TECHNICAL MEMORANDUM

To: MFLNRORD Southern Engineering Group
From: Drew Brayshaw, Ph. D., P. Geo.

Date: April 29, 2021

RE: Wet Weather Shutdown Criteria for Worker Safety – Operational Guidelines

This document outlines the recommended procedure to determine whether forestry operations should be shut down due to adverse weather conditions which present a risk to workers and equipment. It is intended to be used by MFLNRORD staff, licensees, and contractors to help determine safety shutdown procedures for field workers. It is only intended to protect worker safety with respect to landslides, debris flows, and other hazardous geotechnical phenomena and was not designed to address, for example, environmental shutdown criteria to protect water quality or fish habitat.

When to Use the Shutdown Criteria

Shutdown criteria apply when work sites or access routes are located on, downslope of, or are exposed to landslide-prone terrain, as defined in the guidance document. Workers are exposed to terrain stability hazards not only at the work site but also along access routes that reach the work site. Accordingly, shutdown criteria apply not only to work sites such as cutblocks and roads under construction, but also roads used for access to and from these work sites, except for public highways. Shutdown criteria apply to all staff and contractors and provide guidance to licensees.

Workers should check forecasts and predicted/reported rainfall totals before travelling to the work site. Environment Canada provides forecasts and measurements of rainfall of varying accuracy for all areas of the southern Interior of BC. These forecasts are available online, are broadcast, and are updated several times per day. Where forecasts and measurements do not accurately reflect conditions at the work site, they typically underestimate, rather than overestimate, actual rainfall experienced on site. If predicted or recorded rainfall for the day from the Environment Canada weather forecast exceeds the listed shutdown thresholds, it is likely unsafe to travel to the work site,

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and there is no need to expose workers to additional hazards by requiring them to check the rain gauge at the work site. If predicted rainfall for the day, for example, is 50 mm, and the shutdown criteria for the job site is 40 mm/24 hr, it is unnecessary to check an on-site rain gauge: assume that it is not safe to work that day.

How to Use These Shutdown Criteria

The wet weather shutdown criteria are based on a zone model, with four zones identified based on climate criteria, and a fifth zone based on *identified unstable conditions*. The climatic zones are based on mean annual precipitation (Table 1). The fifth zone recognizes the presence of unstable conditions warranting special measures and extra caution to protect worker safety which may be present in any climatic zone. It can and will be identified by MFLNRORD staff before work takes place. Determination of the applicable climatic zone will also be made by MFLNRORD staff or planning and development contractors before work begins. The applicable zone and associated shutdown thresholds can be included within the project particulars (e.g. Contract, License etc.).

Refer to Table 1 to determine shutdown criteria for 1-, 12-, 24-, and 48- hour time periods for the appropriate zone. Temperature and precipitation will be measured at the job site using a rain gauge and thermometer. Snowmelt is estimated from temperature using Table 2. Total rainfall measured by the gauge, air temperature, and estimated are to be recorded at the start and end of every work shift (at minimum, twice a day).

Table 1: Shutdown Criteria by Zone within the Southern Interior

Zone	Zone (annual precipitation)	Time Period			
		One hour	**At start of or before end of shift (12-hr)**	**24-hr**	**48-hr**
1	Very wet (1500 mm to 3000 mm)	n/a	28 mm	35 mm	60 mm
2	Wet (1100 mm to 1500 mm)	n/a	25 mm	30 mm	50 mm
3	Average (600 mm to 1100 mm)	10 mm	22 mm	25 mm	40 mm
4	Dry (100 mm to 600 mm)	8 mm	18 mm	20 mm	30 mm
5	Identified Unstable Conditions	6 mm	10 mm	15 mm	20 mm

Table 1 assumes that rainfall will be measured in the gauge located at the work site. Rain gauges are usually located near where workers enter the job 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 or snowmelt may occur at

higher elevations than is measured at the gauge. The shutdown criteria incorporate this assumption. Hourly rainfall or snowmelt measurements can be determined from Table 1 and 2 but do not need to be recorded hourly unless it is expected that conditions are close to shutdown thresholds (due to unusually heavy rainfall or unusually warm temperatures while snow is present).

If temperature is measured twice per day at start and end of shift, the two temperature measurements can be used the two 12-hour snowmelt totals and those can be summed to estimate 24-hour snowmelt. If a temperature measurement is missing, such as when work starts at a new location, 24-hour snowmelt also can be estimated directly from the last column of Table 2.

