BCTS
BC Timber Sales
Skeena

TERRAIN STABILITY MANAGEMENT MODEL

April 2, 2014

1. Introduction

Forest development (planning and operations) has the potential to cause, or be affected by, landslides.[1] Individuals responsible for forest development need to apply landslide risk management within a decision-making framework to adequately balance environmental and timber supply objectives associated with the planning and operations for forest roads and trails, and timber harvesting.[2]

Members of the Association of British Columbia Forest Professionals (ABCFP) and the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) have professional obligations to protect the interests of the public, worker safety, and the environment.[1]

In addition, BC Timber Sales (BCTS), as well as its Licensees, Permittees, and Contractors (LPCs), have legal obligations under the *Forest and Range Practices Act* (FRPA) to protect the environment, prevent landslides, and to meet practice requirements related to terrain stability.

2. Purpose and Scope

The purpose of this document is to describe the Terrain Stability Management Model (the Model) of the BCTS Skeena Business Area and to provide guidance to professionals involved in the management of terrain stability. The Model sets out the expected standards of practice and due diligence for planning and for all phases of forestry and engineering operations throughout the Business Area.

3. Definitions

The following terms are generally defined as they relate to terrain stability and landslides and are specific to this Practices Document. Several of the definitions are quoted or adapted from the literature cited in Section 6.

Coordinating Professional: *The individual who is responsible for coordinating the activities related to a Forest Development. Responsibilities include determining what studies are required, retaining appropriate specialists, and incorporating the results and recommendations from studies in the overall development. This is a BCTS staff person, although consulting professionals may have an assigned role in some aspects or functions.*

Consequence: *The effect on human well-being, property, the environment, or other things of value; or a combination of these.*

Elements at risk: *Things of value that are put at risk; may include human life, public or private property, recreation site, transportation or utility corridor, domestic water supply, fish habitat, wildlife habitat, visual resource, timber, or other values.*

Forest Development: *Forestry management, existing and proposed, related to planning and operations.*

Hazard: *A source of potential harm, or a situation with a potential for causing harm. With respect to landslide risk management, the landslide is the hazard.*

Likelihood (of landslide occurrence)**:** *Qualitative or quantitative estimate of probability. An estimate of the chance for a landslide to occur.*

Operations: *Physical site work for forest development including construction, maintenance, deactivation and reactivation of forest roads and trails; timber harvesting; and silviculture activities.*

Planning: *Activities involved in preparing plans to carry out operations. These include selection and evaluation of route corridors, preparation of road plans, design of crossing structures or other special designs, identifying harvest areas, layout of cutblock boundaries, and selection of harvesting and silviculture systems or treatments.*

Risk: *The chance of injury or loss, defined as a measure of the probability and the consequence of an adverse effect to things of value.*

Residual Risk: *The risk remaining after all risk control strategies have been applied.***Partial Risk:** *The product of the probability of occurrence of a specific landslide and the probability of that landslide reaching (or affecting) a specific element at risk. The vulnerability of the element is not considered.*

Specific Risk: *The risk of loss or damage to a specific element at risk resulting from a specific hazardous landslide. The vulnerability of the element is estimated and considered.*

Specific Value of Risk: *The worth of loss or damage to a specific element, excluding human life, resulting from a specific hazardous landslide.*

Multiple Risk: *The risk to more than one specific element at risk from a single specific hazardous landslide or the risk to one specific element from more than one hazardous landslide. A multiple risk analysis may be for partial risk or specific risk.*

Incremental Risk: *The risk resulting from proposed forest development above the background existing risk (either natural or development induced).*

Quantitative Risk: The result of an evaluation of risk which provides detailed numerical values for the assessment of the risk.

