RED MOUNTAIN UNDERGROUND GOLD PROJECT
VOLUME 3 | CHAPTER 24
EFFECTS OF THE ENVIRONMENT ON THE PROJECT

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24 EFFECTS OF THE ENVIRONMENT

24.1 Background

Under Section 19(1)(h) of the *Canadian Environmental Assessment Act, 2012*, it is required that consideration of any changes to the proposed Project that may be caused by the environment be assessed as part of the environmental assessment. This chapter assesses the potential for the environment to affect the Red Mountain Underground Gold Project (the Project).

The Project is in the Bitter Creek valley in the Skeena Regional District near Stewart, BC. Mining infrastructure is anticipated to have a disturbance area of approximately 19.5 hectares (ha) for the associated buildings, stockpiles, and tailings management facility (TMF), in addition to 26 kilometres (km) of Access Road and 19 km of Powerline, primarily within the lower valley and the Goldslide Creek cirque (Mine Site).

The identification and mitigation of the inherent risks in the development and operation of a mine is a fundamental part of today's modern mining practices; this process is first initiated during the planning and permitting stage of the mine life cycle. In certain regions, including northwest BC, one of the most significant risks is the environment itself. Environmental conditions determine the location of the mineral deposit, as well as access mining methods, design and management strategies. Where it is impossible or impractical to eliminate an identified risk, the focus turns to mitigation of the effects/consequences of the identified risk to minimize likelihood and potential consequences. This mitigation can take multiple forms, including project design and layout, process design, equipment selection, operational procedures, employee training, and management plans.

24.2 Scope

The scope and approach of the assessment of the effects of the environment on the Project are defined by the Application Information Requirements (AIR). In accordance with the Project AIR (BCMOE, 2017), the following topics are considered in this assessment:

- Predicted climate change effects throughout the Project lifecycle, including extreme weather events (e.g., heavy rain/snowfall, flooding, extreme temperatures, drought and wind);
- Avalanches;
- Landslides;
- Natural seismic events; and,
- Lightning and forest fires.

To effectively meet the AIR requirements, this chapter discusses the potential effects of the environment in the following order:

- Precipitation
- Air Temperatures
- Wind
- Surface Water Flow
- Geophysical Environment (Geohazards)
- Wildfire
- Climate Change

24.3 Approach

The likelihood (probability) and consequences (severity) of the effects of the environment on the Project are evaluated using an approach that parallels the method used in the Accidents and Malfunction Chapter (Chapter 23). In this assessment, IDM evaluated the likelihood that a condition would occur to produce a risk (Table 24.3-1); the likelihood that an incident will occur given design and mitigation measures; and the consequence to the Project should the event occur (Table 24.3-2).

Effects of the environment on the Project have the potential to have secondary effects on VCs and ICs, if they lead to potential Project-related concerns. For example, a flood event could damage a culvert and the damage to the culvert could affect surface water quality and fish habitat. These secondary effects on VCs and ICs are not expected to differ in scale or frequency from the effects assessed within the individual chapters of this Application/EIS (Volume 3 Part B), and are not discussed separately in this chapter.

Table 24.3-1: Attributes of Likelihood

Likelihood Rating	Quantitative Threshold (Chance of Occurrence)	Description of Threshold
1) Negligible	< 0.1%; 1-in-1000 years	Doubtful it could happen
2) Low	0.1 – 1%; 1-in-1000 to 1-in-100 years	Unlikely to happen
3) Moderate	1 – 10%; 1-in-100 to 1-in-10 years	It could happen
4) High	10 – 50%; 1-in-10 to 1-in-2 years	Has happened or probably will happen
5) Very High	> 50%; 1-in-2 years or more frequently	Will happen

Source: Robertson 2012

Table 24.3-2: Severity of Consequences

Category Rating	Description of Consequence
1) Negligible	No measurable impact; negligible- to low-level repairable damage to minor structures; no stoppage in Project activity; no injury to Project employees.
2) Low	Minor impact on Project component or activity; low-level repairable damage to infrastructure; no stoppage in Project activity; no injury to Project employees.
3) Moderate	Significant reversible impact on Project component or activity; substantial damage to infrastructure; potential minor stoppage in Project activity; minor injury to Project employees.
4) High	Significant irreversible impact on Project component or activity; major damage to infrastructure; up to 6 months' delay in Project while damage is repaired; serious injury to Project employees.
5) Severe	Catastrophic irreversible impact on Project component or activity; major damage to significant infrastructure; Project forced into early closure; at least one fatality among Project employees.

Source: Robertson 2012

24.4 Climatic Setting

Weather and climate are primary drivers of the effects of the environment on the Project. Weather refers to atmospheric conditions on time scales ranging from days to weeks, whereas climate refers to longer-term atmospheric conditions. Long-term climatic conditions are important to consider in the context of extreme weather events, since future variability is expected to change as a consequence of climate change. This section provides a brief description of factors controlling weather and climate in the region, including drivers affecting large-scale natural climate variability.

24.4.1 Regional Climate

Climatic conditions at the Project are dictated primarily by its altitude and proximity to the Pacific Ocean. Temperatures are moderated year-round by coastal influence. Precipitation is substantial in all months, with October being the wettest. Even at sea level, over one-third of the annual precipitation falls as snow. This proportion is greater at higher elevations, where snow may fall at almost any time of year. Blizzard conditions are frequent in the immediate vicinity of the Project during winter, and avalanches pose a frequent threat in the Bitter Creek valley and in the upper Bear River Valley, through which Highway 37A passes (Appendix 12-A: Baseline Climate and Hydrology Report).

24.4.2 Regional Climatic Patterns

The winter climate of the region is affected by the strength of the Aleutian Low, a low-pressure cell that forms in winter over the North Pacific Ocean and Aleutian Islands. The Aleutian Low migrates spatially along the coasts of BC and Alaska and advects warm, moisture-laden air into the jet stream. The strength of the Aleutian Low is directly linked to the phase and strength of the Pacific Decadal Oscillation (PDO)[1].

The specific phase of the PDO has been demonstrated to have a moderating effect on the strength and state of the El Niño Southern Oscillation (ENSO)[2]. In practice, during a positive phase of the PDO there is a greater propensity for El Niño events to occur. Conversely, during a negative phase of the PDO, there is a greater propensity for La Niña events to occur. The temporal clustering of El Niño and La Niña events has substantial effects on regional climate patterns.

Sea surface temperature (SST) anomalies generated by ENSO migrate from the equator up the west coast of North America and eventually pool off the coasts of BC and Alaska. Warm (El Niño) phases of ENSO result in above-average SST off the north coast of BC, which then result in greater advection, and therefore, more moisture-laden air masses rising into the Aleutian Low pressure cell and then into the jet stream, to be transported inland.

Positive phases of the PDO tend to result in clustered El Niño events, and it can be expected that the extreme events commensurate with El Niños will also be clustered during positive phases of the PDO. This occurred during the last positive phases of the PDO, specifically in the 1980s and 1990s, when numerous clustered El Niño events were responsible for extreme precipitation events generally, including both rainfall and snowfall. Similarly, negative phases of the PDO tend to result in clustered La Niña events; it can then also be expected that extreme events commensurate with La Niña's will also be clustered during the negative phases of the PDO.

24.4.3 Local Climate

Local climate in the Project area has been characterized using data from three sources (Appendix 12-A), as follows:

- The on-site meteorological station installed in July 2014;
- ClimateWNA; a computer program that provides 30-year climate normal data for western North America on a 2.5 x 2.5 arcminute grid. ClimateWNA data are interpolated and adjusted for elevation effects based on gridded climatic datasets (from the Climate

[1] The PDO is a measure of the difference in sea level air pressure between the Aleutian Low and the Hawaiian High pressure cell. The PDO is characterized by positive phases (i.e., 1925 to 1946, 1977 to 2005) and negative phases (i.e., 1947 to 1976, 2005 to present). The phase and strength of the PDO have been shown to influence changes in precipitation affecting river flow and glacial mass balance in coastal areas of northwestern North America.

[2] The ENSO phenomenon is a measure of the difference in sea surface temperatures (SSTs) between northern Australia and the coastal upwelling zone off western Ecuador.

Research Unit and Global Historical Climatology Network. ClimateWNA uses the climate normal datasets (i.e., 1961 to 1990, 1971 to 2000, and 1981 to 2010) and provides spatially-explicit interpolation for any point in BC; and

- Climate data from regional meteorological stations. These data are used here to assess air temperature and precipitation extremes from stations in proximity to the Project area.

The Baseline Climate and Hydrology Report for the Project is available in Volume 8, Appendix 12-A.

24.5 Effects of the Environment - Precipitation

Mean monthly precipitation at the Mine Site was estimated to range between 66 millimetres/month (mm/month) in July to 291 mm/month in October, with a Mean Annual Precipitation of 1,847 mm (Appendix 7-B). There are likely considerable differences in precipitation throughout the elevational range of the Project; however, data are not available at sufficient resolution to differentiate elevational patterns. Estimated annual precipitation ranged from 1,140 mm (200-year [yr] dry return period) to 2,550 mm (200-yr wet return period). Snowpack depth typically peaks in late March (240 centimetres [cm]) and early April (260 cm).

The Project is situated within the Bitter Creek Watershed, a large catchment area of over 30,000 ha that funnels into a relatively narrow outflow (Appendix 12-A). In addition, the soils near the Project are generally thin and have limited ability to adsorb and retain water (Appendix 9-A: Ecosystems, Vegetation, Terrain, and Soils Baseline Report).

24.5.1 Typical Precipitation

24.5.1.1 Effects of Typical Precipitation

Potential effects arising from typical precipitation patterns include: erosion and sedimentation, limited flooding, and avalanche hazard (due to frequent, low-intensity snowfall; Table 24.5-1).

24.5.1.2 Mitigation Measures for Typical Precipitation

The Project has been designed to accommodate local precipitation patterns (Table 24.5-1). Given the relatively long timeline required for a typical precipitation pattern to result in a potential risk to the Project, IDM will monitor weather conditions throughout construction and operations to establish trends and identify potential problems before they occur.

24.5.2 High Precipitation

24.5.2.1 Effects of Prolonged Wet Weather

Prolonged wet weather in Project catchments could trigger flooding events, especially if they coincide with periods of peak snowmelt. Prolonged wet weather could result in an increase in erosion near roads and infrastructure and in sediment delivered to streams (Table 24.5-1). Precipitation-related effects could include: damage to buildings, site infrastructure, and access roads, in addition to seepage into proposed underground workings or mud rush.