Table 2: Estimated Snowmelt by Air Temperature

Air Temperature (°C)	Expected Melt Rate (mm)		
	Peak Hourly	**12-Hour Total (Day)**	**24-Hour Total (Day+Night)**
1	1	4	6
2		6	8
3		8	11
4		10	14
5		11	17
6		13	20
7		15	23
8	2	17	26
9		19	29
10		21	32
11		23	35
12		25	37
13	3	27	40
14		29	43
15		31	46
16		33	49
17		35	52
18	4	37	55
19		39	58
20		41	61
21		43	64
22		44	66
23	5	46	69
24		48	72
25		50	75
26		52	78
27		54	81
28		56	84
29	6	58	87
30		60	90

When to Consider Snowmelt

Snowmelt should be estimated from temperature and recorded either when snow is present on the ground at a job site or when snow is visible, or is known to be present on the ground upslope of a job site. If no snow is present and no snow is visible, then snowmelt does not need to be estimated in order to evaluate shutdown. Other indicators of instability (Other Shutdown Criteria, below) may result from melting snow upslope and may trigger shutdown even if no melting snow is visible upslope.

Modifiers to Shutdown Criteria

Numerous factors other than direct rainfall or snowmelt can contribute to slope instability, including high winds, blocked drainage structures or diverted drainage upslope, long-term antecedent precipitation, earthquakes, and other less probable events. To account for these factors without requiring multiple difficult and potentially inaccurate calculations, a simpler system is used. Potential additional risk factors beyond simple rainfall or estimated snowmelt 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 additional risk factor present increases the zone number by one. For instance, a project is in Zone 2 which has a 24-hr threshold of 30 mm. A storm brings 20 mm of rainfall in 24 hours, accompanied by high winds of 80 km/h. Zone 2 is therefore shifted to Zone 3 to account for the high winds; 20 mm is still less than the Zone 3 24-hour shutdown criteria of 27 mm, so work can continue..

The presence of, and number of, additional risk factors should be noted and recorded while precipitation and temperature are recorded at the gauge. In cases where weather conditions change quickly, such as if intense precipitation falls, or if recorded values are close to a shutdown threshold, it may be necessary to check the rainfall gauge more than twice a day to determine if unsafe conditions are occurring.

The additional risk factors beyond rainfall and snowmelt totals are:

- 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.)

If the presence of additional risk factors increases the zone beyond Zone 5, 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 or until a qualified professional approves a return to work.

Other Shutdown Criteria

In addition to shutdowns resulting from the exceedance of rainfall or snowmelt 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.

Resumption of Work Following 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 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.

Procedure For Workers At Job Sites Without Weather Gauges

Some workers, such as layout contractors, work in locations which do not have rain gauges in place. Rain gauges are used at many work sites because they provide precise measurements of the amount of rainfall that occurs over time. Measurements of precipitation intensity (amount of precipitation over specified interval of time) therefore provide a reliable means to evaluate whether work should shut down or not. Workers at job sites where rain gauges are not present do not have access to such measurements and must therefore rely on other means that estimate rainfall intensity and snowmelt. If gauges are present, these procedures for ungauged locations should not be used.

It is difficult to estimate rainfall intensity accurately without a rain gauge. Temperature at a work site when snow is present can be measured with reasonable accuracy using a handheld thermometer or a built-in vehicle thermometer, and these measurements can be used to estimate snowmelt even without a weather station.

For workers at ungauged locations the recommended procedure is to check available data sources to evaluate whether it is likely to be safe to work in the field or not. If any sources indicate it is not safe, do not go. If no sources indicate that unsafe conditions have occurred or are likely to occur, then proceed to work, but remain alert for indications of hazard while in the field, and be prepared to leave if conditions become or are likely to become unsafe.

Data sources that are useful for determining whether it is safe to work in terrain subject to hazards include federal and provincial government meteorological observations and forecasts, as well as those made by Crown corporations. Comparing observations from multiple sources located near a work site, as well as those from stations further afield but which might represent comparable environmental conditions, provide enough information to make an informed judgement about whether it is safe to work or not.