Qualitative Risk: The result of an evaluation of risk which uses the professionally accepted word descriptors to provide the assessment of the risk (i.e. very low, low, moderate, high and very high)

Site Review: *A preliminary (office and/or field) review by a Terrain Specialist to determine if further investigation or assessment is required.*

Terrain Specialist: *A registered member of the ABCFP or APEGBC with appropriate levels of education, training and experience (skill sets), as defined in professional guidelines, to conduct a terrain stability assessment.*

Terrain Stability Assessment (TSA): *An assessment of landslide hazard, a landslide hazard analysis or a landslide risk analysis for terrain on or adjacent to which operations may be carried out. A TSA may include options or recommendations to manage hazard or risk.*

Terrain Stability Management Model (Model): *A system, process or procedure for the management of terrain stability related to forest development. A Model provides guidance regarding completion of TSAs, managing terrain stability, establishing risk criteria for specified values, selecting forest development strategies, and establishing a decision-making process to analyse and document decisions concerning the management of terrain stability.*

Vulnerability: *The measure of the robustness (or fragility) of an element at risk. It is a (qualitative or quantitative) estimate of either the probability or the proportion of damage or loss.*

4. Legislated Requirements

The *Forest and Range Practices Act* (FRPA) requires protection of the environment, while the *Forest Planning and Practices Regulation* (FPPR) defines damage to the environment (including landslides), and also specifies a limited number of practice requirements related to terrain stability.

Section 46 of the FRPA is relevant to maintaining terrain stability, while the relevant sections of the FPPR are: Section 3 (damage to the environment), Section 37 (landslides), Section 35 (soil disturbance limits), Section 36 (permanent access structure limits), Section 39 (maintenance of natural surface drainage patterns) and Section 40 (re-vegetation of exposed soils).

In all other aspects of terrain stability management, the FRPA relies on the judgement of professionals ('*Professional Reliance*'), including decisions as to whether a TSA is completed. The FRPA also relies on the regulated professions to provide practice guidance to their members.[3] The Model is consistent with terrain stability guidance provided by the ABCFP / APEGBC Joint Practices Board.

5. Terrain Stability Management Model

a) Development and Maintenance of The Model

The Model was developed by the BCTS Kootenay Business Area using a team approach, involving a BCTS task team of forest professionals and a group of experienced Terrain Specialists (Geoscientist, Engineering Geologist, Geomorphologist, and Geotechnical Engineer). The Skeena Business Area has adopted the central elements of the Kootenay TSM Model and ahs reviewed these with experienced Terrain Specialists in the Skeena Region.

It is intended that the Model be reviewed and updated, using a similar team approach, when warranted as a result of new guidelines or research, relevant environmental audit findings, or based on feedback from practitioners involved in forest development planning, assessments and operations. Reviews and updates will be initiated by the Skeena Sustainable Forest Management Committee.

b) Components of The Model

The Model is comprised of the following documents:

1. ***Terrain Stability Management Model*** *(this paper),*
2. ***Terrain Stability Best Management Practices***

3. ***Terrain Stability Assessments Decision & Documentation Tool****; and*

4. ***Terrain Stability Professional Services and Products Quick Guide****.*

c) Terrain Stability Assessments and Documentation

i. Use of Specialists

Terrain-related assessments for BCTS are conducted by Terrain Specialists with appropriate education, training and experience to conduct the work. Individuals' eligibility to bid on BCTS TSA contracts is assessed based on regional eligibility lists maintained by the Ministry of Forests, Lands and Natural Resource Operations.

Other specialists (e.g. Professional Hydrologists, Biologists, Foresters, Engineers, or other Terrain Stability experts) may be employed where a related or more specialized study, valuation of resources, or assessment of vulnerability is considered by the BCTS Coordinating Professional to be warranted, or where recommended by the primary Terrain Specialist.

ii. Terrain Stability Assessments Decision & Documentation Tool (D&D Tool)

The D&D Tool provides guidance as to when and where a TSA should be carried out. All proposed forest development within the Business Area is evaluated using the D&D Tool. The tool determines a preliminary consequence rating for elements potentially at risk from a landslide caused by forest development. It also documents a decision tree process arriving at decisions about whether a terrain-related assessment is required, the type of assessment required, and the forest development decision resulting from the findings.

