23. EFFECTS OF THE ENVIRONMENT ON THE PROJECT

23.1. INTRODUCTION

This chapter assesses the potential for the environment to affect the Kemess Underground Project . In accordance with the Application Information Requirements (AIR; BC EAO 2016), 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.

Consideration of any changes to the proposed Project that may be caused by the environment is required to be assessed under section 19(1)(h) of the *Canadian Environmental Assessment Act, 2012* (CEAA 2012).

The chapter is organized as follows:

- Section 23.2 describes the methodology for the assessment;
- Section 23.3 considers climate and meteorology, including precipitation, air temperature, and wind;
- Section 23.4 considers surface water flows, including floods and low flows;
- Section 23.5 considers geophysical effects, including typical surface water flows, landslide geohazards, snow avalanches and seismic and volcanic activity;
- Section 23.6 considers lightening;
- Section 23.7 considers wildfires;
- Section 23.8 considers climate change;
- Section 23.9 describes the changes to the design of the Project resulting from the effects of the environment on the Project; and
- Section 23.10 provides a conclusion.

23.2. METHODOLOGY

As per the AIR (BC EAO 2016), the likelihood (probability) and consequences (severity) of the effects of the environment on the Project are evaluated. Probability and consequence definitions used in this assessment are presented in Tables 23.2-1 and 23.2-2, respectively.

Table 23.2-1. Attributes of Probability of Effects of the Environment on the Project

Probability Rating	Quantitative Threshold	Description of Threshold
Negligible	< 0.1% chance of occurrence; 1:1000 years	Doubtful it could happen
Low	0.1 – 1% chance of occurrence; 1:1000 – 1:100 years	Unlikely to happen
Moderate	1 – 10% chance of occurrence; 1:100 – 1:10 years	It could happen
High	10 – 50% chance of occurrence; – 1:10 - 1:2 years	Has or probably will happen
Very high	> 50% chance of occurrence; 1:2 years or more	Will happen

Table 23.2-2. Consequence Severity of Effects of the Environment on the Project

Category Rating	Consequence on Project Component(s)
Negligible	No measurable impact; negligible to low level repairable damage to minor structures; no stoppage in Project activity; no injury to Project employees
Low	Minor impact on Project component or activity; low-level repairable damage to infrastructure; no stoppage in Project activity; no injury to Project employees
Moderate	Moderate impact on Project component or activity; substantial damage to infrastructure; potential minor stoppage in Project activity; minor injury to Project employees
High	Significant 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
Severe	Catastrophic impact on Project component or activity; major damage to significant infrastructure; Project forced into early closure; at least one fatality among Project employees

23.3. CLIMATE AND METEOROLOGY

23.3.1. Climate

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.

23.3.1.1. Regional Climate

The Project is located in the Peace River Regional District in north-central British Columbia (BC) near Thutade Lake. The Project area is located between approximately 1,200 m and 1,800 metres above sea level (masl) and is characterized by warm dry summers and cold wet winters. Temperature extremes in winter and summer range from approximately -35 °C to 25 °C respectively, with November through March being the coldest months. Mean annual precipitation is approximately 700 mm. Maximum snow-pack at the end of March at the Kemess South (KS) Mine site averages approximately 550 mm of snow water equivalent, i.e., the amount of water contained within the snow-pack.

The Project area can be roughly divided into three zones: the high U-shaped hanging valley of South Kemess Creek, the narrow valleys of Kemess Lake, North Kemess and Kemess Creeks (with numerous glaciofluvial terraces and aggregate deposits), and the broad valley outwash deposits of Attichika Creek. The Project is located between Attichika Creek (a tributary to Thutade Lake) and Attycelley Creek in the upper Finlay River watershed. The rivers ultimately drain northeast to the Peace River, east through the Athabasca-Mackenzie delta and into the Arctic Ocean.

Regional Climatic Patterns

The winter climate of the region is affected by the strength of the Aleutian Low, which is a low-pressure cell that forms in winter over the North Pacific Ocean and Aleutian Islands. The Aleutian Low migrates spatially along the coast of BC and Alaska and it 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).

The PDO is a measure of the difference in sea level air pressure between the Aleutian Low and the Hawaiian High pressure cell (Mantua et al. 1997). The PDO is characterized by positive phases (1925 to 1946, 1977 to 2005) and negative phases (1947 to 1976, 2005 to present). The phase and strength of the PDO have been shown to influence changes in precipitation affecting river flow, glacial mass balance, and salmon abundance throughout Oregon, BC, and Alaska (Dettinger et al. 1993; Mantua et al. 1997; Hodge et al. 1998; Bitz and Battisti 1999; Gedalof and Smith 2001; Neal, Walter, and Coffeen 2002).

The PDO was in a negative phase from approximately 1946 to 1976, shifting to a positive phase from approximately 1977 to 2005, when it transitioned back to a negative phase, where it has remained. 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). In practice, during a positive phase of the PDO there is a greater propensity of El Niño events to occur. Conversely, during a negative phase of the PDO there is a greater propensity of La Niña events. This temporal clustering of El Niño and La Niña events has substantial effects on regional hydroclimatology.

The ENSO phenomenon is a measure of difference in sea surface temperatures (SSTs) between northern Australia and the coastal upwelling zone off western Ecuador. The significance of this phenomenon is that the SST anomalies generated by ENSO migrate from the equator up the west coast of North America and eventually pool off the coast of BC and Alaska. These SST anomalies are spatially expansive and, off the coast of northern BC, reside directly below the Aleutian Low. As such, 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.

The significance of the PDO and ENSO for the Project area is how each manifests in air temperature, precipitation, and therefore stream flow conditions. For example, since positive phases of the PDO tend to result in clustered El Niño events, it can be expected that the extreme events commensurate with El Niños will also be clustered during positive phases of the PDO. Similarly, since 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 Niñas will also be clustered during negative phases of the PDO. This was evidenced during the last positive phases of the PDO, and specifically in the 1980s and 1990s when numerous clustered El Niño events were responsible for extreme precipitation events generally, including both rainfall and snowfall.

Changes to regional climatic patterns as a result of climate change are discussed in Section 23.8. The effects of changes to regional climate patterns on the Project are also summarized.

23.3.1.2. Local Climate

The Project has three meteorological stations: one near the formerly proposed Kemess North Project (Kemess North), one near the former Kemess South Mine open pit (Pit), and one near the existing Kemess South Tailings Pond dam (Dam). The monitoring program began when the Kemess North meteorological station was installed in January 2004, with its sensors mounted on a 3 m tripod. Sensors were also mounted on a tripod at the Pit meteorological station in December 2008. New sensors were installed in the fall of 2012 at the Kemess North and Pit meteorological stations. Additionally, a new 10-m station was installed at the Dam in April 2012. Long-term historical datasets from the Meteorological Services of Canada (MSC), a division of Environment Canada, are also summarized. Details of the meteorological station sensors and site layout are provided in the 2015 meteorological baseline report (ERM 2015).

Local climate in the Project area is summarized using data from three sources:

- **The on-site meteorological stations**. The data from the Kemess North, Pit and Dam meteorological stations provide site-specific information starting in 2004.
- **ClimateWNA (a computer program)**. ClimateWNA provides 30-year "climate normal" data for western North America on a 2.5 by 2.5 arcminute grid. ClimateWNA data are interpolated and adjusted for elevation effects based on gridded climatic datasets (from the Climate Research Unit and Global Historical Climatology Network; Wang et al. 2006; Wang et al. 2012).
- **Climate data from regional meteorological stations**. These data are used here to assess air temperature and precipitation extremes from stations close to the Project area. Data from these stations are also summarized in the 2014 meteorology baseline report (ERM Rescan 2014).

23.3.2. Precipitation

The Project area is characterized by warm, dry summers and cold, wet winters. However, during wet years it is common to see significant precipitation events during either the spring, mid-summer or autumn periods.

Mean annual precipitation (MAP) recorded at the Kemess North (1,600 masl) station between 2004 and 2013 was 749 millimetres (mm; ERM Rescan 2014). However, MAP figures as low as 398 mm (2013) and as high as 1,395 mm (2005) were recorded during this time.

Annual precipitation extracted from ClimateWNA for the 1981 to 2010 climate normal period predicts a MAP of 914 mm at the Project area (1,600 masl). MAP for the 1961 to 1990 climate normal period was slightly lower at a mean of 909 mm. ClimateWNA predicts that approximately 47% of the total annual precipitation falls as snow at the Project area based on the 1961 to 1990 and 1981 to 2010 climate normal periods. Further details are provided in Chapter 10, Surface Hydrology, of this Application.

Typical intensity, duration, and frequency of precipitation events in the Project area are low, and will not have substantial effects on Project infrastructure in the short term. However, over long time periods, and in the absence of proper maintenance, the cumulative effects from "typical" precipitation events could undermine the integrity of impoundments and mine waste storage facilities, cause erosion of roadways and sedimentation in drainage lines, and flooding of ditches and roadways. Access to and from the Project area and utility delivery could be affected.

23.3.2.1. High Precipitation (Storms)

Extreme weather events occur in many forms, including windstorms, thunderstorms, and heavy precipitation. Of the extreme weather events likely to affect the Project in the future, this section focuses on heavy precipitation (also referred to as intense or extreme precipitation), thunderstorms, and snow storms. Heavy precipitation occurs as a consequence of the variability in weather conditions caused by the PDO and ENSO.