Snow, sleet, or hail could also affect infrastructure. Prolonged precipitation in solid forms may damage building roofs and other infrastructure. Similar infrastructure damage could occur during warm winter temperature cycles. These warm temperature cycles can act to increase the density of snow, and therefore the force on roofs, anchoring cables, and covered walkways. Greater potential for large snowfall volumes during the winter could result in periods of high snow accumulation on roads. Heavy precipitation events could lead to road damage and/or erosion. Increased maintenance could be required to access various Project locations in winter and maintain road integrity.

24.5.2.2 Effects of Intense Rain and Thunderstorms

The Project is in a zone that receives rainfall that is both frequent and intense (Appendix 12-A). These high-precipitation events can have a range of potential effects (Table 24.5-1) including:

- Increased disruption in operations, including reduced speed along Haul and Access Roads;
- Increased groundwater seepage and surface runoff that flows into proposed underground workings, thus increasing dewatering requirements for these areas;
- Severe rainstorms in the Project catchments could trigger flooding events (Section 24.8.2), especially if they coincide with freshet conditions; and,
- Related surface runoff could trigger debris flows on steep valley slopes. The debris flow could carry large volumes of surficial materials and woody debris downslope, particularly in areas prone to geohazards (Section 24.9).

Thunderstorms may be accompanied by hail, lightning (Section 24.5.2.3), and damaging winds (Section 24.7). A thunderstorm is classified as severe when it contains hail larger than 1.9 cm in diameter and winds gusting in excess of 50 knots (92.6 km/h).

24.5.2.3 Effects of Lightning on the Project

The direct effects of lightning strikes on the Project could include initiating fires (see Section 24.10 for wildfire) and electrical failures (Table 24.5-1). Though the likelihood of being struck would be low, it could also pose a risk of injury or death to workers. Fires resulting from lightning strikes could affect buildings, infrastructure, equipment and machinery, stockpiled materials and the forested area within, or adjacent to, the Project area. Electrical failures could occur if lightning strikes transmission lines, towers, or other related infrastructure.

24.5.2.4 Effects of Snowstorms

The Project area is subject to substantial snowfall during the winter period (Appendix 7-B). High volumes of snowfall could impede the movement of mobile equipment on the Access Roads and at the mine site (Table 24.5-1). Related problems could include reduced traction and visibility during snowstorms. Poor visibility could also become dangerous during a blizzard or fog. Increased loads from snow accumulation on buildings or other infrastructure may cause structural damage. Snowstorms also have the potential to contribute rapidly to the snow-pack in the landscape. Increased snow loading on steep valley walls increases risk factors associated with avalanches (Section 24.9.2).

24.5.2.5 Mitigation Measures for High Precipitation

Current construction design criteria for buildings and roads are likely sufficient to withstand the expected increases in heavy or prolonged precipitation, including thunderstorms (Table 24.5-1). The Project will be designed, constructed, operated, closed and reclaimed per the Canadian Dam Association's (CDA) *Dam Safety Guidelines* (Canadian Dam Association 2007; Revised 2013). Water will be closely managed at the TMF and discharged as allowable to minimize the volume of impounded water. The overall approach to site water management is to divert water around mine workings. Roadways will be cleared during or after snow events, and will be repaired and maintained as needed. Ditches and culverts will be cleared of debris and their condition monitored. Silt fencing and rock-check berms will be provided along ditches to reduce sediment transport to the culvert crossings and thus to the environment. Snow will be shoveled off roofs after heavy snowfalls to prevent roof collapse from excessive loads.

To help mitigate effects on mine infrastructure (e.g., buildings, power poles, and bridges) from hail, high-velocity winds, and lightning strikes, building, conveyor, pipeline and power distribution materials will be stored on site to facilitate timely repairs and reconstruction.

Lightning risk is primarily mitigated to an acceptable level through design codes and standards. Project infrastructure will maintain compliance with building codes (electrical standards and fire suppression systems) and fire control standards. BC building codes will ensure that electrical and fire suppression systems are adequate for the structures. Appropriate fire-suppression equipment will be readily available in buildings, site infrastructure, machinery, and personnel.

Any emergencies triggered by a lightning strike (e.g., personnel injury or forest fire) would trigger the Project's Emergency Response Plan (Volume 5, Chapter 29). Additional mitigation measures are described in detail in the Project's management and monitoring plans (Volume 5 Part E – Management Plans and Monitoring) including:

- Access Management Plan;
- Aquatic Effects Management and Response Plan;

- Erosion and Sediment Control Plan;
- Material Handling & ML/ARD Management Plan;
- Occupational Health and Safety Plan;
- Site Water Management Plan;
- Spill Contingency Plan; and
- Tailings Management Plan.

24.5.3 Low Precipitation

The estimated Mean Annual Precipitation for the Project is estimated at 1,847 mm, and the 200-yr dry return period was estimated at 1,140 mm/yr. Taken together, these data suggest that periods of low precipitation will not be a common occurrence in the operational life of the Project.

24.5.3.1 Effects of Low Precipitation

The effects of low precipitation will generally manifest as low stream flow (Section 24.8.3) and its attendant effects on the Project's water balance. Prolonged periods of low precipitation could also increase the risk of wildfires (Section 24.10) and reduce visibility on roads due to dust (Table 24.5-1).

24.5.3.2 Mitigation Measures for Low Precipitation

Mitigation measures for low flows and wildfire are presented in the relevant sections. Dust mitigation options include spraying water on key surfaces and reducing speed limits during dry periods (Table 24.5-1). To further minimize effects from low precipitation on the Project, IDM has developed management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring) including:

- Material Handling & ML/ARD Management Plan;
- Occupational Health and Safety Plan;
- Site Water Management Plan; and,
- Tailings Management Plan.

Table 24.5-1: Precipitation Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	Typical Precipitation • Erosion and sedimentation • Localized flooding • Small-scale snow drifting or slumping	Very High	High	Low to Moderate	• Project has been designed to accommodate typical precipitation patterns. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	High Precipitation • Erosion and sedimentation • Widespread flooding • Reduced access to Project Site and reduced productivity due to tree hazards, snow drifts and damage to roads. • Damage to key transportation infrastructure (e.g., bridges).	High	Low to Moderate	Low to Moderate	• Major bridges and culverts designed to a 1 in 100 return period. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Low Precipitation • Increase in dust resulting in poor visibility	Low	Low	Low	• Follow relevant management plan (e.g., Air Quality and Dust Management) • Spray water on key surfaces • Reduced speed limits during dry periods
Surface Infrastructure	Typical Precipitation • Snow loading on roofs can place structural stress	Very High	High	Low	• Project has been designed to accommodate typical precipitation patterns • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair).
	High Precipitation • Widespread flooding • Erosion and sedimentation • Snow loading leading to damage of infrastructure and reduced mine productivity • Lightning strikes cause electrical failure • Lightning strikes cause wildfire (Section 24.10)	High	Low to Moderate	Low to Moderate	• Runoff will be diverted from entering infrastructure areas by berms and ditches, while contact water will be collected and routed to settling/holding ponds prior to discharge. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair).
	Low Precipitation • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Tailings Management Facility	Typical Precipitation • Erosion and sedimentation	Very High	High	Low to Moderate	• Project has been designed to accommodate typical precipitation patterns. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	High Precipitation • Overtopping of dam • Failure of embankment	High	Low	High to Severe	• The TMF capacity is designed to store up to 2 million tonnes of tailing, process water, stormwater, and freeboard. • Diversion ditches and collection ponds sized for 1 in 200 year 24-hr precipitation event. • TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines*. • Follow relevant management planes (e.g., Site Water, Tailings Management and Emergency Response Plan. • Dam Breach Assessment • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair).
	Low Precipitation • Effects manifested through low flow (Section 24.8.3)	NA	NA	NA	• See Section 24.8.3 and Table 24.8-3
Access Corridor	Typical Precipitation • Erosion and sedimentation • Localized flooding • Small-scale snow drifting or slumping	Very High	High	Low to Moderate	• Project has been designed to accommodate typical precipitation patterns • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	High Precipitation • Erosion and sedimentation • Widespread flooding • Reduced access to Project Site and reduced productivity due to tree hazards, snow drifts and damage to access corridor	High	Low to Moderate	Low to Moderate	• Construction of purpose-designed runoff collection ditches and sediment ponds. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Low Precipitation • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Water Management Infrastructure	Typical Precipitation • Erosion and sedimentation • Localized flooding • Small-scale snow drifting or slumping	Very High	High	Low to Moderate	• Project has been designed to accommodate typical precipitation patterns. • Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	High Precipitation • Erosion and sedimentation • Widespread flooding • Reduced access to Project Site and reduced productivity due to tree hazards, snow drifts and damage to access corridor	High	Low to Moderate	Low to Moderate	• Construction of purpose-designed runoff collection ditches and sediment ponds. • Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Follow relevant management plans (e.g., Erosion and Sediment Control) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Low Precipitation • Effects manifested through low flow (Section 24.8.3)	NA	NA	NA	• See Section 24.8.3 and Table 24.8-3
Underground Workings	Typical Precipitation • None	NA	NA	NA	NA
	High Precipitation • Increased rainfall could increase groundwater seepage and surface runoff that flows into proposed underground workings, which would increase dewatering requirements for these areas.	High	Low	Low to Moderate	• Purpose-designed dewatering pumping system • Clearing of snow from ventilation shafts. • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Low Precipitation • None	NA	NA	NA	NA
Utilities	Typical Precipitation • None	NA	NA	NA	NA
	High Precipitation • Interrupted power supply. • Erosion at footings.	High	Low	Low to Moderate	• Follow relevant management plans (e.g., Emergency Response) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair) • Backup generators to allow security of energy supply during maintenance or failure.
	Low Precipitation • None	NA	NA	NA	NA

24.6 Effects of the Environment - Air Temperature

The air temperature at the Project is strongly and negatively correlated to elevation. The statistical combination of data from the Project's Redmount meteorological station and the Sandspit A weather station resulted in an estimate of the mean annual air temperature of -0.8°C, with a monthly range from -6.4°C in December and January to 6.9°C in August (Appendix 7-B)

Long-term data from site-specific and regional weather stations reveal a wide range between extreme warm and extreme cold air temperatures. Air temperatures have been recorded as warm as 15.8°C and as cold as -20.7°C. The potential for extremes in cold and warmth is characteristic of the continental climate in the Project area.

