Proposed Protocol for Evaluating Potential Strength-Reducing Characteristics in Lumber after a Catastrophic Event: Pilot Application and Next Steps

Conroy Lum

Mountain Pine Beetle Working Paper 2009-01

FPInnovations – Forintek Division

2665 East Mall

Vancouver BC V6T 1W5

MPBI Project # 8.63

Natural Resources Canada
Canadian Forest Service
Pacific Forestry Centre
506 West Burnside Road
Victoria BC V8Z 1M5

2009

Library and Archives Canada Cataloguing in Publication

Lum, Conroy, 1960-
Proposed protocol for evaluating potential strength-reducing characteristics in lumber after a catastrophic event : pilot application and next steps / Conroy Lum.

(Mountain pine beetle working paper ; 2009-01)
"MPBI Project # 8.63".
Includes abstract in French.
Includes bibliographical references.
ISBN 978-1-100-12088-1
Cat. no.: Fo143-3/2009-1E

1. Lumber--Grading--Canada. 2. Lumber--Testing. 3. Lodgepole pine--Diseases and pests--British Columbia. 4. Mountain pine beetle --British Columbia. I. Pacific Forestry Centre II. Title. III. Series: Mountain Pine Beetle Initiative working paper 2009-01

SB945 M78 L85 2009 674'.5 C2009-980074-8

Abstract

The production of lumber from mountain pine beetle (MPB)-attacked wood with the characteristic bluestain is not new. What is unprecedented is the scale of the attack and the volume of MPB-killed timber that needs to be processed in order to obtain the maximum possible value from the resource. When lumber is produced from dead standing timber, certain types of lumber strength-reducing characteristics appear in higher frequency. Depending on the biogeoclimatic conditions of the site, one might notice, for example, an increase in the occurrence of decay and/or shake in the ungraded lumber. Although much of the production is subsequently downgraded because of these characteristics, the lumber that remains in the grade still may have noticeably more pieces with these potential strength-reducing characteristics.

The industry has responded to the higher frequency of these characteristics by adopting new technology and by better preparing visual graders to deal with this resource. Nevertheless, the MPB epidemic has identified a need for an evaluation tool that helps the industry decide if the quality system needs to be adjusted to respond to the "sudden" appearance or increase in frequency of potential strength-reducing characteristics in a region.

The objective of this study is to develop a protocol for evaluating and responding to potential strength-reducing characteristics that develop in lumber from stands following a regional catastrophic event. This new protocol is intended to be distinct from the standardized lumber testing programs that are in place to support the development of structural design values.

Under this two-year project, a general protocol has been drafted and a limited pilot study was undertaken to demonstrate its efficacy by using shake in post-MPB lumber as an example. This protocol provides guidance on the identification of suitable characteristics for study, the design of an exploratory survey for assessing frequency of appearance, the approach for collecting samples for strength testing, the analysis of the test results, and, if necessary, the development of supplementary grading rules to respond to possible impacts to the lumber strength from these characteristics. The protocol will be presented to an industry Working Group charged with responding to issues arising from the MPB epidemic. It is anticipated that this protocol, when finalized, will form one of the basic Canadian tools on monitoring and assuring that published lumber design values continue to be applicable.

Keywords: lumber grading, strength, mechanical properties, sampling

Résumé

La production de bois d'œuvre à partir de bois infesté par le dendroctone du pin ponderosa (DPP) et présentant la coloration bleue caractéristique n'est pas nouvelle. Ce qui est sans précédent, c'est l'échelle de l'infestation et la quantité de bois d'œuvre tué par le DPP qu'il faut transformer pour maximiser la valorisation de la ressource. Lorsque l'on produit du bois d'œuvre à partir d'arbres morts sur pied, on observe avec plus de fréquence certaines caractéristiques qui réduisent la résistance du bois. Selon les conditions biogéoclimatiques du site, on peut observer, par exemple, une augmentation de la présence de pourriture ou de fentes dans le bois d'œuvre non classé. Bien que la majeure partie de la production soit par la suite déclassée en raison de ces caractéristiques, le bois d'œuvre qui demeure classé peut néanmoins comprendre, avec une fréquence que l'on remarque, des morceaux possédant ces caractéristiques susceptibles de réduire la résistance du bois.

