic Analysis of Damage to Residual Stands During Commercial Thinning

James D. Kiser, Douglas A. Maguire
Initiation Date: FY 00 Completion Date: FY 03

Objectives: (1) to evaluate the effects of carrying damaged trees in stand inventories through traditional growth models, and (2) to evaluate the economic cost of holding damaged trees in inventory to final rotation.

Several studies indicate that growth is inhibited after logging damage. Traditional post-harvest inventories of thinned stands often do not include damage components. If the damage to residual trees is as high as recent studies indicate, then normal inventory growth models likely overestimate production. The value lost from damage is highest in the most valuable trees. Generally these trees are being held for 15–20 yr on industrial lands and longer on public lands. The cost of holding this inventory at lower value should be discounted from an anticipated harvest and the net discounted value of the damage thus assessed. This loss in value at final harvest should be considered as a direct logging cost on the basis of lost volume.

A revised proposal and study plan for the PhD have been completed and reviewed by the graduate committee and outside reviewers. The first objective, assessment of the distribution of damage to the residual stand from mechanized thinning, was dropped in favor of tightening the proposal and work load. A more advanced examination of tree response was added to include the physiological effects of damage. Literature review and experimental design were completed for assessing the physiological response. This will be implemented spring 2004. Field sampling design and methods are being reported. Research accomplishments were not completed as the graduate studies program is not yet complete.

The primary benefits from this study will be (1) development of a fundamental understanding of the physiological response of trees to logging damage, which will assist in the development of an operational model for the prediction of biological and economical impacts from bole wood damage and of model coefficients for the inclusion of mechanical damage sampling in growth and yield simulation; (2) development of a tree-based modeling approach to the inventory and growth of damaged trees, which will assist land and inventory managers in assessing the effects of damage on the assets value of the residual stand; and (3) development of an economic analysis approach that ties the discounted damage of the residual stand to overall logging costs. This information will assist the land manager to better assess the overall efficiency and production of commercial thinning harvesting by linking stand damage to the overall logging costs on a per unit basis.

Structure-Bioactivity Relationships of Some Heartwood Terpenoids and Chemical Transformations to Value Added Products

Joseph J. Karchesy
Study Cooperator: George H. Constantine
Initiation Date: FY 00 Completion Date: FY 03

Objectives: to determine how changes in key terpenoid structures caused by oxidation/reduction and dehydration affect their bioactivities. The terpenoid skeletal systems studied were the ermorphyline, dominant in Alaska cedar heartwood, and the cedrane, dominant in Western juniper heartwood. This represents the parent alkene skeleton, ketone, alcohols, and their dehydration products. Bioactivity systems included microbial and insect. The final objective was to determine how to maximize the amount of desired compound in essential oil mixtures to achieve added value as a product.

The major terpenoid compounds in the essential oil and organic solvent extract of Alaska cedar heartwood were characterized for structure and bioactivity. The most productive avenue for bioactivity was shown for insects and arachnids. Components of these extracts were also active for both human and veterinary microbes. The terpenoid profiles were compared to that of Port Orford cedar heartwood. Both Alaska cedar and Port Orford belong to the genus *Chamaecyparis,* but their essential oil profiles were dramatically different, with different families of dominant sesquiterpenes. Other forest sources were also examined for some of the active terpenoids. In some cases model compounds were needed for structural comparisons.

Structure/biodiversity relationships were studied using both the natural substances isolated from Alaska cedar and semisynthetic derivatives of valencene, a sesquiterpene found in Alaska cedar. Oxidation with placement of an alcohol, ketone, or aldehyde greatly activated the system towards insect activity. Epoxides did little for activation. Too much oxidation dramatically decreased toxicity towards insects, possibly because of decreased volatility. A number of the natural products and semisynthetic derivatives are very toxic to insects and arachnids. Some of these compounds are known, such as carvacrol; others, such as valencene-13-alcohol, are new to science. The dose-mortality results indicated that several compounds were effective pest control agents with good residual activity. We identified the active structures and how to make these substances from less active but more abundant material, specifically, the wood of a commercially important timber species. The chemistry learned will also promote the use of other agricultural waste products containing the same chemical family of compounds.

Publications, Theses, and Technology Transfer Activities

Publications

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Technology Transfer Activities: Presentations and Posters

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Boston, KD. Coordinating author and member of IUFRO Task Force focusing on the role of information and communication technology in forestry. Book chapter under development describes the future role for information and communication technology in supply chain performance.

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Marshall, H, G Murphy, and MC Bolding 2003. Optimally bucking a stand of trees to meet order book constraints. Presentation. Forest Products Society Conference, June, Seattle, WA.