Prolonged Wet Weather

Effects on the Project

High-magnitude rain and snow events are relatively infrequent in the Project area. However, 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. Precipitation-related effects could include damage to buildings, site infrastructure, and the 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 winter warm temperature cycles. These warm temperature cycles can act to increase the density of snow, and therefore the force on roofs, anchoring cables, covered walkways, etc. Greater potential for large snowfall amounts 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.

Mitigation Measures

Risks to the Project related to prolonged precipitation and subsequent mitigation measures are presented in Table 23.4-3, with flooding risks discussed in detail in Section 23.4, Surface Water Flows.

Current construction design criteria for buildings and roads are likely sufficient to withstand the expected increases in heavy precipitation. The existing camp, office and mill buildings that will be used have been standing since the KS Mine was commissioned almost two decades ago. The Kemess Underground (KUG) TSF will be designed, constructed, operated, closed and reclaimed according to the Canadian Dam Association's (CDA) Dam Safety Guidelines (Canadian Dam Association 2007

(Revised 2013)). 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 should be shovelled off roofs after heavy snowfalls to prevent roof collapse from excessive loads. The existing plant site and other buildings have been designed and constructed to withstand periods of heavy precipitation and any new structures will accord with such design. Section 24.15 Surface Erosion and Sediment Control Plan, and Section 24.16 Surface Water Management Plan describe these measures in detail.

To further minimize effects from prolonged wet weather on the Project, AuRico has developed environmental management plans (EMPs) that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan; Section 24.6 Environmental Emergency, Spill and Hazardous Materials Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

Rainstorms and Thunderstorms

Effects on the Project

The Project area is located in a zone that receives rainfall that is relatively low in frequency and intensity. During the typical rainfall periods, there would be little impact to Project operation. If rainfall intensity increases beyond historic norms, there may be increased disruption in Mine Site operation, including reduced speed of traffic along haul roads and access roads. Increased rainfall may also increase groundwater seepage and surface runoff that flows into proposed underground workings, which would increase dewatering requirements for these areas. Severe rainstorms in the Project catchments could trigger flooding events, especially if they were to coincide with freshet conditions. Flood effects and corresponding mitigation measures are presented in Section 23.4.2. 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. Landslide effects on the Project and corresponding mitigation measures are presented in Section 23.5.1.

Thunderstorms may also be accompanied by hail, lightning, and damaging winds. 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). Cases involving either slow-moving thunderstorms or a series of storms that move repeatedly across the same area (sometimes called train-echo storms) frequently result in flash flooding (UIUC Department of Atmospheric Sciences 1999).

Large hail from severe thunderstorms could damage building infrastructure, cause temporary blockages of diversion channels, and create unsafe working conditions. High-velocity winds related to thunderstorms could create waves in the KUG TSF, and could damage buildings, conveyor lines, and power lines. Access roads could also become blocked with downed trees. Lightning could cause forest fires (wildfires are discussed in Section 23.7) under dry conditions, or could damage infrastructure such as power lines. Thunderstorms within the region could also temporarily prevent air traffic, disrupting the mobilization of personnel to and from the Project area.

Mitigation Measures

Precipitation-related risks to the Project and subsequent mitigation measures are presented in Table 23.3-1, and flooding-related risks are discussed in detail in Section 23.4 Surface Water Flows.

To mitigate against damage to infrastructure or personnel as a result of rainstorms and thunderstorms, weather forecasts will be monitored for advanced warning of incoming thunderstorms to allow time for extreme storm preparation, such as securing buildings and equipment, mobilizing equipment to key areas for maintenance, and providing site personnel safe refuge. To help mitigate the 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.

Water management structures and tailing containment dams will be designed to meet CDA standards (Canadian Dam Association 2007 (Revised 2013)). Such purpose-designed structures and impoundments will provide strong resistance to extreme storm events and will protect against waves created by high-velocity winds. Access road stream crossings are designed for a 1:200 year flood (AMEC 2013).

To further minimize effects from rainstorms and thunderstorms on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan; Section 24.6 Environmental Emergency, Spill and Hazardou23-s Materials Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

Snowstorms

Effects on the Project

The Project area is subject to significant snowfall during the winter period (ClimateWNA). Consequently, severe winter snowstorms are possible. During the winter, typical snow-pack ranges from 150 to 200 cm at the Kemess North and from 90 to 150 cm at the Pit meteorological stations. High levels of snowfall could impede the movement of mobile equipment on the access roads and at the mine site. 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 an avalanche occurring. Further details on the potential effects and mitigation measures for avalanches are presented in Section 23.5.2.

Mitigation Measures

The effects of extreme snowfall have been considered in the design of site infrastructure and roads. The existing plant site and other buildings have been designed and constructed to withstand periods of heavy snowfall, and any new structures will accord with such design. Snow will be shovelled off roofs after heavy snowfalls, as needed, to prevent roof damage from excessive loads. Roadways will be cleared during or after snow events. Roadways will be repaired and maintained as needed. The diversion channels are designed to be wide enough for the purpose of channel maintenance, including debris and snow clearing. Ditches and culverts will be cleared of debris and monitored. Removal of excess snow from blast areas and the active areas of waste and ore stockpiles will be managed and scheduled to maintain safe working conditions while minimizing interferences with production.

To further minimize effects from snowstorms on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan; Section 24.6 Environmental Emergency, Spill and Hazardous Materials Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.15 Surface Water Management Plan. These EMPs are presented in Chapter 24 of the Application.

High precipitation risks to the Project and mitigation measures are presented in Table 23.3-1.

23.3.2.2. Low Precipitation (Drought)

Effects on the Project

Effects of low precipitation are more likely in the Project area compared to heavy precipitation. Low precipitation generally manifests as low stream flow (see Section 23.4). A significant reduction in the annual precipitation would reduce the runoff reporting to the KUG TSF and proposed underground workings, thus reducing the amount of water potentially requiring treatment. However, under drought conditions, the dilution capacity of the receiving environment would also be reduced, affecting the volumes which could be discharged from the KUG TSF, ultimately affecting the Project water balance. Prolonged periods of low precipitation could also increase the risk of wildfires (see Section 23.7) and reduce available process water for mill operations. Each of these components is discussed in its relevant section.

Mitigation Measures

Mitigation measures for the effects of low precipitation, and therefore low stream flow, on the Project are also identified in Section 23.4. In the case of an extreme drought and subsequent desiccation of surrounding vegetation, the risk of wildfires is increased. Mitigation measures for wildfires are discussed in Section 23.7.

To further minimize effects from low precipitation on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.11 Mine Waste, Tailings, and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

Table 23.3-1. Summary of High Precipitation Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Infrastructure effects: erosion, sedimentation, flooding. Access effects: reduced access to Project area and reduced productivity due to downed trees, snow drifts, damaged roads.	Low to Moderate	**Low impact -** Road damage/and or erosion from flooding would require increased maintenance to access various Project locations. Mobilization of personnel to and from the Project could be affected by downed trees, poor visibility or heavy snowfall that blocks mine access roads or makes driving unsafe, and/or thunderstorms in the region that temporarily affect air travel.	Early warning system (forecast monitoring). Snow clearing, roadway repair, ditch and culvert clearing.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities.	Flooding, erosion and sedimentation, snow loading leading to damage of infrastructure and reduced mine productivity.	Low to Moderate	**Moderate impact (from forest fire); Low impact otherwise -** Floods, large hail from severe thunderstorms and lightning that could cause forest fires could all cause damage to buildings and site infrastructure. **High impact -** Structural damage or possible roof collapse from excessive snow loads could cause damage to buildings.	Mitigation measures are discussed in Section 23.3.2.1
KUG TSF	Existing KS Mine open pit, East Dam.	Overtopping of KUG TSF or catastrophic failure of embankment.	Low	Catastrophic KUGTSF dam failure would have a **Severe impact** to the Project	Designed to meet all current CDA *Dam Safety Guidelines*. The TSF is designed for an Inflow Design Flood of 1:100 year 15-day snowmelt (winter and spring) and the 5-day probable maximum precipitation (summer).
Access Corridor	Tunnel, surface conveyor, power transmission line, underground dewatering pipeline.	Erosion, sedimentation, flooding.	Low	**Low impact -** Infrastructure damage/and or erosion would increase maintenance of corridor.	Construction of purpose-designed runoff collection ditches and sediment ponds.
Water management infrastructure	Water treatment plant (within the process plant), discharge pipelines, diversion infrastructure.	Erosion, sedimentation, flooding.	Low	**Low impact -** Heavy precipitation could cause sedimentation in drainage lines and flooding in ditches. Large hail from severe thunderstorms could cause temporary blockages of diversion channels.	Ditch and culvert clearing.
Underground workings	Declines, cave gallery, excavations to be created for underground activities.	Increased shallow groundwater seepage and flooding.	Low	**Low impact -** Increased rainfall could increase groundwater seepage and surface runoff that flows into proposed underground workings, which would increase dewatering requirements for these areas.	Purpose-designed dewatering pumping system. Clearing of snow from ventilation shafts.
Utilities	Power transmission line, backup diesel generators.	Interrupted power supply. Erosion at footings, damage due to downed trees leading to reduced mine productivity.	Low	**Moderate impact –** High-velocity winds and lightning related to thunderstorms could damage power lines and affect utility delivery.	Periodic monitoring and repair as needed. Backup generators to allow security of energy supply during maintenance or failure.

23.3.3. Air Temperature

Annual average air temperatures ranged from -2.2ºC (2009) to 2ºC (2010) at Kemess North, from -0.1°C (2011) to 2°C (2010) at the Pit, and was 0.3ºC in 2013 at the Dam meteorological stations. The coldest month was December 2008, when the mean minimum daily air temperature was -14.0ºC. The warmest month was July 2009, when the mean maximum daily air temperature was 13.2ºC (ERM Rescan 2014). Detailed climate information is provided in Chapter 7.1, Air Quality, of the Application.

