Proposed protocol for assessing and responding to lumber strength-reducing characteristics associated with a catastrophic regional event

Addendum to Mountain Pine Beetle Working Paper 2009-01

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This mountain pine beetle working paper is an addendum to Mountain Pine Beetle Working Paper 2009-01: Proposed Protocol for Evaluating Potential Strength-Reducing Characteristics in Lumber after a Catastrophic Event: Pilot Application and Next Steps.

Ce document de travail du dendroctone du pin ponderosa est un addenda au document de travail du dendroctone du pin ponderosa 2009-01 : Projet de protocole pour l'évaluation des caractéristiques susceptibles de réduire la résistance du bois d'œuvre à la suite d'un événement catastrophique : Application pilote et prochaines étapes.

Table of Contents

1 Introduction

1.1 Lumber Grading and the Mountain Pine Beetle Epidemic

Although the manufacturing of structural lumber from post mountain pine beetle (MPB)-killed lodgepole pine wood (post-MPB wood) is not new, the scale of the attack is unprecedented. There are visible characteristics that are present in lumber produced from post-MPB that may or may not be present in lodgepole pine prior to the MPB attack. The most visible and most prominent is the bluestained sapwood. This is not considered a strength-reducing characteristic by lumber grading rules, 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 bluestained lodgepole pine by Lum et al[1] (see also Byrne et al[2]).

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 code. 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 demonstrates the robustness of the approach.

Nevertheless, designers of the program likely did not anticipate having to accommodate the impact of an 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[3], it is not clear if this assumption can be extended to a large regional catastrophic event such as the MPB epidemic.

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

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[1] Lum, C., T. Byrne and R. Casilla. 2006. Mechanical properties of lodgepole pine containing beetle-transmitted blue stain. Forest Prod. J. 56(6):45-50.

[2] T. Byrne, K. Woo, A. Uzunovic and P. Watson. 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. Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada. 60pp.

[3] This refers to monitoring as defined in Clause 13 of the ASTM D 1990.

are assumed to continue to be representative of lumber produced. What distinguishes these characteristics from those identified above as developing in post-MPB wood is that knots and slope of grain are characteristics found in a 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 that the database is inadequate as a basis for developing acceptable lumber design values. 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 catastrophe.

1.3 Determining the Appropriateness of Applying this Protocol

The Protocol would provide a tool to assess the mechanical properties of dimension lumber produced from a region where the forest resource has been subject to a catastrophic event[4]. The Protocol is being developed with the following in mind:

1. **Question to be Answered by the Protocol**: The key decision is whether lumber from a region following a catastrophic event can still be represented by design values developed from tests of in-grade lumber from the region prior to the event. This protocol applies only when the region(s) affected are a part of an assembly of many regions that were sampled as part of a testing program of in-grade lumber.

2. **Evaluation of Visual Grading Rules**: Lumber grading rules have limits on a comprehensive list of potential strength-reducing characteristics.[5] Although these characteristics are limited so that the theoretical impact of each on the clear wood strength is consistent[6], the actual effect of the characteristic on the full size lumber strength is imprecisely known except that, in general, larger characteristics tend to result in a larger strength reduction.[7] Lumber grading rules, when applied properly, ensure that characteristics of a particular size are limited within a grade, but do not restrict the frequency of occurrence or pay attention to whether the characteristics fall near the upper or lower limits of the grade. Thus if, as a result of a catastrophic event, a large number of potential strength-reducing characteristics develop in the wood, not only will grade recovery be impacted, but the amount of lumber with these characteristics, although meeting the grade, will likely increase and overall have a noticeably different appearance

[4] At this time, the size of the region and the nature or duration of the catastrophic event has not been defined. The Protocol is expected to be general enough so that it can be applied to any size region or event. However, it is expected that some judgement may need to be exercised by a committee familiar with the resource and the event.

