Wet Weather Shutdown Criteria Harmonization

BCTS Seaward-tlasta, Chinook, and Strait of Georgia Business Areas

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EXECUTIVE SUMMARY

In 2018, BC Timber Sales' Chinook and Strait of Georgia Business Areas harmonized their procedures to determine whether or not environmental conditions warrant the shutdown of forestry work by their staff, licensees, and contractors. In 2021, the Seaward-tlasta Business Area proposed to adopt the same guidelines.

This document consists of two components. The first is a detailed review of the previous procedures and of comparable procedures used by other units of BC Timber Sales and other licensees in the same geographic area, and a review of the relevant literature related to environmental shutdown procedures in southwestern British Columbia. The second component follows from the first and is a recommended shutdown procedure that updates, harmonizes, and streamlines the existing guidelines.

The second component has also been made into a stand-alone document circulated to contractors and licensees for their use in determining whether environmental conditions warrant shut down.

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1.0 INTRODUCTION

BC Timber Sales' (BCTS) Chinook (TCH) and Strait of Georgia (TSG) Business Units, acting together, retained Statlu Environmental Consulting Ltd. (Statlu) to recommend measures to harmonize their environmental shutdown criteria for forestry operations. The two business units currently use different criteria to determine whether forestry operations should shut down during wet and potentially hazardous weather. The criteria were developed at different times using differing rationales and methodology. A harmonized set of guidelines that provide consistent direction for BCTS staff and contractors as to whether forest operations should proceed or shut down in wet weather will increase safety and ease implementation across the combined business area.

2.0 THEORY OF ENVIRONMENTAL SHUTDOWN CRITERIA

Hazardous geotechnical processes are more likely to occur under some environmental conditions than others. Specifically, many mass movement processes, such as landslides and debris flows, occur when the ground is unusually wet because increased pore water pressure in surficial materials and fractured bedrock decreases cohesive forces, which increase slope instability. In Coastal British Columbia, decreased terrain stability most commonly occurs during or immediately after storms with intense precipitation or rain-on-snow precipitation that are sometimes accompanied by high winds.

Environmental shutdown criteria are determined by defining conditions that are likely to result in mass movements. Typically, the criteria use the amount of precipitation over a period of time to set thresholds. When there is more precipitation than the threshold, field work is shut down, limiting worker exposure to precipitation-driven terrain hazards.

Climatic variation makes it difficult to define unusually wet conditions. A storm that is large enough to be significant and to cause landslides in dry parts of the province is neither unusual nor significant in wetter regions because landscapes adapt to the prevailing environmental conditions. Regions which are characteristically wetter, such as the west coasts of Vancouver Island and Haida Gwaii, require more precipitation than drier inland or sheltered areas, such as Pemberton or Boston Bar, to trigger landslides.

A number of other factors complicate the issue and make it difficult to define simple, broadly applicable criteria for environmental shutdown. In addition to the climatic factors already identified, antecedent moisture conditions, the nature of surficial materials and bedrock present, the contribution to ground moisture from snowmelt and rainfall, the spatial variability of precipitation at different scales, the varying intensity of precipitation, and the varying timing of response of shallow and deep groundwater to climatic forcing all contribute to the likelihood of mass movement. Of these factors, antecedent moisture conditions are perhaps the hardest to adequately account for. Finally, climate stations in British Columbia are scattered in space and have discontinuous temporal records. They are usually located in low elevation valley bottoms and mostly absent from high elevation mountainous locales. Models and inferences must be used to refine uncertain estimates, especially in areas without measured climate values.

Environmental shutdown criteria are intended to reduce the risk to workers from unstable terrain. The mass movement events themselves do not create the risk, the potential exposure of workers and equipment to them do. If shutdown criteria are too stringent, work will be needlessly shut down, incurring an economic cost, and possibly making workers and managers less likely to follow shutdown procedures in future. Conversely, if shutdown criteria are too lenient workers, vehicles, and equipment will be at placed at unacceptable risk of injury or death, and damage or destruction respectively.