L'industrie a réagi à la présence plus fréquente de ces caractéristiques en adoptant de nouvelles technologies et en donnant une meilleure formation au personnel chargé du classement visuel du bois, afin de pouvoir valoriser la ressource. Néanmoins, l'épidémie de DPP a montré la nécessité d'avoir un outil d'évaluation qui aide l'industrie à déterminer si le système de contrôle de la qualité doit être adapté pour réagir à l'apparition « soudaine » ou à la présence plus fréquente, dans une région donnée, de caractéristiques susceptibles de réduire la résistance du bois d'œuvre.

L'objectif de cette étude est l'élaboration d'un protocole d'évaluation et de réaction à appliquer lorsque l'on observe la présence de caractéristiques susceptibles de réduire la résistance du bois d'œuvre provenant de peuplements qui ont subi un événement catastrophique à une échelle régionale. Ce nouveau protocole doit être distinct des programmes d'essais normalisés pour le bois d'œuvre qui sont en place pour soutenir l'établissement de valeurs de calcul structural.

Dans le cadre de ce projet de deux ans, on a élaboré une ébauche de protocole général et entrepris une étude pilote limitée visant à démontrer l'efficacité de ce protocole dans laquelle on a utilisé, à titre d'exemple, les fentes que l'on observe dans le bois d'œuvre provenant d'arbres infestés par le DPP. Ce protocole permet d'orienter l'identification des caractéristiques qui se prêtent à l'étude, la conception d'une enquête exploratoire visant à déterminer la fréquence d'apparition de ces caractéristiques, le choix de la méthode de collecte d'échantillons pour les essais de résistance, le choix de la méthode d'analyse des résultats des essais et, au besoin, l'élaboration de règles de classement supplémentaires en réponse aux incidences potentielles de ces caractéristiques sur la résistance du bois d'œuvre. Le protocole sera présenté à un groupe de travail de l'industrie chargé de trouver des solutions aux problèmes liés à l'épidémie de DPP. On s'attend à ce que ce protocole, une fois finalisé, soit un des outils de base au Canada pour surveiller le bois d'œuvre et s'assurer que les valeurs de calcul publiées pour ce matériau sont toujours applicables.

Mots clés : classification, résistance, propriétés mécaniques, échantillonnage du bois d'œuvre.

Table of Contents

List of Tables

1 Introduction

1.1 Lumber Grading and the Mountain Pine Beetle Epidemic

Although the manufacturing of structural lumber from post mountain pine beetle-killed lodgepole pine wood (post-MPB wood) is not new, the scale of the attack is unprecedented. There are visible characteristics in lumber produced from post-MPB that generally do not appear in the same frequency and severity in lodgepole pine prior to the MPB attack. The most visible and most prominent characteristic is the bluestained sapwood, which is not considered a strength-reducing characteristic by lumber grading rules; this is a position supported by past experience, knowledge of the effect of the staining fungi on the structural components of the wood, and a recent study of basic mechanical properties of blue-stained lodgepole pine by Lum et al. (2006) (see also Byrne et al. *2005*).

Other visible characteristics that develop in post-MPB wood are, however, classified as "strength-reducing" by the lumber grading rules. These include, for example, shake, checks and decay, which are not unique to post-MPB wood but develop as a result of a combination of the effects of the bio- and geo-climatic conditions on dead stands. Comprehensive lumber grading rules, such as those in effect in North America, were developed to consider the effects of these potential strength-reducing characteristics and place individual pieces of lumber in grades or categories such that appropriate strength properties are assigned. As noted above, the lumber grading system has demonstrated its ability to accommodate post-MPB wood.

