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Risk Management

**Canadian Technical Guidelines and Best Practices related to
Landslides: a national initiative for loss reduction**

D. VanDine

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Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction

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Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction

RISK MANAGEMENT

Note to Reader

This is the fourth in a series of Geological Survey of Canada Open Files that will be published over the next several years. The series forms the basis of the *Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction*. Once all Open Files have been published, they will be compiled into, and published as, a GSC Bulletin. The intent is to have each Open File in the series correspond to a chapter in the Bulletin.

Comments on this Open File, or any of the Open Files in this series should be sent before September 2012 to Dr. R. Couture, Rejean.Couture@NRCan-RNCan.gc.ca

1. INTRODUCTION

In 2009, the International Organization for Standardization (ISO) released a generic guidance document related to risk management (ISO, 2009). The guidance provided is not specific to any country, industry or sector and is intended for use by any public, private or community enterprise, association, group or individual. In 1997, the Canadian Standard Association (CSA) published a generic Canadian standard for risk management (CSA, 1997). This CSA document was used as a basis for a BC Ministry of Forests' document that was specific to landslide risk management (BC MOF, 2004). In 2010, CSA adopted ISO (2009) as the Canadian national standard on risk management (CSA, 2010a), and also published a draft companion guidance document to help implement the new standard (CSA, 2010b). Neither of these documents are specific to landslides.

This Open File draws upon CSA (1997), BC MOF (2004), Australian Geomechanics Society (AGS, 2007), ISO (2009) and CSA (2010a and 2010b) for the discussion on landslide risk management. Because the definitions in CSA (2010a and 2010b) are identical to ISO (2009) the latter document is referenced where required.

Risk is generically defined by ISO (2009, page 1) as an *effect of uncertainty on objectives*. The notes that accompany this definition indicate that:

- *effect* is a deviation from the expected and can be positive and/or negative;
- *uncertainty* is the state of lack of understanding or knowledge of an event, either its likelihood or probability of occurrence and/or its consequence;
- *objectives* can have different aspects such as financial, health and safety, and environmental goals and can apply at different levels such as strategic, organization-wide, or project, product or process-specific; and
- *risk* can be expressed in terms of a combination of the likelihood or probability of occurrence of an event and the associated consequences.

Specific to landslides, risk is typically a measure of the effect of uncertainty, the effect is typically negative or adverse, and the objective is to reduce the adverse effects on assets, typically referred to as elements at risk.

As adapted from CSA (1997), *risk* related to landslides was defined as the *chance of injury or loss as defined as a measure of the probability and consequence of an adverse effect to health, property the environment or other things of value* (BC MOF, 2004). Combining this landslide-

specific definition with the ISO (2009) generic definition, *landslide risk is a measure of the probability and consequence of an adverse effect to human health and safety, property, aspects of the environment and/or financial interests.*

The *risk management process* is defined as the *systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analyzing, evaluating, treating, monitoring and reviewing risk* (ISO, 2009, page 2).

This Open File introduces the ISO (2009) risk management process as adapted to both natural and human-related landslides and engineered slope failures (collectively referred to as landslides), briefly describes some of the terminology involved in the process and describes how the other Open Files in this series relate to the process.

2. RISK MANAGEMENT PROCESS FOR LANDSLIDES

Figure 1 summarizes the landslide risk management process adapted from ISO (2009). The process is depicted as five horizontal single outlined boxes in the centre of the figure, with descriptors specific to landslides. The double outlined boxes indicate that *risk assessment* is a combination of *risk identification*, *risk analysis* and *risk evaluation*. The right hand vertical box, *monitoring and review*, indicates that risk monitoring and review of methodology is a process that should be carried out on an ongoing basis throughout the risk management process. Similarly, the left hand vertical box, *communication and consultation*, indicates that risk communication and consultation with all stakeholders (including the appropriate government agencies) should be carried out on an ongoing basis throughout the process.