3.0 REVIEW OF RELEVANT RESEARCH AND APPLICATION

There has been considerable interest in using environmental shutdown criteria to manage risk, both in British Columbia, and internationally. Caine (1980) was one of the first to propose a simple criterion in the form of an equation relating intensity and duration of rainfall. Caine's proposed equation indicated that approximately 100 mm of rain over 24 hours was likely to cause landsliding or debris flows. The relationship was based on a wide range of climates and terrains, and consequently there was scatter in the data points from which the equation was derived. Church and Miles (1987) examined thresholds for debris flow initiation in British Columbia and found that, due to the unrepresentative nature of the climate station network, a threshold value of 50 mm of rainfall in 24 hours measured at a climate station was a predictor of landslides and debris flows in nearby mountainous terrain. Slaymaker (1990) criticized Caine's 100 mm/24 h value as being insensitive to climatic differences, as well as runoff generation mechanisms, and called for the development of different thresholds for different parts of BC. Howes (1987) noted that for the southern Coast Mountains near Norrish Creek, estimated one-day and three-day precipitation totals for storms with an approximate one-in-ten year return period were respectively 93 and 123 mm, and that it was storms of approximately this frequency that typically triggered extensive landsliding and debris flows. This was an important early acknowledgement that storm frequency (return period) might be a better predictor of instability than storm magnitude (precipitation total). Crozier (1999) was one of the first to rigorously monitor and model antecedent moisture conditions and incorporate them into a 24-hour forecast model for landslide occurrence.

Chatterton (1984) was an early developer of rainfall shutdown thresholds for specific regions of BC, in this case Vancouver Island and the South Coast region. He used two zones, designating them as the "dry zone" and "wet zone", with shutdown values of 55 mm/24 h for the dry zone and 100 mm/24 h for the wet zone. These criteria were adopted by the BC Ministry of Forests in 1994.

Jakob and Weatherly (2003) developed a set of shutdown criteria for the District of North Vancouver that combined 4-week rainfall prior to a storm, 6-hour rainfall intensity during a storm, and reference to nearby stream gauges to identify two levels of landslide hazard. The first level is a warning threshold (landslides may occur – warnings are issued and personnel moved out of hazardous areas), while the second is a shutdown threshold. Jakob et al. (2006), building on earlier work by Hogan and Schwab (1991) and White and Schwab (2005) continued this analysis trend by developing shutdown criteria for forestry operations on the North Coast that incorporated wind speed, wind direction, differential air pressure at two elevations, and air temperature at elevation, as well as four-week antecedent precipitation and 24-hour rainfall intensity, to define low, moderate, and high levels of landslide hazard. Low and moderate hazards correspond to local hazard shutdowns being possible and evaluated by on-site operators, while high hazards entail region-wide shutdowns.

Guthrie and Evans (2004) and Guthrie (2010) considered individual large storms that caused landslides on the mid-Coast (in 2001) and southern Vancouver Island (in 2006) respectively. Both studies found that local-scale effects (small storm cells, slope aspect, and wind direction) played an important role in landslide initiation. The 2001 storm caused several significant clusters of landslides although overall precipitation recorded at nearby gauges was less than 50 mm/24 h. The 2006 storm had a wide range of precipitation intensities across Vancouver Island, and most landslides occurred when between 80 mm and 140 mm of total rainfall had fallen. Landslides did occur at a few locations when only about 50 mm to 75 mm of rain occurred, but landslides occurring at less than 80 mm of rainfall together comprised only 12% of the total number of landslides.

Sutton (2011) examined 27 years of debris flows in the Fraser Valley over a wide range of antecedent moisture conditions. She found that although high-intensity rainfall (>50 mm/24 hr) and seasonality of precipitation were the most significant variables in predicting debris flow initiation, overall predictive power of her model was low because of complex confounding factors including land use and sediment supply. Rain-on-snow precipitation events produced more debris flows than did pure rainfall-driven events.