1.2 Lumber Grading and the In-grade Lumber Methodology

The basic philosophy of in-grade lumber testing is to base lumber design values on data from tests of representative samples of commercially produced lumber. It has been more than 25 years since the introduction of in-grade lumber based design values in North American design codes. The satisfactory performance of lumber in a wide range of engineered applications over this period and the fact that a common grading, sampling and testing methodology was applied to clearly distinct growth regions and species in North America demonstrate the robustness of the approach.

Nevertheless, designers of the program likely did not anticipate having to accommodate the impact of a regional event such as the MPB epidemic. While the use of large sample sizes distributed across all producing regions can identify most of the product variability due to resource differences and production practices, leaving only the gradual and longer-term changes to be dealt with through monitoring, it is not clear if this assumption can be extended to a large regional catastrophic event such as the MPB epidemic where certain potential strength-reducing characteristics develop in the wood over a relatively short time compared to the working life of the forest.

In any in-grade lumber sample, the majority of the strength-reducing characteristics associated with failure are knots and slope of grain. These are characteristics that are understood to have the largest impact on the lumber strength, are dominant in the original in-grade lumber sample and are assumed to continue to be representative of lumber produced. What distinguished these characteristics from those identified above as developing in post-MPB wood is that knots and

slope of grain are characteristics found in a generally healthy forest resource that, if sufficiently large in volume and properly sampled, can be considered relatively stable over time. On the other hand, the strength-reducing characteristics specific to post-MPB wood develop relatively rapidly compared to the typical characteristics that develop in a healthy stand, and therefore may not be adequately represented in the in-grade lumber database.

This observation, however, is not to imply in any way that the in-grade database is inadequate as a basis for developing acceptable lumber design values. But the North American in-grade lumber sampling procedure was designed so that it reflects the variability in strength properties from a number of sources, which may mask any potential change due to a regional catastrophic event.

1.3 Motivation for the Project

The lumber grading rules handle the types of strength-reducing characteristics that develop in the standing dead timber and which ultimately appear in the lumber. This comprehensive system of rules that limit the types and sizes of these strength-reducing characteristics has coped well with lumber produced from stands subject to catastrophic events ranging from ice- or windstorms, to fire and insect attack. However, given the scale of the current mountain pine beetle epidemic in British Columbia and the likelihood that mills will be processing this timber for a number of years, it seemed prudent to develop guidelines for a systematic approach to evaluate and respond to strength-reducing characteristics that may appear more frequently in lumber from standing dead timber. In particular, there is a need to assess whether or not the increased frequency of potential strength-reducing characteristics developed in post-MPB wood impacts the strength such that the assigned design properties are no longer applicable.

2 Project Objectives

- To put in place a monitoring system supplementing the current lumber quality program that would guide lumber surveys and/or sampling to collect information necessary for developing responses to questions about the quality of lumber affected by a regional catastrophic event.
- To promote this monitoring and response system as a viable and more reliable alternative to full-size and full-scale lumber testing.

3 Project Plan

The project spanned two years with the goal of preparing a draft "protocol" to industry committees responsible for lumber quality by the end of the project. In Year 1 of the project, a draft protocol (revision 0-2) for assessing potential strength-reducing characteristics that develop in the standing dead timber and which ultimately appear in the lumber was prepared (Lum 2007). The protocol is designed to apply to full-size lumber and consists of six stages:

1. Exploratory Survey
2. Design and Execution of the Sampling Plan (Purposive Sampling)
3. Data Analysis
4. Adjustments to the Lumber Grading Rules
5. Verification

6. Reversal of Grading Rules Adjustment

The objectives of Year 2 were to carry out trials using the protocol, provide some test data for development of analytical procedures, and start the process for obtaining recognition of the protocol. Development of analytical procedures requires fundamental work in two areas: 1) what level of change justifies action; and 2) how should lumber grade rules be evaluated and adjusted. These activities and an assessment of the efficacy of the protocol were planned for the second year.