23.3.3.1. Typical Air Temperature

The Canadian climate normals represent average climate variables (air temperature, precipitation, etc.) over a period of three decades for many cities across Canada. At the end of each decade, the Canadian government updates the climate normals and provides online access for public use. ClimateWNA[1] is a web-interface software tool developed by the University of British Columbia to provide online mapping tools for climate data. ClimateWNA uses the climate normal datasets (1961 to 1990, 1971 to 2000, and 1981 to 2010) and provides spatially explicit interpolation for any point in BC.

Climate normal air temperature data extracted from ClimateWNA for the Project area (57º03′27″N latitude, 126º46′46″W; 1,600 masl) suggest that mean annual air temperature in the Project area is -1.2ºC, based on the 1981 to 2010 dataset. The coldest mean minimum monthly air temperature was -14.8ºC (December), and the warmest mean maximum monthly air temperature was 15.9ºC (July). Average annual air temperature was lower for the 1961 to 1990 climate normal dataset at -1.7ºC.

Extreme Air Temperature

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

Effects of Extreme Cold on the Project

Given the climatic setting of the Project area, effects on the Project might be expected primarily from extremely cold air temperatures. These extreme temperatures may affect workers, infrastructure, or machinery. Extremely low air temperatures could adversely affect workers' health, causing 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.

[1] http://climatewna.com/

Extended cold spells could result in a prolonged winter and increased snow accumulation. As a result, 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 roadcuts. Cold spells could cause later melting of the winter snow-pack, delaying spring runoff.

Effects of Extreme Warmth on the Project

Extreme warm weather, though unlikely given the climatic setting of the Project, could also affect worker health, infrastructure, and machinery. Extremely high air temperatures may adversely affect workers' health, potentially causing heat exhaustion, dehydration, and heat stroke. 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, DCS 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 where 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 (discussed in Section 23.7).

To further minimize effects from extreme air temperatures on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan; Section 24.6 Environmental Emergency, Spill and Hazardous Materials Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

23.3.3.2. Freeze-Thaw Cycles

At high elevations in BC (over 1,000 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 cause damage to power line tower foundations.

Effects of Freeze-Thaw Cycles on the Project

Given that air temperatures in winter can range above and below the freezing point, freeze-thaw cycles and frost heave in winter are likely. Freeze-thaw cycles are a well-recognized causal factor 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.

Mitigation Measures for Air Temperature

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 they understand the risks of working under extreme high or low temperatures, and to ensure they have good knowledge of the related procedures. Daily job safety analysis will be conducted. Personnel will be required to wear appropriate personal protective equipment, including cold-weather gear, while working outside. Section 24.5 Emergency Response Plan, 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 enable 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. The KS Mine has operated effectively in this environment since 1998, demonstrating the appropriateness of the mitigation measures. The final crest and core of the East Dam will be covered with a 1-m thick cap of fine non-acid-generating (NAG) rock fill to provide long-term protection of the till core from freeze and thaw degradation and desiccation. The TSF will also be designed to meet all CDA guidelines relating to temperature risks (Canadian Dam Association 2007 (Revised 2013)).

To further minimize effects from freeze-thaw cycles on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan, Section 24.6 Environmental Emergency, Spill and Hazardous Materials Plan; Section 24.11 Mine Waste, Tailings, and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

Air temperature-related risks to the Project and mitigation measures are presented in Table 23.3-2.

23.3.4. Wind

Based on the approximately 116-month dataset from the three Kemess meteorological stations, 1 to 2 m/s winds were the most frequent, occurring approximately 30% of the time at the Kemess North station. The average wind speed from 2004 to 2014 was 2 m/s. The frequency of calm winds (less than 0.5 m/s) was 5.7% of the time at the Kemess North station and 2.3% of the time at the Dam station. The maximum gust speed recorded on-site was 16.4 m/s (59.0 km/h) on November 9, 2005. This is classified as a near-gale-force wind in which whole trees can be in motion and resistance can be felt while walking against the wind.

Effects on the Project

Overall, as described above, 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 do occur. High winds during below-freezing air temperatures would contribute to greater wind chill 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.

High winds could also:

- 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 power lines and building services; and
- cause electrical supply failure.

Mitigation Measures

The effects of extreme wind and the relevant mitigation measures are summarized in Table 23.3-3. Surface infrastructure will be constructed using purpose-designed technology to mitigate wind damage. 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.

The meteorological stations at Kemess North and the Dam 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 severe winds. During blackouts, non-essential machinery will be shut down until power is re-established and a backup power generator will provide power in the case of outages.

To further minimize effects from wind on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.2 Access Management Plan; Section 24.5 Emergency Response Plan, Section 24.6 Environmental Emergency, Spill and Hazardous Materials Plan; Section 24.11 Mine Waste, Tailings, and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

Table 23.3-2. Summary of Air Temperature Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts.	Blowing snow, frost heave.	High	**Low impact -** Extreme low temperatures may be accompanied by blowing snow, which could affect surface transport of materials and personnel, and could temporarily slow mine operations. Freeze-thaw cycles are a well-recognized causal factor of cracked hardened surfaces which would require more frequent maintenance.	Early-warning system (forecast monitoring). Frequent snow clearing. Use of appropriate design standards and management practices to minimize frost heave.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazine, potable water and sewage treatment facility, surface portal facilities.	Effects to workers from cold: frostbite, hypothermia, distraction, accidents. Effects to infrastructure from cold: increased heating (and power) demands, freeze-thaw damage. Effects to workers from warmth: heat exhaustion, dehydration, heat stroke. Effects to infrastructure from warmth: increased air conditioning and power demands.	High	**Moderate impact** - Equipment and machinery is more likely to malfunction or become damaged during extreme low temperatures, increasing the potential for worker-related exposure and accidents. Frequent freeze-thaw cycling and frost heave also have the potential to compromise the integrity of building foundations. **Low impact** - Increased heating and cooling from extreme low or high temperatures would mean an increase in power demand.	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 and cold. Air heating at top of intake air raise to avoid freezing of pipes and creation of unsafe ground conditions.
KUG TSF	Existing KS Mine open pit, East Dam.	Freeze-thaw damage.	High	**Moderate impact -** Frequent freeze-thaw cycling and frost heave also have the potential to compromise impoundment.	Designed to meet all current CDA *Dam Safety Guidelines.*
Access corridor	Tunnel, surface conveyor, power transmission line, underground dewatering pipeline.	Effects to workers from cold: frostbite, hypothermia, distraction, accidents. Effects to infrastructure from cold: increased heating and power demands, freeze-thaw damage.	High	**Low impact -** Extreme low temperatures could increase the risk of pipelines freezing.	Air heating at decline portal to minimize freeze-thaw damage 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.
Water management infrastructure	Water treatment plant (within the process plant), discharge pipelines, diversion infrastructure.	Freeze-thaw damage.	High	**Low impact** - Frequent freeze-thaw cycling and frost heave also have the potential to compromise the integrity of water management infrastructure.	Appropriate engineering design.
Underground workings	Declines, cave gallery, excavations to be created for underground activities.	n/a	n/a	n/a	n/a
Utilities	Power transmission line, back-up diesel generators.	Interrupted power supply. During extreme cold temperatures, ice accumulation may damage the conductors which could in turn result in electrical supply failure.	Moderate	**Low impact** - Frequent freeze-thaw cycling and frost heave also have the potential to compromise the integrity of power transmission towers.	Towers and conductor specifications should be appropriate for expected climate extremes. Additionally, routine inspections should be performed to monitor potentially problematic sections of the power line.

Table 23.3-3. Summary of Wind Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Downing of trees.	Low	**Low impact -**Wind effects 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 and blowing snow. Blowing snow would reduce visibility, limiting access to and from the mine site. Wind could also cause the downing of trees which could temporarily block access roads.	Early-warning system (forecast monitoring). Construction clearing methods to reduce edge effects. Clear debris as needed. Maintenance thinning.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazine, potable water and sewage treatment facility, surface portal facilities	Dislodged roofing, destabilized walkways, damage to equipment covers, damage to buildings. Combined with snow and low temperatures, reduced visibility and risk of exposure to personnel. Flying debris.	Low	**Low impact -** Excessive winds could cause damage to buildings and mean increased costs for maintenance and repairs. Flying debris from stockpiles and laydown areas could reduce visibility for personnel at the site and possibly cause injury.	Construction techniques to mitigate wind damage. Staff will wear appropriate clothing, and be trained in risk and risk-mitigation relating to extreme winds.
KUG TSF	Existing KS Mine open pit, East Dam	Wind-generated wave could overtop East Dam	Low	**Low impact** – risk of overtopping of dam from wind-generated waves	TSF is designed to meet all current CDA *Dam Safety Guidelines* (Canadian Dam Association 2007 (Revised 2013)). The TSF is designed with a minimum 2 m of freeboard over the pond level.
Access corridor	Tunnel, surface conveyor, power transmission line, underground dewatering pipeline	Dislodged covers, damage to equipment, damage to infrastructure.	Low	**Low impact -** Wind effects 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 and blowing snow. Blowing snow would reduce visibility, limiting access to and from the mine site. Wind could also cause the downing of trees which could temporarily block access roads.	Construction techniques to mitigate wind damage. Clear debris as needed. Vegetation setbacks.
Water management infrastructure	Water treatment plant (housed in the process plant), discharge waterline, diversion infrastructure	Dislodged roofing and covers, damage to equipment, damage to infrastructure.	Low	**Low impact –**increased repair and maintenance of infrastructure	Construction techniques to mitigate wind damage. Clear debris as needed.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	n/a	n/a	n/a	n/a
Utilities	Power transmission lines, backup diesel generators	Damage to powerlines, electrical supply failure.	Low	**Low impact -** Excessive wind could cause the downing of trees which could damage power lines and affect the power supply temporarily.	Construction techniques to mitigate wind damage. 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.