4.0 PREVIOUS TCH AND TSG ENVIRONMENTAL SHUTDOWN CRITERIA

The previous shutdown criteria used by the Chinook Business Area (TCH) and Strait of Georgia Business Area (TSG) are summarized below (Table 1). The TCH shutdown criteria were developed by Tom Millard, P. Geo. of the BC Ministry of Forests and Range in 2010. The TCH guidelines define four zones. Three of the zones were climate-based (very wet zone, wet zone, and dry zone) while the fourth zone was a site-specific case for areas where old, undeactivated, unstable road networks are located upslope of a work area. Shutdown criteria were presented for half-day (i.e. 12 hours to start of shift or shift end), 24-hour, 48-hour, and 72-hour intervals for each zone. Modifiers were presented to account for the effective precipitation derived from snowmelt for windy and sunny conditions, based on temperature and wind speed. After work is shut down, it remained shut down for a minimum of 24 hours, and could continue to be shut down for longer if ongoing precipitation inputs remained above the threshold criteria. No explicit assumptions concerning soil drainage rates were made.

The TSG shutdown criteria were developed by R.W. Askin, P. Eng., P. Geo. of Integrated Watersheds Ltd. in 2006. There were five zones based on mean annual precipitation, each with a different 24-hour rainfall intensity shutdown threshold. The zone-based threshold values were modified by surficial material type and slope steepness of local work areas to arrive at a specific shutdown threshold for a specific work site. Return to work after a shutdown depended on the slope position of the work site, with different elevations on the slope assumed to drain at different rates. Once total precipitation had been modified by drainage over time to be below shutdown threshold, work could recommence. Therefore, this method used precipitation to guide shutdown but water balance to guide resumption of work.

In both cases, whether to shut down or not was determined locally (on or near the work site) based on readings of an on-site precipitation gauge or gauges. No additional information (such as weather forecasts, stream gauges, or measured conditions at locations other than the work site) was used, although the TCH guidelines noted that using a base station and weather forecasts can help avoid having to travel to the site during shut down to determine if conditions are safe to restart.

Table 1: Comparison of 24-Hour Precipitation Shutdown Thresholds by Zone, Present TCH and TSG Guidelines

TCH Zone	Unmodified[1] Shutdown Threshold (mm)	TSG Zone	Unmodified[2] Shutdown Threshold (mm)
Very Wet (>2500 mm/yr)	100	>3500 mm/yr	90
		>3000 mm/yr	75
		>2500 mm/yr	60
Wet (1500-2500 mm/yr)	80	>1500 mm/yr	40
Dry (<1500 mm/yr)	50	>750 mm/yr	20

4.1 Other Relevant BC Timber Sales Operating Areas

For comparison purposes, I also evaluated BC Timber Sales' current Seaward-tlasta (TST) and Skeena (TSK) shutdown criteria. I did not want to directly compare their shutdown criteria thresholds to the TCH/TSK criteria, because the climate and local hydrology differ, but rather to compare and contrast their underlying methodology. The TST shutdown criteria are based on a water balance value, rather than a rainfall value, and are modified by estimates of rain-on-snow and snowmelt. The water balance is computed on a day-by-day basis based on total precipitation and snowmelt over the previous 24 hours modified by a single soil drainage rate of 50 mm/day. Work is shut down whenever the daily water balance exceeds 80 mm and resumes whenever the water balance drops below 80 mm.

The TSK criteria are the simplest of those I reviewed. The Skeena Business Unit is divided into three climate zones. Shutdown criteria are based on 24-hour precipitation, with values of 100 mm, 75 mm, and 50 mm respectively (from wettest zone to driest zone) resulting in

[1] If unstable upslope roads are present, the 24-hour shutdown threshold is 20 mm, regardless of zone.

[2] Slope gradient and surficial material type modify the listed threshold. The modified threshold may range from a high of 100% to a low of only 28% of the unmodified value.

shutdown. Operations may resume one day after shutdown conditions cease. There are no modifiers for snowmelt, slope position, soil drainage, or other factors.