Table 1. Summary of Key Activities in Year 2 (2007/2008)

Activity	**Summary of Status**
Trial application of protocol	Completed.
Statistical model for developing survey and sampling plans.	Background for calculating sample sizes for surveys completed. Studies on lot sampling, predicting lot properties, and methods of analysis are still in progress.
Finalize protocol for presentation to the Canadian Lumber Properties Steering Committee.	Draft protocol (See Appendix A) and future work plan to be presented to the industry Mountain Pine Beetle (MPB) Working Group (WG) in early 2008-09.
Final project reporting of 2007-08 activities.	Completed.

4 Results and Discussion

4.1 Overview

Work on the draft protocol, mainly the development of statistical and analytical procedures, is anticipated to continue beyond the completion of this 2-year project. The following describe the results of work carried out in the second year: a pilot application of the protocol, and preparation of background information on the role of the protocol and additional work for presentation to the MPB Working Group in early 2008-09.

4.2 Pilot Application of the Protocol

To assess the efficacy of the protocol (e.g., is it a practical approach for collecting lumber strength data for developing a response to a regional event?), a trial application of the protocol was carried out this year. Due to the limited resources and the fact that the draft protocol was still under development, the trial was limited to two mills that were close enough to visit in consecutive days but far apart enough that the wood resource can be considered different. Planning for the mill visits and information on the mill visit are at Appendix B and C.

4.2.1 Preparation for Mill Visits

The draft protocol relies on agencies to raise the need for an evaluation based on observed changes in the appearance of lumber processed from stands subject to a catastrophic event. In

the case of the MPB epidemic, grading agencies servicing the MPB-affected areas had an opportunity to examine a large sample of SPF 2x4 grade No. 2 lumber. This sample consisted of smaller samples of lumber collected from a number of mills in BC.[1] After confirming that all the samples were on grade, the agency graders were asked to identify the MPB-related characteristic that most frequently appeared. From this, "No. 2 shake" was identified as the class of characteristic that should be examined using the draft protocol.

A critical decision when undertaking a survey is the selection of the sample size. There are two steps in the protocol requiring decisions on sample size: the *Exploratory Survey*, which collects information on the severity and frequency of appearance of strength-reducing characteristics associated with the event; and the *Purposive Sample*, which consists of collecting a number of 10-piece lots that have at least one piece with the characteristic(s) of question.[2] Guidance on sample sizes for the *Exploratory Survey* is provided in Appendix E. For the trial exploratory study, the following assumptions were made to help in the selection of an appropriate sample size:

- Up to 10% of the pieces with shake is not an issue except if the shake is found to be all of the maximum type permitted in the grade (this was not judged to be likely);
- If 20% of the pieces contain shake of any type, the effect of shake will need to be sampled for testing; and
- A precision of ±5% is acceptable.

In a formal application of the protocol, a committee will need to be consulted to establish the above assumptions. Based on these assumptions, an *Exploratory Survey* sample size of 1500 pieces was targeted for each mill. However, there was insufficient time to permit the necessary analysis to be developed to determine the optimum sample size for collecting the *Purposive Sample*. So that the program could continue, 29 *Purposive Sample* lots were targeted at each mill.[3] During discussions on the merits of the sampling scheme proposed for the protocol, alternative procedures were also suggested. These are discussed in Appendix F, which consists of separately sampling pieces with and without the target characteristic, as opposed to 10-piece lots. The intent would be to build the lots by computer simulation.