24.6.1 Effects of Extreme Cold

Given the climatic setting of the Project area, effects on the Project might be expected from extremely cold air temperatures (Table 24.6-1). These extreme temperatures may affect workers, infrastructure, or machinery. Extremely low air temperatures could adversely affect workers' health (e.g., frostbite and hypothermia). Workers can become distracted and prone to accidents under extreme low temperatures. Equipment and machinery is more likely to malfunction or become damaged during extreme low temperatures, increasing the potential for worker-related exposure and accidents. Extreme low temperatures may be accompanied by blowing snow, which could affect surface transport of materials and personnel, and could temporarily slow mine operations. Increased heating requirements on site would result from extreme low temperatures, increasing power demand.

Extended cold spells could result in a prolonged winter and increased snow accumulation. Extended cold spells accompanied by high winds can create period Arctic outflow conditions (see Section 27.4.1). Thus, access roads and diversion channels would require more frequent maintenance. Extreme low temperatures could also increase the risk of pipelines freezing and frost heave forming on pit walls and road cuts. Cold spells could cause later melting of the winter snow-pack, delaying spring runoff.

24.6.2 Effects of Extreme Warmth

Extremely high air temperatures may adversely affect workers' health, potentially causing heat exhaustion, dehydration, and heat stroke (Table 24.6-1). Workers can become distracted and more prone to accidents under extreme high temperatures. Equipment and machinery is more likely to malfunction during extreme high temperatures, increasing the risk of accidents. Increased short-term air conditioning requirements on site (e.g., for control room, offices and lunch rooms in the process plant complex) would result from extreme high temperatures, increasing power demand.

With sustained warm air temperatures, more precipitation would fall as rain than as snow, and earlier melting of the snow-pack could cause increases in runoff during the late winter and early spring. Storms in which precipitation falls as rain rather than snow could cause more rapid runoff, potentially increasing the erosive capabilities of surface flows. Costs of maintaining diversion channels and access roads could increase. Extremely high temperatures coinciding with dry periods could increase the likelihood of wildfires occurring in the area (Section 24.10).

24.6.3 Effects of Freeze-Thaw Cycles

At high elevations in BC (over 1,000 metres above sea level [masl]), freeze-thaw is likely a concern in spring, summer, and fall; at lower elevations in BC (under 1,000 masl), it is more of a concern in the fall, winter, and spring. Freeze-thaw cycles are a causal factor of cracked pavement and road surfaces, and can result in damage to powerline tower foundations.

Given that air temperatures in winter can range above and below the freezing point, freeze-thaw cycles and frost heave in winter are likely (Table 24.6-1). Freeze-thaw cycles are a well-recognized causal factor of cracking of hardened surfaces. This would accelerate road deterioration and would increase maintenance costs. Frequent freeze-thaw cycling and frost heave also have the potential to compromise the integrity of other site infrastructure, including: building foundations, dam walls, tunnels, and power transmission towers.

Table 24.6-1: Air Temperature Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	Extreme Cold • Blowing snow creating visibility concerns • Increased snowfall and snowpack on roadways can affect movement of workers and materials • Cold spells can delay snowmelt, delaying and shortening spring runoff	High	High	Low	• Follow relevant management plans (e.g., Emergency Response) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Extreme Warmth • Rapid snowmelt could increase surface flows, with attendant effects (Section 24.8.2)	NA	NA	NA	• See Section 24.8.2 and Table 24.8-3
	Freeze-Thaw Cycles • Frost heave on gravel roads and surfaces can create driving or equipment hazards. • Cracked hardened surfaces	High	High	Low to Moderate	• Roads and other transportation infrastructure have been engineered to standards appropriate for local climate and conditions. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
Surface Infrastructure	Extreme Cold • Workers at risk of frostbite and hypothermia; workers prone to distraction and increased accidents when working in cold environments. • Equipment and machinery is more likely to malfunction or become damaged during extreme low temperatures, increasing the potential for accidents. • Increased heating (and power) demands	High	High	Low to Moderate	• Follow relevant management plans (e.g., Emergency Response; Occupational Health and Safety) • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair) • Staff will wear appropriate clothing, and be trained in risk and risk-mitigation relating to extreme temperatures. • Suitable equipment will be used in mine infrastructure to withstand extremes of cold. • Air heating at top of intake air raise to avoid freezing of pipes and creation of unsafe ground conditions.
	Extreme Warmth • Workers could suffer from heat exhaustion, dehydration, heat stroke • Increased air conditioning and power demands. • Rapid snowmelt could increase surface flows, with attendant effects (Section 24.8.2) • Increase probability of wildfires (Section 24.10)	Low	Low	Low	• Follow relevant management plans (e.g., Emergency Response; Occupational Health and Safety) • Weather monitoring program • Ongoing maintenance (e.g., road and ditch repair) • Staff will wear appropriate clothing, and be trained in risk and risk-mitigation relating to extreme temperatures. • Suitable equipment will be used in mine infrastructure to withstand extremes of heat.
	Freeze-Thaw Cycles • Frequent freeze-thaw cycling and frost heave have the potential to compromise the integrity of building foundations	High	Moderate	Low to Moderate	• Building foundations have been engineered to standards appropriate for local conditions and climate. • Ongoing maintenance (e.g., snow clearing, road and ditch repair)

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Tailings Management Facility	Extreme Cold • None	NA	NA	NA	NA
	Extreme Warmth • None	NA	NA	NA	NA
	Freeze-Thaw Cycles • Frequent freeze-thaw cycling and frost heave also have the potential to compromise impoundment.	High	High	Moderate	• TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines*.
Access Corridor	Extreme Cold • Effects to workers from cold: frostbite, hypothermia, distraction, accidents. • Extreme low temperatures could increase the risk of pipelines freezing • Low temperatures will increase heating and power demands	High	Moderate	Low	• Air heating at decline portal to and provide safe and comfortable working environment. • Where the risk of pump failure exists, valves will be installed to allow pipes to be drained if they are not gravity draining at the discharge point.
	Extreme Warmth • Increase probability of wildfires (Section 24.10)	NA	NA	NA	• See Section 24.10 and Table 24.10-1
	Freeze-Thaw Cycles • Frequent freeze-thaw cycling and frost heave have the potential to compromise impoundment.	High	Moderate	Low	• Air heating at decline portal to minimize freeze-thaw damage
Water Management Infrastructure	Extreme Cold • Extreme low temperatures could increase the risk of pipelines freezing • Cold spells can delay snowmelt, delaying and shortening spring runoff	High	High	Low	• Water management infrastructure has been engineered to standards appropriate for local climate and conditions. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
	Extreme Warmth • Potential effects manifested through low flow (Section 24.8.3) • Increase probability of wildfires (Section 24.10)	NA	NA	NA	• See Section 24.8.3 and Table 24.8-3 • See Section 24.10 and Table 24.10-1
	Freeze-Thaw Cycles • Frequent freeze-thaw cycling and frost heave have the potential to compromise the integrity of water management infrastructure.	High	Moderate	Low to Moderate	• Water management infrastructure has been engineered to standards appropriate for local climate and conditions. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair)
Underground Workings	Extreme Cold • None	NA	NA	NA	NA
	Extreme Warmth • None	NA	NA	NA	NA
	Freeze-Thaw Cycles • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Utilities	Extreme Cold • During extreme cold temperatures, ice accumulation may damage the conductors which could result in electrical supply failure.	High	Moderate	Low to Moderate	• Towers and conductor specifications should be appropriate for expected climate extremes. • Routine inspections should be performed to monitor potentially problematic sections of the powerline.
	Extreme Warmth • Increase probability of wildfires (Section 24.10)	NA	NA	NA	• See Section 24.10 and Table 24.10-1
	Freeze-Thaw Cycles • Frequent freeze-thaw cycling and frost heave have the potential to compromise the integrity of power transmission towers.	High	Moderate	Low to Moderate	• Towers and conductor specifications will be appropriate for expected climate extremes. • Routine inspections will be performed to monitor potentially problematic sections of the powerline.

24.6.4 Mitigation Measures for Extreme Air Temperatures

Current construction design criteria for buildings and roads are likely sufficient to withstand the expected extremes in temperature (Table 24.6-1). The Project will be designed, constructed, operated, closed, and reclaimed per the CDA *Dam Safety Guidelines* (Canadian Dam Association 2007; Revised 2013).

Weather forecasts will be monitored, which will provide time to prepare for air temperature extremes. Health and safety policies will be implemented, and risk assessments will be undertaken before working in adverse weather conditions. Staff will be educated through formal training programs to ensure that they understand the risks of working under extreme high or low temperatures, and to ensure that they have good knowledge of the related procedures. Daily job safety analyses will be conducted. Personnel will be required to wear appropriate personal protective equipment, including cold-weather gear, while working outside.

The Project's Emergency Response Plan (Chapter 29) describes these measures in detail. Radio communication will be maintained with anyone working away from the Project area. Air heating will be required at the access decline portal and at the top of the intake air raise. This is required to provide a comfortable and safe working environment, avoid freezing of systems (such as water pipes), and avoid freeze-thaw that could create unstable ground conditions. Suitable equipment and design systems will be purchased and implemented for the Project to allow for operation under extreme temperatures. Equipment will be maintained to ensure reliable operation. Potentially vulnerable infrastructure will be built to withstand freeze-thaw cycles, especially infrastructure related to transportation and utilities where layer works or foundations may be affected.

To further minimize effects from extreme air temperatures and freeze-thaw cycles on the Project, IDM has developed additional management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring) including:

- Access Management Plan;
- Occupational, Health and Safety Plan;
- Site Water Management Plan; and,
- Spill Contingency Plan.

24.7 Effects of the Environment - Wind

Based on the approximately two-year dataset from the Project's Redmount meteorological station, average wind speeds ranged from 2.3 m/s in July to 6.1 m/s in January and March (Appendix 12-A). During the winter, most recorded wind speeds were below 8 m/s, with infrequent gusts as high as 16 to 18 m/s (i.e., the strongest winds recorded at the Project). Spring wind speeds tended to stay below 10 m/s, summer wind speeds below 6 m/s, and fall wind speeds below 12 m/s. The predominant wind direction is east and southeast in the spring, fall and winter, and there was no dominant directional pattern in the summer.