4.2 Other Forest Licensee Shutdown Criteria

Rainfall shutdown criteria have not been standardized across BC, let alone in the Coastal region. WorkSafeBC prescribes that certain forestry operations, such as cable yarding of steep slopes, must have shutdown procedures in place, but does not specify the criteria for such shutdown. Currently, each forest licensee or contractor can use their own set of criteria, as long as such criteria are documented, are developed by a qualified professional using due diligence, and are provided to workers to guide shutdown of operations. For instance, Island Timberlands, a private forest land owner, has developed a Terrain Management Code of Practice that includes terrain vulnerability maps with defined regional rainfall criteria to guide operational shutdown (Higman and Horel, 2006).

In some cases, especially with smaller licensees, shutdown criteria developed for one area may later be reused in another area for which the developed criteria are inappropriate. Qualified professionals should always be consulted to determine if existing shutdown procedures are appropriate before the existing procedures are applied to new work areas, unless the existing procedures explicitly define the area(s) in which they should be applied.

4.3 Other Shutdown Criteria

Shutdown criteria are also used in other resource industries, and not just in the forest industry. Some of these contain detailed prescriptions for site-specific conditions. For instance, Pierre Friele, P. Geo of Cordilleran Geoscience (2012) developed shutdown criteria for the Upper Lillooet River run-of-river hydroelectric project that included specific shutdown criteria based on air temperature, because of the local hazard of very large landslides from the Mt Meager Volcanic Complex caused by glacial melt. Cordilleran (2013) has also provided recommendations to MoFLNRO's Squamish office for shut down criteria for users of the Squamish River FSR that incorporate air temperature, in this case because of frequent debris flows from the Mount Cayley volcanic complex.

4.4 Effectiveness of Existing Shutdown Criteria

There is evident variation in the nature of shutdown criteria applied across Coastal BC. Some sets of criteria are complex while others are simpler. Some account for factors such as wind speed and snow melt while others do not. For the same geographic area, two separate licensees may have two separate sets of shutdown criteria which use different methods and result in differing thresholds to determine if and when work should shut down, resulting in different acceptance of risk by workers.

Deaths or injuries due to landslides or debris flows are relatively rare events within the forest industry. Only one such event has occurred in the past decade in the TCH/TSG region, when a logging truck driver was killed by a debris flow in Emory Creek in November 2015. Case studies of such events can determine whether the shutdown criteria that were in place were followed or not, but the total number of events is too small to permit a statistically significant analysis of the comparative effectiveness of different shutdown criteria. Therefore, the design and implementation of new shutdown criteria cannot be entirely evidence-based, because the existing evidence is inadequate; they must incorporate professional knowledge and experience, as well as discussions of acceptable risk levels.

There are two measures of effectiveness (Table 2). When no shutdown is recommended and landslides do not happen, and when shutdown is recommended and landslides happen, the shutdown guidelines are functioning as designed. The possibility of landslides occurring when shutdown is not recommended, as discussed above, is an obvious potential failure of the shutdown guidelines, but occurs too rarely to be successfully analyzed statistically to determine the comparative effectiveness of different shutdown thresholds.

Table 2: Success and Failure Matrix for Shutdown Guidelines

Shutdown Recommended?	Landslides Happen?	
	Yes	No
Yes	Success	Failure
No	Failure	Success

The last case to be considered is the failure of shutdown guidelines that happens when shutdown is recommended but no landslides occur. This incurs an economic cost that must be balanced against the decrease in safety incurred by less conservative shutdown guidelines. Although the sample size for deaths, injuries, and damage to equipment caused by lenient shutdown criteria is very small and thus difficult to analyze, it is relatively easy to evaluate the potential relative and absolute cost of any recommended shutdown criterion by comparing it to (measured or modelled) rainfall intensity and determining the return period of the shutdown criterion, i.e. a shutdown criterion that results in work being stopped, on average, for four days per year will be twice as expensive as one that results in work being shut down for only two days per year on average.