The mills selected for the trials were located in Williams Lake and Prince George. The mill selection process was limited to discussions with the participating agency staff.[4] For this trial, there was no attempt at assessing how representative the two mills selected were to mills operating in the MPB-affected areas or at defining the source of the logs for these mills other than to confirm that the harvest areas of the two mills did not overlap. These would be decisions that would need to be made if the finalized protocol is applied formally. For example, the mill selection would likely need to be randomized with consideration given to the mill's production

[1] This is the sampling practice typically employed in larger programs that span all regions in Canada that produce the species and grade (e.g., SPF No.2).
[2] In the original version of the protocol and in many of the Appendices drafted earlier in the program, these samples were referred to as "biased sampling samples".
[3] Treating each lot as a data point, non-parametric statistics requires a minimum sample size of 28 to establish the lower tolerance limit for the 5th percentile at a 75% confidence level.
[4] Because the purpose of the study is to test the efficacy of the protocol and is not an official study carried out under the supervision of the National Lumber Grades Authority, the names of the mill are being kept confidential.

volumes and location to ensure that conclusions from the study are representative of production from the areas of interest.

4.2.2 Exploratory Survey and Purposive Sample Selection Mill Visits

Trip reports and the specific planning that took place prior to and during the visits are documented in Appendix B and C.

From the mill trials, it was concluded that the sampling required by the protocol can be reliably applied and that the resource requirements (time and expenses) are reasonable. The trials were carried out on 2x4 lumber and it was noted that the protocol might be problematic when applied to wider widths (See Sections 4.2.4 and 4.4.2).

4.2.3 Specimen Destructive Testing and Documentation

The samples were tested following standard in-grade lumber bending procedures. All specimens were tested for edgewise-bending strength and stiffness under third-point loading with a span of 59.5 inches. The tension edge was randomly selected and the maximum strength-reducing characteristic, visually determined, was randomly located within the test span.

Following the testing, the cause of failure for each piece was assessed visually and documented. Here the issue is the level of effort that should be expended to describe the event-related characteristics. With the understanding that the standard procedures normally used to document lumber test samples (e.g., the Forintek failure coding schemes) may not be sufficient for developing alternate grade rules under the protocol, it is recommended that the supplemental coding be only applied to the level necessary for developing alternate grade rules, but that the standard coding also be carried out so that comparisons can be made to the standard in-grade lumber data base. Therefore, these studies should be coordinated with the Canadian Wood Council (CWC) who maintains the in-grade lumber database on behalf of the National Lumber Grades Authority (NLGA).

4.2.4 Additional Mill Visit

The grading agency participating in the trials suggested a visit to a third mill. The concern was whether the protocol should cover only one size of lumber or a range of sizes. Applying the protocol to wider widths raises issues with sample handling at the mill (e.g., more pieces to handle and more manpower requirements), and availability. Wider widths, particularly 2x8 or wider, may either not be produced or not produced on a regular basis. This creates logistical problems for sampling. These difficulties are not unique to the protocol; they are equally applicable to the standard in-grade lumber sampling and testing programs.

A problem that is unique to the protocol is that tests on wider widths of lumber require longer specimen lengths in order to maintain the standard span-to-depth ratios for testing. When selecting specific characteristics for testing, the limited specimen length may prevent the target characteristics from being properly positioned in the test span.

In anticipation that the protocol may need to be applied to wider widths of lumber and not just 2x4's, it is recommended that other approaches be studied. For example, the protocol may direct that the survey and testing as proposed be applied to 2x4's, and based on the 2x4 results, a

similar survey with reduced testing program could be carried out on 2x8 or wider widths (see Appendix J).

4.3 Preliminary Observations

Test results have been forwarded to the Canadian Wood Council (CWC) for further analysis. Once completed, the proposed protocol and results of the analysis will be forwarded to relevant industry committees that are tasked with providing direction on the maintenance of Canadian lumber properties to the NLGA. Committees that will be approached include the Lumber Properties Steering Committee (LPSC) and the Lumber Properties Technical Advisory Committee (LPTAC).