The identification of elements at risk, preliminary evaluation of consequence, and assessment of site factors can result in a Site Review, which, in turn, may progress to a full TSA. The process can also lead to a decision where no assessment is required. Where a site factor or the risk to an element is discounted by the professional, or where a decision is made to override an indicated assessment, the D&D Tool directs that a written rationale be prepared.

Where a TSA or other terrain-related assessment is commissioned, a copy of the completed D&D Tool is provided to the Terrain Specialist as a part of the work assignment. The Terrain Specialist reviews the identified elements at risk, decision

factors, and supporting/background information and verifies the appropriate elements at risk to consider in the assessment and risk analysis.

The completed D&D Tool is signed, dated, and permanently retained for documentation and due diligence according to the current KBA *Records Management Guidance Document.*

iii. Terrain Stability Professional Services and Products Quick Guide (Quick Guide)

As guidance to BCTS staff regarding professional studies, the Quick Guide provides a summary of the types of specialized services and assessments which may be commissioned, including their recommended application, the level of field investigation involved, information requirements, expected report content and format, and relative costs.

Professional guidance[3] from the ABCFP / APEGBC Joint Practices Board identifies content requirements for a TSA report. The Quick Guide document reiterates these, with some additions.

d) Risk Criteria & Decision Making

(i) Model Basis

As described above, the D&D Tool is a significant component of the Model. It identifies elements at risk and also utilizes known site information (including any known hazards) to guide decision making. The Model, therefore, is a combination of an *elements-at-risk-based* model and a *hazards-based* model. A key aspect is the identification of moderate and high potential consequence ratings for high value elements at risk. Where human safety, residential infrastructure, or major transportation or utility corridors are involved, the D&D Tool directs the user to initiate a field-based Site Review by a Terrain Specialist (regardless of hazards).

TSAs completed for BCTS are required to include a description of the qualitative hazard and risk ratings used and an analysis of partial risk for the proposed forest development. In this regard, the Model is also a *risk-based* model in guiding decision making.

(ii) Partial Risk Analysis

Partial Risk is the product of the probability of occurrence of a specific hazardous landslide and the probability of that landslide reaching or otherwise affecting the site occupied by a specific element. It does not consider the potential consequence to the element. To determine if a considered landslide is a hazard to, and could reach or

otherwise affect the site occupied by, a considered element, spatial and temporal probabilities must be considered.

TSAs completed for BCTS will utilize an equation method for partial risk analysis, expressed mathematically as:

$$P(HA) = P(H) \times P(S:H) \times P(T:S)$$

where;

P(HA) is partial risk; **P** is the probability, **H** is the Hazard and **A** is affecting

P(H) is the probability of a specific hazardous landslide, again **H** is the hazard;

P(S:H) is the probability of a specific hazardous landslide reaching an element; where **S** is spatial and **H** is hazard, and

P(T:S) is the probability of the element being present at the time of the event. **T** is the temporal aspect and **S** is the spatial. If an element is always present (such as a permanent infrastructure) then P(T:S) is equal to 1, whereas if the element is mobile P(T:S) will be less than 1, depending on the proportion of time exposed.

Table 1 below provides qualitative descriptions for the relative likelihood of occurrence ratings for a considered event, and the related approximate quantitative probability ranges. While there is an inherent degree of uncertainty in estimating the probability of a specific landslide, and it is a subjective interpretation that is dependent on numerous factors, these relationships can give some physical meaning to the qualitative terms applied.