24.7.1 Effects of Wind

Winds in the Project area are generally of low velocity and are unlikely to have significant effects on the Project. However, rare high-velocity winds have been known to occur. High winds during below-freezing air temperatures would contribute to greater wind chill (i.e., create temporary Arctic outflow conditions) and blowing snow. Blowing snow would reduce visibility, limiting access to and from the mine site. High winds in the event of a forest fire can also accelerate the spread of fire (Table 24.7-1).

High winds could also potentially:

- Dislodge roofing;
- Destabilize covered walkways;
- Damage or remove equipment shrouds and covers, which could then present a safety hazard;
- Cause downed trees (particularly on new development), which could temporarily block roads;
- Damage powerlines and building services; and,
- Cause electrical supply failure.

24.7.2 Mitigation Measures for Wind

Surface infrastructure will be constructed using purpose-designed technology to mitigate wind damage (Table 24.7-1). Vegetation thinning methods such as pruning, topping, and feathering could minimize edge effects and reduce risks associated with the downing of trees. Vegetation setbacks will also be established for facilities and utility infrastructure to minimize possible damage by downed trees. Staff will be required to wear appropriate clothing, particularly when high winds occur in conjunction with heavy snow or rainfall.

An on-site meteorological station will continue to record on-site winds. Data from these stations will guide construction techniques necessary to mitigate potential damage by wind. Weather forecasts will be monitored to anticipate, and prepare for, any severe winds. During blackouts, non-essential machinery will be shut down until power is re-established and a back-up power generator will provide power in the case of outages.

To further minimize effects from wind on the Project, IDM has developed management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring) including:

- Access Management Plan;
- Emergency Response Plan;
- Occupational, Health and Safety Plan;
- Site Water Management Plan; and,
- Spill Contingency Plan.

Table 24.7-1: Wind Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	• Downing of trees blocking transportation corridors. • Increase in blowing snow or dust resulting in poor visibility • High winds could affect the movement of people or materials to the Project area; • High winds during below-freezing air temperatures would contribute to higher wind chill (i.e., Arctic outflow conditions) • Blowing snow could accumulate on road surfaces, affecting on-site movement.	Low to Moderate	Low to Moderate	Low	• Weather monitoring program • Ongoing maintenance (e.g., snow clearing, road and ditch repair, vegetation management)
Surface Infrastructure	• Dislodged roofing • Destabilized walkways • Damage to equipment covers and buildings • Combined with snow and low temperatures, reduced visibility and risk of exposure to personnel • Flying debris could reduce visibility for personnel at the site and possibly cause injury	Low to Moderate	Low to Moderate	Low	• Surface infrastructure has been engineered to standards appropriate for local climate and conditions. • Staff will wear appropriate clothing, and be trained in risk and risk-mitigation relating to extreme winds.
Tailings Management Facility	• Wind-generated waves could overtop dam.	Low to Moderate	Low to Moderate	Moderate to High	• TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines*.
Access Corridor	• Damage to equipment and infrastructure • Increase in blowing snow or dust resulting in poor visibility • High winds could affect the movement of people or materials to the Project area; • High winds during below-freezing air temperatures would contribute to higher wind chill (i.e., Arctic outflow conditions).	Low to Moderate	Low to Moderate	Low	• Weather monitoring program. • Ongoing maintenance (e.g., snow clearing, vegetation clearing).
Water Management Infrastructure	• Dislodged covers • Damage to equipment • Damage to infrastructure	Low to Moderate	Low to Moderate	Low	• Water management infrastructure has been engineered to standards appropriate for local climate and conditions. • Weather monitoring program. • Ongoing maintenance (e.g., snow clearing, vegetation clearing).
Underground Workings	• None	NA	NA	NA	NA
Utilities	• Damage to powerlines resulting in electrical supply failure.	Low to Moderate	Low to Moderate	Low to Moderate	• Utility infrastructure has been engineered to standards appropriate for local climate and conditions. • Shut down of non-essential machinery in the case of electrical supply failure. • Back-up generators to allow security of supply during maintenance or failure. • Weather monitoring program. • Ongoing maintenance (e.g., snow clearing, vegetation clearing).

24.8 Effects of the Environment - Surface Water Flow

Underground mining is proposed to take place in the Red Mountain cirque. The cirque is drained by Goldslide Creek, which flows southwest to the side of Bromley Glacier close to its current extent; Goldslide Creek is not glacially influenced. Goldslide Creek is one of the two uppermost tributaries to Bitter Creek. Other Bitter Creek tributaries relevant to the baseline hydrological evaluation are Otter Creek and Roosevelt Creek. Otter Creek is glacially influenced. Like Otter Creek, Bitter Creek is glacially influenced and flows peak in summer (typically in July). Bitter Creek is a tributary to the Bear River, which flows into the Portland Canal near Stewart. The Bitter Creek watershed is a large catchment area of over 30,000 ha that funnels into a relatively narrow outflow (Appendix 12-A). In addition, the soils in the vicinity of the Project are generally thin and have limited ability to adsorb and retain water (Appendix 9-A).

Streams and hydrologic features within the Project area were surveyed with a baseline hydrometric monitoring program that utilized four monitoring stations. All four stations were within the Bitter Creek Watershed; three were in operation from 2014 to 2016 (Table 24.8-1). A fourth station was added to lower Otter Creek in 2016 to accommodate a change in the Project footprint, and to augment data from the existing Otter Creek station (OC04).

Table 24.8-1: Key Characteristics of Project Hydrometric Monitoring Stations

Station ID	Description	Years Active	Catchment Area (km^2)	Average Watershed Elevation (masl)	Average Watershed Slope (degrees)
GCS05	Goldslide Creek before drop off	2014-2016	1.61	1756.13	26.31
OC04	Otter Creek before drop off	2014-2016	2.15	1849.90	28.32
BC02	Bitter Creek at Hwy 37A bridge	2014-2016	267.10	1483.84	20.87

Source: Appendix 7-B.

Hydrometric stations were installed and operated in accordance with the requirements of the *Manual of British Columbia Hydrometric Standards, March 12, 2009* (BC MOE 2009). Baseline monitoring included continuous measurement of water level and monthly flow measurements.

24.8.1 Typical Surface Water Flow

The flow regime in the area is closely related to the seasonal distribution of precipitation and temperature. Watercourses in this region are predominantly fed by spring and early summer freshet and rainfall in the summer. High discharges occur during the freshet period (May through July), with a low-flow period during winter and early spring (Table 24.8-2).

Table 24.8-2: Mean Monthly Discharge Data from Hydrometric Sections in the Baseline Study Area

Watercourse	Parameter ($l/s/km^2$)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bitter-Otter Creek	Mean Runoff (Annual = 2,981 mm/yr)	7.6	17	14	26	56	217	342	245	119	62	10	13
Goldslide Creek	Mean Runoff (Annual = 1,584 mm/yr)	8.3	7.6	7.1	15	61	158	148	68	47	43	24	12
Bitter-Otter Creek	Unit Base Flow	4.8	7.8	10	13	23	67	172	139	59	23	5.9	6.4
Goldslide Creek	Unit Base Flow	6.5	6	5.7	7.1	18	61	84	42	26	21	14	8.6

Source: Modified from Table 6-1 in Appendix 7-B

24.8.1.1 Effects of Typical Surface Water Flow

The Project has been designed to accommodate, at a minimum, the typical hydrological regime in the Project area. Therefore, there are no predicted effects of typical flow patterns (Table 24.8-3).

24.8.1.2 Mitigation Measures for Typical Surface Water Flow

Due to the specifications of Project design, no additional mitigation measures are required to address potential effects of a typical hydrological regime.

24.8.2 High Flows and Floods

The greatest risks associated with stream flows are those related to flooding, including flooding as a result of ice jams. An understanding of flood potential is an important consideration in the Project area. Floods in BC are typically produced through two main mechanisms that could cause high-flow events at the Project:

- Rapid snowmelt during freshet conditions in spring and early summer; and,
- Rain falling on melting snow during freshet conditions in spring and early summer, or during early winter.

Table 24.8-3: Surface Water Flow Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	Typical Flow • None	NA	NA	NA	NA
	High Flow and Floods • Erosion and sedimentation; mass wasting • Delay of materials and personnel if access to mine site is limited • Damage to river crossing structures, including bridges and culverts • Ice jams blocking water flow • Rapid channel avulsion, and could cause damage to any infrastructure in the new channel. Can trigger mass wasting, when stream beds undercut steep banks • Road closures caused by excess water on the road surface, erosion of the road surface, damage to stream crossings, or debris blocking the roads	Moderate to High	Moderate	Low to Moderate	• Major bridges and culverts designed to a 1 in 100 return period • Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Frequent monitoring of bridges and culverts for icing or debris blockage • Follow relevant management plans (e.g., Site Water Management, Access Management)
	Low Flows • None	NA	NA	NA	NA
Surface Infrastructure	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • Water damage to infrastructure • Foundations compromised	Moderate to High	Low	Low	• Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Follow relevant management plans (e.g., Site Water Management, Access Management)
	Low Flows • Reduction in water available for use in process and operations resulting in slowed production	Low	Low	Low	• Efficient process design that incorporates water reuse and recirculation to minimize the need for external water sources.