At the time of this report, methods to analyze the test data are still under discussion and development. The work was complicated by the need to have the methods integrate well with other lumber property research activities. A key question is how best to express regional lot properties and whether these lot statistics will provide a better assessment of how well the lumber would perform in the field. As described in the trip reports, the *Purposive Samples* were collected by sequentially going through approximately five bundles of No.2&Btr 2x4 lumber. When a piece of lumber containing the characteristic of interest was encountered, it and the next nine pieces were set aside as a single 10-piece lot. Then depending on whether the 10-piece lot contained one, two or more pieces with the characteristic of interest, one, two or more pieces without the characteristic of interest were sequentially selected from production and added as "augment" pieces to the 10-piece lot. Therefore as sampled, the 10-piece lot would represent a 10-piece lot where the characteristic of interest is left in the production. By replacing these pieces with the augment pieces, the 10-piece lot would then represent a lot where the characteristic of interest had been graded out. Empirically, this would simulate the effect of imposing an alternate grading rule on the lot, and the within and between lot properties could be used with advanced structural system computer simulations.

At this time, preliminary comparisons were made of the lots as sampled and replaced by the augment pieces (e.g., to simulate the impact of applying an additional grading rule). A comparison was also made between the pieces with the characteristic and the augment pieces (Appendix D). The analysis is provided as an example of how the data may be presented. At this time, analytical tools to assess these data are still being discussed.

It is recommended that while suitable analytical procedures are being developed, data from the draft protocol can be used by the committees to assess empirically the effects of imposing alternate or supplementary visual grade rules on potential strength-reducing characteristics. The resulting data can also be used with advanced systems analysis modes that can take into consideration the individual member strength in predicting system performance.

4.4 Next Steps and Additional/Continuing Work Items

4.4.1 Development of Statistical Tools and Analytical Procedures

Development of statistical tools to analyze and simulate the results is still underway. A description of the statistical framework for rationally revising grading rules is included in Appendix G, and notes to support the work are in Appendix H. The area requiring more

fundamental study is how to characterize and predict lot properties (Appendix I). Data from this study will be used to further develop the statistical theory for supporting the protocol.

4.4.2 Issues with Current Protocol

From the visit to the third mill, Mill C, it was clear that it would be difficult to apply the protocol to wide widths of lumber (e.g., 2x8 or wider). A phased approach could be used where as many iterations as required of the protocol is applied to the 2x4 size. Once one or more alternate grade rules are identified, they can be scaled up proportionately to the wider widths and simply verified. But even verification testing requires the selection of sample sizes. A study on optimizing the sample size with consideration given to the cost of sampling is recommended; such a study would help decide the amount of effort directed at each size (see Appendix J).

In the current protocol, it was decided that 29 lots from each mill would be sufficient to assess the impact of an alternate grading rule. When the statistical analysis work is completed, one may conclude that more lots are required to provide the precision necessary to determine the effectiveness of an alternate grading rule. If the currently proposed lot-sampling scheme needs to be increased to a level where it is no longer practical, an alternative method for generating sampling lots is required. To prepare for this, an alternate method based on simulating lots using information from the Exploratory Survey and tests on pieces with and without the target characteristics is proposed (see Appendix F). This would involve more careful sampling and documentation at the exploratory survey stage of the program, with the advantage of minimizing the overall number of pieces tested.

4.4.3 Protocol Recognition and Other Lumber Assessment Tools

The role of the protocol has been discussed with various committees tasked with providing input to the maintenance of the Canadian lumber quality system. This includes the MPB Working Group established to deal with issues arising from the MPB epidemic, and the Canadian Lumber Properties Steering Committee.

The original role of the protocol, which is to deal with the appearance of potential strength-reducing characteristics, will be presented to the committees (see Appendix K). This fills the immediate need to deal with issues arising from the MPB epidemic. A more beneficial longer-term application would be to take the program findings and recommendations for additional study and redirect them to develop the protocol into a “first response” tool for responding to questions about regional events that potentially impact lumber design values. Since the introduction of in-grade lumber testing, much effort has been directed at establishing global or national properties, and very little at understanding what can be done at the regional level. Although the MPB epidemic is the regional issue of concern at this time, it is envisioned that there are other related issues that can fall under the scope of this protocol. The work done under this project represents the first steps in defining how a regional assessment can be carried out. The discussions on how to integrate this with other lumber properties assessment tools are summarized Appendix L.