[5] There are other characteristics that are not deemed to be strength-reducing characteristics (e.g., wane) but may affect the appearance and utility of the piece. Optimization of production methods may change the distribution of these characteristics but because they are not known to impact the strength, their higher frequency of appearance within a grade is not considered important.

[6] Based on the strength ratio concept as outlined in ASTM D245.

[7] A consistent set of grade rules, defined in the National Grading Rules, is implemented in North America. For a given grade designation, a common limitation is placed on the size of the characteristic regardless of the species.

from the lumber tested to develop design values.[8] This Protocol will focus on the frequency and distribution of strength-reducing characteristics within a grade and assess if there is evidence of a significant change in mechanical properties for on-grade pieces.

3. **Duration of the Effect is Short Relative to Working Life of Resource**: A distinction needs to be made between assessing longer-term changes at the national level, and changes due to a catastrophic short-term event at the regional level. This is necessary because the approaches taken to monitor and detect gradual but permanent changes to the global resource will differ from that used to assess change over a period of time that is short relative to the working life of a forest.[9]

4. **Effect is Limited to One or a Few Regions**: Catastrophic events such as those due to high wind, ice storms, fire and insect attack may result in a change of finite duration to a wood resource in a defined region. Such events can be assumed to occur randomly over time, impacting different region(s) each time. It would be rare for the event to impact the entire sampling region (e.g., all producing regions in Canada). Given time the region may return to its former state, but the assumption is that processing will either continue or expand in the affected area, eventually shifting to areas outside of the affected region once the resource is processed.[10] Thus, the Protocol will be designed to assess production from a defined region or group of regions affected by the same event.

1.4 Resulting Action Taken under the Protocol

1. **Assessing the Need for Grade Rule Adjustments**: Adhering to global sampling principles will make the assessment of changes to the grading rules difficult. Although lumber design values are developed from data intended to represent the global population, it should be recognized that the data set is actually assembled from 10-piece lots collected from all producing regions and distributed roughly in proportion to production. Data may be pooled to create a global sample, or the same data can be reduced to lot statistics (e.g., distribution of average lot values). Although these lot statistics or lot properties consist of the same samples that make up the global sample, it is anticipated that lot properties are likely more sensitive than global properties to grade rule adjustments. Therefore, the Protocol will include provisions to assess the need for a grade rule change by examining the lot statistics that correlate with the cross-sectional mean and near minimum[11] baseline property estimates for a region and the same statistic for all producing regions.

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[8] Because of the increased frequency of certain characteristics, it is also likely that the probability of pieces with these characteristics being misgraded will increase. This is an issue associated with enforcing the existing grading rules and is not within the scope of the Protocol.

[9] The terms “long-term” or “short-term”, and “regional” or “national” are relative and will need to be defined by a committee familiar with the resource. Consideration should be given to how the resource is subdivided for the purposes of sampling at the national level.

[10] For certain catastrophic events where the trees are selectively impacted, there may be a mixing of lumber from affected and unaffected trees. Because the Protocol focuses on the lumber produced, the results will vary depending on the proportions of affected and unaffected trees processed. The Protocol is not intended to target affected trees only or trees at a certain time since death, but the lumber that is produced from the region where there may be a mix. It is likely that the mix or the resource will continue to change over time, so some form of monitoring will be required.

[11] In an in-grade program, the global near minimum value would be the lower 5^{th}.

2. **Quantifying the Grade Rule Adjustments**: Following the assessment that identifies a need for an adjustment to the grading rules, the size of the adjustment will need to be quantified.

1.5 Actions Outside the Scope of this Protocol

1. **Assessing Regional Cross-sectional Study**: The development of design values from a national global sample of lumber implicitly accepts variability between the sampling units (e.g., pieces, lots, mills and regions). Any program focused on assessing the impact of a regional catastrophic event will likely not benefit from a nationally distributed sample for purposes of assessing the impact from a regional event, nor will it be viewed as a good use of resources.