5.0 FEEDBACK ON PREVIOUS SHUTDOWN CRITERIA

BCTS staff from both TCH and TSG reported that the then-existing procedures worked, in that shutdown were not felt to idle workers too frequently, nor were workers exposed to unacceptable risk by criteria that indicate work should proceed when conditions are notably unsafe. They reported that clients and contractors sometimes found the calculations required to determine if shutting down operations was necessary, or if restart of operations was recommended, to be complex and require interpretation. Hence, a revised procedure using simpler calculations, with the potential to be developed into an app-based option for use on phones or tablets, was desirable.

The current system of using rainfall gauges at the work site provides accurate estimates of local precipitation, but BCTS staff suggested that advances and improvements in climate measurement, such as the new network of BC Wildfire Branch meteorological stations, might be able to improve on local-gauge-only calculations.

It is important to distinguish between environmental shutdown criteria designed for worker safety and environmental shutdown criteria designed for environmental management. From discussion with BCTS staff, shutdown criteria intended to manage worker safety have sometimes been used to manage for other values in the absence of more specific criteria. Typically, shutdown criteria designed to manage environmental values, such as to protect water quality in community watersheds, are much more stringent than criteria designed to protect worker safety, because safe work is still possible under environmental conditions where water quality may be adversely affected. Shutdown criteria for worker safety may be defined broadly (by climatic region) whereas shutdown criteria for environmental values would typically be best defined locally, depending on the environmental value(s) to be managed, through means such as watershed assessments or terrain stability and sedimentation hazard assessments.

6.0 RECOMMENDED HARMONIZED SHUTDOWN CRITERIA FOR TCH, TSG, AND TST BUSINESS AREAS

The combined TCH, TSG, and TST business areas are very large, covering all of the BC South Coast from Boston Bar to the west coast of Vancouver Island, northern Vancouver Island and the mid-Coast, and Haida Gwaii. Accordingly, the harmonized criteria must be capable of predicting when shutdown of operations is warranted over a wide range of environmental conditions from dry to wet, and over a similarly wide range of surficial geologies, flood generation processes, timings of runoff, and past histories of disturbance.

6.1 When to Use Shutdown Criteria

Workers are exposed to geotechnical hazards not only at the work site but also along access routes that reach the work site. Accordingly, shutdown criteria must apply to not only work sites such as cutblocks and roads under construction, but also roads used for access to and from these work sites.

Environment Canada provides forecasts and measurements of rainfall of varying accuracy for all of the areas of the TSG, TCH, and TST business areas. Where forecasts and measurements do not accurately reflect conditions at the work site, they typically underestimate, rather than overestimate, actual rainfall. Therefore, workers should check forecasts and reported rainfall totals before travelling to the work site. If predicted or recorded rainfall for the day exceeds the listed shutdown thresholds, it is likely unsafe to travel to the work site, and there is no need to expose workers to hazards while checking the rain gauge at the work site.

Otherwise, shutdown criteria should apply when work sites or access routes are located on, downslope of, or exposed to landslide-prone terrain. "Landslide-prone terrain" includes, but is not limited to:

- areas with greater than 60% slope gradients (greater than 50% on Haida Gwaii),
- areas mapped as unstable or potentially unstable (U or P) on reconnaissance terrain stability mapping,
- areas mapped as Class III, IV, IVR, or V on detailed terrain stability mapping,
- areas identified as being subject to slope instability or where landslides would deposit in terrain stability field assessments,
- gullies or alluvial fans,
- areas where past instability has occurred.

Exceptions may be made where the nearest landslide-prone terrain is more than 300 m upslope of the work site or access route and the intervening terrain is low-gradient (i.e., with slope gradients of 30% or less throughout).