It is recommended that steps be taken to identify these related issues so that the protocol can be further generalized before it is integrated with the industry’s program on establishing lumber

properties monitoring tools. It is proposed that development and implementation of the protocol continue under the industry-led Lumber Properties program.

5 Conclusions

When lumber is produced from dead standing timber, certain types of lumber strength-reducing characteristics appear in higher frequency. Although much of the production is subsequently downgraded because of these characteristics, the lumber that remains in the grade still may have noticeably more pieces with these potential strength-reducing characteristics. This is a regional issue and there is currently no accepted method of assessing whether action needs to be taken on this observed change.

Under this two-year project, a general protocol has been drafted to address this need. A limited pilot study was undertaken to demonstrate its efficacy by using shake in post-MPB lumber as an example. This protocol provides guidance on the identification of suitable characteristics for study, the design of an exploratory survey for assessing frequency of appearance, the approach for collecting samples for strength testing, the analysis of the test results, and, if necessary, the development of supplementary grading rules to respond to possible impacts to the lumber strength from these characteristics.

The protocol will be presented to an industry Working Group charged with responding to issues arising from the MPB epidemic. Because this protocol offers a novel approach to evaluating the quality of lumber, it is important to assess how well it applies to similar issues and not necessarily MPB or characteristics that develop following a catastrophic event. While the protocol may be available for use by the industry in its draft form, it is recommended that more general applications of the protocol be investigated before details are finalized. These include ensuring that the protocol is compatible with procedures used for species grouping or assessing product withdrawals.

6 Acknowledgements

This project was funded by the Government of Canada through the Mountain Pine Beetle Initiative, a program administered by Natural Resources Canada, Canadian Forest Service. Publication does not necessarily signify that the contents of this report reflect the views or policies of Natural Resources Canada – Canadian Forest Service.

7 Literature Cited

Byrne, T.; Woo, K.; Uzunovic, A.; Watson, P. 2005. An Annotated Bibliography on the Effect of Bluestain on Wood Utilization with Emphasis on Mountain Pine Beetle-Vectored Bluestain. Mountain Beetle Initiative Working Paper 2005-4. Canadian Forest Service. 60 pp.

Lum, C. 2007. Development of Protocols for Quality Assessment for Structural Lumber from Mountain Pine Beetle Attacked Timber. Annual Information Report 2006/2007. MPBI Project #8.63. Available through Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre's Mountain Pine Beetle Program office, Victoria, BC. 9 pp.

Lum, C.; Byrne, T.; Casilla, R. 2006. Mechanical properties of lodgepole pine containing beetle-transmitted blue stain. Forest Products Journal 56(6):45-50.

Contacts:

C. Lum
FPInnovations – Forintek Division
2665 East Mall
Vancouver, BC V6T 1W5
E-mail: conroy.lum@fpinnovations.ca

Appendices

Appendix A – Draft Protocol (rev 1-1)
Appendix B – Trial Study Preparation Notes
Appendix C – Reports on MPBI Sponsored Mill Visits
Appendix D – Preliminary Analysis of Impact of Characteristics Studied
Appendix E – Calculating Global Sample Sizes (rev 1)
Appendix F – Alternative Protocol Sampling
Appendix G – Statistical Framework for Revising Grading Rules
Appendix H – Predicting Lot Properties
Appendix I – Observational Survey Technical Notes Jan07 (rev)
Appendix J – Cost Constrained Sample Sizes
Appendix K – Proposed Role of the Protocol
Appendix L – Integrating Long-term Monitoring and Regional Assessment

Appendices A through L listed above are available through Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre's Mountain Pine Beetle Program office, Victoria, BC.