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Tailings Management Facility	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • Inundation in the TMF, potentially causing an overtopping of the TMF or failure of the TMF embankment • Ice jams compromising normal operation	Moderate to High	Low	High to Severe	• The TMF capacity is designed to store up to 2 million tonnes of tailing, process water, stormwater, and freeboard • Diversion ditches and collection ponds sized for 1 in 200 year 24-hr precipitation event. • TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines* • Follow relevant management planes (e.g., Site Water Management, Tailings Management and Emergency Response Plan) • Dam Breach Assessment • The TMF is designed for an Inflow Design Flood of 1 in 100 years
	Low Flows • None	NA	NA	NA	NA
Access Corridor	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • Erosion and sedimentation • Damage to equipment or infrastructure • Ice jams blocking water flow	Moderate to High	Moderate	Low	• Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Follow relevant management plans (e.g., Site Water Management, Access Management)
	Low Flows • None	NA	NA	NA	NA
Water Management Infrastructure	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • increased repair and maintenance of infrastructure	Moderate to High	Low	Low	• Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Follow relevant management plans (e.g., Site Water Management, Access Management)
	Low Flows • Reduction in water available for use in process	Low	Low	Low	• Efficient process design that incorporates water reuse and recirculation to minimize the need for external water sources

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Underground Workings	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • Potential increase in shallow groundwater infiltration rates	Low to Moderate	Low	Low	• Sufficient pump capacity will be available to dewater underground areas
	Low Flows • None	NA	NA	NA	NA
Utilities	Typical Flow • None	NA	NA	NA	NA
	High Flows and Floods • Erosion near transmission line towers could destabilize foundations • Flooding near back-up diesel generators removing backup power supply, thereby reducing operational effectiveness	Moderate to High	Low to Moderate	Low	• Back-up generators will allow security of electricity supply during maintenance or failure • Non-contact water diversion channel designed for the 1 in 5-year peak flow. • Weather monitoring program • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Follow relevant management plans (e.g., Site Water Management, Access Management)
	Low Flows • None	NA	NA	NA	NA

Unit peak flows were estimated to be higher in Goldslide Creek than in Bitter-Otter Creek for all return periods (Table 24.8-4). However, when the sizes of the catchment areas are considered, higher peak flows are expected in the Bitter-Otter Creek drainage. The probability of a given return period peak flow occurring within the six-year operational life of the Project ranged from 98.4% for a 2-yr return period to 3.0% for a 200-yr return period (Table 24.8-4).

Table 24.8-4: Unit Peak Flows and Peak Flows in the Project Area

Return Period (yr)	Goldslide Creek		Bitter-Otter Creek		Probability of Occurrence in Operational Life of Project (%) **
	Unit Peak Flow ($m^3/s/km^2$)	Peak Flow (m^3/s)*	Unit Peak Flow ($m^3/s/km^2$)	Peak Flow (m^3/s)	
200	2.09	3.36	1.03	277.33	3.0
100	1.91	3.08	0.94	253.10	5.9
50	1.74	2.75	0.84	226.17	11.4
25	1.56	2.51	0.75	201.94	21.7
10	1.32	2.13	0.63	169.63	46.9
5	1.12	1.80	0.53	142.70	73.9
2	0.82	1.32	0.39	105.01	98.4

Source: Table 5-10 in Appendix 7-B;
*Peak flow = Unit Peak Flow x Catchment Area.
**Calculations based on Bedient et al. 2012.

24.8.2.1 Effects of Floods

Floods can damage river crossing structures, including bridges and culverts (Table 24.8-3). Floods can also cause erosion and deposition of sediment, thereby potentially negatively affecting water quality. Floods can also cause rapid channel avulsion, and in turn, damage infrastructure in the new channel. They can also trigger mass wasting, when stream beds undercut steep banks.

Floods occurring within the Project area and along access roads can result in road closures caused by excess water on the road surface, erosion of the road surface, damage to stream crossings, and/or debris blocking the roads. Road closures under these conditions would be temporary and the road would re-open once water levels recede and structural checks of the crossings have been made.

Under the most extreme flood events there is the potential washouts of drainage structures (i.e., bridges, culverts, and cross-drains), which could, in turn, affect site haulage and operations, as well as transportation of concentrate from the Project area. Extreme surface water flows could cause inundation in the TMF, potentially causing an overtopping of the

TMF or failure of the TMF embankment. An analysis of a hypothetical TMF failure is provided in Appendix 23-A, Tailings Dam Breach Assessment.

24.8.2.2 Mitigation Measures for Floods

Flood mitigation measures can be broadly grouped into two categories: design measures and detection/response measures. Design measures that have been incorporated into Project design include (Table 24.8-3):

- Drainage swales and water-diversion ditches intended to manage the volume of water collected within the Project area, including:
  - Non-contact water diversion channel, designed for the 1-in-5-year peak flow; and,
  - Collection ponds (and associated diversion ditches), designed for a 1-in-200 year 24-hr precipitation event.
- The TMF capacity is designed to store up to 2 million tonnes of tailing, process water, stormwater, and freeboard;
- The TMF has a HIGH classification as defined by the CDA's *Dam Safety Guidelines*;
- Dam Breach Assessment;
- Road, bridge and culvert design, including:
  - All proposed structures (e.g., bridges and culverts) have been designed to safely accommodate flows associated with a 1 in 100-year flood;
  - All ditch water approaching a water crossing will be redirected away from the stream using cross-drain culverts and off-take ditches; where it is impractical to redirect ditch water away before entering a watercourse, armoured settling sumps will be constructed to reduce sediment delivery to the stream; and,
  - The Access Road has been designed to minimize sediment deposition and erosion, including appropriately reinforcing stream channels at road crossings to minimize sediment movement.

Detection/response measures for extremely high stream flow and flooding (Table 24.8-3) include:

- Monitoring weather forecasts to anticipate, and prepare for, large precipitation events; and,
- Slowing or stopping work if rainfall runoff is anticipated to cause unsafe working conditions.

To further minimize effects from flooding on the Project, IDM has developed management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring) including:

- Access Management Plan;
- Emergency Response Plan;
- Material Handling & ML/ARD Management Plan;
- Occupational Health and Safety Plan;
- Site Water Management Plan;
- Spill Contingency Plan; and,
- Tailings Management Plan.

24.8.3 Low Flows

24.8.3.1 Effects of Low Flows

Current hydrological modelling suggests that the Project will have a net positive precipitation budget (Table 24.8-5). In the unlikely event of a low-flow period, the primary effect of low flows on the Project is the potential limitation of water available for use in process and operations (Table 24.8-3). Water will be closely managed at the TMF and discharged as allowable to minimize the volume of impounded water. There will be no discharge from the TMF during periods of low flow.

Table 24.8-5: Annual Seven-Day Low Flow for Return Periods of 2, 5, 10, 25, 50, and 100 years

Location	Low Flows ($L/s/km^2$) per Return Period (yrs)						
	2	5	10	25	50	100	200
Bitter-Otter Creek	3.9	3.1	2.9	2.8	2.8	2.7	2.7
Goldslide Creek	4.8	4	3.6	3.3	3.1	2.9	2.8

Source: Modified from Table 5-9 in Appendix 7-B

24.8.3.2 Mitigation Measures for Low Flows

Storage capacity within the TMF has been designed to provide the necessary capacity when discharge is halted during periods of low flow (Table 24.8-3). The Project includes several design features related to water reclamation and recycling. For example, the current design allows for approximately 30% of process water is re-used and re-circulated within the plant.

To further minimize effects from low flows on the Project, IDM has developed management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring), including:

- Hazardous Materials Plan;
- Material Handling & ML/ARD Management Plan;
- Occupational Health and Safety Plan;
- Site Water Management Plan;
- Spill Contingency Plan; and,
- Tailings Management Plan.

24.9 Effects of the Environment - Geophysical Conditions

Geophysical phenomena are important drivers of the effects that the environment may have on the Project. Evidence of mass movement and soil erosion has been noted in the vicinity of the Project, including: rapid slope failure, slow mass movement, and gully erosion. The Geological Survey of Canada has created a relative seismic hazard rating map of Canada, which places the Project in a moderately high hazard area (Appendix 9-B: Geophysical Baseline Report).

Analysis of geophysical interactions was carried out at 1:20,000 for the Bitter Creek Watershed (LSA), and for 1:5000 for the Project footprint (Appendix 9-A). Mapping at a 1:20,000 resolution is adequate for identifying moderate- and high-magnitude geohazard events; detailed mapping using a resolution of 1:5,000 can also identify all magnitude of events, as well as conditions that may lead to a future geohazard event.

24.9.1 Landslides

Landslide hazards are widespread, with a total of 251 landslides and 92 avalanches identified within the Project RSA (Appendix 9-B). Of these slides, rapid mass movements (RMM) constitute 94.4% of the failures, while 5.6% are slow mass movements (SMM). In addition, the recently-glaciated nature of the Project area has oversteepened and undercut much of the Bitter Creek Watershed, an area that is a relatively active geologic environment (Appendix 9-B).

24.9.1.1 Effects of Rapid Mass Movements

The most common RMMs observed within the RSA include: rock falls, debris flows and slides (Appendix 9-B). Most RMMs are in areas of over steepened morainal deposits along valley walls recently exposed by glacial recession.

24.9.1.1.1 Rock Falls

Rock falls are typically limited to steeply-sloping bedrock exposures. The runout potential (and, therefore, potential effect) is relatively low in comparison to flows and slides, with most deposition occurring on slopes immediately below the initiation zone. However, the deposits provide an important source of debris within steep mountain creeks which may be entrained in a debris flow or flood event.

Rock falls occur throughout the Project area. Although most of the rock fall events have occurred outside of the Project footprint, the proposed Access Road does intersect with the location of historic events. Detailed survey and mapping at 1:5,000 of the Haul Road route (Appendix 9-A) revealed numerous minor rock fall events, including (but not exclusive to) the following km marks of the Access Road: 1.14 km, 1.45 km, 1.73 km, 2.26 km, 4.66 km, and 12.9 km. These are small-scale rock detachments from fractured bluffs up-slope with runout onto, or overtop of, the proposed road alignment.

Potential impacts of rock falls (Table 24.9-1) include: damage to transportation corridor, damage to mine infrastructure, and human injury.

24.9.1.1.2 Debris Flows and Slides

Material movements associated with debris flows and slides lack a defined rupture surface and typically initiate from unconsolidated morainal and colluvial deposits. These failures are most commonly observed at high elevations in regions with sparse or absent vegetation cover. However, debris falls are also noted in the lower valley along steep river banks and on colluvial slopes above the proposed Access Road and the TMF.

Debris flows have a longer runout distance than rock falls. The source areas are primarily located at high elevations within the steep mountain creek watersheds, on the steep valley sides and in the channels where loose debris has accumulated. Entrained material is transported through the major channels, and deposited in the lower valley on fans.

Debris flows are associated with drainage channels and streams. They are most likely to interact with the Project along the Haul Road, the TMF, and the Process Plant. Along the Haul Road, moderate debris flow hazards have been documented at Unnamed Creek 4, Radio Creek, Unnamed Creek 5, and Roosevelt Creek, and very high hazards have been documented at both Cambria Creek and Hartley Gulch. The Access Road has very high debris flow hazard at Otter Creek, Rio Blanco Creek, Unnamed Creek and Goldslide Creek.