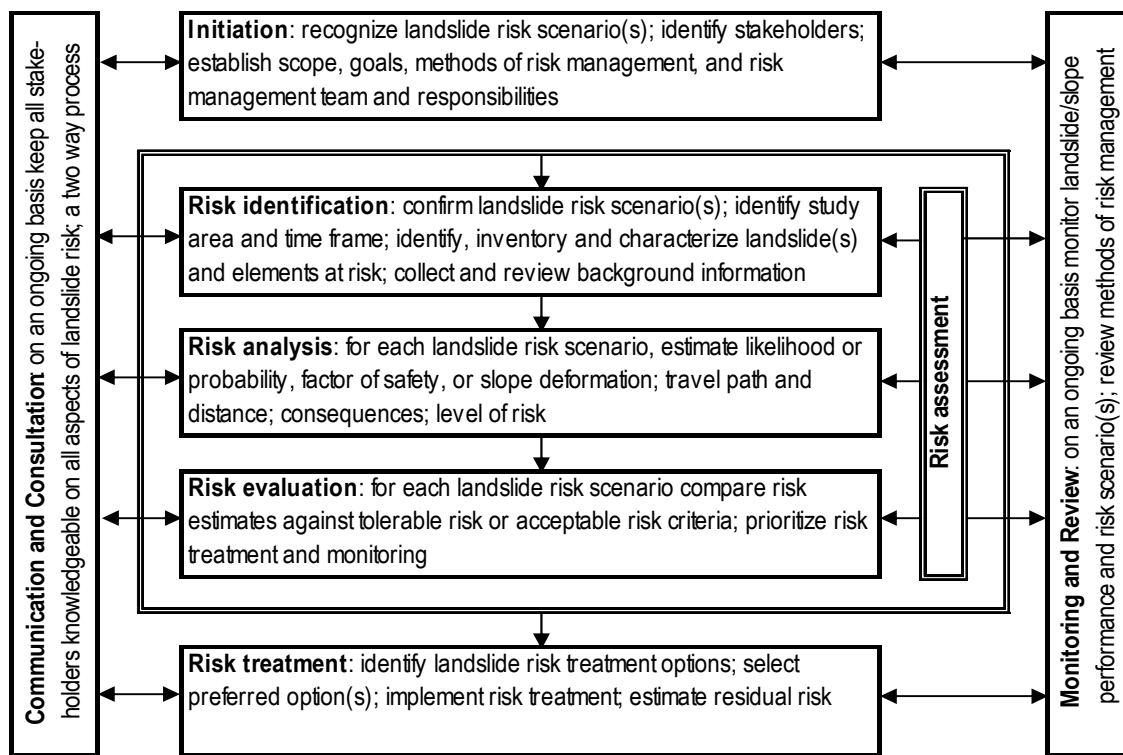


Figure 1: Landslide Risk Management Process. Adapted from (ISO, 2009)

Other important terms in Figure 1 are:

- *stakeholders*: person or organization that can affect, be affected by, or perceive themselves to be affected by a landslide, or by associated decisions or activities (adapted from ISO, 2009); includes appropriate government agencies;
- *elements at risk*: objects or assets such as human health and safety, property, aspects of the environment and/or financial interests that could be adversely affected by a landslide (adapted from BC MOF, 2004)
- *risk scenario*: sequence of events with an associated likelihood or probability of occurrence and consequences (adapted from CSA, 1997);
- *level of risk*: magnitude of risk, expressed in terms of the combination of the likelihood or probability of occurrence of a landslide and the consequences (adapted from ISO, 2009);
- *likelihood or probability of occurrence*: chance of a landslide occurring, whether defined qualitatively or quantitatively; objectively or subjectively, typically likelihood is a qualitative estimate and probability is a quantitative estimate of the chance (adapted from ISO, 2009);
- *consequence*: outcome of a landslide that adversely affects human health and safety, property, aspects of the environmental and/or financial interests; can be expressed qualitatively or quantitatively (adapted from ISO, 2009);
- *risk treatment*: process to modify a risk from a landslide; includes avoidance, changes to the likelihood or probability of occurrence and/or the consequences; also referred to as *risk mitigation*, *risk prevention* and *risk reduction* (adapted from ISO, 2009);
- *residual risk*: risk remaining after risk treatment; includes unidentified risk (adapted from ISO, 2009);
- *acceptable risk*: risk that society is prepared to accept and for which no risk treatment is required (adapted from AGS, 2007); and
- *tolerable risk*: risk within a range that society can live with so as to secure certain net benefits; a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible (adapted from AGS, 2007); this can also be thought of as *risk appetite*: defined as the amount and type of risk that society is prepared to pursue, retain or take (adapted from ISO, 2009).