   Sampling programs for national global samples do not normally have sufficient size to enable precise inference about their subpopulation's characteristics. Therefore, when regional assessments are required, a suitable baseline for assessing change is not available and other avenues such as that outlined in this protocol are required. Regional assessments were not anticipated in the design of the national program so it should also be noted that any assessment of regional change using data from a national sample should be interpreted with caution. Although data gathered from this Protocol may be used as a preliminary cross-sectional study of the region's production, further study is required to assess how variability over time observed in regional cross-sectional studies relates variability observed in one-time national cross-sectional studies.

2. **Assessment of a National Cross-sectional Study:** This step is beyond the scope of this proposal. Action could be in the form of an on-going monitoring program, which is currently being studied, or a reassessment as outlined in ASTM Practice D1990.

2 Protocol Elements

This is the first draft of a lumber sampling and testing protocol, which will be applied in one or more trials, to assess the effectiveness of the guidelines to help in assessing and responding to visual changes in the lumber produced from wood subjected to a catastrophic event over a finite region.

This protocol consists of six stages, each of which identifies decisions that will determine whether the next stage of the Protocol should be undertaken:

I. **Exploratory Survey** – to document the extent of the visible changes to the lumber produced which would question the representativeness of the data set that is on file.

II. **Design and Execution of the Sampling Plan** – to determine how best to sample lumber containing the observed characteristics and what tests to carry out which would provide meaningful information suitable for re-establishing lumber grade rule limits.

III. **Data Analysis** – to quantify the changes to the lot and regional properties when the proposed grading rules are applied to control the severity and frequency of the target characteristics.

IV. **Adjustments to the Lumber Grading Rules** – development of the adjustment to the grading rules that take into account practical issues and the change to be reflected, and the scope of their application.

V. **Verification** – verify that application of the adjusted grading rules is having the desired effects on the lumber properties.

VI. **Reversal of Grading Rules Adjustment** – monitor to determine when the adjustments to the grading rules can be reversed.

Stage I – Exploratory Survey[12]

2.1.1 Objectives

- To decide if it is appropriate to apply this Protocol to the event.
- To identify and rank **potential** strength-reducing characteristics to be evaluated in accordance with this protocol.

2.1.2 Activities and Decisions

NOTE: Preliminary analysis by the Canadian Wood Council (CWC) using available data showed a poor correlation between strength and the target characteristic. Given that the characteristic is already considered by the grade rule and the poor correlation with strength, assume a 20% trigger point for studying the characteristic and that not all the characteristics observed will be "low-line" (e.g., just makes the grade).

A trial study suggests a sample size of 1500 in order to adequately survey characteristics that may appear in 10% to 20% of the population. If there is a large variation in the severity of these characteristics, either a larger sample size or further iterations of the exploratory survey should be applied. Handling of wider width lumber (e.g., 2x8 or wider) may be problematic. Alternate procedures are being investigated.

- Is it appropriate to apply this Protocol?

  This Protocol only applies when a catastrophic event impacts the resource base supplying a portion of the total population represented by a national in-grade lumber sample. When this happens, the desire is to 1) assess if the event has significantly affected the mechanical properties of graded lumber from the impacted regions, and 2) if so, whether adjusting the visual grading rules can compensate for the impact.

  The Protocol will not necessarily quantify the change or suggest an adjustment that will completely reverse the change. Instead, it is likely that the portion of the national in-grade sample that covers the region impacted is limited and not adequate to use as a reference for detecting change due to the event. However, quantifying the change precisely may not be as important as ensuring that any remaining differences after adjusting the grading rules are comparable to variations generally accepted between that of actual production and the global sample that is used to represent the production.[13]

- Identify the target item (e.g., grade, size and species) and affected areas for applying the Protocol.