6.2 Basic Shutdown Criteria By Zone

Table 3 provides the recommended shutdown criteria based on rainfall for five climatic zones plus one "identified unstable conditions" zone, over four time intervals, combining the previously used TSG and TCH methods. Climatic zones may be determined from maps showing the distribution of average annual precipitation or can be determined easily for a specific location from an online climate model such as ClimateBC (Wang et al, 2016). It is relatively simple for foresters, geoscientists, or BCTS staff to use such models and specify the annual precipitation in a terrain report or project particulars for a proposed cutblock or road and thus to identify the appropriate zone for workers to use when evaluating shutdown criteria.

Table 3: Proposed Shutdown Criteria by Zone, Harmonized TSG, TCH, and TST Business Areas

		Time Period			
Zone	**Zone (annual precipitation)**	At start of or before end of shift (12-hr)	24-hr	48-hr	72-hr
1	Very wet (3000 mm to 4000 mm or more)	60 mm	100 mm	150 mm	200 mm
2	Wet (2500 mm to 3000 mm)	50 mm	80 mm	120 mm	160 mm
3	Average (1500 mm to 2500 mm)	40 mm	70 mm	100 mm	130 mm
4	Dry (750 mm to 1500 mm)	30 mm	50 mm	80 mm	110 mm
5	Very dry (less than 750 mm)	20 mm	30 mm	50 mm	80 mm
6	Identified Unstable Conditions	10 mm	20 mm	30 mm	40 mm

Table 3 assumes that rainfall will be measured in a gauge at the work site. It is expected that in some forestry settings, there may be a considerable elevation range between the elevation of the rainfall gauge and the highest elevation at which work is taking place, and that more rainfall may occur at higher elevations than is measured at the gauge; the shutdown criteria incorporate this assumption.

"Identified unstable conditions" refers to conditions where a qualified professional has identified and documented conditions at or upslope of the work site which require special precautions for safe work beyond those which are normally applicable. Identified unstable conditions can occur in any precipitation zone. This category might be used, for instance, to guide operations when attempting to determine if it is safe to rebuild a road across the deposit of a recent landslide. Examples of items from terrain stability field assessment reports that might indicate "identified unstable conditions" include old, undeactivated roads with tension cracks and drainage diversions upslope of a work site, landslide scars upslope of a work site, roads which cross gullies identified as experiencing debris flows, or terrain identified as having high or very high terrain stability hazard upslope of a work site.

6.3 Modifiers to Shutdown Criteria

Numerous factors other than direct rainfall can contribute to slope instability, including snow melt (either from rain-on-snow precipitation, high temperatures, or both), high winds, blocked drainage structures or diverted drainage upslope, long-term antecedent precipitation, earthquakes, and other less probable events. Unlike rainfall, these factors can be difficult for on-site workers to measure accurately; snow accumulation and snow melt are both more spatially variable than rainfall, and other factors like wind speed are even less amenable to simple measurement by workers. The variability of these factors with elevation can also be greater than the variability of rainfall with elevation.

To account for these factors without requiring multiple difficult and potentially inaccurate calculations, a simpler system is proposed. Potential additional risk factors beyond simple rainfall totals are listed below. The presence of one or more of these additional risk factors cause the zone number used to determine the shutdown criteria to change. Each risk factor present shifts the zone number up by one. For instance, a project is located in Zone 2 which has a 24-hr threshold of 80 mm. A storm brings 60 mm of rainfall in 24 hours, accompanied by warm temperatures with snow present (one factor) and rain-on-snow (one factor). Zone 2 is therefore shifted to Zone 4: 60 mm of rainfall is greater than the Zone 4 24-hr shutdown value of 50 mm, so work shuts down.

The additional risk factors beyond rainfall totals are:

- Rain falling on snow at the job site;
- Warm temperatures (greater than 5 °C at the gauge) with snow present on the ground at the job site;

For these two conditions, any snow, even small amounts of patchy snow, at the job site is counted as snow. Small amounts of snow at a job site indicate larger amounts of snow upslope.