Detailed 1:5,000 mapping along the proposed haul and Access Roads (Appendix 9-A) has identified numerous minor to moderate debris flow events, including the following km marks of the Access Road: 12.9 km, 16.8 km, 18.0 km, 18.5 km and 21.6 km. Potential impacts of debris flows and slides (Table 24.9-1) include damage to transportation corridor, damage to mine infrastructure, and human injury. All the documented debris flow events could potentially result in temporary closure of the road to remove minor debris deposited on the road surface, and subsequently, surface repair.

Table 24.9-1: Geophysical Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	Landslides • Damage to transportation infrastructure • Compromised worker safety • Delivery of materials and personnel interrupted if access to mine site is limited	High	Moderate	Moderate to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern (e.g., north bank of Bitter Creek above confluence of Radio Creek) • Regular maintenance of roads. • Worker safety and awareness training
	Snow Avalanches • Damage to transportation infrastructure • Compromised worker safety • Road blockage and movement restrictions	High	Low to Moderate	Moderate to High	• Limit construction in areas of high risk • Implementation of avalanche-management procedures • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Worker safety and awareness training
	Seismic Activity • Damage to transportation infrastructure • Compromised worker safety. • Delivery of materials and personnel interrupted if access to mine site is limited • Evacuation from site in case of emergency may be affected	Low to Moderate	Low to Moderate	Moderate to High	• Limit construction in areas of high risk • Transportation infrastructure has been engineered to standards appropriate for local seismic conditions • Follow relevant management plans (e.g., Emergency Response Plan) • Worker safety and awareness training
	Fluvial Hazards • Encroachment of Bitter Creek and erosion of banks along Access Road	High	Moderate	Moderate	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern (e.g., north bank of Bitter Creek above confluence of Radio Creek) •
Surface Infrastructure	Landslides • Damage to surface infrastructure • Compromised worker safety	High	Low to Moderate	Moderate to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Worker safety and awareness training
	Snow Avalanches • Damage to surface infrastructure • Compromised worker safety	High	Low	Moderate to High	• Limit construction in areas of high risk • Implementation of avalanche-management procedures • Ongoing maintenance (e.g., snow clearing, vegetation clearing, road and ditch repair) • Worker safety and awareness training
	Seismic Activity • Damage to surface infrastructure • Compromised worker safety	Low to Moderate	Low	Moderate to High	• Limit construction in areas of high risk • Surface infrastructure has been engineered to standards appropriate for local seismic conditions • Follow relevant management plans (e.g., Emergency Response Plan) • Worker safety and awareness training
	Fluvial Hazards • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Tailings Management Facility	Landslides • Damage to TMF infrastructure could lead to potential breach • Compromised worker safety	High	Low	Moderate to Severe	• Limit construction in areas of high risk • TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines* • Worker safety and awareness training
	Snow Avalanches • Damage to TMF infrastructure could lead to potential breach • Compromised worker safety	High	Low	Moderate to Severe	• Limit construction in areas of high risk • TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines* • Worker safety and awareness training
	Seismic Activity • Damage to TMF infrastructure could lead to potential breach • Compromised worker safety.	Low to Moderate	Low to Moderate	Moderate to Severe	• Limit construction in areas of high risk • TMF has a HIGH classification as defined by the Canadian Dam Association's *Dam Safety Guidelines*, which incorporates engineering standards appropriate to local seismic conditions • Project design incorporates a Maximum Credible Earthquake with a horizontal PGA of 0.120 g. • Worker safety and awareness training
	Fluvial Hazards • None	NA	NA	NA	NA
Access Corridor	Landslides • Damage to surface infrastructure • Compromised worker safety	High	Low to Moderate	Low to High	• Limit construction in areas of high risk • Access corridor has been engineered to standards appropriate for local conditions (e.g., addressed slope stability, and prescribed stable cut slope angles for gravel deposit) • Worker safety and awareness training
	Snow Avalanches • Damage to surface infrastructure • Compromised worker safety	High	Low to Moderate	Low to High	• Limit construction in areas of high risk • Implementation of avalanche-management procedures • Worker safety and awareness training
	Seismic Activity • Damage to surface infrastructure • Compromised worker safety • Evacuation from site in case of emergency may be affected	Low to Moderate	Low to Moderate	Moderate to High	• Limit construction in areas of high risk • Access corridor has been engineered to standards appropriate for local conditions. • Project design incorporates a Maximum Credible Earthquake with a horizontal PGA of 0.120 g. • Follow relevant management plans (e.g., Emergency Response Plan) • Worker safety and awareness training
	Fluvial Hazards • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Water Management Infrastructure	Landslides • Damage to water management infrastructure • Compromised worker safety	High	Low	Moderate to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Worker safety and awareness training
	Snow Avalanches • Damage to water management infrastructure • Compromised worker safety	High	Low	Moderate to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Worker safety and awareness training
	Seismic Activity • Damage to water management infrastructure • Compromised worker safety.	Low to Moderate	Low	Moderate to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Project design incorporates a Maximum Credible Earthquake with a horizontal PGA of 0.120 g. • Worker safety and awareness training
	Fluvial Hazards • None	NA	NA	NA	NA
Underground Workings	Landslides • None	NA	NA	NA	NA
	Snow Avalanches • None	NA	NA	NA	NA
	Seismic Activity • Subsidence and cave-ins	Low to Moderate	Low to Moderate	High to Severe	• Underground workings have been engineered to standards appropriate for local seismic conditions • Project design incorporates a Maximum Credible Earthquake with a horizontal PGA of 0.120 g. • A seismicity measurement system will be installed to continuously monitor the inelastic response of the rock mass to underground mining. • Follow relevant management plans (e.g., Emergency Response Plan) • Worker safety and awareness training
	Fluvial Hazards • None	NA	NA	NA	NA

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Utilities	Landslides • Damage to surface infrastructure • Electrical supply failure • Compromised worker safety	High	Low	Low to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Backup generators to allow security of supply during maintenance or failure • Worker safety and awareness training
	Snow Avalanches • Damage to surface infrastructure • Electrical supply failure • Compromised worker safety	High	Low	Low to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Backup generators to allow security of supply during maintenance or failure • Worker safety and awareness training
	Seismic Activity • Damage to surface infrastructure • Electrical supply failure • Compromised worker safety	Low to Moderate	Low to Moderate	Low to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Backup generators to allow security of supply during maintenance or failure • Worker safety and awareness training
	Fluvial Hazards • Damage to surface infrastructure • Electrical supply failure • Compromised	High	Low	Low to High	• Limit construction in areas of high risk • Implement engineering improvements in areas of concern • Backup generators to allow security of supply during maintenance or failure • Worker safety and awareness training

24.9.1.2 Effects of Slow Mass Movements

SMMs represent a minority of the landslides identified in the Project RSA (Appendix 9-B). Landslide types in this group include slow rotational sliding in unconsolidated material or bedrock, as well as lateral spreading in bedrock. Failures in this class may be well vegetated due to the slow rate of activity.

Appendix 9-B identifies SMM events that could interact with the Project above and to the east of the proposed TMF, as well as along a single location along the proposed Access Road. The SMM event located above the TMF was investigated in detail in the field during the 1:5,000 mapping (Appendix 9-A). It was identified as a massive active failure scarp on the east abutment, extending 800 m from upstream toe of embankment to Otter Creek, comprising sandy silt, overburdened along minor amounts of clay and gravel till with cobbles. Small landslide tracks extend off the scarp and down into the TMF. No indication of larger-scale slope SMM was identified.

Detailed 1:5000 mapping (Appendix 9-A) has shown little interaction of SMM with the proposed access and haul roads. SMM was identified at Km 1.7 along the Access Road, where surficial materials, consisting of medium and coarse-grained colluvial veneers, were observed to demonstrate slow downward creep over an impermeable bedrock substrate.

Potential impacts of SMMs (Table 24.9-1) include: damage to transportation corridor, damage to mine infrastructure, and human injury.

24.9.1.3 Mitigation Measures for Landslides

Landslide mitigation measures can be broadly grouped into two categories: design measures and detection/response measures. Design measures that have been incorporated into Project design include (Table 24.9-1):

- Limiting construction of Project infrastructure in high-risk locations;
- Where avoidance of high-risk locations was not feasible, additional design considerations included:
  - Implementing road design standards to minimize water diversion (i.e., runoff) onto areas of steep surficial or unconsolidated sediment;
  - Roadside ditch design to capture rock fall on upslope sides of roads; and,
  - Additional armouring of watercourse crossing structures.

Examples of detection/response measures include:

- Worker safety and awareness training;
- Development of comprehensive management plans (e.g., Emergency Response Plan);

- Monitoring weather forecasts to anticipate and prepare for large precipitation events; and,
- Regular maintenance of infrastructure in high-risk areas.

24.9.2 Snow Avalanches

Based on an inventory within the terrain stability mapping area (Appendix 9-B), there is a total of 92 avalanches covering approximately 2,610 ha: 29 major avalanches (509 ha), 45 mixed major and minor avalanches (1,719 ha) and 18 minor avalanches (388 ha).

Snow avalanche processes are common along the steep hillslopes of the Bitter Creek valley, as well as the valley sides and channels of the major tributary creeks. Avalanche risk may exist for the valley wall just above the north entrance to the access corridor tunnel and, in particular, above the adjacent road section. Portions of this area are 50% in slope and are subject to localized movement of fractured and frost-affected bedrock and seasonally frozen soil.

Snow avalanches are very common along the entire length of Bitter Creek, and will interact with the Haul and Access Road at numerous locations. Mapping at the 1:5,000 resolution (Appendix 9-A) identified existing avalanche tracks along the proposed haul road at the following km marks of the Access Road: 2.9 km, 3.4 km, 4.0 km, 4.3 km, 4.7 km, 6.6 km, 7.5 km, 9.5 km, 15.4 km, 17.4 km, and 17.6 km. Avalanches will also interact with the proposed TMF and all infrastructure at the Mine Site.

24.9.2.1 Effects of Snow Avalanches

Avalanches have the potential to damage infrastructure and facilities and pose hazards to workers (Table 24.9-1), including injury or death. Avalanches occurring along roadways could be capable of severely damaging vehicles, injuring occupants, and interrupting the flow of traffic, especially during storms, when helicopter-based avalanche control is not feasible. Potential effects of avalanches occurring near transmission lines or towers could include damage to the infrastructure or interruption of power service.