  The nature of the catastrophic event should be studied to determine if the potential effects are likely to impact all grades, sizes and, in the case of species groups, all subspecies. If it is judged that the impact is not specific to a particular segment of the population in the geographic areas, then for simplicity and economy, the most common size and grade

[12] The draft will be used to describe the plan for the pilot study as well as a template for the final Protocol. Where there are differences in the steps between the two functions, the document will show a table containing two columns: one listing the steps for the pilot study, and the other listing the parallel steps proposed for the final protocol, the key deliverable from this study.

[13] The trial program will investigate how the global sample may be used to decide if an observed difference warrants a grade rule adjustment and when the adjustment is sufficient.

should be selected in order to ensure that there is a geographically broad area for sampling. If only a subset of the population within the geographic area is impacted, then the reference item should be targeted in only that portion of the population affected[14]. This Protocol has been designed to deal with the evaluation of events that affect a subset of the population; however, it can also be applied to the entire population from a region or multiple subpopulations.

- Stratify "large" areas into sub-regions that recognize differences in bio- geo-climatic conditions or wood resource but recognize that there are likely still other factors influencing the formation of strength-reducing characteristics that may not be known.

  The impact of catastrophic events may be determined in part by the bio- geo-climatic conditions or wood resource. If it is desirable to have different levels of responses to the event depending on the severity of the impact, then sampling areas should be subdivided into smaller regions for the purposes of sampling and establishing the levels of response.[15] Other considerations when stratifying are that production constraints are such that each producer will likely only be able to implement one level of response at any given time, and that each new implementation may require retraining, calibration and verification, costs that should be balanced against maximizing the maximum lumber value. Having access to a sizeable number of producers within a region enables the sample from that sub-region to be maximally distributed when a sample is taken at point in time.

  From experience, bio- and geo-climatic conditions and the wood resource are the most likely factors to influence type and nature of strength-reducing characteristics to form during or after the event, but there are likely many other unaccounted factors. To ensure an unbiased sample, the survey should, as much as possible, be maximally distributed within each of the identified sub-regions.

- Develop a system for coding the target strength-reducing characteristic[16], which will assist in the identification and ranking of such characteristics.

  In advance of the exploratory survey, it is necessary to develop a consistent means of documenting what is observed in the survey and to document the characteristics such that they are expressed in terms that can be readily converted to adjustments to the visual grading rules.[17] Doing so will avoid having to again sample material and collect information in a form suitable for simulating the effects of the grading.

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[14] A good example of this would the mountain pine beetle epidemic, which affects only the lodgepole pine species within the Canadian Spruce-Pine-Fir species group. Following this protocol, the target item would focus only on lodgepole pine samples, although in a random sample other species may be present.

[15] The disadvantage of having too many small regions is that the imposition of minimum sub-region sample size requirements may inflate the overall sample size.

[16] In the case of this project, the focus would be on characteristics that develop in post-MPB wood.

[17] An example of this is the Forintek coding system for lumber strength-reducing characteristics. However, most coding systems, such as the one used at Forintek, are developed around accurately coding common characteristics such as knots. This may not be adequate as catastrophic events impacting a forest resource are more likely to result in characteristics associated with drying defects and decay, as opposed to more normal growth characteristics. Other types of characteristics following a catastrophic event include burls, bark pocket, etc.

- Sub-divide adjacent grade limits into two or three levels or "bins" for the purposes of establishing new grade limits.

  The need for that subdivision arises from the fact that grading rules do not themselves consider the severity or frequency of a characteristic within the defined grade limit. Table 1 outlines how an existing grade rule can be subdivided for the purposes of this Protocol.