23.4. SURFACE WATER FLOWS

23.4.1. Typical Surface Water Flows

Streams and hydrologic features within the Project area were surveyed as part of the baseline hydrometric monitoring program within the Project area. The monitoring program operated from 2003 to 2007 and then from 2012 to the present. In 2012, one new hydrometric station was added to the network, expanding the monitoring program to six. Installation and operation of the hydrometric stations were in accordance with the requirements of the Manual of British Columbia Hydrometric Standards (BC MOE 2009). The hydrometric stations recorded water levels during open-water periods to monitor surface water flows in order to characterize the hydrological variation in these watersheds. Detailed results from the hydrometric monitoring program are provided in baseline studies and the 2015 Kemess Underground Project: Baseline Hydrology Report (Appendix 10-A), as well as Chapter 10, Surface Hydrology.

The flow regime in the area is closely related to the seasonal distribution of precipitation and temperature. Rivers 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. The seasonal distribution of stream discharge is summarized in Table 23.4-1.

Table 23.4-1. Mean Monthly Discharge Data from Hydrometric Stations in the Baseline Study Area

Name	Area (km^2)	Mean Monthly Discharge (m^3/s)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kem-01	25.6	0.29	0.27	0.25	0.22	0.50	1.70	1.04	0.56	0.38	0.33	0.34	0.32
Kem-02	101.4	0.60	0.54	0.42	0.46	3.23	6.80	3.47	1.70	1.44	1.26	1.04	0.77
Kem-03	8.3	0.04	0.03	0.02	0.02	0.30	0.56	0.31	0.13	0.13	0.12	0.04	0.05
Kem-04	132.9	-	-	0.51	0.72	4.47	9.73	3.91	1.55	1.20	1.03	1.17	1.14
Kem-05	1,875.5	6.69	6.58	5.22	4.47	71.22	204.88	85.28	32.43	22.93	21.38	16.22	9.74
Kem-07	3.4	-	-	-	-	0.13	0.33	0.13	0.04	0.03	0.04	0.04	-

23.4.2. Floods

The greatest risks associated with stream flows are those related to flooding. An understanding of flood potential is important to consider at the Project area, as it could affect the design characteristics such as roads, ditches, dams, and dikes. Floods in BC are typically produced through two main mechanisms:

- 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.

Both mechanisms could cause high-flow events in the Project area. In addition to consideration of historical high-flow records, climate change should be considered when assessing flood risk.

Projections show an increase in the median precipitation in the figure, with the possibility of shorter return periods for heavy precipitation events. These issues are discussed further in Section 23.8.

Effects on the Project

Floods can damage river crossing structures, including bridges and culverts. Floods can cause erosion and deposition of sediment, negatively affecting water quality. Floods can cause rapid channel avulsion, and could cause damage to any infrastructure in the new channel. They can also trigger mass wasting, when stream beds undercut steep banks.

Drainage swales and water-diversion ditches are intended to manage the volume of water collected within the Project area. The ditches have been designed to accommodate a 1:100-year flood event. Should design flows be exceeded, the ditches will overflow, causing excess water to flow through the Project area. Such an occurrence would be relatively short-lived and, with on-site management, would be of manageable consequence for Project infrastructure.

Floods occurring along the Project area and access roads could result in road closures caused by excess water on the road surface, erosion of the road surface, damage to stream crossings, or debris blocking the roads. Under the most extreme flood events there is the potential for drainage structure washouts (bridges, culverts, and cross-drains) which could affect site haulage and operations, as well as transport of concentrate from the Project area.

Extreme surface water flows could cause inundation in the KUG TSF, potentially causing an overtopping of the KUG TSF or, in the worst-case scenario, catastrophic failure of the KUG TSF embankment.

Mitigation Measures

Project infrastructure will be designed to withstand flood events. Mitigation measures for extremely high stream flow are presented in Table 23.4-2 and flooding in particular will be mitigated by:

- monitoring weather forecasts to anticipate and prepare for large rainfall events;
- slowing or stopping work if rainfall runoff is anticipated to cause unsafe working conditions;
- placing Project-related infrastructure above flood high-water marks wherever possible; and
- appropriately reinforcing stream channels at road crossings to minimize sediment movement.

For floods in excess of the design criteria, it is likely that road closures would be put into effect as there is potential for crossings to partially obstruct flows, resulting in elevated upstream water levels (backwatering) and overtopping onto the road surface. 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.

Table 23.4-2. Summary of Surface Water Flows Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Floods: erosion and sedimentation at ditches, culverts, and road surface. Negative effect on water quality if sediment concentrations increase. Delay of materials and personnel if access to mine site is limited. Droughts: negative effects on water quality	Low to Moderate	**Low impact -**Floods can damage river crossing structures, including bridges and culverts, cause erosion and deposition of sediment, which would negatively affect water quality. Floods can cause rapid channel avulsion, and could cause damage to any infrastructure in the new channel. They can also trigger mass wasting, when stream beds undercut steep banks. Floods occurring along the Project area and access roads could result in road closures caused by excess water on the road surface, erosion of the road surface, damage to stream crossings, or debris blocking the roads.	Development of an appropriate water management plan. Constructing infrastructure away from flood zones and to withstand flood events (i.e., > 1:50 year event for culverts and 1:200 year event for drainage ditches).
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities	Drought: reduction in water quality in receiving environment. Reduction in water available for use in process, resulting in slowed production.	Low to Moderate	**Low impact -** In the event of drought, water quality may decline. In the event that there is less water available for mine production, this could result in lost production or increased costs to bring in additional water supplies.	Development of appropriate water balance model, water management plan, and environmental management plans. Maintaining water quality by limiting sediment erosion, and reducing inputs of contaminated materials.
KUG TSF	Existing KS Mine open pit, East Dam	Catastrophic failure of TSF embankment	Low	**Severe impact -** Extreme surface water flows could cause inundation in the TSF, potentially causing an overtopping of the TSF or in the worst-case scenario, catastrophic failure of the TSF embankment.	Designed to meet all current CDA *Dam Safety Guidelines* (Canadian Dam Association 2007 (Revised 2013)). The TSF is designed for an Inflow Design Flood of 1:100 year 15-day snowmelt (winter and spring) and the 5-day probable maximum precipitation (summer).
Access corridor	Tunnel, surface conveyor, power transmission line, underground dewatering pipeline	Floods: Erosion, sedimentation, flooding	Low to Moderate	**Low impact -** drainage swales and water diversion ditches would manage the volume of water collected within the Project area.	Construction of runoff collection ditches and sediment ponds.
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Drought: reduction in water quality in receiving environment. Reduction in water available for use in process, resulting in slowed production.	Low to Moderate	**Low to Moderate impact -** In the event of drought, water quality may decline. In the event that there is less water available for mine production, this could result in lost production or increased costs to bring in additional water supplies.	Development of appropriate water balance model, water management plan, and environmental management plans. Maintaining water quality by limiting sediment erosion, and reducing inputs of contaminated materials.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	Floods: increased need for pumping if shallow groundwater infiltration rates increase.	Low to Moderate	**Low impact** - There could be increased costs/lost time if additional pumping resources are required.	Increased pumping.
Utilities	Power transmission line, backup diesel generators	Floods: erosion or sedimentation where transmission line towers are near streams or areas prone to flooding.	Low to Moderate	**Low impact -** Flooding near back-up diesel generators could mean a loss in operational effectiveness, thereby removing backup power supply.	Constructing infrastructure to withstand flood events (i.e., > 1:50 year event for culverts and 1:200 year event for drainage ditches). Back-up generators to allow security of supply during maintenance or failure.

The proposed access roads and stream crossings on site roads are expected to withstand the related instantaneous peak flow as they will be designed to accommodate a 1:100 year flood. Appropriately sized rip-rap will be placed at the inlet and outlet of bridges and culverts to protect structures from erosion. A regular inspection and maintenance program will be established to ensure that stream crossings are free of obstructions and able to convey design flows. This will be especially important during early spring before freshet conditions, in early fall ahead of potential fall rain storms, and following any major flood events. The TSF will be designed, constructed, operated, closed, and reclaimed according to the CDA Dam Safety Guidelines (Canadian Dam Association 2007 (Revised 2013)). The KUG TSF is designed to store, without overtopping, an Inflow Design Flood of 1:100-year 15-day snowmelt (winter and spring) and the five-day probable maximum precipitation (summer). The optimal means of managing tailings in a secure fashion is addressed in Chapter 4: Design and Alternatives Assessment.

To further minimize effects from floods on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.5 Emergency Response Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and Safety Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

23.4.3. Low Flows

<u>Effects on the Project</u>

Low flows are an important consideration for the Project because they are a limiting factor for discharge. While the annual low flow will typically occur during winter months, flow volumes during the summer season (June to September) are also important as they can influence the ability of the receiving environment to dilute discharge. Low flows are characterized using different indices, with the most common measure being the seven-day low flow over a given time period.