For other definitions refer to ISO (2009), AGS (2007), BC MOF (2004) and (Couture, 2011)¹

The risk management process may be similar for most landslide projects, but the level of effort involved in the process for a particular project should be tailored to the level of risk(s) involved, considering both the likelihood or probability of occurrence of the landslide and the consequences of the landslide.

3. STEPS IN THE RISK MANAGEMENT PROCESS

This section briefly describes each of the steps in the risk management process, each relating to an outlined box in Figure 1. These steps are described more fully in other Open Files in this series, as referenced in Section 4, below.

For a description of the risk management process as related to landslides specific to forest development planning and operations, refer to BC MOF (2004), particularly Chapters 2 and 3. Chapter 4 of that publication presents eight different examples of the landslide risk management

¹ *Terminology*, Open File 6824 in the series *Canadian Technical Guidelines and Best Practices related to Landslides* (Couture, 2011)

process applied to forest development planning and operations. Similar techniques used in those examples can be adapted to the landslide risk management process in any industry and sector.

3.1 Initiation

Initiation: recognize landslide risk scenario(s); identify stakeholders; establish scope, goals, methods of risk management, and risk management team and responsibilities

The *initiation* step of the landslide risk management process follows the recognition that a landslide has occurred, or could occur, and that human health and safety, aspects of the environment and/or financial interests have been, or could be, affected. The recognition of landslide risk scenarios can result from a wide variety of circumstances such as: the occurrence of a landslide; a proposed development of some type; general land use planning; an environmental or geological survey, inventory or review; or just happenstance.

The landslide risk management process and the ensuing project can be initiated by a wide variety of individuals or organizations that are typically, but not necessarily, stakeholders. During this *initiation* step, all stakeholders should be identified, and the scope, goals and methods of managing the landslide risks should be established. Note that the project can have multiple goals and the scope and methods of managing the landslide risks can be different for each goal.

The knowledge and experience of stakeholders who select and retain landslide professionals for any given risk management project can vary. Stakeholders should involve only qualified landslide professionals in a landslide risk management project. That requires stakeholders to identify the required training, experience and specialization of landslide professionals, considering the type of landslide or potential landslide, the geology and terrain conditions of the affected area, the complexity of the site, the relative scale of consequences, and the level of tolerable risk and/or acceptable risk². At this *initiation* step, responsibilities for all aspects of the risk management process should be assigned to, or among, the landslide professionals. It is important for landslide professionals to initiate ongoing risk monitoring and review of methodology with the team and stakeholders, and similarly to initiate ongoing communication and consultation with the team and stakeholders, including the appropriate government agencies.

3.2 Risk Identification

Risk identification: confirm landslide risk scenario(s); identify study area and time frame; identify, inventory and characterize landslide(s) and elements at risk; collect and review background information

The *risk identification* step of the landslide risk management process initially confirms the landslide risk scenarios recognized in the *initiation* step. If qualified landslide professionals were not involved in the *initiation* step, they must begin their involvement with the *risk identification* step.

Landslide professionals should fully identify the area and time frame of the landslide or potential landslide, and the areas both directly and indirectly affected or potentially affected by the landslide. If more than one landslide is involved, all landslides should be similarly identified and addressed. All elements at risk should be similarly identified.

During this step all background information should be collected and reviewed. Background information should include a review of landslides with similar characteristics in the general area.

² Refer to *Professional Practice and Insurance Issues*, Open File 6981 in the series *Canadian Technical Guidelines and Best Practices related to Landslides* (VanDine, 2011)

As an early result of the *risk identification* step, the scope of further study can be better defined. It is possible that during this step a decision can be made that no further study is warranted.

If further study is warranted, the landslide should be mapped and technically described, both using collected background information and data collected from surface and subsurface field studies. The type, size and character of the landslide should be described. Cause and trigger mechanisms should be investigated.