- High winds (windspeed reported or predicted >60 km/h, or visibly breaking branches, or causing windthrow) at job site;
- Very wet conditions (defined as any period of 21 days or longer with precipitation recorded on every day). Periods longer than 21 days do not increase the very wet conditions hazard further;
- Visibly high stream flow (ditches full and overflowing onto roads, culverts discharging at capacity, culverts blocked by debris flow and diverting water to adjacent streams, floodwater present on adjacent highways, etc.)
- Earthquakes of magnitude 5.0 or greater within last week, reported with epicenter within 50 km of job site.

If the presence of additional risk factors increases the zone beyond Zone 6, i.e. beyond the "identified unstable conditions" zone, work should shut down regardless of whether or not the rainfall shutdown value has been exceeded, and should remain shut down until the additional risk factors are no longer present.

6.4 Other Shutdown Criteria

In addition to shutdowns resulting from the exceedance of rainfall criteria, workers and supervisors should remain aware of other indicators of geotechnical instability. These can include, but are not limited to:

- pulses of sediment-laden water in streams, especially in gullies,
- streams suddenly drying up when conditions are otherwise wet,
- constant small rock falls,
- cutslope slumps that block ditches and/or roads,
- tension cracks appearing in road fills or slopes,
- fresh avalanches, landslides, or debris flows or their deposits observed that were not present during the last shift,
- anchor stumps pulling out of wet ground during cable yarding,
- diverted streams with flow appearing in new stream courses that were previously dry.

If any of these indicators of instability are observed, work should shut down until a qualified professional can be brought in to determine if it is safe for work to proceed.

These shutdown criteria apply to landslides and debris flows that form the predominant geotechnical hazards to workers. Snow avalanches pose seasonal hazards to workers and exposure to snow avalanches should be managed by qualified professional avalanche technicians.

Rockfalls often pose an additional hazard to workers. Many rockfalls occur under the same environmental conditions that cause landslides and debris flows. In addition, freeze-thaw cycling, especially on clear days during winter with warm days and cold nights, can cause rockfall. If rockfall is an identified hazard that can affect a work site, workers should be aware of the potential for freeze-thaw conditions to trigger rockfall and take appropriate precautions. In most cases, freeze-thaw generated rockfall does not occur at scales necessitating complete shut down of work, and can be managed to reduce risk to tolerable levels by reducing worker exposure to areas in which rock fall is likely to occur.

6.5 Resumption of Work after Shut Down

Once shutdown criteria have been exceeded, work should remain shut down for at least 24 hours after the hazardous conditions end. In the case of 48-hour or 72-hour rainfall criteria being exceeded, work should remain shut down for at least two days (48 hours) after shutdown criteria have been exceeded. If workers and supervisors believe it is safe for work to resume before the recommended 24- or 48-hour period is over, they should consult a qualified professional to confirm and document this before resuming work.

7.0 LIMITATIONS

WorkSafeBC Section 20.78 (Excavations) requires written instructions by a qualified professional that specifies the influence of changing weather conditions on the stability of an excavation. This procedure does not waive or take precedence over the requirements of WorkSafeBC Section 20.78.

The recommendations provided in this report are based on observations made by Statlu and are supported by information Statlu gathered. Observations are inherently imprecise. Conditions other than those indicated above may exist. If such conditions are observed or if additional information becomes available, Statlu should be contacted so that this report may be reviewed and amended accordingly.

This report was prepared considering circumstances applying specifically to the client. It is intended only for internal use by the client for the purposes for which it was commissioned and for use by government agencies regulating the specific activities to which it pertains. It is not reasonable for other parties to rely on the observations or conclusions contained herein.

Statlu prepared the report in a manner consistent with current provincial standards and on par or better than the level of care normally exercised by Professional Geoscientists currently practicing in the area under similar conditions and budgetary constraints. Statlu offers no other warranties, either expressed or implied.

8.0 CLOSURE

Please contact me should you have any questions or if you require further clarification.

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