These sources include:

- Environment Canada weather warnings and special weather statements.
    - These are updated several times per day and typically include warnings of ongoing or predicted heavy rainfall and high winds, together with estimates of precipitation amounts and wind speeds: https://weather.gc.ca/warnings/index_e.html?prov=bc

- Environment Canada meteorological observations.
    - Environment Canada weather stations record and report hourly and daily summary statistics for the past 24 hours and past days of a month and list (at the bottom of the page, under "Yesterday's data" heading) the previous day's 24-hour precipitation total. For example, for job sites near Kamloops, consult the Kamloops climate data page. It provides the wind speed and temperature over the last 24 hours:
      https://weather.gc.ca/city/pages/bc-45_metric_e.html
    - The "Historical Weather" link button on that page takes one to another page where previous 24 hour rainfall totals for previous days are recorded:
      https://climate.weather.gc.ca/climate_data/daily_data_e.html?StationID=51423

- Some, but not all, of the DriveBC highway cams include weather data from nearby climate stations. For instance, along Highway 3, the Paulson Summit webcam includes a weather data link that displays whether precipitation has fallen within the last hour, and depth of snow on the ground (if present) as well as total precipitation measured since 0600 or 1800 hrs (which, if checked in the morning or evening, provides a good proxy for 12-hour precipitation totals):
  https://images.drivebc.ca/bchighwaycam/pub/html/www/174.html

- BC Hydro maintains its own network of hydrometeorological gauges near its reservoirs, and the data from these gauges is also available online, although it is not archived and so is typically only available for the preceding four or seven days. The information is not always in a directly useable format, but can be checked anyway:
  https://www.bchydro.com/energy-in-bc/operations/transmission-reservoir-data/hydrometeorologic-data.html
    - For an example job site near Needles, it would be possible to use the Fauquier Water Treatment site climate gauge. This gauge records snow depth in cm, air temperature in °C, and total precipitation in mm, at 15 minute intervals. These gauges are sensitive to small errors (such as showing snow depth fluctuating between 0 cm and – 1 cm) but show temperature and larger trends well.
      https://www.bchydro.com/info/res_hydromet/data/faq.txt?WT.ac=gmap_hd_faq&WT.mc_id=BCHGglMap

- The BC River Forecast Centre's high streamflow warnings, flood watches, and flood advisories are also useful: http://bcrfc.env.gov.bc.ca/warnings/index.htm

- The BC Wildfire Service maintains a network of weather stations which can be accessed by users with either an IDIR or BCeid. The page requires either Internet Explorer, or Chrome configured to work like Explorer, as a browser in order to work: https://bcfireweatherp2.nrs.gov.bc.ca/scripts/menu/BC/ShowPage.asp?page=fireweather

After checking all of these sources online in the morning before going to a job site, evaluate if it is safe to go or not, and determine whether any hazardous conditions are forecast to occur later in the day that might prompt shutdown partway through the day of work.

Once in the field, field observations are the most reliable indicators of unsafe conditions, particularly levels of runoff in streams and ditches, seepage from cutslopes, and the presence or absence of rockfall, cutslope slumping, high winds, rain-on-snow conditions, and other factors that can contribute to unsafe conditions when work should be shut down. These observations, in conjunction with the previous forecast, are used to evaluate whether or not it is safe to continue to work at the present location and locations where other work is planned for the day.

Finally, once the field day is over, review the online data sources for the day, and compare the previous predictions to field observations and to the data actually recorded over the course of the day. In this way, the differences between predicted conditions and what actually occurs, can be used to refine safe work thresholds and can help determine which stations are most representative of conditions in the work area.

Yours truly

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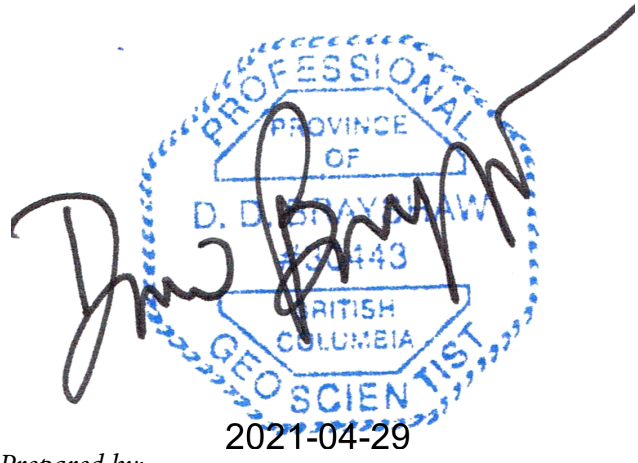

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