Similarly all elements at risk should be identified, inventoried and fully described. A complete description of an element at risk can include spatial probability (the probability of the landslide affecting the site that is occupied by the element at risk), temporal probability (the probability that the element at risk is at the site when the site is affected by the landslide), and vulnerability of the element at risk. Vulnerability can be either the robustness or fragility of the element at risk, and its exposure to, or protection from, the landslide, or the probability or degree of loss of the element at risk.

3.3 Risk Analysis

Risk analysis: for each landslide risk scenario, estimate likelihood or probability, factor of safety, or slope deformation; travel path and distance; consequences; level of risk

During the *risk analysis* step of the landslide risk management process, estimates are made to determine the level of risk from the landslide, or from each landslide if there are multiple landslides.

Hazard analysis involves either estimating factors such as the likelihood or probability of occurrence of the landslide, the factor of safety of the slope, or the slope deformation, and combining the results with the potential travel path and travel distance of the landslide. Which method of hazard analysis is used depends on the failure mode, material type, availability and quality of appropriate information and where the elements at risk are located relative to the slope. When an estimate of the hazard is combined with an estimate of the consequences, the result is a risk analysis. For some situations, a hazard analysis is sufficient.

Estimations of hazard and/or risk can be either qualitative or quantitative, and can use either objective probability or subjective probability. Qualitative vs quantitative and objective probability vs subjective probability, as related to landslide risk analysis, are further discussed in BC MOF (2004: Chapter 3).

Risk can be estimated in a number of ways including, but not limited to, risk matrices, event trees, and quantitative risk analysis (QRA). An example of a QRA method is the F-N (frequency-number of fatalities) plot.

Which method(s) of hazard and risk analyses are used depends upon a number of factors that include the type of landslide and elements at risk, the purpose and scope of the analysis, the availability, quality and reliability of the required information, and the tolerable risk and/or acceptable risk criteria that is available and/or appropriate.

3.4 Risk Evaluation

Risk evaluation: for each landslide risk scenario compare risk estimates against tolerable risk or acceptable risk criteria; prioritize risk treatment and monitoring
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Once the landslide and the elements at risk have been described and, to the extent possible, understood (*risk identification*) and analysed (*risk analysis*), the estimated hazard or risk can be

compared to established tolerable risk or acceptable risk criteria. This is the *risk evaluation* step in the risk management process.

One relatively major difficulty in the *risk evaluation* step is that there are very few established landslide tolerable risk or acceptable risk criteria in Canada. There is no national criteria. BC is the province that is furthest advanced in this area, although there is no province-wide criteria.

Tolerable risk or acceptable risk criteria, including those for landslides, should consider a wide range of socio-economic values, such as human life, damage to and anticipated replacement costs of property, assets and the environment, and indirect economic and social costs. It is not the role of landslide professionals to establish such criteria. The criteria should be established or selected by owners and/or local, regional, provincial and/or national governments, in consultation with or assisted by landslide professionals. These various organizations can much better consider the appropriate socio-economic values.

The *risk evaluation* step also includes prioritizing risk treatment and the monitoring of the landslide(s) or potential landslide(s) involved.

3.5 Risk Assessment

Risk assessment: combination of risk identification, risk analysis and risk evaluation

Risk assessment is a combination of the previous three steps, *risk identification*, *risk analysis* and *risk evaluation*. It is implied that *risk assessment* and *risk treatment* (the following step) are reiterative.

3.6 Risk Treatment

Risk treatment: identify landslide risk treatment options; select preferred option(s); implement risk treatment; estimate residual risk
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The *risk treatment* step of the risk management process involves identifying a range of risk possible treatment options. Such options should consider reducing the landslide hazard (reducing the likelihood or probability of occurrence, increasing the factor of safety, or reducing the slope deformation), modifying the travel path or travel distance, or modifying the elements at risk by modifying the spatial probability, temporal probability and/or vulnerability. In certain circumstances doing nothing can be considered an option.

Risk treatment can either be active (requires some engineering design to prevent, reduce or eliminate the hazard, or to design protection for the element at risk), passive (requires no engineering design; methods such as avoidance, land use regulations, education and warning systems), or some combination of both active and passive treatments.

As part of this step, the residual risk that would remain after implementing each of the possible risk treatment options should also be considered.