Table 1: Template for Subdividing Target Characteristic for Study

Subcategories*	**Secondary Divisions of Severity**			
	Existing low limit of target grade	First intermediate cutoff	Second intermediate cutoff	Existing low limit of grade above target
Main category				
Subcategory 1				
…				
Subcategory 2				

"Subcategories" divide a general description of a characteristic into more specific categories that relate to categorical attributes such as the characteristic's general location within the cross-section (e.g., wide face, edge of wide face, narrow face) or along the length (e.g., middle third, outer third). It does not relate to qualities such as characteristic size or spacing, which are measured on a continuous scale. The intent of the subcategories is to recognize that the same size of characteristics may have a different effect on the strength, depending on its general location within the piece. Typical examples are knots, which have different size limits depending on whether they are classified as edge knot or centerline knots.[18]

"Secondary Divisions of Severity" are new measurable limits on the size and/or spacing of the characteristic within an existing grade (i.e., between the limits of two adjacent grades). Although the measurements are generally continuous, the limits should be selected so that they are still sufficiently large for a visual grader to identify.

- Select a survey sample size such that the total sample size is larger than X, and samples from each sub-region is no less than Y.

  The survey size will determine the number of pieces to be examined to estimate the percentages in each category. The suggested target sample size is appropriate to detect those characteristics that form Z% of the population.

- Analyze the survey results to identify those characteristics that have a higher frequency of occurrence than that observed in the available in-grade lumber data sets.

  The purpose of the analysis is to rank the characteristics in increasing order of priority for study. When this is done, no consideration is given to the severity of the characteristic within the existing grade limits. This step is not meant to exclude low priority characteristics, only to establish the order in which they are studied.

[18] Interpolation is used to deal with knots that are neither on the piece's centreline nor on the edge.

2.1.3 Optional Steps

- The exploratory survey may be carried out on a continuous basis. Data from a fixed period can then be studied in accordance with this Protocol to determine what action should be taken. However, because the survey requires a priori alternate grade rules, the amount of data collected (and thus effort) on an ongoing basis may be much greater than several iterations of an exploratory survey when conditions warrant a recalibration of the grading rules.[19]

[19] Responses to findings in other bio- and geo-climatic zones may be sufficient to provide guidance on subsequent adjustments without having to carry out all the steps in this Protocol.

2.2 Stage II – Design and Execution of Sampling Plan

2.2.1 Objectives

- To strategically collect samples containing the characteristic that is to be evaluated by testing.
- To test the sample such that the data can be used to assess the impact of applying grading rules to cull production containing the target characteristics.

2.2.2 Activities and Decisions

NOTE: In the trial study carried out under year 2, it was decided to select twenty-nine 10-piece lots from each mill. The optimum number of lots and the lot size needs further study. This will require the development of statistical tools and metrics for lots, which could not be completed under this project.

NOTE: It may not be practical to sample and test wide widths of lumber (e.g., 2 x 8 or wider). Alternate approaches that enable the characteristics to be evaluated using smaller sample sizes should be investigated.

- Collect samples in 5- or 10-piece lots such that each lot contains one or more pieces with the range of characteristics targeted. Augment the lots with pieces that contain pieces without the characteristic targeted, or with the characteristic but at a lower severity level.[20]

  To simulate the effect of applying the grading rules, the information on characteristic frequency of occurrence and their appearance in 5- or 10-piece[21] lots will be combined. The choice of 5- or 10-piece lots will depend on the frequency of occurrence. Control samples will be taken at the same time by counting the number of occurrences of the characteristic to be graded out and augmenting the sample with additional pieces that either does not contain the characteristic, or only contains the characteristic but at a lower severity level. The procedure for augmenting the samples can be adjusted to collect data that can then be analyzed to assess the culling of one or several alternate severity levels.[22]

- Select the non-destructive or destructive test method and whether the location of the characteristic in the test span will be random or non-random.

  Match lots should be provided for each test mode considered. Although any in-grade lumber test mode may be used, consideration should be given to selecting a test method that allows specimens of convenient size to be selected over many sources. For simplicity, bending tests are considered appropriate as they generate both a non-destructive measure (e.g., modulus of elasticity) and a destructive measure (e.g., modulus of rupture). Furthermore, portions of the specimen are stressed in either tension or compression.

  Where possible, the sample should be tested under standard conditions (e.g., moisture content and loading rates).

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[20] It may be possible to "augment" the sample by use of statistical formulae.