24.9.2.2 Mitigation Measures for Snow Avalanches

Avalanche management is an integral part of winter operations (Table 24.9-1). Snow-pack monitoring and controlled blasts will help protect workers and reduce the risk of damage to facilities and infrastructure. The north entrance to the access corridor tunnel will require specific management strategies. IDM has an established avalanche management program that has been in effect throughout the exploration period of the Project. This program includes appropriate avalanche training and safety equipment provided to employees and contractors who are working in areas with avalanche risk. Approved check-in and work procedures are to be followed at all times while operating in these areas.

24.9.3 Seismic Activity

The Pacific and North America plate boundary off the west coast of British Columbia is a complex system of faults capable of producing very large earthquakes (e.g., in 1949: Richter scale - 8.1 magnitude). The best known active fault in the greater Stewart region is the Queen Charlotte Fault, a strike-slip (or transitional [left-right]) fault, located approximately 400 km southwest of Red Mountain. Historical records indicate that five large earthquakes (i.e., larger than Richter scale - 7.0 magnitude) have been centred on the Queen Charlotte Fault area since 1920 (Appendix 9-B).

The National Building Code of Canada seismic source model places Stewart in Zone 2 (Low) for peak ground acceleration (PGA) and Zone 4 (Moderate) for peak ground velocity, on a Risk Zone scale of 1 (low risk) to 6 (high risk). A site-specific seismic hazard assessment was carried out using the Cornell method incorporated in the McGuire program “RISKLL,” and ground motion attenuation relationships. This analysis (Table 24.9-2) indicates that the Project is in a region of moderate seismic risk. Seismic events occurring in the earthquake-prone zone, which runs along the length of the Coast Mountains, may result in ground motion in the Project area.

Table 24.9-2: Exceedance Probability, Return Period, and Peak Ground Acceleration for Seismic Events in the Project Area

Annual Probability of Exceeding	Return Period (years)	Peak Ground Acceleration (g)	Peak Ground Velocity (cm/sec)
0.05	20	0.021	4.0
0.01	100	0.046	10.0
0.005	200	0.061	13.2
0.0021	476	0.083	18.2
0.001	1,000	0.104	23.0
0.0005	2,000	0.126	28.0
0.0001	10,000	0.188	41.9

Source: JDS (2014) Preliminary Economic Assessment for the Red Mountain Gold Project. Prepared for IDM Mining Ltd.

24.9.3.1 Effects of Seismic Activity

The two primary effects of seismic activity are damage to Project infrastructure and compromised worker safety (Table 24.9-1). The potential effects are largest near the TMF and within the underground workings.

24.9.3.2 Mitigation Measures for Seismic Effects

An important means of mitigating potentially-harmful seismic events is in the engineering design of the Project (Table 24.9-1). The Maximum Design Earthquake (MDE) is the earthquake expected to produce the highest degree of shaking in the Project area. The Maximum Credible Earthquake (MCE) is the largest earthquake that may be possible under the known tectonic conditions, given available geologic and seismic data. The MCE parameters incorporated into Project design reflect a horizontal PGA of 0.120 g.

The crown pillar will be mined using a combination of drift-and-fill and longhole stoping to mine in close proximity to the surface. The crown pillar will be mined at the end of the mine life to minimize the effects of subsidence on the operation. The planned drift-and-fill excavations have a minimum pillar thickness of 12.5 m and longhole stoping will create a 20 m thick crown pillar. The crown pillar falls within the Red Domain based on the geotechnical domain classification (Section 6.1, Appendix 1-E). The crown pillar was assessed using the Scaled Crown Pillar method to determine the short- and long-term stability. The crown pillar falls within Classes A to C (Figure 7.12, Appendix 1-E) indicating limited stand-up time. In order to achieve long-term crown pillar stability, crushed rock fill will be used to tightly backfill the drift-and-fill and long-hole excavations. Based on the current mine design, the crown pillar is expected to be temporarily stable and long-term stability will be achieved through tight backfilling of excavations.

A seismic event of any significance would constitute an emergency and the Project's Emergency Response Plan (Chapter 29) will include stipulations related to mine rescue. The plan will ensure that there are always trained first response personnel on site when there are workers active underground. The number and type of first responders will depend on the number of workers employed at the various Project work sites. There will also be personnel on site trained in first aid, firefighting, mine rescue, and hazardous material handling and spill remediation. Appropriate emergency equipment will be made available on site and kept in good working order. Site infrastructure will be in areas that avoid or minimize exposure to weak, unconsolidated soils or soils that are assessed to be potentially liquefiable, where practical. All structures will be thoroughly assessed after seismic events for stability and integrity.

24.9.4 Fluvial Hazards

24.9.4.1 Effects of Channel Change

Bitter Creek presents several hazards to the proposed Access Road primarily via lateral erosion and flood events below the Cambria Creek crossing (Table 24.9-1). Channel change detection has identified a few locations where Bitter Creek is migrating towards the Access Road and actively eroding into the north bank. One of the most hazardous sections, where the proposed Access Road is slated to follow (i.e., between Radio Creek and Unnamed Creek 3), has been washed out in a number of places, due to lateral erosion by Bitter Creek. At Radio Creek, the right bank is underlain by glaciolacustrine silts and clays which are actively failing as material is removed by the river at the toe of the slope (Appendix 9-B).

24.9.4.2 Effects on Water Crossings

The Access Road is exposed to hydrogeomorphic processes in the form of debris floods or debris flows at 15 water crossing locations. There is potential for undesired consequences to the Project at 11 of these locations (Appendix 9-A), including damage to the surface of the road and vehicles, injuries to drivers and construction workers, and disruption to the mine access, resulting in Project delays (Table 24.9-1).

24.9.4.3 Mitigation Measures for Fluvial Hazards

Two primary mitigation measures (Table 24.9-1) for fluvial hazards were incorporated in the Project design: careful routing of the Access Road to avoid areas of high risk to the greatest extent possible, and designing all water-crossing features to 1-in-100-year peak flow conditions. The latter measure includes increasing armouring (among other measures) at key locations along the route.

24.9.5 Summary of Geohazard Mitigation Measures

In addition to the geohazard mitigation measures discussed previously in this section, IDM has developed relevant management plans that will be followed during the life of the Project (Volume 5 Part E – Management Plans and Monitoring), including:

- Access Management Plan;
- Emergency Response Plan;
- Erosion and Sediment Control Plan;
- Hazardous Materials Management Plan;
- Material Handling & ML/ARD Management Plan;
- Occupational Health and Safety Plan;
- Site Water Management Plan;
- Spill Contingency Plan;
- Tailings Management Plan;
- Terrain and Soil Management Plan; and
- Waste Management Plan.

24.10 Wildfires

The characterization of forest health and fire history aids in predicting fire frequency and severity. Natural disturbance frequencies and types have been identified for ecosystems across BC, and five classes have been created and assigned to Biogeoclimatic Ecosystem Classification (BEC) zones. Based on the ecosystems present within the Project LSA, the Project falls within the natural disturbance type (NDT) classifications of NDT1 (Rare Stand Initiating Events: 1-in-250-350 years) and NDT5 (Alpine Tundra and Subalpine Parkland: no predicted frequency) (BC Environment 1995).

The BC Government Wildfire Management Branch maintains a spatial database of fires; this database (available at: http://www2.gov.bc.ca/gov/content/safety/wildfire-status/wildfirestatistics) does not indicate the occurrence of any forest fires in the immediate vicinity of the Project. However, wildfires have occurred near Meziadin Junction in 1999, 2000, 2007, 2008, 2009, 2013, and 2015.

Based on the wildfire record and the NDTs within the Project area, ignition potential and wildfire probability are considered low. The region receives substantial precipitation throughout the year and snow typically remains well into the growing season.

24.10.1 Effects of Wildfires on the Project

The effects of wildfires on the Project primarily involve damage to Project infrastructure and potential effects to human health and safety (Table 24.10-1). Fire could harm individuals and smoke could result in respiratory issues. Fire along the Access Road could also affect egress for workers using the road. Alternative wildfire evacuation planning that considers multiple egress points is critical to ensure mining personnel safety. A wildfire could also have secondary effects related to the loss of surface vegetation cover in the local catchment area. Increased amounts of runoff with elevated levels of total suspended solids would report to the diversion channels, requiring increased maintenance. Additionally, slope stability may be compromised by vegetation loss.

Linear infrastructure (e.g., powerlines and transmission lines) is vulnerable to damage by wildfire. These features also have the potential to act as an ignition source in the event of a flash-over from a tree strike, or growth of vegetation into the clearance zone around energized conductors or other components.

24.10.2 Mitigation Measures for Wildfires

Mitigation measures for wildfire involve preparation, prevention, and response (Table 24.10-1). Key measures to be implemented at the Project include:

- Worker awareness, response, and safety training (e.g., designated permanent personnel will receive Provincial S100 Basic Fire Suppression and Safety training);
- Ensuring worker access to fire protection and fire-fighting equipment (e.g., water pumps, Pulaskis) in strategic locations on site;
- Implementation of a hazard-tree inspection program along the powerline to ensure that the right-of-way is maintained in a condition that reduces the risk of tree failure;
- Vegetation maintenance around surface infrastructure;
- Development and communication of evacuation plan (within the Emergency Response Plan), including ‘safe haven’ sites, should evacuation not be possible;
- Proper handling and storage of flammable materials;
- Provision of back-up generators in case of powerline damage or failure;
- Monitoring of provincial fire alerts; and,
- Compliance with all relevant aspects of the BC *Wildfire Act*.