After a range of risk treatment options has been identified and considered, and possibly narrowed down, they should be presented to the stakeholders with appropriate cost estimates and estimates of residual risk for the stakeholders' input with respect to the broader socio-economic implications.

The preferred option(s) should then be selected and implemented.

3.7 Monitoring and Review

Monitoring and Review: on an ongoing basis monitor landslide/slope performance and risk scenario(s); review methods of risk management

Monitoring and review should be carried out on an ongoing basis throughout the entire risk management process. The landslide or potential landslide and associated risks should be continually monitored, at least to some extent. Similarly, the methods used throughout the management process should be continually monitored to ensure that they are appropriate to the landslide and the elements at risk.

3.8 Communication and Consultation

Communication and Consultation: on an ongoing basis keep all stakeholders knowledgeable on all aspects of landslide risk; a two way process

Communication and consultation should also be carried out on an ongoing basis throughout the entire risk management process. This step refers to both landslide professionals keeping stakeholders informed as to the landslide, associated risks and the study being carried out, and the stakeholders keeping the landslide professionals informed as to any and all concerns that they have with respect to the landslide, associated risks and the study being carried out. It is useful to establish a communication and consultation protocol between the two groups, so that information is transferred in an efficient and effective manner.

If there are no established tolerable risk or acceptable risk criteria in the jurisdiction of the landslide, the landslide professionals should consult with and assist the owners and/or the appropriate government agency to establish such criteria, at least for the project at hand.

4. RISK MANAGEMENT PROCESS RELATED TO OTHER OPEN FILES IN THIS SERIES

The technical aspects of the various steps of the risk management process, following the initiation step, are developed more fully throughout portions of other Open Files in this series, as summarized in Table 1, below.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Australian Geomechanics Society (AGS), 2007. Guideline for landslide susceptibility, hazard and risk zoning for land use management; Australian Geomechanics, v. 42, no. 1, p. 13-36.

- BC Ministry of Forests (BC MOF), 2004. Landslide risk case studies in forest development planning and operations. (ed.) Wise, M.P., Moore, G.D. and VanDine, D.F.; Land Management Handbook no. 56, 119 p.
- Canadian Standard Association (CSA), 1997. Risk management: Guidelines for decision-makers, a national standard of Canada; CAN/CSAQ850-97, 46 p.
- Canadian Standard Association (CSA), 2010a. Risk management – principles and guidelines, National Standard of Canada; CAN/CSAISO 31000-10, 24 p.
- Canadian Standard Association (CSA), 2010b. Draft Standard CAN/CSA Q850, Implementation of CAN/CSA-ISO 31000, 2nd Edition of CSA Standard; CAN/CSA Q850-10, 37 p.
- Couture, R., 2011. Terminology - Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction; Geological Survey of Canada, Open File 6824, 12 p.
- International Organization for Standardization (ISO), 2009. Risk management – principles and guidelines; ISO 31000, 24 p.
- VanDine, D., 2011. Professional Practice - Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction; Geological Survey of Canada, Open File 6981, 13 p.

Table 1: Relation between the steps in the risk management process and other Open Files in this series *Canadian Technical Guidelines and Best Practices related to Landslides*.

Steps in the Risk Management Process	Title* or Tentative Title of Open File	Comments
Initiation	-Risk Management*	-initiation of the risk management process -this Open File, Section 3.1
Risk identification	-Identification and Mapping	-identification -regional and site mapping of landslides
Risk analysis	-Site Investigation, Analysis, Monitoring and Treatment	-office and field investigations -laboratory testing -various methods of landslide analysis -modeling, including runout
Risk evaluation Risk assessment	-Risk Evaluation & Communication -Identification and Mapping -Site Investigation, Analysis, Monitoring and Treatment -Risk Evaluation & Communication	-general principles; risk tolerance criteria -combination of risk identification, risk analysis and risk evaluation, described above
Risk treatment	-Site Investigation, Analysis, Monitoring and Treatment	-mitigation and remediation -design constraints and planning -passive and active methods -emergency response
Monitoring & Review	-Site Investigation, Analysis, Monitoring and Treatment	-monitoring
Communication & Consultation	-Risk Evaluation & Communication	-communication and consultation