<u>Mitigation Measures</u>

Project infrastructure will be designed to accommodate drought events. Specific mitigation measures for extreme low stream flow are presented in Table 23.4-2 and, specifically, mitigation measures relating to reducing drought-induced water quality deterioration include:

- separating hazardous waste from non-hazardous waste to maintain water quality and transporting it off site for disposal (Section 24.17 Waste Management Plan);
- constructing storage areas to minimize spills of fuel and other hazardous materials (Section 24.17 Waste Management Plan);
- diverting non-contact water around Project area infrastructure (Section 24.16, Surface Water Management Plan);
- constructing drainage ditches to collect Project area contact water (Section 24.16, Surface Water Management Plan); and
- developing a water management plan that accounts for low-runoff years (Section 24.16, Surface Water Management Plan).

Storage capacity within the KUG TSF will allow for temporary reduction in discharge from the KUG TSF to the receiving environment during periods of low flow to account for reduced assimilation capacity of the receiver during these events.

23.5. GEOPHYSICAL EFFECTS

23.5.1. Landslide Geohazards

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. Rapid mass movement refers to a rapid gravity-induced down-slope movement by sliding, falling, rolling, or flowing of either bedrock or surficial materials. Conversely, slow mass movement typically refers to slope movement that occurs at a very slow rate and usually travels a short distance. Gully erosion refers to localized erosion and removal of soil along drainage lines as a result of surface water runoff. Geohazard mapping was completed for the Project area in 2014 to describe the distribution of terrain, surficial materials, and geomorphic processes to identify potential geohazards in the vicinity of the Project (Weiland 2014). Geohazard mapping extends from just east of Amazay Lake to Attichika Creek in the south, which covers the area of surface Project facilities. This mapping identified that there is low probability of landslides and other geohazards occurring in the area of existing infrastructure (Table 23.5-1).

A terrain stability map was created, based on terrain classification and slope gradient information presented in the Terrain Stability Mapping and Assessment report (Weiland 2014). The terrain stability map provides a relative assessment of stability but provides no indication of the expected frequency, magnitude, or consequence of a failure.

Effects on the Project

Terrain stability classifications range from Class I (stable) to Class V (unstable). Terrain classified as unstable implies that the area is expected to contain a high likelihood of landslide initiation following disturbance activities such as timber harvesting or road construction. No substantial stability concerns are expected in Class I or Class II terrain, and minor stability problems are expected on moderately stable (Class III) terrain. Marginally stable (Class IV) terrain comprises slopes that are generally steeper than 60% and are often overlain by surficial material veneers. The terrain may comprise gullied slopes steeper than 50% (27°) with steeper gully sidewalls. Terrain mapped as unstable (Class V) typically contains debris or rock fall initiation zones or failing ground.

Areas of Terrain stability Class IV and Class V are located in the vicinity of Project infrastructure situated along steep slopes flanking the ridges and high ground. The region surrounding the underground workings areas is characterized by multiple regions of stability Class IV and Class V. Because project activities in this area are subsurface, landslides would be unlikely to affect project infrastructure.

Table 23.5-1. Summary of Landslide Geohazard Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Damage to infrastructure and compromised worker safety. Delivery of materials and personnel interrupted if access to mine site is limited.	Low	**High impact** – a landslide geohazard is capable of severely damaging vehicles, injuring occupants, and interrupting the flow of traffic.	Regular maintenance of roads. On-site geotechnical evaluation of road construction.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities	Damage to infrastructure and compromised worker safety.	Low	**High impact –** a landslide occurring in this area could cause damage to infrastructure and pose a safety hazard to personnel.	Infrastructure constructed in areas of low geohazard risk.
KUG TSF	Existing KS Mine open pit, East Dam	Damage to infrastructure and compromised worker safety.	Negligible	No impact	Infrastructure constructed in areas of low geohazard risk.
Access corridor	Tunnel, surface conveyor, power transmission line, underground dewatering pipeline	Damage to infrastructure in the vicinity of decline portal.	Low; however, activities such as stripping and excavation increase the risk of landslides.	**High impact** – a landslide occurring in this area could cause damage to infrastructure and pose a safety hazard to personnel.	Avoid over-steepening the cut slopes into the gravel terrace. Engineering design will address slope stability of the gravel terrace during land clearing and excavation, and prescribes stable cut slope angles for gravel deposit.
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Damage to infrastructure and compromised worker safety.	Low	**Low impact** - if a landslide were to occur, it could affect stream water quality and sediment loading where the landslide path intersects streams and waterways.	Infrastructure constructed in areas of low geohazard risk.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	n/a	n/a	n/a	n/a
Utilities	Power transmission line, back-up diesel generators	Damage to tower infrastructure.	Low	**Low impact -** In the event of a landslide, damage to transmission tower infrastructure would be minimal.	Infrastructure constructed in areas of low geohazard risk. Backup generators to allow security of supply during maintenance or failure.

There are two areas of possible concern at the decline portal: the slope at the portal where excavation is required and upslope of this area where the possibility of geohazard initiation exists. While the hazard of landslides in this area is low in its natural state, project activities such as stripping and excavation could cause moderate to high risk of landslides. A landslide occurring in this area could cause damage to infrastructure and pose safety hazards to workers.

Access roads associated with the Project also cross regions with mass-wasting hazard and thus may be subject to landslides or mass-wasting events. Though the probability of such events occurring along roadways is low, they could be capable of severely damaging vehicles, injuring occupants, and interrupting the flow of traffic, particularly near the northern access corridor tunnel portal and adjacent access road (Weiland 2014). Landslides can cause damage to infrastructure and facilities and pose hazards to workers, including injury or death. Landslides can also affect stream water quality and sediment loading where the landslide path intersects streams and waterways.

Mitigation Measures

Mitigation measures can help to reduce damage to infrastructure and minimize potential hazards to personnel (Table 23.5-1). Landslide mitigation strategies can reduce the risk in the following ways:

- reduce the probability of the geohazard occurring;
- reduce the geohazard magnitude (e.g., volume and peak discharge);
- reduce the geohazard intensity (e.g., run-out distance, velocity, and impact forces);
- reduce the spatial probability of impact (likelihood that the geohazard will reach or impact the element at risk);
- reduce the temporal probability of impact (likelihood of workers being present in the zone subject to the hazard); and
- reduce the vulnerability (the degree of loss to a given element at risk within the area affected by the landslide hazard).

To avoid a Class V hazard, the explosives magazines locations and access road were moved from an area of unstable terrain near the portal to the existing magazine locations within the KS Mine site.

Excavation at the decline portal will avoid over-steepening the cut slopes into the gravel terrace. The engineering design of the decline portal will address slope stability of the gravel terrace during land clearing and excavation and will prescribe stable cut slope angles for gravel deposit.

On-site geotechnical evaluation will be conducted for road construction. Roads will be avoided on Class IV terrain and when unavoidable, special construction techniques and on-site supervision will be applied. Roads will be regularly maintained, particularly before and after wet-weather periods.

To minimize effects from landslide geohazards on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.5 Emergency Response Plan; Section 24.11 Mine Waste, Tailings and ML/ARD Management Plan; Section 24.12 Occupational Health and

Safety Plan; Section 24.15 Surface Erosion and Sediment Control Management Plan; and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

23.5.2. Snow Avalanches

A combination of terrain and climatic conditions primarily influences the extent of a snow avalanche hazard. Generally, snow avalanches occur in areas where there are steep, open slopes or gullies that are covered with a deep snow-pack. The initiation zone of an avalanche typically has an incline slope of greater than 60% (58º). Avalanches will begin to decelerate in the runout zone and stop on slopes less than 30% (17º). The dense flowing component of an avalanche can reach speeds up to 200 km/h. Avalanche activity can be identified through terrain properties and from historic avalanche tracks.

Effects on the Project

In the absence of mitigation measures, avalanches can pose significant hazards to people and damage to property. 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. Avalanche risk also exists at high elevations north and southwest of the surface subsidence zone and north of Kemess Lake as a result of an average snowfall of 350 mm on steep mountain slopes.

Avalanches can cause damage to infrastructure and facilities and pose hazards to workers, including injury or death. Portions of the access road may be subject to avalanches. 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.

Mitigation Measures

Avalanche management is an integral part of winter operations. 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. AuRico has an established avalanche management program at Kemess South and along a portion of the Omineca Resource Access Road (ORAR), which will be expanded to encompass avalanche hazards associated with the KUG Project (Section 24.12 Occupation Health and Safety Plan). This program is operational from October to April of each year. The program would be extended to include the Project area.

Avalanche training and safety equipment is provided for workers who are working in areas with avalanche risk. Approved check-in and work procedures are required to be followed at all times while operating in these areas. Snow avalanche risks and mitigations are summarized in Table 23.5-2.

Table 23.5-2. Summary of Snow Avalanche Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Compromised worker safety, vehicle and equipment damage, road blocks, road damage.	Moderate to high	**Moderate impact -** Portions of the site access road may be subject to avalanches. Avalanches occurring along roadways could be capable of severely damaging vehicles, injuring occupants. 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.	Implementation of avalanche-management procedures.
Surface infrastructure	Surface portal facilities, process plant, administration complex, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility	Compromised worker safety, infrastructure damage.	Moderate to high	**Moderate impact** - Avalanches can cause damage to infrastructure and facilities and pose hazards to workers, including injury or death.	Implementation of avalanche-management procedures, avoid building near avalanche tracks, snow-pack monitoring and controlled blasts.
TSF	Existing KS Mine open pit, East Dam.	n/a	n/a	n/a	n/a
Access corridor	Tunnel, surface conveyor, transmission line, underground dewatering pipeline	Compromised worker safety, infrastructure damage.	Moderate- to high	**Moderate impact** - Avalanche risk may exist for the valley wall just above the north entrance to the access corridor tunnel. The north entrance to the access corridor tunnel will require specific management strategies.	Implementation of avalanche-management procedures, avoid building near avalanche tracks, snow-pack monitoring and controlled blasts.
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Damage to infrastructure and compromised worker safety.	Low	**Low impact** -Avalanches can cause damage to infrastructure and facilities.	Infrastructure constructed in areas of low avalanche risk.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	n/a	n/a	n/a	n/a
Utilities	Transmission line, backup diesel generators	Damage to infrastructure, power outages.	Moderate	**Low impact** - Potential effects of avalanches occurring near transmission lines or towers could include damage to the infrastructure or interruption of power service.	Implementation of avalanche-management procedures, avoid building near avalanche tracks, snow pack monitoring, and controlled blasts.