[21] Preliminary analysis suggests that a 10-piece lot will be noticeably more robust to change.

[22] Although the latter provides more flexibility in the analysis, it increases the complexity of the sampling considerably and the possibility of error.

2.2.3 Optional Steps

- Studies can be carried out to determine the ability of the non-destructive methods to assess the impact of specific strength-reducing characteristics. If the correlation between the destructive and non-destructive test methods is acceptable, considerable cost savings can be realized by carrying out only non-destructive testing.[23] But if correlations are poor, proof testing methods (where test load levels are limited, resulting in only the weakest pieces being destroyed) could be used.
- Provided suitable measures are taken to ensure repeatability and reproducibility of test results, testing can be carried out in the field or with portable test equipment.[24]

[23] The use of previously developed correlations is not recommended as the catastrophic event may have altered the property relationship. However, this approach can be used for subsequent tests after an initial study has been carried out to establish a suitable property relationship.

[24] An assessment of the repeatability and reproducibility of field or portable test set-ups is important, especially when results are to be pooled or compared with test results from other test facilities. If this is not done, differences due to equipment or test procedures may lead to incorrect conclusions about changes to lumber properties.

2.3 Stage III – Data Analysis

2.3.1 Objectives

- To quantify the changes to the lot and regional properties, when the proposed grading rules are applied to control the severity and frequency of the target characteristics.

2.3.2 Activities and Decisions

NOTE: Existing in-grade databases provide only limited information on lot properties. This is because for any item (size/grade/species) only a maximum of two 10-piece lots were collected from each mill. Two approaches are available. The empirical approach is based on analyzing the test data with and without the pieces containing the characteristic(s) of question. Alternate approaches include sampling separately pieces with and without the characteristic, testing the samples, and then using computer simulations to generate the lots.

- Analyze the lot properties.

  Determine the lot statistics for bending stiffness and a selected strength property with each of the proposed grade limits in effect and compare the resulting statistics to the same data with only the current grade rules in effect. Repeat for each grade limit.

- Analyze the pooled data properties.

  Pool the data for each sub-region and determine the cross-sectional properties with and without each of the proposed grade limits in effect. Weight the lot data using the exploratory survey data from Stage I.

- Compare the pooled data results to available regional data from existing in-grade or monitoring program.

  An initial estimate of the frequency and severity of characteristic may be obtained from any in-grade testing program that includes the affected region. Compare this with the frequency observed in Stage I.

  Compare the characteristic values from available in-grade testing programs with the weighted pooled data from the current study.

2.3.3 Optional Steps

- Comparisons may be made to on-going monitoring studies that maintain the lot-sampling scheme (either 5- or 10-piece lots). This should be taken into account when designing on-going monitoring schemes.

2.4 Stage IV – Adjustments to the Lumber Grading Rules

2.4.1 Objectives

- Identify new grading rules or subdivisions of existing limits to apply.
- Determine the production areas where the adjusted grading rules should be applied.

2.4.2 Activities and Decisions

NOTE: This section will need to be developed in consultation with the Grading Agency. Additional details will be provided from analysis of data from the trial study, and notes will be provided to assist in weighting and pooling test results from sub-regions.

- Develop a policy to apply the grading rule adjustment either to the entire area or to the area represented by the sample. Test if sub-regional data can be pooled into larger regions for the purposes of applying common grade adjustments.

  Considerations should be given to the number of manufacturing facilities in each sub-region and the number of agencies involved. Small pockets with different grading rules can be avoided by developing the grade rule adjustments from pooled production-weighted results collected from several sub-regions.

- Determine if the grade rule adjustment can be put in place in anticipation that the catastrophe-related characteristics may increase in frequency. [25]

  Changes to the grade rules may disrupt production, as staff need to be trained and the application of the new grade rules need to be verified. Therefore, consideration should be given to anticipating any additional adjustment in the near future based on, for example, observation from other regional studies which have been subjected to the event much earlier on.