Table 1: Qualitative description of the likelihood of occurrence, and related quantitative probability ranges[1]

Likelihood of Occurrence	Qualitative Description	Annual probability of occurrence[4]	Probability of occurrence over a 20 year term
Very High (VH)	An event is imminent or likely to occur frequently; well within the lifetime of a typical forest road[2] or soon after logging[3].	>0.05 (>1/20)	>0.65
High (H)	An event can happen or is probable within the lifetime of a typical forest road[2] or soon after logging[3].	0.01 - 0.05 (1/100 - 1/20)	0.18 - 0.64
Moderate (M)	An event is not likely, but possible within the lifetime of a typical forest road[2] or soon after logging[3].	0.002 - 0.01 (1/500 - 1/100)	0.04 - 0.18
Low (L)	An event is unlikely to occur (remote possibility) within the lifetime of a typical forest road[2] or soon after logging[3].	0.0004 - 0.002 (1/2500 – 1/500)	0.01 - 0.04
Very Low (VL)	The likelihood of an event occurring is extremely remote to nil within the lifetime of a typical forest road[2] or soon after logging[3].	<0.0004 (<1/2500)	<0.01

1) Modified from Wise et al (2004), Table 2, pg 14; and B.C. MoF (2002), Appendix 10.2., and refers to a 1 km segment of road or a specified area of development.
2) Assumes a 20 year+ design life.
3) Time period between logging and establishment of a new-growth forest (generally on the order of 20 to 30 years).
4) Annual probability of occurrence does not consider the design life of the road.

(iii) Specific Risk Analysis

Specific risk analysis assesses the risk of loss or damage to a specific element resulting from a specific hazardous affecting landslide. The consequence to the element is estimated and considered.

Where the value of an element and the potential consequences are high, a decision to proceed to a Specific Risk Analysis is usually warranted. Because specific risk analysis considers consequences, including the vulnerability of the element, involvement by other specialists with expertise related to the element (e.g., a biologist for fish habitat or a utility engineer for a transmission line, etc.) may be required.

Specific risk analysis may be mathematically expressed as any of the following equations:

$$R(S) = P(HA) \times V(L:T)$$

$$R(S) = P(H) \times P(S:H) \times P(T:S) \times V(L:T)$$

$$R(S) = P(H) \times C$$

R(S) **R** is the risk and **S** is the specific item at risk;
P(HA) is again the partial risk, where **P** is the probability , **H** is the hazard and **A** is affecting;
P(H) is the probability of a specific hazardous landslide, again **H** is the hazard;
P(S:H) is the probability of a specific hazardous landslide reaching an element; where **S** is spatial and **H** is hazard;
P(T:S) is the probability of the element being present at the time of the event. **T** is the temporal aspect and **S** is the spatial;
where the additional factors;

V(L:T) is vulnerability; and

C is consequence.

The decision whether to proceed to a specific risk analysis, or specific value of risk analysis, is made by the Coordinating Professional, and documented with the D&D Tool.

e) Forest Development Strategies

(i) Where an Assessment Has Been Completed

Where a terrain-related assessment provides recommendations to manage hazard or risk, BCTS professionals incorporate these into business practices, site plans, contract conditions, road designs, or licence/permit obligations, as appropriate. If alternatives or options are sought, these are reviewed with a Terrain Specialist and confirmed in writing prior to works on the ground.

(ii) General Best Practices

Where forest development planning and operations take place without a terrain-related assessment, management of terrain stability is still an important consideration and good practices related to sound engineering and maintenance of natural drainage patterns are expected. Best practices should be followed in these situations, but they can also augment the standard of performance and reduce risks where TSA recommendations do exist. Examples of general best practices for maintaining terrain stability are provided in the *Skeena Business Area Terrain Stability Best Management Practices* document.

(iii) Communication of Operational Requirements and Conformance

In all cases where the risks and consequences of a terrain stability event are significant, the prescribed measures and recommendations from a TSA (and applicable general best practices, as appropriate) are transferred to the relevant contract as requirements of the contractor or to the licence/permit as obligations of the licensee/permitee. These requirements or obligations are specifically reviewed with LPCs during pre-work meetings and/or field reviews and are monitored during inspections to ensure conformance.

Operational implementation of TSA recommendations and appropriate best practices are important since incremental residual partial risk within professional assessments is based on the assumption that the prescribed measures and practices will be followed.

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