To further minimize effects from snow avalanche on the Project, AuRico has developed EMPs that will be followed during the life of the Project, including: Section 24.5 Emergency Response Plan and Section 24.16 Surface Water Management Plan. These EMPs are provided in Chapter 24 of the Application.

23.5.3. Seismic Activity

The Project is located within the Northern British Columbia (NBC) seismic source zone in the National Building Code of Canada. This zone extends from the northern British Columbia Cordillera to the Yukon Territory and is characterized by relatively low seismicity. The Pacific Coast is the most earthquake-prone region of Canada due to the presence of offshore active faults, particularly dominated by the north-westward tectonic motion of the Pacific Plate relative to the North American Plate. However, the Project is distant from these faults (more than 600 km) and earthquake frequency and magnitude decreases moving inland from the coast.

Seismicity in the vicinity of the Project was characterized through compilation of records of all earthquakes greater than magnitude 3.0 that have occurred within 1,000 km between 1843 and 2003 (Klohn-Crippen 2005). Of those events, two events of magnitude 6.0 occurred over 400 km away in the Rocky Mountain Trench.

Peak Ground Acceleration (PGA) is a measure of how hard the earth shakes, and is measured in units of acceleration due to gravity (g). PGA was calculated for the Project area for five return periods as reflected in Table 23.5-3 (Klohn-Crippen 2005). The United States Geological Survey (USGS) has developed a table of intensity descriptions for PGA (USGS 2013). A PGA of 0.025 g would be perceived as “light”, and would not cause structural damage. A PGA of 0.080 would be perceived as a moderate quake, with “very light” potential structural damage.

Table 23.5-3. Exceedance Probability, Return Period, and Peak Ground Acceleration for Seismic Events at the Project

Annual Exceedance Probability	Return Period (Years)	Peak Ground Acceleration PGA (g)
0.01	100	0.007
0.005	200	0.013
0.002	475	0.022
0.001	1000	0.033
0.0004	2475	0.049

Effects on the Project

Analysis of Table 23.5-3 points toward the Project being at low risk of a damaging seismic event. For example, even in the case of a 1:1,000 year event occurring, with a PGA of 0.033, the earthquake would be perceived as light and structural damage would be unlikely to occur. However, where infrastructure is not built on firm ground, or where unconsolidated material is deposited on slopes, damage to infrastructure and risk to workers could be greater. Other areas where earthquake-induced slope failures are a potential concern are those areas that are susceptible to landslides, as described in Section 23.5.1.

Mitigation Measures

An important means of mitigating potentially harmful seismic events is in the engineering design of the Project. The Maximum Design Earthquake (MDE) is the earthquake expected to produce the highest degree of shaking at the site. The Maximum Credible Earthquake (MCE) is the largest earthquake that may be possible under the known tectonic conditions given geologic and seismic data. The MDE for the TSF dam has been designed to be the MCE, based on the seismicity studies discussed above (Klohn-Crippen 2005). The MCE parameters reflect a magnitude 6.0 earthquake with a horizontal PGA of 0.19 g. This design parameter for the TSF is considered conservative given the low earthquake risk in the area.

A seismic event of any significance would constitute an emergency situation and Section 24.5, Emergency Response Plan, 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 depends on the number of workers employed at the various Project worksites. 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 located 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. Table 23.5-4 summarizes the seismic activity risks and mitigation measures to the Project.

23.5.4. Volcanic Activity

The Project is located within 250 km of the Stikine Volcanic Belt (also called the Northern Cordilleran Volcanic Province), which extends from just north of Prince Rupert into the Yukon Territory. This belt includes Lava Fork, Hoodoo Mountain, and Mount Edziza to the north and west of the Project, and Tseax Cone to the southwest of the Project, all at a distance of approximately 250 km.

The area has been active in recent history, with an eruption at Tseax Cone as recently as 1775. This eruption resulted in a prolonged period of disruption by the volcano, and Nisga'a oral tradition tells of "poisonous smoke" from the eruption that was responsible for the destruction of a Nisga'a village and the death of some 2,000 people, most likely due to CO_2 gas inhalation (Bobbink and Lamers 2002).

Recent volcanic activity has also occurred at Lava Fork with scientific dating techniques indicating that lava flows most likely occurred within the last 150 years.

Scientific evidence indicates that Hoodoo Mountain last erupted approximately 9,000 years ago, while Mount Edziza has erupted on numerous occasions within the last 10,000 years, with the most recent activity (about 1,400 years ago) forming two large lava fields and several smaller cinder cones.

Table 23.5-4. Summary of Seismic Activity Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Damage to infrastructure and compromised worker safety. Delivery of materials and personnel interrupted if access to mine site is limited.	Negligible	**Moderate impact -** Should a seismic event occur, productivity as well as emergency egress could be affected if fallen trees block the road, preventing personnel from entering or leaving the site.	Regular maintenance of roads. On-site geotechnical evaluation of road construction. Emergency Response Plan.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities	Damage to infrastructure and compromised worker safety.	Negligible	**Low to High impact -** While structural damage would be unlikely to occur, if infrastructure is not built on firm ground or where unconsolidated material is deposited on slopes, damage to infrastructure and risk to workers could be greater.	Site infrastructure will be located in areas that avoid or minimize exposure to weak or unconsolidated soils. Emergency Response Plan.
KUG TSF	Existing KS Mine open pit, East Dam.	Damage to infrastructure and compromised worker safety.	Low	**Negligible impact –** KUG TSF East Dam is designed for MCE, based on seismicity studies	Site infrastructure will be located in areas that avoid or minimize exposure to weak or unconsolidated soils. Emergency Response Plan.
Access corridor	Tunnel, surface conveyor, transmission line, underground dewatering pipeline	Damage to infrastructure and compromised worker safety.	Low	**Moderate impact -** Should a seismic event occur, productivity as well as emergency egress could be affected if fallen trees block the road, preventing personnel from entering or leaving the site.	Site infrastructure will be located in areas that avoid or minimize exposure to weak or unconsolidated soils. Emergency Response Plan.
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Damage to infrastructure and compromised worker safety.	Low	**Low impact**	Site infrastructure will be located in areas that avoid or minimize exposure to weak or unconsolidated soils. Emergency Response Plan.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	Subsidence.	Low	**Severe impact -** A seismic event of any significance would constitute an emergency situation to underground workings.	A seismicity measurement system will be installed to continuously monitor the inelastic response of the rock mass to cave mining. Emergency Response Plan.
Utilities	Transmission line, back-up diesel generators	Damage to infrastructure and compromised worker safety.	Low	**Minor impact -** Foundations for power line towers could be affected and require repair for structural integrity.	Site infrastructure will be located in areas that avoid or minimize exposure to weak or unconsolidated soils. Backup generators to allow security of supply during maintenance or failure. Emergency Response Plan.

Volcanoes present a number of immediate hazards, although they are difficult to predict because they depend largely on the size of the eruption, the composition of the erupting magma, and the environment in which the eruption occurs. Hazards normally associated with eruptions include lava flows, ballistic projectiles, widespread ash, pyroclastic flows (avalanches of hot ash, hot gas, and volcanic rock), pyroclastic surges (similar to flows but less dense and can travel much faster), landslides and debris avalanches, and lahars (slurry of water and rock particles).

Effects on the Project

The pumice deposit near Mount Edziza highlights one of the important volcanic hazards in relation to the Project, namely the possibility of large, explosive volcanic eruptions (Everett 1980). An explosive eruption of the order of the Mount Edziza eruptions could produce an ash cloud that would affect large parts of northwestern Canada. The associated gas and ash released during a volcanic eruption could contaminate the local atmosphere, and airborne ash could disrupt air traffic to and from mining camps. The ash and debris could also pose health concerns for workers at the site. Volcanic eruptions can also initiate wildfires, dam rivers, and cause flooding due to melting of glaciers, although these effects are unlikely to pose a threat to the Project due to its distance from the volcanically active areas.

Mitigation Measures

Though the risk of impacts on the Project related to volcanic activity is low, risks cannot be managed pre-emptively. Mitigation measures therefore are primarily reactive. Should a volcanic eruption occur in the region, assigned site personnel will maintain contact with authorities to determine the likely hazards for the Project area. All site personnel will be informed of the eruption and a risk assessment will determine whether normal operation should be adjusted. Ongoing monitoring would occur and travel restrictions would be implemented if necessary.

In the event of an ash cloud, individual worker exposure will be limited and face masks or other respiratory devices will be used. Ongoing air monitoring will test for gases emitted, to protect human health against inhalation of volcanic gas such as increased CO_2 concentrations.

Any volcanic activity at the Project would trigger mine rescue actions per the Project's Emergency Response Plan, as presented in Section 24.5 in Chapter 24.