2.4.3 Optional Steps

- In most cases, the study will be restricted to a target item that can be readily sampled at all manufacturing facilities. For untested items such as other sizes, rational procedures for extrapolating the results should be developed. Typically, grade rules are associated with "strength ratios". Expressing the new grade rule as a "strength ratio" can be used to adjust the grade rule for sizes not tested.

[25] Responses to findings in other bio- and geo-climatic zones may be sufficient to provide guidance on subsequent adjustments without having to carry out all the steps in this Protocol.

2.5 Stage V – Verification

2.5.1 Objectives

- To verify that the proposed rule changes, if any, are appropriate and, if not, to redo the study or take steps beyond this Protocol.

2.5.2 Activities and Decisions

NOTE: The verification step in the trial study will be used to further develop this section. More guidance will be provided on how to analyze the results of the verification sample.

NOTE: A separate study consisting of a limited global sample will be used to compare the results of a regional global sample to results from the protocol.

- Collect samples and compare lot and cross-section statistics from the pooled samples to determine the effect of the grade rule adjustment.

  Verification consists of following the sampling portions of this Protocol again to collect and test an independent sample to determine whether the resulting lumber has similar property distributions as that used to develop the grade rule adjustment. If the verification is successful, no further adjustment will be required. If the verification is not successful, the collected sample can be reanalyzed to fine-tune the grade rule adjustment.

- Decide whether steps beyond this Protocol need to be taken.

  There may be instances where the application of more stricter visual grade rules is not able to account for observed differences in lumber properties.[26] In this case, steps similar to that used to establish design values will need to be taken to determine whether the differences in characteristic property values under the existing visual grading rules need to be adjusted. These steps are beyond the scope of this Protocol, as it requires an understanding of the normal variability in lumber properties.

2.5.3 Optional Steps

- If successive applications of the Protocol are closely spaced in time, the verification stage may be omitted.

[26] Currently, the differences are based on the lot statistics containing the target characteristics, and the lot statistics derived from monitoring studies, or global cross-sectional studies.

2.6 Stage VI – Reversal of Grading Rules Adjustment

2.6.1 Objectives

- Establish criteria for monitoring to determine when the grade rules adjustment can be reversed.

2.6.2 Activities and Decisions

NOTE: It is assumed that a formal procedure for reversing the grade rule adjustment is preferred. The Protocol will be further developed to provide guidance to address practical concerns such as the possible mixing of logs from multiple sources and where the proportions of logs impacted by the event diminishes.

- Implement an ongoing monitoring program to collect and test samples from the target and reject grade to determine when the grade rules adjustment is not longer required.

  The decision to reverse the grading rules adjustment will be based on periodic surveys similar to that in the Exploratory Survey stage, but focussed on reject grade and distributed over a longer period of time.[27] The absence of pieces rejected by the adjusted grade rules in the reject grade (e.g., grade below the target grade) will be used to indicate when grade rule adjustments are no longer required.

  Table 1 from the Exploratory Stage can be used to collect characteristic frequency information.

2.6.3 Optional Steps

- Technically, the grade adjustments can be permanently added to the rules as they automatically become moot when the affected resource is depleted. However, because of the need to have harmonized visual grading rules within Canada and North America, it is likely necessary to reverse the grade rule changes.[28]
- The Protocol will not consider removing the grade rules adjustment in steps, as there is not likely to be any benefit.

[27] It is anticipated that as the impacted resource is depleted, the fluctuations in the observed frequency of strength-reducing characterisitics may be greater as other fibre sources may be mixed into the production. Care should be taken in either identifying when alternate fibre sources are involved; otherwise, it may be necessary to spread the survey over a longer period of time.

[28] Grade rule adjustments that are not reversed may result in a failed reinspection if, by chance, the characteristic were to appear again. In a reinspection, no consideration is given to the possiblity that the appearance of such characteristics may not have a practical impact on the in-grade lumber properties.