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Reeb, JE, ES Baker, and WF Reiter. 2003. Analyzing manufacturing system changes using discrete event simulation. Advanced Information Technology Systems for Predictive Modeling of Wood Composite Properties Technical Interest Group, Forest Products Society 57th Annual Meeting, June 22–25, Bellevue, WA.

Reeb, JE, ES Baker, and WF Reiter. 2003. Using discrete event simulation to measure impact of changing from traditional manufacturing to cell manufacturing in a value-added wood processing facility. Portland International Conference on Management of Engineering and Technology, July 20–24, Portland State University, Portland, OR.

Scott, R, R Leichti, and T Miller. 2003. Lateral force resisting pathways in log structures. Technical poster. Forest Products Society, International Meeting, June 22–25, Seattle, WA.

Sessions, J. 2003. Planning for fire-killed timber salvage considering economic values and environmental risks. Presentation, Oregon Forest Resource Institute-sponsored seminar on Managing Forest Risk, August, Medford, OR; the Society of American Foresters-sponsored Restoration Workshop, September, Bend, OR; 6th Annual Business Economics Outlook Forum, December, Roseburg, OR.

Skaugset, AE, and JJ McDonnell. 2003. Presentation on the Hinkle Creek Paired Watershed Study to the Oregon Board of Forestry during a field trip to Hinkle Creek for their monthly meeting, July 24, 2003. Jeff McDonnell and members of his lab toured Hinkle Creek to encourage cooperation and solicit research, October 17.

Skaugset, AE, and JJ McDonnell. 2003. Presentation to the Advisory Committee of the Watersheds Research Cooperative regarding progress on the hydrology and water quality component of the Hinkle Creek Paired Watershed study, December 4.

Skaugset, AE, and JJ McDonnell. 2003. Presentation to the Oregon Forest Resource Institute Board of Directors regarding the status of Hinkle Creek, December 12.

Skaugset, AE, and JJ McDonnell. 2003. The ecological and watershed staff of the Bureau of Land Management toured Hinkle Creek, December 18. Approximately 65 high school students and 20 adults (teachers and chaperones) from Roseburg High School spent the day learning about forests, forest management, water, and watersheds as part of the Hinkle Creek outreach program in October.

Skaugset, AE, E Gilbert, E Marbet, K Ellingson, E Toman, and J Amann. 2003. The hydrology of forest roads. Presentation to the LTER group, Forestry Sciences Lab, PNWFRES, December 5, Corvallis, OR.

Skaugset, AE, JJ McDonnell, RF Keim, and EM Toman. 2003. Use of stable isotope tracers as a diagnostic tool for determining connectedness of road runoff to stream peak flows in disturbed forest environments. Poster. Annual meeting of the American Geophysical Union, December 11, San Francisco, CA.

Skaugset, AE, and MR Pyles. 2003. Putting environmental engineering into forestry's engineers. 26th Annual Meeting of the Council on Forest Engineering, September 7–10, Bar Harbor, ME.

Solmie, D, L Kellogg, J Kiser, and M Wing. 2003. Strategies to complete corridor layout. Council on Forest Engineering, September 7–10, University of Maine, Orono.

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Taylor, AM. 2003. A change of heart? The future of wood quality. Invited presentation. Council of Regents, June 12, Oregon State University, Corvallis.

Taylor, AM. 2003. The nature and nurture of heartwood formation. Invited presentation. Forest Products Society, Willamette Valley Chapter, May 22, Corvallis, OR.

Taylor, AM. 2003. The nature and nurture of heartwood formation. Invited presentation. Wood Research Department, Weyerhaeuser Company, Weyerhaeuser Technology Center, February 21, Federal Way, WA.

Toman, EM. 2003. Forest road hydrology: The magnitude and timing of runoff from forest roads relative to stream flow at live stream crossing culverts. Forest Engineering Department Winter Seminar Series.

Wilson, J. 2003. Determining the cost of drying lumber: The role energy plays in this cost. Talk. Lumber Drying Course, December 9, Oregon State University, Corvallis.

Wilson, J. 2003. An environmental justification for wood products–Modeling the plywood process. Talk. Plywood Manufacturing Course, April 28, Oregon State University, Corvallis.

Wing, MG. 2003. FE 308—Forest Surveying. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2003. FE 357—GIS and Forest Engineering Applications. Department of Forest Engineering, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2003. Introduction to ArcView GIS: Applications in Natural Resources, February 6–7, College of Forestry, Oregon State University, Corvallis.

Wing, MG. 2003. Introduction to ArcView GIS Applications in Natural Resources, April 17–18, College of Forestry, Oregon State University, Corvallis.