23.6. LIGHTNING

Thunderstorms may be accompanied by lightning strikes, hail, and occasionally tornadoes. Lightning strikes and flashes are monitored on an ongoing basis through the Canadian Lightning Detection Network. Although there are no data available in the vicinity of the mine, data do exist for Fort Nelson (300 km northeast of the Project), Dease Lake (250 km northwest of the Project), and Smithers (250 km south of the Project). On average, Fort Nelson experiences 40 lightning strikes/ 100 km^2/year, Dease Lake experiences 12 lightning strikes/100 km^2/year, and Smithers 2 lightning strikes/100 km^2/year (Environment Canada 2014).

Effects on the Project

The direct effects of lightning strikes on the Project could include initiating fires and electrical failures. Though 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. Section 23.7 describes additional effects and mitigation measures related to wildfires.

Mitigation Measures

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, as presented in Section 24.5 of Chapter 24.

23.7. WILDFIRES

A wildfire is an unplanned or unwanted natural or anthropogenic fire. Wildfires are common landscape disturbances throughout forested and grassland ecosystems in BC. On average, 1,900 wildfires occur in BC ever year; approximately 39% are caused by human activity and 61% by lightning ignition (BC MFLNRO 2012). The probability of wildfire occurrence is dependent upon fire behavior, ignition potential, and suppression capability.

Effects on the Project

The characterization of 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 (Table 23.7-1). These Natural Disturbance Types (NDTs) summarize the dominant disturbances for each BEC zone and provide an indication of the disturbance type, extent, and frequency (BC MOF 1995).

Table 23.7-1. Natural Disturbance Types in the Local Study Area and Fire Return Interval

Natural Disturbance Type	BEC Unit	Stand Replacement Disturbance Cycle	Area in the LSA (ha)	Description
NDT2	SWBmks, SWMmk	200 years	14,480.8	Ecosystems with infrequent stand-initiating events. Wildfires are often of moderate size (20 to 1,000 ha) with unburned areas due to terrain, soil moisture, or fire behavior.
NDT5	BAFAun	-	2,124.6	Alpine tundra and subalpine parkland – rare low-intensity fires.

In the Project area, there are three BEC zones assigned to NDTs: the Spruce Willow Birch Moist Cool (SWBmk) subzone; the Spruce Willow Birch Moist Cool Scrub (SWBmks) subzone, and the undifferentiated Boreal Altai Fescue Alpine (BAFAun) subzone. The majority of project infrastructure is located within the SWB zone in NDT2, although the underground workings are situated in the BAFA zone. Full stand-replacing fires, which burn entire forest communities, are infrequent in the NDT2 (every 200 years). While this indicates a reduced risk of wildfire due to the long fire-return interval, climate change, the effects of forest health pathogens, and increasing fuel loading and human-caused ignitions elevate the risk posed to Project infrastructure in comparison with historical fire regimes.

Forest health is also a consideration when addressing fire hazard. Mortality associated with mountain pine bark beetle (*Dendroctonus ponderosae*) has occurred in the low elevation SWB regions of the local study area (LSA). The majority of the disturbance due to the beetle is considered low to moderate in severity and has occurred since 2012. Tree mortality caused by the beetle can result in increased ignition potential and fire behaviour due to cured standing and downed fuels. Fire behaviour is highest during the red-attack phase (1 to 4 years) and decreases in grey-attack phases as fine fuels (less than 7.5 cm in diameter) decrease over time (2 to 10 years)[2]. As the standing grey-attack trees fall, they contribute to surface fuels. These surface fuels, in combination with tree regeneration during this stage, can result in an increase in expected fire behaviour during this stage (approximately 10 to 30 years).

To provide a more locally specific assessment of fire history, the use of fire ignition records is pertinent. The BC Government Wildfire Management Branch maintains a spatial database of fires back to 1950 (BC WMB 2014). The database indicates fire location, date, and cause (human or lightning), and is useful in determining wildfire probability for an area. In the 150,010-ha regional study area (RSA), 60% of the fires were human-caused and the remainder were started by lightning (39%) or unknown causes (1%; Table 23.7-2). Since 1955 there have been 109 fires within the RSA.

Table 23.7-2. Fire Occurrences for Each Decade by Cause in the Regional Study Area

Decade	Number of Fires by Cause in the RSA			
	Lightning	Human	Unknown	Grand Total
1950	3	6	0	9
1960	5	4	0	9
1970	14	9	0	23
1980	15	11	0	26
1990	16	9	0	25
2000	12	4	0	16
2010	0	0	1	1
Grand Total	**65**	**43**	**1**	**109**

Source: British Columbia Wildfire Management Branch. 2014. http://bcwildfire.ca/default.htm (accessed August 2014)

[2] Red- and grey-attack phases are indications of the percentage of tree volume killed by beetles.

Within the LSA, a single fire incident was recorded in 2004, which was initiated by lightning. An additional two fire perimeters are delineated within the LSA. One fire that occurred in 1931 was identified along Thutade Lake shoreline and another from 1958 was delineated on the southern edge of the LSA. Both delineated fires were human-initiated.

Linear infrastructure, such as power lines and transmission lines, are 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. A vegetation maintenance plan and hazard tree removal program are key to reducing power-line-induced fires.

Human safety is one of the key focuses in developing mitigation measures for the effects of wildfire on the Project. Fire could harm individuals and smoke could cause 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.

Mitigation Measures

Mitigation measures related to wildfires are summarized in Table 23.7-3. To reduce the chance of infrastructure loss and/or damage due to wildfires, the following will be incorporated:

- using wildfire-related vegetation management and building design, where possible;
- creating zones of 30 m around all structures where vegetation is maintained in a low-hazard state;
- implementing a hazard-tree inspection program for the power line to ensure the right-of- way is maintained in a condition that reduces the risk of tree failure;
- training for designated permanent employees (e.g., Provincial S100 Basic Fire Suppression and Safety training) and ensuring sufficient trained personnel are on site during the fire season to initiate a fire response;
- ensuring employees have access to appropriate personal protective gear to action a wildfire response;
- developing an evacuation plan in case of wildfire, including a backup plan in case of loss of the egress route along the access road;
- identifying safe zones for workers at the Project area in the event that evacuation is not possible;
- ensuring water sources have adequate volumes to fight fires and that pumps or other water-delivery systems can provide sufficient pressure for the effective use of hoses, sprinklers, and other fire suppression tools;

Table 23.7-3. Summary of Forest Fire Risks and Mitigation Measures

Project Component	Area Affected	Risks to Project	Probability	Consequence	Mitigation Measures
Transportation	Existing and proposed access roads and culverts	Effects to workers: compromised health and accessibility issues due to fire or smoke. Effects on infrastructure: damage to infrastructure and facilities.	Moderate	**Moderate impact -** If there is fire along the access road, personnel could be prevented from leaving the site and face injury or death. At the very least, smoke could cause respiratory issues. Fire along an access road could have secondary effects related to the loss of surface vegetation cover in the local catchment area. Slope stability may also be compromised by vegetation loss.	Development of alternative evacuation routes and of evacuation procedures. Implementation of building designs to minimize fire risk. Provide training and equipment to personnel. Monitoring of BC MFLNRO fire alerts.
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities	Effects to workers: compromised health. Effects on infrastructure: loss or damage to infrastructure and facilities.	Moderate	**High impact -** If egress of personnel is not possible, injury or death could occur. There could be damage to project infrastructure. Fuel storage tanks pose a significant risk for explosion if ignited.	Development of evacuation procedures. Implementation of building designs to minimize fire risk. Provision of training and equipment to personnel. Monitoring of BC MFLNRO fire alerts.
KUG TSF	Existing KS Mine open pit, East Dam.		Moderate	**Low impact**	
Access corridor	Tunnel, surface conveyor, transmission line, underground dewatering pipeline		Moderate	**High impact –** infrastructure is vulnerable to wildfire.	
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Effects to workers: compromised health. Effects on infrastructure: loss or damage to infrastructure and facilities.	Moderate	**Low to moderate impacts –** A wildfire could 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.	Development of evacuation procedures. Implementation of building designs to minimize fire risk. Provision of training and equipment to personnel. Monitoring of BC MFLNRO fire alerts.
Underground workings	Declines, cave gallery, excavations to be created for underground activities	n/a	Negligible	**Negligible impact**	n/a
Utilities	Transmission line, backup diesel generators	Ignition of fires; damage by fires.	Moderate	**High impact -** Linear infrastructure, such as power lines and transmission lines, are 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. Diesel generators could pose a significant risk for explosion if ignited.	Use of backup generator to avoid power outage.

- locating water pumps and fire-fighting equipment strategically around the Project to help contain/extinguish any fire;
- equipping a vehicle with firefighting tools (shovels, pulaskis, and axes), water, and portable pumps to supply initial attack to accessible fires;
- using mining equipment such as dozers in the case of a fire to remove vegetation around the infrastructure, thus removing fuel for the fire;
- providing backup generators for use in the event of power line loss. The generators will have enough power capacity to operate essential equipment (e.g., ventilation, fire suppression);
- properly storing flammable materials, banning heat and flame in these areas, and providing proper signage;
- training personnel in fire response and containment, including using fire extinguishers for small fires in buildings and raising an alarm and seeking assistance;
- monitoring BC Ministry of Forests, Lands and Natural Resource Operations (BC FLNRO) fire alerts; and
- complying with all relevant legislation in the BC *Wildfire Act* (2004).

A severe wildfire that posed risks to Project employees or infrastructure would trigger the Project's Emergency Response Plan, as presented in Section 24.15 in Chapter 24.