Table 24.10-1: Wildfire Risks and Mitigation Measures

Project Area Affected	Risk to Project	Likelihood of Condition that Produces Risk	Likelihood of Incident Occurring	Consequence	Mitigation Measures
Transportation Infrastructure	• Compromised health concerns due to fire or smoke • Loss of or damage to infrastructure and facilities. • Loss of vegetation could affect long-term slope stability, thereby comprising road integrity	Low	Low	Low to Moderate	• Proper maintenance of transportation corridors (i.e., regular monitoring and brushing) • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)
Surface Infrastructure	• Compromised health concerns due to fire or smoke • Loss of or damage to infrastructure and facilities • Fuel tank explosion	Low	Low	Moderate to Severe	• Proper vegetation maintenance around surface infrastructure (i.e., maintenance of a low hazard condition) • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)
Tailings Management Facility	• Loss of or damage to infrastructure	Low	Low	Low	• Proper vegetation maintenance near the TMF • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)
Access Corridor	• Compromised health concerns due to fire or smoke • Loss of or damage to infrastructure and facilities	Low	Low	Low to Moderate	• Proper vegetation maintenance in vicinity of access corridors (i.e., maintenance of a low hazard condition) • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)
Water Management Infrastructure	• Loss of or damage to infrastructure	Low	Low	Low to Moderate	• Proper vegetation maintenance around water management infrastructure (i.e., maintenance of a low hazard condition) • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)
Underground Workings	None	NA	NA	NA	NA
Utilities	• Loss of or damage to transmission infrastructure and facilities • Diesel generators could pose a significant risk for explosion if ignited	Low	Low	Moderate to Severe	• Proper maintenance of transmission line corridors (i.e., regular monitoring and brushing) • Use of backup generator to avoid power outage • Worker training and awareness • Monitoring of fire alerts • Follow relevant management plans (e.g., Emergency Response Plan)

24.11 Climate Change

24.11.1 Climate Change Regulatory Context

The BC government has drafted an Adaptation Strategy (BC MOE 2010) to address climate change. The province is also currently drafting policy regarding climate change adaptation and how to integrate climate change adaptation into other regulatory and guidance documents.

The mining sector in BC has been identified by the BC Regional Adaptation Collaborative program (Phase 2) as having some unique climate change risks, and some risks shared with other natural resource industries. In addition, the mining sector needs “access to the best climate change information available by region” to evaluate risks and weigh adaptation options (Fraser Basin Council 2015). As yet, there is no specific legislation applicable to adapting Project components to climate-change risk. Infrastructure design for water structures in BC is currently regulated for a wide variety of meteorological risk factors (i.e., temperature extremes, storms, and floods), but these provisions are based on analyses of past climate and so do not currently explicitly address climate change projections that may differ from past ranges (APEGBC 2012).

The report *Incorporating Climate Change Considerations in the Environmental Assessment: General Guidance for Practitioners* (CEA Agency 2003) was used to guide the assessment of effects of climate change on the Project. This report recommends that potential risks to the Project, providing they do not affect the public, public resources, the environment, other businesses or individuals, may be borne by the Project proponent and are not generally a concern for jurisdictions. It is believed that climate change effects on the Project will not increase risks to the public, public resources, the environment, other businesses, or individuals. However, this chapter discusses the likely effects of climate change on the Project, and related mitigation measures, in a manner that should allow for informed decision-making.

24.11.2 Past and Projected Climate Change in the Project Region

Global climate is changing and will continue to change in the future (APEGBC 2010; AMS 2012; BCWWA 2013a; IPCC 2013). Weather extremes have become more intense and frequent, and will continue to do so, although confidence in the direction and magnitude of change in precipitation is lower than that of air temperature (AMS 2012).

As noted previously, several cyclical climatic patterns influence the climate of the Project area, including the PDO and ENSO. The effects of global warming on these patterns are not well understood. However, in a review of GCM results from the IPCC AR5 (IPCC 2013) report, it was determined that, overall, the climate of the Project area is expected to warm and experience more precipitation.

24.11.3 Project-related Adaptation and Mitigation Measures

Climate change impacts are difficult to predict by extrapolating from historical measurements and return periods (Appendix 12-A; BCWWA 2013b); however, by analyzing extreme return-period events for temperature, precipitation, and stream flow, climate change impacts have been, and continue to be, implicitly considered in the Project's engineering design. As noted above, most extreme weather in BC is related to ENSO conditions. Thus, by considering extreme events, the direct impacts of climate change on current patterns are accounted for within the scope of the assessment (Table 24.11-1).

The Project's sensitivity to climate change evaluated in the context of interactions between predicted climate changes and individual Project components. In this assessment, a qualitative ranking of sensitivity was implemented that incorporated the likelihood of a change in a given interaction between environmental and Project components, the potential risk or consequence to the Project, and subsequent effects on the environment. All three of these factors were evaluated in the previous sections (Section 24.5 to 24.10). Sensitivity ranks were None (i.e., no consequence associated with projected change, regardless of likelihood), Low (i.e., low likelihood and low consequence), Moderate (i.e., Moderate likelihood or Moderate consequence), and High (i.e., High likelihood or High consequence).

24.11.3.1 Precipitation

Project components will be designed to accommodate rain and snow and will have management plans in place for handling these two forms of precipitation. It is possible that high-precipitation events will increase in frequency and magnitude (PCIC 2011). The transportation corridor has moderate potential sensitivity to climate change effects on precipitation (ranked as Moderate). Existing mitigation measures are expected to accommodate the potential increases in precipitation during the operational life of the Project.

24.11.3.2 Temperature

Project components can withstand a wide range of air temperatures; therefore, no sensitivities are expected, including to increases in extreme heat conditions. The expected milder winters in the Project area would likely increase the frequency of freeze-thaw cycles and their attendant negative effects on roads and foundations. As such, most Project roadways and transportation corridors have Low to Moderate sensitivities to increased freeze-thaw cycles during the operational life of the Project. The exceptions are the underground workings and the TMF, which, due to location and robust design, are not expected to yield any negative interactions with potential temperature-related changes.

24.11.3.3 Surface Water Flow

The Project will likely experience long return-period stream flows for both dry and wet conditions. Given the relationship between the PDO and ENSO, it is probable that the Project will experience both extreme low flows (i.e., PDO negative, La Niña) as well as extreme high flows (i.e., PDO positive, El Niño). Water management systems within the Project area have been designed to withstand floods with long return periods. Access and site roads will have the most exposure and will likely require increased maintenance during high precipitation and stream flow years. The transportation and access components are ranked as Moderate in terms of climate sensitivity for the Project, due to increased stream flow. All other Project components are ranked as having Low (or None) sensitivities to increased or decreased stream flow due to climate change during the operational life of the Project.

24.11.3.4 Geohazards

The projected increases in extreme precipitation and runoff in the Project area may lead to secondary effects of increased geohazard risks. Geohazard risks have been assessed and provisions have been made to mitigate those risks. Though the chances of a landslide occurring in a particular area may increase with changes in precipitation regimes, since there are already monitoring and mitigation systems in place for known geohazards, the change in the level of risk is considered Low during the operational life of the Project.

24.11.3.5 Wind

Project components will be designed to withstand extreme winds. The anticipated effects of climate change with respect to wind will likely be secondary effects. For example, wind is a primary component of evaporation: as wind increases, so too does evaporation. Thus, the likely effects of climate change on the Project will be increased evaporation of water in the TMF. A possible implication of this would be less water available for processing, although this potential effect would likely occur well beyond the life of the Project. However, the Project components are predicted to have Low (or None) sensitivities to increased or decreased wind velocities due to climate change during the operational life of the Project.

24.11.3.6 Wildfires

The Project area may experience increased probability of wildfires as a secondary effect of increased temperature. However, as the increase in temperatures will likely be accompanied by increases in precipitation, this increase may not be substantial. As such, all Project components have Low sensitivities to increased wildfire due to climate change during the operational life of the Project.

24.11.4 Climate Change Adaptation

Climate change adaptation is defined as: the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). This definition does not include climate change mitigation, which is the reduction in factors contributing to the magnitude and rate of change of climate change.

Planning for adaptation is difficult; however, Project planning and decision-making will take climate change into account, wherever possible. This includes the following activities: obtaining relevant climate information, assessing likely effects, considering infrastructure vulnerability, and adopting a cooperative approach with governments, stakeholders, and Aboriginal groups. Recommendations and position statements from relevant scientific literature, institutions, bodies (e.g., AMS 2012; IPCC 2013), and professional associations (e.g., APEGBC 2010, 2012; BCWWA 2013a,b) will be followed, wherever applicable or possible.

Several Project components were identified as having a Moderate sensitivity to climate change effects, most notably, transportation and access infrastructure. These components will be monitored throughout the life of the Project.

24.11.5 Climate Change Conclusion

None of the identified and evaluated potential effects of the environment on the Project are expected to have ancillary effects on identified VCs nor ICs that have not already been evaluated in the individual VC/IC effects assessment chapters. For example, current Project design criteria for buildings and roads are considered sufficient to withstand heavy and prolonged precipitation. In addition, water will be closely managed at the TMF and discharged, as allowable, to minimize the volume of impounded water. Similar measures have been or will be implemented to minimize the consequence to the Project of effects of lightning, snowstorms, low precipitation, extreme temperatures, freeze-thaw cycles, wind, surface water flow variability, geophysical instability (including landslides, snow avalanches, seismic activity, and fluvial hazards), and wildfires. Adopting strategies that minimize the effects of the environment on the Project, by extension, in turn, minimize any potential ensuing risks to identified VCs and ICs.

Similarly, the Project is not expected to be unduly affected by climate change factors given proposed Project design, construction and operations considerations. By analyzing extreme return-period events for temperature, precipitation, and stream flow, climate change impacts have been, and continue to be, implicitly considered in the Project’s design and management strategies. Therefore, climate change-driven environmental interactions with the Project are not expected to affect identified VCs and ICs in ways that have not already been evaluated in the individual VC/IC effects assessment chapters.

Table 24.11-1: Sensitivities of Project Infrastructure to Potential Climate Change Effects

Project Areas Affected	Precipitation		Air Temperature			Surface Water Flow			Other		
	Increase in Mean Climate Normal	Increased Precipitation	Increase from Mean Climate Normal	Freeze-thaw Cycles	Extreme Heat	Increase from Current Normal	High Flows and Flooding	Low Flows	Increased Geohazards	Increased Wind Velocity	Increased Wildfires
Transportation Infrastructure	Moderate	Moderate	None	Low to Moderate	None	Low to Moderate	Moderate	None	Low	Low	Low
Surface Infrastructure	Low to Moderate	Low to Moderate	None	Low to Moderate	None	Low	Low	None	Low	Low	Low
Tailings Management Facility	None	None	None	None	None	None	None	None	Low	None	Low
Access Corridor	Low to Moderate	Low to Moderate	None	Low to Moderate	None	Low	Moderate	None	Low	None	Low
Water Management Infrastructure	Low to Moderate	Low to Moderate	None	Low to Moderate	None	Low	Low	Low	Low	None	Low
Underground Workings	None	None	None	None	None	None	Low	None	Low	None	Low
Utilities	Low to Moderate	Low to Moderate	None	Low to Moderate	None	Low	Low	Low	Low	Low	Low

24.12 References

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