23.8. CLIMATE CHANGE

23.8.1. Climate Change Regulatory Context

The BC government has drafted an Adaptation Strategy (BC MOE 2015) to address climate change. The province is also currently drafting policy regarding climate change adaptation and how to mainstream adaptation considerations 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 (FBC 2015). In addition, the mining sector needs "access to the best climate change information available by region" to evaluate risks and weigh adaptation options (FBC 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). To address the gap, as part of the initiative to address the climate change adaptation needs of the mining sector, two case studies have been developed to investigate what challenges the impacts of climate change—such as increases in the intensity and frequency of extreme weather events as well as more gradual changes to parameters like temperature and precipitation—pose for mining projects (FBC 2014a, 2014b).

The report "Incorporating Climate Change Considerations in the Environmental Assessment: General Guidance for Practitioners" was used to guide the assessment of effects of climate change on the Project. In particular, 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* (CEAA 2003).

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 has discussed the likely effects of climate change on the Project and the related mitigation measures in a manner that should allow for informed decision-making.

23.8.2. Climate Change Adaptation

Climate change adaptation is 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). It is distinct from climate change mitigation, which is the reduction in the magnitude and rate of the factors leading to climate change itself (West Coast Environmental Law 2012). Planning for adaptation is difficult, given unknowns in the timing and magnitude of climate change, and the environmental effects of this change.

Planning and decision-making will take climate change into account wherever possible. This includes 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 2013b), and professional associations will be followed wherever applicable or possible (e.g., APEGBC 2010, 2012; BCWWA, 2013a, 2013b).

To respond to the known uncertainties surrounding climate change impacts, an adaptive management approach to climate change will be taken. Adaptive management involves using learning to continuously improve policies and practices. Adaptive management is useful because it allows for flexible responses to early signals of change when timing and magnitude are not known. Adaptive management has six components: assess the problem, design a solution, implement the solution, monitor the results, evaluate the outcome, and make adjustments (Ministry of Forests and Range 2013). Employing adaptive management and planning for the likely effects of climate change may iteratively bridge the gap between Global Circulation Model (GCM) projections and the actual climate impacts experienced in the Project area, thereby allowing the Project to adapt to such effects by formulating appropriate mitigation to the extent possible.

23.8.3. Scope of Climate Change

23.8.3.1. Past and Projected Climate Change in the Project Region

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

As noted in Section 23.2.1, 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 2013a) report, it was found that overall, the climate of the Project area is expected to warm and experience more precipitation in the future. However, if the PDO were to increasingly experience a negative phase, then these effects would be dampened, but not reversed. As global sea-surface temperatures continue to warm, the ENSO is expected to experience an "El Niño-like" mean state change, but no change in amplitude (Lapp et al. 2012).

Extreme weather in the Project weather area is correlated with both the PDO and ENSO, including each phase. For example, during a negative phase of the PDO (2005 to 2013) there is a greater propensity for La Niña events, and during La Niña events the interior of BC tends to experience colder winters and drier summers. Conversely, during a positive phase of the PDO (1977 to 2005, and from 2014 to time of writing) there is a greater propensity for El Niño events, and during El Niño events the interior of BC tends to experience warmer winters, record-high snow-pack, increased rainfall, and extensive flooding. Given this understanding of local weather conditions, climate change in the Project area will likely continue to result in extreme weather from both the PDO and ENSO cycles. According to climate change projections, both the frequency and magnitude of these events are likely to increase.

23.8.3.2. Project-related Adaptation and Mitigation Measures

Climate change impacts are unique in that they cannot be predicted by extrapolating from historical measurements and return periods (BCWWA 2012b). By analyzing extreme return-period events for temperature, precipitation, and stream flow, climate change impacts are 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 ENSO phases on possible extremes in air temperature, precipitation, and stream flow are accounted for within the scope of the assessment.

Components of the environment and Project affected by climate change are reflected in Table 23.8-1 and in the sections below. Each component is discussed and categorized in terms of its sensitivity from anticipated impacts. Categories are **negligible, low, moderate,** and **high**. Each is defined relative to the likelihood of change in interaction, risk of effects to Project, and consequent effects to the environment, human health, and safety.

Temperature

Project components will be designed to withstand a wide range of air temperatures, including the temperature ranges for extreme events (Table 23.8-1). Increasing the number of freeze-free days would be beneficial to the Project in some respects, such as reducing heating costs and reducing exposure of personnel to extreme cold. Climate change is predicted to induce milder winters in this region, which would likely produce more freeze-thaw cycles that may result in accelerated roadway deterioration, and increase maintenance costs. More frequent freeze-thaw cycling also has the potential to compromise the strength of other site infrastructure, including power lines and building foundations. As such, the majority of Project components roadways and transportation corridors have **moderate** sensitivities to increased freeze-thaw cycles. The exception is the underground workings and the KUG TSF, which, due to location and robust design, should have low sensitivities to increased freeze-thaw cycles (Table 23.8-1).

Precipitation

Project components will be designed to accommodate rain and snow and will have management plans in place for handling rain and snow (refer to Sections 24.4 and 24.5). It is possible that extreme snowfall events will increase in frequency and magnitude. Increases in the frequency and magnitude of extreme snow and rain may occasionally limit travel on access roads and therefore the sensitivity of these components to climate change is considered **moderate**. All other Project components are ranked as having **low** to **moderate** sensitivities to increased precipitation due to climate change (Table 23.8-1).

Surface Water

As precipitation extremes unfold, 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 (PDO negative, La Niña) as well as extreme high flows (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 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 **negligible** to **low** sensitivities to increased or decreased stream flow due to climate change (Table 23.8-1).

Landslides

Landslides geohazards for the Project are discussed in Sections 23.5.1. The projected increases in extreme precipitation and runoff in the Project region may lead to secondary effects of increased risks of geohazards (BC MWLAP 2003). Geohazard risks have been assessed and provisions have been made to mitigate those risks. Though the chances of a landslide happening 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** (Table 23.8-1).

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 KUG TSF. 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 as a whole are believed to have **low** sensitivities to increased or decreased wind velocities due to climate change (Table 23.8-1).

Table 23.8-1. Potential Project Component Sensitivities Arising from Climate Change

		Air Temperature			Precipitation		Stream Flow				
Category	Component	Increase from Mean Climate Normal	Freeze-Thaw Cycles	Extreme Heat	Increase from Mean Climate Normal	Extreme Rain and Snow	Flooding	Drought	Increased Geohazards	Increased Wind Velocity	Increased Wildfires
Transportation	Existing and proposed access roads and culverts	Low	Moderate	Low	Low	Moderate	High	Low	Low	Low	High
Surface infrastructure	Administration complex, process plant, workshop, stores, concrete batch plant, electrical substation, decline ventilation system, stockpiles (waste, ore, and organics), laydown areas, fuel storage tanks, explosives magazines, potable water and sewage treatment facility, surface portal facilities	Low	Moderate	Low	Low	Low	Moderate	Low	Low	Low	High
KUG TSF	Existing KS Mine open pit, East Dam	Negligible to Low	Low	Negligible	Low	Low	Low	Low	Low	Low	High
Access corridor	Tunnel, surface conveyor, transmission line, underground dewatering pipeline	Low	Moderate	Low	Moderate	Moderate	Moderate	Low	Low	Low	High
Water management infrastructure	Water treatment plant (housed in the process plant), discharge pipelines, diversion infrastructure	Low	Moderate	Low	Moderate	Low	Moderate to High	Moderate	Low	Low	High
Proposed underground workings	Declines, cave gallery, and excavations to be created for underground activities	Low	Low	Low	Low	Low	Low	Low	Low	Low	High
Utilities	Electrical transmission line, backup diesel generators	Low	Moderate	Low	Low	Low	Low	Low	Low	Low	High

Wildfires

As wildfire extremes as a consequence of climate change emerge over time, the Project area may experience increased fire behaviour. Given the relationship between the PDO and ENSO, it is probable that fire occurrences will increase during the negative phase of the PDO, which have resulted in frequent La Niña events between 2005 and 2014. In the southeast region of the province, the coupling of negative PDO phases with La Niña events has been demonstrated to significantly increase both fire weather as well as wildfire occurrences (Daniels, 2004). As such, all Project components have **high** sensitivities to increased wildfire due to climate change (Table 23.8-1).

23.9. PROJECT DESIGN CHANGES RESULTING FROM THE EFFECTS OF THE ENVIRONMENT ON THE PROPOSED PROJECT

AuRico has incorporated the following changes to mitigate the risk of the effects of the environment to the Project:

- designed the Project to target an ore body in a high-avalanche-risk area by using underground block caving accessed by three declines, with entrances in a portal located in a sheltered saddle in the upper El Condor Creek catchment;
- selection of the access corridor route in consultation with Aboriginal groups, and avoidance of potential avalanche and landslides areas ;
- tunnelling through the ridgeline between the mill site and the portal area to reduce landslide, avalanche, and extreme-weather risk to the Project;
- removal of explosives magazines from the portal area due to potential landslide/avalanche risk; the Project will use existing explosives magazines near the KS Mine site; and
- reduction of seismic risks to the Project through the design of a water management strategy to reduce the need for a large tailings dam.

23.10. CONCLUSION

This chapter assessed the following environmental effects that may affect the Project:

- 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 wildfires or forest fires.

Through application of mitigation measures described in this chapter, including design to minimize or eliminate potential effects, monitoring of weather and fire conditions, and the Project's environmental management plans provided in Chapter 24 of this Application, the risk of environmental effects on the Project are reduced to acceptable levels.

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